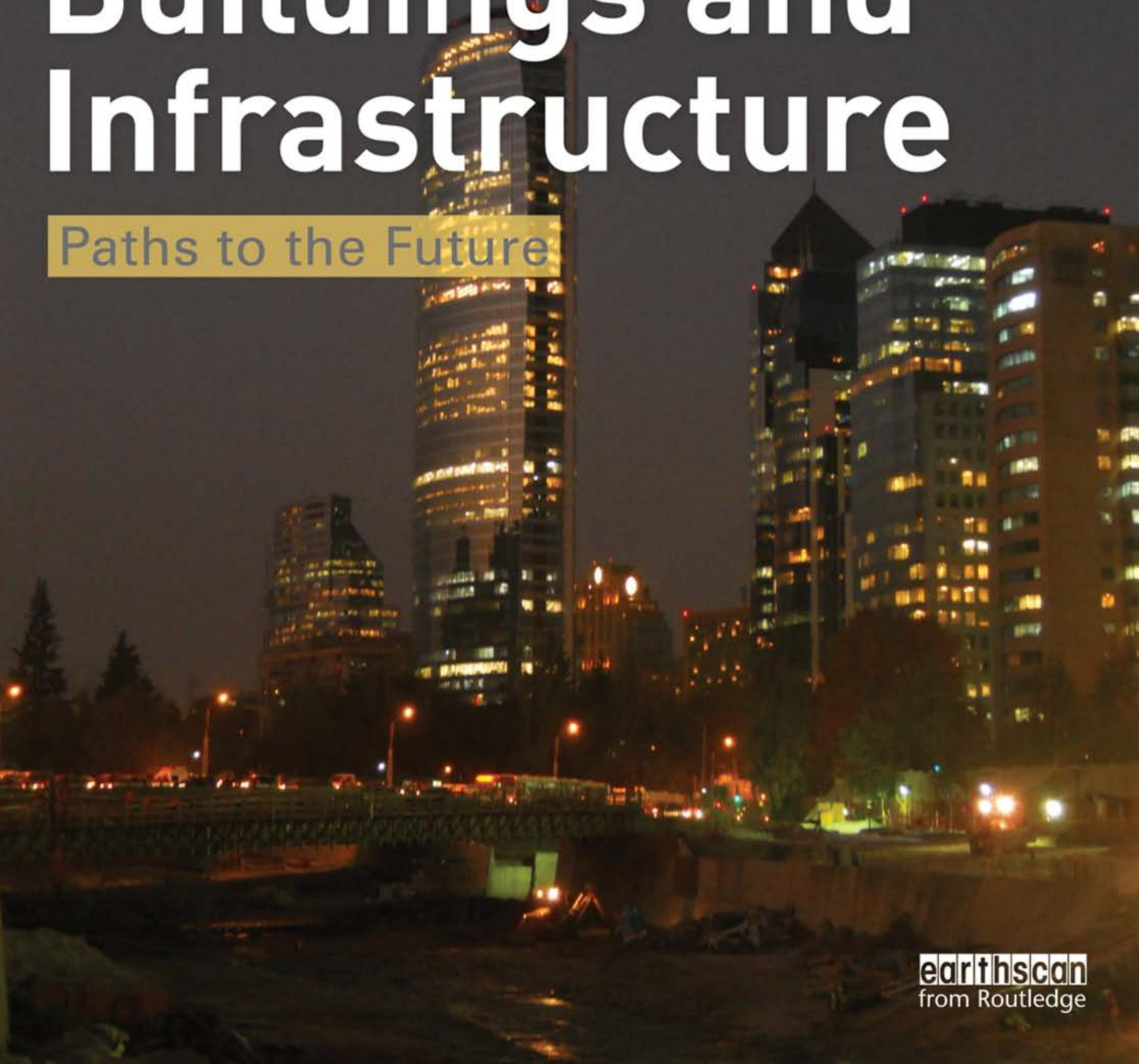
Annie R. Pearce, Yong Han Ahn and HanmiGlobal

Sustainable Buildings and Infrastructure

Paths to the Future



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SUSTAINABLE BUILDINGS AND INFRASTRUCTURE

Construction is one of the biggest industries in the world, providing necessary facilities for human prosperity ranging from the homes in which we live to the highways on which we drive, the power plants that provide energy for our daily activities, and the very infrastructure on which human society is built.

The construction sector, including the building sector, has among the largest potential of any industry to contribute to the reduction of energy and greenhouse gas emissions. This ambitious and comprehensive textbook covers the concept of embedding sustainability across all construction activities. It is aimed at students taking courses in Construction Management and the Built Environment. Written in a lively and engaging style, the book sets out the practical requirements for making the transition to a sustainable construction industry by 2020. Case studies are included throughout, making the book both a core reference and a practical guide.

Annie R. Pearce is an Associate Professor in the Department of Building Construction, Myers-Lawson School of Construction at Virginia Tech specializing in sustainable facilities and infrastructure systems. Her areas of expertise include metrics of sustainability for built facilities, green building materials and systems, cost modeling to support sustainability implementation, and in situ performance of sustainable facility technologies.

Yong Han Ahn is an Assistant Professor in the Department of Construction Management at East Carolina University and a leader of the Sustainable Design and Construction Management (SDCM) research group. Dr. Ahn's research and teaching focuses on motivating students, the construction profession and the wider construction industry to incorporate sustainability into their practices.

HanmiGlobal Co., Ltd. currently a member of the U.S. Green Building Council (USGBC), is a global project and construction management company with a subsidiary in the U.S. (OTAK, Inc.). Being the first company to provide LEED consulting services in the Republic of Korea, they have accumulated experience and capabilities to meet the requirements of the USGBC. HanmiGlobal has been ranked as the 18th largest PM/CM firm of all non-US based firms by the Engineering News Record (ENR).

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This book is dedicated to a sustainable future for the built environment and new ways of thinking for the people who occupy it.

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Foreword by Jong Hoon Kim

HanmiGlobal has established environmental standards for high performance buildings and eco-friendly infrastructures. These environmental standards conform to the standards of sustainability we have established. It is our goal to create future construction management practices in our projects that will employ project/sustainable techniques through continuous research and development of new technologies.

Our effort is not only a passive approach to reducing the corporate carbon footprint, but also to proactively participate in the global sustainability business. In moving forward with these issues, our company is interested in preparing a sustainability business which includes: sustainable design management, sustainability knowledge support and sustainability due diligence. We will also undertake research and consulting on Green Buildings and new renewable energy resources.

In order to initiate our vision of sustainable management practices, we have enacted sustainability policies with the joint applications of ISO 14001, LEED (Leadership in Energy and Environmental Design), BEMS (Building Energy Management System), and other global environmental policies. By providing a total solution concept using optimized sustainable guidelines, HanmiGlobal plans to develop into a sustainable PM/CM consultancy, from the design process to construction.

However, is it possible to provide sustainable construction using only pre-established environmental standards and systems provided?

It is more important to establish a workable tool for construction professionals to understand both the administrative and the technical requirements of a sustainable construction project. This book draws attention to the current way of thinking and offers practical approaches to sustainability. In addition, the book will call for contributions concerning sustainability concepts, theories, and case studies to combine better decision making with practical relevance to sustainable developments.

We are pleased to collaborate with Professor Annie Pearce at Virginia Tech and Professor Yong Han Ahn at East Carolina University in order to conduct research about sustainability opportunities throughout the construction lifecycle to establish the best practices in industry standards. We are very satisfied with the outcome of this research and look forward to seeing the results implemented as a guideline for sustainable project management.

One of the most critical issues in the current construction industry concerns not only green building issues and high efficiency structures, but also the need to form an ecological balance with the environment. We hope this publication provides readers with an overall understanding of sustainable building and practical business cases that will encourage the government, construction experts, and students who are interested in sustainability objectives to present approaches to future projects.

Jong Hoon Kim
Chairman & CEO of HanmiGlobal

Foreword by Norbert Lechner

Sustainability is now widely recognized as a major priority in all sectors of the economy, and the building sector is especially important because it is a major consumer of both materials and energy, with buildings consuming about 50 per cent of the energy in the United States. The consumption of materials not only depletes our physical resources, the process of getting raw materials from the ground into the fabric of a building being constructed requires huge amounts of energy that then becomes embodied in the finished building. The endless depletion of our material and energy resources is certainly not sustainable. However, the greatest threat by far is climate change brought about by global warming. Both the operational and embodied energy required by buildings comes mainly from the burning of fossil fuels which are rapidly increasing the carbon dioxide content of the atmosphere. There is no sector of the economy that is causing climate change as much as the construction sector.

In the process of creating a building, the early decisions have the greatest impact (see Figure F1). Although the actual construction comes late in the process, constructors have critically important knowledge at all points in the design process. Before the first line is drawn, the

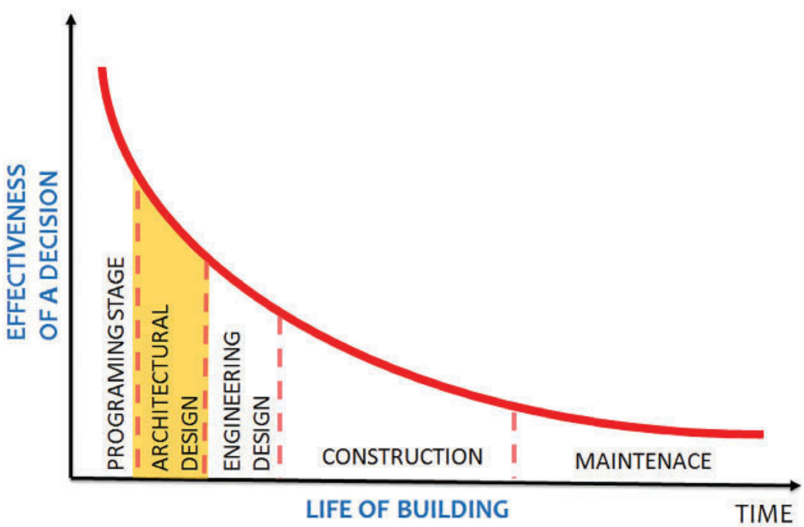

Figure F1 The change in the effectiveness of a decision over the life of a building architect needs the knowledge of both the engineers and constructors in order to design a sustainable building. However, that knowledge must be integrated by the interchange of ideas by the building professionals. Thus, from the very first step in the building process, it is necessary to use the team approach in order to create high-performance sustainable buildings. Low-performing buildings are not acceptable because they will not create a sustainable future.

This very comprehensive and scholarly book presents the knowledge needed by the constructor for construction to be sustainable, and the numerous case studies anchor this book in reality. It presents the drivers of sustainability, its history, and the required policies and programmes. The book gives an in-depth description of the available green rating systems as well as the opportunities in project delivery and pre-design for the constructor. It also provides information on sustainable design strategies to help the constructor be a more effective member of the design team.

The many opportunities for saving energy and materials during the actual construction process are covered in the book. Since constructors are in an excellent position to help in post-occupancy activities and strategies, the book explains how they can help to maximize energy savings.

Fortunately, there are many immediate benefits to sustainable design, and the book makes it clear that many sustainable practices are good for business. The last chapter lays out the trends for the future of sustainable design and construction, which will only increase with time. Since the world's population and affluence will both keep increasing, there will be a continuing need for not only more buildings but ever more complicated buildings. Building professionals well informed about sustainable design will be in great demand, and this book is a great resource for creating sustainable constructors.

Norbert Lechner, Professor Emeritus, Auburn University

Foreword by Jerry Yudelson, Yudelson Associates

In the past decade, sustainable building construction and operations have taken on increasing importance, as the realization has dawned that buildings contribute, directly and indirectly, to nearly half of global carbon dioxide emissions. Indeed, the entire modern green building movement has shifted to a strong focus on building sustainability, as measured by energy and water use. This is not to diminish the importance of other green building attributes such as land use, material and resource conservation, transport alternatives and indoor environmental quality, but rather to emphasize the need to focus on a broad spectrum of building key performance indicators (Building KPI's).

Sustainable Building and Infrastructure: Paths to the Future addresses the opportunities for the construction industry to work with design, finance and operations to achieve sustainability goals that have global importance. There are goals internal to the process by which buildings are procured, including the important role of Integrated Project Delivery systems, along with the increasing use of Building Information Modeling (BIM) as a design and construction tool for the industry.

In this book, the authors focus on sustainability opportunities in four key areas: pre-design, design, construction, and operations or post-occupancy practices. Each is important in its own right, but equally important is the over-riding need to integrate them into a seamless system, so that the business case for sustainability can rest on a firm foundation of industry practice.

How can this be done in actual practice, when schedules are ever shortened and budgets ever reduced? Perhaps the most fundamental rule is this: begin with the end in mind! If the end is a truly sustainable built environment, then the project will begin with this goal, which will find expression in site selection, the building program and a close alignment of goals with user needs. At the beginning of design, a fundamental best practice is to bring together all stakeholders in a one-day (or longer) eco-charrette, in which the environmental goals begin to find form in alternatives for building form.

During the design process, we find that more architects each year are beginning to realize that "form follows performance" in sustainable buildings. In other words, if zero net energy is a goal and on-site energy production (typically with solar power) will only yield "x" amount of energy, then the design must result in a building energy use no more than "x." That in turn, begins to dictate window area ratios, envelope design and so forth.

Equally important are the use of early stage energy modeling and a full range of BIM tools to speed design while resolving conflicts between systems and meeting budget and schedule requirements. During later design stages and into procurement and construction, there will be opportunities to introduce high-performance building products and systems into the project. Then, the "hand off" to occupancy and operations must be accomplished smoothly, through processes such as building commissioning, operator training and similar means. Lastly, there should be a commitment to Post-Occupancy Evaluation that provides a feedback mechanism to design and construction as to how well the sustainable systems actually perform.

The Building Team must adapt quickly to new technologies, products, processes and systems, if it is to be seen as an integral part of the sustainable solution to a growing number of economic, environmental and social issues in the global economy. Indeed, the next big challenge facing the Building Team is not just making the individual building more sustainable, but working to create sustainable cities for a global population that will be three-quarters urban dwellers by 2050. To accomplish this goal, it is vital that tools such as BIM be used not just for building construction documents, but as a complete support system for building sustainability.

I am confident that books such as this will serve a noble purpose in bringing the entire Building Team into a more harmonious relationship with sustainable construction and operations and, in so doing, help to solve significant and pressing global problems facing urban civilization.

Jerry Yudelson, PE, LEED Fellow
Tucson, Arizona
October 2011

Preface

Imagine this: you are given a very important task to complete, one that is too complex to do alone. You must spend millions of dollars to get it done, work closely with people you have never met before, and finish the work with limited time and resources. Every decision will be monitored closely, and you are likely to have less money to complete the project than you need. Now imagine that everyone on your team speaks a different language, has different and sometimes conflicting interests, and uses different tools and techniques to do their part. Imagine further that you may not even be allowed to talk to each other some of the time. Your solution has to remain valid and useful for 30 years, 50 years, or even 100 years or more, although the environment in which it is used and the uses to which it will be put will change dramatically over that time in ways you cannot imagine. Imagine that if you fail to complete your task as assigned, very bad things could happen – people could become ill, be injured or killed. If you make a mistake, the penalties could be staggering.

Feel the pressure? This is the world of modern construction, in all its technical and legal complexity. Now add a whole range of additional challenges: new codes, standards and environmental requirements, a very competitive market with extremely low profit margins, well-informed clients who have new ideas that they aggressively want to implement on their projects, and thousands of components with different attributes and sources in the marketplace. Imagine further that your clients want you to keep track of each of those components, where they came from, and the problems that were created in their manufacture or will be created during and after their service life. You also have to understand how they should work together, connect them all in the right ways, and verify that those connections were made correctly so that the project meets your predictions for performance. Finally, put this all in the context of a world where our actions as a species appear to be leading to runaway changes on a global scale. We don't know what those changes will be, exactly, but we know they will affect the kinds of resources available in the future, the ecological and socio-political conditions in which our buildings must perform, and the expectations of the people who use and rely upon our creations during their life-cycle.

We wrote this book because we recognize the challenges facing the people who create the built environment. As educators and practitioners, we are acutely aware of the complexity inherent in the construction industry, both technical and otherwise. Even as new technologies emerge to improve the performance of constructed systems, there is evidence to suggest that we do not even use existing technologies as effectively as we could. We have dedicated our lives to try to make things better, and we hope this book will play a role in achieving that outcome.

We want the next generation to inherit a world that has fewer, not more, problems than our generation has had to face. Many of those problems have been caused in large part by the built environment and the legacies of how it has been constructed over time. We see enormous challenges in figuring out how to fix those problems, but we also see enormous potential for change and a whole host of opportunities. Solving the problems that result from our industry will take the contributions of many people working together, but we believe it can be done.

This book is a tool for those who seek to change the architecture, engineering and construction (AEC) industry. It was designed to offer a new way to think about how we create the built environment, along with a sampling of promising technologies and practices, and a look ahead to what the future may hold. The first two chapters provide an introduction to why sustainability is important for stakeholders of the built environment and an overview of the history of past efforts to make our built environment more sustainable. These chapters lay the foundation for understanding both the human and organizational dimensions of the problem, discussed in Chapter 3, and the technological and process dimensions over the building life-cycle, discussed in Chapters 4 to 8. In Chapter 9, we use a detailed case study to illuminate how these dimensions come together in a real project, and we show how decisions can be analysed according to the economic criteria that shape how most organizations operate. Finally, in Chapter 10, we offer our best projection of what the future holds for our industry. Each chapter also has a section on upcoming trends and a set of questions for reflection and discussion. We hope these resources will help our readers consider what is to come as they develop a strategy for sustainability for their own organizations.

We welcome your comments about what this book does well, and how it could be better in future editions. We hope you find it useful both for learning more about built environment sustainability and as a tool for day-to-day practice. Please contact us with your comments and good ideas, and we wish you well in your quest for sustainability.

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Annie R. Pearce and Yong Han Ahn

1

Drivers of Sustainability in the Built Environment

The concept of sustainability has gained popular momentum over the last 20 years. The goals of sustainability are to enable all people to meet their basic needs and improve their quality of life, while ensuring that the natural systems, resources and diversity upon which they depend are maintained and enhanced, for both their benefit and that of future generations. The construction industry is beginning to adopt the concept of sustainability in all construction activities and has significant opportunity to mitigate environmental problems associated with construction activities while contributing to a high quality of life for its clients. This chapter explains the drivers of sustainability in the built environment by describing how construction activities affect the natural environment, the economy and society.

Construction and its impacts

Construction is one of the biggest industries in the world, providing necessary facilities for human prosperity ranging from the homes in which we live to the highways we drive on, the power plants that provide energy for our daily activities, and the very infrastructure on which human society is built. The construction industry constitutes around one-tenth of gross domestic product (GDP) worldwide. It is a significant employment generator and provides work to almost 7 per cent of the total employed population globally. For example, in the United States, the construction industry is a major player in the nation's economy, contributing over $1 trillion including $770.4 billion of private construction and $316.6 billion in the public sector as of December 2008 (US Census 2009). In addition, the construction industry accounts for more than 12 per cent of the national GDP and provides critical civil infrastructure including bridges, roads, rail, water and wastewater treatment, plants for the production and transmission of energy, and facility assets such as office buildings and the houses in which we live, work and play (Russell et al 2007). Furthermore, the construction industry total annual average employment in the United States was about 7.69 million as of 2008 in 883,000 construction establishments, of which 268,000 were building construction contractors, 64,000 were heavy and civil engineering construction or highway contractors, and 550,000 were speciality trade contractors (USDOL 2009).

Due to their magnitude, construction activities have a major impact on physical development, government policies, community activities and welfare programmes. Construction projects and the facilities that result can improve social welfare, well-being and quality of life. Construction activities including the construction, operation, maintenance and demolition of built facilities are also connected with the broader problems and issues affecting the environment, including global warming, climate change, ozone depletion, soil erosion, desertification, deforestation, eutrophication, acidification, loss of diversity, land pollution, water pollution, air pollution, depletion of fisheries, and consumption of valuable resources such as fossil fuels, minerals and gravels. In addition, built facilities also significantly impact human health, comfort, and productivity.

Energy use

A great amount of energy is consumed by construction activities, mainly the operation of buildings. The building sector accounts for around 25–30 per cent of total energy consumption in Organisation for Economic Co-operation and Development (OECD) countries, including the United States, the European Union, Japan, and others (OECD 2003). In the United States, about 40 per cent of all energy is consumed by buildings, shown in Figure 1.1 (EIA 2010). In addition, as shown in Figure 1.2, energy consumption in the building sector has long been on the increase, and it is predicted that this trend will continue (EIA 2010). As shown in Figure 1.3, U.S. building energy end-use is consumed mainly for space heating (around 20 per cent), lighting (around 18 per cent), space cooling (around 12 per cent), and water heating (around 10 per cent). Based on this data, it is clear that heating, cooling, and lighting in buildings are the major cause of energy consumption in the U.S. (USDOE 2008). In addition, buildings accounted for 72 per cent of total U.S. electricity consumption in 2008 and this number will rise to 75 per cent by 2025 (USDOE 2008).

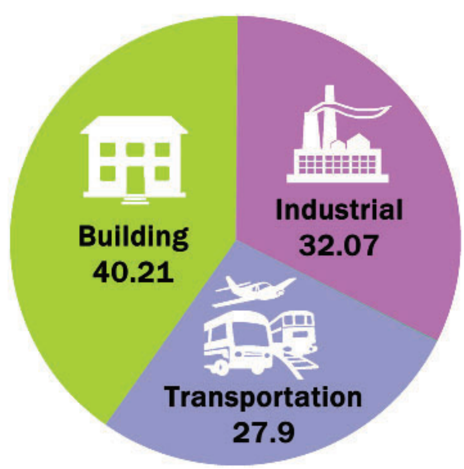


Figure 1.1 Energy use by sector of the economy

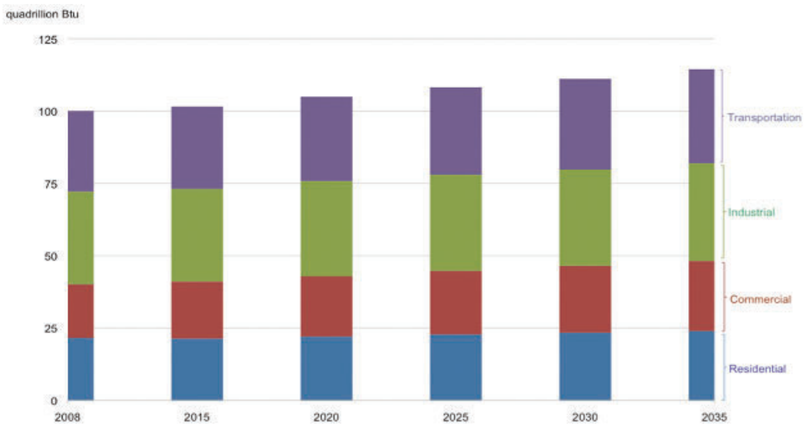


Figure 1.2 Forecast energy consumption trends

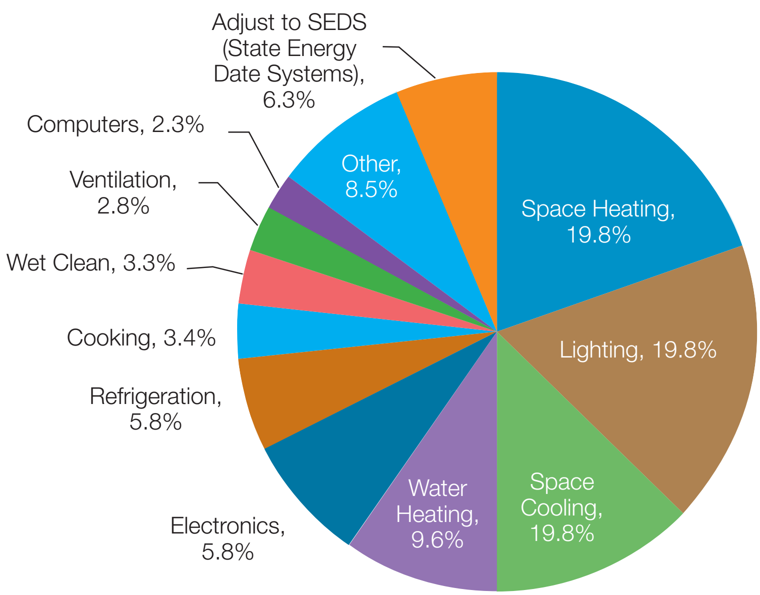


Figure 1.3 US building sector energy consumption by end-use

Air quality and atmosphere

With buildings being responsible for more than 40 per cent of energy use worldwide, one third of global greenhouse gas emissions can be attributed to buildings (UNEP 2009). In the United States, buildings contribute approximately 39 per cent of nation's total carbon dioxide (CO_2) emissions, including 21 per cent from the residential sector and 18 per cent from the commercial sector. The main source of greenhouse gas emissions from buildings is energy consumption, but buildings are also major emitters of other non-CO_2 greenhouse emissions such as halocarbons, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) as a result of their use for cooling, refrigeration, fire suppression, and in the case of halocarbons, insulation materials. Energy in the building sector is consumed during:

- Manufacturing of building materials ('embedded' or 'embodied' energy).
- Transport of these materials from production plants to building sites ('grey' energy).
- Construction of the building ('induced' energy).
- Operation of the building ('operational' energy).
- Demolition of the building and recycling of their parts, where this occurs.

Many scientists claim that greenhouse gas emissions are closely related to global warming and climate change, including rising sea levels, increased occurrence of severe weather events, and resulting food shortages. The construction sector, including the building sector, has among the largest potential of any industry to contribute to the reduction of greenhouse gas emissions as a means of addressing these problems.

In addition to energy consumption, the annual mean air temperature of a city with 1 million people or more can be 1–3°C (1.8–5.4°F) warmer than its surroundings. In the evening, the temperature difference can be as high as 12°C (22°F). This phenomenon, known as the urban heat island effect, can also increase summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, and heat-related illness and mortality.

Water use

Buildings are also one of the largest water consumers. Buildings in the United States consume about 16 per cent of total water withdrawals, in the amount of nearly 39 billion gallons per day (Roodman and Lenssen 1995; USDOE 2008). This water comes from a variety of sources (Figure 1.4)

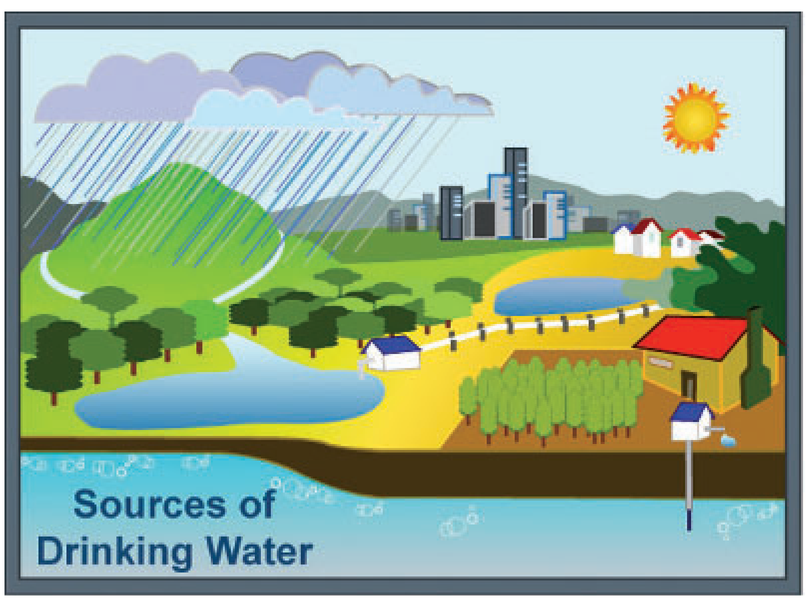


Figure 1.4 Sources of drinking water

and is generally treated to drinking water standards, even though such a high level of water quality is not required for most building uses. Eight per cent of US energy demand goes to treating, pumping and heating water for human use. This is enough electricity to power more than 5 million homes for an entire year (USEPA 2010b). Furthermore, over $4 billion is spent annually in the United States to run drinking water and wastewater utilities (USEPA 2010a).

Indoor environment

The indoor environment is very important for human health, comfort and productivity. However, pollutant levels indoors are often higher than those outside. One of the major studies related to indoor air quality conducted by the US Environmental Protection Agency (USEPA) indicated that indoor air levels of many pollutants may be 2.5 times and occasionally more than 100 times higher than outdoor levels. These high levels of indoor air pollutants are of particular concern because it is estimated that most people spend as much as 90 per cent of their time indoors (USEPA 2010c). Health problems resulting from indoor air pollution have become one of the most acute environmental problems related to the built environment. These high levels of pollutants are generated by building materials and components, including furnishings, carpets, finishes, paints and backing materials; household cleaning, maintenance, personal care or hobby products; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides and outdoor air pollution (Figure 1.5). These pollutants can lead to a variety of health problems, such as irritation of the eyes, nose and throat, headaches and dizziness. They are also thought to contribute to thousands of cancer deaths and hundreds of thousands of respiratory health problems each year. For example, more than 20 million people in the United States, including over 6 million

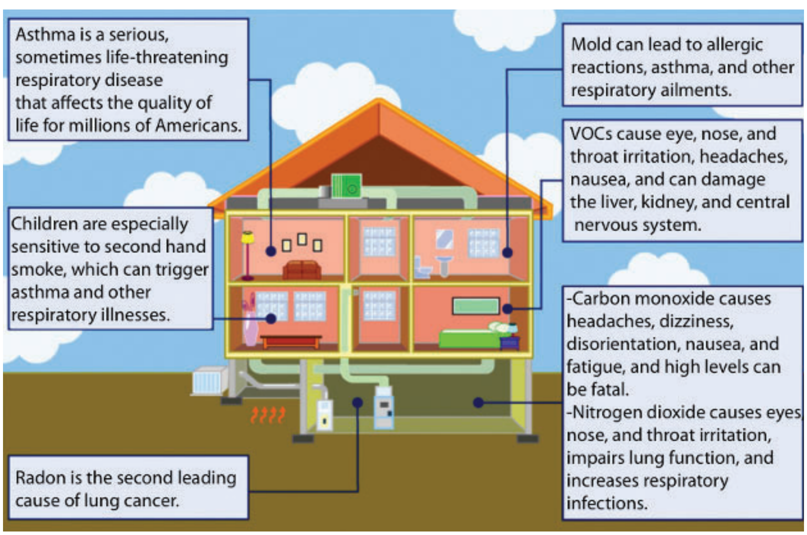


Figure 1.5 Sources of air pollutants

children, have asthma. Asthma accounts for over 10 million outpatient clinic visits, nearly 2 million emergency department visits, and nearly 4,500 deaths annually. In 2007, the estimated cost for treating asthma in those under 18 was $3.2 billion (CDC 2007). In addition, hundreds of thousands of children experienced elevated blood lead levels resulting from their exposure to indoor pollutants (USEPA 2001).

Materials and wastes

In addition to many pollutants to air, water and land, construction activities inevitably produce a significant amount of solid waste from the production, transportation and use of materials (Figure 1.6). Even without considering construction waste, the United States generated approximately 250 million tons of municipal solid waste excluding industrial, hazardous and construction waste in 2007, which amounts to 4.50 pounds per person per day (USEPA 2008). In addition to this number, building-related construction and demolition (C&D) debris totals approximately 160 million tons per year, accounting for nearly 16 per cent of total non-industrial waste generation in the United States. Comparing C&D waste with municipal solid waste, an estimated two-thirds of all non-industrial solid waste in the United States results from building construction, renovation, use and demolition together (USEPA 2008).

Figure 1.6 Construction waste

In relation to material consumption, the construction sector in the United States consumes approximately 3 billion tons of raw materials, 40 per cent of the raw stone, gravel and sand, and 25 per cent of the virgin wood consumed each year (Roodman and Lenssen 1995).

Land use

In addition to generating waste, construction activities also irreversibly transform valuable land such as farmland and forests into physical assets such as buildings, roads, dams or other civil infrastructure (Spence and Mulligan 1995). Construction activities also disturb the soil on a site, resulting in damage to the ecological viability of the land (Figure 1.7). About 7 per cent of the world's farmland was lost between 1980 and 1990 mainly through construction activities (Langford et al 1999). According to Ding (2004), arable land is also lost or destroyed through quarrying and mining the raw materials used in construction. In addition, construction contributes to the loss of forest through timber use in construction and in providing energy for manufacturing building materials (Ding 2004). For example, 10 million hectares of ancient forests are being cleared and destroyed every year – the equivalent size of a soccer field every two seconds (Shah 2006, Uher 1999). By reducing and destroying agricultural land and farmland, construction affects biodiversity, crop production, photosynthesis which purifies the air, and removes the ability to sequester CO_2, thereby affecting global warming.

Figure 1.7 Construction has significant impacts on the land

Based on growing awareness of environmental and health issues and problems associated with construction activities and built facilities, there is a need for the construction industry to consider implementing the concept of sustainability or sustainable development to reduce or mitigate those impacts.

Sustainable design and construction

As a result of the significant impacts it has on ecological and human health, the construction industry has a growing interest in the concept of sustainability. In the construction industry, sustainable design and construction (also referred to as green building, high-performance building or environmental friendly building) is considered as a way for the construction industry to move toward achieving the objectives of sustainability. Sustainable design and construction has a focus on reducing or eliminating environmental problems and issues associated with built facilities and construction activities while maximizing the potential benefits to society and the economy. However, since there are many definitions related to sustainable design, sustainable construction and green building, consensus is lacking regarding what sustainable design and construction really means (Ofori 1998). Table 1.1 highlights several different definitions of sustainable design, sustainable construction and green building from the literature as a starting point to synthesize the key considerations of sustainable design and construction in the construction industry.

By synthesizing the elements identified in Table 1.1, more sustainable design and construction is a practice that integrates design and construction processes to improve sustainable site development, improve water and energy efficiency, increase the use of renewable resources, conserve materials and resources, reduce waste and toxics, and improve indoor environmental quality (Figure 1.8). Although we are unable to achieve completely sustainable design and construction using available technologies at this time, we can certainly improve the sustainability of conventional construction using these practices.

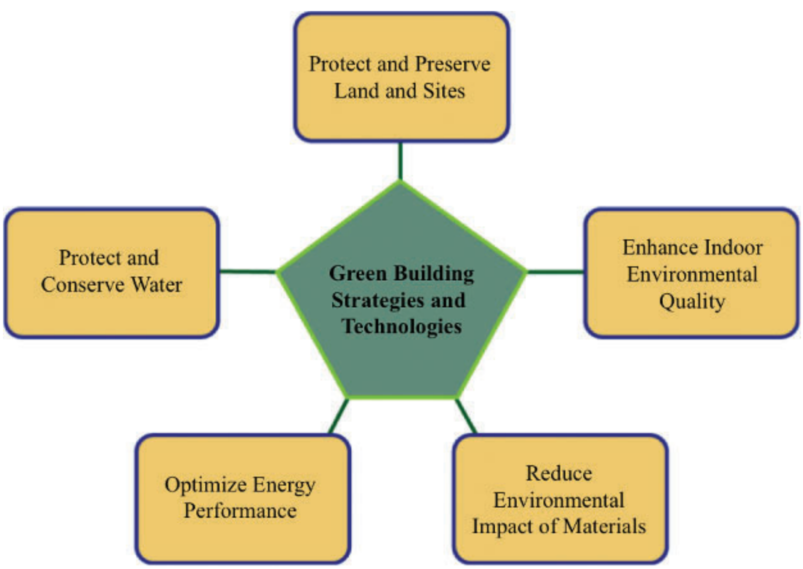


Figure 1.8 Key sustainable design and construction strategies and technologies

Table 1.1 Definitions and components of green building

Sources	Definition	Components
Sustainable Construction: Green Building Design and Delivery	'Healthy facilities designed and built in a resource efficient manner, using ecologically based principles.'	• Reduce resource consumption • Reuse resources • Use recyclable resources • Protect nature • Eliminate toxics • Apply life-cycle costing • Focus on quality
Office of the Federal Environmental Executive	'The practice of increasing the efficiency with which buildings and their sites use energy, water, and materials and reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal – the complete building life cycle.'	• Adopt a holistic design approach • Reduce energy consumption • Reduce water consumption • Reduce material consumption • Improve indoor air quality
US Environmental Protection Agency	'The practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction'	• Increase energy efficiency and renewable energy use • Improve water efficiency • Use environmentally preferable building materials and specifications • Reduce waste • Reduce toxics • Improve indoor air quality • Achieve smart growth and sustainable development
US Green Building Council	'The practice which reduces or eliminates the negative impact of buildings on the environment and on the building occupants'	• Improve sustainable site development • Improve water efficiency • Improve energy efficiency • Conserve materials and resources • Improve indoor environmental quality

Benefits of implementing sustainable design and construction

Three types of benefits arise from implementing sustainable design and construction strategies on capital projects, including both new and existing facilities. First, sustainable construction offers significant ***environmental benefits*** compared with conventional construction. By reducing the amount of energy and resources needed to construct and operate built facilities, the loads imposed by the built environment on the natural environment can be reduced, and the Earth's finite resources can be conserved for use by future generations. Not only do sustainable facilities and infrastructure systems reduce demands placed on the natural environment, they can also contribute to and enhance the carrying capacity and environmental quality of the natural environment, which is diminished by conventional construction practices. For example, green roofs, rain gardens and other similar structures treat stormwater arising from impervious surfaces as well as providing green space as part of a development that can serve as habitat for local species of insects, birds and other animals and plants. These and other building features help to reduce the negative impacts of the built environment on natural ecosystems and buffer the effects of human development. The increased efficiency in use of energy and resources also helps to reduce the impacts of humans on global climate change by reducing the amount of energy that is needed from fossil fuels. Incorporating renewable energy generation as part of sustainable construction projects further reduces energy demand from non-renewable sources, reducing the amount of carbon produced during energy production.

Selling points for sustainable design and construction

Environmental benefits

- ☐ Enhance and protect biodiversity and ecosystems
- ☐ Improve air and water quality
- ☐ Reduce waste streams
- ☐ Conserve and restore natural resources
- ☐ Reduce global warming

Economic benefits

- ☐ Reduce operating and maintenance costs
- ☐ Create, expand, and shape markets for green product and services
- ☐ Improve occupant productivity
- ☐ Minimize occupant absenteeism
- ☐ Optimize life-cycle economic performance
- ☐ Improve the image of building
- ☐ Reduce the civil infrastructure costs

Social benefits

- ☐ Enhance occupant comfort and health
- ☐ Heighten aesthetic qualities
- ☐ Create new and enhanced employment and business opportunities
- ☐ Minimize strain on local infrastructure
- ☐ Improve overall quality of life

These environmental benefits also have direct implications for the economics of capital projects. Accordingly, sustainable design and construction can offer significant *economic benefits* in addition to their benefits for the natural environment. Sustainable facilities and infrastructure systems require fewer resources to meet the needs of their users, thus reducing the costs over time to operate and maintain these facilities. The array of new technologies that is evolving to improve the sustainability of the built environment creates jobs and establishes new markets. For example, new technologies for renewable energy have resulted in the growth of new manufacturing enterprises and supply chains to produce these technologies. New jobs are also created for people who install and maintain these systems, and new educational programmes and degrees are needed to train these new workers in the green economy. New business models such as long-term product leases have also been developed as an alternative to conventional purchase of building technologies, resulting in the need for new businesses who manage the leasing and upgrade process. All of these changes in construction technology help to stimulate the economy and provide new opportunities to replace and enhance the inefficient and unsustainable industries of the past.

Finally, sustainable design and construction tactics can result in significant *social benefits* to both facility stakeholders and society at large in addition to their environmental and economic benefits. In the building sector, sustainable facilities have been observed to enhance occupant comfort, health and productivity. For example, daylighting in green buildings has been correlated with reduced absenteeism among employees in general, increased productivity among factory workers, and improved test scores, growth rates and dental health in schoolchildren. The use of sustainable technologies and practices creates new employment opportunities that can stimulate local economies and help to stabilize communities, especially those that are suffering from loss of jobs as a result of industry downsizing and outmoded technologies. Sustainable buildings, with their reduced needs for energy, water and other resources, can reduce the loads imposed on centralized infrastructure systems, thereby reducing the need to expand already strained capacity. New approaches to development that reduce dependence on automobile transportation, such as mixed-use development and alternative transportation systems, also reduce infrastructure demand while improving quality of life and reducing threats to environmental quality.

The world in 2020: why sustainability is essential

Together, the benefits of sustainable design and construction offer the potential to change the way in which we as humans face the challenges of the next decade. These challenges are not insignificant. Both at the level of the built environment and for global development overall, the next decade will bring major changes that must be addressed in how we create and maintain the built environment.

Overall global trends for the next decade

"[E]xpect the dragon ascendant, the eagle descending, the South rising, and the planet possibly trumping all of these."
Dr Michael Klare, author of *Rising Powers, Shrinking Planet: The new geopolitics of energy*

From a global standpoint, both sociopolitical and environmental trends will shape the next ten years. Author Thomas Friedman, in his best-selling book *Hot, Flat, and Crowded* (2009), characterizes the current state of global development in terms of three primary influences: climate change exacerbated by human activities (*hot*), reduction of geopolitical and social stratification due to ubiquitous and cheap telecommunications (*flat*), and having a growing global population that is increasingly concentrated in large urban centres (*crowded*). Together with major shifts in the balance of geopolitical and economic power worldwide, these three characteristics will provide the context throughout the next decade for a new way of thinking about the built environment. In a world where energy and water are the lifeblood of civilization, competition for scarce resources is already becoming fierce as nations dam their rivers, mine their aquifers, and strive to establish long-term contracts with oil-producing nations to ensure future energy security.

We have been aware since at least the 1970s of the reinforcing relationship between world population (P), the standard of living/level of affluence (A) expected and sought by that population, and the technology (T) used to achieve the desired standard of living. Together, these factors define the influence of human beings on the world's finite resource bases and the ecosystems that renew and restore them (Figure 1.9). Critical to our management of those impacts is the evolution of three complementary strategies (Ehrlich & Holdren, 1971):

- Control of population growth to reduce consumption of earth's finite resources.
- Evolution of our expectations for quality of life to favour increases in standards of living that are not dependent upon increasing resource consumption.
- Development of new technologies that contribute to increased standards of living with dramatically reduced impacts on the planet's resources and natural ecosystems.

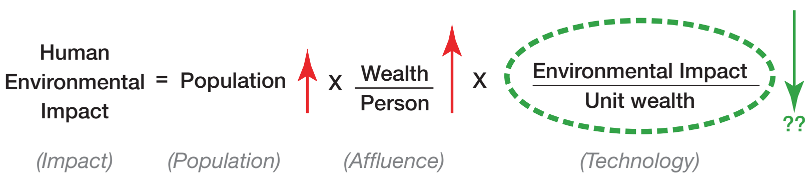


Figure 1.9 The relationship between population, affluence and technology in creating human impact on the planetary environment

Although birth rates have become more moderate over time due to the influence of education, availability of birth control, improved access to medical care and other factors, increased life expectancy worldwide has led to continued population growth. The increasing global population has led to ever-increasing demand for resources so that people in both developed and developing countries can meet their aspirations for the improved standards of living modelled by the richest countries in the developing world.

At the same time that demand for resources is increasing, the unwanted side-effects of using those resources are continuing to grow and interact in unpredictable ways. Current predictions about the exact impacts of climate change vary widely, but there is widespread consensus that the world in the next ten years will be subject to more severe weather patterns, rising sea levels, melting ice-caps and glaciers, and changes in precipitation levels in key agricultural areas (IPCC 2007). These changes will have impacts on food production and security, water resources, production of biofuels to replace dwindling fossil fuels, and the vulnerability of human settlements to flooding, droughts, and other severe weather patterns.

Consensus is also widespread that we are very close to the peak of global crude oil production (Figure 1.10). Similar peaks are also approaching for a number of other key resources critical to the prosperity of modern society, including coal, platinum uranium and aquifer-level groundwater (as described by Heinberg 2007 and others).

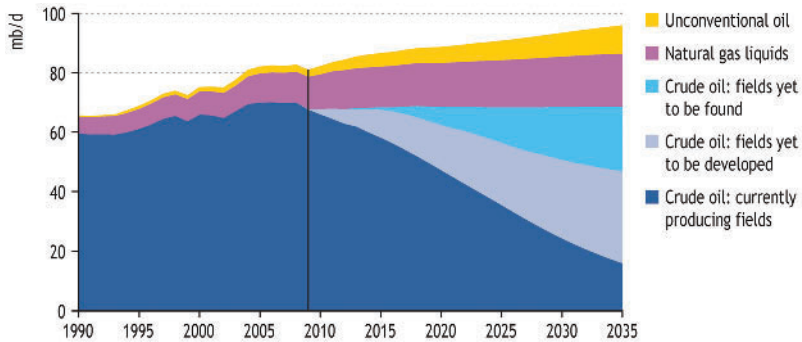


Figure 1.10 Global oil and gas production forecast
Source: OECD/IEA (2010)

In summary, the next ten years are likely to see growing pressure from increased demand for resources by a population hungry for a better life, coupled with reduced supply and a reduced basis for resource regeneration as a result of the ecological impacts of human activities. Changes to climate on a global scale are beyond our current ability to predict with great certainty, but direct observations in recent history suggest that we will see changes in weather, especially rainfall and severe storm events, that will negatively impact our ability to meet human needs. The concentration of human populations in coastal areas will increase the vulnerability of development to the negative effects of climate change such as sea level rise and increasingly violent weather patterns (IPCC 2007). The challenge is to find new ways of developing the built environment that are robust in the face of these coming changes at a global scale.

Significant trends related to the built environment

All of the challenges described in the previous section have implications for the built environment. Reduction in supply of nonrenewable resources coupled with an awareness of the negative climate impacts of fossil fuel consumption will significantly increase the cost of energy and the volatility of its supply, leading to a demand for buildings that have reduced reliance on external energy supply. Energy cost and raw material shortages will also impact the cost and availability of other types of materials used in construction, leading to a need for low- or net zero energy alternatives. These trends will also enhance the attractiveness of resource recovery from existing buildings and infrastructure, as will a reduction in landfill capacity for waste products and dramatic increase in the costs of transportation.

Top ten green trends for 2020

1. **Renewable fuels for electric power generation**
   - Increased demand, especially in China and India
   - Awareness of greenhouse gas problems
   - Development of new fuels for power production
2. **Water resource management, including reuse and recycling of water**
   - Better technologies for conservation, treatment, and desalination
3. **Carbon regulations and policy**
   - Limitations on carbon production
   - Increase in renewable energy generation
   - Market-based solutions
4. **'Green' as good business**
   - Increased industrial efficiency
   - Balanced scorecard reporting
   - Green labelling
5. **Greening of transportation**
   - Renewable and sustainable fuels
   - New hybrid, plug-in and fuel cell vehicles
   - Carbon capture technologies
6. **Increased availability of green products/services**
   - Better consumer education and information availability
   - Product design for end-of-life-cycle
   - Reduction in waste by design
7. **Systems approach to environmental analysis**
   - Increased computational abilities
   - Evaluation of products and systems in terms of their context at a macro scale
8. **Increased resource needs of growing urban population**
   - Increased stress on urban infrastructure
   - Increased life spans
9. **Information and communication technologies use instead of traveling**
   - Use of telecommuting to reduce impacts and increase productivity
   - Increased use of the internet for shopping, recreation, and socialization
10. **Green building**
    - Increased focus on whole life cycle
    - Integrated systems optimization
    - Planned communities and eco-cities
    - Integrated energy production

Source: Battelle (www.battelle.org).

Demographic changes, in both developed and developing countries, will lead to a need to build facilities and infrastructure that can accommodate the needs of the changing world population. Due to increased life expectancy and improved medical care, an overall increase in the population of ageing people in developed countries has led to new types of functional requirements for the built environment and infrastructure to provide for their needs. This demographic segment of the population is expected to continue to grow over the next ten years, and with it will grow the market for accessible, affordable communities and housing that can accommodate the ageing in place for the current generation.

The movement of population to urban centres will create a need for new types of development that can accommodate higher human density without compromising quality of life. These new developments will need to provide for human needs such as food, water and energy which in the past were imported from non-urban areas, leading to net zero energy and net zero water buildings. Vertical farming, which involves using urban infrastructure and buildings as a base for agriculture and food growing, will increase as the cost of transportation increases and city dwellers seek to become less dependent on external supplies of resources. New solutions to address the challenges of urban farming, such as limitations of solar geometry and energy requirements for pumping and lighting, will need to be developed. Ubiquitous communication systems via the internet will also affect transportation patterns of people within urban areas as an increasing number of people telecommute and socialize online instead of physically travelling from place to place.

While the built environment of 2020 is certain to look and behave differently from today's facilities and infrastructure, no one knows exactly what form it will take or what functions it will provide. What *is* certain is that it must be dramatically more resource efficient than the built environment of today to accommodate the ever-increasing needs of a changing and growing population. Sustainable practices for the planning, design, construction, operations, and end-of-life-cycle of facility and infrastructure systems offer an approach to achieve this end.

Overview of the book

With all of the potential benefits associated with sustainable design and construction and the challenges to be faced in the next ten years, many organizations are seeking ways to improve the sustainability of their buildings. The purpose of this book is to provide an introduction on how to improve the sustainability of the built environment.

Chapter 2, History of Sustainability in the Built Environment describes major initiatives in the United States and worldwide that have led to the current state of practice in sustainable construction. It covers major historical events that have shaped contemporary policy and practices, and describes the organizations involved in the ongoing evolution of sustainable design and construction. It concludes with a look ahead to organizations and governance in the year 2020.

Chapter 3, Sustainability Policies and Programmes presents an overview of the elements of sustainability policies based on a review of key initiatives in the United States in the public and private sector. It covers the social, economic, and environmental considerations of a policy, the issues associated with implementability of a policy, and the pros and cons of major policy options. It presents the major components of a green building programme, and provides examples of existing programs in the United States and elsewhere. It concludes with a look at leading corporate sustainability policies and a look ahead to sustainability-related policy in the year 2020.

Chapter 4, Green Rating Systems introduces major rating systems available around the world to guide decision making for sustainability at the raw material, product, building and infrastructure scales. It discusses the ways in which stakeholders use rating systems, the two major types of tools (threshold and profile) that are presently in use, and the labelling and logo systems that can be found on products for sustainable construction. The chapter uses a case study of the Duke Energy Center to show how a rating system can guide decision making in a capital project. It also describes considerations and information sources that are important in product selection and decision making, and provides an overview of the systems available for corporate rating and sustainability reporting. It concludes with a look at trends in rating systems that are likely to be prevalent in the year 2020.

Chapter 5, Project Delivery and Pre-design Sustainability Opportunities describes the overall process for planning, programming and delivering a capital facility and the players who are involved at various stages. It identifies best practices and opportunities that can be employed prior to the facility design process, and introduces a case study of the Trees Atlanta Kendeda Center that will be used in this and the following three chapters to provide specific examples of best practices in use. It also provides an overview of the charrette process that is often employed in the earliest phases of a project to obtain stakeholder input, and describes likely changes to the pre-design process that may occur between now and the year 2020.

Chapter 6, Sustainable Design Opportunities and Best Practices introduces the integrated design process employed on green projects. It provides an overview of best practices for the design of green buildings in the areas of sustainable sites, energy optimization, water and wastewater performance, materials optimization and indoor environmental quality. It also reviews overarching best practices that affect multiple systems and have multiple benefits at once. The second half of the chapter presents design-phase sustainability strategies and best practices at employed the Trees Atlanta Kendeda Center along with a case study of the Bank of America Tower in New York City. It concludes with an overview of how the design process is likely to change by the year 2020.

Chapter 7, Sustainable Construction Opportunities and Best Practices covers the major practices and technologies that can be employed during preconstruction and construction to improve and maintain project sustainability. It presents key components of major sustainability implementation plans that are used during the

Case Study: Torre Titanium La Portada, Santiago, Chile

Completed in January 2010, the Torre Titanium La Portada (as seen on the front cover) was the first building in South America to be certified using the LEED Core and Shell Green Building Rating system, receiving a Gold Rating under the LEED Core and Shell 1.0 Pilot Program at its completion. At 194 m in height, it was at the time of its construction the tallest skyscraper in Santiago. With over 120,000 sq m of floor area, the Titanium Tower provides office space for a variety of firms in Santiago. It was completed at a construction cost of approximately US$120 million. Located in the city's financial district, the building has 52 storeys above ground and an additional 7 storeys below ground, primarily used for parking. The shape of the building was inspired by wind-filled sails, and its location was meant to inspire visions of a great urban door between the natural areas in Santiago's Metropolitan Park and the city itself.

Structurally, the reinforced concrete building was engineered to resist severe earthquakes and extreme winds using special energy dissipators in perimeter framing and the foundation that allow the building's structure to flex under stress. The patented U-shaped energy dissipaters were jointly developed by university and industry researchers and tested for the first time in practice in the Titanium Tower. The building survived a magnitude 8.8 earthquake soon after it opened in February 2010 with no damage. Wind tunnel testing was also used to optimize the building's design to reduce unnecessary turbulence. Notable environmental features of the building include:

- A pedestrian-, bicycle-, and transit-friendly location in a vibrant area of santiago linked to the rest of the city by metropolitan park.
- Rainwater harvesting and condensate recovery for landscape irrigation.
- LED lighting.
- Light exterior colours to minimize urban heat island impacts.
- Use of local labour in construction and manufacture of products used in the building.
- Operable windows to allow natural ventilation.
- Energy modelling to optimize facility design.
- 20 high-speed elevators to service the building that use a system of call anticipation to increase level of service while reducing energy consumption.

Sources

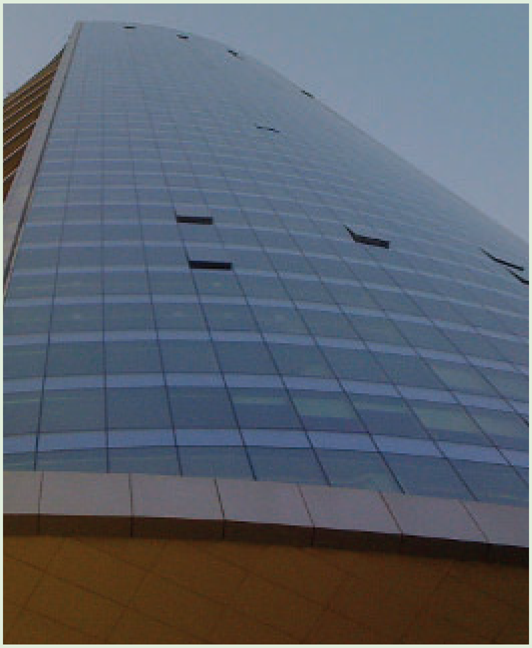
Inmobiliaria Titanium. (2011). 'Titanium La Portada: Global Business Center.' <www.titaniumlaportada.cl/en/proyecto.html> (accessed 10 October 2011).

Wikipedia. (2011). 'Torre Titanium La Portada,'. <http://en.wikipedia.org/wiki/Torre_Titanium_La_Portada> (accessed 10 October 2011).

This is Chile (2011). 'Patent for technology that kept Chile's tallest tower standing during an 8.8 magnitude earthquake.' <www.thisischile.cl/Articles.aspx?id=5504> (accessed 10 October 2011).

Landscape irrigation is provided by harvested rainwater and recycled condensate

The lobby of the Titanium Tower provides access to the building's 20 high-efficiency elevators



Operable windows allow occupants to control natural ventilation to their spaces construction phase to ensure that sustainability goals are met. The second half of the chapter presents construction-phase sustainability strategies and best practices employed at the Trees Atlanta Kendeda Center along with a case study of the first LEED Platinum certified hotel, the Proximity Hotel and Bistro Center in Greensboro, North Carolina. It concludes with a look ahead to how construction is likely to change between now and the year 2020.

Chapter 8, Post-Occupancy Sustainability Opportunities and Best Practices describes the array of strategies that can be employed during the operations, maintenance and end-of-life-cycle phases of a facility's life cycle to enhance sustainability and maintain ongoing high performance. The second half of the chapter introduces sustainability strategies and best practices for sustainability used after occupancy began at the Trees Atlanta Kendeda Center. It also covers end-of-life-cycle tactics used for deconstruction, demolition and adaptive reuse of the old warehouse that occupied the site where the Trees Atlanta Kendeda Center was later built. A case study of major renovations to the Empire State Building in New York City is also included to illustrate the process of prioritizing energy-related decisions in high-rise building rehabilitation. The chapter concludes with a look at how post-occupancy practices are likely to change between now and the year 2020.

Chapter 9, The Business Case for Sustainability presents a detailed case study of the Reedy Fork Elementary School in North Carolina as a means of illustrating the decision process used to select strategies that make good business sense for a sustainable project. It also provides an overview of the evidence to support the business case for project sustainability, including a holistic perspective on project costs. This holistic perspective includes both tangible and intangible project costs along with externalities that should be considered in developing sustainable projects.

Chapter 10, Trends for the Future of Sustainable Design and Construction concludes the book by presenting an overview of upcoming research, trends and philosophies that will shape the future of sustainable design and construction for both buildings and infrastructure systems. It introduces emerging technologies that are likely to significantly change the marketplace, significant process improvements that will influence practice, and broader trends that should be taken into account in planning for a future in this field.

Discussion questions and exercises

1.1 The built environment is directly or indirectly responsible for many types of impacts on resource bases and natural ecosystems. How does your home, office or classroom building contribute to those impacts? Conduct an inventory of your building and identify all of the resources necessary to operate it over the course of a year, including energy, water, materials and others. From what sources do those resources come? What impacts do these flows of matter and energy have on the world at large?
1.2 How do buildings contribute to global climate change? Choose a construction project in your community and identify the ways in which that project will contribute emissions of greenhouse gases throughout its life-cycle. Then inventory the ways in which the project will affect the ability of natural systems to absorb and mitigate greenhouse gases. What are some strategies for reducing these impacts?
1.3 What are the possible threats to indoor environmental quality in your building? Consider possible sources of air pollutants as well as sources of unwanted noise, light and visual impacts. Are there areas where thermal comfort is a problem?
1.4 What waste streams – solid, liquid or other – leave your building, and what is their destination? What impacts do these flows of matter and energy have on the world at large?
1.5 How has land use in your community changed over time? Using a source for archival aerial photographs such as http://www.historicaerials.com, examine how land use has changed over time. Visit your local government office to determine the history of development on your lot or site. What was the site originally before it was developed?
1.6 Sustainable design and construction of the built environment offers the potential for numerous benefits to those who implement it. Which of the major selling points for sustainable design and construction applies to your situation? Who makes decisions about operating practices and remodels/retrofits for your facility? How would you formulate an argument to convince decision makers to invest in sustainable technologies and practices in your home, school or workplace?
1.7 What is the population growth rate in your region or country? Plot the historical trends as well as future projections. How does it compare with the projected global population growth through 2050 shown in Chapter 1?
1.8 Which of the top ten green trends for 2020 will be most important to you, your organization or your community? Why?

References

Ahn, Y. H. and Pearce, A. R. (2007). 'Green construction: contractor experiences, expectations, and perceptions.' *Journal of Green Building*, 2(3), 106–22.

Ahn, Y. H., Pearce, A. R. and Ku, K. H. (2009). 'Green construction: U.S. contractors' status and perception.' *Proceedings of International Conference on Construction Engineering and Management (ICCEM)*, Jeju, Republic of Korea.

Battelle. (2010). 'Top ten green trends for the next decade.' <http://www.reliableplant.com/Read/11575/battelle-top-10-list-forecasts-emerging-green-trends> (accessed 6 November 2010).

BREEAM. (2010). 'What is BREEAM?' <www.breeam.org/page.jsp?id=66> (accessed 20 July 2010).

Center for Chronic Disease Prevention and Health Promotion (CDC) (USA). (2007). 'Healthy youth.' <www.cdc.gov/healthyyouth/asthma/> (accessed 10 July 2010).

Construction Industries Board (CIB). (1997). 'Research information CIB Task Groups and Working Commissions.' *Building Research & Information*, 25(6), 321–34.

Ding, G. K. (2004). 'The development of a multi-criteria approach for the measurement of sustainable performance for built projects and facilities,' PhD dissertation, University of Technology, Sydney, Sydney, Australia.

Ehrlich, P. R. and Holdren, J. P. (1971). 'Impact of population growth.' *Science,*171, 1212–17.

US Energy Information Administration (EIA). (2010). 'Annual energy outlook 2010.' <www.eia.doe.gov/oiaf/aeo/pdf/0383(2010).pdf> (accessed 20 July 2010).

Friedman, T. L. (2009). *Hot, Flat, and Crowded 2.0.* Picador Press, New York.

Heinberg, R. (2007). *Peak Everything: Waking up to the century of declines.* New Society Publishers, Gabriola Island, BC, Canada.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate Change 2007: Impacts, Adaptation, and Vulnerability* <www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm> (accessed 6 November 2010).

Kibert, C. J. (1994). 'Principles of sustainable construction.' *Proceeding of the First International Conference on Sustainable Construction*, Tampa, FL.

Kibert, C. J. (2005). *Sustainable Construction: Green building design and delivery*, John Wiley, Hoboken, NJ.

Kibert, C. J. (2008). *Sustainable Construction: Green Building Design and Delivery*, 2nd edn., John Wiley, Hoboken, NJ.

Klare, M. (2008) *Rising Powers, Shrinking Planet: The new geopolitics of energy.* Metropolitan Books, New York.

Langford, D. A., Zhang, X. Q., Maver, T., MacLeod, I. and Dimitrijeic, B. (1999). 'Design and managing for sustainable buildings in the UK.' *Profitable partnering in construction procurement CIB W92 and CIB 23 Joint Symposium*, London, 373–82.

McGraw Hill Construction. (2008). *2009 Green Outlook: Trends driving change report*, McGraw Hill Construction, New York.

Office of the Federal Environmental Executive (OFEE). (2003). *The Federal Commitment to Green Building: Experiences and expectations*, OFEE, Washington, DC.

Ofori, G. (1998). 'Sustainable construction: principles and a framework for attainment ' *Construction Management and Economics*, 16(3), 141–5.

Organisation for Economic Co-operation and Development (OECD). (2003). *Environmentally Sustainable Buildings: Challenges and policies*, OECD, Paris.

OECD/EIA (2010). 'World energy outlook 2010.' <www.worldenergyoutlook.org/> (accessed 10 January 2011).

Roodman, D. M. and Lenssen, N. (1995). *A Building Revolution: How ecology and health concerns are transforming construction*, Worldwatch Institute, Washington, DC.

Russell, J. S., Hanna, A., Bank, L. C. and Shapira, A. (2007). 'Education in construction engineering and management built on tradition: blueprint or tomorrow.' *Journal of Construction Engineering and Management*, 133(9), 661–8.

Shah, S. (2006). *Sustainable Practice for the Facility Manager*, Blackwell, Oxford, UK.

Sjostrom, C. and Bakens, W. (1999). 'CIB Agenda 21 for sustainable construction: why, how and what.' *Building Research and Information*, 27(6), 347–53.

Spence, R. and Mulligan, H. (1995). 'Sustainable development and the construction industry.' *Habitat International*, 19(3), 279–92.

US Census. (2009). 'November 2008 construction at $1,078.4 billion annual rate.' <www.census.gov/const/C30/release.pdf> (accessed 20 January 2009).

Uher, T. E. (1999). 'Absolute indicator of sustainable construction.' *Proceedings of COBRA 1999*, 243–53, London.

United Nations Environmental Programme (UNEP) (2009). *Building and Climate Change*, UNEP, Paris,.

US Department of Energy (USDOE) (2003). *The Business Case for Sustainable Design in Federal Facilities,* USDOE, Washington, DC.

USDOE (2008). '2008 energy building data book.' , USDOE, Washington, DC. <http://buildingsdatabook.eren.doe.gov/docs/2007-bedb-0921.pdf> (accessed 10 January 2009).

US Department of Labor (USDOL) (2009). 'Construction.' U.SDOL, Washington, DC. <www.bls.gov/oco/cg/cgs003.htm> (accessed 18 February 2009).

US Environmental Protection Agency (USEPA) (2001). *Healthy Buildings, Healthy People: A vision for the 21st century*, USEPA, Washington, DC.

USEPA (2008). 'Municipal solid waste in the United States.' <www.epa.gov/osw/nonhaz/municipal/pubs/msw2008rpt.pdf> (accessed 12 July 2010).

USEPA (2009). 'Green building.' <www.epa.gov/greenbuilding/pubs/about.htm> (accessed 15 April 2009).

USEPA (2010a). 'EPA Energy Star for wastewater plants and drinking water systems.' <www.energystar.gov/index.cfm?c=water.wastewater_drinking_water> (accessed 10 July 2010).

USEPA (2010b). 'EPA promotes water efficiency in the home.' <http://epa.gov/water/water_efficiency.html> (accessed 15 September 2011).

USEPA (2010c). 'The inside story: a guide to indoor air quality.' <www.epa.gov/iaq/pubs/insidest.html> (accessed 15 July 2010).
US Green Building Council (USGBC) (2007). *New Construction and Major Renovation: Reference guide*, USGBC, Washington, DC.
US National Research Council (USNRC). (2004). *Investments in Federal Facilities: Asset management strategies for the 21st century*, National Academies Press, Washington, DC.
USNRC (2008). *Core Competencies for Federal Facilities Asset Management through 2020*, National Academies Press, Washington, DC.

2

History of Sustainability in the Built Environment

To understand the motivation and context for sustainable projects today, it is important to review the history of the sustainability movement and the historical events that influenced it. This chapter describes the origins of the sustainability movement, important meetings, summits, and declarations that set sustainability goals, and the issues that have emerged on an international scale as being important for sustainability.

The birth of the sustainability movement

The birth of the sustainability movement and evolution of contemporary ideas about sustainability can be directly linked to the ideas and principles of environmentalism, which was developed over time in response to the ecosystem problems, resource depletion, and pollution associated with industrial development. A major cornerstone for the ecological movement was the publication of *Silent Spring* by Rachel Carson in the early 1960s describing a world made barren of life because of the hazards of industrial chemicals (Carson 1962). With its emphasis on the harmful effects of insecticides and other chemical products, as well as the use of sprays in agriculture, *Silent Spring* was one of the first instances when the negative impacts of modern development were brought to light. The publication of this book was recognized as the starting point of the modern environmental movement in the United States. In addition to *Silent Spring*, the first Earth Day in 1970 was also a major step in the path to recognize environmental issues. Earth Day is a day that inspires awareness and appreciation for the Earth's natural environment.

Following the first Earth Day, public awareness of the need for concern and action on sustainability-related issues continued to grow. For instance, debate about the role of overpopulation as a threat to the global environment was promoted by the Club of Rome's report *The Limits to Growth* during the 1970s. This book described the 'World3 model', which simulated the consequence of interactions between the Earth and human systems caused by the rapid growth of world population coupled with depletion of finite resource supplies (Meadows et al 1972). Ongoing debate resulting from these ideas led to the First United

Nations Conference on the Human Environment, held in Stockholm in 1972, where an international agreement on desired behaviour and responsibilities to ensure environmental protection were discussed (Ding 2004). In the 1970s, the international oil embargo and energy crisis also led to greater interest in energy efficiency and renewable energy sources including solar, wind and nuclear power.

The actual term 'sustainable development' was first expressed at the World Conservation Strategy meeting in 1980. The aim of the World Conservation Strategy, developed as a result of that meeting, is to help advance the achievement of sustainable development through the conservation of living resources (IUCN 1980). Since the first Strategy meeting, sustainable development has been further popularized as an idea in *Our Common Future*, derived from the findings of the Brundtland Commission on Environment and Development and widely known as the Brundtland Report (WCED 1987). The definition of sustainable development made popular from this report is:

> Development that meets the needs of present generations without compromising the ability of future generations to meet their needs and aspirations.
>
> (WCED 1987)

Actions necessary to achieve sustainable development

- Eliminate poverty and deprivation.
- Conserve and enhance natural resources
- Encapsulate the concepts of economic growth and social and cultural variations into development
- Incorporate economic growth and ecological decision-making.

The Brundtland Report (1987)

The Brundtland Report emphasized a variety of actions needed to achieve the goals of sustainable development. To achieve its stated goals, the report emphasized three fundamental components for sustainable development: environmental protection, social equity and economic growth. The critical objectives of these three fundamental components, known as the triple bottom line, are synthesized in Table 2.1. In the context of these goals, sustainable development must not only minimize environmental problems including global climate change and depletion of fossil fuel resources, but also achieve social components including poverty reduction, equity, and well-being, along with economic components such as economic growth and prosperity.

A wide variety of approaches have been taken around the globe to change the direction of human development toward greater sustainability. A broad spectrum of possible actions is available to support this change, but each specific context requires a solution tailored to its needs, opportunities and constraints. The next section presents examples of specific initiatives within leading nations in the domain of sustainable development and sustainable construction.

Table 2.1 Approaches for achieving the goals of sustainability

Environmental protection	Social equity	Economic growth
• Protecting air, water, land ecosystems • Conserving natural resources (fossil fuels) • Preserving animal species and genetic diversity • Protecting the biosphere • Using renewable natural resources • Minimizing waste production or disposal • Minimizing CO_2 emission and other pollutants • Maintaining essential ecological processes and life support systems • Pursuing active recycling • Maintaining the integrity of the environment • Preventing global warming • Preventing climate changes	• Improving quality of life for individuals, and society as a whole • Alleviating poverty • Achieving satisfaction of human needs • Incorporating cultural data into development • Optimizing social benefits • Improving health, comfort and well-being • Having concern for inter-generational equity • Minimizing cultural disruption • Providing education services • Promoting harmony among human beings and between humanity and nature • Understanding the importance of social and cultural capital • Understanding multidisciplinary communities	• Improving economic growth • Reducing energy consumption and costs • Raising real income • Improving productivity • Lowering infrastructure costs • Decreasing environmental damage costs • Reducing water consumption and costs • Decreasing health care costs • Decreasing absenteeism in organizations • Improving return on investments (ROI)

Sustainability initiatives at a national scale

At the level of individual nations, actions to move toward sustainability have evolved to meet the specific needs of the people of each nation and the conditions in which they live. Each national context has resulted in a variety of approaches to sustainability for the built environment and for development in general. The following subsections describe advances in the sustainability movement over the past 50 years in the United Kingdom, the United States, Australia, Japan and the Republic of Korea. Together, these different nations represent a spectrum of approaches that illustrate the variety of initiatives undertaken worldwide.

Sustainability initiatives in the United Kingdom

The United Kingdom was one of the first countries to initiate strategies to achieve the goals of sustainability. Like other countries such as the United States, members of the environmental movement in the mid-20th century pointed out that there were environmental costs associated with products and materials that were now being consumed. In addition, energy crises in 1973 and 1979 demonstrated that all participants in the construction industry had to consider incorporating energy-saving strategies into all buildings and using renewable energy sources to minimize dependency on non-renewable resources. In its position as a leader of the sustainability movement in the United Kingdom, in 1990 the Building Research Establishment (BRE) created the BRE Environmental Assessment Method (BREEAM) to achieve the goals of sustainability in the construction sector. The purpose of BREEAM was to not only reduce the broad range of environment impacts caused by construction, but also to provide healthy indoor environments to improve occupants' health, well-being and productivity. BREEAM was the first sustainable design and construction assessment tool in the world targeted to buildings. It aimed to provide clients, developers, designers and others with (BREEAM 2010):

- Market recognition for low environmental impact buildings
- Assurance that best environmental practice is incorporated into a building
- Inspiration to find innovative solutions that minimize environmental impact
- A benchmark that is higher than regulation
- A tool to help reduce operating costs and improve working and living environments
- A standard that demonstrates progress towards corporate and organizational environmental objectives.

Its release stimulated the development of green building rating systems in many other countries, including the Leadership in Energy and Environmental Design (LEED) rating system in the United States.

Along with the first green building rating system, the UK government also committed to reduce global and atmospheric environment impacts through a variety of initiatives that had gathered momentum through the development of common strategies and objectives. In addition, the Earth Summit in Rio in 1992, the drafting of Agenda 21 and the subsequent Kyoto conference, described later in this chapter, have led the United Kingdom to a commitment to reduce atmospheric emissions and energy consumption as part of a more sustainable approach to economic development (HM Government 1994).

In 2001, the climate change levy (CCL) was introduced in the United Kingdom to encourage business to become more energy efficient and reduce carbon emissions. The UK government's Department of Energy and Climate Change launched a scheme called the Low Carbon Buildings Program in 2006 toward the same end.

In 2008, the Climate Change Act made the United Kingdom the first country in the world to have a legally binding long-term framework to cut carbon emissions. The Act sets a target for the United Kingdom to reduce carbon emissions to 80 per cent below 1990 levels by 2050. In addition, it also set an interim target of a 34 per cent reduction by 2020 (with the potential to increase this to a 42 per cent cut given an international agreement) and established the concept of carbon budgets. The Act also created a framework for building the United Kingdom's ability to adapt to climate change. This Act requires construction participants to implement sustainable design and construction practices since the construction sector is the single largest sector to produce the carbon emissions leading to climate change. Since the UK building sector accounts for 40 per cent of UK energy usage, and offers the largest single potential opportunity for energy efficiency, the primary components of interest in this legislation are:

- the energy certificate
- Building regulation Part L 2006.

The purpose of the energy certificates is for a building's energy performance to be measured consistently and objectively. This certification helps better-performing buildings to attract a premium, thereby increasing the business case for energy-efficient buildings. Certificates grade a building's energy performance on a scale from A–G. Currently, there are two types for commercial buildings:

- Asset certifications – Measure the intrinsic energy performance of the building based on its design. They have to be renewed every 10 years and must be shown at the point of sale, lease and lease renewal.
- Operating certificates – Measure the building's actual performance based on metered energy usage. They are renewed annually and apply to public-sector buildings with a usable floor area greater than 1000 square metres. They must be displayed publicly.

The Building Regulations Part L 2006 was revised in 2010 to comply with the EU Directive on the Energy Performance of Buildings (EU EPBD). The revisions to Part L set maximum carbon emissions for whole buildings. Such emissions occur primarily through energy consumption. The regulations apply to both the construction of new buildings and renovations of existing buildings. For new buildings, Part L reduces carbon emissions by 25 per cent from 2002 standards. The net reduction of 40 per cent from pre-2002 is often used as an indicator of improvement (www.carbontrust.co.uk). In addition, the UK government has announced targets for all new housing to be 'zero carbon' by 2016, with new commercial buildings following suit by 2019.

Sustainability in the United States

From the first Earth Day in 1970 to today, sustainability has had a rich and evolving history in the United States. Unlike the European countries from which much of today's American population originated, the United States offered a vast land area and abundant natural resources which have shaped both US development patterns and the environmental problems of the past 40 years. The influence of presidential leadership and priorities has also had a significant effect on both policy and public sector investment during this time.

Beginning with the signing into law on 1 January 1970 of the National Environmental Policy Act (NEPA), the decade from 1970 to 1980 saw a significant increase in attention to environmental problems. NEPA was the first formal legislation to require all federal government agencies to prepare environmental assessments and environmental impact assessments for federal projects, and formally incorporate public input as part of the project decision-making process. Followed by amendments to the Clean Air Act and passage of the Occupational Safety and Health Act in 1970 and Clean Water Act in 1972, this period saw a significant strengthening of environmental regulations governing both public and private-sector activities. Substantial investment was made in the construction of infrastructure for water and waste treatment. It also was the first time provisions were made for citizens to bring lawsuits against other citizens, corporations or government agencies for violating environmental laws. Over time, citizen suits have become an important way to ensure compliance with environmental laws. Non-profit groups often prosecute these suits on behalf of citizens who have legal standing to sue under various environmental laws.

The years between 1980 and 1992 saw an overall weakening of environmental policy as a reflection of the economic and corporate priorities of the administration during that time. Through administrative changes such as budget reductions and changes in agency leadership through political appointments, the federal government's role in environmental protection was significantly reduced. A significant action during this period was the awarding of new powers to the federal Office of Management and Budget (OMB) to require a favourable cost–benefit analysis of regulations before they were implemented. This resulted in the delay of new environmental regulations, among other effects. Overall, the atmosphere was one of relief from regulatory requirements in favor of industry-driven, voluntary compliance.

In 1992, the American Institute of Architects launched a sustainability initiative with the development of the Environmental Resource Guide (ERG). The aim of the ERG was to create a simplified methodology for assessing the environmental impact of building materials and to serve as a vehicle for disseminating that information to the building community at large. In addition, the ERG acknowledged for the first time the use of life cycle assessment (LCA) methods in mainstream architectural practices. In 1992, the US Environmental Protection Agency (USEPA) and the US Department of Energy (USDOE) also launched the Energy Star programme to save money and protect the environment through energy-efficient products and practices.

In 1992, the first local residential green building programme was introduced in Austin, Texas. At the commercial level and spanning both the public and private sector, the creation of the USGBC and its development and implementation of the Leadership in Energy and Environmental Design (LEED) green building rating system were significant milestones in the sustainable design and construction movement in the United States (Ahn and Pearce 2007; Ahn et al 2009). LEED was launched in a pilot programme in 1993, as a third-party certification scheme with hopes of becoming the nationally accepted benchmark for the design, construction and operation of high-performance sustainable buildings.

Between 1993 and 2000, a new administration prompted an overall change in the direction of environmental policy, with many of the influences of the previous decade being reversed. Since 2000, several major influences have shaped both public and private-sector priorities related to sustainability in the United States. First, the change of administration in 2000, followed soon after by the terrorist attacks of September 11, 2001 marked a significant shift in investment and facility-related priorities in the public sector. In response to potential terrorist threats including both the 9/11 attacks and an earlier attack by a domestic terrorist on the Oklahoma City Federal Building in 1995, a number of new standards were put into place for public-sector built facilities to reduce damage in the event of a terrorist attack. These standards have sometimes been perceived to conflict with sustainability objectives, although they are also complementary in some regards. For instance, some materials such as aerated concrete exhibit both enhanced blast resistance and outstanding energy performance, resulting in more energy-efficient buildings that meet anti-terrorism standards.

Another key influence in the past decade has been an increased awareness of factors contributing to global climate change such as fossil fuel emissions. Since this has been coupled with a lengthy military engagement overseas in the Middle East, the US public is becoming increasingly aware of risks posed by future fossil fuel shortages, climate change, and dependence on international sources of oil in politically unstable areas. In response to this awareness, the most recent administration taking office in 2009 has implemented aggressive policy measures directed toward increasing sustainability of federal government buildings. Government investment in the development of new energy assets and technologies has also increased, as have programmes directed toward achieving high-performance, net-zero-energy buildings. Overall, the climate at present is favourable to sustainable construction, with a variety of government policies and incentives in place to stimulate both the development and broad adoption of new technologies.

US governments at federal, state and local levels have attempted to boost the use of sustainable design and construction practices by legislation, executive orders, resolutions, ordinances, policies and incentives. The US federal government, which is the single largest facility owner with about 500,000 facilities worldwide, has been instructed by many federal policies to implement certain aspects of sustainable design and construction in its own facilities, including energy and water efficiency, use of recycled content, bio-based or other environmentally preferable building products, and waste recycling, including demolition debris (NRC 2004, 2008; OFEE 2003; USDOE 2003). Table 2.2 lists some of the current sustainability-related policies, both legislative and executive orders, applicable in the United States at the federal level.

In addition to federal policies, many US state and local governments also mandate sustainable design and construction for their new construction and existing facilities. For example, in January 2010, the State of California adopted the first statewide mandatory building code in the United States. Known as CALGreen, the code sets a new framework for recognizing and codifying an important set of risks to public health and safety not previously considered or addressed in the state's code of

Table 2.2 US federal government policies for green building

Policy	Name of Policy	Content
EISA 2007	Energy Independence and Security Act of 2007	The EISA of 2007 is the energy legislation to save energy in areas including the automotive, fuels production, agribusiness, appliance manufacturing, and building design and construction sectors. Vehicle fuel economy must improve substantially by 2020 to meet prescribed standards. Biofuel production must increase ninefold by 2022 to meet the renewable fuel standard for gasoline. Numerous electric appliances and products are subject to new minimum efficiency standards. Federal agencies must reduce their energy consumption by 30 per cent within eight years, and new commercial buildings are targeted to produce as much energy as they consume by 2030.
EPACT 2005	Energy Policy Act of 2005	The EPACT of 2005 contains legislation to change energy issues in the United States. The major provisions affecting Federal facilities include: • energy management goals • energy use measurement and accounting • procurement of energy-efficient products • energy-efficient products in federal categories • federal building performance standards • enhancing efficiency in management of federal lands • federal purchase requirements (renewable) • use of photovoltaic energy in public buildings • installation of photovoltaic systems • study of energy-efficiency standards • renewable energy on federal land.
Executive Order 13514 (2009)	Federal Leadership in Environmental, Energy, and Economic Performance	The order builds on and expands the energy reduction and environmental requirements of EO 13423 by making reductions of carbon emissions a priority of the federal government, and by requiring agencies to develop sustainability plans focused on cost-effective projects and programmes. It also requires agencies to meet a number of energy, water and waste reduction targets, including 30 per cent reduction in vehicle fleet petroleum use by 2020; 26 per cent improvement in water efficiency by 2020; 50 per cent recycling and waste diversion by 2015; 95 per cent of all applicable contracts will meet sustainability requirements; implementation of the stormwater provisions of EISA 2007; and development of guidance for sustainable federal building locations.

regulations. The code, effective in January 2011, slashes water use, mandates the recycling of construction waste, and cuts back on polluting materials in new homes, schools, hospitals and commercial buildings statewide (CBSC 2010). In addition to the State of California, in 2009 the International Code Council launched the development of a new International Green Construction Code (IGCC) initiative, denoted ‘Safe and Sustainable: By the Book’. The IGCC is committed to developing a model code focused on new and existing commercial buildings addressing green building design and performance. The purpose of the IGCC is to provide a comprehensive set of requirements intended to reduce the negative impact of buildings on the natural environment.

Due to the efforts of multiple organizations in promoting green building in the United States, the value of sustainable design and construction has significantly grown from a small, burgeoning market of approximately 2 per cent of both nonresidential and residential construction, valued at a total of $10 billion ($3 billion for residential and $7 billion for nonresidential) to $36–49 billion (approximately 6 per cent to 9 per cent) in 2008 (McGraw Hill Construction 2008). The *2009 Green Outlook* report published by McGraw Hill Construction (2008) estimates that sustainable design and construction starts could triple over the next five years and reach $96–140 billion. From this prediction, it can be seen that sustainable design and construction is moving toward becoming general practice for developing new facilities and operating and maintaining existing ones.

Sustainability initiatives in Australia

Australia's sustainability movement in the 20th century evolved from a strong ethic of environmentalism that seeks to preserve wilderness from development, including campaigning for the creation of national parks and preserving wilderness. In the construction sector, the National Australian Built Environmental Rating System (NABERS) was launched as the Australia Building Greenhouse Rating (ABGR) in 1998 to rate buildings on the basis of their measured operational impacts on the environment, and provide a simple indication of how to manage these environmental impacts compared with peers and neighbours. NABERS is a 'world first initiative' to help building owners and tenants measure and benchmark their operational impact on the environment. It is administered and managed by the New South Wales Department of Environment and Climate Change (DECC). NABERS rates buildings from one to five stars, with five stars representing exceptional greenhouse and environmental performance.

In 2003, the Green Building Council of Australia (GBCA) developed a green building standard called Green Star, a voluntary environmental rating system for buildings in Australia. The Green Star rating system, discussed further in Chapter 4, considers a broad range of practices for reducing the environmental impact of buildings, improving occupant health and productivity, and cost-saving opportunities. Currently, the Green Star rating system assesses nine categories including management, indoor environmental quality, energy, transport, water, materials, land use and ecology, emissions, and innovation. Since the first Green Star rating in Australia was awarded to 8 Brindabella Circuit at Canberra Airport in 2004, 361 Green Star Projects have been certified as of October 2010. As of this time, 11 per cent of all Australia's central business district (CBD) commercial office buildings had been certified by Green Star. Clearly, green building is becoming a business imperative in Australia.

The Australian government has led the way in the use of green leases, introducing the Green Lease Schedule in 2006 as a key component to its Energy Efficiency in Government Operation policy. Green leases are an innovative management mechanism to enable tenants and building owners to monitor and meet a building's energy target annually.

In 2007, the Rudd government finally ratified the Kyoto Protocol to reduce carbon emissions, even though the previous John Howard government had refused to ratify in 1997. At the 2009 United Nations Framework on Climate Change (2009 Copenhagen) Summit, Australia committed to reduce its carbon emissions from 5 per cent to 25 per cent by 2020 compared to the year 2000.

In October 2008, the Council of Australian Government (COAG) agreed to develop a National Strategy for Energy Efficiency (the Strategy) to accelerate energy-efficiency efforts, to streamline roles and responsibilities across levels of governments, and to help households and business prepare for the introduction of the Carbon Pollution Reduction Scheme. These efforts are all contributing toward the growing awareness and change in Australia to become more environmentally friendly.

Japanese sustainability initiatives

Japanese sustainability initiatives in construction have been influenced by the homeland attributes of the country. Japan is an island nation with high density (127 million people in 146,000 square miles) and has limited natural resources including domestic fossil fuels. In the context of these circumstances, the 1970s oil supply shock caused the Japanese government to be interested in sustainability initiatives, especially energy efficiency in the construction sector. As a result of the oil shock, the Japan government legislated a Law Concerning the Rational Use of Energy in 1972 to reduce energy consumption. Since then, Japan has created additional energy conservation laws that regulate energy consumption by factories, commercial buildings, and now residential buildings. In addition to regulations, consumer demand has been dramatically reduced by higher energy costs (twice those of the United States). For example, according to a recent *Forbes Magazine* report, Japan consumes only 4500 BTUs for every US$1 of GDP compared with 9000 BTUs in the United States, 6100 BTUs in Germany, and 35,000 BTUs in China.

In addition to energy issues, Japan is one of the leaders in relation to carbon emissions. Since the Kyoto Protocol was adopted in Kyoto, Japan on 11 December 1997 to reduce greenhouse gas emissions, the Japanese government has committed to a 6 per cent reduction by 2012 from the 1990 level, even though the Kyoto Protocol only requires 5.2 per cent for 37 industrialized countries, of which Japan is one. This commitment also indicates that the Japanese government has demonstrated an interest in environmental issues. Furthermore, Japan has committed to reduce 25 per cent of carbon emissions by 2020 from 1990 levels at the United Nations Framework Convention on Climate Change (UNFCCC), the Copenhagen Accord in December 2009.

Along with these sustainability initiatives, the sustainable design and construction movement in Japan is a bottom-up process. There are no top-down, mandatory sustainable design and construction regulations in Japan, as in many European countries. One of the significant initiatives related to sustainable design and construction was a joint industrial/government/academic project that was initiated with the support of the Housing Bureau's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in April 2001. This project led to the establishment of a new organization, the Japan GreenBuild Council (JaGBC)/Japan Sustainable Building Consortium (JSBC), with its secretariat administered by the Institute for Building Environment and Energy Conservation (IBEC). JaGBC, JSBC and subcommittees worked together on research for the development of the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), described in detail in Chapter 4. CASBEE measures both the improvement in living amenities for building users within a property and the negative environmental impacts within and outside the property. It has two main categories, environmental quality and environmental load. The environmental quality category emphasizes:

- indoor environment
- quality of service
- outdoor environment on site.

Environmental load focuses on:

- energy
- resources and materials
- off-site environment.

Since its inception, the enhancement and diffusion of CASBEE have been promoted under the MLIT Environmental Action Plan (June 2004) and Kyoto Protocol Target Achievement Plan, which was approved by the Cabinet on 28 April 2005. In recent years, several local authorities have introduced CASBEE into their building administration to promote the rating system. Currently, 15 major local governments across the country have mandated the use of CASBEE, or have created incentive programmes to help promote its adoption. For example, Osaka City and Nagoya City subsidize highly rated projects, Kawasaki City provides lower-interest-rate home loans, and other cities provide some flexibility in the building permit and review process. As of January 2009, more than 3600 buildings have been submitted for CASBEE evaluation.

Republic of Korea sustainability initiatives

Korea's sustainability movement in the construction industry was initiated by the 1970s oil shock along with the underlying nature of the country, since the Republic of Korea is a small country with dense population and also imports significant amounts of natural resources including fossil fuels. As a result of the severe shock of two oil embargos, the Korean government implemented several energy-related government policies to reduce energy consumption in the construction sector. As a result of these government policies, construction participants have been implementing energy-saving strategies and technologies to reduce energy consumption in the building sector.

In addition to energy issues, the Republic of Korea also has participated in the UNFCCC. For example, the Korean government ratified the Kyoto Protocol in 2002 to reduce carbon emissions to mitigate global warming. Furthermore, Korea has committed to reduce 4 per cent of carbon emissions by 2020 from 2005 levels at the UNFCCC Copenhagen Accord in December 2009.

Along with these sustainability-related initiatives, sustainable design and construction practices have been implemented in various construction projects to achieve the goals of sustainability. One of the major initiatives was to develop and implement a Green Building Certification System (GBCS) to evaluate the environmental performance of buildings. In 2000, GBCSs were developed by the Korea National Housing Corporation (KNHC), Korea Management Association Quality Assurance (KMAQA), Korea Institute of Energy Research (KIER), and KICT (Korea Institute of Construction Technology) for office and multi-unit residential buildings. In 2002, a GBCS for mixed-use buildings and office buildings was implemented by the Ministry of Construction and Transportation and the Ministry of Environment. This GBCS in Korean includes four major categories to achieve the goals of sustainability in the building sector:

- land use and commuter transportation
- energy resources consumption and environmental loads
- ecological environment
- indoor environmental quality.

Then with the revision to the construction ordinance in 2005, the system was overseen as certification based on law. Since then, the GBCS in Korea has expanded to other building types including multi-family housing units, office buildings, mixed-use residential buildings, schools, retail markets and lodging facilities. In 2010, the Ministry of Land, Transport and Maritime Affairs and the Ministry of Environment to GBCC amended the law to implement GBCS for all types of building to achieve the goals of sustainability. The sustainable design and construction movement in the Republic of Korea is a top-down process from the government to construction participants.

Multinational sustainability initiatives

Beyond the multitude of national efforts to increase sustainability, there have been several significant international initiatives to achieve the goals of sustainability. The following sections describe the drivers and significant outcomes of these initiatives, including the 1992 Earth Summit and its follow-on events, the UN Environment Programme, the UNFCCC, the G8 and G20 Summits, and concluding with an overview of building-specific international efforts.

1992 Earth Summit and Agenda 21 Principles

The first significant international initiative following the Brundtland Commission was the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 and known popularly as the Earth Summit. At this Summit, sustainable development was discussed with the primary goal of:

> com[ing] to an understanding of 'development' that would support socio-economic development and prevent the continued deterioration of the environment, and to lay a foundation for a global partnership between developing and the more industrialized countries, based on mutual needs and common interests, that would ensure a healthy future for the planet,
>
> (UNCED 1992)

In Rio, 178 countries' governments adopted three major agreements aimed at changing the traditional approach to development (UNCED 1992):

- Agenda 21 – a comprehensive programme for global action in all areas of sustainable development.
- The Rio Declaration on Environment and Development – a series of principles defining the rights and responsibilities of States.
- The Statement of Forest Principles – a series of principles to underlie the sustainable management of forests worldwide.

Based on these three agreements, the implementation of Agenda 21, a sustainable development action plan, was a key role given to the United Nations because it helped governments to take steps to integrate the concept of sustainable development into all relevant policies and areas. The other two documents were legally binding international treaties. Table 2.3 lists the 27 core principles defined in Agenda 21.

Table 2.3 Agenda 21 principles

Principle 1 Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.
Principle 2 States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.
Principle 3 The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

Principle 4
In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.

Principle 5
All States and all people shall cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to decrease the disparities in standards of living and better meet the needs of the majority of the people of the world.

Principle 6
The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, shall be given special priority. International actions in the field of environment and development should also address the interests and needs of all countries.

Principle 7
States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command.

Principle 8
To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.

Principle 9
States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies.

Principle 10
Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress/remedy, shall be provided.

Principle 11
States shall enact effective environmental legislation. Environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries.

Principle 12
States should cooperate to promote a supportive and open international economic system that would lead to economic growth and sustainable development in all countries, to better address the problems of environmental degradation. Trade policy measures for environmental purposes should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade. Unilateral actions to deal with environmental challenges outside the jurisdiction of the importing country should be avoided. Environmental measures addressing transboundary or global environmental problems should, as far as possible, be based on an international consensus.

Principle 13
States shall develop national law regarding liability and compensation for the victims of pollution and other environmental damage. States shall also cooperate in an expeditious and more determined manner to develop further international law regarding liability/compensation for adverse effects of environmental damage caused by activities within their jurisdiction or control to areas beyond their jurisdiction.

Table 2.3 Continued

Principle 14
States should effectively cooperate to discourage or prevent the relocation and transfer to other States of any activities and substances that cause severe environmental degradation or are found to be harmful to human health.

Principle 15
In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Principle 16
National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade/investment.

Principle 17
Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.

Principle 18
States shall immediately notify other States of any natural disasters or other emergencies that are likely to produce sudden harmful effects on the environment of those States. Every effort shall be made by the international community to help States so afflicted.

Principle 19
States shall provide prior and timely notification and relevant information to potentially affected States on activities that may have a significant adverse transboundary environmental effect and shall consult with those States at an early stage and in good faith.

Principle 20
Women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainable development.

Principle 21
The creativity, ideals and courage of the youth of the world should be mobilized to forge a global partnership in order to achieve sustainable development and ensure a better future for all.

Principle 22
Indigenous people and their communities and other local communities have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development.

Principle 23
The environment and natural resources of people under oppression, domination and occupation shall be protected.

Principle 24
Warfare is inherently destructive of sustainable development. States shall therefore respect international law providing protection for the environment in times of armed conflict and cooperate in its further development, as necessary.

Principle 25
Peace, development and environmental protection are interdependent and indivisible.

Principle 26
States shall resolve all their environmental disputes peacefully and by appropriate means in accordance with the Charter of the United Nations.

Principle 27
States and people shall cooperate in good faith and in a spirit of partnership in the fulfillment of the principles embodied in this Declaration and in the further development of international law in the field of sustainable development.

Subsequent world summits on sustainability

After the Earth Summit, the Commission on Sustainable Development (CSD) in the UN Division for Sustainable Development (DSD) was created in December 1992 to ensure effective follow-up of UNCED and to monitor and report on implementation of the agreements at the local, national, regional and international levels. In 1994, the global conference on Sustainable Development of Small Island Developing States (SIDS), held in Bridgetown, Barbados, adopted the Barbados Programme of Action (BPOA), which set forth specific actions and measures for the sustainable development of SIDS. In 1997, the special session of the General Assembly Earth Summit adopted a Programme for the Further Implementation of Agenda 21, including a programme of work to be undertaken by CSD from 1998 to 2002. The World Summit on Sustainable Development (WSDD), held in Johannesburg, South Africa from 26 August to 4 September 2002, evaluated obstacles to progress and results achieved since the 1992 Earth Summit. WSDD adopted the Johannesburg Plan of Implementation (JPOI), which provided a more focused approach with concrete steps and quantifiable, time-bound targets and goals. In 2005, at the ten-year review of the Barbados Programme of Action for SIDS held in Port Luis, Mauritius, participating states adopted the Mauritius Strategy for the Further Implementation of the BPOA. Currently, the UNDSD focuses on the following topics:

- climate change
- energy
- small island developing states
- sustainable consumption and production patterns
- water.

United Nations Environment Programme

One of the significant organizations for sustainability today is the United Nations Environment Programme (UNEP) that was established after the UN Conference on the Human Environment in 1972. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing and enabling nations and peoples to improve their quality of life without compromising that of future generations. UNEP currently undertakes a variety of actions to promote sustainability, including (UNEP 2010b):

- Assessing global, regional and national environmental conditions and trends.
- Developing international agreements and national environmental instruments.
- Strengthening institutions for the wise management of the environment.
- Integrating economic development and environmental protection
- Facilitating the transfer of knowledge and technology for sustainable development.

- Encouraging new partnerships and mind-sets within civil society and the private sector.

One of the key tasks UNEP has undertaken to achieve the goals of sustainability was to make UNEP itself climate-neutral through installing solar photovoltaic systems along with other sustainable design and construction features in its new headquarters building in Nairobi, Kenya. The 215,000 square foot building was planned to be a global showcase of a clean and sustainable building, with the following features (UNEP 2010a):

- the promotion and use of local building materials
- rainwater harvesting
- water recycling and reuse in an artificial wetland
- green zones inside the building
- sustainability guidelines for the users of the building
- natural cooling, with no need for air conditioning
- an environmental management system
- energy neutrality (net zero energy) through an integrated photovoltaic (PV) system.

United Nations Framework Convention on Climate Change

Even though there are many factors impacting on sustainability as described in Table 2.1, energy and carbon emissions have been an extensive focus of many organizations and governments, with the aim to minimize climate change. In relation to carbon emissions, one of the major efforts was the Kyoto Protocol adopted in Kyoto, Japan, on 11 December 1997. This protocol was an international agreement linked to the UNFCCC. The major feature of the Kyoto Protocol was that it set binding targets for 37 industrialized countries and the European community for reducing carbon emissions. This amounted to an average of 5 percent against 1990 levels over the five-year period from 2008 to 2012. The basic mechanisms of the Kyoto Protocol are to:

- create emission trading – known as the carbon market
- create clean development mechanisms
- conduct joint implementation among countries.

This mechanism was designed to help countries stimulate green investment and meet their emission targets in a cost-effective way. In addition, under the Kyoto Protocol, countries' actual emissions have to be monitored and precise records have to be kept of the trades carried out. The recorded data has to be kept as part of an international transaction log in the registry system to verify compliance with the rules and commitments of the Protocol. The Kyoto Protocol is an important first step towards a truly global emission reduction regime that can stabilize carbon emissions and provide the essential architecture for any future international agreement on climate change. In anticipation of the Kyoto

Protocol's expiration in 2012, world leaders held the 2009 United Nations Climate Change Conference, known as the Copenhagen Summit, at Copenhagen, Denmark, from 7 to 18 December 2009. At the summit, the Copenhagen Accord was drafted by the United States, India, China, Brazil and South Africa and signed by 114 countries. The accord recognized that climate change is one of the greatest challenges of the present day and that actions should be taken to keep any temperature increases to below 2°C. To mediate climate change, countries have proposed to reduce carbon emissions by increasing energy efficiency and developing renewable energy sources.

The Group of Eight (G8) Summit

The Group of Eight (G8) is a forum created by France in 1975 for the governments of France, Germany, Italy, Japan, the United Kingdom, Canada, Russia and the United States. Since G8 countries represent the world's leaders in sustainability, G8 leaders have recognized the importance of promoting energy efficiency as a means to save valuable resources and money, reduce pollution, and mitigate climate change. The 2005 Gleneagles Declaration expressed support for specific energy-efficiency activities and policies related to buildings, appliances, transportation, industry, power generation and other sectors. At the St Petersburg Summit in 2006, global energy security including climate change was the main topic of discussion to minimize global energy challenges. The 2006 St Petersburg Declaration reiterated support for existing proposals and extended discussions to improve energy efficiency to the following key areas (G8 2006):

- increasing transparency, predictability, and stability of global energy markets
- improving the investment climate in the energy sector
- enhancing energy efficiency and energy saving
- diversifying energy mix
- ensuring physical security of critical energy infrastructure
- reducing energy poverty
- addressing climate change and sustainable development.

At their 2007 Summit in Heiligendamm, Germany, the G8 leaders issued a declaration that placed even more emphasis on improving energy efficiency as a means to address climate change, energy security and sustainable development. At the Hokkaido G8 Summit in 2008, the International Energy Agency (IEA) provided the first assessment of the progress in G8 member countries and the European Commission in meeting the Global Energy Security Principles agreed upon at the 2006 St Petersburg summit. In addition, at the Hokkaido Summit leaders reaffirmed the critical role improved energy efficiency can play in addressing energy security, environmental and economic objectives (IEA 2009a). Participants went even further than in previous summits and committed to maximizing implementation of the 25 IEA energy-efficiency

Case Study: United Nations Office Complex, Nairobi, Kenya

Opened in spring 2011, the new United Nations Office Complex located in Nairobi, Kenya has received acclaim for its innovative features designed to reduce the carbon footprint of the building. Part of the UN 'Greening the Blue' initiative, the project's four buildings house the headquarters of the United Nations Environment Programme (UNEP) and the UN Human Settlements Programme (UN-HABITAT). Approximately 1200 staff are housed in the complex, which is net zero energy or energy neutral due to its 6000 sq m of solar panels and energy-efficient design features including extensive daylighting, innovative IT design and elimination of mechanical HVAC. While the facility is not completely energy independent, over the course of a given year, the grid-tied complex is expected to produce as much power as it consumes overall. Additional features of the complex include:

- A smart location in Nairobi, where the mild climate means that no mechanical ventilation, heating or cooling is required, and within the city itself, as part of a 'green lung' area on the city's outskirts that serves as a habitat for indigenous trees, birds, and small mammals.
- Rainwater collection from roof areas that feeds fountains and ponds at the four entrances to the complex, eliminating the use of potable water for this purpose.
- Water reuse for landscaping from sewage treated on site through a state-of-the-art aeration system, and use of indigenous plants to minimize irrigation needs.
- Daylighting design using central atria and light wells of toughened glass located at floor level and stacked to allow light penetration to ground level, supplemented with low-energy automated lighting systems.
- Central atrium using a thermal chimney effect to naturally ventilate the buildings.
- Four distinct landscaped areas along the atria in the centre of the buildings (representing Kenya's four major climatic zones of coastal, desert, savannah, and high-altitude forest) that are designed to require minimal water, encourage biodiversity, and provide cool and beautiful interior gardens.
- Innovative data center design using information technology pre-assembled component (ITPAC) external server rooms, which employ negative air pressure to draw air through cool water to manage server temperatures, thus removing the need for air conditioning.
- Use of notebook computers instead of desktop pcs to reduce plug loads.
- Solar hot water heating for kitchen areas.
- Operable windows of high quality solar glass and open office plans.
- North–south orientation to achieve maximum daylight with minimum heat intake.
- High recycled content carpet that is also recyclable, and environmentally friendly paint.
- Dual-flush toilets, expected to reduce water use in bathrooms by up to 60 per cent.

Source

UNEP (2011). 'Building for the future: a United Nations showcase in Nairobi.' <www.unep.org/gc/gc26/Building-for-the-Future.pdf> (accessed 10 October 2011).

The central atrium in each building contains a landscaped area featuring one of the four major climatic zones of Kenya. All atria use minimal water and highlight biodiversity.

Translucent glass blocks provide a path for light from rooftop skylights to pass through to lower floors.

Local contractors were used during construction to help build capacity for green building.

Table 2.4 G8/IEA energy-efficiency recommendations

- Across sectors
  1. Measures for increasing investment in energy efficiency
  2. National energy-efficiency strategies and goals
  3. Compliance, monitoring, enforcement and evaluation of energy-efficiency measures
  4. Energy-efficiency indicators
  5. Monitoring and reporting progress with the IEA energy-efficiency recommendations themselves
- Buildings
  1. Building codes for new buildings
  2. Passive energy houses and zero-energy buildings
  3. Policy packages to promote energy efficiency in existing buildings
  4. Building certification schemes
  5. Energy-efficiency improvements in glazed areas
- Appliances
  1. Mandatory energy performance requirements or labels
  2. Low-power modes, including standby power, for electronic and networked equipment
  3. Televisions and set-top boxes
  4. Energy performance test standards and measurement protocols
- Lighting
  1. Best practice lighting and the phasing-out of incandescent bulbs
  2. Ensuring least-cost lighting in non-residential buildings and the phasing-out of inefficient fuel-based lighting
- Transport
  1. Fuel-efficient tires
  2. Mandatory fuel-efficiency standards for light-duty vehicles
  3. Fuel economy of heavy-duty vehicles
  4. Eco-driving
- Industry
  1. Collection of high-quality energy-efficiency data for industry
  2. Energy performance of electric motors
  3. Assistance in developing energy management capability
  4. Policy packages to promote energy efficiency in small and medium-sized enterprises
- Utilities
  1. Utility end-use energy-efficiency schemes

recommendations prepared for the G8 (IEA 2009b). Table 2.4 lists these 25 energy efficiency policy recommendations across seven priority areas (IEA 2009b).

In addition, at the 2009 L'Aquila Summit in Italy, participants also assessed G8 countries' and the European Commission's progress on the seven key areas. Based on G8 World Summits and declarations, global energy security is one of the main topics for sustainable development and sustainable growth.

The Group of Twenty (G20) Summit

The Group of Twenty (G20) was formally established in 1999 to bring together major industrialized and developing economies to discuss key issues in the global economy. The member nations are the United

States, Japan, the United Kingdom, France, Germany, Italy, Canada, South Korea, Russia, China, India, Indonesia, Argentina, Brazil, Mexico, Australia, South Africa, Saudi Arabia, Turkey, and the European Union (G20 2010). In the third summit held in Pittsburgh, USA, from 24 to 25 September 2009, member countries agreed to prepare international cooperative measures for sustainable and balanced growth of the world economy. Leaders' statements at the Pittsburgh Summit also emphasized the importance of 'energy security and climate change'.

Several key statements were made at the Pittsburgh Summit. First, world leaders stated that 'Access to diverse, reliable, affordable and clean energy is critical for sustainable growth' (G20 2009). Leaders noted the St Petersburg Principles on Global Energy Security, which recognize the shared interest of energy producing, consuming and transmitting countries in promoting global energy security. Thus, world leaders committed to:

- Increase energy market transparency and market stability by publishing complete, accurate and timely data on oil production, consumption, refining and stock levels, as appropriate, on a regular basis, ideally monthly, beginning by January 2010.
- Improve regulatory oversight of energy markets by implementing the International Organization of Securities Commissions (IOSCO) recommendations on commodity futures markets and calling on relevant regulators to collect data on large concentrations of trader positions on oil in the national commodities future market.

In addition, world leaders emphasized the importance of enhancing energy efficiency, which could play an important, positive role in promoting energy security and fighting climate change. To increase energy efficiency, leaders committed to ration and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption. In addition, leaders agreed to support clean energy, renewables, and technologies that dramatically reduce carbon emissions.

World leaders also stated that 'Increasing clean and renewable energy supplies, improving energy efficiency, and promoting conservation are critical steps to protect our environment, promote sustainable growth and address the threat of climate change.' Thus, world leaders committed to:

- Make stimulus investment in clean energy, renewables, and energy efficiency and provide financial and technical support for such projects in developing countries.
- Take steps to facilitate the diffusion or transfer of clean energy technology, including conducting joint research and building capacity.

Finally, world leaders agreed to work for a resilient, sustainable and green recovery. In addition, they will take strong action to address the threat of dangerous climate change.

The concept of sustainability must balance the social, economic, and environmental components of development to enable all people to meet their basic needs and improve their quality of life, while ensuring that the natural systems, resources and diversity upon which they depend are maintained and enhanced, for both their benefit and that of future generations. The construction industry with its many activities has a major role in maintaining economic growth and quality of life. But it is also a major contributor to negative impact on the environment, including carbon emissions, pollution, global energy security and resource depletion, so it could make a significant potential contribution to achieving the goals of sustainability. The next section describes several significant construction-specific efforts to achieve sustainability at the international level.

Construction-specific international efforts

The international sustainable design and construction movement was spurred in the early 1990s with the UK BRE's development of BREEAM in 1990 (see Chapter 4). Following soon thereafter to achieve the goals of Agenda 21 in the built environment, the Counseil International du Batiment (CIB), the leading international organization for research collaboration in building and construction, recognized the importance of environmental concerns and commitment in the construction industry. In the early 1990s, a number of CIB activities were initiated where work was expressly aimed at contributing to achieving more sustainable design and construction.

For example, Task Group 8 (TG8) was established in 1992 and in 1998 was transformed into the working commission W100 on Environmental Assessment of Buildings (Sjostrom and Bakens 1999). TG8 provided an international forum for coordination of research and exchange of information. It also aimed to promote awareness of key sustainability issues among those who commission, design, building, maintain and use buildings (Kibert 1994). The scope of the Task Group covers the effects on the environment of buildings, the materials used in their construction, and their eventual demolition.

Task Group 16 (TG16), 'Best practice for sustainable construction', was established in 1996 to collect, analyse and disseminate international best practice for sustainable construction within a consensus-based conceptual framework that defined topics and aspects of sustainable development in construction (CIB 1997). Likewise, Task Group 39, 'Deconstruction', focused on the technical, economic and policy issues that had to be addressed to foster disassembly rather than demolition of buildings, in order to make salvaged building materials a viable alternative to landfilling (Sjostrom and Bakens 1999).

In June 1998, the Working Commission published a report as the first result of the International CIB W082 Project, 'What will be the consequences of sustainable development on the construction industry by the year 2010?' The study focused on investigating the relationship, and clearly defining the links, between the principles of sustainable development and the construction sector. Later, CIB W100, the Working Group on Environmental Assessment on Buildings, found a number of countries developing and implementing environmental assessment methods and tools for building (Boonstra and Pettersen 2003).

In parallel to CIB's efforts, the International Initiative for Sustainable Built Environment (iiSBE) was established to actively facilitate and promote the adoption of policies, methods and tools to accelerate the movement towards a global sustainable built environment. The iiSBE has sponsored the SB global conference series that began at Maastricht in 2000. It then went on to Oslo in 2002, Tokyo in 2005 and Melbourne in 2008. The aim of iiSBE is to facilitate international sustainable building assessment. Its main assessment method, the Sustainable Building Tool (SBT), is used at the conference to assess or rate exemplary buildings worldwide. The SBT is discussed in greater detail in Chapter 4.

Organizations and governance in 2020

What will society say of the history of sustainability in 2020? To a large extent, this history will be shaped by the organizations that provide structure and governance to society as it develops.

The future will also be shaped by the needs of humans for shelter and infrastructure as they evolve over time. The types of facilities we need and the features they have will be different in 2020 due to changes in population demographics, human expectations, climate and other factors. Trends that will be reflected in our built environment include resource scarcity, climate change, ageing populations and the urbanification of society. The organizations responsible for those facilities, including private sector, public sector and non-governmental organizations such as code and standards development institutions, will also change in response to the changing context of the built environment. In particular, the many gaps inherent in the project delivery process today will necessarily need to be removed through systematic integration of function, management, communication and coordination (Figure 2.1).

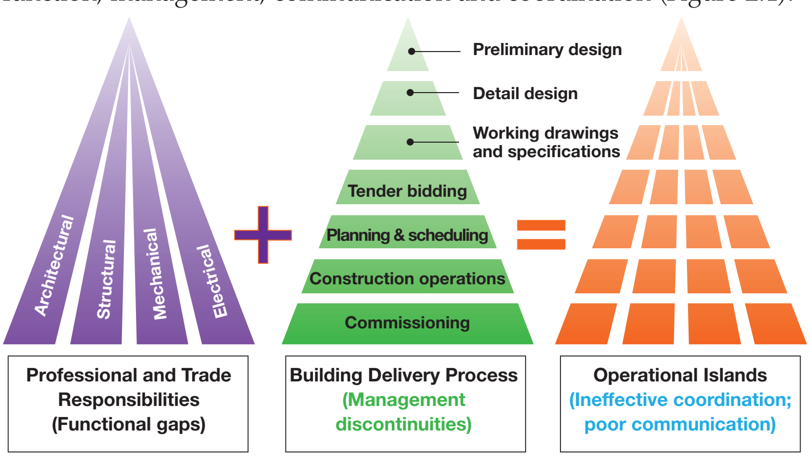


Figure 2.1 Opportunities for integration in the project delivery process
Source: WBCSD (2010a).

There is growing recognition that sustainability can be influenced at the organizational level. The World Business Council for Sustainable Development is one entity taking an active role in envisioning the future from this standpoint and making it happen in a sustainable way. This organization consists of the chief executive officers of 200 leading corporations from more than 30 countries and 20 industrial sectors who are interested in sustainable development as it applies to business. Its Vision 2050 study (WBCSD 2010b) lays out a pathway for the future where 9 billion people can live well together on the planet, within its resource limits. The leading conclusion of the study is that while the technologies and resources already exist to achieve the vision laid out in the report, it cannot be achieved without a dramatically different perspective from business leaders with regard to how they operate their businesses. The study identifies several key requirements that must be part of the pathway to achieving the vision (see box). Specific 'must haves' for 2020 identified in the report include changes in:

- People's values and human development, including new measures of success, deeper local and environmental understanding, economic empowerment of women, access to basic services, opportunities for an ageing population, incentives for behaviour change, and integrated urban management.
- Economy, including global, local and corporate leadership, removal of subsidies, commitment to true value pricing, long-term financing models and dissemination of technologies.
- Agriculture, including training of farmers, more free and fair trade, yield gains, water efficiency, more research and development, and new crop varieties.
- Forests, energy and power, including water efficiency, commitment to carbon cuts, yield gains, global carbon prices, agreement on how to manage greenhouse gases, lower-cost renewables and demand-side efficiency.
- Buildings, including business models that integrate all stakeholders, tough energy-efficiency rules, energy awareness, demand-side efficiency and infrastructure investment.
- Mobility, including energy awareness, biofuel standards, infrastructure investment, integrated transport solutions, more efficient and alternative drivetrains and innovation.
- Materials, including the phasing-out of landfills, closed loop design, value chain innovation, energy efficiency in production and innovation with consumers.

In the future described in this vision, improvements in information technology will provide the mechanisms needed for companies to be transparent in reporting their impacts on society and the environment as well as the economy, the triple bottom line. In fact, a recent report from the Volans Corporation (Volans 2010) identifies six key factors that will characterize the transparent economy of 2020 and provide the foundation for transparent corporate operations:

World Business Council for Sustainable Development

Key Steps for a Sustainable 2050

- Addressing the development needs of billions of people, enabling education and economic empowerment, particularly of women, and developing radically more eco-efficient solutions, lifestyles and behaviour.
- Incorporating the cost of externalities, starting with carbon, ecosystem services and water.
- Doubling of agricultural output without increasing the amount of land or water used.
- Halting deforestation and increasing yields from planted forests.
- Halving carbon emissions worldwide (based on 2005 levels) by 2050, with greenhouse gas emissions peaking around 2020 through a shift to low-carbon energy systems and highly improved demand-side energy efficiency.
- Providing universal access to low carbon mobility.
- Delivering a four-to-tenfold improvement in the use of resources and materials.

- Traceability – the provision of verified information about every step in a business production chain.
- Integrated reporting – providing information about a company's economic performance that is linked with its sustainability performance in terms of social and environmental factors.
- Government leadership – increased transparency of government operations even as it encourages better reporting through disclosure rules for companies and provides enhanced data analysis and aggregation services for disclosed data.
- Environmental boundaries – awareness of limitations on human activity imposed by global ecological systems in terms of climate change, stratospheric ozone depletion, land use change, freshwater use, biodiversity, ocean acidification, nitrogen/phosphorus inputs to the biosphere, aerosol loading and chemical pollution, and reporting on the impacts of corporate activities on those boundaries.
- Rating and ranking – improved use of third-party, centrally managed measurement systems to promote competition and benchmark performance.
- Shadow economies – improved monitoring and disclosure of business activities not presently tracked by accounting measures.

Concurrent with these improvements, globalization and increasing consumer sophistication will result in a growing demand for information about corporate sustainability. With purchasing choices becoming more seamless in the information age, by 2020 consumers will have at their fingertips the information needed to vote with their wallets for the most sustainable choices in nearly every decision they make. This will bring to the forefront a need for architecture, engineering and construction organizations to document the sustainability impacts of both their products – the capital projects they bring into being – and their own corporate operations. At the level of the individual construction professional, there

Figure 2.2 Attitudinal segments among building professionals
Source: WBCSD (2010a).

will be strong pressure to move from being unengaged, sceptical or uninformed to playing the role of leader in achieving sustainability goals for construction projects (see Figure 2.2).

In particular, individuals in the construction industry who wish to advocate sustainability must be aware of four key factors that influence decision makers' consideration of sustainability with regard to built facilities (WBCSD 2010a):

- Personal know-how – whether people understand how to improve the sustainability of a capital project, and where to go for more information.
- Business community acceptance – whether the market is perceived to consider sustainability a priority.
- Supportive corporate environment – whether one's own organization is perceived to be supportive of decisions in favor of sustainability.
- Personal commitment – whether action on the environment is important to the individual.

From a governance standpoint, perhaps the most notable change worldwide between the present day and 2020 will be a shift in economic and political power in favor of the world's most populous nations, China and India. By 2020, and most likely earlier, China is expected to replace the United States as the number one generator of greenhouse gases and contributions to climate change. To date, like many developing nations, China has placed economic development over environmental concerns. However, this attitude is changing as standards of living improve and awareness of environmental problems has increased. China leads the world in the development of completely new cities to meet the needs of its people, and it is taking aggressive steps to experiment with sustainability and principles of industrial ecology in the development of these areas. For example, the Coastal New District of Tianjin City in northern China, the Dongtan Eco-city and Huangbaiyu are all examples of eco-cities being developed deliberately to minimize ecological footprint and reduce reliance on external sources of food, energy, materials and infrastructure. Similarly, India is developing several world-class eco-cities including the Gujarat International Finance Tec-City (GIFT) and the district of Manimekala, Karaikal in south India.

Discussion questions and exercises

2.1 What was your first exposure to the idea of sustainability in your personal or professional life? What sources of information did you find most impactful? What convinced you that sustainability was worthy of your attention?

2.2 Map the evolution of sustainability in your region or country. What were the major milestones in time? How do they correlate with other significant historical, social or political events occurring in your country at that time? Were any associated with significant natural or human-made disasters? How have these external events shaped your society's reactions to the tenets of sustainability and sustainable development?

2.3 How have advances in sustainability in other countries impacted its evolution in your region or country? What elements of sustainability have derived from actions in other countries? For example, was the prevalent green building rating system used in your country developed elsewhere? How did it spread to your country? How has it evolved since then?

2.4 How do the principles of Agenda 21 apply to your country or region? Which principles are easiest for your country to achieve? Which are most difficult? Why? Which principle seems most critical to you for achieving sustainability? Why?

2.5 Principle 15 of Agenda 21 mentions the precautionary approach, also known as the precautionary principle. Restate this principle in your own words. What arguments can be raised against the precautionary principle? What arguments can be made in favour of it?

2.6 How large is your personal carbon footprint? Using an online calculator (search 'carbon footprint calculator'), determine how many pounds of carbon your activities generate on an annual basis. What is the most significant source of carbon among your activities? What could you do to reduce your carbon footprint?

2.7 Of the four major trends related to the built environment – resource scarcity, climate change, ageing populations and urbanification – which will have the greatest impact on you as a professional and an individual? How will each of these trends change your professional practice over the next 10–20 years?

2.8 Think about the most recent significant purchase you have made. What information did you consider in making the decision? What additional factors from the triple bottom line could you have considered? What information would you have needed to incorporate these factors into your decision?

2.9 Which of the four attitudinal segments shown in Figure 2.2 best describes you? What are the major factors that inhibit your leadership of sustainability in your personal and professional life?

References

Ahn, Y. H. and Pearce, A. R. (2007). 'Green construction: contractor experiences, expectations, and perceptions.' *Journal of Green Building*, 2(3), 106–22.

Ahn, Y. H., Pearce, A. R. and Ku, K. H. (2009). 'Green construction: U.S. contractors' status and perception.' *Proceedings of International Conference on Construction Engineering and Management (ICCEM)*, Jeju, Republic of Korea.

Boonstra, C. and Pettersen, T. D. (2003). 'Tools for environmental assessment of existing buildings.' <www.bvsde.paho.org/bvsaia/fulltext/tools.pdf> (accessed 5 July 2010).

California Green Building Standards Code (CBSC). (2010). '2010 California Green Building Standards Code.' <www.documents.dgs.ca.gov/bsc/documents/2010/Draft-2010-CALGreenCode.pdf> (accessed 10 May 2010).

Carson, R. (1962). *Silent Spring*, Houghton Mifflin, Boston, MA.

Conseil International du Bâtiment - International Council for Research and Innovation in Building and Construction (CIB). (1997). 'Research information CIB Task Groups and Working Commissions.' Building Research and Information, 25(6), 321–34.

Center for Chronic Disease Prevention and Health Promotion (CDC) (USA) (2007). 'Healthy youth.' <http://www.cdc.gov/healthyyouth/asthma/> (accessed 10 July 2010).

Ding, G. K. (2004). 'The development of a multi-criteria approach for the measurement of sustainable performance for built projects and facilities,' PhD dissertation, University of Technology, Sydney, Australia.

US Energy Information Administration (EIA). (2010). 'Annual energy outlook 2010.' < www.eia.doe.gov/oiaf/aeo/pdf/0383(2010).pdf> (accessed 20 July 2010).

G8. (2006). 'Global energy security.' <http://en.g8russia.ru/docs/11.html> (accessed 5 July 2010).

G20. (2009) 'Leaders' Statement: The Pittsburgh Summit', <www.g20.org/Documents/pittsburgh_summit_leaders_statement_250909.pdf> (accessed 10 October 2011)

G20. (2010). 'What is the G-20.' <http://www.g20.org/about_what_is_g20.aspx> (accessed 10 June 2010).

HM Government. (1994). *Sustainable Development: The UK strategy*. HMSO, London.

International Energy Agency (IEA). (2009a). 'IEA Evaluation of G8 Countries' and the European Commission's Progress on the 7 Key Action Areas.' <www.g8italia2009.it/static/G8_Allegato/StPETERSBURG,0.pdf> (accessed 20 May 2010).

IEA. (2009b). 'Implementing energy efficiency policies in the G8.' <www.iea.org/G8/docs/Efficiency_progress_g8july09.pdf> (accessed 10 June 2010).

International Union for Conservation of Nature (IUCN). (1980). 'World conservation strategy.' <http://data.iucn.org/dbtw-wpd/edocs/WCS-004.pdf> (accessed 10 July 2010).

Kibert, C. J. (1994). 'Principles of sustainable construction.' *Proceeding of the First International Conference on Sustainable Construction*, Tampa, FL.

Langford, D. A., Zhang, X. Q., Maver, T., MacLeod, I. and Dimitrijeic, B. (1999). 'Design and managing for sustainable buildings in the UK.' *Profitable Partnering in Construction Procurement CIB W92 and CIB 23 Joint Symposium*, London, 373–82.

Meadows, D., Randers, J. and Behrens, W. W. (1972). *The Limits to Growth*, Universe Books, New York.

McGraw Hill Construction. (2008). *2009 Green Outlook: Trends Driving Change Report*, McGraw Hill Construction, New York.

US National Research Council (NRC). (2004). *Investments in Federal Facilities: Asset Management Strategies for the 21st Century*, National Academies Press, Washington, DC.

NRC. (2008). *Core Competencies for Federal Facilities Asset Management through 2020*, National Academies Press, Washington, DC.

Office of the Federal Environmental Executive (OFEE) (USA). (2003). *The Federal Commitment to Green Building: Experiences and Expectations*, OFEE, Washington, DC.

Roodman, D. M. and Lenssen, N. (1995). *A Building Revolution: How ecology and health concerns are transforming construction*, Worldwatch Institute, Washington, DC.

Russell, J. S., Hanna, A., Bank, L. C. and Shapira, A. (2007). 'Education in construction engineering and management built on tradition: blueprint for tomorrow.' *Journal of Construction Engineering and Management*, 133(9), 661–8.

Shah, S. (2006). *Sustainable Practice for the Facility Manager*, Blackwell, Oxford.

Sjostrom, C. and Bakens, W. (1999). 'CIB Agenda 21 for sustainable construction: why, how and what.' *Building Research and Information*, 27(6), 347–53.

Spence, R. and Mulligan, H. (1995). 'Sustainable development and the construction industry.' *Habitat International*, 19(3), 279–92.

Uher, T. E. (1999). 'Absolute indicator of sustainable construction.' *Proceedings of COBRA 1999*, 243–53, London.

United Nations Conference on Environment and Development (UNCED). (1992). 'The Earth Summit.' UNCED, Rio De Janeiro, Brazil. www.un.org/geninfo/bp/enviro.html (accessed 15 February 2009).

United Nations Environmental Programme (UNEP). (2009). *Building and Climate Change*, UNEP, Paris.

UNEP. (2010a). 'Making UNEP climate neutral.' <www.unep.org/Documents.Multilingual/Default.asp?DocumentID=43> (accessed 25 July 2010).

UNEP. (2010b). 'United Nations Environment Programme.' < www.unep.org/PDF/ABOUT_UNEP_ENGLISH.pdf> (accessed 20 July 2010).

US Census. (2009). 'November 2008 construction at $1,078.4 billion annual rate.' <www.census.gov/const/C30/release.pdf> (accessed 20 January 2009).

US Department of Energy (USDOE). (2003). The Business Case for Sustainable Design in Federal Facilities. USDOE, Washington, DC.

USDOE. (2008). *2008 Energy Building Data Book*, USDOE, Washington, DC. <http://buildingsdatabook.eren.doe.gov/docs/2007-bedb-0921.pdf> (accessed 10 January 2009).

US Department of Labor (USDOL). (2009). 'Construction.' <www.bls.gov/oco/cg/cgs003.htm> (accessed 18 February 2009).

US Environmental Protection Agency (USEPA). (2001). *Healthy Buildings, Healthy People: A vision for the 21st century*, USEPA, Washington, DC.

USEPA. (2008). 'Municipal solid waste in the United States.' <www.epa.gov/osw/nonhaz/municipal/pubs/msw2008rpt.pdf> (accessed 12 July 2010).

USEPA. (2010a). 'EPA Energy Star for wastewater plants and drinking water systems.' <www.energystar.gov/index.cfm?c=water.wastewater_drinking_water> (accessed 10 July 010).

USEPA. (2010b). 'EPA promotes water efficiency in the home.' http://epa.gov/water/water_efficiency.html (accessed 4 December 2011).

USEPA. (2010c). 'The inside story: a guide to indoor air quality.' < www.epa.gov/iaq/pubs/insidest.html> (accessed 15 July 2010).

Volans Corporation. (2010). 'The transparent economy: six tigers stalk the global recovery – and how to tame them.' <www.globalreporting.org/NR/rdonlyres/D97CA5F7-EB0C-43CD-A9BB-C9AF72B44F03/4187/Explorations_TheTransparentEconomy _FINAL.pdf> (accessed 6 November 2010).

World Business Council for Sustainable Development (WBCSD). (2010a). *Energy Efficient Buildings: Facts and trends.* <www.wbcsd.org/DocRoot/qUjY7w54vY1KncL32OVQ/EEB-Facts-and-trends.pdf> (accessed 6 November 2010).

WBCSD. (2010b). *Vision 2050.* <www.wbcsd.org/Plugins/DocSearch/details.asp?DocTypeId=33&ObjectId=Mzc0MDE> (accessed 19 December 2010).

World Commission on Environment and Development (WCED). (1987). *Our Common Future* (the Brundtland Report), Oxford, UK.

3

Sustainability Policies and Programmes

With growing interest in developing sustainability policies among national, state and local governments as well as the private sector, the options available to encourage sustainability best practice are many and varied, with potentially substantial differences in likelihood of success across different implementation contexts. In the context of this chapter, a sustainability policy is a plan or specified course of action that guides the decisions and behaviours of individuals with regard to the goal of improving sustainability within an organization. Sustainability policies are typically supported by specific programmes, or packages of actions and associated resources directed to achieve specific objectives within the larger policy. This chapter defines, compares and contrasts these generalized options to provide key information for designing effective sustainability policies to have maximal effect in different contexts.[1]

The owner's perspective: what does a sustainability policy need to succeed?

Designing a successful sustainability policy and associated programmes within the complex context of an organization is difficult by any standard. Multiple stakeholder perspectives must be considered and aligned behind a common vision and plan of action. Clear benefits that outweigh potential risks must be shown from social, environmental and economic perspectives to support the social and business case for changing the status quo. Finally, the implementability of the specific programme elements themselves must be carefully considered in designing the programmes and policies to ensure their sustainability and effectiveness in the long term, despite the constantly evolving and shifting political nature of organizations. The following subsections describe each of these considerations in greater detail.

Stakeholders of a sustainability policy

One of the most important challenges in designing a sustainability policy is considering the perspectives and interests of each of the categories of stakeholders who will be affected by such a policy. These stakeholders include, in no particular order:

- Owner facilities personnel, including organization leaders and facilities staff who will be responsible for interpreting the policy, implementing its requirements, and evaluating the results with regard to capital projects.
- Supporting personnel, such as state energy offices, state property offices departments of general services in the case of public agencies, or finance departments in private organizations, who may be responsible for managing funding to implement sustainability programmes.
- Management, leadership, or elected officials, whose endorsement of a sustainability policy exposes them to the potential political risks and rewards the policy might bring as it is implemented.
- Facility occupants, who will benefit from high-performing buildings but may suffer if facility scope must be reduced to achieve high performance, or if building technologies do not perform as anticipated.
- Shareholders or taxpayers, who will provide some or all of the funding to support sustainability programmes and who will benefit from increased environmental quality and enhanced productivity of facility users, as well as lower operating expenses.
- The architecture, engineering and construction industry, which provides capital project-related services for facilities and will be required to comply with policy requirements and deal with associated implications for how they do business.
- Lobbies, who represent key industries or non-profits in the jurisdiction, who are sensitive to the potential influence of policies on their constituencies.

Any one of these stakeholder groups has the potential to either offer support or contribute to derailing a sustainability policy or programme as it is put forth. Owners and supporting personnel in particular will play a strong role in the ongoing success and sustainability of a sustainability programme for built facilities.

Potential sustainability policy and programme risks and rewards

A variety of potential risks and rewards are associated with sustainability policies and programmes, and must be considered when designing a policy or programme configuration. Since the ultimate objective of a sustainability policy for built facilities is to increase the sustainability of facilities in the organization or jurisdiction, the three basic elements of sustainability (social, environmental and economic criteria) provide a balanced basis to evaluate and compare potential programme designs (Munasinghe 1993; discussed as the 'triple bottom line' by Elkington 1997 and others). Figure 3.1 illustrates how these considerations balance each other to work toward a stable human society in which stakeholder needs and aspirations are met in the present while capacity to meet the needs and aspirations of future generations is preserved (after WCED 1987).

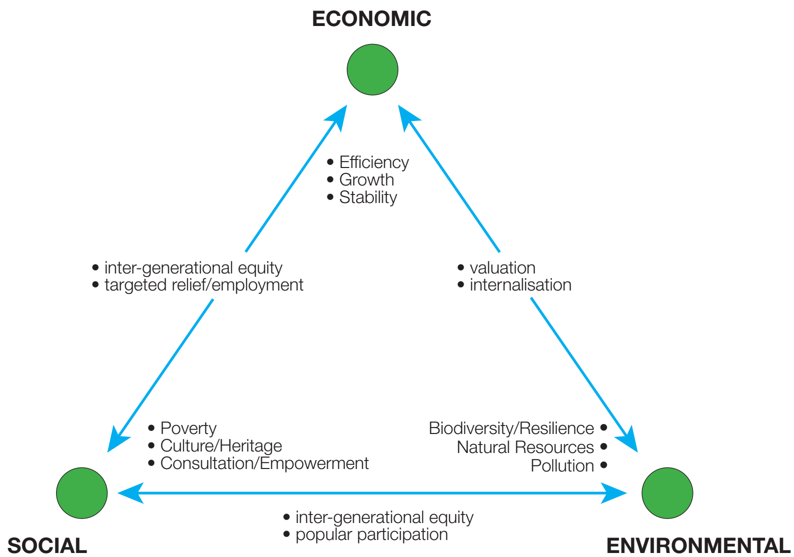


Figure 3.1 Sustainability considerations
Source: Munasinghe (1993).

Social considerations

From a social standpoint, multiple factors contribute to the success of a sustainability policy or programme. Since this chapter is primarily focused on sustainable construction programmes undertaken by public or private-sector organizations, sociopolitical factors are considered here from the standpoint of organizational leadership or elected officials who will mandate or endorse sustainability policies, the users and operational staff of buildings and infrastructure subject to the policies, and the shareholders, taxpayers and supporting industries whose interests those organizations serve.

From the government standpoint, including both elected officials who make policy and agency stakeholders who implement or experience the direct impacts of public policy, social considerations include how well these agents are able to meet their obligations to the public toward achieving greater good. Similar concerns exist for the shareholders of private-sector organizations, except that they are defined by how well the overall organization is able to meet its individual social goals. Potential rewards of sustainable construction programmes and policies include (e.g. Kats 2003, Portland Energy Office 1999, Romm and Browning 1995, USDOE 2003, US Green Building Council 2004, Wilson 2005):

- Increased effectiveness of facility users/occupants, potentially resulting in better services provided by those organizations to their customers or constituencies.
- Improved image/reputation of environmental leadership both within the organization and with respect to other organizations.

From the standpoint of the constituencies whose interests the organization serves, effective sustainability programmes and policies can indirectly offer, in terms of potential social rewards (same sources as above):

- Support for economic development for local industries and resultant increase in wealth and quality of life.
- Increased health and productivity due to improved environmental quality.
- Availability of funding to enhance other programmes that is no longer needed for facility operations and maintenance.
- Better service from more efficient and effective employees.

These potential rewards are likely to result from effective implementation of sustainability policies and programmes, but there are also social risks if programmes do not perform as expected, primarily associated with the opportunity costs of funding invested in sustainable facilities if they do not result in performance improvements (e.g. Athena 2002, Best 2005, Bray and McCurray 2006, Greenspirit Strategies 2004, Johnston 2000, Myers 2005, Winter 2004). If programmes do not perform well, the organizations who have implemented those programmes are accountable to shareholders or taxpayers for how funds have been spent. With programmes that are new or not well understood, the perceived political risk associated with endorsing them may outweigh the promise of benefits (e.g. Pearce 2001, Pearce et al 2005a).

Environmental considerations

The second category of considerations centres on the natural environment and the impacts on ecological systems and resource bases that can be mitigated and/or improved by implementing sustainability programmes. Potential rewards include (see Wilson 2005 for a good overview):

- Reduction in likely levels of resource consumption: for instance water, energy, materials.
- Reduction in likely levels of waste, destruction and pollution that lead to ecosystem degradation and biodiversity loss, for example solid waste, wastewater/water pollution, air pollution and site disturbance.
- Increase in sustainable site development practices and improvements in transportation efficiency.

Policy alternatives can be compared environmentally in terms of likely numbers of projects or facilities affected by each proposed scenario over time and the scale of change in those facilities or projects. As with social rewards, potential environmental rewards must also be weighed against potential risks if policies and their programmes do not behave as expected. Environmental risks include considerations such as unproven or unfamiliar construction materials and technologies that fail in operation and must be replaced, requiring additional resources to address the problem. While the potential for innovative technologies and practices to backfire is inherent in all innovation (Rogers 2003), it is especially ironic in the case of environmental technologies, where replacement potentially entails more waste and resource consumption than installing a traditional alternative in the first place (Pearce 2001).

Economic considerations

The third category of evaluation criteria focuses on economics, including direct costs and benefits associated with sustainability policies and programmes, and indirect costs and benefits that occur as a result of better-performing capital construction processes, the facilities that result from them, and the impacts of those facilities on their occupants. The most obvious economic cost impacts of sustainable construction programmes and policies are the direct costs of implementation. Categories of programme implementation costs include (e.g. Bennett and James 1998, Pearce 2004):

- Programme administration costs.
- Cost of project registration/documentation/certification.
- Increased first cost of projects due to improved systems, additional design and construction requirements, building commissioning and so on.
- Increased life cycle costs of projects for maintenance of unfamiliar systems and so on.
- Programme marketing costs.
- Training costs.
- Technical assistance costs.
- Evaluation/compliance costs.

These costs are coupled with the risk of remediation costs if unknown sustainable technologies do not perform as expected. Potential quantifiable areas of savings resulting from effective sustainable construction programme implementation include (same sources; see Wilson 2005 for a good overview):

- Savings in operating and maintenance costs, such as energy costs, system replacement, water/wastewater treatment, waste disposal.
- Savings in first cost due to system optimization, design right-sizing, reduced waste generation, recycling revenues and so on.
- Reduced liability, for instance for human health risks.
- Reduced environmental management/compliance costs.
- Improved productivity and employee retention.

Many indirect economic benefits can also stem from sustainable construction programmes, including value of resources saved for future use, value of environmental image, and value of environmental quality due to avoided negative impacts, although these kinds of costs are not typically included directly in decision making since they are difficult to quantify or attribute to specific project decisions (e.g. Bennett and James 1998). Nevertheless, all of these factors should be considered at least conceptually in terms of evaluating the costs and benefits of green building programmes and designing policies that optimize benefits for stakeholders (see also Chapter 9, 'Making the business case').

Together, social, environmental and economic impacts of a policy and its programmes provide a balanced measure of the ultimate performance of that policy in terms of its influence on the sustainability of capital facilities for an organization. These three categories of impacts serve as the fundamental basis for evaluating policy and programme designs in this chapter, along with programme implementability, which is discussed next.

Implementability considerations

In addition to the likely social, environmental and economic impacts that may result from a sustainability policy, the design of the policy itself and its accompanying programmes contributes to its potential to succeed within its organizational and political context. From an organizational standpoint, implementability considerations focus on the compatibility of potential policies and programmes with the standard operating procedures, constraints and conventions of implementing organizations. Specific considerations for implementability include (Rogers 2003, Vanegas and Pearce 2000):

- Compatibility with statutory requirements and funding processes.
- Availability of a trigger to establish urgency of need for the programme, such as an energy crisis or environmental disaster.
- Degree of change required of individuals within the organization who are affected by the policy or programme.
- Level of additional burden imposed by the policy or programme on implementing agents.
- Existence of enthusiastic change agents and support networks with appropriate stature and resources within the organization.
- Existence and observability of rewards or benefits for policy and programme achievement.
- Absence or ability to mitigate potential risks associated with policy and programme implementation.
- Likelihood of strong political or leadership endorsement or, conversely, significant political opposition to the programme by leadership, lobbies or other constituencies.

These factors influence the degree and rapidity with which individuals and organizations adopt new or unfamiliar technologies and practices that have the potential to improve their existence. Together with the potential risks and rewards each policy or programme option offers, implementability considerations can help predict which designs will take hold and be successful in achieving their full potential while avoiding risk of failure.

The next part of the chapter identifies candidate options that can be considered as elements of a sustainability policy or programme for an owner organization, and evaluates those elements in terms of the criteria of social impacts, environmental impacts, economic impacts and implementability. These then form a basis for constructing potential policy approaches that can serve as paths for action by an organization toward greater sustainability.

Sustainability policy options

In defining the elements that could be incorporated as part of an overall sustainability policy or programme for an owner organization, particularly with respect to capital facilities, three basic categories of options emerge: **policy options**, whereby formal guidance is put in place to require or encourage sustainability-related activities; **programme options**, which may provide funding, information or other needed resources to make sustainability easier to achieve; and **evaluation options**, which serve to measure the outcomes of the programme and evaluate its success. The next three subsections describe potential options within each of these three categories, along with their pros and cons in terms of the evaluation criteria identified in the previous section.

Policy options

Policies can come in the form of an executive order signed by a CEO, governor, or public leader, a bill passed by legislature, or even an internal organizational directive issued by the executive staff. The following options could be made in any of these forms:

- **Require a specified level of performance** – A policy can mandate compliance with a specific set of sustainability guidelines or achievement of a measurable, specified level of performance. A straightforward method would be to require that a project or development meet some specified level of rating under a standard such as the US Green Building Council's (USGBC's) LEED standard[2] or a similar applicable standard, but a different set of guidelines or alternative rating system could also be used. This option can be implemented with varying degrees of rigour ranging from requiring facilities to simply meet the standard on an honour basis to requiring a formal third-party certification process. The scope of the mandate can also be varied by limiting the policy to specific facility types; limiting it to facilities or projects of a certain scale, such as over $1 million or greater than 25,000 sq ft; applying it to all projects for a specific subset of the organization or agency; or only requiring each subset of the organization or agency to do one pilot project under the policy (DuBose, Bosch and Pearce 2007).
- **Endorse and encourage performance** – Another policy-based approach is to issue a policy which does not mandate any specific action but instead officially endorses sustainability as a priority for

the organization's facilities and encourages members of the organization to voluntarily adopt sustainable construction practices. Such a policy could make specific mention of a rating system and/or a level within a rating system that it is desirable to achieve.

- **Create programmes to encourage sustainable construction activity** – In addition to being used to show support for sustainability, policies can also be used to create programmatic elements that provide inspiration and support for implementation of sustainability practices by organizations and agencies, as discussed in greater detail in the next section of the chapter under 'Programme options'. While these programmes can be created outside of official policy documents, in some cases a policy such as an executive order gives leaders an opportunity to officially put their support and endorsement behind a programme; this can be beneficial to the leader and can encourage members of the organization to take advantage of the programmes because they know those programmes have support from the top. Creating supporting programmes can be done in conjunction with a requirement to meet a specified sustainability performance standard.
- **Create a working group to develop standards or plans** – In a situation where there is support for sustainability but not a consensus about what standards to use and/or how far reaching and firm a policy needs to be, creating a policy to establish a working group to take up the issue is a possible option. This option is a useful first step and gives a clear signal of a leader's support for the issue. Creating a working group in the form of a council or task force gives leadership the opportunity to have input from critical stakeholders in a fair and open process. This approach also avoids some of the political risks inherent in mandating a specific set of guidelines to a resistant population of potential adopters.

Table 3.1 on the next page lists each of these options along with their possible impacts in terms of the four evaluation criteria.

Programme options

A variety of programme options have been developed by agencies and organizations for increasing uptake of sustainability-related techniques and practices in the built environment. Programmes can be established through formal policies or can be created on an ad-hoc basis. Critical to the success of all programmes is a source of funding and support to build, promote and continue the efforts undertaken by those programmes. Potential programme options include:

- **Technical support** – Providing technical support can be useful for creating capacity for sustainable construction and overcoming ignorance about new and innovative sustainable construction techniques that may be different from the ways things have typically been done. Technical assistance can be provided directly by the specific organization designated to promote sustainability or indirectly by providing funding for technical assistance by external providers.

Table 3.1 Sustainability policy options – pros and cons

	Require specified level of performance	Endorse and encourage performance	Encourage sustainability in general	Create working group to set standards
Social	May increase jobs if done externally. Occupants may be healthier and happier in their workplaces. Increased productivity is possible.	Same as requiring performance, but with likely fewer participants and subsequent reduced costs and benefits.	Benefits and costs are programme-specific.	Long-term impacts may result from eventual greater uptake of subsequent policies. Resulting network can provide inspiration for independent action and opportunity to share lessons and experiences.
Environmental	Reduced environmental impact and demands on infrastructure.	Reduced environmental impacts and demands on infrastructure, although lower impact than mandate due to lower uptake.	Benefits and costs are programme-specific.	Long-term impacts may result from eventual greater uptake of subsequent policies.
Economic	Increased costs because of certification fees and other costs associated with each standard, but expected life cycle operational savings.	Lower cost of implementation than mandate due to lower uptake; potentially lower life-cycle cost savings as well.	Could be costly to implement; depends on the nature of the programmes specified. Benefits are also programme-dependent.	There may be direct implementation costs for meeting support and documentation.
Implementability	Greater personal load for implementers if done in-house. Some oppose particular standards for various reasons. Often constitutes an unfunded mandate. Provides temptation to do things that may not be cost-effective or appropriate just to get points.	Potentially lower uptake, but those who do adopt are less resistant. Can be used as a springboard for a future requirement while building support. Gives formal political endorsement to people inside agencies who already aspire to do green building. Lower probability of 'point-mongering'.	Gives formal political endorsement to people inside agencies who already aspire to do green building, and gives specific direction on how to proceed. Does not offend people by imposing requirements without support. Provides tools and resources to support the end goals.	Works well to achieve broad consensus and buy-in as long as all key parties are represented. Adds additional workload to volunteer participants. Requires strong leadership and effective facilitation. Recommendations from the council may carry more weight than simple political mandates. Gives alternative factions the chance to present themselves to the council and be carefully evaluated. Provides a mechanism for figuring out the most appropriate way to get things done.

- **Training** – Unlike technical support which provides assistance for specific projects, training opportunities can be used to inform facility stakeholders on topics ranging from general sustainability, sustainable construction principles, or rating system requirements, to technical details of specific technologies. Organizations may not need to implement training internally but instead may find ways to increase the number of personnel attending existing sustainable building training events such as subsidizing the cost of training, providing release time to attend, or merely encouraging attendance at training seminars.
- **Guidance documents** – Many implementing organizations have found that it is useful to create guidance documents to distil the wide variety of available information on sustainability into a more concise format that contains information relevant for their specific context. These documents can be a tailored version of relevant rating systems that highlight strategies that have been most successful for similar projects (e.g., Pearce et al 2005c), tailored checklists to address attributes of that organization's projects, or guidebooks containing more detailed information (see Bosch and Pearce 2003).
- **Demonstration projects** – Demonstration or pilot projects are implemented to show what sustainable construction entails and demonstrate its benefits in the context of a real project, without necessarily committing to an ongoing policy of constructing in this way for future projects. A successful pilot project can help dispel the fears and objections of opponents, and incurs a much lower political cost and risk than formally putting a policy put into place. If successful, it can be a precedent toward establishing a policy later on.
- **Incentives/subsidies** – Rather than mandating that organizations adopt sustainability practices, another approach is to reward organizations or parts of the organization that are 'ahead of the curve' in already pursuing these practices and provide motivation for other parts of the organization to follow their lead. Incentives observed in some organizations, for instance, include reimbursing the cost of rating system certification, leadership awards for most sustainable new projects, improved performance reviews for involved individuals, and positive press coverage.
- **Modified organizational practices** – Procedural barriers can make achieving sustainability difficult, and programmes to modify internal organizational constraints can help to facilitate sustainability-related actions. Examples include contract vehicles for commissioning or energy savings performance contracting, waiving one-year contract limit requirements, and prequalification of contractors or products (see DuBose, Bosch and Pearce 2007 for examples).

Table 3.2 lists each of these programme options along with possible impacts they may have in terms of the four evaluation criteria.

Table 3.2 Sustainability programme options – pros and cons

	Technical support	Training	Guidance documents/tools	Demonstration projects	Incentives/ subsidies	Modified organizational practices
Social	May increase confidence to try innovations; adds capabilities to teams that don't already have them; can make sustainable construction seem like something that requires expert assistance and disempower individuals.	May increase confidence to try innovations; may provide networking opportunity and peer interaction; may build greater internal capacity and support since it empowers individuals who receive training.	May increase confidence to try innovations. Individually empowering, but essentially an individual effort; no specific opportunities for networking.	Occupant benefits can derive from sustainable design. Long-term impacts may result from eventual greater uptake of sustainability best practices that are effectively demonstrated on these projects.	Impacts may result from greater uptake of sustainability best practices.	Impacts may result from greater uptake of sustainability best practices.
Environmental	Impacts may result from eventual greater uptake of sustainability best practices.	Impacts may result from eventual greater uptake of sustainability best practices.	Impacts may result from eventual greater uptake of sustainability best practices. Depending on the nature of the document, can help to tailor efforts to those most effective for the specific context, e.g., what works best in a given climate.	Environmental benefits from sustainable design of demonstration facility. Long-term impacts may result from eventual greater uptake of sustainability best practices that are effectively demonstrated on these projects.	Impacts may result from greater uptake of sustainability best practices.	Impacts may result from greater uptake of sustainability best practices.

	Technical support	Training	Guidance documents/tools	Demonstration projects	Incentives/ subsidies	Modified organizational practices
Economic	Have to pay for implementation, but ultimately will speed learning curve and build broadly applicable capacity that can result in long-term savings.	Have to pay for implementation, but ultimately will speed learning curve and build broadly applicable capacity that can result in long-term savings.	Less expensive because it is generated once but used many times. Relatively minimal ongoing costs for updating, and dynamic options that are self-updating are possible.	Could capitalize on existing sustainability projects by designating them as demonstration projects and promoting them. Access to different funding sources and donations is often possible. Funding commitment is project by project, not an ongoing commitment.	Direct first cost of implementation varies by program type, e.g., paying for rating system third-party certification or commissioning. Should be phased out over time.	No cost outside normal operating costs for organization, unless feasibility studies or similar are required.
Implementability	Technical assistance does not ensure uptake, but at least it applies to an immediate real project situation. Potential exists to capture and transfer lessons learned via centralized tech support provider. Depending on who provides the support, can generate or suppress market capacity.	Providing training does not ensure uptake. The next relevant project may not happen soon.	Requires individual adaptation to specific cases. May have to provide dissemination and training to ensure widespread effective use. Can be tailored to meet the culture, constraints and needs of the organizational context, and therefore be more easily adopted. Does not ensure uptake.	Lower risk of perceived failure on these projects (since they are designated as pilots/ demonstrations) encourages greater innovation. Improves the implementability of future projects due to ability to learn from these special cases.	Greatly reduces the most significant barrier to implementation: perceived increased first cost.	One effort can be used multiple times by multiple agencies and projects. Examples include contract vehicles for commissioning, waiving one-year contract limit requirements, prequalification of contractors or products, etc.

Evaluation options

Evaluation can cover programme compliance and/or the effectiveness of the policy at the individual project level and overall. Sometimes but not always, policies explicitly specify how compliance should be measured or demonstrated, and they sometimes specify reporting and accountability requirements that programme implementers must follow to document compliance (Pearce et al 2005a). These measures also provide data for oversight to use as a basis to evaluate the effectiveness of the programme as a whole. Voluntary programme evaluation is also possible. Options include:

- **Third-party certification or evaluation** – This method is effective for ensuring that specific projects follow prescribed sustainability guidelines. This mechanism creates a clear metric with reduced administrative burden on the organization for ensuring compliance, but it does put responsibility on the agents managing the construction process. Certification through third parties also carries a price tag that some organizations have found to be a barrier when they would rather invest that funding directly into the building. Developing other forms of third-party validation is also possible.
- **Regular reporting requirements** – This requirement can be combined with third-party certification. Some state governments in the United States, for instance, have set periodic reporting requirements for their agencies to report back to a central agency, committee or council on their sustainable construction accomplishments and whether or not they followed any policies that have been established (Pearce et al 2005a). Reporting requirements may create a greater sense of accountability, which ultimately results in greater action.
- **Performance monitoring and reporting** – If the goal is to achieve better-performing projects that consume fewer resources, requiring that organizations monitor their capital projects and facilities and regularly report this data to a central authority may be effective. A requirement that organizations develop and implement an action plan for how they will remedy any performance deficiencies can be even more powerful.
- **Post-construction evaluation** – In addition to rating systems that help to guide design and operationalize sustainability during a project, evaluation of post-construction performance is a useful tool to ensure that projects are indeed meeting their design intent and thereby making progress toward the underlying or driving goals of the sustainability policy such as energy savings. Post-construction evaluations may range from a simple walk-through to intense investigative studies using a variety of research methods to correlate physical factors with user-related outcomes. Post-construction evaluation can include (Federal Facilities Council 2002):
  - utility studies, including power and water consumption
  - employee productivity studies
  - absenteeism studies

- indoor air quality testing for buildings
- user satisfaction evaluations
- acoustical studies.

Whatever the mechanism or mechanisms for evaluation, measuring the impacts of sustainability policies and programmes is essential to remain accountable to the shareholders or taxpayers who ultimately support those programmes and benefit from their existence. Table 3.3 lists each of these evaluation options along with possible impacts they may have in terms of the four evaluation criteria.

Table 3.3 Sustainability evaluation options – pros and cons

	Third-party certification	Regular reporting requirements	Performance monitoring and reporting	Post-construction Evaluation
Social	Pride in certification outcomes; external validation; visible reward for achievement.	Introduces accountability. Can also introduce a spirit of competitiveness and motivation to excel. Visible and public acknowledgement of achievements.	Introduces accountability. Opportunity for feedback and action may empower facility manager to proactively deal with problems, resulting in greater occupant satisfaction and productivity.	Most likely option to give good information on true social impacts that can be applied as lessons to future projects. Can be empowering to occupants.
Environmental	Ensures that basic standards are met, but doesn't necessarily guarantee environmentally beneficial outcomes during operation.	Can build on third-party certification and encourage positive environmental outcomes.	Encourages meeting environmental performance goals during operation rather than just meeting standards up front.	Encourages meeting environmental performance goals during operation rather than just meeting standards up front.
Economic	First cost of implementation can be considerable; risk that certification is not achieved.	Can be minimal cost to implement; work imposed on existing personnel.	Ongoing programme costs can be considerable, but afford the opportunity for operational adjustments that can result in savings.	Ongoing programme costs can be considerable, but afford the opportunity for operational adjustments that can result in savings. Likely to employ a third-party to perform.
Implementability	Generally a limited-time event per project with standardized milestones. Considerable opposition may exist regarding the level of effort and cost required. Many stakeholders have to provide data to meet third-party certification requirements, making documentation complex and difficult. Risk that certification is not achieved.	May require a centralized person to continually pester agencies for data. Can be piggybacked on other data submittal requirements such as annual performance or status reporting.	Requires initial investment in monitoring equipment or possible employment of a third-party. Benefits from ongoing data analysis and interpretation. Agency maintains control and can take immediate action to remedy defects as they are discovered. Proactive.	Fear of identifying problems that are otherwise not obvious. Could be embarrassing or reflect poorly on the project team or building. Perception of less control than with performance monitoring. Likely to be a one-time event, not ongoing.

Case Study: Social Sustainability for Construction

Sustainable construction requires improvements not only in the environmental and economic pillars of sustainability but also in its social one. Social sustainability is fundamentally about people, both current and future. In the construction industry, social sustainability is defined in different ways, depending upon the stakeholder's perspective and where it is applied during the project life-cycle. For instance, during the planning and design phase, one focus involves estimating the impact of construction projects in relation to where users live, work, play, and engage in cultural activities (Burdge 2004). These estimations are normally embedded in the environmental impact assessments required by government agencies. In addition, in these early phases, community involvement approaches such as public hearings are used by external stakeholders and government agencies to influence design decisions (Solitare 2005). Social sustainability also relates to the aspects required to improve the decisions during the design phase such as transparency (Kaatz et al. 2005).

During construction, a focus of social sustainability from the perspective of construction firms relates to the application of corporate social responsibility practices (Lamprinidi and Ringland 2008), which consider how the organization can meet the needs of stakeholders affected by its operations (Kolk 2003). Construction companies and designers advocate for worker safety by eliminating potential safety hazards from the work site during the design phase (Gambatese, Behm and Rajendaran 2008). Other considerations include engagement among employees, local communities, clients and the supply chain to ensure the needs of current and future populations and communities are met (Herd-Smith and Fewings 2008).

Table SS1 Social sustainability considerations in construction projects

Conceptual area	General description
Corporate social responsibility	Considers the accountability of an organization to care for all of the stakeholders affected by its operations
Community involvement	Emphasizes the influence of public constituencies on private and governmental proposed projects
Safety through design	Ensures worker safety by eliminating potential construction/operation safety hazards from the work site during the design phase
Social design	Focuses on enhancing the safety, health, productivity and inclusion of the end users and on improving the decision-making process of the design team

A truly sustainable construction project needs to take into account social considerations such as its effect on the community and the safety, health and education of the workers. Failure to include these considerations will impact both people and performance of projects in the long run.

Sources: Roldofo Valdes-Vasquez, PhD and Leidy Klotz, PhD.

Sources

Burdge, R. J. (2004). *The Concepts, Process, and Methods of Social Impact Assessment.* Social Ecology Press, USA.

Gambatese, J., Behm, M. and Rajendran, S. (2008). 'Design's role in construction accident causality and prevention: perspectives from an expert panel.' *Safety Science*, 46(4), 675–91.

Herd-Smith, A. and Fewings, P. (2008). 'The implementation of social sustainability in regeneration projects: myth or reality?' RICS, COBRA 2008, London. <www.rics.org/site/download_feed.aspx?fileID=3178&fileExtension=PDFwww.rics.org/site/scripts/download_info.aspx?fileID=3178&categoryID=525> (accessed 10 October 2011).

Kaatz, E., Root, D. and Bowen, P. (2005). 'Broadening project participation through a modified building sustainability assessment.' *Building Research and Information*, 33(5), 441–54.

Kolk A. (2003). 'Trends in sustainability reporting by the Fortune Global 250', *Business Strategy and the Environment*, 12(5), 279–91.

Lamprinidi, S. and Ringland, L. (2008). 'A snapshot of sustainability reporting in the construction and real estate sector.' Global Reporting Initiative (GRI). <www.globalreporting.org/NR/rdonlyres/13865428-9EAC-4EB0-A8E3-A31AA2F5C38C/3470/CRESSReport.pdf> (accessed 10 October 2011).

Solitare, L. (2005). 'Prerequisite conditions for meaningful participation in brownfields redevelopment', *Journal of Environmental Planning and Management*, 48(6), 917–35.

Valdes-Vasques, R. (2011). 'Social sustainability considerations during planning and design: a framework of processes for construction projects.' PhD dissertation, Department of Civil Engineering, Clemson University, Clemson, S.C.

Valdes-Vasquez, R. and Klotz, L. (2010). 'Considering social dimensions of sustainability during construction project planning and design', *International Journal of Environmental, Cultural, Economic, and Social Sustainability*, 6.

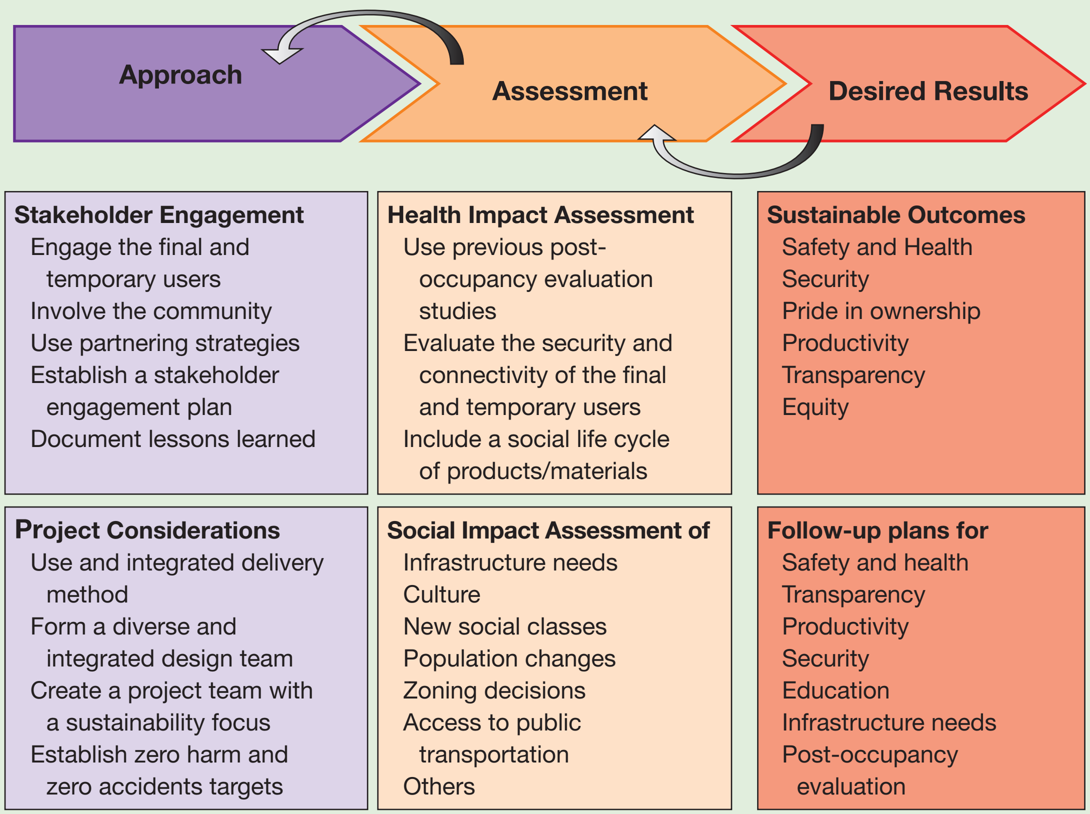


Fig SS1 Practical considerations for social sustainability in construction

Source: Valdes-Vasquez (2011).

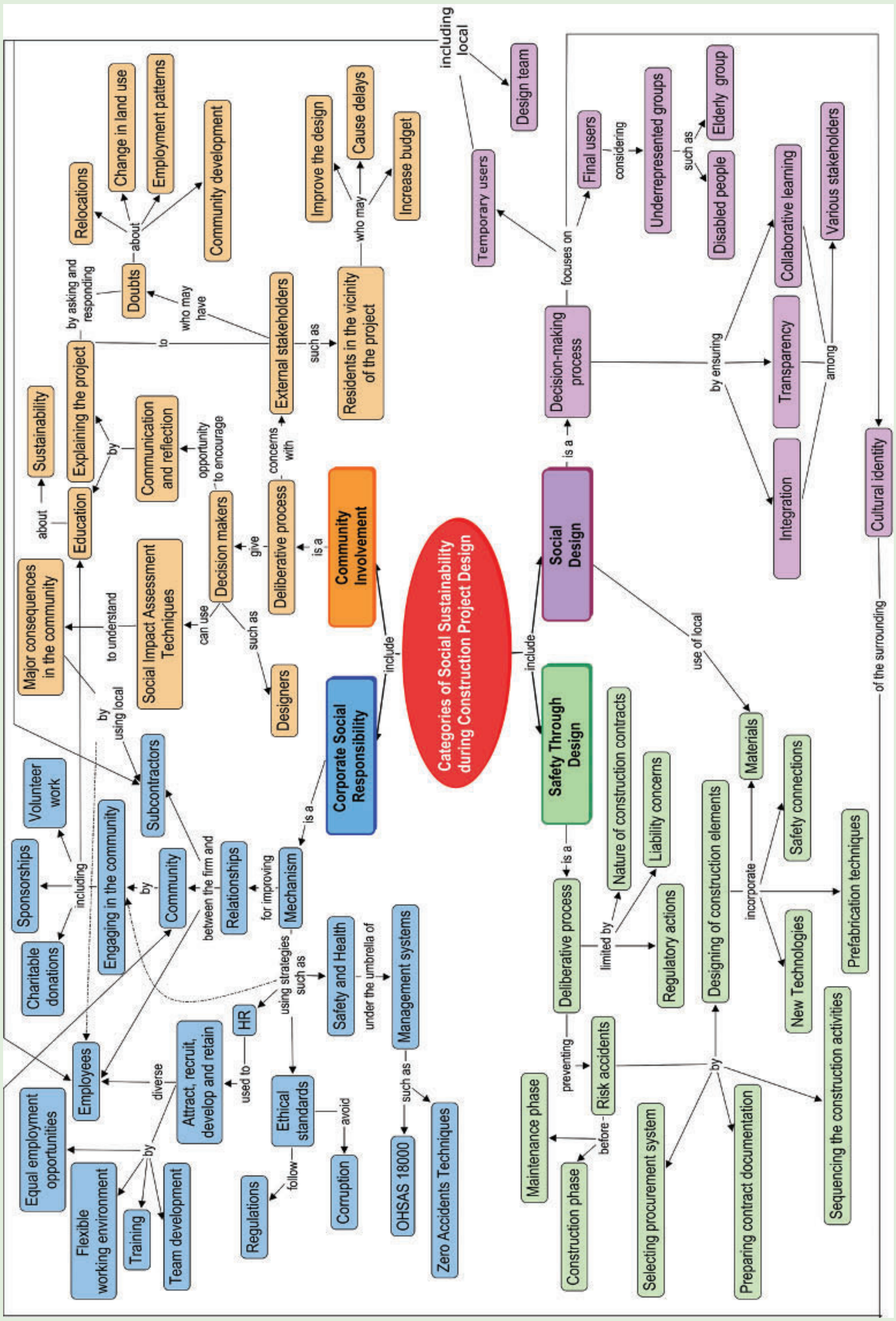


Fig SS2 Concepts related to social sustainability for the construction industry
Source: Valdes-Vasquez and Klotz (2010).

Components of a sustainability programme for owners of capital projects

Sustainability programmes generally consist of four basic elements (DuBose et al 2007, Pearce et al 2005a), as shown in Figure 3.2. These elements are essential to the success of any sustainability programme, although they may be implemented in different ways by different stakeholders in different contexts. The elements mirror an innovation adoption process (Rogers 2003), beginning with an Inspiration phase that includes knowledge, awareness and persuasion that move a person or organization to adopt a sustainability policy or practices. Inspiration may, at some point, be followed by Motivation, the stage in which a formal or informal policy is developed to shape subsequent organizational actions toward meeting sustainability goals. Motivation is followed by Implementation, where programmes are developed to support the activities needed to meet the goals of the policy, followed by Evaluation, where compliance with policy requirements and assessment of programme performance is undertaken.

These four elements provide a structure for mapping the different ways in which owner organizations have approached each step in creating a sustainability programme. The following subsections describe each element in greater detail, including specific examples of different ways in which organizations have designed each of these elements. Additional information about the examples and cases is available in Pearce et al (2005a).

Figure 3.2 Elements of a sustainability programme

Element 1: Inspiration

Inspiration can be defined as any activity that increases awareness about sustainability goals. It includes formal and informal mechanisms by which stakeholders become informed about the benefits and opportunities of more sustainable design and begin to consider its application in their own situations. Exposure of stakeholders to sustainability concepts can come through a variety of channels, including:

- Reading about sustainability in trade publications or journals.
- Attending meetings with speakers who address the subject.
- Interacting with colleagues who have sustainability interest or experience.
- Participating in formal training or conferences on sustainability.
- Having discussions with sales/marketing people from sustainability-related product manufacturers.

Such exposure can be intentional or unintentional on the part of any given stakeholder, but even uninterested stakeholders have an increasing likelihood of hearing about sustainable construction concepts just by virtue of doing their jobs on a daily basis. Coverage of sustainability and sustainable development concepts has increased considerably over the past years, as evidenced by the growing number of articles in general trade publications and sustainability-related tracks in traditional industry conferences, the emergence of publications, courses and conferences dedicated specifically to sustainable construction issues, and even coverage in popular press and television.

Some stakeholders may become inspired to pursue sustainability by virtue of being faced with an external threat or crisis that requires a change in the status quo, such as energy or water shortages, volatility in fuel or building material prices, specific environmental constraints associated with project sites, or human-induced or natural disasters that offer significant opportunities to rebuild. With their focus on resource efficiency and reduced environmental impact, sustainable capital projects offer a chance to invest in solutions that reduce demands on resource bases and ecosystems both initially and over their substantial life-cycle. This benefit means that sustainable solutions can emerge as leading contenders in crisis situations.

Prevailing conditions

As with the adoption of most policies or programmes, a variety of circumstances create a climate in which new ideas are accepted and allowed to flourish, even in the midst of opposition. The presence of a crisis cannot be underestimated as an impetus for garnering support for sustainability policies and programmes. For example, in the United States, Chesapeake Bay, Maryland had been suffering from many years of pollution, causing several administrations to work toward improving the quality of the bay. In Arizona, Phoenix experienced brownouts in the summer of 2004 due to the failure of a large transformer. In Maine, extremely high energy costs made sustainable construction more attractive. In addition to crises, other conditions, such as the recognition that high operation and maintenance costs of facilities could be reduced through sustainable design, help to create a climate that is conducive to sustainability policy and programme development. Organizations with rapid growth recognize the importance of implementing sustainability policies and programmes to ensure that the capital projects they will add to their inventory are well designed, provide a better working environment, and are more efficient to operate.

Leadership

Whether initiated by organizational leadership or workers, sustainability-related activities are more likely to occur in an organization if there are champions to promote them. Whether motivated by personal conviction, political gain, economic benefits or some other impetus, someone (or a group of persons) becomes inspired to launch new programmes or policies. Advancing a more sustainable approach to building design, construction and operation/maintenance from an occasional occurrence to standard operating procedures within an organization requires dedication, determination and tenacity on the part of sustainability champions. They will encounter a number of people who are opposed to changing existing practice because of fear, a lack of understanding about sustainability strategies, or an unwillingness to part with the old way of doing things. Typically, it takes a larger number of champions working from the bottom up within organizations compared with fewer champions at higher levels with greater decision- and policy-making authority to make significant changes in a relatively short period of time.

Government activities to encourage private sector sustainability

Sustainability activities in the private sector may advance the rate of adoption of sustainable design and construction practices in the market at large. The existence of prominent private-sector sustainable projects increases awareness of the importance of sustainability among the general population. As the private sector builds more sustainable facilities, members of the design and construction community gain valuable knowledge and experience in creating sustainable facilities and infrastructure systems, and therefore build capacity among professionals.

Rewarding organizations and individuals that choose to build sustainable facilities is an effective method to motivate the adoption of best practices in design, construction and operations while simultaneously improving health, prosperity and quality of life for all. Thus, many governments have begun to implement different types of incentive programmes, along with structural and financial incentives. Structural incentives such as density bonuses and expedited permitting can be implemented at low or no cost to government authorities, and encourage developers to build more sustainably by making healthy, efficient and high-performance development an even more attractive option.

One example of a procedural incentive is simple modification in zoning permissions and review processes that can yield impressive dividends for developers and building owners alike. The city of Dallas, Texas adopted a green building ordinance requiring energy and water efficiency improvements for new residential and commercial buildings. In Dallas, expedited permitting is available if the organization planning new residential construction submits a residential green building checklist (LEED for Homes, GreenPoint Rated, Green Communities, GreenBuilt North Texas or equivalents). For commercial construction greater than 50,000 sq ft, expedited permitting is available if a project attempts a number of priority LEED credits.

Financial incentives are also a highly successful means of encouraging developers to follow sustainable design and construction practices. While these incentives necessarily require a financial investment in more sustainable projects, state and local governments are finding that these investments pay dividends to a community's triple bottom line: ecology, economy and equity.

Major financial incentives for sustainable construction include tax credits and abatements, fee reductions or waivers, grants, and revolving loan programmes. For example, the state of New Mexico created legislation that provides tax credits based on the square footage of a green facility. For commercial buildings, the tax credits range from $3.50/sq ft for a building that achieves LEED-NC Silver certification, to $6.25 for a building that achieves LEED-NC Platinum certification by the USGBC. For residential buildings, the tax credits range from $5.00/sq ft for buildings that achieve LEED for Homes Silver certification to $9.00/sq ft for a building that achieves LEED for Homes Platinum certification.

Facing opponents

Some organizations or people are more difficult to inspire to change their practices than others. Organizations typically find opposition from those who believe that sustainability best practices will increase design and construction costs more than is reasonable. Other opponents represent industry trade associations (for example, forestry, vinyl and refrigerant manufacturers) that do not agree with a particular credit or point within a rating system, such as the point in the LEED Green Building Rating System awarded when 50 per cent of the lumber has been certified sustainably harvested by the Forest Stewardship Council. Building owners sometimes oppose specific prerequisites such as commissioning in rating systems like LEED because they feel as though they already pay for proper design and installation and commissioning should not be necessary. In order to pass sustainable construction policies, it is important to address the questions and concerns of opponents. It is not necessary, and in fact is nearly impossible, to appease everyone, however. Some organizations have effectively addressed some opponents by allowing exemptions and providing allowances that address their concerns.

Inspiration may come from a variety of sources encouraging sustainability best practices. When an organization finally decides that sustainable design and construction is important enough to develop a policy, this phase is called Motivation. The next section describes this phase of the sustainability programme development process.

Element 2: Motivation

The second element, Motivation, refers to formal and informal drivers that compel people to actually try sustainability techniques on their projects. These can range from internal motivation where people become convinced through repeated exposure to sustainability information during the Inspiration stage that they would like to try sustainable construction tactics on their own projects, to formal, external motivators such as executive orders, legislation, or internal policies that encourage or require sustainability action. At the Motivation stage, some stakeholders may have already had exposure to sustainability through the Inspiration process, but others may be suddenly subject to the concept without prior exposure, particularly in the case of mandates such as executive orders or legislation.

Sustainability policies in this stage fall along a spectrum of permanence corresponding to the mechanism used to institute them. For instance, at the state level in the United States, policies can be issued as executive orders by a governor, or as legislation formally passed by the legislature. The former is less permanent since it can be rescinded or superseded by subsequent governors when the issuing governor leaves office, or it can lose urgency even if it remains in effect when a new governor with different priorities takes office. Executive orders typically have no formal enforcement mechanism, although they may include metrics or formal evaluation and reporting procedures to encourage compliance.

Legislation, on the other hand, is considerably more permanent since it is passed by the state legislature and is therefore unaffected by changes in administration. It is also typically much more difficult to put in place, since it must receive majority support across multiple elected officials through the formal legislative process, and is subjected to more scrutiny and possible opposition from lobbying groups. Legislation also has teeth to encourage compliance, since failure to comply is actually breaking the law. While the nature of penalties depends on the specific legislation, a legislation-based sustainability policy has a much higher likelihood of being successful in the implementation phase due to the broader level of sustained support it must achieve in order to be issued in the first place.

While some organizational sustainability policies are focused solely on establishing sustainability standards for capital projects, many policies also include a wide array of additional issues such as transportation fleets, operating procedures and investment criteria. For instance, in the United States:

- Some policies reach beyond buildings alone. For example, in California, the state policy requires that the Teacher Retirement

System seek investments in green buildings and green technologies.

- In order to equip future building professionals to design and construct sustainable facilities, Nevada's legislation requires that the university system provide students with the essentials of sustainable design and construction to help them prepare to become LEED accredited professionals.
- New York's executive order policy includes some very specific operating requirements to save energy such as turning off lights in unoccupied areas, shutting off unused equipment and adjusting thermostats. New York's policy also includes goals for improving the fuel economy of state-owned vehicle fleets.

Sustainability policies have also included the establishment of programmes to support organizations as they implement sustainability programmes. Specific programmes to support sustainability implementation are broad and varied, and the next section of this chapter, Implementation, discusses examples of such programmes in greater detail.

Element 3: Implementation

The third element of the sustainability programme framework is Implementation. This is the phase in which parties responsible for implementing a formal or informal policy decide what programmes and actions will be needed to meet policy goals and execute those programmes and actions to achieve the goals. Examples of Implementation programmes and actions include:

- Technical assistance programmes, both internal and privatized.
- Education and outreach programmes, both internal and privatized.
- Incentive programmes, including subsidies and grants to offset project costs.
- Award programmes.
- Organization-specific guidelines or application guides.
- Modified operating practices.

The programmes that are most effective in a given context depends on the level of market expertise on sustainability, the structure and culture of the organization in which the programmes are being implemented, and the financial resources and/or third party funding such as grants. Programmes that are specifically mentioned and established as part of formal policy typically have more success in motivating change, since they are formally endorsed by leaders and have resources explicitly provided for them. Some specific types of activities to assist organizations in implementing a sustainability policy include technical support, training, the development of guidance documents, and demonstration projects. The following subsections describe these programmes in greater detail.

Technical support

In order to increase sustainable design and construction capacity and ensure that sustainability principles are followed, some organizations in the public sector offer technical assistance, either directly using their own experienced staff or indirectly by providing funding for technical assistance by other entities. For example, in the United States, the New York State Energy Research and Development Authority (NYSERDA) administers an innovative and successful technical assistance programme called FlexTech. Through this programme, NYSERDA approves a list of qualified providers in various fields of expertise and makes these contractors available to its clients to perform customized technical assistance on a cost-share basis. In Colorado, the Office of Energy Management and Conservation provides free technical assistance to all public agencies in the state of Colorado through its Rebuild Colorado programme to support energy performance contracting. In Pennsylvania, the Governor's Green Government Council has an experienced engineer on staff that provides direct assistance, primarily to state agencies but also to private sector clients, depending on availability.

Training

Training opportunities are used to inform facility stakeholders on topics ranging from general sustainability awareness to technical details of sustainability best practices. In the state of Maine, for example, state government provided several training courses on green building techniques, including official LEED training conducted by USGBC trainers, as well as other courses taught by volunteers with the knowledge and experience to train the building community. In California, the Division of the State Architect, Department of General Services (DGS) has developed and participated in the development of sustainability-related training materials, including a series of videos, to advance green building in California. Pennsylvania has also produced a series of videos that is widely available via a website. By making these resources publicly available on their websites, organizations can help a countless number of others with their sustainable construction efforts.

Guidance documents

Organizations sometimes develop guidance documents to assist their staff in implementing sustainability. In the US state of Washington, for example, school districts adopted the Washington Sustainable School Design Protocol and were allowed use it instead of LEED as a rating system. NYSERDA worked with a coalition of other agencies to fund the development of University at Buffalo's High Performance Building Guidelines. In Colorado, the State Energy Office produced a guidebook for how to implement LEED based on strategies that have worked given the unique climate, utility costs, typical payback, construction styles, and other factors unique to that state. The Commonwealth of Pennsylvania has produced several well-known guidance documents not only on sustainable design, but also on requirements for leased facilities to meet sustainability objectives.

Demonstration projects

There is perhaps nothing like the success of others to inspire one to try something innovative, including sustainable design and construction. For instance, in the Maryland, a long-abandoned warehouse building was converted into offices for the Maryland Department of Environment and several other state agencies. This project, which includes a 30,000 sq ft green roof, is considered to be quite successful and has been used as demonstration facility to encourage others to try similar tactics on their own projects. The state of Arizona Department of Environmental Quality (DEQ) building in Phoenix, completed in July 2002, was designed to be LEED certified and is expected to achieve either certified or silver level. The building is very energy efficient – utility bills have been about $1.16/sq ft versus about $1.50/sq ft for a conventional Phoenix-area building built in the same year. In addition, the local utility installed a 100 kW photovoltaic array on the roof of the parking garage to demonstrate renewable energy. The building has performed very well as an efficient building, a useful showcase and an educational tool.

Organizations with sustainability policies can demonstrate a commitment to assisting their staff through programmes like those described in this chapter. How does an organization know whether or not it is complying with requirements and effectively implementing appropriate actions? The element of a sustainability programme designed to measure compliance with sustainability policies, Evaluation, is discussed next.

Element 4: Evaluation

The fourth key element of a sustainability programme is Evaluation. Evaluation can cover programme compliance and/or the effectiveness of the policy, either at the individual facility level or over an entire portfolio of facilities or functional areas. Sometimes but not always, policies explicitly specify how compliance should be measured or demonstrated and specify reporting and accountability requirements that programme implementers must follow. In the case of green building policies in the United States, most evaluation approaches either reference or explicitly incorporate the USGBC LEED Green Building Rating System as an evaluation mechanism and/or support tool. Some organizations require that all projects become certified by the USGBC at a particular level. For example, California governor Arnold Schwarzenegger signed Executive Order S-20-04 in 2004 requiring LEED Silver certification for all state-funded ‘significant’ (50,000 sq ft, prototype or highly visible buildings with an educational purpose) new and renovation projects. Other organizations do not explicitly require certification but simply say that buildings ‘shall meet the requirements for certification’. This is done for a variety of reasons such as to avoid the costs associated with formal certification, to make the policy more amenable to opponents of the referenced rating system, or to encourage a diversity of sustainability programmes and approaches within the organization.

While many policies do refer to rating systems such as LEED, they do not all require formal certification. In addition to the prevalent rating system within a particular context, some policies provide for the possibility of using an alternative rating system instead. One alternative to LEED being considered by some organizations in the United States is Green Globes, described further in Chapter 4. Other policies specify that it is acceptable to use a particular rating system 'or equivalent'. Many states in the United States, as well as federal and local government entities, have realized that LEED is not necessarily a perfect match for their building types and contexts, and have developed application guides or variants on the basic LEED framework to better meet their goals.

The most straightforward evaluation method is to require certification by a third party for all projects covered by a policy directive. This creates a clear metric with little administrative burden on the organization for ensuring compliance, but it does put considerable responsibility on the individuals managing the capital project process. Whatever the evaluation mechanism selected, the importance of evaluation as part of the policy is paramount to ensuring that the goals of the policy are being met. Careless specification and use of a rating system to get points for the sake of points can lead to counter-productive project decisions. For example, increasing evidence suggests the possibility that highly rated projects under the LEED system may not always perform as expected, and some project teams are so eager to obtain points under LEED that they may pursue aspects that are not relevant or appropriate for their projects (Bray and McCurray 2006, Myers 2005).

Many organizations require their staff to regularly report sustainability-related initiatives and activities as a way to measure compliance and overall programme effectiveness. In many cases, this also entails periodically reporting specific data consistently, which is helpful in monitoring progress. For example, in the United States, Colorado's policy contains a requirement that all state agencies give an annual report to the Greening Government Council enumerating all their accomplishments related to the state's Executive Order, including data on the savings from those measures. In other states and at the federal government level, the reporting requirement is given to one agency tasked with overseeing the programme. For instance, the Maryland Green Building Council must produce an annual report to the governor and General Assembly describing the efforts of state agencies, including green buildings, clean energy procurement and greenhouse gas reduction. Likewise, Pennsylvania's policy tasks the Department of Environmental Protection with compiling an annual report on the progress of all the commonwealth's agencies in reaching their goals set forth in their green plans.

Evaluation of policies themselves can include provisions for periodic review and updating of the policy over time and requirements for periodic reporting and accountability, as mentioned in the previous subsection. Although funding may not be specifically provided for these activities in the policy, other resources such as grants and/or partnerships with universities can often be tapped to conduct these studies and monitor progress toward policy goals. Together, these elements combine to achieve change toward the goal of increased sustainability through best practices.

Sustainable construction policies and programmes: international examples

The number of policies and programmes devoted to improving sustainability performance, especially of capital facilities, continues to grow around the world. The following subsections provide examples of current policies in place in the United States, United Kingdom, Japan and Australia to promote the use of sustainability best practice in construction in those countries.

Sustainable construction policy in the United States

As described in Chapter 2, policy related to sustainability has been evolving at a rapid rate since the early 1970s in the United States. In the public sector, three different levels of government exist and overlap to provide services and oversight for the people. Federal government exists at the national level and applies equally to all parts of the country. Each of the 50 US states also has its own state government to establish policies, pass legislation, and provide programmes and services within the state boundary. The priorities and perspectives of each state differ considerably due to factors such as local or regional climate, demographics, industries within the state, and political orientation of the state's population. At the local level, many towns, cities and counties also have individual governments that are even more focused on the nuances of local issues and constraints. Building codes and design are generally enforced at the local level, although they may reference larger state, national or international codes with local adaptations. Construction practice, on the other hand, is typically regulated and enforced at the national level by organizations such as the Environmental Protection Agency (EPA) or the Occupational Safety and Health Administration (OSHA). Baseline appliance and facility efficiency and performance standards are typically established at the national level, and may be enforced at any level of government. Some states with particular local issues may also establish their own, more rigorous performance standards for efficiency or environmental performance. California, with its serious environmental issues such as poor air quality, is one such example of a state that has more stringent standards for many products related to the construction industry.

Federal policy in the United States

The US federal government has initiated several construction-specific policies to achieve the goals of sustainability, including the reduction of greenhouse gas emissions and energy consumption in the building sector. Chapter 2 provides an overview of the most significant policies in this area. One of the latest policies is Federal Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance, signed by President Obama in 2009. This executive order sets numerous green requirements for federal government-owned or leased facilities. The executive order requires agencies to meet a number of energy, water, and waste reduction goals:

- 26 per cent improvement in water efficiency by 2020.
- 50 per cent of construction, recycling and waste materials will be diverted from landfills by 2015.
- 95 per cent of all applicable federal contracts will meet sustainability requirements.
- Implementation of a 2030 net-zero-energy building requirement.
- Implementation of the stormwater provisions of the Energy Independence Security Act of 2007.
- Development of guidance for sustainable federal building locations in alignment with the Liveability Principles put forward by the Department of Housing and Urban Development, the Department of Transportation, and the EPA.

This executive order supersedes similar orders signed into place by previous administrations. In general, later executive orders and regulations are more stringent than earlier ones, although this is not always the case. Chapter 2 discussed additional examples of sustainability-related federal policies and regulations in the United States.

State and local policy in the United States

At the state and local level, significant variability exists in the scope, provisions and language of sustainability-related policies and programmes. Many examples of specific provisions and language have been provided throughout this chapter. The USGBC maintains a searchable database of public policy in the United States pertaining to green building and sustainable development at local, state, and federal levels (USGBC 2010). The database covers three types of policy: regulatory policy developed by government agencies, legislative policy developed using democratic procedures by elected officials, and executive policy put in place by elected leaders such as the president, governors, mayors or town councils. The database covers both public sector and private sector developments.

The Department of Energy also provides ongoing sponsorship for an online database of state, local, utility and federal incentives and policies that promote energy efficiency and renewable energy (USDOE 2010). This searchable database, the Database of State Incentives for

Renewables and Efficiency (DSIRE), identifies residential and commercial incentives for building owners, government agencies and commercial enterprises that pertain to sustainable energy topics. Examples of policies captured in this database for the Commonwealth of Virginia, for example, include a state personal income tax deduction for energy-efficient products targeted to individuals, and a green jobs tax credit and Solar Manufacturing Incentive Grant programme for corporations that create sustainability-related jobs or manufacture solar thermal or photovoltaic technologies within the boundaries of Virginia. The database also provides a geographically organized reference to applicable energy-related rules, regulations and policies as well as related government programmes and initiatives that could be tapped for non-financial support. While programmes and policies are constantly changing in the United States the USGBC and DSIRE databases provide updated links to the most currently applicable policies pertaining to sustainability.

Sustainable construction policy in the United Kingdom

The UK government is advocating the goals of sustainability to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations. The government at the national level has confirmed a number of policy and legislative initiatives to secure sustainability in construction which include:

- **Zero carbon new nondomestic buildings** – All new commercial buildings are to be zero carbon/carbon neutral starting in 2019.
- **Zero carbon new homes** – From 2016, all new homes are to be zero carbon/carbon neutral.
- **Building regulations** – New homes must reduce greenhouse gas emissions due to energy consumption by 25 per cent in 2010 against 2006 requirements, and by 44 per cent by 2013.
- **Climate Change Act 2008** – Provides legally binding greenhouse gas reduction targets for industry, intended to result in reductions of 80 per cent by 2050.
- **Renewable Energy Strategy** – Defines programmes and strategies to meet EU targets for renewable energy generation at a level of 15 per cent by 2020.
- **Strategy for Sustainable Construction 2008** – A joint industry and government strategy and set of programmes to deliver sustainability in construction.
- **Water efficiency in new buildings** – Establishes building regulations to include minimum water efficiency standards in new dwellings (no more than 125 litres/person/day).
- **Site waste management plan** – Introduced in 2008 to enable effective management of waste on construction and demolition sites and to encourage reduction and recycling of waste.
- **Planning Policy Statement (PPS) on Planning and Climate Change** – Sets out how planning should ensure that new

developments reduce greenhouse gas emissions through their location, form, layout, and the use of renewable and low-carbon energy, and also that they are resilient to the impacts of future climate change.

In addition to the national policies related to sustainability in construction, the regional spatial strategy (RSS) developed by the Regional Assembly in each region sets policies and targets for the next two decades. For example, the draft RSS for the South West includes the requirement for 10 per cent renewable or low-carbon energy in new development. Furthermore, local governments have also adopted policies to move towards sustainability in construction in particular, including:

- **The Local Development Framework Core Strategy Policy 3** – All new nonresidential developments will be completed to a Building Research Establishment Environmental Assessment Method (BREEAM) certification level of 'very good' up to 2013 and thereafter a minimum rating of 'excellent'.
- **Climate Change Action Plan 2009** – Sets out how to reduce greenhouse gas emissions by 21 per cent by 2020 against the 2005 baseline Renewable Energy Strategy with the aim of delivering EU targets for renewable energy generation of 15 per cent by 2020.
- **Carbon Management Programme** – Sets a target to reduce carbon emissions by 25 per cent by 2013, part of which will be delivered through better design of new buildings and refurbishment of existing stock.
- **Sustainable Procurement and Commissioning Strategy 2009–2012** – All new buildings and major refurbishment shall aim for at least BREEAM level 'very good'. This shall be validated through a peer review process involving technical services and the council's consultant partners.

Sustainable construction policy in Japan

The Japanese government has also demonstrated an interest in environmental and energy issues in the building sector. Two of the major indications of this interest are its ratification of the Kyoto Protocol to reduce 6 per cent of greenhouse gas emissions based on 1990 levels, and its more recent commitment to reduce 25 per cent of greenhouse gas emissions by 2020 compared with 1990 levels at the United Nations Framework Convention on Climate Change (UNFCCC), the Copenhagen Accord in December 2009. To achieve these goals, the Japanese government has implemented policies related to energy conservation and greenhouse gas reduction in the built environment. One of Japan's implementing policies is the Energy Conservation Law, launched in 2003 to reduce energy consumption in commercial buildings. The Law specifies a requirement for energy control systems in commercial buildings, and emphasizes the rational use of energy related to the prevention of heat loss and efficient energy use in buildings. In addition, this law also provides for subsidies, low-interest loans and tax incentives for energy conservation measures. In 2006, mandatory energy conservation measures were released to strengthen the Law. Buildings with a total floor space of 2,000 sq m or larger are now required to report conservation measures in new construction, extension or rebuilding.

The Top Runner Programme is a leading Japanese regulatory tool designed to help achieve the goals of the Energy Conservation Law. Rather than setting a minimum efficiency requirement for equipment, it identifies products with the highest energy efficiency ratings in the market and sets them as the market standard. That standard then becomes the requirement imposed on manufacturers. Given the ambitious nature of this approach, notable energy savings impacts have been associated with the introduction of the programme.

In parallel to these policies and programmes, the Energy Conservation Centre of Japan (ECCJ) was established to promote rational energy use, and to act as a resource for technical advice to local governments. The ECCJ has also adopted a list of policies entitled the Fundamental Policies for Rational Use of Energy, which outlines various measures for builders, owners and local governments to encourage adoption of energy efficiency measures. Local governments are also encouraged to support capital investment, technology, research and development, and education as it relates to energy conservation.

The CASBEE rating system has been used to measure the environmental performance of building, both the environmental impact and quality of life provide by the building. Since its inception, 15 major local governments across the country have mandated the use of CASBEE, or have created incentive programmes to help promote its adoption. Osaka City and Nagoya City will subsidize highly rated projects, Kawasaki City provides lower-interest home loans for rated projects, and other cities provide some flexibility in the building permit and review process.

Tokyo Metropolitan Government has implemented the Tokyo Green Building Programme based on the Tokyo Metropolitan Environmental Security Ordinance since 2002. The rating system applies to all newly constructed large-scale buildings (10,000 sq m and over) in Tokyo. This programme is designed to require building owners to care about the environment when constructing or expanding large buildings in four key areas: rationalization of energy use, appropriate use of resources, conservation of the natural environment, and abatement of the urban heat island effect.

The urban scale CASBEE-City is used to assess the environmental performance of the Eco-Model Cities project. Eco-Model Cities is a demonstration programme of multiple sustainability projects in 13 cities across the country. The Eco-Model Cities programme was established by the Japanese government to create and promote a low-carbon society on a city level, both domestically and worldwide. Six cities were originally selected as a pilot in 2008, and seven additional cities were selected in 2009 (see Table 3.4). All of the cities prominently feature activities and future plans to drastically reduce greenhouse gas emissions.

Table 3.4 Japanese cities implementing the Eco–Model Cities Program

City	Population	Mid–term reduction goal (2030)	Long–term reduction goal (2050)	Base year
Shimokawa	3,800	32%	66%	1990
Obihiro	170,000	30%	50%	2000
Yokohama	3.67M	Over 30%/Person	Over 60%/Person	2004
Toyama	420,000	30%	50%	2005
Kitakyushu	0.99M	30%	50–60%	2005
Minamata	29,000	33%	50%	2005
Chiyoda	45,000	25%	50%	1990
Iida	107,000	40–50%	70%	2005
Toyota	420,000	30–50%	50–70%	1990
Kyoto	1.47M	40%	60%	1990
Sakai	840,000	15%	60%	2005
Yusuhara	4,000	50%	70%	1990
Miyakojima	55,000	30–40%	70–80%	2003

Each city highlights a unique attribute of sustainability such as renewable energy, waste reduction, agriculture and transportation. For example, the small town of Shimokawa, with a population of 3900 people, is implementing programmes on renewable forest management and fast-growing willows for a non-food biofuel. The medium-sized Toyota, with a population of 420,000, is developing an eco-friendly car society through next-generation car sharing and solar-powered car charging. Yokohama, one of the largest cities in Japan with a population of 3.65 million, has a goal of ten times more renewable electricity by 2025.

Sustainable construction policy in Australia

As of 2010, there is no legislation in Australia that mandates buildings to meet a Green Star Rating system performance level or comply with other green building rating systems. However, the Australian government heavily emphasizes performance in the areas of energy efficiency and greenhouse gas emission reductions. This emphasis is based on the decision of the Australian government to ratify the Kyoto Protocol and commit to reduce greenhouse gas emissions from 5 per cent to 25 per cent from the 2000 baseline by 2020, at the 2009 UNFCCC Copenhagen Summit. To achieve its goals, the Australian government combines a policy approach of regulations, financial support, and information and support to industry.

One significant step was to publish the National Strategy on Energy Efficiency in 2009, authored by the Council of Australian Governments

(COAG), to accelerate energy efficiency efforts, to streamline roles and responsibilities across levels of government, and to help households and businesses. The National Strategy on Energy Efficiency has committed to reducing travel related to government business through the use of video conferencing, improving sustainability in procurement and energy performance contracting, developing a national green lease policy, and developing a national framework for sustainable government office buildings.

Since all buildings in Australia must comply with the Building Code of Australia (BCA), the Australian government includes requirements related to sustainable design and construction strategies, especially related to energy efficiency, to reduce energy consumption and greenhouse gas emissions in the construction sector. The section on Energy Efficiency focuses on requirements for (for example) building fabric, external glazing, building sealing, air movement, air conditioning and ventilation systems, artificial lighting and power, hot water supply, and access for maintenance (Australia Building Code 2008). Under the National Strategy on Energy Efficiency, the construction of new buildings as well as major renovations must comply with stronger energy-efficiency requirements that are being proposed as part of the 2010 update to the Building Code Australia. The proposed stronger energy efficiency requirements ensure more efficient:

- construction, walls, floors, glazing and sealing
- air conditioning, ventilation and heating systems
- lighting types and power controls
- hot water systems, swimming pools and spas
- monitoring, maintenance and ongoing improvements.

In the commercial office sector, the Australian government has launched Commercial Building Disclosure (CBD), established by the Building Energy Efficiency Disclosure Act 2010, to improve the energy efficiency of Australia's large office buildings. Under this programme, most sellers or letters of office space with net leasable area of 2,000 sq m or more are required to obtain and disclose an up-to-date energy efficiency rating by a full Building Energy Efficiency Certificate (BEEC).

Incentives and financial support

A variety of incentives and opportunities for financial support also motivate sustainable construction in Australia. The Green Building Fund forms part of the Australian government's Clean Business Australia Initiative. The Fund, delivered by AusIndustry, allocates grants to reduce greenhouse gas emissions from Australia's built environment by reducing the energy consumed in the operation of commercial office buildings. Businesses that install eligible small-scale solar photovoltaic, wind and hydroelectricity systems may be eligible to receive extra renewable energy certificates under Solar Credits (www.orer.gov.au). There are also additional financial resources including the

$50 million Energy Efficiency Trust and the $2.75 billion Climate Change Action Fund to support energy-efficient buildings in Australia.

The Australian government takes its role as a leader in energy efficiency seriously. It is focused on improving sustainability by:

- More energy-efficient government buildings.
- Strong policy on energy efficiency in government.
- Annual whole-of-government reporting on energy use.
- Committing national, state and territory governments to proposed legislation requiring commercial office buildings to provide energy-efficiency information when selling or leasing.
- Leading the way in the use of green leases.
- Developing a whole of government information and communication technology (ICT) sustainability policy.
- Encouraging environmental performance reporting and the use of environmental management systems.

Energy Efficiency in Government Operations (EEGO) has been implemented to improve energy efficiency and consequently reduce the total cost of ownership and environmental impact of government operations. The EEGO policy has three major elements:

- annual reporting of energy performance by agencies
- portfolio energy intensity targets by 2011
- minimum energy performance standards for office buildings, appliances and vehicles.

Although this policy only focuses on energy as of this time, other sustainability outcomes such as water conservation and waste reduction can be integrated into the framework in the future.

The Australian government has also led the way in the use of green leases, introducing Green Lease Schedules in 2006 as a key component to the EEGO policy. Green leases are an innovative management mechanism to enable tenants and building owners to monitor and meet a building's energy target annually. Green leases are a strategy for some of Australia's government agencies that lease facilities to supplement their own capital portfolio.

Water efficiency labelling and standards

The growing need to reduce water consumption across Australia has resulted in collaboration between state, territory and national governments to introduce a Water Efficiency Labeling and Standards (WELS) scheme. Established on 1 July 2006, the WELS scheme requires certain water-using products to be labelled for water efficiency, helping Australian households to save water and money. The scheme also allows industry to showcase its most water-efficient products. Under the scheme, product suppliers are required to provide water efficiency information, and star-ratings to consumers for clothes washers, dishwashers, showers, taps, toilets, urinals and flow controllers. Industry must register these products with the WELS regulator (the secretary of the Department of the Environment, Water, Heritage and the Arts).

These public sector sustainability initiatives in leading countries have stimulated society to adopt more sustainable practices, especially with respect to construction. However, they form only part of the whole picture. The other key perspective in delivering green projects is the corporate perspective, focusing on the architecture, engineering and construction companies that work together to design and deliver capital projects. The next section explores this perspective in more detail.

The corporate perspective: how to transform a construction company to deliver more sustainable projects

From the perspective of a government agency trying to incentivize more sustainable practices in the built environment, there are many ways to promote and encourage owners to seek to adopt sustainability as they develop and operate their capital facilities. However, this perspective can differ drastically from the perspective of the architecture, engineering and construction (AEC) industry that must respond to the needs of owners to actually deliver more sustainable projects. From the perspective of construction as a production process, contractors and subcontractors represent the general and specialized units within the process that accomplish the actual production of the desired product (Gil et al 2000). With design–build procurement and pre-construction services on the rise, these players also have an increasingly important role in the planning and design phases of capital projects (Horman et al 2006), and their input has the potential to shape how projects are realized in multiple ways (Errasti et al 2007), including influencing planning and design decisions that have cost implications for the project. Together with the supply chain that provides materials and products for the production process, these actors constitute the constructor subsystem within the larger socio-enviro-technical (S-E-T) system that comprises a capital project (Rohracher 2001).

The stakeholders that collaborate in the delivery of green capital projects must deal with a number of unique qualities that characterize more sustainable projects, including (Pearce 2010):

- Tightly coupled designs and multifunction materials and systems (Riley, Pexton and Drilling 2003, Rohracher 2001).
- Procurement of unusual products with limited sources (Klotz, Horman and Bodenschatz 2007, Pulaski et al 2003, Syphers et al 2003).
- Existence of incentives and resources not available to other projects (Grosskopf and Kibert 2006, Pearce 2008, Rohracher 2001).
- Requirements for additional information and documentation (Lapinski, Horman and Riley 2005, 2006; Pulaski et al 2003).

- Greater involvement of later stakeholders in earlier project phases along with greater integration of their input (Cole 2000; Gil et al 2000; Matthews, Tyler and Thorpe 1996; Pulaski and Horman 2005; Pulaski, Horman and Riley 2006; Reed and Gordon 2000; Rohracher 2001).

Considered from the standpoint of contractors and subcontractors, sustainability as an innovation may not always seem to offer immediate benefits over the status quo, especially for later adopters who miss the opportunity to use sustainability expertise as a market differentiator. In terms of relative advantage, the benefits of sustainable construction tend to accrue to other stakeholders or even non-stakeholders, particularly the owners and occupants of the facility and future generations who may benefit from reduced environmental impacts and resource consumption (Taylor and Wilkie 2008). These benefits may also be difficult for the constructor to see since they are typically spatially and temporally distant from decisions made during construction (Gardner and Stern 1996, Khalfan 2006), thereby reflecting poor observability. From the standpoint of trialability, integrated design and delivery tactics require contractors to jump in with both feet rather than being able to try sustainability concepts and practices at their own pace (Lapinski et al 2005, Horman et al 2006). The use of new technologies and products may require deviation from established subcontractor and supplier networks, thereby reflecting poor compatibility with contractor assets that traditionally afford a source of competitive advantage (Kale and Arditi 2001). Finally, all of these factors combined with the demands of extensive new documentation, product qualification requirements, and additional general requirements such as waste management, indoor air quality best practices and commissioning, lead to a disadvantage in terms of complexity (Klotz et al 2007). From this perspective, it should come as no surprise that members of the constructor subsystem have not yet universally embraced sustainability (Panzano et al 2004). How, then, to align a construction company with the goals of sustainability and address those goals to strategic advantage?

The evolution of corporate sustainability for the construction sector

Despite the challenges associated with diffusing sustainability throughout the construction industry, the concept has a history in this sector that evolved from some of the fundamental trends that have shaped construction over the last 50 years or more. This section describes some of the major trends that were precursors to sustainability in the construction industry, leading to today's approaches for strategic sustainability in corporate operations in the construction industry.

Environment, safety and occupational health (ESOH)

Although ideas pertaining to safety in the construction sector have been around since the time of Hammurabi, corporate attention to protecting the environment, safety and occupational health in the workplace has evolved comparatively recently. Driven by both regulation and corporate liability, these notions emerged most strongly in the United States in the 1970s with the establishment of the Occupational Safety and Health Act and numerous environmental regulations discussed in Chapter 2. Since that time, construction along with many other industries has invested significant attention and resources to improving the safety and occupational health of its workers, and reducing impact on the natural environment. Many construction companies have special departments or personnel within the organization devoted specifically to managing and improving safety and occupational health within the organization and establishing a safety culture within the company.

Increasingly, companies have personnel or resources specifically dedicated to management of environmental compliance as well. For example, managing stormwater on construction sites in the United States has gained significant importance since the development of the National Pollutant Discharge Elimination System (NPDES) permit programme under the Clean Water Act. This programme requires permitting and enforcement of stormwater controls on construction sites, and imposes site shutdowns and/or fines for violations. As requirements to comply with the Clean Water Act have become increasingly more stringent, construction companies have begun to realize the real impacts noncompliance will have on project budgets and schedules, and they have taken actions accordingly. Some companies manage these issues internally through special departments or functionalities within the project team, while others choose to outsource specific responsibilities for stormwater management to outside firms.

In either case, the importance of systematic management of ESOH issues for company success and competitive advantage is becoming more universally recognized. Although these issues have historically been driven by regulation, legal liability or both, in today's market they form the underpinning for a company's reputation and success in the marketplace. Some industry experts have suggested that eventual adoption and internalization of sustainability principles within the construction industry will follow a similar path.

Total quality management (TQM)

TQM is another trend that has been applied across multiple industry sectors before being embraced by the construction sector. The concept originated in the early 20th century as an application of statistical theory to product quality control, and saw widespread evolution and adoption in domains such as the automotive industry in the 1940s and 1950s, especially in Japan and the United States. Eventually, TQM evolved from a narrow focus on improving the quality of products and began to be applied more broadly to the task of improving all aspects of a company's operations, with a focus on 100 per cent customer satisfaction. By the 1990s, TQM broadly included concepts addressing multiple aspects of corporate management, including customer focus, employee involvement, continuous improvement, and integration of quality management into the total organization.

Often called 'business excellence' today instead of TQM, the concept of systematic, holistic management of an organization's operations based on consistently and competitively meeting customer needs eventually gained attention from other organizations such as service industries, government agencies, and charitable organizations or nonprofits. Today, it has been more widely adopted by companies in the construction sector, especially outside the United States (Pheng and Teo 2004). Benefits of adoption cited by construction firms who have adopted TQM include reduction in quality remediation costs, better employee job satisfaction because employees do not need to attend to defects and client complaints, recognition by clients, work carried out correctly right from the start, subcontractors with proper quality management systems, and closer relationships with subcontractors and suppliers.

Characteristics of successful corporate TQM and sustainability programmes

- A CEO champion.
- Carefully chosen initiative leaders.
- Multidisciplinary teams.
- Dual focus on risk and opportunity.

Source: Fust and Walker (2007).

TQM is a significant precursor to sustainability in the construction industry because of its similarities to the concept during corporate adoption (Fust and Walker 2007). Both concepts have initially been ambiguous with regard to implementation, and both have been often perceived by firms as a cost or risk rather than an opportunity for competitive advantage. As with TQM, the firms most likely to reap competitive advantage from early adoption of sustainability principles are those that see the opportunities it presents for improvement rather than 'an added cost to absorb, another risk to manage, or one more regulation with which to comply' (Fust and Walker 2007). There are a number of parallels between the two concepts based on a review of early leaders in multiple sectors (Fust and Walker 2007), and four important attributes characterize successful programmes in TQM that also apply to sustainability initiatives (see box).

Environmental management systems (EMS)

Along with TQM, the trend of EMS represents an influence in the construction sector that has promoted a more systematic, deliberate approach to addressing both need and opportunity in how business is conducted. While TQM focuses its systematic approach on ensuring 100 per cent customer satisfaction with a company's products or services, EMS focuses instead on reducing unwanted impacts on the environment resulting from a company's operations, and increasing environmental benefits as an outcome.

Key elements of an EMS

- Purpose and scope.
- Policy statement.
- Identification of significant environmental impacts.
- Development of objectives and targets.
- Implementation plan/programme.
- Training plan/programme.
- Review/update plan.

Most EMS initiatives follow the ISO 14001 standard, which incorporates a four-step, cyclical approach to continual improvement of environmental performance in operations (see Figure 3.3).

This problem-solving process, also known as the Deming cycle after its originator, originally evolved from the ideas of TQM, and is also a part of the ISO 9000 standard for TQM. The cycle begins with a planning step, where objectives are set and a course of action is developed to achieve those objectives. This is followed with a 'Do' step in which the course of action is implemented, often on a small scale at first. Following this step, a 'Check' process is used to evaluate the results of the action and compare them with the original objectives. Any differences between planned and actual outcomes are noted and analysed in an 'Act' process, where changes to the course of action are made to address any identified problems. The process then begins again, and continues until no need to further improve is noted. At this point, the process is standardized, shown as a wedge in Figure 3.3, to stabilize the improved results and prevent backsliding. Then, a new, refined scope is selected to continue the improvement process.

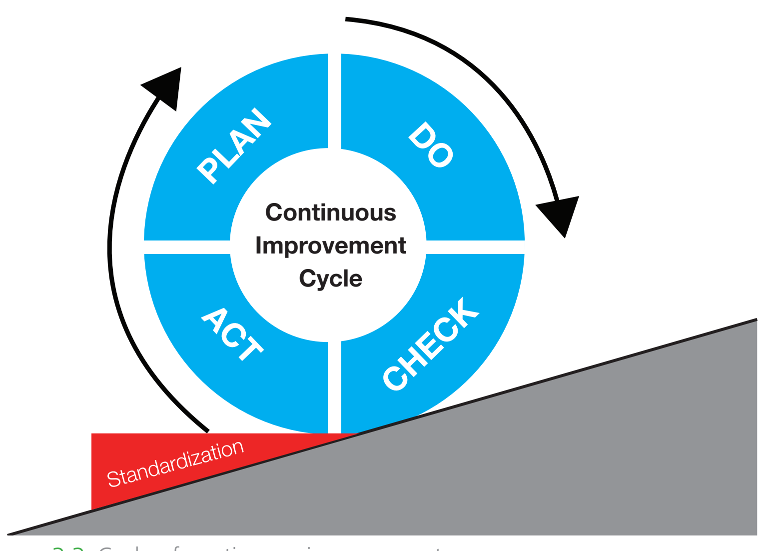


Figure 3.3 Cycle of continuous improvement

An EMS is generally developed as a written plan and then implemented in practice (see box). Several common issues have been noted in practice that must be addressed for the successful implementation of an EMS (Burden 2010):

- Full commitment of management to the EMS.
- User friendliness.
- Clear identification of environmental compliance requirements.
- Degree of complexity.
- Adequate financial, physical and human resources.
- Measurable objectives and targets that facilitate continuous improvement.
- An organizational culture of continuous improvement.

In Europe in particular, there has been widespread adoption of EMS by organizations in the construction industry under the ISO 14001 standard, whereas in the United States and many other countries, adoption has been slower. However, EMS and TQM have set the stage for the next step in the evolution of corporate sustainability for construction: sustainability management systems.

Sustainability management systems (SMS)

Similar in form to EMS, SMS plans take a broader focus to include social and economic goals relevant for the business being managed. With this broader scope, companies can move beyond simple conformance with standards or compliance with regulations into managing the effectiveness and strategic sustainability of their enterprises as a whole.

PricewaterhouseCoopers has identified four key questions companies should ask as part of developing sustainability management systems (PWC 2004):

- What are the key sustainability risks and challenges relevant to our business goals, and are we effectively managing these issues?
- Are our sustainability objectives complementary with, or competing with, our other business objectives?
- Are our division-level SMS concordant with our corporate-level systems, and are these systems aligned with our overall business strategies?
- Are our SMS designed to deal with emerging sustainability risks that could affect the company's long-term success?

To address these questions and create a framework for evaluating effectiveness of SMS, PWC has developed an approach for assessment called ORCA, which stands for:

- Objectives: what are the company's key business and sustainability objectives?
- Risks: what are the main sustainability risks and challenges the company faces?

- Controls: what management practices have been implemented to manage these risks and challenges?
- Alignment: to what extent is the SMS aligned with overall business goals?

The ORCA approach is organized around relevant corporate objectives for growth, production levels, cost control, reputation, environment, health and safety, and external stakeholders. As mentioned in earlier sections, alignment of business and sustainability objectives is an essential feature of companies that can successfully pursue sustainability goals to strategic advantage. The next section addresses this and other key issues that are part of an effective corporate sustainability strategy.

Organizational strategies for corporate sustainability in the construction sector

Given the evolution over time of increasingly holistic and outcome-oriented approaches for managing corporations, how should a firm proceed in developing a plan or management system for corporate sustainability? Developing sustainability objectives, forming an effective sustainability team, finding opportunities within the firm to increase sustainability, and choosing the right strategies for implementation are key aspects of a strategy to pursue corporate sustainability. The following subsections describe these issues in greater detail.

SMART characteristics of effective objectives

The five characteristics of effective objectives are:

S	Specific
M	Measurable
A	Attainable
R	Relevant
T	Time-bound

Source: Duran (1981).

Setting effective sustainability goals and objectives

There are many ways to set sustainability goals and objectives, and many levels at which these goals and objectives can apply. At the overall corporate level, for example, sustainability goals for companies in the construction sector may deal with overall impacts of the business across all of its projects and operations. Other goals may be developed for individual projects and pertain to the specific context and requirements for that project. Some projects pursuing formal certification under a recognized rating system may choose to use the framework of the rating system as a starting point. Other projects may have goals outside any particular framework. The details of specific rating systems and standards at both these levels are covered in more detail in Chapter 4.

However, no matter what external points of reference are employed, the principles of effective goals and objectives remain the same.

Goals are broad statements of what should be achieved for or by the company or project as a whole. Objectives are more specific, and have the characteristics of being both measurable and time-bound. Both objectives and goals for a project should be attainable and relevant to the company or project and issues at hand. The SMART acronym provides a way to remember what are the characteristics of effective objectives: they should be Specific, Measurable, Attainable, Relevant, and Time-bound (see box).

Measurable means that it is possible to definitively say whether or not an objective has been achieved at a certain point in time. Some objectives can be expressed in terms of quantifiable performance – for instance, 'Reduce water use by 50 per cent'. These objectives require modelling or measurement to determine whether the specified level has been met. Others may be measurable in terms of 'yes' or 'no' – for instance, 'Use bio-based form release oil for all concrete forms', or 'Develop an education plan to ensure that 50 per cent of all field employees have at least one external sustainability accreditation'.

Time-bound means that the point at which the objective will be evaluated is defined at the beginning. For instance, the objective 'Reduce water use by 50 per cent' does not explicitly specify the measurement period. If developed at the project level, must this objective be met during construction, or is it meant to be evaluated for a typical year of operation? The objective only makes sense if the time period for evaluation is specified.

The objective 'Reduce water use by 50 per cent' must also be made more *specific* to be useful. The scope of the objective should be clear. What water uses will be counted? What is the baseline against which the reduction should be measured?

To be relevant, the objective should have a scope that is meaningful for the time period and project being considered. For instance, reducing water use may be meaningful for a building during operations, but is not likely to be relevant for a highway project during operations. However, water use might be relevant for certain aspects of the construction of a highway project, depending on the means and methods involved.

Lastly, effective objectives should be *attainable*, given the resources and parameters of the organization. Objectives are most useful when they require additional effort beyond common practice. However, they should be reasonably achievable when considering the additional costs and efforts of achieving them. Determining what makes an objective attainable is a balance between the cost of meeting the objective and the benefits that can result. Setting unattainable objectives may result in unwise investment of resources. It may also be bad for morale when the unattainable objective is inevitably not met.

In general, sustainability goals for a company or project can be organized into three overlapping categories corresponding to the triple bottom line (Figure 3.4). Goals and objectives should focus on the

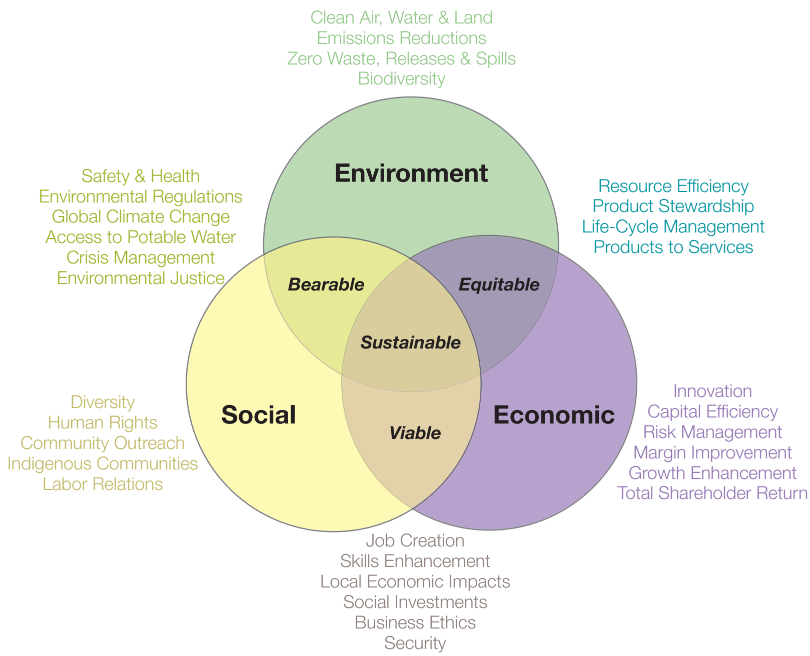


Figure 3.4 Triple bottom line factors

'what' rather than the 'how'. For instance, specifying a goal of diverting 50 per cent by weight of construction waste from landfill disposal retains flexibility for the project team to determine the most effective way to achieve the objective in practice, rather than requiring them to use a particular means to achieve the objective.

Forming effective sustainability teams

Concurrently with the development of sustainability objectives at the corporate level, a key element of corporate sustainability is forming an effective corporate sustainability team. Various approaches exist within a corporation to develop and roll out such a team, including horizontal approaches, vertical approaches and SWAT team approaches.

The horizontal approach to sustainability rollout involves training everyone at a particular level or key function within a firm to have basic skills and capabilities pertaining to sustainability. For example, a general contractor firm may elect to train all of its site superintendents on sustainability principles and encourage them to obtain credentials under a relevant accreditation programme such as the Sustainable Construction Supervisor programme managed by the National Center for Construction Education and Research in the United States. In this way, the company can be certain that on every project, there will be at least one person to serve as a sustainability champion and identify opportunities that can be pursued.

The vertical approach to sustainability teams involves developing deep expertise about every relevant aspect of sustainability for project delivery by educating all of the players involved with 'greening' a particular project. In this approach, each player from project manager to labourer receives basic sustainability training followed by additional training relevant for their particular project role. For firms just getting started with sustainable construction, this type of training may happen when the firm becomes involved with an owner or design organization that demands sustainability best practices for a capital project. In this case, members of the project team will learn on the job rather than in any organized fashion. The vertical approach can also be achieved through corporate-wide sustainability awareness or training programmes for everyone in the firm, not just a particular project, although it may be difficult to provide information at a level that can be used by everyone in their day-to-day activities using this approach. If done in a focused way for a particular project, the result may be a sustainability SWAT team that takes on a specialized role within the firm to provide sustainability services across multiple projects.

The SWAT team approach is so named for the special weapons and tactics teams commonly found in law enforcement organizations. These elite teams receive special training and resources to perform high-risk operations, and are called upon for difficult tasks that are beyond the capabilities of regular police officers. In similar fashion, a corporate sustainability team formed using the SWAT team approach has the specialized capabilities to internally address sustainability challenges from any aspect of the company's operations, and may be deployed anywhere within the company to solve specific sustainability problems. Such teams are often part of the resources available within a corporate sustainability office, and may be led by the corporate sustainability director if such a role exists within the firm.

In any of these approaches, the organization should take advantage of expertise from all aspects of the company to have the most holistic perspective (Table 3.5). If internal expertise does not exist within the firm to address relevant issues, it may be brought in through the use of external consultants or new hires, or internally cultivated via education or training of existing personnel.

As mentioned earlier, the support of upper management correlates highly with the overall success of a corporate sustainability policy, especially in firms with centralized organizational structures (Accenture 2010a). A different approach may be preferable in decentralized organizations. In any event, the design and governance of sustainability initiatives in an organization should be structured in a way that makes the most sense for a given business environment. A strong change management orientation, coupled with a clear understanding of how sustainability can support business objectives, is also essential.

Table 3.5 Expertise on the corporate sustainability team

Function	Expertise
Board of directors	Shareholder value impact; outside knowledge of emerging best practices and opportunity initiatives
Research & development	Perspectives on how current and future products and practices relate to sustainability
Marketing	Understanding how sustainability supports marketing strategy and provides differentiation with target markets
Supply chain	Understanding of sustainability issues related to material and product inputs and natural resource utilization
Operations	Insights and ideas on process and product improvements with sustainability benefits
Environmental/safety/ occupational health	Historical compliance perspective to expand initiatives *beyond* compliance; incubation of new sustainability-related revenue opportunities such as carbon trading
Finance	Evaluation of the costs and benefits of sustainability programs; risk management expertise
Human resources	Performance management links and recruitment support
Legal/compliance	Knowledge of current and pending laws and regulations; understanding of how sustainability risks affect regulatory risks and vice versa
Public relations	Communications to external stakeholders; corporate social responsibility

Source: adapted from Fust & Walker (2007).

Finding opportunities for increasing sustainability in the firm

As the organization begins to consider how it can improve the sustainability of its operations and business practices, management frameworks such as the ISO standards or the British standard BS 8900:2006 – Guidance for Managing Sustainable Development provide a useful starting point. In general, each organization will identify things it can do from the standpoint of the primary product or service it provides to the market, and the internal support practices it uses to deliver those products or services. Figure 3.5 shows a model of corporate functions that can serve as a starting point for inventory sustainability improvement opportunities. In the construction industry, the ultimate product is the capital projects that result in our built environment, and all members of the industry contribute to that outcome according to their own functional capabilities. Chapters 5 to 9 of this book explore the range of best practices that are used in the market today to improve the sustainability of capital projects, and can be a resource for firms seeking ideas to improve their own projects.

From the standpoint of improving internal operating practices, a variety of best practices exist to increase the sustainability of internal operations. Table 3.6 provides a checklist of some of the most common practices adopted by companies in general in their quest to increase operational sustainability. Additional examples are provided in the last part of this chapter on case studies of corporate sustainability.

Table 3.6 Checklist of organizational best practices for sustainability

Practice
☐ A formal policy on sustainability
☐ Green team(s) or sustainability working groups
☐ An orientation programme that includes sustainability or social/environmental issues
☐ A training programme that includes sustainability or social/environmental issues
☐ A formal process for capturing lessons learned
☐ Access to external sustainability specialists/partners/consultants
☐ Employees with sustainability expertise
☐ An employee handbook/guide on sustainability
☐ A website or newsletter on sustainability programmes
☐ Marketing information on the company's green practices
☐ Technical information on the company's green practices
☐ Listings in major green guides/directories for products/services
☐ A programme for customer/client education on sustainability
☐ A programme for supply chain education on sustainability
☐ Formal sustainability metrics/evaluation programme
☐ Regular sustainability audits of products/processes
☐ A sustainability accounting system (triple bottom line)
☐ A strategic plan for sustainability implementation
☐ A recycling programme for office waste
☐ A green housekeeping programme
☐ A programme for greening the company's capital facilities
☐ A policy of sustainable/green purchasing/procurement
☐ A programme for reusing resources (e.g. coffee mugs)
☐ A telecommuting/flextime policy
☐ Alternative fuel fleet vehicles
☐ Bicycle facilities/carpool incentives
☐ A teleconference-instead-of-travel policy
☐ A policy of paperless operations
☐ A community/social service/philanthropy programme
☐ Public transport passes for employees
☐ A green investment programme for retirement/pension plans
☐ Lunch'n'learn programmes on sustainability
☐ A policy of letting employees participate in external committees
☐ An annual sustainability report to shareholders/stakeholders
☐ A green travel policy (e.g. environmentally friendly hotels)
☐ An environmental code of conduct for employees
☐ Energy-efficient office equipment

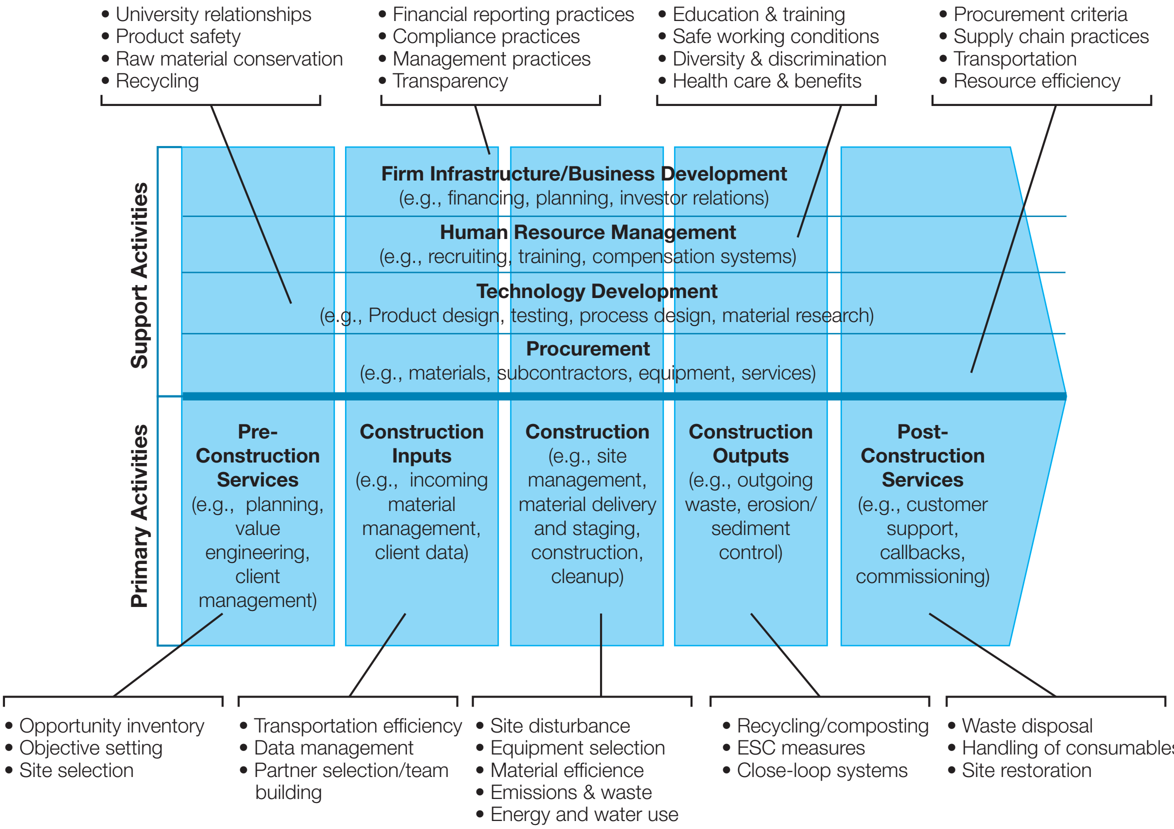


Figure 3.5 Corporate functional model with sustainable construction opportunities

Source: adapted from Porter (1985).

Of these practices, some of the most foundational deal with increasing the level of knowledge of stakeholders within and outside the firm about sustainability opportunities and practices. The next section describes various approaches to corporate education, training and awareness which are an essential part of creating a corporate sustainability culture.

Increasing sustainability knowledge: training, education and awareness

Ultimately, improving corporate sustainability requires both increasing the levels of knowledge about sustainability within the firm, and creating a sustainability culture that values and rewards sustainable choices at all levels of organizational decision-making. The following subsections describe the critical skills and competencies necessary for stakeholders of built environment sustainability, the many different approaches to training programme delivery and knowledge acquisition within the firm, opportunities for obtaining credentials and knowledge assessment, and recommendations for creating a sustainability culture.

Critical sustainability skills and competencies

Before a training, education, and awareness plan can be designed, the first step is to identify the desired competencies, skills and educational outcomes that will be achieved by the plan. A variety of competencies are necessary to achieve sustainability in the built environment, and the competencies required of different stakeholders in the capital projects delivery process differ in both functional role in the project and level of management in each organization. At the highest levels of management, a basic understanding and awareness of sustainability principles is necessary, as is the ability to see the firm within its larger environmental and societal context and forecast how the firm will evolve in the future. At the line level where technical decisions are being made, more discipline-specific knowledge is required, as well as an understanding of how each decision contributes to the bigger picture. At the worker level, a sound knowledge of basic sustainability principles will help ensure that sustainability is achieved even when novel circumstances arrive. Even supporting functions such as finance, marketing, and other functions are essential to the success of the organization and critical to its sustainability objectives. A framework such as the one shown in Figure 3.5 can be a useful basis for systematically identifying what critical skills are required and what opportunities exist for each key function within the organization.

Pearce and Ahn (2010) have identified a range of sustainability competencies developed by professional societies and documented in the literature that are thought to be important for achieving sustainability in engineering and construction, especially among technical disciplines:

- Ability to communicate and solve problems effectively and professionally with people from other disciplines and cultures.
- Ability to decide and competence to act in ways that favour sustainable development; having an attitude of care or stewardship; self-efficacy.
- Understanding the influence of culture and context on attitude toward sustainability, being able to contextualize knowledge, and valuing diversity.
- Ability to understand the complexity of real-world problems, differentiate between problems and symptoms, tolerate uncertainty and ambiguity, and resolve conflicts.
- Knowledge and tolerance of disciplinary perspectives that are not one's own.
- Ability to think holistically, comprehend interrelatedness, and search for integrated solutions.
- Ability to challenge dominant ideologies.
- Awareness of the role of humans within a larger systems context, and humility regarding current state of knowledge.
- Ability to expand the scale of thinking in spatial, temporal, biological, and intellectual terms; breakthrough or lateral thinking in the context of complexity.
- Ability to evaluate impacts and manage tradeoffs between technological, ecological, human, and economic elements.

In addition to these core sustainability competencies, an array of more fundamental skills are also essential for achieving sustainability in the construction industry include (Pearce and Ahn 2010):

- Knowledge of people and how to motivate action, especially in collaboration with other disciplines.
- Ability to work in teams, undertake inclusive visioning, implement stakeholder management, and communicate effectively.
- Ability to cope with novel situations, analyse requirements, identify resources, develop solutions, monitor progress and learn from the process.
- Ability to filter, interpret and integrate information and evidence, evaluate the testimony of experts, and situate and explain one's own perspective in this context.
- Performance under constraints.
- Ethical judgement.
- Leadership, change management, project/process management, and life-long learning.

From the standpoint of domain-specific knowledge, the Construction Industry Council (CIC) in the United Kingdom has used an industry-based forum to develop its sustainability skills matrix, which identifies critical sustainability requirements and associated functional skills required to achieve them. These skills are mapped against an array of functions representing all phases and steps in the capital project delivery function, and the role of each function is identified in terms of required skills it should have to achieve sustainability. Skills are identified in the three core dimensions of sustainability, as shown in Table 3.7.

Table 3.7 Essential sustainability skills for the built environment

Social sustainability

Optimize opportunities and social benefits:
- Create usable public and private space to deliver successful communities.
- Improve health, well-being, accessibility, and security of community.
- Enhance employment and skills development opportunities for the local community.

Promote sustainable communities through planning and design:
- Meet requirements of local, regional and national development and regeneration strategies.
- Ensure appropriateness of development to needs of the community, including multiple use and adaptability.

Engage stakeholders:
- Consult with public authorities, the general public, and other stakeholders including end users, and respond accordingly.
- Involve and manage expectations of stakeholders in the development process, from concept to commissioning.
- Consult and manage expectations of stakeholders on changes to ongoing use and operation.

Minimize negative impacts:
- Plan for effective public and private transport use.
- Control nuisance (noise, dust, light, etc.).
- Ensure a secure site during construction.
- Ensure health and safety of site workers and local community.
- Protect, enhance and maintain appropriate social access to environmentally sensitive areas.
- Assess and mitigate flood risk.

Environmental sustainability

Take account of natural capacity:

- Assess and mitigate wider environmental impacts, such as water supply, sewerage, transport, waste.
- Respond to projected impacts of climate change.

Optimize environmental benefits:

- Minimize energy demand and meet it efficiently, aiming to achieve carbon neutrality.
- Minimize water demand and aim to maintain water sufficiency from public supply.
- Optimize efficiency of materials use.
- Maximize range of environmental benefits in design.
- Maintain and enhance biodiversity.

Minimize negative impacts:

- Reduce, reuse, recycle, recover waste.
- Reduce emissions to air, land and water.
- Reduce transport impacts.
- Protect ecological resources.
- Minimize taking of environmentally valuable land.
- Minimize pollution of air, land and water.
- Manage and control in situ contamination of land.
- Protect archaeological and historically valuable resources.

Economic sustainability

Ensure economic viability and improve processes:

- Use technologies and materials consistent with sustainability principles.
- Keep up to date with advances in construction/technology.
- Establish cost and benefit on the basis of whole life value.
- Manage the supply chain effectively.
- Keep up to date on regulatory and planning requirements.
- Operate effective project management and contingency planning procedures.
- Maximize range of economic benefits including flexibility of use.
- Achieve cost-effective outperformance of statutory requirements.

Enhance business opportunities:

- Meet requirements of national, regional and local economic strategy.
- Capitalize on funding/grants available for more sustainable development.

Source: CIC (2008).

At the most basic level, *everyone* in the organization should understand how the company has operationalized sustainability for its own operations, and how their job functions and decisions affect that sustainability overall. They should also be able to follow a process for sustainable decision making that enables them to identify opportunities to improve sustainability and make sound decisions about actions to take when addressing those opportunities (see Table 3.8).

Table 3.8 Steps in a sustainable decision process

To improve the sustainability of a system, stakeholders must:

- Recognize opportunities to improve the sustainability performance of a system in terms of key dimensions including the environmental, social and economic dimensions.
- Identify a range of feasible and contextually appropriate best practices that could be used to address those opportunities.
- Evaluate and compare these practices in terms of their likely impacts according to traditional qualitative and quantitative criteria such as first- and life-cycle cost, performance, time and quality, and in terms of their relative impacts on system sustainability.
- Design a recommended course of action to increase the sustainability of the system that takes into account the context of implementation.
- Support recommendations with convincing evidence and well-organized analysis delivered in a professional fashion.
- Plan and execute the implementation of recommended actions within the system.
- Evaluate the impacts of implementing those recommendations on specific system attributes in terms of sustainability.

Approaches for knowledge acquisition

Given the broad array of desired characteristics required of construction stakeholders pursuing sustainability, how should a firm design a sustainability awareness, education and training plan that can move its employees to master these skills and abilities, and apply them in the workplace? Designing a plan for acquiring sustainability knowledge requires identifying potential sources of knowledge and means of delivering it, then integrating those sources of knowledge as part of a training plan to support corporate operations.

Sustainability knowledge can come from a variety of sources. It can be brought to the firm through new hires with outside training or experience, by hiring consultants, or by partnering with other organizations that have complementary sustainability expertise or experience. It can be cultivated among the firm's existing employees through training, self-study, or participation in outside events such as conferences, local green building councils or standards development. It can also be brought into the firm through investment in physical resources such as a sustainability library or resource centre, or access to online sustainability databases and tools. Finally, sustainability knowledge may also be provided at no cost to the firm through the outreach and educational efforts of other stakeholders in the capital projects industry such as product manufacturers wishing to educate the firm about its green products, or clients sponsoring training for project team members involved in their products.

If a firm decides to pursue formal training or education options for its employees, the array of possible choices is vast. Firms that expect to have ongoing training needs due to factors such as acquisitions or employee turnover, or firms that are large in size with significant support departments, may elect to develop their own in-house training programmes. External consultants or universities can be employed to assist with designing and rolling out these programmes. Firms with less intensive training needs may elect to bring in outside trainers from various sources for a one-time kick-off training event, then integrate key sustainability concepts throughout other existing training programmes to provide a mechanism for ongoing updates. Outside trainers and their training programmes can be offered to cover generic course content, or customized to address the specific needs of the firm. It is even possible to integrate training with real projects to provide authentic experiences with project decision making. Some sustainability consultants routinely provide basic training on sustainability as part of their services when they have been employed to facilitate pursuit of project certification. This helps to ensure that everyone understands certification requirements and is on the same page with regard to project goals and objectives.

One decision that will have to be made in designing a training plan is *who* will receive *what* training *when*. In other words, will different functional groups and management levels in the firm be trained separately, or will multiple functions be integrated as part of a single training event? Although more technical sustainability training is difficult to design when multiple functions (such as procurement, design, construction safety, financing and marketing) are included, this type of training also offers the benefit of allowing trainees to become more familiar with what other functions in the company do, and what challenges they face with regard to implementing sustainability. Designing training to incorporate active learning and discussions can also serve the strategic purpose of identifying potential implementation barriers and designing remedies to overcome them.

Another decision that must be made is to decide what topics and skill sets will be covered in different elements of the training. Often, training may begin with an awareness-level event for everyone together that introduces basic sustainability principles and the company's goals and objectives for corporate sustainability. This general training is then followed by more detailed training for each functional unit that covers issues specific to that unit. Integration events can be included in the training design to allow different functions to interact as part of active learning exercises. Periodic refresher or update training is also a good idea as new practices, standards and technologies emerge.

It is often easy to engage external sources of knowledge in training programmes because organizations with such knowledge have a desire to promote their products or services. For example, it is quite common for product manufacturers to offer seminars or lunch'n'learns at no cost to the firm to introduce new products or systems. These activities are a valuable way to expand a company's knowledge base, but care should be taken to ensure that a variety of competing firms are represented so that employees receive a balanced perspective on the state of the art in industry.

Another key part of knowledge acquisition is a formal mechanism for sharing lessons learned across project teams or throughout the firm.

Some companies already have formal data systems in place to capture this knowledge. Other possibilities are to assign mentors from experienced project teams to guide novice teams during initial pilot testing of sustainability. Firms often develop case studies of their projects as part of marketing or annual reporting, and these case studies can be formally presented or made available across the firm as a means of sharing lessons learned. Field trips to active projects, or even other projects of current clients or partners, can also be a useful way to learn in practice.

Not all sustainability training has to be exclusively sustainability-oriented. Many firms seek to incorporate sustainability ideas throughout the training programmes already in place in the firm. For example, including sustainability concepts as part of safety training makes a great deal of sense when discussing topics like management of hazardous materials and spill prevention. Such training could emphasize the benefits of using products that are less hazardous in the beginning, and the reduced intervention and control requirements for non-toxic or low-emitting products.

Finally, many opportunities exist for a firm to support formal and informal learning among employees outside formal training programmes. Some firms may choose to support employees in obtaining advanced degrees or specialized training outside the company in areas that support the sustainability mission. Many technical programmes are available for graduate study in sustainable construction topic areas, as are sustainability-related business and MBA programmes. Firms can also create opportunities for learning by sending employees to sustainability-related conferences, seminars and trade shows. Employees can also learn a great deal by becoming involved in external service activities such as serving on standards development committees or the boards of local green building non-profit organizations. Obtaining subscriptions to relevant publications, databases and online tools also supports the transfer of knowledge. Many trade publications with relevant information are even available at no cost from industry associations. Firms can further encourage the sharing of knowledge by facilitating opportunities to discuss sustainability knowledge in formal or informal seminars, symposia or lunch’n’learn sessions.

Obtaining credentials and knowledge assessment

For many firms, having employees earn formal credentials as evidence of their sustainability knowledge is useful for professional credibility and market recognition. Firms often set goals to have some percentage of their technical staff obtain credentials under relevant rating systems, for example. Credentials come in many forms and may be associated with rating systems, technical specialties, or completion of formal education programmes offered through colleges or universities.

Many major rating systems such as LEED and BREEAM (see Chapter 4) have formal accreditation or licensing requirements for individuals who participate in the project certification process. For example, the LEED rating system has associated credentials at three levels of expertise: the Green Associate, LEED Accredited Professional, and LEED Fellow levels. Green Associate is the entry certification, and requires either LEED project experience or other evidence of green expertise such as a university class in order to sit for the exam. LEED Accredited Professionals must provide a history of project experience as well as additional expertise or training to take the LEED AP exam, and are accredited with regard to a particular specialty within the LEED rating system, including Interiors, Building Construction, and Existing Buildings/Operations and Maintenance. Different exams exist for each of these specialties. LEED Fellows are selected by the US Green Building Council (USGBC) in recognition for their extraordinary expertise or contributions to the field of green building. All of these credentials except the LEED Fellow level must be maintained through documented maintenance activities such as taking or teaching continuing education courses, attendance at green building conferences or formal events, or participating in events with a local USGBC chapter.

Other sustainable construction-related systems to provide credentials also exist for various stakeholders in the project delivery process. For example, in the United States, two different certifications have been independently developed for builders, craft workers and trade workers. The Green Advantage certification is targeted at builders, and offers three different certification exams: Commercial, Residential and Commercial + Residential. Green Advantage Certified Practitioners (GACPs) have passed one or more of these exams and thereby demonstrated their knowledge of green building principles, materials and techniques. There is precedent under the LEED rating system for obtaining innovation credits if all construction personnel on a job have received green building training and successfully passed the GACP exam, for example.

The other construction-oriented certification exam will be released in 2011 and is targeted at site superintendents responsible for supervising craft workers on site. The Sustainable Construction Supervisor exam will be administered by the US National Center for Construction Education and Research (NCCER), and will serve to identify individuals who, through training or on-the-job experience, are capable of managing the on-site aspects of administering a sustainable construction project. NCCER has also developed training to support this certification, and it is expected to be formally endorsed by the Green Building Certification Institute, which manages credentials associated with the LEED rating system.

In addition to licensing or credential requirements associated with rating systems, some universities or colleges offer degrees or certificates associated with sustainable construction. Multiple Masters of Science degree programmes are available in sustainable construction from a variety of reputable universities, and the University of Florida even offers a Certificate in Sustainable Construction through its distance learning programmes. There are also more technically specialized certifications available from various licensing boards that deal with various aspects of the built environment (see Table 3.9).

Table 3.9 Examples of professional credentials for sustainable construction

Credential	Source
Green Building Engineer Certification	Association of Energy Engineers
Certified Sustainable Development Professional	Association of Energy Engineers
Certified Energy Manager	Association of Energy Engineers
Certified Indoor Air Quality Professional	Association of Energy Engineers
Certified Lighting Efficiency Professional	Association of Energy Engineers
Building Performance Institute Certification	Building Performance Institute
Certified EcoBroker	Association of Energy and Environmental Real Estate Professionals
EEBA Master Builder	Energy and Environmental Building Alliance
Certified Energy Rater	Residential Energy Services Network
Building Energy Modeling Professional	American Society of Heating, Refrigeration, and Air Conditioning Engineers
Building Biology Practitioner	Institute for Bau-Biologie & Ecology
Building Biology Environmental Consultant	Institute for Bau-Biologie & Ecology
Sustainable Engineering Certification	American Society of Civil Engineers
Certified Commissioning Professional	Building Commissioning Association

New credentials are being established at a very rapid pace, and not all credentials are equally rigorous. Before pursuing a credential in an area of interest, individuals should carefully review the requirements and testing standards, and choose credentials that are offered and maintained by reputable organizations in the field. Firms should work with their employees to make informed choices about what credentials may have the greatest long-term impacts for the organization when considering which to sponsor. It is also important to be aware that many reputable credentials require ongoing maintenance costs, either directly to maintain registration as an individual with credentials (such as with a professional engineering license), indirectly in the form of ongoing training requirements, or both.

Creating a sustainability culture

Creating a culture of sustainability within a firm is an important step toward achieving corporate sustainability goals. How can sustainability be incorporated as part of the day-to-day activities of everyone in the firm? What can be done to raise awareness? What is the most effective way to communicate about sustainability to influence behaviour?

These questions and others are important for ensuring that sustainability truly becomes part of the corporate culture and not just another management fad. The Golden Thread principle is one way to infuse sustainability as part of the basic business infrastructure of the firm. This principle highlights the importance of making explicit links between the external drivers of the business enterprise, corporate and divisional strategic and operational plans, and individual work plans and performance appraisal. Aligning sustainability goals with performance incentives helps to ensure that employees are not faced with the challenge of resolving trade-offs between sustainability and some other competing objective. Instead, they can direct their energy toward achieving desirable outcomes.

Another tactic is to make sustainability real by relating actions to easily understood outcomes. The Carbon Trust, a non-profit organization dedicated to reducing carbon emissions, recommends using posters with easily understood facts, such as 'Lighting an office overnight wastes enough energy to heat water for 1,000 cups of tea'. These facts should be based on the specific company in question to further increase the relevance to employees.

The Prince of Wales Accounting for Sustainability Project recommends focusing communications in a way that ensures each person receives the messages most relevant to their own opportunities, rather than taking a blanket approach and saturating people's attention. Overwhelming individuals with sustainability messages can lead to what the authors call 'communication fatigue', which results in important messages being obscured or ignored. The authors also recommend using sustainability champions in each business or functional unit in the firm to disseminate sustainability information in a way that is relevant to each particular business area. Combined with a corporate sustainability team, this tactic helps sustainability team members internalize and endorse corporate sustainability goals as they communicate and teach those goals to others. Having a green team with rotating representation from different parts of the firm will allow a continuous flow of new ideas and ongoing institutional learning.

One key aspect of a sustainability culture is a tolerance for failure in the quest for innovation. Many firms have found success in using pilot projects as a way to provide a 'safe' environment for trial and error. By designating a project as a pilot, there is an implicit understanding that new, unfamiliar tactics will be tried that are outside the realm of the firm's current practice. This understanding protects employees who innovate and often results in a greater willingness to try new ideas that can lead to competitive advantage.

Ultimately, a firm's sustainability culture and knowledge should be formalized via corporate guidelines for sustainability and performance goals at both the corporate and project levels. Individuals are more likely to make the most sustainable choices in a given situation if it is clear to them what that choice is, and they believe that their efforts will be recognized and/or rewarded.

After an overall education and training strategy and plan has been developed for the firm, the next step is to plan and implement the necessary operational actions that will allow the company to achieve its sustainability goals. Two sides of the coin exist for companies in the construction sector to obtain competitive advantage from implementing sustainability principles. First, a company embarking on this quest must first carefully evaluate its own operational practices and actions to ensure that how it does business is as aligned with sustainability principles as possible, from the standpoint of an internal perspective. Second, the company should evaluate opportunities for increasing the sustainability of the products and services it offers, thus aligning the company from an external perspective with sustainability principles. The next section explores these two areas of opportunity using case studies of leading firms in the design, construction, and product manufacturing components of the construction sector.

Corporate sustainability policies in construction-related firms

In deciding to adopt sustainability principles as a guiding force for a company, leaders within that company have a wide variety of choices in actions to take. The concept of sustainability is no longer unfamiliar to the construction industry, and most companies have at least an awareness of the term, if not some basic competencies in delivering more sustainable capital projects. However, comparatively few firms have thoroughly internalized the concepts of sustainability both internally within the firm and externally with respect to the projects or products that firm delivers. The following subsections present cases of leading companies with notable sustainability philosophies, policies or programmes that can serve as models for others in the construction industry in the areas of engineering and design, construction and project management, and product manufacturing.

Engineering and design firms

Increasingly, firms engaged in designing and engineering solutions to challenges in the built environment are including sustainability as a driving criterion for their projects. Whether due to client demand from outside the company or strategic choice from within, design firms increasingly look for ways to ensure that their projects meet core sustainability objectives. Beyond what they do on their projects, however, some firms are also taking active steps to increase the sustainability of their own operations, provide resources that are useful and groundbreaking to the industry at large, and weave principles of sustainability into their core values and practices for everything they do. The following case studies provide examples of companies who are leading the way in sustainability among engineering and design firms worldwide.

Case Study: Foster + Partners

Foster + Partners is a design firm headquartered in London, UK. With offices in 22 countries, the firm has more than 1000 design professionals from more than 50 different countries. Their practice is organized into six design groups, each with a senior partner as leader. Design groups are not limited by geographic area or building type; instead, each group has a rich cross-section of projects of various sizes around the world to promote diversity in thinking, creativity, innovation and motivation. Team members maintain a close relationship with clients, and move with each project to the building site, maintaining a local office until the project is complete. Designs are regularly reviewed by a company-wide design board bringing expertise and perspectives from multiple disciplines to guide the direction of each design. Supporting elements of the organization include departments for research and development, information technology, contract management and construction, and business development.

Foster + Partners: sustainability practices

- Design review
- Use of sustainable materials and technologies
- Project sustainability profiles
- Capture of lessons learned
- Sustainability Forum
- Formal and informal training
- Partnering with industry to develop new technologies

The firm has actively been investigating sustainable materials and technologies to incorporate into design since the 1970s, long before sustainability became a significant industry trend. The firm aims to establish a sustainability profile at the beginning of every project which includes specific sustainability objectives and methods for achieving them. The profile serves as a system to monitor the sustainability agenda of individual projects and to promote a strong sustainable design ethic. Each team is also encouraged to record methods used on a project for sustainable design that are then collected into a central database that can be accessed to inform future projects.

While not every project meets every sustainability goal set in its profile, the firm believes it has an obligation to try to persuade clients to adopt sustainable strategies on each project. The firm has created a Sustainability Forum with the purpose of promoting the use of sustainable technologies and methods throughout the practice. The Forum, which is part of the research and development group, is an interdisciplinary working group that has representatives from each of the six design groups, the information group, communications, training and research departments. With representation from all key parts of the company, the Forum provides a means to integrate sustainability knowledge across the company and its projects.

Foster + Partners ensures ongoing sustainability expertise by providing formal and informal training to staff on a range of issues including

Case Study: Songdo IBD: South Korea's new sustainable city

Sondo International Business District (Songdo IBD) is a new sustainable development located on the waterfront of Incheon, South Korea covering 1500 acres. The development team of Songdo IBD shows its commitment to sustainability for this new city with six development goals: open and green space; transportation; water consumption, storage and reuse; carbon emissions and energy use; material flows and recycling; and sustainable city operation. The Songdo IBD expects to be an international business district area, house 75,000 residents and handle 300,000 commuters. The developers will achieve this through investing over $30 billion. To achieve the goals of this sustainable development, the development team has incorporated the LEED rating systems for new construction and neighborhood development. Sustainable strategies to achieve six goals are:

Open and green space

- Songdo IBD has been designated with 40 per cent open space – 600 acres – to maximize the connection to nature within the city for residents, workers and visitors.
- A 100 acre Central Park (which is modelled after New York City's Central Park) provides an open space for residents, workers and visitors.
- All blocks connect pedestrians to open space, walking/biking corridors and public park.
- Native and adapted species have been planted to reduce water needs in its open space.

Transportation

- Incheon subway line runs through the centre of Songdo IBD.
- A 25 km network of bicycle lanes within the project facilitates safe, carbon-free transportation.
- 5 per cent of parking capacity within each project block is set aside as parking for fuel-efficient and low-emitting vehicles. Office and commercial blocks reserve an additional 5 per cent of parking capacity for carpool vehicles.
- Parking is primarily located underground or under a canopy to minimize the urban heat island effect and maximize pedestrian-oriented open space above ground.
- Infrastructure for electrical vehicle charging stations is integrated into parking garage designs to facilitate the transition to low emissions transportation.

Water consumption, storage and reuse

- The Central Park canal uses seawater instead of fresh water, saving thousands of litres of potable water per day.
- Irrigation-based potable water use targets a 90 per cent reduction versus international baseline, reduced through the use of efficient landscape design, water-saving irrigation systems, reclaimed stormwater and reuse of treated greywater from a city-wide central system.
- Potable water consumption in plumbing fixtures targets a 20–40 per cent reduction based on the use type of the project.
- Stormwater runoff is reused to the maximum extent possible given the project's climate zone and annual rainfall pattern.
- A vegetated green roof can reduce stormwater runoff, mitigate the urban heat island effect and promote biodiversity and species habitat preservation.

Carbon emissions and energy use

- All buildings in Songdo IBD have to integrate many energy-saving strategies to reduce energy consumptions and carbon emissions.
- A central-city-wide co-generation facility fuelled by natural gas provides clean power and hot water to the project.
- Energy-efficient LED traffic lights and energy efficient pumps and motors are planned for installation throughout Songdo IBD.
- A centralized pneumatic waste collection system is being installed to collect wet and dry waste, eliminating the need for waste removal vehicles.

Material flows and recycling

- 75 per cent of construction waste is targeted to be recycled.
- Recycled materials and locally produced/manufactured materials are utilized to the maximum extent possible.
- Low-VOC materials are incorporated into all buildings.

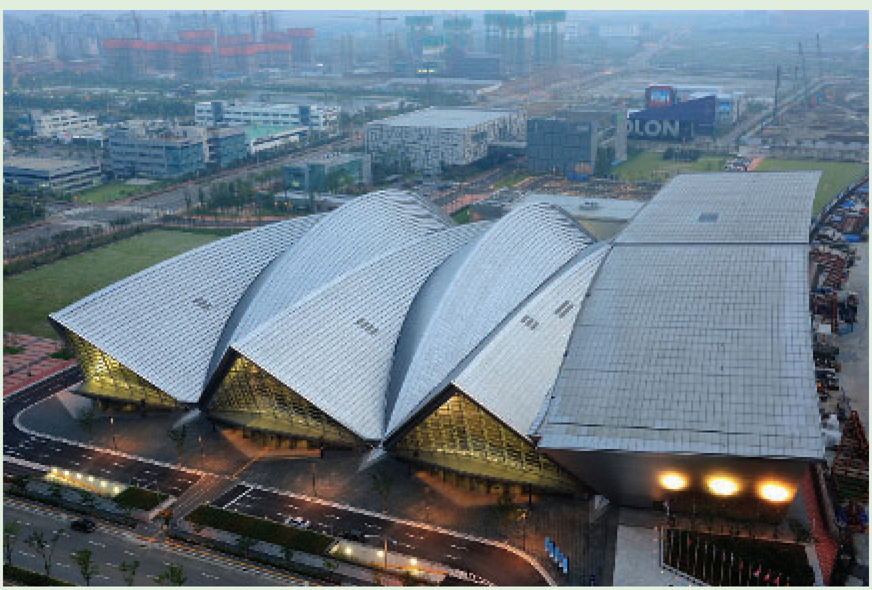
Sustainable city operations

- Sustainable procurement goals and recycling guidelines are integrated into the operational structure of the city through the facilities management digital interface.
- Facilities management and maintenance contracts mandate environmentally friendly (low/zero VOC, EcoLabel, Good Recycled designations or equivalent) products.
- Smoking is prohibited in public areas and office buildings except for specially designated areas.

The Songdo IBD project is an exemplary sustainable development that sets a new standard for sustainable design for large-scale city development across the globe.

Songdo IBD has been designated with 40 per cent open space – 600 acres – to maximize the connection to nature within the city for residents, workers and visitors

A 100 acre Central Park located in the middle of Songdo IBD provides an open spaces for residents, workers and visitors



Songdo Convensia has incorporated many sustainable features including public transportation systems, energy-saving lighting systems, water-saving fixtures, a construction waste management programme and low-VOC materials to achieve the goals of sustainability in the building. Songdo Convensia is the first LEED certified convention centre in Asia.

renewable energy, sustainability criteria and assessment, environmental analysis, and visualization techniques. It has a strong commitment to research, actively scanning the industry for new knowledge and techniques and systematically evaluating their relevance and appropriateness for individual projects. The firm counts among its projects some of the most well-known examples of sustainable design worldwide, including the Commerzbank Headquarters in Frankfurt, Germany, the new German Parliament at the Reichstag in Berlin, and the Masdar Initiative in Abu Dhabi. It is presently working on the development of a new mixed-use development, dubbed the 'Sustainable Super-City', at Incheon, just north of Seoul, South Korea. This development is expected to be a model of self-sufficiency, including integrated ecosystems to offset existing agricultural land displaced by construction, and will be centred around incubation of green industry and green technologies. The firm has also partnered with industry in the development of new integrated systems for renewable energy, including super-efficient wind turbines and new cladding systems that can harvest solar energy.

Case Study: HOK

Founded in 1955, Hellmuth, Obata + Kassabaum (HOK) is a firm that provides planning, design, and delivery solutions for the built environment. With 25 offices in Europe, Asia and North America, HOK employs more than 1800 professionals to complete its award-winning projects in multiple sectors including education, government, hospitality, residential, commercial, health care, institutional, retail and transportation. HOK brings what it calls a 'whole world design ability' to built environment challenges, with disciplines serving the entire facility life-cycle including architecture, engineering, construction services, interiors, planning, urban design and landscape architecture.

HOK sustainability policies and programmes

- Sustainable Operations Plan:
  - LEED certified office spaces
  - Purchasing
  - Model shop practices
  - Recycling and waste reduction
- Carbon neutral as a firm and for client projects by 2030
- LEED accreditation of all design professionals within the firm
- Sustainable design services and industry-recognized resources

HOK as a company began to focus on sustainable design beginning around 1990. In 1993, the company formally established sustainable design as one of its core values. As early players in the USGBC, leaders from HOK helped with the development of the LEED Green Building rating system. Today, HOK is leading design practice through an alliance with the Biomimicry Guild that enables a new focus on living buildings and the use of living systems as a model for the built environment. The firm is also an industry leader in integrating building information modelling (BIM) as part of the process of sustainable design and project delivery.

Notable elements of HOK's policy on sustainability include a firmwide Sustainable Operations Plan that comprehensively addresses opportunities for the firm to green its operations, including LEED certification of office spaces, purchasing, model shop practices, recycling and waste reduction. The firm has taken numerous steps to address its carbon footprint, in both its projects and its own operations. Annual carbon footprint analyses are conducted for every HOK office worldwide, which include energy use, air travel, employee community and other factors. Each employee receives an electronic copy of the report, and the firm has committed as a company to meet the American Institute of Architects' 2030 Challenge to achieve carbon neutrality by 2030. It also has a goal for all design professionals within the firm to become LEED accredited. As of the time of writing, more than half had achieved this goal.

HOK has been employed by multiple clients including the US Department of Defense and the US General Services Administration to develop educational programmes, web tools, and design guidelines to support sustainability in public-sector facilities. Its recently developed sustainable development guide for the US federal government, *The New Sustainable Frontier: Principles of sustainable development*, has won several awards for its contributions to sustainability in the public sector. The firm has also played an industry-wide leadership role in sustainability by developing some of the first widely used information resources for the construction industry. Authored by two professionals in the firm, the *HOK Guidebook to Sustainable Design* (Mendler, Odell and Lazarus 2005) is now in its second edition and is a widely used resource based on extensive databases and resources developed within the company.

One notable feature of this book especially reflects HOK's unique design philosophy with regard to sustainability: its coding of best practices based on whether or not they require owner approval to implement. In the book, the authors acknowledge that while some sustainability best practices require involvement of the owner in the decision to move forward because of additional cost or other constraints, some practices should be included in every project without question. This perspective highlights the important role of the architect in moving sustainability into the industry, and emphasizes the fact that many practices for sustainability in construction represent the best choice from a technical and economic standpoint as well as an environmental or social standpoint.

Case Study: URS Asia Pacific

URS Corporation is a fully integrated engineering, environmental, construction and technical services company with the ability to offer services at every stage of a project, from inception to decommissioning and closure. Opening its doors in 1904, the company now has over 46,000 employees worldwide, locations in more than 40 countries, and nearly US$10 billion in annual revenues. Its Asia Pacific regional operations boast 18 offices with approximately 1500 professionals.

URS 3i Principles of Sustainability

Sustainability is INTEGRATED in all of our decision making.
We INVOLVE all of our employees and stakeholders.
We seek INNOVATIVE solutions.

The Asia Pacific operations have undertaken a special focus on sustainability as part of the firm's core values. Their vision statement, 'Creating tomorrow's solutions today – Sustainable outcomes for a better world', reflects this focus. A notable manifestation of these values is the firm's annual 'The Things We Value' reports, produced each year for operations in New Zealand and Australia, to measure and monitor progress with regard to economic, social and environmental targets set by the company. The objectives in these reports are aligned with URS's corporate strategy and Asia Pacific Vision, and based upon sustainability principles.

The firm takes what it calls a '3i' approach to sustainability. It acknowledges that social, economic and environmental considerations are becoming more and more relevant to its organizational strategy, products and services, individual projects and clients, and its operational practices. Moreover, it acknowledges that sustainable outcomes cannot be achieved through 'business as usual' approaches, but instead rely on a new way of thinking about delivering solutions. URS defines sustainable business as 'integrating sustainability practices into our own operations and delivering projects with an economic, social, and environmental legacy of which our clients, employees, and communities can be proud'. The 3i principles operationalize how the firm will achieve this objective (see box). Specifically, URS Asia Pacific aims to achieve three basic organizational outcomes correlating to the dimensions of sustainability, as follows:

- **Social** – Fair, respectful, and beneficial practices for employees and the communities in which the organization conducts its business.
- **Economic** – Economic benefits enjoyed by the organization, its customers and stakeholders, and further along the value chain.
- **Environmental** – Using resources wisely and reducing direct and indirect impacts on the natural environment from products and services; working to enhance the environment.

To achieve these desired outcomes, the firm has identified three specific enablers that guide decisions and behaviours within the firm:

- **Involvement** – Recognition that sustainability cannot be achieved, nor can significant progress made towards it, without the support and involvement of organizational and community stakeholders.
- **Innovation** – Net benefits across all key outcomes cannot be achieved with 'business as usual' thinking. We need to develop smart solutions that provide better sustainability outcomes for the environment and the communities in which we operate.

- **Integration** – Sustainability outcomes are not about trade-offs, but rather about achieving the effective integration of environmental, social, and economic considerations in decision making and project management.

Together, the people at URS have internalized sustainability not just as a buzzword of interest to their clients, but a way to promote 'smart ideas, effective long-term solutions, and strong commercial outcomes'. In this way, they have created a corporate understanding of the concept of sustainability that weaves throughout all of the company's operations and practices.

Construction and project management firms

Sustainable innovation has also resulted in significant evolution of firms playing the roles of general contractor, project management or programme management. The following cases present two exemplary companies whose sustainability programmes and initiatives have been recognized internationally for the leadership they represent to the industry.

Case Study: Hyundai Engineering and Construction

Hyundai Engineering & Construction (E&C) was formed in 1947, and since that time has taken a leading role in development activities in South Korea and the world at large, with a goal to become one of the 20 largest construction companies in the world by 2015. Its competencies include design engineering, procurement, construction management and project management. With offices in Europe, Africa, North America, and throughout Asia and the Middle East, Hyundai E&C specializes in industrial construction, civil works, building works, and power plant construction, including nuclear power plants, substations and renewable energy plants. In the industrial construction sector, the firm specializes in desalination plants, power plants, hydrocarbon processing plants and industrial plants of many types.

Particularly in the power and infrastructure sectors, Hyundai E&C envisions itself as a 'total provider' offering a range of services from engineering, procurement, and construction through actual operation and management (EPCM). Its strategic plan is aggressively committed to foster new growth in the green sector, particularly with regard to South Korea's 'Green New Deal' initiative, in which considerable sums on the order of US$38 billion initially and an additional $85 billion over the following five years will be invested in a variety of infrastructure projects devoted to energy conservation, recycling, carbon reduction, flood prevention, green development, and maintenance of forest resources.

Hyundai E&C's commitment to sustainability is reflected in its sustainability report, the first of which was issued in 2009 and won acclaim for the company from the Dow Jones Sustainability Index (DJSI) as a global leader in sustainability management in 2010. It displaced Germany's Hochtief and Spain's Acciona construction companies as the sector leader for the heavy construction category of the DJSI. The company's sustainability report meets the Global Reporting Initiative's requirements for corporate social responsibility reporting in the areas of economic, environmental and social activities. In addition, it also presents data relevant for the new ISO 26000 standard on Social Responsibility (see box).

ISO 26000: Social Responsibility core subjects

- Organizational governance
- Human rights
- Labour practices
- The environment
- Fair operating practices
- Consumer issues
- Community involvement and development

The company underwent a systematic process in developing its award-winning sustainability report, starting with identification of key groups of stakeholders including employees and staff; customers; partner firms including subcontractors; local communities; shareholders and investors; and government, media, associations, and academic institutions. Surveys of key stakeholder groups were used to identify issues of influence on the company and relevant for sustainability management (Figure 3.6). These issues then formed the basis for development of metrics for reporting of social responsibility and sustainability.

In April 2010, Hyundai E&C also publicly committed to join the United Nations Global Compact, an initiative between private industry, institutions and other groups to master the challenges of globalization and achieve sustainable development. As part of this commitment, it has committed to meeting the Global Compact's ten principles, centred around respecting human rights, promoting social and environmental standards, and fighting corruption (see box). These principles were derived from the Universal Declaration of Human Rights, the

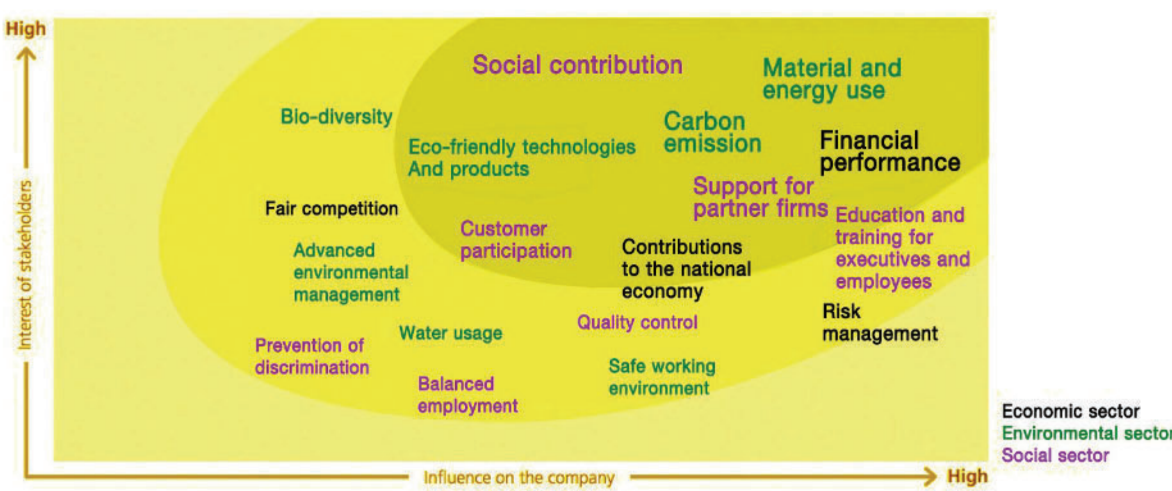


Figure 3.6 Key reporting issues for sustainability management

International Labor Organization's Declaration on Fundamental Principles and Rights at Work, and the Rio Declaration on Environment and Development. The commitment will be honoured through annual reporting on activities and performance relevant to each of the ten principles through the company's annual sustainability report.

United Nations Global Compact – ten principles for business

1. Businesses should support and respect the protection of internationally proclaimed human rights.
2. Businesses should make sure that they are not complicit in human rights abuses.
3. Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining.
4. Businesses should uphold the elimination of all forms of forced and compulsory labour.
5. Businesses should uphold the effective abolition of child labour.
6. Businesses should uphold the elimination of discrimination on respect of employment and occupation.
7. Businesses should support a precautionary approach to environmental challenges.
8. Businesses should undertake initiatives to promote greater environmental responsibility.
9. Businesses should encourage the development and diffusion of environmentally friendly technologies.
10. Businesses should work against all forms of corruption, including extortion and bribery.

The company has also established a vision and associated green management activities to achieve its corporate sustainability goals, beginning with a discrete set of actions to be undertaken between 2010 and 2015 to become a leader in global green management (Figure 3.7). These activities begin with actions to establish the underlying infrastructure for becoming a green company, and continue through a set of steps to assess and optimize the company's performance in key sustainability areas, and ultimately differentiate itself on the global market as a green leader that can show increased profitability based on core green technologies and practices.

To support implementation of its sustainability goals, Hyundai E&C has established a company-wide training programme in environmental management, with different types of training for onsite employees and managers, legal managers, and partner companies and their employees. All employees within the company receive at least basic training in environmental issues, and environmental managers at the company's worksites receive additional training in environmental pollution, pollution-reducing technologies, accident prevention and ISO 14000 standards before they are sent out into the field. The company weaves environmental education throughout all of its other training programmes as well.

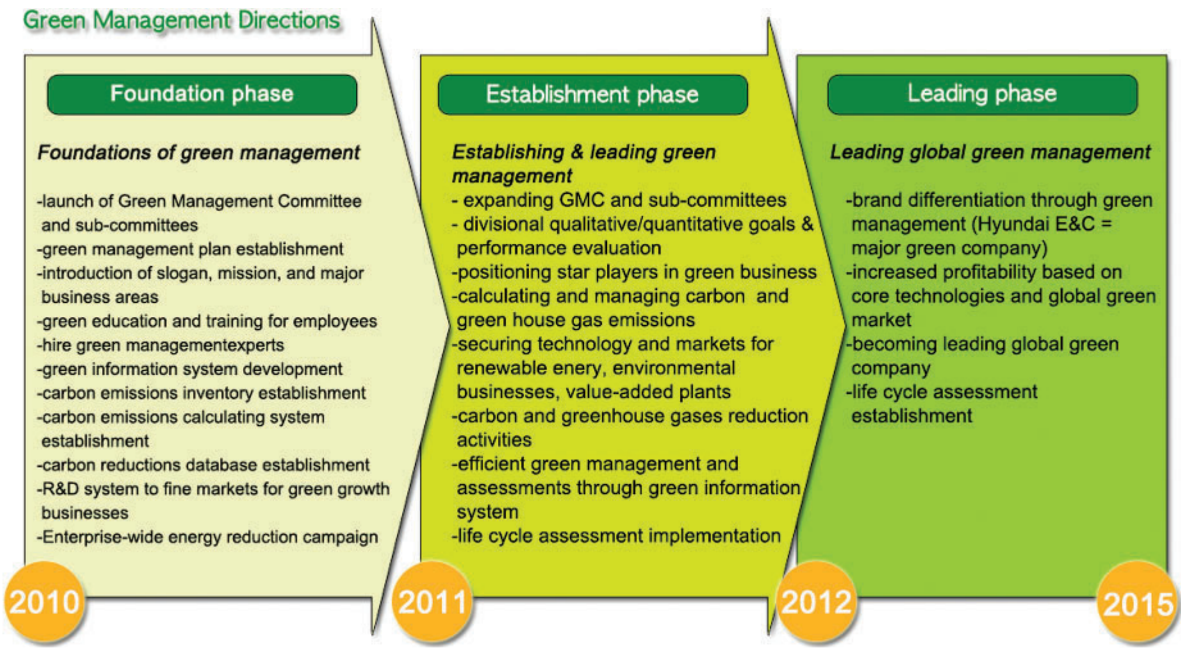


Figure 3.7 Hyundai E&C's timeline for green management activities

Figure 3.8 Hyundai E&C's environmentally friendly purchasing programme

For both internal and external operations, Hyundai E&C has made a commitment and instituted a formal process for purchasing of environmentally preferable products to support both projects and corporate support activities (Figure 3.8). The plan involves goal-setting, evaluation and management of activities in the form of purchasing plans, standards for subcontractors and suppliers, selection of suppliers and products, and formal evaluation of alternatives before final product selection.

A variety of other measures are also in place to enhance green corporate operations, including environmentally friendly vehicles and driver training.

In addition to its internal management changes, Hyundai E&C has also made a commitment to implementing sustainability best practices on the job site (Figure 3.9). These practices include on-site energy generation on office roofs and via wind power, careful selection of construction equipment and methods to prevent noise and vibration complaints, life-cycle analysis of construction alternatives, and use of alternate materials and systems such as permeable concrete and

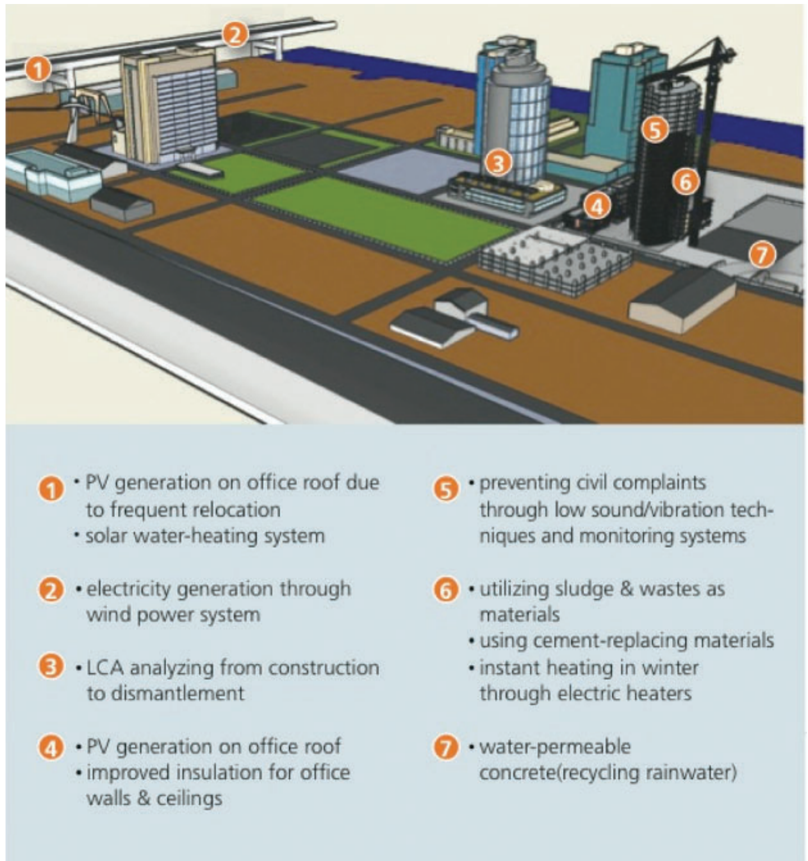


Figure 3.9 Hyundai E&C's eco-friendly construction site practices

waste-based materials. The company is especially focusing on developing super-strong, eco-friendly concrete with greater technological performance than conventional concrete while posing reduced environmental burdens, finish and cladding materials, and environmentally friendly asphalt products.

Hyundai E&C also takes active steps to manage air quality and water quality during construction to reduce negative impacts to ecosystems from construction activities. Measures used on its job sites to protect biological diversity include ecosystem impact assessments before construction begins, measures to protect threatened and endangered species during construction, and environmental restoration of sites following construction. Waste generated on the construction site is carefully monitored and recycled or treated as it is produced. Special focus is being given to organic wastes, and the company has developed a technology for converting organic waste into biogas as a source of energy on site.

Among its many activities to improve the social condition of its employees and their communities, Hyundai E&C has implemented many practices such as incentives for performance, workforce training and proactive health management. One such practice that has both significant environmental and social benefits is its extensive videoconferencing system. Employees no longer have to travel to field sites to obtain updates, which not only reduces transportation costs and impacts but also increases productivity and reduces risk in the field. The system was completed in 2010, and includes on-site cameras that can transmit live feeds from the company's construction sites.

Through these and multiple other activities, Hyundai E&C has emerged as not only a leader within the construction sector, but also an acknowledged corporate leader across the whole set of sectors that are part of the DJSI. Its sustainability report (Hyundai 2010) is also an excellent example of comprehensive and transparent reporting of sustainability-related issues and accomplishments.

Case Study: Skanska

Among the top ten largest construction firms worldwide, Skanska is a leading international project development and construction company. Founded in 1887 and headquartered in Stockholm, it employs 51,000 employees and nearly four times as many subcontractors in markets throughout Europe, the United States and Latin America on an average of 10,000 projects annually. Within these markets, Skanska is well known for its building and civil engineering projects as well as projects in the oil, gas and energy sector. In the United States in particular, Skanska targets projects undertaken through public–private partnerships (PPP). Its offerings also include single-family and multi-family housing projects; property investment, planning, development and management; and large infrastructure projects such as bridges, tunnels and roads.

Skanska began its quest for sustainability in 1995 by joining the World Business Council for Sustainable Development. In the next several years, it obtained ISO 14001 certification for various business units, with all operations worldwide being certified by 2000. The firm produced its first environmental report in 1997, which evolved into its first corporate sustainability report in 2002, organized around the Global Reporting Initiative (GRI) elements. It was first listed in the DJSI in 1999, and in the FTSE4Good social responsibility index in 2003. In 2005, it was the only construction firm listed in the initial launch of the Global 100 Most Sustainable Corporations list. In 2007, it ranked #1 in *Engineering News Record*'s first ever Top Green Contractors listing. Some of its notable projects include the first LEED Certified McDonald's restaurant in the United States, a LEED-CI Platinum office in the Empire State Building in New York City, the 100 GWh El Totorial Wind Farm in Chile, Boston Logan International Airport Terminal A, and the Swiss Reinsurance Headquarters building in London.

As a firm, Skanska has incorporated sustainability as part of its core values through both a code of conduct and its Five Zeros, which are qualitative performance goals to which it holds itself:

- Zero loss-making projects. Loss makers destroy profitability and customer relationships.

- Zero accidents, whereby the safety of our personnel as well as subcontractors, suppliers and general public is ensured at and around our projects.
- Zero environmental incidents, by which our projects should be executed in a manner that minimizes environmental impact.
- Zero ethical breaches, meaning that we take a zero tolerance approach to any form of bribery or corruption.
- Zero defects, with the double aim of improving the bottom line and increasing customer satisfaction.

These goals reflect the economic, environmental and social goals of sustainability, and include key stakeholders both within and outside the firm. Skanska encourages both internal and external stakeholders to hold it to these goals, providing a means on its website to report breaches in its code of conduct. It further integrates these core values in its business practices by linking incentives to performance at various levels within the company. It also integrates sustainability management at the line level in each of its core business units. The decentralized nature of the organization has led to a matrix organizational structure for sustainability at the level of each business unit. Skanska's sustainability agenda is coordinated across units by Group Staff Unit (GSU) Sustainability, which is also responsible for safety, occupational health and environment functions. The GSU Sustainability reports to an executive vice president of Skanska AB.

Among the things Skanska is doing to reflect its sustainability principles in practice, the company has begun what it calls a Green Initiative. Some notable accomplishments resulting from this initiative are two resources that have been made freely available to the public to promote green thinking: a book titled *Green Thinking: There's more to building a green society than just building* (Skanska 2010), and Skanska's green screen saver, which is downloadable from the company's website and provides a series of tips on how to improve environmental performance. The book includes an overview of ways in which the firm is taking steps to contribute to a green society in terms of energy conservation, carbon reduction, water conservation, material use, lifecycle planning, community involvement and local impact. It also ends with a section on things you can do, targeted specifically to key stakeholders such as politicians and public officials, along with developers, planners, financiers, investors, tenants and clients (see box).

Skanska's top ten green tips

1. Ask yourself if there's any reason not to build green.
2. Involve affected parties early in the process, so you can incorporate their opinion and concerns into the solution, rather than try to find remedies afterwards. Make 'suppliers' into 'partners' so you can take advantage of their knowledge, experience and enthusiasm.
3. Take the entire life-cycle of the building or structure into account when planning it. What's interesting isn't the cost of construction, but the total cost over the structure's lifetime. Also, you avoid future environmental issues.

4 Think long-term flexibility to avoid the high costs and environmental impact generated by complicated rebuilding when having to respond to evolving needs.
5 Look at new financial planning models that support long-term gains rather than short-term low costs.
6 Be open to innovative solutions. Consider the local conditions and utilize the best technology. Use local materials to avoid unnecessary transport, and use local renewable energy sources as much as possible.
7 In the planning and design process, keep the four Rs in mind – reduce, reuse, recycle and recover.
8 Define your own plan for the Deep Green journey and make it visible. Start now. Communicate the strategy and operations so everyone involved understands their necessity and what they need to do. Inspire others to think greener.
9 Consider the positive effects of green building on the brand equity of your company.
10 Again, ask yourself if there's any reason not to build green.

Skanska also issued its first in a series of reports on Green Urban Development in November 2010, also available on its Green Initiative website. In it, the company focuses on local energy communities and their role in the urban landscape of the future. It addresses this new development trend from the standpoint of planning, development, construction and urban life. The report also highlights Skanska's approach to green construction, organized around four key points: low environmental impact during the entire life-cycle, life-cycle cost, flexibility, and simplicity. The green construction initiatives in the firm are closely linked to the corporate sustainability initiatives and priorities in the firm, as reflected by the sustainability agenda. In particular, the firm believes that significant market opportunities exist for environmentally sound structures. To be credible in this market, Skanska believes it is essential to have its 'own house in order' (Skanska 2008).

Construction product manufacturers

In the manufacturing sector, sustainability initiatives among construction materials and systems producers are as diverse as the materials and systems themselves. The following two case studies illustrate different approaches to sustainability from one of the very early leaders in the sustainability arena (Interface) and one of today's leading international sustainability advocates (Holcim).

Case Study: Interface Global

Founded in 1973, Interface is known as a world leader in soft-surface modular floor coverings, also known as carpet tiles. It also produces broadloom carpet through its subsidiary Bentley Prince Street, Inc. The company produces primarily commercial carpets, although it entered the residential carpet market in 2003 with the production of FLOR carpet tiles. Since its founding, Interface has grown into a global enterprise with sales in 110 countries, manufacturing facilities on four continents, and sales of over US$1 billion.

In 1994, founder, chairman and CEO Ray Anderson transformed the company's business strategy and practices with the aim of achieving sustainability in its manufacturing enterprises without sacrificing business goals. The story of this transformation, based on Anderson's personal awakening to environmental concerns, is well-known in the sustainability world and documented along with his business model for sustainability in his 1999 book, *Mid-Course Correction* (Anderson 1999).

Today, Interface continues to lead the field and has set a goal to achieve 100 per cent sustainability by the year 2020 through three primary paths: innovative solutions for reducing its footprint, new ways to design and make products, and an inspired and engaged culture. Its efforts have included developing new processes for recycling old carpets, inventing a leased carpet programme, utilizing the work of indigenous peoples, switching to solar and other alternative energy sources, and reducing water use and contamination. In 2007, the company achieved third-party certified negative net greenhouse gas emissions. During this time, Interface concurrently grew its profits, not just in the United States but internationally as well.

The Natural Step: system conditions

In a sustainable society, nature is not subject to systematically increasing:

- concentrations of substances extracted from the Earth's crust
- concentrations of substances produced by society
- degradation by physical means.

In that society, people are not subject to conditions that systematically undermine their capacity to meet their needs.

Therefore, to become a sustainable society, we must:

- eliminate our contribution to the progressive buildup of substances extracted from the Earth's crust, such as metals and fossil fuels
- eliminate our contribution to the progressive build-up of chemicals and compounds produced by society, such as dioxins, PCBs and DDT
- eliminate our contribution to the progressive physical degradation and destruction of nature and natural processes, such as over-harvesting forests and paving over wildlife habitat
- eliminate our contribution to conditions that undermine people's capacity to meet their basic human needs, such as unsafe working conditions or lack of a living wage.

Source: www.naturalstep.org

Interface has characterized its quest as 'climbing Mount Sustainability', and its programme for achieving its goals is called Mission Zero. Following principles of the Natural Step (see box), the company bases its industrial processes on an understanding of natural systems. As part of its goal to eliminate its ecological footprint, the company runs eight of its nine manufacturing facilities with 100 per cent renewable energy, including on-site solar photovoltaics at multiple sites and landfill gas at one site. Six of its facilities have received LEED certification, including the first ever LEED-CI Platinum office space, located in Atlanta, Georgia. All of its manufacturing facilities conform to ISO 14001. It has achieved a 42 per cent reduction in waste cost since 1995, with an estimated $433 million in avoided waste costs since that time. The unit energy used to produce its products has been reduced by 43 per cent, its water use reduced by 80 per cent, and 36 per cent of the raw materials used to produce its products are from recycled or bio-based sources. It has also employed principles of biomimicry in designing carpet systems that are more sustainable and cost-effective, including carpet tiles with patterns modelled after natural systems that can be installed in any orientation, thus reducing installation time.

Perhaps the most notable influence of Interface within the sustainability movement has been from an organizational culture standpoint. Ray Anderson has widely shared his vision and models with peer organizations worldwide, serving as a model and inspiration for those who believed that sustainability was incompatible with business success. Within the firm, employees are encouraged and rewarded to present new ideas that can contribute to the firm's goals, and many of these ideas have been adopted with positive results. Employees are infused with the company's philosophies and then take these ideas into their local communities through volunteering and philanthropy. Finally, Interface pioneered the idea of an Eco Dream Team, where influential thought leaders in the sustainability domain are regularly brought into the firm to provide fresh perspectives, learning, and ideas.

In keeping with its mountain-climbing analogy, the company has identified seven 'Fronts of Mount Sustainability' that must be achieved to result in true corporate sustainability (see box). Among its most fundamental challenges is the reality that carpet is essentially a product of materials derived from non-renewable fossil fuels, such as nylon. To address this challenge, Interface has developed its ReEntry 2.0 programme as a means to recover reusable materials from among the 5 billion lb of carpet that ends up in landfills each year, and displace the use of virgin non-renewable resources in its products. It has also led the way in achieving carbon neutrality for its products, beginning in 2003 for its first carbon neutral product, Cool Carpet. This product is a result of a systematic process to inventory and reduce greenhouse gas emissions resulting from the product's life-cycle, then offset the remaining emissions through the purchase of carbon offsets. Greenhouse gases that cannot be eliminated from the product's life-cycle are balanced by buying and retiring carbon offsets on the carbon market, or sponsoring other projects that reduce, avoid, or sequester carbon dioxide to prevent it from entering the atmosphere.

By 2020, Interface intends to be a completely sustainable company from an environmental footprint perspective, serving a restorative function within its economic, social and environmental contexts worldwide. The company acknowledges that being truly restorative involves not only reducing its own impacts, but also returning more than it takes to the global ecosystem. Toward this end, it has set a goal of helping other organizations reduce their own footprints and achieve sustainability even as it pursues its own goal.

Interface's Seven Fronts of Mount Sustainability

1. Eliminate waste.
2. Benign emissions.
3. Renewable energy.
4. Closing the loop.
5. Resource-efficient transportation.
6. Sensitizing stakeholders.
7. Redesigning commerce.

Case Study: Holcim

Founded in Switzerland in 1912, Holcim is a leading supplier of cement and aggregates worldwide. It also supplies ready-mix concrete and asphalt along with related services to markets on every continent. With 80,000 employees in over 70 countries around the world, it has annual sales of over SF21 billion (US$22.5 billion). Holcim has been acknowledged for its leadership in sustainability by being named 'Leader of the Industry' in the building materials industry segment of the DJSI from 2005 to 2008.

Holcim's environmental and CSR priorities

- Occupational health and safety
- Climate and energy
- Community involvement
- Stakeholder engagement and partnerships
- Sustainable construction
- Resource conservation
- Sustainable product and service solutions

To achieve its vision of 'providing foundations for society's future' and its aspiration of being the world's most respected and attractive company in the industry, Holcim has integrated sustainable development at the fundamental core of its business strategy (see Figure 3.10). Two of its key mindsets, sustainable environmental performance and corporate social responsibility (CSR), underlie its basic business strategies, priorities, and ultimate goal of value creation (see box).

In terms of reducing the environmental impact of its operations, Holcim employs strategies aimed to decrease carbon emissions via the development of new products such as composite cements, and by promoting the use of alternative energy sources such as waste for fuel. Specifically, substitutions for the clinker in cement using slag, fly ash, pozzolans and other minerals have been highly effective in reducing fuel use, raw materials required, and carbon dioxide emissions resulting from cement production. As a result, the firm has shifted its portfolio to comprise 80 per cent of composite cements, with only 20 per cent of ordinary Portland cement being part of its production.

On the social dimension, Holcim has a strong commitment to worker health and safety, as exemplified through its Passion for Safety

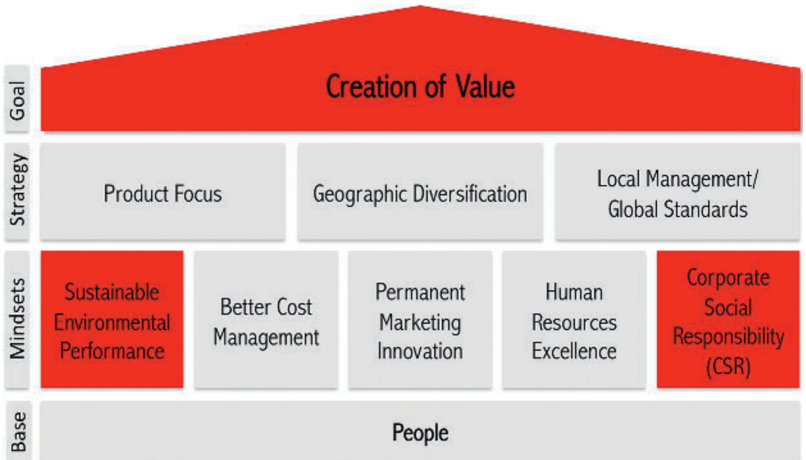


Figure 3.10 Holcim's approach to value creation

programme, which focuses on cultivating a safety culture in the company. In addition, Holcim takes aggressive measures to reach out to its stakeholders, assess local needs in areas where it operates, promote community involvement, and improve educational, cultural and social development.

As part of its sustainability programmes, Holcim has undertaken a materiality review to ensure that sustainability risks and opportunities identified by the company are in alignment with stakeholder perspectives outside the company. An area of particular importance to the firm is sustainable construction, since its products represent the very foundation of the construction industry and contribute significantly to its impact on energy use and climate change. Toward that end, the firm established the Holcim Foundation for Sustainable Construction, whose activities include sponsoring an international competition for excellent projects in sustainable construction. The competition awards US$2 million in cash prizes to its winners. The competition celebrates innovative, future-oriented projects from around the world, and is open to architects, planners, engineers, project owners, builders and construction firms. Students in the final year of undergraduate study or in graduate programmes are also eligible to apply for the 'Next Generation' category of the award. 100 projects received awards in the first two rounds of the competition, and the third round was underway at the time of writing.

Also as part of its support for the future of sustainable construction, the Holcim Foundation has recently sponsored a 440-page book, *Re-inventing Construction*, which features articles and case studies from 38 internationally renowned architects, engineers and scholars that address the question of how architecture, engineering and construction must evolve so that sustainability is automatically embedded in the way the built environment is designed, constructed, used and recycled. It has provided seed funding to set up a new Center of Excellence in Sustainable Housing and Rural Infrastructure in India, as well as supporting microfinance and capacity building in developing nations. It currently spends on the order of SF36 million (US$38.5 million) annually on community initiatives, donations, and in-kind support for its corporate social responsibility initiatives, representing more than 1 per cent of net income before tax. Community initiatives are evaluated using a social engagement scorecard which facilitates the selection of projects that are aligned with the company's CSR priorities. As of 2009, over 3 million people worldwide have benefitted from Holcim's social engagement programmes.

From an operational standpoint, Holcim acknowledges that the ongoing sustainability of its enterprise relies on long-term access to raw materials acquired through quarrying. Accordingly, the firm pays special attention to the ecological and biodiversity impacts of quarrying. Nearly all of its quarries have rehabilitation guidelines and plans that have led to conservation and restoration projects resulting in new habitats such as wetlands, forests and natural grasslands on previous quarry sites. The use of water in quarrying, aggregate production and cement production is also a top priority emerging from the stakeholder materiality assessment, and a new water management scheme for all business units is slated for implementation by 2013.

Common themes

An effective corporate sustainability policy:

- clearly states the company's vision statement and presents core values and principles
- contains content relevant to the company's existing culture and operation
- is signed and dated by either the owner or a company official representing the executive level, demonstrating personal commitment at the top of the company
- is made public, both on the company's website and in the facility where all employees and visitors can see it
- is reviewed and renewed annually to ensure the policy is current and applicable
- has supporting documents and resources
- is audited by a third party for conformance.

Source: Gary Jones, director of environment, health, and safety affairs, PIA International.

What can we learn from these and other cases of leaders in sustainable construction? There are many opportunities at the corporate and project levels to reduce an organization's impacts on the planet and increase its positive contribution to society. No matter what portfolio of strategies a company chooses to adopt, several common themes emerge in common across the leaders examined here.

First, the organizations that are most successful in becoming sustainability leaders have a clear picture of the firm within its larger global and societal contexts. They understand how their actions have the potential to influence that context both positively and negatively, and they pay careful attention to integrate their sustainability actions within that context in a way that capitalizes on their individual strengths.

Second, the leading firms examined here make special effort to internalize sustainability within the firm and integrate it with core business principles and practices. These companies are not content to add sustainability as just one more requirement they must meet to achieve compliance, or one more fad in which the market is interested today. Instead, they look for sustainability impacts in what they already do – their core strengths and liabilities – and weave the concept throughout their core values, standard operating procedures and policies.

Third, many of the firms that are leaders in sustainability have become recognized as such through their stature in the sustainability community. One key way they achieve this is through active participation in the development of industry resources, organizations and systems such as green building councils, rating systems, scorecards, books and guidelines. By giving their time and expertise to support the development of resources that can benefit everyone, they increase both visibility and credibility among their peers.

Finally, the firms explored in this chapter clearly understand the relationship between credibility in the green market and their own corporate behaviour. They have taken steps to improve not only their products and contributions to value in the market, but also the operations and internal practices used to generate their company's value added. These companies contribute to the sustainability of the world in which we all live by truly walking the talk of sustainability.

Ultimately, the tactics that are most effective for achieving change in a given context depend on many factors, including the level of expertise and experience with sustainability already existing in that context, the structure and culture of the organization in which the programmes are being implemented, and the financial and other resources and that can be applied to the programme. While observations made in this chapter are based on a synthesis of data collected across multiple organizations, the most effective approach for a given organization will depend where that organization is in its process of sustainability adoption. Stakeholders interested in developing sustainability policies and programmes in their organizations can draw from these lessons and ideas in constructing programmes that fit the context and requirements of their situations. The matrices and criteria established in this chapter can be adapted contextually and developed in more detail as needed to support the most effective selection of programme elements to maximize the chances of success of those programmes within their individual context.

Sustainability policy in 2020

What will be the relationships between and among stakeholders in the construction industry in 2020? How will business-driven corporations be held accountable for impacts of their actions that are borne by society at large? Much controversy exists about the best way to achieve sustainability goals that are seemingly at odds with the interests of business, and even at the national level, some nations still place the economy ahead of the environment. In reality, the economy cannot and will not exist without the environment, so ultimately this way of thinking must change.

Recent reports on industry sustainability leaders by Accenture (2010a, 2010b) found that those companies considered to be leaders in their fields were finding new ways to drive value delivered by their firms. First, firms that are successful sustainability leaders are growing revenue through new products and services that leapfrog current thinking about today's solutions. Second, they are reaping benefits to their own bottom line by reducing costs through efficiency gains, energy and water use, raw material use, waste generation, and human productivity gains. Third, these firms' proactive approaches to sustainability enable them to manage operational and regulatory risk more effectively. Finally, by considering sustainability as a core value for their business, they are able to build intangible assets such as their brand, reputation and collaborative networks that will ultimately serve them well in the market.

In 2020, we will see an evolution of current thinking about value in the corporate world. Companies that do not align themselves with sustainability principles will be less competitive in a climate of increased resource scarcity, more stringent public policy and greater transparency. At the same time, greater success will come to firms that are early movers in their domains with regard to operationalizing sustainability for their industry and implementing it through effective policy. Carbon in particular will be a major driver of industry opportunity, with poor performers subject to penalties and sustainability leaders being able to reap benefits from carbon trading. Figure 3.11 shows a continuum of corporate maturity with regard to sustainability developed by the Accenture Corporation (2008). In the future, more firms will gravitate toward the right side of the continuum to their continued advantage.

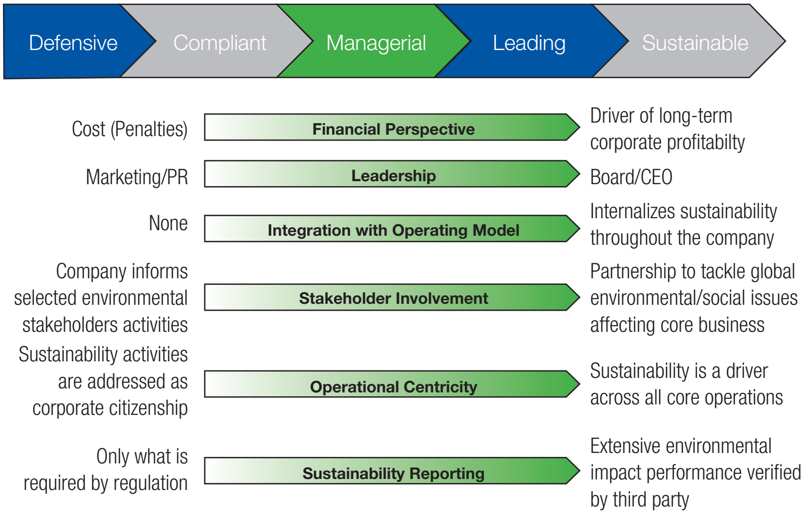


Figure 3.11 Corporate maturity with respect to sustainability
Source: Accenture (2008).

From the standpoint of public policy, it is difficult to predict how government will structure initiatives to promote greater sustainability. To date, sustainability leaders of industry have increasingly employed self-regulation as a way to preempt government mandates. Although today's trends suggest that the future will hold more self-regulation, voluntary compliance and market-based policy, increases in economic instability, political unrest, undeniable evidence of climate change and other factors may lead to a more regulatory approach by many government entities. Overall, there is likely to be increasing attention to the developing world by developed nations as they enter world markets and compete for finite resources. Hopefully, such attention will focus on a just and equitable distribution of resources, and effective policy initiatives to ensure ongoing global stability and prosperity for all.

Notes

1 Portions of this chapter have been adapted from work previously published by the author in the *Journal of Green Building* (DuBose et al 2007; Pearce et al 2005a; Pearce, Du Bose and Bosch 2007) and are included with the author's permission.

2 See Chapter 4 for more information on the Leadership in Energy and Environmental Design Green Building Rating System.

Discussion questions and exercises

3.1 What stakeholder group(s) do you represent with respect to the various facilities with which you interact? What role(s) would you play in implementing a sustainability policy for those facilities?

3.2 Inventory the existing sustainability policies of your organization and/or for the built facilities with which you interact. What are the major elements of these policies? What elements are missing?

3.3 What social risks would be associated with a sustainability policy for your organization's facilities? If you already have a sustainability policy, talk with the people responsible for putting that policy in place. What challenges did they face in implementing the policy? How did they overcome those challenges? If you do not already have a policy, what challenges do you imagine you would face in implementing one?

3.4 If your organization has a sustainable facilities policy, how does that policy reduce negative impacts on natural ecosystems and minimize resource consumption? If you do not already have a policy, what would you recommend including in a new policy to address these issues?

3.5 If your organization has a sustainable facilities policy, what costs are associated with implementing that policy? Consider both direct costs such as enforcement and training, and indirect costs such as the potential for the failure of unfamiliar technology. What economic benefits might result from implementing the policy?

3.6 Consider your organization's structure and standard operating procedures. Who would be involved in implementing a sustainability policy? What arguments might be most effective in getting the support of those stakeholders?

3.7 Which of the four policy options – require a specified level of performance, endorse and encourage performance, encourage sustainability in general, or create a working group to set standards – would be most effective in the context of your organization's current views on sustainability? Why?

3.8 If your organization already has a sustainable facilities policy, which programme options have been developed as part of its implementation? Which additional programme options would be beneficial for your organization beyond what already exists?

3.9 If your organization already has a sustainable facilities policy, how is the effectiveness of the policy evaluated? If no policy exists, which approach to evaluation would be most successful in the context of your organization?

3.10 What building or infrastructure-related policies have been put in place by your local, regional or national government? Which of them apply to the facilities with which you interact? Identify specific features in the buildings you occupy that are a result of those policies.

3.11 Does your organization have sustainability goals and objectives? If yes, evaluate those goals and objectives using the SMART characteristics described in the chapter. If no sustainability goals and objectives exist, draft a set that meets SMART criteria.

3.12 Does your organization have a sustainability team? If yes, identify the members of that team and the roles they play. Where are they located on the organizational chart? If no team presently exists, where would a team best fit on the organizational chart if one were created? Why?

3.13 Adapt the corporate functional model shown in Figure 3.5 to your organization. What opportunities exist in your organization to increase sustainability for each functional area of the model? Consider each of the major areas of the Triple Bottom Line. How specifically can you affect organizational sustainability within the responsibilities of your present position or job?

3.14 Review the checklist of organizational best practices for sustainability shown in Table 3.6. Which practices is your organization already following? Which should be considered for future implementation? Are there any sustainability practices your company implements that are not already on the checklist?

3.15 Which of the core sustainability competencies discussed in the chapter do you possess? Which of these critical skills and abilities should be further developed? Think of examples where you have demonstrated these competencies, skills and abilities in your personal and professional life.

3.16 To what extent does your organization have a sustainability culture? How can your organization's sustainability culture be enhanced?

3.17 Where on the spectrum of corporate maturity with regard to sustainability (Figure 3.11) does your organization fall? Discuss the spectrum with people in your organization responsible for sustainability functions and document the history of your firm in progressing through the spectrum.

References

Accenture. (2008). *Compatible Aims: Sustainability and High Performance.* <https://microsite.accenture.com/NonSecureSiteCollectionDocuments/CompatibleAims.pdf> (accessed 4 January 2011).

Accenture. (2010a). *Driving Value from Integrated Sustainability: High performance lessons from the leaders.* <https://microsite.accenture.com/sustainability/Documents/Driving_Value_from_Integrated_Sustainability_High_Performance_Lessons_from_the_Leaders.pdf> (accessed 4 January 2011).

Accenture. (2010b). *Sustainability and its Impact on the Corporate Agenda.* <https://microsite.accenture.com/NonSecureSiteCollectionDocuments/By_Subject/Strategy/PDF/Accenture_POV_Management_Consulting_Sustainability_and_its_Impact_on_the_Sustainabiliy_Agenda.pdf> (accessed 4 January 2011).

Anderson, R. (1999). *Mid-Course Correction*. Peregrinzilla Press, White River Junction, Vt.

Athena Sustainable Materials Institute. (2002). *U.S. Federal and Military Applications of LEED: Lessons Learned.* Report prepared for the Department of National Defence and Public Works and Government Services, Canada, March.

Australia Building Code. (2008).

Bennett, M. and James, P. (eds) (1998). *The Green Bottom Line: Environmental accounting for management*. Greenleaf Publishing, Sheffield, UK.

Best, A. M. (2005). 'Building on common ground: green buildings and the University of Washington.' MS degree project final report, Public Administration Programme, University of Washington, Seattle, WA.

Bosch, S. L. and Pearce, A. R. (2003). 'Sustainability in public facilities: analysis of guidance documents.' *Journal of Performance of Constructed Facilities, Special Issue on Facilities Design and Management*, 17(1), 9–18.

Bray, J., and McCurray, N. (2006). 'Unintended consequences: how the use of LEED can inadvertently damage the environment.' *Journal of Green Building*, 1(4).

Burden, L. (2010). 'How to up the EMS ante.' <www.environmentalmanagementsystem.com.au/ems.html>. (accessed 1 January 2011).

Construction Industry Council (CIC). (2008). 'Sustainability skills matrix for the built environment functions.' <www.cic.org.uk/activities/sustainabilityskillsmatrix.pdf> (accessed 31 December 2010).

City of Portland Office of Sustainable Development (2003). *ReThinking Development: Portland's strategic investment in green building*, City of Portland Office of Sustainable Development, Portland, OR.

Cole, R.J. (2000). 'Cost and value in building green.' *Building Research and Information*, 28(5/6), 304–9.

DuBose, J. R., Bosch, S. J. and Pearce, A. R. (2007). 'Analysis of state-wide green building policies,' *Journal of Green Building*, 2(2), 161–77.

Duran, G. (1981). 'There's a S.M.A.R.T. way to write management's goals and objectives.' *Management Review*, 70(11).

Elkington, J. (1997). *Cannibals with Forks: The triple bottom line of 21st century business.* Capstone, Oxford, UK.

Errasti, A., Beach, R., Oyarbide, A. and Santos, J. (2007). 'A process for developing partnerships with subcontractors in the construction industry: an empirical study.' *International Journal of Project Management*, 25(3), 250–6.

Federal Facilities Council. (2002). *Learning from our Buildings: A state-of-practice summary of post-occupancy evaluation*. National Academies Press, Washington, DC.

Fust, S.F. and Walker, L.L. (2007). 'Corporate sustainability initiatives: the next TQM?' *Executive Insights*, Korn/Ferry International. <www.kornferryinstitute.com/files/pdf1/KFsustainability.pdf> (accessed 1 January 2011).

Gardner, G. T. and Stern, P. C. (1996). *Environmental Problems and Human Behavior.* Allyn & Bacon, Boston, MA.

Gil, N., Tommelein, I. D., Kirkendall, B. and Ballard, G. (2000). 'Lean product-process development process to support contractor involvement during design.' *Proceedings, ASCE 8th International Conference on Computing in Civil and Building Engineering*, August 14–17, Stanford, CA, 1086–93.

Greenspirit Strategies. (2004). 'The cost of green: a closer look at State of California sustainable building claims.' Engineered Wood Association, < www.apawood.org/level_b.cfm?content=pub_ewj_arch_f04_green> (accessed 2 August 2005).

Grosskopf, K. R. and Kibert, C. J. (2006). 'Developing market-based incentives for green building alternatives.' *Journal of Green Building*, 1(1), 141–7.

Horman, M. J., Riley, D. R., Lapinski, A. R., Korkmaz, S., Pulaski, M. H., Magent, C. S., Luo, Y., Harding, N. and Dahl, P. K. (2006). 'Delivering green buildings: process improvements for sustainable construction.' *Journal of Green Building*, 1(1), 123–40.

Hyundai Engineering and Construction. (2010). *We Build Tomorrow: Sustainability report 2010.* <http://en.hdec.kr/eng/data/csr_report.pdf> (accessed 2 January 2011).

Johnston, D. R. (2000). 'Actual costs – is building green too expensive?' *Building Green in a Black and White World*, New Society, Saint Paul, MN, 59–62.

Kale, S. and Arditi, D. (2001). 'General contractors' relationships with subcontractors: a strategic asset.' *Construction Management and Economics*, 19(5), 541–9.

Kats, G. (2003). The costs and benefits of green buildings: a report to California's Sustainable Building Task Force. California's Sustainable Building Task Force, Sacramento, CA.

Khalfan, M. M. A. (2006). 'Managing sustainability within construction projects.' *Journal of Environmental Assessment Policy and Management*, 8(1), 41–60.

Klotz, L., Horman, M. and Bodenschatz, M. (2007). 'A lean modeling protocol for evaluating green project delivery.' *Lean Construction Journal*, 3(1), 1–18, April.

Lapinski, A., Horman, M. and Riley, D. (2005). 'Delivering sustainability: lean principles for green projects.' *Proceedings, 2005 ASCE Construction Research Congress.*

Lapinski, A. R., Horman, M. J. and Riley, D. R. (2006). 'Lean processes for sustainable project delivery.' *Journal of Construction Engineering and Management*, 132(10), 1083–91.

Matthews, J., Tyler, A. and Thorpe, A. (1996). 'Pre-construction project partnering: developing the process.' *Engineering, Construction and Architectural Management*, 3(1/2), 117–31.

Matthiessen, L. F. and Morris, P. (2004). *Costing Green: A comprehensive cost database and budgeting methodology.* Davis Langdon SEAH International, Boston, MA. <www.davislangdon.com/upload/images/publications/USA/2004%20Costing%20Green%20Comprehensive%20Cost%20Database.pdf> (accessed 10 October 2011).

Mendler, S. F., Odell, W. and Lazarus, M. A. (2005). *HOK Guidebook to Sustainable Design*, 2nd edn. Wiley, New York.

Munasinghe, M. (1993). *Environmental Economics and Sustainable Developmen*t. World Bank, Washington, DC.

Myers, T. (2005). *Should the State Follow LEED or Get out of the Way?* Washington Policy Center, Washington, DC. <www.washingtonpolicy.org/publications/opinion/should-state-follow-leed-or-get-out-way> (accessed 10 October 2011).

Northbridge Environmental Management Consultants (NEMC). (2003). *Analyzing the Cost of Obtaining LEED Certification.* American Chemistry Council, Arlington, Va. <www.cleanair-coolplanet.org/for_communities/LEED_links/AnalyzingtheCostofLEED.pdf> (accessed 10 October 2011).

Packard Foundation. (2002). *Building for Sustainability Report: Six scenarios for the David and Lucile Packard Foundation Los Altos Project*. David and Lucile Packard Foundation, Los Altos, CA.

Panzano, P. C., Roth, D., Crane-Ross, D., Massatti, R. and Carstens, C. (2004). 'The innovation diffusion and adoption research project (IDARP): Moving from the diffusion of research results to promoting the adoption of evidence-based innovations in the Ohio Mental Health System.' *New Research in Mental Health*, Vol. 15, ed. D. Roth, Ohio Department of Mental Health, Columbus, OH.

Pearce, A. R. (2001). 'Sustainable vs. traditional facility projects: a holistic cost management approach to decision making,' paper for US Army Forces Command, Fort McPherson, GA.

Pearce, A. R. (2003). 'An online knowledge base for sustainable military facilities and infrastructure.' Final Project Report to Region IV Department of Defense Pollution Prevention Partnership, University of South Carolina.

Pearce, A. R. (2004). 'Sustainability design cost differential analysis for constructed projects using the LEED Green Building rating system.' Project report to US Air Force Reserve Command Headquarters, Robins AFB, GA.

Pearce, A. R. (2008). 'Sustainable capital projects: leapfrogging the first cost barrier.' *Civil Engineering and Environmental Systems*, 25(4), 291–301.

Pearce, A. R. (2010). 'Costing sustainable capital projects: the human factor.' *Proceedings, Transitions to Sustainability Conference*, New Zealand Society for Sustainability Engineering and Science, 1–3 December, Auckland, NZ.

Pearce, A. R. and Ahn, Y. H. (2010). 'Strategic entry points for sustainability in university construction and engineering curricula.' Proceedings, Transitions to Sustainability Conference, New Zealand Society for Sustainability Engineering and Science, 1–3 December, Auckland, NZ.

Pearce, A. R., DuBose, J. R., Bosch, S. J. and Carpenter, A. M. (2005a). 'Greening Georgia facilities: an analysis of LEED requirement impacts.' Final project report to the Georgia Environmental Facilities Authority, Atlanta, GA, 30 September.

Pearce, A. R., Bosch, S. J., DuBose, J. R., Carpenter, A. M., Black, G. L. and Harbert, J. A. (2005b). 'The Kresge Foundation and GTRI: the far-reaching impacts of green facility planning.' Final project report to the Kresge Foundation, Troy, MI, 30 June.

Pearce, A. R., DuBose, J. R.,and Bosch, S.J. (2007). 'Green building policy options for the public sector.' *Journal of Green Building*, 2(1), 156–74.

Pearce, A. R., DuBose, J. R., Bosch, S. J. and Carpenter, A. M. (2005c). 'Sustainability and the State Construction Manual: Georgia-specific voluntary guidelines.' Final project report to the Georgia State Finance and Investment Commission, Atlanta, GA, December.

Pearce, A. R. and Fischer, C. L. J. (2001a). 'Systems-based sustainability analysis of Building 170, Ft. McPherson, Atlanta, GA.' Summary analysis report to the Army Environmental Policy Institute, Atlanta, GA, May.

Pearce, A. R. and Fischer, C. L. J. (2001b). 'Resource guide for systems-based sustainability analysis of Building 170, Ft. McPherson, Atlanta, GA.' Report to the Army Environmental Policy Institute, Atlanta, GA, May.

Pheng, L. S. and Teo, J. A. (2004). 'Implementing total quality management in construction firms.' *Journal of Management in Engineering*, 20(1), 8–15.

Porter, M. E. (1985). *Competitive Advantage: Creating and sustaining superior performance.* Free Press, New York.

Portland Energy Office. (1999). *Green Building Options Study: The city's role in promoting resource efficient and healthy building practices.* City of Portland Office of Sustainable Development, Portland, OR.

PricewaterhouseCoopers (PWC). (2004). 'Sustainability management system assessments.' <www.pwc.com/en_CA/ca/sustainability/publications/sustainability-management-system-assessments-2004-en.pdf> (accessed 1 January 2011).

Pulaski, M. H. and Horman, M. J. (2005c). 'Organizing constructability knowledge for design.' *Journal of Construction Engineering and Management,* 131(8), 911–19.

Pulaski, M. H., Horman, M. J. and Riley, D. R. (2006). 'Constructability practices to manage sustainable building knowledge.' *Journal of Architectural Engineering*, 12 (2), 83–92.

Pulaski, M., Pohlman, T., Horman, M. and Riley, D. (2003). 'Synergies between sustainable design and construction at the Pentagon.' *Proceedings, 2003 ASCE Construction Research Congress.*

Reed, W. G. and Gordon, E. B. (2000). 'Integrated design and building process: what research and methodologies are needed?' *Building Research and Information*, 28(5/6), 325–37.

Riley, D., Pexton, K. and Drilling, J. (2003). 'Procurement of sustainable construction services in the United States: the contractor's role in green building.' *UNEP Industry and Environment*, 26(2/3), 66–9.

Rogers, E. (2003). *Diffusion of Innovations,* 5th edn. Free Press, New York.

Rohracher, H. (2001). 'Managing the technical transition to sustainable construction of buildings: a socio-technical perspective.' *Technology Analysis and Strategic Management*, 13(1), 137–50.

Romm, J. J. and Browning, W. D. (1995). *Greening the Building and the Bottom Line: Increasing productivity through energy-efficient design.* Rocky Mountain Institute, Snowmass, CO.

SBW Consulting. (2003). *Achieving Silver LEED: Preliminary benefit-cost analysis for two City of Seattle facilities.* City of Seattle, WA <www.seattle.gov/dpd/cms/groups/pan/@pan/@sustainableblding/documents/web_informational/dpds_007573.pdf> (accessed 10 October 2011).

Skanska. (2008). 'Our sustainability agenda.' <www.skanska.com/upload/About per cent20Skanska/Sustainability/Skanska_Sustainability_Agenda_Overview_Master_Copy_Release_1_2008_05_15.pdf> (accessed 3 January 2011).

Skanska. (2010). *Green Thinking: There's more to building a green society than just building.* <www.skanska.com/en/About-Skanska/Our-green-initiative/Green-thinking/> (accessed 3 January 2011).

Sustainable Construction Task Group (SCTG). (2002). *Reputation, Risk, and Reward: The business case for sustainability in the UK property markets*. <www.dti.gov.uk/construction/sustain/rrnr.pdf/> (accessed 31 December 2010).

Syphers, G., Baum, M., Bouton, D. and Sullens, W. (2003). *Managing the Cost of Green Buildings.* State of California's Sustainable Building Task Force, Sacramento, CA.

Tan, Y., Shen, L. and Yao, H. (2010). 'Sustainable construction practice and contractors' competitiveness: a preliminary study.' *Habitat International*, 1–6.

Taylor, B. and Wilkie, P. (2008). 'Briefing: Sustainable construction through improved information flows.' *Proceedings of the Institution of Civil Engineers – Engineering Sustainability*. 161(ES4), 197–201.

United Nations Environment Programme (UNEP). (2010). Carrots and Sticks – Promoting Transparency and Sustainability: An update on trends in Voluntary and Mandatory Approaches to Sustainability Reporting. <http://www.unep.fr/shared/publications/pdf/WEBx0161xPA-Carrots per cent20& per cent20Sticks per cent20II.pdf> (November 6, 2010).

United Nations World Commission on Environment and Development (WCED). (1987). *Our Common Future.* Oxford University Press, Oxford, UK.

US Department of Energy (USDOE). (2003). *The Business Case for Sustainable Design in Federal Facilities.* Energy Efficiency and Renewable Energy Programme, Federal Energy Management Programme, USDOE, Washington, DC.

USDOE. (2010). *Database of State Incentives for Renewables and Efficiency (DSIRE).* <www.dsireusa.org/>. (accessed 31 December 2010).

US Green Building Council (USGBC). (2003). *Building Momentum: National trends and prospects for high-performance*. USGBC, Washington, DC.

USGBC. (2004). *Making the Business Case for High Performance Green Buildings.* USGBC, Washington, DC.

USGBC. (2010). *Public Policy Search* < www.usgbc.org/PublicPolicy/SearchPublicPolicies.aspx?PageID=1776> (accessed 31 December 2010).

Vanegas, J. A. and Pearce, A. R. (2000). 'Drivers for change: an organizational perspective on sustainable construction.' *Proceedings, Construction Congress VI*, 20–22 February, Orlando, FL.

Wilson, A. (2005). 'Making the case for green building.' *Environmental Building News*, 14(4), 1 ff.

Winter, S. (2004). 'GSA LEED cost study.' United States General Services Administration (GSA), Washington, DC <http://www.wbdg.org/ccb/GSAMAN/gsaleed.pdf> (accessed 10 October 2011).

4

Green Rating Systems

Objective measurement is critical to evaluate progress toward sustainability. A variety of rating systems, standards and information sources exist that can help decision makers evaluate sustainability-related attributes at multiple scales. Rating or measuring the sustainability of capital projects and their components can be undertaken for a variety of purposes, including:

- **Baselining** – establishing an initial measurement against which to calibrate future performance.
- **Benchmarking** – providing a basis for comparison with competitors and identifying what is the state-of-the-art in a given practice.
- **Prioritization, decision support or selection** – establishing a basis to choose and implement solutions with the objective of maximizing benefits.
- **Documentation** – capturing evidence to support conformance with standards, compliance with regulations or progress being made toward improvement.

Various tools have been developed to accomplish these purposes, at scales ranging from raw materials and individual building products through assemblies, buildings, developments, cities or business enterprises. Table 4.1 shows examples of such systems.

Table 4.1 Examples of assessment tools at various scales

Scale	Threshold tools	Profile tools
Raw material	Forest Stewardship Council Certification (www.fsc.org)	BEES (www.bfrl.nist.gov/oae/software/bees/)
Product or assembly	GreenSeal(http://www.greenseal.org), GreenLabel Plus (www.carpet-rug.org)	Athena (www.athenasmi.ca)
Building	LEED (http://www.usgbc.org), GreenGlobes (www.greenglobes.com)	SB Tool (www.iisbe.org)
Development, city, or region	LEED-ND (http://www.usgbc.org), Ecological Footprint (http://www.gdrc.org/uem/footprints/index.html), Carbon Footprint (various)	ICLEI Profile (www.iclei.org)
Enterprise	Ranking in Dow Jones Sustainability Index (http://www.sustainability-indexes.com), Carbon Footprint (various)	Global Reporting Initiative's Triple Bottom Line (http://www.globalreporting.org), SAM Corporate Sustainability Assessment (www.sam-group.com)

Threshold measurement tools establish a single result, value or outcome to represent the sustainability of a material, product or facility. For instance, forest products certified by the Forest Stewardship Council (FSC) either do or do not meet FSC certification requirements. Likewise, buildings receive a single certification level under the Leadership in Energy and Environmental Design (LEED) rating system (Certified, Silver, Gold or Platinum) based on the number of points achieved in the rating system. It is possible to review the specific credits and points awarded to a project under LEED. However, certified buildings are generally known by their certification level rather than the specific profile of points they have achieved.

Profile tools, in contrast, provide values for multiple indicators of sustainability. For instance, in the Building for Environmental and Economic Sustainability (BEES) tool, building materials are evaluated in terms of both economic and environmental variables, and both sets of information are presented as a profile. Likewise, the Athena life-cycle analysis tool provides an inventory of information about the life-cycle impacts of building assemblies and whole buildings, including embodied energy and energy consumption; global warming potential; air, water and land emissions; and weighted and absolute resource use. This chapter explores a sample of both types of green rating systems at the material or product, whole facility, site and organizational scales, including prevalent systems used in countries around the world.

Evaluating material and product sustainability

Green product rating and labelling systems are one way to make sense of the many material attributes affecting product sustainability. Many sources have developed information that helps building stakeholders understand how materials will perform and what impacts they have. The following subsections describe major information sources for green building materials and products, common labelling systems and logos, and overarching principles of life-cycle assessment for building.

Sources of green product information

Green product information is available in a variety of forms. For some attributes such as recycled content or sustainable harvest, certification systems are available that allow third parties to review and objectively confirm a manufacturer's claim. Certification systems usually have multiple criteria that must be met in order for a product to be certified.

Multiple directories of green products are also available. Some directories may allow product manufacturers to suggest products to be listed. These directories function like *Yellow Pages* and do not necessarily have any third party review or qualification of what products are listed. Other directories such as the GreenSpec database of green building products (BuildingGreen 2010) provide screening of products before they are listed. A product's qualifications are explicitly listed as part of its listing in the GreenSpec database.

Still other directories are available in print form (Figure 4.1). These guides can quickly become outdated as new products enter the market, but they are still a good starting point. R.S. Means Inc. offers cost information on green products in its guide *Green Building: Project planning and cost estimating* (R.S. Means Inc. 2010). Both *GreenSpec* (BuildingGreen 2010) and *Green Building Materials* (Spiegel and Meadows 2006) contain examples of specification language that can be used to ensure green products are used in a project. *GreenSpec* also includes listings of products by manufacturer. It is the print version of the BuildingGreen database. *The Handbook of Sustainable Building* (Anink, Boonstra and Mak 1996), *Green Building Handbook* (Howard, Shiers and Sinclair 1998), and *Environmental Resource Guide* (AIA 1990) all contain more general information about the environmental performance and life-cycle impacts of building materials in general. They do not provide specific manufacturer or brand information, but they are useful in understanding and comparing the environmental and social impacts of different types of construction materials such as steel vs. aluminium, for example.

Product labelling systems also provide various kinds of information about a product's green attributes. Labels may provide values for specific qualities about a product, such as grams per litre of volatile organic compounds or percentage of recycled content. They may display a logo that indicates the product has met some requirement. Life-cycle assessment is a still more detailed set of information about a product. It is used as the basis for some green product certifications. Resources such as the Environmental Resource Guide contain life-cycle assessment information about building products from their manufacture to end-of-life-cycle. This can also be called 'cradle to grave' analysis.

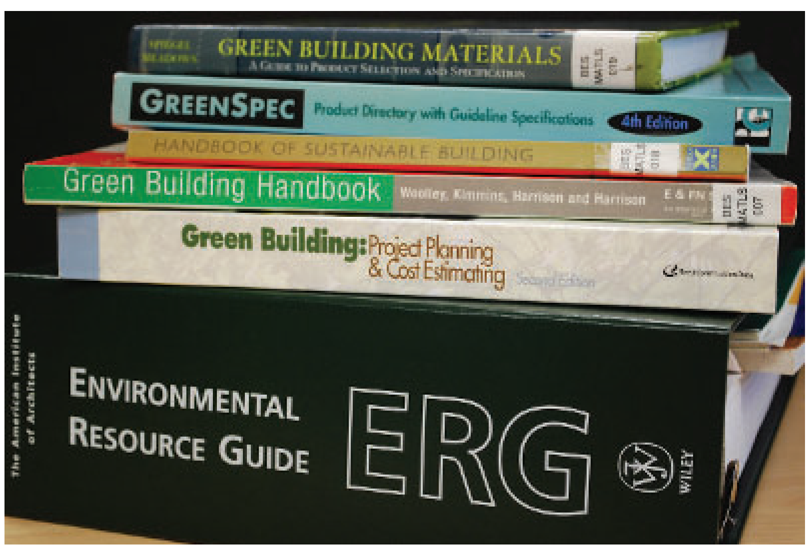


Figure 4.1 A variety of directories of green products are available

Product evaluation, rating and labelling systems

A variety of green product labels can be found on materials and products used in green building. Figure 4.2 shows the country of origin of some representative product ecolabels from various parts of the world, a listing of these ecolabels and their attributes and requirements follow.

Blue Angel Certification (Germany)

The Blue Angel ecolabel was developed in 1978 by the German government to recognize products that are more environmentally friendly than their conventional counterpoints in terms of health, climate, water and/or resource use. Conformance with label requirements is established by the Environmental Label Jury, an independent decision-making body consisting of a variety of product stakeholders. It applies to building products, transportation, waste management, and a variety of other products and services.

BRE Certified Environmental Profile (UK)

The Building Research Establishment Environmental Profiles Certification Scheme was developed to compare the environmental performance of building materials, products and systems. Environmental profiles developed under this system allow designers to compare products across a variety of parameters. Profiles are reviewed annually by an independent third party and recalculated every three years to ensure ongoing validity. They focus primarily on the production and end-of-life-cycle phases of the product life cycle, and cover social attributes such as human rights, labour relations, training and education, and safety, along with environmental attributes including biodiversity, carbon/greenhouse gas emissions, energy, chemical and material use, toxics, solid waste and recycling, water quality and use, and wastewater.

CarbonFree Certification (USA/UK)

The CarbonFree product certification label is awarded to products that have eliminated or offset all carbon emissions associated with the production of the product. It covers carbon and greenhouse gas emissions preceding the use phase of the product. The protocol for this certification was originally developed jointly by organizations in the United States and United Kingdom. It is presently administered by Carbonfund.org in the United States.

China Environmental Logo (China)

Initiated by the Ministry of Environmental Protection of the People's Republic of China in 1993, this label provides environmental standards for construction materials, packaging and other products. 56 individual standards exist under this labelling system. It tracks environmental performance over the whole life-cycle of a product in terms of

Figure 4.2 Selected product ecolabels and their countries of origin

chemicals and raw materials used, energy type and quantity, solid waste and recycling, pesticides/herbicides/fungicides, water use and wastewater generation. It carries reciprocity with the Environmental Choice New Zealand label. Conformity is established by an independent third-party organization.

Eco-Leaf (Japan)

Developed in 2002, the eco-leaf label is awarded to building products, services and whole buildings based on life-cycle analysis consisting of (1) a product environmental aspects declaration, (2) a product environmental information data sheet, and (3) a product data sheet. Organizations applying for this certification self-certify conformance with the ecolabel criteria, including carbon and greenhouse gas emissions, energy production and use, chemical and material use, toxics, water use and quality, solid waste and wastewater generation. The primary recipients of this label to date are consumer electronics products.

EcoLeaf is a type III label.

EcoLogo (Canada)

Originally developed by the government of Canada in 1988 but now recognized worldwide, EcoLogo now appears throughout North America, Mexico and the United Kingdom. It is applied for energy, buildings, waste management, building products, and a variety of other products and services. The EcoLogo programme examines the entire life-cycle of products in developing product standards, although not all phases are included for all standards. Issues considered include biodiversity, carbon and greenhouse gas emissions, energy, genetically modified organisms, pesticide/herbicide/fungicide use, recycling and solid waste, water quality and use, and wastewater. 91 product standards presently exist, with additional standards under development. Conformity is determined by an independent third party, and ongoing audits are conducted randomly/by surprise to ensure ongoing authenticity.

EcoMark (Japan)

Developed in 1989 by the Japan Environment Association (JEA), this standard applies to building products, cleaning products and other types of goods, and considers the whole product life-cycle in terms of energy, material use, impacts on natural resources, pesticides/herbicides/fungicides use, recycling and solid waste, toxics, and water quality/use. It is considered equivalent to the Environmental Choice New Zealand label and the Korean Ecolabel. Conformity is assessed by the JEA and audited annually.

Energy Star (USA)

Energy Star is a voluntary certification program developed by the US Environmental Protection Agency (USEPA). Certification is awarded for meeting standards with respect to energy use and associated impacts during the manufacturing and use phases of a product's life-cycle. It is applicable to appliances, building products, home electronics, office equipment and whole buildings. USEPA provides technical reviews of product attributes before awarding permission for a product to display the Energy Star logo. Products must perform in the top 25 per cent of all products in their class in order to display the Energy Star logo.

Environmental Choice (New Zealand)

This labelling programme provides voluntary environmental specifications for 33 different types of products at the time of writing. It covers the whole life-cycle of a product in terms of carbon and greenhouse gas emissions and offsets, chemicals, energy production and use, material use, solid waste and recycling, toxics, water use and wastewater generation. It carries reciprocity with multiple other ecolabels including the Korean Ecolabel, certain Green Seal standards and the EcoMark label from Japan. Conformity with the standard is established by independent third parties.

EU Ecolabel (European Union)

This voluntary standard was developed in 1992 by the European Commission and applies to building products, cleaning products, retail goods, tourism, and other products and services. It is found throughout the European Union. It considers a variety of environmental issues throughout the whole product life-cycle, including chemical and material use, energy use, recycling and solid waste, toxics, water quality and use, and wastewater generation.

Forest Stewardship Council (FSC) Certification (USA)

The Forest Stewardship Council standards for certified sustainably harvested wood and wood products are used to indicate that labelled products are made from wood that is harvested in a sustainable way. Scientific Certification Systems is the organization that provides third-party certification of claims under FSC's standards. Products meeting FSC requirements must have chain-of-custody certification from initial harvest of wood products through final manufacture.

Good Environmental Choice (Australia)

Australia's Good Environmental Choice rating was developed in 1991 to meet ISO 14024 standards and is applicable to a wide variety of products including building materials and retail goods. A total of 44 standards exist under this programme, which considers both social factors such as labour relations and work safety and environmental factors such as chemical and material use, energy, recycling, toxics and wastewater generation. This certification is equivalent to a number of standards in Asia and Oceana, and conformity is assured by third-party verification.

GREENGUARD (USA)

The GREENGUARD Indoor Air Quality Certified® mark and the GREENGUARD Children & Schools Certified℠ mark indicate that a product meets strict chemical emissions standards and therefore contributes to healthier indoor air quality. GREENGUARD Certification is awarded by the GREENGUARD Environmental Institute, an independent, third-party certification organization. Products certified by the GREENGUARD Environmental Institute include construction materials such as paint, adhesives, insulation, flooring, and furnishings. GREENGUARD Certified products can contribute to points in the LEED Green Building Rating System and satisfy the requirements of hundreds of green building codes, standards, and procurement policies.

GreenLabel Plus (USA)

The CRI Green Label and Green Label Plus are standards that apply to carpets, adhesives and cushions. Developed by the Carpet and Rug Institute, a trade association for the carpet industry, this logo indicates that a product has been tested to meet emissions standards for multiple chemicals including benzene and formaldehyde. The GreenLabel Plus standard is a reference standard for flooring products under the LEED rating system.

GreenSeal (USA)

The GreenSeal logo is awarded to products that meet requirements developed by the GreenSeal organization for environmental or human health performance. The GreenSeal logo is awarded to paint and other products for meeting indoor air quality standards. GreenSeal also certifies the environmental and energy performance of windows, occupancy sensors, cleaning chemicals and services, and other building-related products. Each standard measures a single attribute of products of a particular type.

Hong Kong Green Label (Hong Kong)

The HKGL system is an environmentally preferable product certification scheme applied to a variety of products in Hong Kong including whole buildings, building products, appliances and electronics. It can be found throughout China, Hong Kong, India and Taiwan. Factors considered over the whole product life-cycle include carbon/greenhouse gas emissions, energy production and use, material and natural resource use, toxics, waste generation, water use and wastewater generation. Conformity with the standard is verified by independent third parties under the ISO 17025 testing standard, with ongoing random audits to ensure compliance.

Korean Ecolabel (Republic of Korea)

This labelling programme developed by the Korea Eco-Products Institute establishes and manages eco-product standards for building materials, forest products, packaging and a variety of other products. It provides environmental trend information to the public and otherwise supports the diffusion of environmentally friendly products in the market. 143 individual products are covered by standards under this labelling scheme, which considers the production, use and end-of-life-cycle phases of product life-cycles in terms of chemicals and materials used, toxics, solid waste and recycling, energy use and wastewater generation. Conformance is assessed by independent third-party organizations under ISO 17025 standard testing procedures.

NSF International (USA)

The National Sanitation Foundation, now known as NSF International, develops US national standards and provides third-party certification for building products and other types of food, water and consumer products. Products certified by NSF International display the NSF certification mark on their label or packaging. Founded in 1944, NSF is well known for testing and certifying plumbing system components such as piping, valves and fittings, and treatment system components. The organization also certifies products using methods such as eco-efficiency analysis.

Nordic Ecolabel/Swan (Denmark)

The Nordic ecolabel was established in 1989 and can be found throughout the Nordic countries of Denmark, Sweden, Finland, Norway and Iceland. It addresses the major life-cycle phases of building products, forest products and other retail goods in terms of safety considerations and environmental considerations, including carbon/greenhouse gas emissions, energy, material and chemical use, solid waste and recycling, toxics, water quality/use and wastewater generation. It is recognized as an equivalent to the EU Ecolabel, and is verified by independent third-party certification.

Scientific Certification Systems Recycled Content (USA)

Scientific Certification Systems (SCS) is a nonprofit organization that certifies a variety of environmental claims by product manufacturers, including recycled content. Many products make claims of recycled content. However, these claims should be third-party certified by a reputable organization such as SCS in order to be credible. They should also indicate the source for the recycled content (pre- or post-consumer/recovered). Most often, recycled content is expressed in terms of unit weight of the product. SCS certification is found throughout the world, including North and South America, Europe and Asia.

Singapore Green Label Scheme (Singapore)

This green labelling scheme applies to buildings and building products as well as services and the companies that provide such products and services. There are 50 standards in the labelling scheme, which includes whole life-cycle consideration of social and environmental attributes including worker health and safety, community, housing and living conditions, animal welfare, biodiversity, greenhouse gas emissions and offsets, energy and material use, toxics, recycling and solid waste, and impacts to soil and water. Conformity is assessed by the Singapore Environment Council on an annual basis.

Thai Green Label (Thailand)

TGL-27-R2-09

The Thai green label is an environmental certification that applies to building products, water, energy, transportation and other products, with 44 standards presently existing and several others under development. Developed in 1994, this standard evaluates products over the whole life-cycle in terms of animal welfare, carbon/greenhouse gas emissions and offsets, chemical and material use, genetically modified organisms, recycling and solid waste, impacts on soil and water, and a variety of other factors. It is considered equivalent to the Environmental Choice New Zealand certification. Initial certification and ongoing audits are provided by an independent third party.

Water Efficiency Labeling & Standards (WELS) Scheme (Australia)

This rating label provides water efficiency information for water-using household products in Australia. It applies to building products and appliances, and considers water use during the use phase of the life-cycle. Verification is self-performed by the company seeking the WELS label for their products, with random audits by the Australian Federal Government to ensure compliance.

WaterSense (USA)

WaterSense is a programme developed by the USEPA to indicate water-conserving devices. WaterSense applies to residential and commercial plumbing products. All products displaying the WaterSense logo have been third-party certified to meet EPA standards. WaterSense specifications are available for toilets, urinals, faucets for bathroom sinks, showerheads, and new homes. New specifications are under development for irrigation controllers and other water-consuming devices. Rebates are also available for WaterSense-labelled products.

Waterwise Marque (UK)

The Waterwise Marque is awarded annually to products that reduce water use/waste and raise awareness of water efficiency in the United Kingdom. Established in 2006, this label is applied to buildings, retail products and building products in the United Kingdom. It focuses on water use during the use phase of the product life-cycle. Waterwise UK is the non-profit organization that manages the label and verifies conformance with standard requirements.

Life-cycle assessment

The life-cycle of a construction material can be divided into three phases: upstream of use, the use of the material itself and downstream of use. Upstream impacts are all of the side-effects a product has before it is actually used. Depending on the product, these may include the effects of:

- Harvesting the raw materials for the product from the natural environment.
- Transporting those raw materials to factories for processing.
- Processing the raw materials into finished components.
- Transporting components to other factories for assembly.
- Assembling the components into the finished product.
- Packaging the finished product for transportation.
- Transporting the finished product through the supply and distribution network to the project.

Complex products such as window and door assemblies have many steps along the way. Products such as aggregate may have far fewer steps. Each of these steps consumes materials and energy, and each step also produces waste. Keeping track of all of the materials, energy, and waste associated with the product is known as life-cycle assessment, and tools such as the Athena Impact Estimator for Buildings (Athena Institute 2010) or the BEES database (NIST 2010) are available to facilitate this analysis at the material, assembly or building level. Ecological Footprint Analysis (described further in UEM 2010) is a variant on life-cycle assessment applied at the community or development scale that expresses sustainability ratings in terms of the amount of land area it would take to provide the necessary resources and absorb the waste generated by a community. This area is then compared with the actual area taken up by the development as a basis to evaluate the sustainability of its continuing existence.

In addition to the materials and energy consumed to make a product, waste is also produced during harvesting of raw materials, manufacturing and transport. A product's emissions, including solid waste, liquid waste and air pollutants, are also tracked in a life-cycle analysis. Depending on how and where the product is manufactured, it may have significant emissions from the energy used in the manufacturing process. If it is complex with many components, the transportation required to bring those components together may be a significant factor. Emissions such as sedimentation from timber operations may be tracked as soil loss. All of these factors are considered when evaluating the ecological history of a building material. Building materials and products also have impacts while they are in use in a building, and at the end of their life-cycle. A life-cycle assessment takes all of these phases into account.

One important consideration in evaluating a product is its durability and fitness for purpose. Choosing a product because its upstream environmental impacts are reduced is a bad choice if the product does not perform well in use and has to often be replaced. Life-cycle costing is a method used to take into account a product's expected service life. Service life is the length of time a product is expected to remain in service before it fails or is otherwise unusable. Life-cycle costing of a product takes into account the product's initial purchase price and cost of construction, plus the cost of operations, repairs and replacement over the life-cycle of the building. Products with longer service lives may cost more to purchase, but they may have a lower life-cycle cost when taking into account reduced future purchases.

During operations and maintenance, building materials and products have differing requirements. Some products may require considerable maintenance using special cleaning products. Other products may require energy to operate and maintain. As mentioned earlier, choosing products with fewer upstream impacts is not the best choice if significant negative impacts are required during operations and maintenance. Although some products may cost more to purchase in the first place, their life-cycle maintenance requirements may be much less. The whole life-cycle of a product should be considered in making material selection decisions.

The end-of-life-cycle requirements of a product are also important in life-cycle assessment. Some products are difficult to dispose due to the materials they contain. For example, products containing multiple types of plastic may be difficult to recycle and dangerous to incinerate. Many types of plastics generate dangerous chemical compounds when burned, such as dioxins. These compounds are released into the air and can cause diseases such as asthma and certain types of cancer when breathed. They can also fall out and be absorbed into the soil or groundwater, creating much more long-term pollution problems.

Other products, such as structural elements of steel or aluminium, may have a high recycled value at the end of their life. The length of the product's service life, the difficulty of disassembly and recycling, and the hazardous effects of disposal all should be considered as part of life-cycle assessment. Life-cycle assessment can thus be useful in choosing products that are most sustainable for a building.

Evaluating product sustainability information

As evidenced by the variety of evaluation, rating and labelling systems described in this section, there is no lack of information about sustainability in the marketplace. However, the quality, accuracy and reliability of that information may not always be suitable to support decision making. It is essential to critically evaluate sustainability-related claims before using information as part of decision making for the built environment. The following subsections describe important considerations for evaluating sustainability information for products and with respect to rating systems overall.

Figure 4.3 shows an environment-related claim on a product label. This label is one example of the types of information that is provided to consumers about a product's environmental performance. In this case, the label does not make a product-specific claim but instead quotes a government agency about how general energy-saving practices can influence heating and cooling costs. By reference, the implication is that using this product can provide similar performance, although no specific evidence is provided.

Messages such as this one can be confusing to the uninformed consumer. Since the label does not make any product-specific claims about energy savings, it is technically correct. However, it does not provide the necessary details to evaluate what the product itself can do. When reviewing information about a product, it is important to consider the following critical factors.

Reviewing sustainability claims

- What is the source of the information, and what is their interest in the product?
- What is the basis of the information? Is it supported by third-party verification?
- Are standardized tests and protocols used to produce product data? Are they regularly reviewed and updated?
- Are ecolabels from recognized, credible sources?
- Is extraneous information provided that is vague, irrelevant or distracting?

Figure 4.3 Extraneous information on a product label can distract from a product's actual features. This label implies a specific level of energy savings but does not provide enough information to substantiate the claim

First, what is the source of the information, and what is its interest in the product? Information from independent sources (such as universities or government organizations) may be more reliable than information from sources with a vested interest in the product (such as trade associations). Second, what is the basis of the information? Is it supported by third-party verification, or is it provided by the product manufacturer without external review? Is contact or reference information provided for the third-party verifier? Third, are standardized tests from recognized agencies such as ASTM or ANSI used to produce data about the product? Using standardized test methods to evaluate products allows them to be compared with other similar products. Fourth, if the product has an eco-label, is the label from a recognized, credible third-party source? Labels such as the one shown in Figure 4.3 may appear to be supportive of environmental benefits, but there are no limitations on their use and they are not based on an objective standard of review. Finally, is extraneous information provided that is vague, irrelevant or distracting? The label shown in Figure 4.3 is an example of this type of information. It may lead to conclusions about the product that are not substantiated in fact.

Some labels and logos appear on product packaging without any reference to an established standard. For example, the earth smart label (Figure 4.4) has been trademarked as a graphic and is used on the labels of various building products. However, it is not linked with a recognized standard and does not require any testing or verification prior to use. As such, it is not a reliable basis for decision making during product selection.

Figure 4.4 Eco-labels do not necessarily indicate compliance with a recognized environmental standard. The earth smart label is not based on a recognized standard

Obtaining information about the environmental benefits or sustainability of a product, building or service can be challenging, although the sources of such information are growing. One valuable source of product information is the manufacturers, vendors and suppliers from whom the product is obtained (see the checklist in the box).

Checklist of questions for product manufacturers

- Where is the product made?
- Where are the raw materials from?
- What environmental claims does the manufacturer make regarding:
  - recycled content?
  - recyclability?
  - rapid renewability?
  - certified sustainable harvest?
  - toxicity?
  - biodegradability?
  - low emissions?
- Are these claims backed up by third-party certification?
- What organization certifies the product or verifies manufacturer claims?
- What documentation is available? Where can it be obtained?
- Are any special certifications or training required to install the product and maintain the warranty?
- Any special requirements for purchase or shipping?
- Are there any comparable alternative products? How do they compare?

When collecting product information, the project team should coordinate efforts within their companies. For commonly used products, this information can be collected and archived for use in future projects and green building rating certifications. This can save considerable time in subsequent projects.

When considering rating or measurement systems in general at the product, project, development, corporate, national or other level, it is similarly important to consider issues of accuracy, reliability and quality of information.

Misleading claims about the environmental benefits of a product, company, or other entity are known as *greenwash*. Greenwash is the act of misleading customers regarding the environmental practices of a company or the environmental benefits of a product or service. Common types of greenwash identified by TerraChoice, an organization that specializes in validating environmental marketing claims, include the following (TerraChoice 2009):

- **Hidden trade-offs** – a claim based on a small number of environmental attributes without attention to other important environmental issues. An example is a product advertised as having recycled content packaging while the main content of the product contains highly toxic compounds.
- **Irrelevance** – a claim that may be truthful but is unimportant for decision making. 'CFC-free' is a good example – Chlorofluorocarbons

are banned by law, so all products should be CFC-free, and most already are.

- **Lesser of two evils** – a claim that may be true within the product category but distracts the consumer from other negative product attributes. A commonly cited example is organic cigarettes.
- **Fibbing** – a claim that is completely false. Such claims are increasingly infrequent, but may still occur from time to time, especially in sectors where sustainability is a relatively new concept.
- **False labels** – a claim made using a counterfeit or fake eco-label, or a claim of third-party endorsement where none exists.
- **No proof** – a claim that cannot be supported with easily accessible data or reliable third-party certification.
- **Vagueness** – a claim that is so broad that its meaning is likely to be misunderstood by the consumer. An example is the term 'all natural' – while 'natural' implies an inherently good and safe product, there are many substances such as mercury and formaldehyde that are natural but not safe in products.

As information sources about the sustainability of products, buildings and services become more widely available, so too will the challenges of ensuring that information is valid and reliable. This is also a challenge with regard to rating the sustainability of built facilities and infrastructure systems, discussed next.

Building rating systems

At the scale of whole buildings, various rating systems have been developed around the world to evaluate capital project sustainability. Green building rating systems are particularly important to owners and purchasers of buildings – they offer valuable information about the building's overall environmental performance. Green building rating systems also provides a way to help the construction market improve in terms of meeting green project goals. Most green building rating systems include explicit performance thresholds that buildings must meet in order to be certified. They also typically come with guidelines that help project teams meet or exceed those performance thresholds.

Most of the green building rating systems on the market today were developed in a particular country to serve the specific needs of that country's buildings. However, many of these tools have been applied across multiple countries to meet the demand for green building ratings in countries that do not yet have their own rating system. Figure 4.5 shows the green building rating systems discussed in this section, mapped by country of origin and initial application. The colours in Figure 4.5 are used to differentiate between continents. The following subsections describe each system in more detail, beginning with rating systems originating in specific countries. The two international rating systems, Living Building Challenge and Sustainable Building Challenge, are discussed next, followed by a brief overview of local and regional rating systems for other types of buildings. It is important to note that

Figure 4.5 Green building rating systems by country of origin

some of the rating systems such as BREEAM and LEED have been widely applied in countries outside their country of origin. Rating systems relevant for a single country are noted as such in the description.

Building Research Establishment Environmental Assessment Method (BREEAM)

One of the first assessment methods to be developed for evaluating project sustainability is BREEAM. As of 2011, over 200,000 buildings worldwide have been certified under the BREEAM family of rating systems, and over one million more are registered for future certification (www.breeam.org). Developed in the United Kingdom, specific versions of this rating system exist for the United Kingdom, Europe and the Gulf, and it has also been adapted for use in other contexts to take into account environmental weightings; local codes, standards and building methods; and important local environmental issues. BREEAM has been applied to a wide range of building types, including offices, retail, education, prisons, courts, healthcare and industrial facilities, and housing. It awards points or credits for performance above regulation in ten major areas:

- **Energy**, covering both operational energy and carbon dioxide generated as a result of the facility.
- **Management**, which deals with management policy, commissioning, site management, and procurement.
- **Health and wellbeing,** covering both indoor and external issues such as noise, light, and air quality.
- **Transport**, including transport-related carbon dioxide and factors related to the location of the project.

- **Water,** including both consumption and efficiency inside and outside the facility.
- **Materials**, including embodied impacts of building materials over their life-cycle such as embodied carbon dioxide.
- **Waste**, including construction resource efficiency as well as operational waste management and minimization.
- **Land use**, dealing with the type of site and the building footprint.
- **Pollution**, including external air and water pollution resulting from the project.
- **Ecology**, focusing on ecological value, conservation, and enhancement of the project site.

The total number of points or credits in each category is multiplied by a weighting factor reflecting the relative importance of each represented issue. The total score for the building is then translated into a rating on a scale of one to five stars corresponding to pass, good, very good, excellent and outstanding. Assessment of BREEAM ratings is provided by trained and licensed assessors who produce a report outlining the project's performance and its overall rating.

Comprehensive Assessment System for Building Environment Efficiency (CASBEE)

CASBEE was developed by the Japan Sustainable Building Consortium and Japan Green Building Council in conjunction with several other Japanese government agencies including the Ministry of Land, Infrastructure and Transportation (MLIT) in 2002. The CASBEE system measures both the improvement in living amenities for building users within a property and the negative environmental impacts caused by the building and its construction within and outside the property. The CASBEE rating system is structured into two main categories. The first category, Environmental Quality, measures:

- indoor environment
- quality of service
- outdoor environment on site.

The second category, Environmental Load, measures:

- energy
- resources and materials
- off-site environment.

CASBEE is a method for assessing and rating the environmental performance of buildings, ranked in five grades: excellent (S), very good (A), good (B+), fairly poor (B–) and poor (C). Currently, CASBEE has three different scales of rating system including the housing scale, building scale and urban scale. The CASBEE for New Construction was the first rating system developed (Figure 4.6).

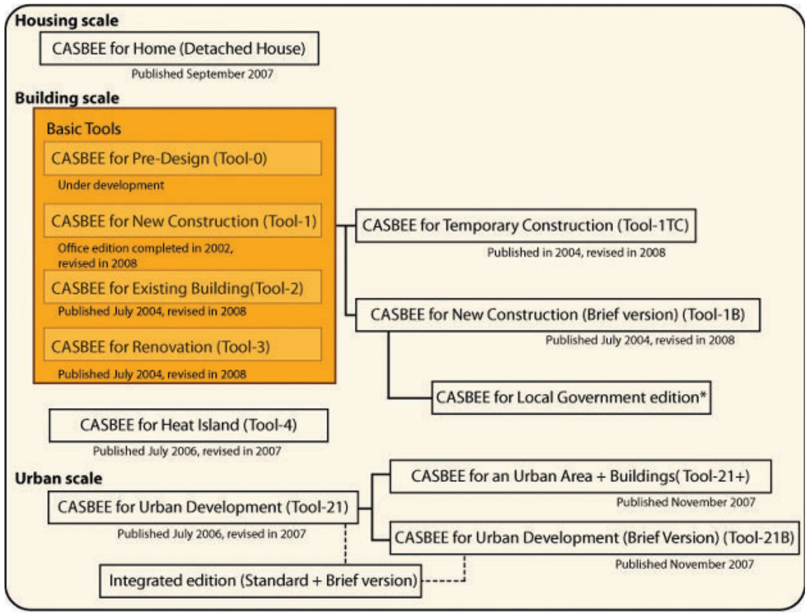


Figure 4.6 Structure of the CASBEE rating system

The CASBEE rating system is composed of three major concepts. First, CASBEE is designed for assessment of buildings over their life-cycle. Second, CASBEE has two assessment targets including environmental load (L) and quality of building performance (Q) that are clearly distinguished. Third, CASBEE applies the concept of eco-efficiency as building environmental efficiency (BEE), which is measured as the overall result of environmental assessment of building by Quality/Load shown in Figure 4.7.

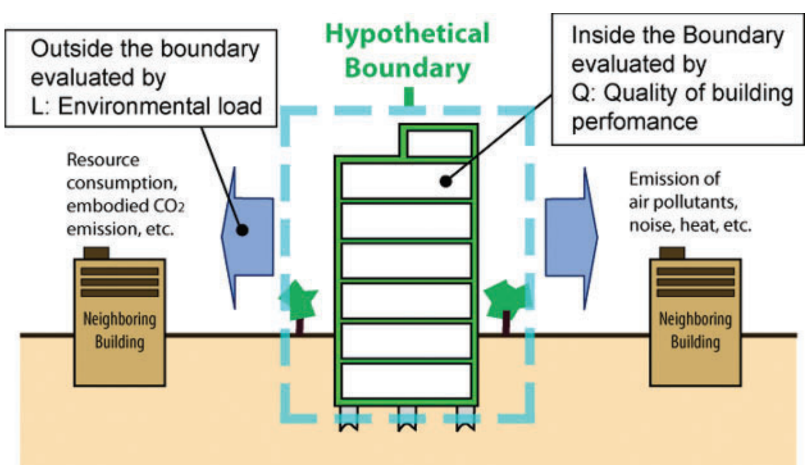


Figure 4.7 Definition of quality and load with respect to a hypothetical boundary

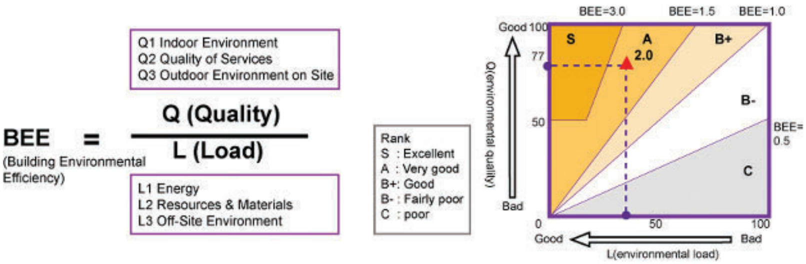


Figure 4.8 The rating mechanism of CASBEE

The basic approach for CASBEE certification is to assess the improvement of environmental quality within the virtual enclosed space corresponding to the building and its immediate site (Q), and the negative impacts on the environment outside the virtual enclosed space: that is, the world at large (L). The assessment results are applied within the graph shown in Figure 4.8 to evaluate grades within CASBEE.

Since the introduction of CASBEE in Japan, 15 major local governments across Japan have mandated its use or have created incentive programmes to help promote its adoption. For example, the cities of Osaka and Nagoya subsidize highly rated projects in their city limits. The city of Kawasaki provides lower interest rate home loans to promote the CASBEE rating system, and other cities also provide some flexibility in obtaining building permits and expediting the review process. CASBEE has been primarily used in the country of Japan, although its principles could also be applied in other contexts.

Green Globes

Initially developed in Canada, Green Globes was modelled after the BREEAM rating system as an offshoot of the BREEAM Canada for Existing Buildings Rating System in 2000. Presently deployed both in Canada and the United States, Green Globes is in process of being established as an official standard recognized by the American National Standards Institute (ANSI). The primary market for Green Globes is large developers, institutional owners and property management companies.

In contrast with BREEAM, Green Globes uses an online questionnaire-based approach to rating, with information provided by the project team. The rating system also provides feedback on the environmental impact of project decisions and suggests advice and resources to improve performance. One of the primary advantages claimed by the developers of Green Globes is that it is written in plain language and can be used by a wide range of people with different experience levels. This applicability to laypeople contrasts with BREEAM and other rating systems such as LEED, where expertise and formal training, while not required, are necessary to apply the rating system effectively to a project.

The system can be applied to both new and existing buildings and is suitable for projects including offices, multi-family facilities, and institutional buildings such as schools, universities and libraries. It can also be applied across portfolios to compare the performance of multiple buildings of a single owner. Green Globes can be used throughout the design process to evaluate the impacts of project decisions on point scores. Third-party verification and certification is provided by trained regional verifiers who audit the project information provided by the team.

Ratings under Green Globes are expressed as one, two, three or four globes, indicating increasing levels of environmental performance. Projects are evaluated based on a 1000-point scale including variables in seven categories (management, site, energy, water, resources, emissions and indoor environment). Data submitted online by a project team is verified both through document review and an on-site walk through assessment. The on-site verification by a third party is another major difference between rating systems such as LEED and Green Globes. Green Globes has been applied primarily in the United States and Canada.

GreenStar Australia

The Australian Green Building Council has developed a green building rating system to promote sustainable development and the transition of the property industry by promoting green building programmes, technologies, design practices and operations. The Green Star environmental rating system for buildings was developed by the Green Building Council of Australia (GBCA) based on existing systems and tools in overseas markets including the British BREEAM system and the North American LEED system. Green Star is Australia's first comprehensive rating system for evaluating the environmental design and performance of Australian buildings based on a number of criteria, including management, indoor environmental quality, energy, water, materials, land use and ecology, emissions and innovation, as shown in Figure 4.9. These categories are divided into credits, each of which addresses an initiative that improves or has the potential to improve environmental performance. Points are awarded under each credit for actions that demonstrate that the project has met the overall objectives of Green Star. Once all claimed credits in each category are assessed, a percentage score is calculated and Green Star environmental weighting factors are the applied. The Green Star rating tool uses six stars to measure environmental performance of buildings. Projects that obtain a predicted rating of one, two or three stars are not eligible for formal certification. Projects that obtain a predicted four-star rating or above are eligible to apply for formal certification, as follows:

- four-star Green Star certified rating recognizes and rewards 'Best practice'.
- five-star Green Star certified rating recognizes and rewards 'Australian excellence'.
- six-star Green Star certified rating recognizes and rewards 'World leadership'.

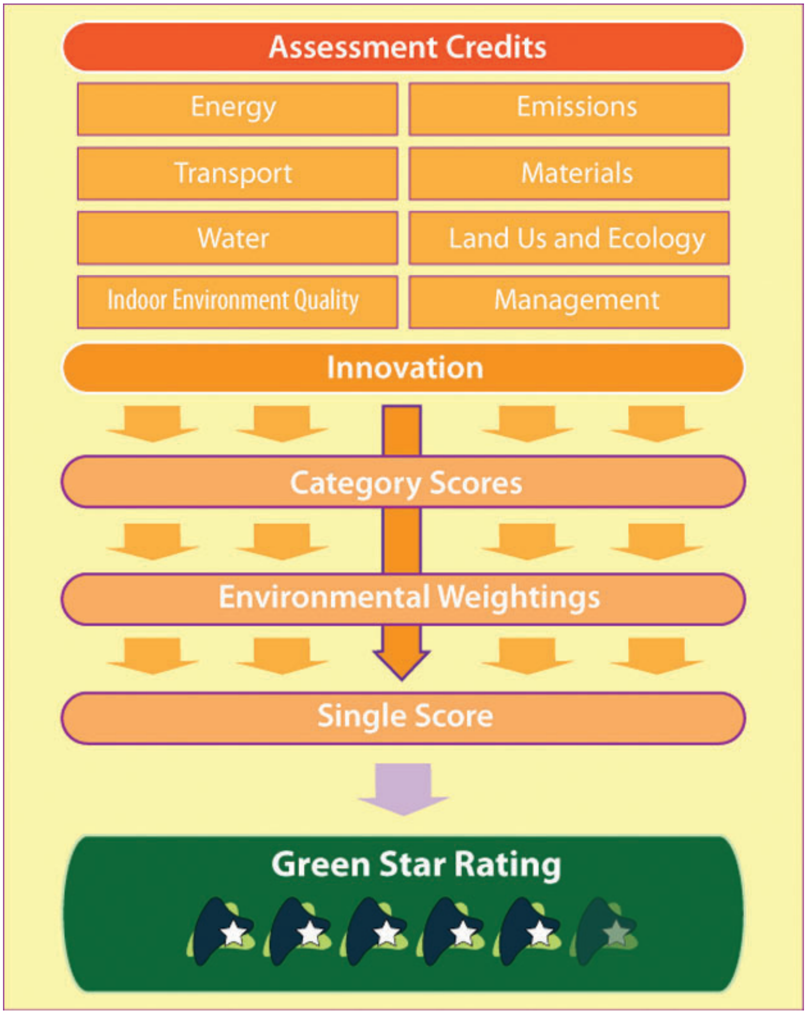


Figure 4.9 Structure of the Green Star rating system in Australia

Currently, Green Star has several rating tools to cover different types of building including education, healthcare, multi-unit residential, industrial, office, office interiors, retail centre, office design and office as-built. Since its inception in 2003 by the Green Building Council Australia, 357 projects have been certified as of September 2010. Green Star Australia complements the National Australian Built Environmental Rating System (NABERS) managed by the New South Wales Department of Environment and Climate Change (DECC), which rates existing buildings based on their environmental performance and climate change impact during operations (see Chapter 2 for additional information). Green Star has also been adopted by other nations such as South Africa and New Zealand, where it has been adapted to fit local contexts.

GreenStar New Zealand

Based heavily on the Australian version of Green Star, the first Green Star New Zealand rating system was launched in New Zealand in 2007, focusing on office design, and has since evolved to cover multiple building types and multiple phases of the project life-cycle. The Green Star NZ rating system is designed as a three-stage system including design, build and use/performance. This structure reflects the process used by industry to deliver a built facility and also captures unique opportunities to realize environmental benefits at each stage.

In the design phase, the tool rates the design of the building as a reflection of what will ultimately be built. This phase is important because decisions made during design greatly influence subsequent practices for sustainability during later life-cycle phases. Achievement of the design phase certification generally happens prior to construction. Documentation includes submittal of design documents, reports from the design team and statements from owners demonstrating that Green Star requirements have been met. Green Star Accredited Professionals (GSAP) are typically involved in compiling documentation for the project.

In the built phase, the focus is on confirming environmental initiatives proposed in the design phase and measuring and assessing what has actually been built. The credit aims and criteria are the same as for design, but in the built phase, documentation includes actual evidence from the construction phase of the project, including supplier and subcontractor submittals, commissioning reports, as-built drawings, product data sheets and other information. Projects can be certified under Green Star NZ during the built phase without having previously completed design phase certification, and it can also apply for different credits than pursued in the design phase if changes occur during construction.

Requirements are grouped into nine major categories, as follows:

- **Management**, covering issues related to commissioning, use of a Green Star accredited professional, development of a building user's guide, and environmental and waste management planning.
- **Indoor environmental quality**, covering indoor air quality, ventilation, daylighting, thermal comfort, views, noise levels and other issues.
- **Energy**, addressing overall energy performance, peak demand reduction, lighting power density and zoning, sub-metering and carbon dioxide emissions.
- **Transport**, including provision of car parking, cyclist and pedestrian facilities, public transport and small parking spaces.
- **Water**, including potable water efficiency, water meters, landscape water efficiency and cooling tower water consumption.
- **Materials**, including recycling, reuse of building components, recycled content, minimization of PVC, sustainable timber, carpets, paints, thermal insulation and floor coverings.

- **Land use and ecology**, including ecological value of site, reuse of land, reclamation of contaminated land, change in ecological value and topsoil issues.
- **Emissions**, including ozone depletion and global warming potential, recovery of refrigerants, pollution of watercourses, light pollution and cooling towers.
- **Innovation**, covering strategies not already addressed in other categories, greatly exceeding Green Star benchmarks and other environmental design initiatives.

As with Green Star Australia, points are awarded under each credit for actions that demonstrate that the project has met the overall objectives of Green Star NZ. Once all claimed credits in each category are assessed, a percentage score is calculated and Green Star environmental weighting factors are the applied. The Green Star NZ rating tool uses six stars to measure environmental performance of buildings. Projects that obtain a predicted rating of one, two or three stars are not eligible for formal certification. Projects that obtain a predicted four-star rating or above are eligible to apply for formal certification on the same basis as Green Star Australia.

Green Star NZ also has rating tools tailored to building interiors, industrial buildings and educational facilities. A tool for the third major phase of the building's life-cycle, Performance, is presently under development to complement the design and build tools.

Leadership in Energy and Environmental Design (LEED)

Of all the tools in the market today, the LEED rating system is one of the most well known worldwide for rating and evaluating green buildings, and has been applied to projects in the United States and beyond. Initially modelled after the BREEAM system, the LEED rating system applies to a wide variety of project types, including new commercial construction and major renovations, existing buildings, commercial interiors, building cores and shells, residential construction and neighbourhood development. It is designed to be applicable in different climates and contexts throughout the United States, and has been awarded to buildings in other countries as well. LEED has four levels of certification (Certified, Silver, Gold and Platinum). The LEED rating system consists of a series of performance goals and requirements in six categories, as follows:

- **Sustainable sites**, covering issues related to the location of the project site, impacts to the site during construction, site amenities and impacts resulting from building operations.
- **Water efficiency**, which deals with water consumption and wastewater generation by the building in operation.
- **Energy and atmosphere**, which addresses all aspects of the building's energy performance, energy source(s) and atmospheric impacts.

- **Materials and resources**, which pertains to the sources and types of materials used on the project, the amount of waste generated and the degree to which the project makes use of existing buildings.
- **Indoor environmental quality**, which covers aspects of the building's indoor environment ranging from ventilation to air quality to daylight and views.
- **Innovation in design**, which rewards the project for going beyond the minimum credit requirements and for using a LEED accredited professional.

Each category consists of a series of credits and points that can be earned by a project. Five out of the six categories also have prerequisites that the project must meet to be considered for certification. A project must meet all prerequisites in all categories in order to pursue certification. It also must obtain a minimum number of energy performance credits to exceed energy code requirements.

The LEED system was initially developed to apply to new commercial construction. As the system grew in popularity, it became apparent that different types of projects would require different criteria to be properly rated. Accordingly, the original rating system was first customized through the development of application guides for specific project types such as hotels and dormitories. These types of projects have characteristics that require special interpretation of LEED credit requirements, but they can still use the basic LEED-NC structure. Different versions of the rating system were also developed for other project types, including:

- Existing buildings (LEED-EB) for buildings not rated during construction which have already been occupied.
- Commercial Interiors (LEED-CI) for individual tenant spaces in commercial buildings.
- Core and shell (LEED-CS) for the site and base building for buildings that lease tenant space.
- Homes (LEED-H) for residential construction.
- Neighbourhood development (LEED-ND) for residential and mixed-use developments of various types.

LEED-CS and LEED-CI are complementary products and reinforce each other. For instance, tenant spaces seeking certification under LEED-CI can obtain points for locating in buildings that have received LEED-CS certification. The same applies to LEED-H and LEED-ND. Homes seeking certification under LEED-H can receive extra points if the neighbourhood in which they are developed has received LEED-ND certification. Likewise, additional points can be earned under LEED-ND if the buildings in the development are also certified under an appropriate rating system such as LEED-H or LEED-NC.

The process of certifying a building under LEED has several steps (Figure 4.10). Once the decision is made to proceed with LEED certification of a project, each subsequent step is undertaken using the LEED

Online documentation system. The first step in the certification process is to register the project with the US Green Building Council (USGBC) to declare intent to pursue certification. This allows the project team to access USGBC databases. It also provides an online workspace for the team to manage project documentation. Registering the project requires paying a fee to the USGBC that is the same for all projects.

After the project has been registered, the next step is to document green features incorporated into the project design that meet credit requirements. Typically, the project team will kick off this step by having a meeting to review the LEED checklist and decide which points and credits to pursue. The process of documentation to prove compliance with LEED credit requirements continues throughout construction and possibly for the first year of occupancy depending on the credits pursued.

The project team can submit documentation to the USGBC for review at two points in time: at the end of the design process, and after construction is complete. The project team may also opt to submit everything at once when the project is complete. All documentation compiled up to the point of submittal is assembled by the project team using LEED Online. Submittal of documentation for review involves paying a review fee based on project size. This prompts the USGBC to conduct the review. If the team submits a design review, USGBC will evaluate points under the rating system that can be measured at the end of the design process. It will not evaluate credits that require documentation during the construction phase. Design phase review is useful for the project team to get an idea of how many points they are likely to obtain in the project. It provides a basis for deciding how hard to work for additional points during construction.

At the conclusion of the project, final documentation is assembled online. A fee is paid, and the package is reviewed by the USGBC. Upon review of the full project documentation, USGBC may elect to request additional clarification as part of a point audit. The Council makes a final determination as to which points should be awarded. It determines a level of certification for the project. The project team has the right to appeal any credits declined in the review by paying an additional fee and providing additional documentation. The ruling of the USGBC following appeals is final.

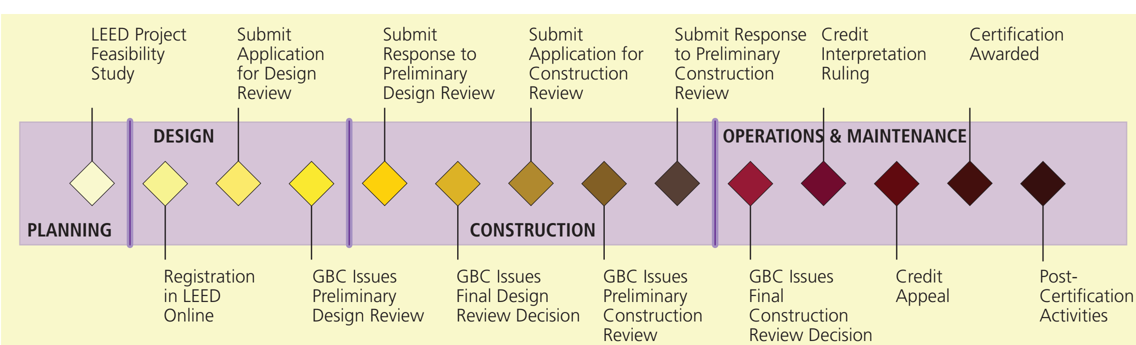


Figure 4.10 LEED-related activities during project delivery

MOHURD 3 Star Rating System (China)

In China, the Ministry of Housing, Urban, and Rural Development (MOHURD) has developed a voluntary, context-specific rating system to encourage the development of green buildings beyond what has already occurred due to the use of international rating systems such as LEED. The 3 Star Rating System, developed in 2008, is a green building labelling system that evaluates a building's performance and publishes relevant information about the building to verify the performance. The system targets both residential and public buildings, and awards certifications at one star, two-star and three-star levels. The rating system considers building performance in six major areas: land saving, energy saving, water saving, material saving, indoor environment and operations. Buildings can be evaluated at the completion of the construction document phase, at which point a Green Building Design Label is awarded that has a two-year validity. This evaluation provides a path for subsequent award of the Green Building Label, which is awarded after operation for at least one year and is valid for three years following certification.

The rating system contains a checklist to guide performance and a composite index for evaluating performance. It was developed to reflect the unique practices in the Chinese construction supervisory system and the unique attributes of Chinese standards and regulations. Management and enforcement of rating requirements and the labelling process are undertaken by the Center of Science and Technology of Construction (CSTC) within MOHURD, with technical support from several Chinese universities specializing in building science, construction and performance.

South Korea Green Building Certification System (GBCS)

Korea has been dramatically developed over the last 40 years with little regard for the environment. Since Korea became a member of the Organization for Economic Co-Operation and Development (OECD) along with endorsing other international environmental movements including the Kyoto Protocol, the Korean government has been interested in comprehensive environmental action plans to achieve the goals of sustainability in the construction industry. One of Korea's initiatives as part of this effort has been to develop and implement a green building rating system called Green Building Certification System (GBCS), which began in 2001. The purpose of the GBCS in Korea is to:

- Reduce the environmental impacts of buildings by incorporating green building principles and practices into every aspect of a building's life-cycle, from design and construction to use, maintenance and even demolition.
- Provide comfortable living and working environments for occupants and visitors.
- Raise the awareness of the importance of the natural environment.

- Encourage the development and use of environmental friendly technologies and materials.
- Promote environmental research and development.

Since its introduction in 2001, GBCS has expanded to different types of building including multi-family housing units, office buildings, mixed-use residential buildings, schools, retail markets and lodging facilities. GBCS in Korea includes four major categories to achieve the goals of sustainability in the building sector including:

- land use and commuter transportation
- energy resources consumption and environmental loads
- ecological environment
- indoor environmental quality.

In addition, GBCS has four different certification grades including:

- first grade of green buildings (above 80 out of 100)
- second grade of green building (above 70 – below 80)
- third grade of green building (above 60 – below 70)
- fourth grade of green building (above 50 – below 60).

The Korean government also offers real estate acquisition and registration tax exemption (5 per cent to 15 per cent) for first and second grades of green buildings to motivate the adoption of GBCS in Korea. Since GBCS in Korea is mainly implemented and enforced by the government, it has been very effectively spread throughout the construction industry within a short period of time.

Sustainable Building Challenge (International Rating Standard)

The Sustainable Building Challenge is a continuing programme to feature high-performance buildings worldwide and examine their performance at World Sustainable Building conferences. Begun as the Green Building Challenge in 1996, this programme has engaged over 75 teams in the process of evaluating their buildings in terms of key performance indicators and bringing those projects forward for discussion internationally. It is managed by the International Initiative for a Sustainable Built Environment (IISBE).

An outcome of the Sustainable Building Challenge Process has been the SB Method and the SB Tool. The SB Method is a generic framework for rating the sustainability performance of capital projects. As such, it can be used as a toolkit to help countries, local organizations or other authorized third parties to develop commensurable versions of the SB Tool that apply to local or regional conditions and building types. The SB Method takes into account region-specific and site-specific context factors and uses them to adjust weightings to account for project conditions. Local criteria or language can also be easily inserted to result in a truly context-specific rating tool. The structure of the tool remains common across all versions, and enables benchmarking and comparison on an international basis across multiple contexts.

Projects are measured through a series of parameters nested into eight issues containing 29 categories containing 125 different criteria. Criteria are the most detailed level of parameter, and are scored for a project as deficient, minimum acceptable performance, good practice or best practice. Unlike other rating systems discussed earlier, the SB Tool actually deducts credit for facility features that are worse than a specified minimum. Each criterion is weighted according to context-specific conditions, and rolled up to constitute a total score. Projects can also be represented by a performance profile where the details of performance for each parameter are presented.

The eight major issues covered by the SB Tool are:

- **Site selection, project planning and urban design**, including issues such as availability of infrastructure, site resources, and proximity to local assets and resources.
- **Energy and resource consumption**, including total life-cycle non-renewable energy, electrical peak demand during operations, renewable energy, materials and potable water use.
- **Environmental loadings**, including greenhouse gas emissions; other atmospheric emissions; solid wastes; rainwater, stormwater and wastewater; impacts on site; and other local and regional impacts.
- **Indoor environmental quality**, including indoor air quality; ventilation; air temperature and relative humidity; daylighting and illumination; and noise and acoustics.
- **Service quality**, including safety and security during operations; functionality and efficiency; controllability; flexibility and adaptability; commissioning of facility systems; and maintenance of operating performance.
- **Social and economic aspects**, including social issues such as accessibility, views and construction safety, and cost/economic issues including first cost, life-cycle cost, affordability, commercial viability and support of the local economy.
- **Cultural and perceptual aspects**, including culture and heritage issues.

Projects are evaluated across four phases of their life-cycle: pre-design, design, construction and commissioning, and operations. The phases and criteria constitute a matrix that can be considered in full or in part based on the decision support needs of the organization. The SB Tool has influenced national rating systems being used in Austria, Spain, Japan and Korea. It has been developed into a customized tool for judging an international design competition and has also been adapted for use by the country of Italy, a bank and an insurance firm.

Living Building Challenge (International Rating Standard)

Developed by the International Living Building Institute, the Living Building Challenge is a standard that can be used to rate built facilities in terms of the degree to which they restore the natural and social environment and function effectively as contributors to, not parasites of, the context in which they are built. As described on the Living Building Challenge website, the aim behind the tool is to ask:

> What if every intervention resulted in greater biodiversity; increased soil health; additional outlets for beauty and personal expression; a deeper understanding of climate, culture and place; a realignment of our food and transportation systems; and a more profound sense of what it means to be a citizen of a planet where resources and opportunities are provided fairly and equitably?
>
> Indeed, 'Living Building Challenge' is not a merely a noun that defines the character of a particular solution for development, but more relevant if classified as a series of verbs – calls for action that describe not only the 'building' of all of humanity's longest lasting artefacts, but also of the relationships and broader sense of community and connectivity they engender. It is a challenge to immerse ourselves in such a pursuit – and many refer to the ability to do so as a 'paradigm shift'.

The Living Building Challenge is comprised of seven performance areas, or 'petals', which are subdivided into 20 'imperatives' focusing on a specific sphere of influence, as follows:

- **Site**, including limits to growth, urban agriculture, habitat exchange and car-free living.
- **Water**, including net zero water and ecological water flow.
- **Energy**, including net zero energy.
- **Health**, including civilized environments, healthy air and biophilia.
- **Materials**, including avoiding materials on a defined 'red list', embodied carbon footprint, responsible industry, appropriate sourcing, and conservation and reuse.
- **Equity**, including human scale and humane places, democracy and social justice, and rights to nature.
- **Beauty**, including beauty and spirit, and inspiration and education.

In each petal, the intent of that petal is clearly articulated, along with a vision of ideal conditions under that category and current limitations faced by market and technological conditions. Imperatives state required conditions that must all be met in order to achieve certification requirements. The system can be adapted to many different project types, grouped into four major typologies:

- renovation
- landscape/infrastructure

- building
- neighbourhood.

Projects are encouraged to look for synergies with regard to their natural and built environment context. This is known as 'scale jumping', and encourages multiple buildings or projects to operate in a cooperative fashion to achieve sustainability goals. Not all of the typologies are required to achieve all 20 imperatives due to differences in the nature of different projects, and many imperatives have temporary exceptions that acknowledge current market limitations. The expectation is that these exceptions will be eliminated over time as the market evolves.

Certification under the Living Building Challenge is based on actual, rather than modelled, project performance. Accordingly, projects cannot be certified until at least 12 consecutive months of operation have been completed. Documentation must also be compiled during planning, design and construction to demonstrate compliance with certification requirements.

Local/regional building rating systems

In addition to the national and international rating systems described in the previous subsections, many local and regional building rating systems have also evolved over time, especially at the level of residential construction. In the United States, many of these local systems were initially developed by local homebuilder associations to highlight high-performance housing features to the residential market, and some of them preceded the development of national rating systems such as LEED. In many cases, the rating systems evolved over time and were taken on by local non-profit organizations or utility companies who managed and administered the rating system. Examples of such locally developed systems in the United States include the Austin Energy Green Builder Program at the local level (Austin Energy 2010), the Colorado Built Green Program at the state level (Built Green 2010), and the Earthcraft House program at the regional level (Earthcraft 2010).

Case Study: Duke Energy Center's choice of a green building rating system[1]

The Duke Energy Center was the first and tallest office building in the United States to use LEED®)for Core & Shell rating system Version 2.0, a green building rating system created by the USGBC, to achieve its sustainability goals. This tower project, initiated in 2005, was a response to an emerging awareness of the importance of corporate sustainability and climate change by owner Wachovia Bank. At its early development stage, the project team set up sustainable project goals based on Wachovia's recognition of the triple bottom line, specifically examining how the new facility should affect the three Ps: people, planet and profit. The established sustainability goals motivated the project team to complete what was at the time the tallest sustainable office tower in the United States with a LEED Platinum rating. The Duke Energy Center contains 1.5 million sq ft in its 51 storeys (see box). Office space comprises 48 floors of the office tower with three additional mechanical floors.

To guide its design and construction processes, the Duke Energy Center project team chose the LEED Core & Shell (CS) Rating System as a measuring tool. LEED CS was developed by the USGBC especially for buildings such as the Duke Energy Center, where a single developer designed and built the building's core, shell and central services such as conveyance, water and energy supply, but did not have responsibility for decisions about the interior configuration and performance of individual tenant spaces within the building. To go along with LEED CS, the LEED for Commercial Interiors (CI) rating system was developed in parallel to be used by tenants to develop and evaluate the sustainability of their individual leased spaces. Users of the LEED CI rating tool gain extra points by developing their space within a building that is already LEED CS certified, thus providing extra market appeal to potential tenants of LEED CS certified buildings.

Duke Energy Centre

- Location: Charlotte, North Carolina, USA.
- Building type: Office.
- Date of groundbreaking: February 2006.
- Date of completion: January 2010.
- Total area: 139,000 sq m (1,500,000 sq ft).
- Total height: 240 m (786 ft)/51 floors.
- Green Building: LEED CS v2 Platinum Certification.
- Owner: Wells Fargo & Company (formerly Wachovia Corporation).
- Architect: tvsdesign.
- Structural engineer: TRC Worldwide Engineering.
- Contractor: Batson-Cook Company.

Although there are some differences in the credits and points between LEED CS and LEED NC, the primary categories of credits are the same. The Duke Energy Center project team thus pursued credits in five primary areas:

- sustainable sites
- energy efficiency
- water efficiency
- materials and resources
- indoor environmental quality.

The following subsections describe specific core and shell tactics used in each category.

Figure 4.11 The Duke Energy Center has several public transport options
Courtesy of Wells Fargo & Co.

Sustainable sites

The Duke Energy Center incorporates many sustainable features related to sustainable sites that are applicable to not only to new construction projects but also core and shell projects. These include:

- Its location in the city centre area of Charlotte, North Carolina. The tower project provides walking access to many amenities and services such as a pharmacy, coffee house, restaurant, hotels and museums.
- The chosen site was classified as brownfield because there had been petrol (gas) station located there. Through the removal and remediation of 75,000 cu yd of soil, the site was restored, which has helped to revitalize this area of the city.
- Tenants and visitors to the Duke Energy Center have multiple transportation options (Figure 4.11) which have been calculated to save over 110,000 gallons of gasoline and 1,000 metric tons of carbon emissions per year, including:
  - secure bicycle racks in the parking deck along with showers/changing rooms
  - easy accessibility by the Charlotte Area Transit System, bus and rail
  - limited parking for automobiles; enough only to meet minimum city requirements.
- The parking deck, approximately 23 acres, is stacked under the building to minimize the project footprint and eliminate surface parking, which helps to reduce the heat island effect by reducing the amount of heat-absorbing surfaces.
- The building has a green roof (Figure 4.12) that is planted with native and adapted plants. This reduces the heat island effect, reduces heating and cooling loads on the building, mitigates stormwater runoff, and provides an enjoyable outdoor space for tenants.

Figure 4.12 The green roof alleviates the heat island effect and mitigates stormwater while simultaneously proving tenants a connection between the indoors and outdoors
Courtesy of Wells Fargo & Co.

Water efficiency

The Duke Energy Center includes many water efficiency strategies to not only reduce water consumption and usage but also minimize wastewater generation. Sustainable features for water efficiency include:

- Water use by tenants and visitors to the building has been reduced by more than 46 per cent through the use of highly efficient fixtures in bathrooms located in the building core. Use of these fixtures save more than 4.3 million gallons of potable water from being flushed (Figure 4.13).
- All restrooms are equipped with 0.5 gallons per minute (gpm) lavatories while code requires a maximum of 2.2 gpm.
- All male restrooms are equipped with waterless urinals rather than conventional urinals that use 1 gallon per flush.
- All restrooms are equipped with dual flush water closets that use either 1 gallon or 1.6 gallons of water per flush. Conventional water closets use 1.6 gallons of water for each flush.
- Approximately 25 million gallons of water per year are required to operate the heating, ventilation and air conditioning (HVAC) system in a building of this size. Contaminated ground water is being captured and treated to supply 100 per cent of the water required for HVAC systems to cool the building, thus avoiding the purchase of this water from the city and reducing the demand on city infrastructure.
- 100 per cent of water for irrigation is provided by collected rainwater and condensate from the site.

Using these strategies, it is estimated that the building avoids the purchase of 30 million gallons of water each year, and provides annual savings of $125,000.

Figure 4.13 Water-efficient fixtures can reduce water consumption in the tower

Energy efficiency

The Duke Energy Center has incorporated significant energy saving features, including:

- Daylight is maximized through the use of daylight harvesting blinds (Nysan) that reduce energy used for lighting and reduce demands on cooling (Figure 4.14).
- The exterior wall utilizes well-insulated spandrel glass between floors along with high-performance ‘low-e’ glazing to reduce the amount of heat gain from sunlight while also allowing natural daylight into workspaces.
- Automatic daylight sensors and electronic dimming controls allow for the artificial lighting to be adjusted based on the amount of available daylight (Figure 4.14).
- Occupancy sensors are located throughout tenant spaces and in restrooms so that lights are off unless tenants need them.
- Highly efficient HVAC systems and controls reduce demand for cooling.

- Each floor is equipped with an electrical sub-meter for the purpose of capturing all the energy consumed on that floor. This feature allows tenants to pay for their own utilities, in turn empowering them to exercise control of the quantity used.

The result of incorporating energy saving features in the Duke Energy Center is estimated to reduce the energy consumption by 22 per cent (5 million kW hours/year saved) over conventional office buildings. This amount of energy saving is enough to power 455 typical US houses for one year. In addition, the Duke Energy Center has commissioned the building's energy-related systems to verify they are installed, calibrated and functioning according to the owner's project requirements, basis of design and construction documents. Finally, the Duke Energy Center has committed to purchase over 70 per cent of its energy needs using green power. Green power is electricity produced from renewable resources, including solar, wind, geothermal, biomass and low-impact hydro. Since many utilities companies do not offer green power for direct purchase, the Duke Energy Center purchased renewable energy certificates (RECs) that ultimately support new green power facilities and increase production of energy from renewable and low-impact sources.

Figure 4.14 Energy-efficient strategies for the Duke Energy Center
Courtesy of Wells Fargo & Co.

Materials and resources

To achieve its goals related to materials and resources, the project team led by constructor Batson-Cook incorporated multiple strategies in the Duke Energy Center during the construction phase:

- More than 93 per cent of the construction waste (16,500 tons) generated during the excavation and construction of the project were diverted from landfills over the course of four years (Figure 4.15).
- During the excavation, 350,000 cubic yards or 40,000 dump trucks of stone were removed and taken to Martin Marietta Quarry to be crushed and recycled for roads or fill.
- More than 24 per cent of the materials used in construction of this project contain post-consumer and/or pre-consumer recycled content. Examples include structural steel, drywall, concrete masonry units, concrete and rebar, and the aluminium in the curtain wall (Figure 4.15).
- More than 40 per cent of all the materials used in the construction of this project were harvested or extracted and manufactured within a 500 mile radius of Charlotte, North Carolina, reducing the environmental impacts of transportation.
- More than 50 per cent of all of the wood used to construct the building came from sustainably managed forests that use Forest Stewardship Council guidelines to manage their forestland.
- Recycling areas are an integral part of the building infrastructure, facilitating the collection of paper, cardboard, metal, plastic and glass.

Indoor air quality

The Duke Energy Center includes the following features related to indoor air quality:

- All adhesive, sealants, paints, coatings, carpet and composite wood (such as plywood) used in the building's core and shell components meet strict standards for limiting the amount of chemical elements which offgas harmful volatile organic compounds (VOCs) into the air. All tenants are also required to use products that meet these same standards as they design and build out their interior spaces (Figure 4.16).
- The Duke Energy Center has installed permanent outdoor air delivery monitoring systems to check the airflow values and carbon dioxide (CO_2) levels. These systems help promote occupant comfort and well-being.
- Daylit spaces can increase occupant productivity and reduce absenteeism. The layout and floor plan of the building allows for well-daylit space. With thoughtful interior design, most occupied spaces have been provided with views to the outside that help create a connection to the outdoors (Figure 4.14).
- The project team developed and implemented an IAQ management plan for the construction and preoccupancy phase of the building to reduce indoor air quality problems resulting from construction. This practice promoted the comfort and well-being of both construction workers and building occupants.

Figure 4.15 Sustainable strategies related to building materials, including on-site waste recycling and recycled content structural steel
Courtesy of Wells Fargo & Co.

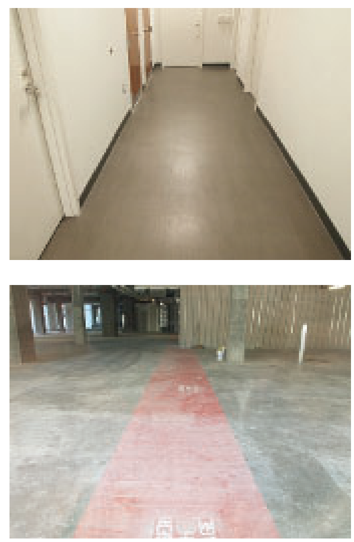


Figure 4.16 Indoor air quality strategies in the Duke Energy Center, including low-VOC flooring (top) and protection of finishes during construction (bottom)

Tenants

In addition to the sustainable features in the building's core and shell, Wells Fargo published 'Sustainability guidelines' for tenants to use during the design and construction of their spaces. These provisions establish a uniform, building-wide standard for sustainable design and construction practices, thereby achieving a meaningful green development standard for the Duke Energy Center. Some tenant lease requirements related to sustainable features are:

- Reduced lighting power density – 15 per cent minimum reduction below code requirements.
- Tenants must use the daylight blinds and dimming lighting ballasts provided by the base building.
- Tenants must divert from the landfill at least 50 per cent of their construction, demolition and packaging wastes.
- Tenant construction teams must employ an IAQ management plan during the construction of their space.
- Tenants are required to use low-emitting materials that comply with the LEED standards for adhesives, sealants, paints, coatings, carpet and composite wood products.
- Green housekeeping practices will be employed throughout the building, reducing the exposure of building occupants and maintenance

personnel to potentially hazardous chemical contaminants that adversely impact occupant well-being and the environment.

Through this project, owner Wells Fargo (which merged with Wachovia Corporation in 2009) has implemented its corporate sustainability practices to support the environment and the health, comfort and well-being of its employees and customers. The lessons learned and the strategies implemented as part of the Duke Energy Center can be extended and applied to other similar high-rise buildings worldwide as they seek a rating system to support their sustainable project goals.

Infrastructure, regional and country rating systems

Beyond the individual building scale, other rating and assessment schemes have also been developed that address sustainability for infrastructure projects, for project sites, cities or regions, and business enterprises. This section presents an overview of the most well-known of these systems pertaining to the built environment: the CEEQUAL system for infrastructure rating, the Greenroads Sustainability Performance Metric for roadways, the Sustainable Sites Initiative for land development, the Australian Green Infrastructure Council (AGIC) rating system and Institute for Sustainable Infrastructure's envision rating system. Figure 4.17 shows the country of origin of each of these systems. The colours in Figure 4.17 are used to differentiate between continents. The section concludes with a look at measurement and evaluation systems at the regional and corporate scales.

Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL)

CEEQUAL is a rating system targeted toward civil engineering and public works projects. Developed in the United Kingdom by the Institution of Civil Engineers and related organizations, it was formally launched in 2003. CEEQUAL uses a point-based assessment system made up of 200 questions in 12 topic areas:

Figure 4.17 Measurement schemes for infrastructure systems

- project management
- land use
- landscape
- ecology and biodiversity
- historic environment
- water resources and water environment
- energy and carbon
- material use
- waste management
- transport
- effects on neighbours
- relations with local community and other stakeholders.

Projects can seek awards of five different types based on who applies for the rating: a whole project award, a client and design award, a design only award, a construction only award, or a design and build award. Projects are assessed by an assessor within the project team and verified by a certified and trained verifier, who assigns the final rating for the project. Assessment begins by reviewing the list of questions and determining which ones are not relevant for the project. Some questions can be removed from consideration if they are not relevant for the specific type of project, while others are mandatory for all projects.

Four levels of rating are available, including 'pass' (>25 per cent of points), 'good' (>40 per cent), 'very good' (>60 per cent), and 'excellent' (>75 per cent). A variety of projects have received awards under CEEQUAL, including bridges, public buildings, rail projects, river/coastal defence structures, roads and water supply/sewer projects.

Australian Green Infrastructure Council (AGIC) Rating Scheme

Currently under development, the AGIC Rating Scheme is a new rating system applicable to a variety of infrastructure projects that will build on the CEEQUAL rating scheme developed in the UK (AGIC 2010). Developed by the Australian Green Infrastructure Council, a membership organization of design and construction professionals from both public and private organizations, the new rating scheme will apply to projects ranging from roads, rail, bridges and tunnels, to airports, distribution grids, waterway and port projects, and others. The most notable difference between the AGIC scheme and CEEQUAL is its inclusion of social and economic sustainability metrics in addition to the environmental metrics developed under the CEEQUAL system. Key categories of metrics under development include:

- **Project management and governance**, including purchasing and procurement; reporting and responsibilities; making decisions; climate change adaptation; and knowledge sharing and capacity building.
- **Economic performance**, including value for money; due diligence; and economic life.

- **Using resources**, including energy use; water; and materials selection and use.
- **Emissions, pollution and waste**, including greenhouse gas management; discharges to air, water and land; land management; and waste management.
- **Biodiversity**, including functioning of ecosystems and enhanced biodiversity.
- **People and place**, including health, well-being, and safety; heritage values; participatory processes; positive legacy for current and future generations; high quality urban and landscape design and aesthetics; and knowledge sharing.
- **Workforce,** including safety, health, and well-being of workforce; capacity building; increased knowledge of applied sustainability; and equity.

The AGIC scheme will have an accreditation process for interested professionals as well as a third-party review process similar to CEEQUAL.

Greenroads Sustainability Performance Metric

The Greenroads Sustainability Performance Metric is a voluntary rating system developed jointly by the University of Washington and CH2MHill, a private company. It targets both new and reconstructed/rehabilitated roads based on sustainable best management practices targeted toward reducing environmental impact, minimizing life-cycle costs, and enabling more positive social outcomes. Rating under this system is available at four levels: certified, silver, gold and evergreen. The system has 11 requirements as well as a number of additional voluntary credits that can be pursued to achieve a rating. While the system has not yet been formally adopted by any organizations in the United States, 20 case studies are under development to pilot test and refine the system.

Institute for Sustainable Infrastructure's envision™ Rating System

Launched in February 2011, the envision™ Rating System is managed by the Institute for Sustainable Infrastructure in the United States as a tool to guide engineers, owners, constructors, regulators and policymakers toward the development of more sustainable infrastructure systems. It is based on a set of objective-based goals associated with reliability, resilience, efficiency, organizational adaptability and overall project performance. The rating system was collaboratively developed by the American Society of Civil Engineers (ASCE), the American Council of Engineering Companies (ACEC) and the American Public Works Association (APWA). The rating system consists of 10 primary criteria and 74 sub-criteria in a structured, four-phase process to guide users through the planning and project delivery process in increasing levels of detail. The rating system includes a strong focus on social sustainability factors and community interaction to facilitate broad acceptance and support of its recommendations. The system can be applied to infrastructure projects including roads and bridges, transit systems, airports, seaports, water and wastewater systems, energy generation and transmission systems, and other physical facilities at the local or regional scale.

Sustainable Sites Initiative (SITES)

SITES was collaboratively developed by the American Society of Landscape Architects (ASLA), the Lady Bird Johnson Wildflower Center, and the United States Botanical Garden. It is a voluntary national guideline and performance benchmark system. A rating system based on the guidelines and performance benchmarks offers 15 prerequisites and 51 credits and can be applied to sites both with and without buildings which will be protected, developed or redeveloped for public or private purposes. It has five major focus areas: hydrology, soils, vegetation, materials, and human health and well-being. The rating system has received considerable attention from the USGBC, which intends to fold some of the criteria into its own rating systems in the future.

Local, regional and national sustainability metrics

Other rating systems and schemes exist, and new tools and approaches are continuously being developed to support measurement and decision making for sustainability. Organizations such as the International Council for Local Environmental Initiatives (ICLEI) have evolved to work hand in hand with local governments to establish local and regional action plans to achieve national and international goals set in Agenda 21, the Rio Conventions, the Millennium Development Goals and others. At the heart of these efforts lies the task of choosing appropriate metrics to evaluate the issues most critical to each context of application, and such context specificity is a goal to which more general rating systems for facilities and products aspire.

At the international scale, the Environmental Sustainability Index (ESI) is becoming a broadly accepted means of benchmarking and comparing the environmental performance of whole countries. Such metrics are relevant to the built environment not only because of the role the built environment plays in environmental sustainability, but also because they may provide clues as to areas of future opportunity for new types of development. The ESI, developed in partnership between Yale and Columbia Universities and recognized by the World Economic Forum, rates 146 countries on 21 elements of environmental sustainability covering natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons, and a society's capacity to improve its environmental performance over time. ESI rankings were released most recently in 2005.

High rankings under the ESI suggest better environmental stewardship, and coupled with other metrics of economic competitiveness, suggest that economic development need not always come at a high environmental price. Top-ranked countries in 2005 were Finland,

Key building blocks environmental sustainability index

Environmental systems
A country is more likely to be environmentally sustainable to the extent that its vital environmental systems are maintained at healthy levels, and to the extent to which levels are improving rather than deteriorating.

Reducing environmental stresses
A country is more likely to be environmentally sustainable if the levels of anthropogenic stress are low enough to engender no demonstrable harm to its environmental systems.

Reducing human vulnerability
A country is more likely to be environmentally sustainable to the extent that people and social systems are not vulnerable to environmental disturbances that affect basic human wellbeing; becoming less vulnerable is a sign that a society is on a track to greater sustainability.

Social and institutional capacity
A country is more likely to be environmentally sustainable to the extent that it has in place institutions and underlying social patterns of skills, attitudes and networks that foster effective responses to environmental challenges.

Global stewardship
A country is more likely to be environmentally sustainable if it cooperates with other countries to manage common environmental problems, and if it reduces negative trans-boundary environmental impacts on other countries to levels that cause no serious harm.

Source: www.yale.edu/esi

Norway, Uruguay, Sweden and Iceland, all of which have substantial natural resource endowments, low population density and a history of success in managing development challenges. Lowest ranked countries included North Korea, Iraq, Taiwan, Turkmenistan and Uzbekistan. These countries face numerous issues, both natural and human-induced, and have not managed their policy choices well.

Corporate rating systems, reporting and strategic actions

In addition to rating projects and building components, a growing area of interest lies in rating enterprises or corporations as a means of increasing market visibility and customer recognition or approval. Such evaluation can be done from two complementary perspectives: (1) evaluating companies in terms of a broad set of metrics that reflect not just conventional economic performance but also social and environmental performance metrics; or (2) rating companies predetermined to be sustainability leaders in terms of conventional performance metrics (such as financial performance). The following subsections describe these two approaches in greater detail.

Top 10 firms: Dow Jones Sustainability World Index (2010)

1. Nestle S.A.
2. International Business Machines Corp.
3. HSBC Holdings PLC
4. Johnson & Johnson
5. General Electric Co.
6. BHP Billiton Ltd
7. Coca-Cola Co.
8. Vodafone Group PLC
9. Novartis AG
10. Intel Corp.

Measuring financial performance of sustainability-driven companies

The market is a powerful driver for change in the corporate world. Environmentally and socially responsible investing is an approach taken by some market investors to 'steer' the market in general toward more sustainable practices. It is also undertaken by investors who believe that companies pursuing sustainability goals will ultimately be more successful in the marketplace than their conventional counterparts. To effectively guide these types of responsible investments, the market needs a way to monitor the individual and collective financial performance of environmentally and socially responsible companies being traded on the open market.

The Dow Jones Sustainability Index (DJSI) is one metric that tracks the financial performance of leading sustainability-driven companies worldwide (DJSI 2010). Launched in 1999, this index is a means for asset managers to obtain reliable and objective benchmarks to manage sustainability portfolios. The SAM Research Group's Corporate Sustainability Assessment questionnaire (SAM 2010) is used as a basis to determine which companies are included in the DJSI. Currently more than 70 DJSI licences are held by asset managers in 19 countries to manage a variety of financial products including active and passive funds, certificates and segregated accounts. In total, these licensees presently manage over US$8 billion based on the DJSI.

The family of indices under the DJSI includes multiple groupings of firms based on top-performing firms by geographic region, as well as several international groupings. Each year, invitations are sent to the 2500 largest global companies in terms of free-float market capitalization to participate in corporate sustainability assessment as a basis for possible listing under the DJSI. The corporate sustainability assessment itself consists of approximately 100 questions on economic, environmental and social aspects, with a focus on the long-term development of corporate value. General topics cover such issues as corporate governance, risk and crisis management, human capital development, and the quality of environmental and social reporting. In addition, sector-specific risks and opportunities arising from various sustainability trends are analysed (SAM 2010). Following the analysis of the corporate data, SAM selects the leading companies from each sector. For example, the top 10 per cent in each industry will be included in the Dow Jones Sustainability World Indexes (DJSI World). The top 15 per cent of companies per industry sector are also featured in the annual *SAM Sustainability Yearbook*, the reference work on the world's most sustainable companies (see www.sam-group.com/htmle/yearbook/). In 2010, the *Sustainability Yearbook* provided an overview of 58 sectors and 367 individual companies. The leading companies from each sector are recognized as 'SAM sector leaders'. In addition, companies included in the *Yearbook* can qualify to the categories of 'SAM gold class', 'SAM silver class' and 'SAM bronze class'. Companies that have made particular progress in their sector are recognized as 'SAM sector movers' (SAM 2010).

Measuring the sustainability performance of organizations

Several distinct perspectives exist for measuring sustainability performance at the organizational or corporate level. At one end of the spectrum, corporate sustainability reporting is a means for an organization to self-report its goals, accomplishments and future plans and strategies pertaining to sustainability. Corporate sustainability reports are becoming more commonplace in the market as consumers increasingly base their purchasing decisions on factors beyond cost. These reports, often updated annually, contain key information about an organization's sustainability initiatives, and typically include similar types of information from firm to firm (see box below).

Elements of a corporate sustainability report

Executive summary

- Sustainability vision
- Benefits and business case
- Notable achievements
- Barriers and responses

Initiatives

- Current year initiatives
- Rationale for selection
- Progress and achievements
- Impact of initiatives on corporate goals

Accounting

- Inventory of current social and environmental impacts
- Tools and metrics used to measure and reduce impacts
- Goals for impact reduction
- Progress during reporting period

Future plans

- Future plans and initiatives
- Measuring success

Conclusion

- Significant sustainability achievements and benefits
- Reiterate sustainability vision
- Company profile
- External partners

Source: www.TEDgreenroom.com

The Global Reporting Initiative's (GRI's) triple bottom line offers a standardized reporting framework for disclosing corporate sustainability performance in terms of social, economic and environmental performance. The GRI standards (GRI 2010) are used for public reporting of performance as well as voluntary performance improvement within corporations. Links to the corporate sustainability reports of hundreds of companies can be found on GRI's website. The GRI's Amsterdam Declaration underscores the importance of having integrated sustainability reporting based on standardized frameworks for performance accounting to allow comparison across industry. According to the Declaration (GRI 2010a), an integrated report presents information about an organization's financial performance with information about its environmental, social and governance (ESG) performance in an integrated way. In order for integrated reporting to be a viable and useful activity for companies, it must be underpinned by standardized financial and ESG reporting frameworks. Financial reporting standards, such as International Financial Reporting Standards (IFRS) and US Generally Accepted Accounting Principles (US GAAP) and ESG reporting frameworks, principally the GRI Guidelines, act as structural supports for integrated reporting frameworks for corporate sustainability.

For some metrics of critical significance in the market, special third-party standards are being developed to measure performance at the corporate scale. For instance, carbon footprint analysis and reporting is an approach being adopted by companies to benchmark their performance. One example of such a standard is the new Greenhouse Gas Protocol Accounting Standards developed by the World Resources Institute in partnership with the World Business Council for Sustainable Development (WBCSD 2010). The Greenhouse Gas Protocol Standard for products studies all potential contributions to the emissions of a product, including suppliers, transportation, production and disposal. In contrast, the Corporate Value Chain Standard allows corporations to measure and manage their greenhouse gas emissions across their entire supply chain (WBCSD 2010). A variety of third-party organizations such as Climate Neutral Network have emerged to provide verification of carbon-related claims at the corporate, not just product, level. As market-based measures for carbon management (cap and trade) become more prominent in the marketplace, these types of evaluation metrics and standards will become more commonplace in the construction industry.

Other organizations such as the Leonardo Academy, a standards developer accredited by the American National Standards Institute (ANSI), are working to develop new standards to evaluate the sustainability of organizations (Leonardo Academy 2010). Investors, companies and procurement organizations are driving the need for such standards and consumers as they seek to evaluate and compare sustainability attributes of companies and organizations beyond what can be evaluated using financially driven indices such as the SAM assessment. The forthcoming ANSI Standard for Sustainable Organizations will define what a sustainable company or organization is and how its level of sustainability achievements can be measured and documented. The standard is expected to make it easier to evaluate and compare the sustainability of organizations in terms of environmental stewardship, social equity and economic prosperity.

Sustainability evaluation and assessment in 2020

Specific challenges abound with regard to measuring the sustainability of the built environment and the products, services and organizations associated with it. At the foundation of the problem is the lack of a widely accepted operational definition of the construct of sustainability. As a context-dependent attribute, the sustainability of a system or artefact will be affected by different factors in different situations. It will also necessarily involve different factors and considerations for different types of products or systems. Thus, there is no 'one size fits all' approach to evaluating sustainability. This is one of the major challenges that will be addressed in the next ten years with regard to sustainability evaluation and assessment. Other challenges include continuing accountability for ratings, and information accessibility and transparency overall, as discussed in the following subsections.

Project specificity of rating systems

One of the first challenges of rating systems that will be addressed in the next decade is the development of rating systems that can capture specific nuances of very different types of projects while still providing a basis for comparison across those projects. Trends to date in rating system development, especially at the building scale, have shown a tendency to start with a rating system that is applicable to a common situation or case (such as Green Star Offices or LEED for New Construction), then expand and customize that original rating system to be able to address details found in other project types (such as LEED for Schools and LEED for Healthcare). At one end of the spectrum is the notion of having completely customized rating systems for each different type of product or facility. At the other end of the spectrum is the approach of having a single universal rating system that can apply equally to all situations. While frameworks exist that could serve the purpose of a universal measurement tool, they often require information about performance that requires technical expertise to model accurately.

One significant trend that may lead to greater adoption of more universal rating system schemes is the development of new types of user interfaces to those systems. These new interfaces will make complex and powerful performance models accessible to a wider range of users by using case-based reasoning, visual matching, inference, data mining and heuristic methods to make accurate assumptions about a user's specific situation, rather than requiring the user to obtain and manipulate detailed information. By 2020, the ability to access and manipulate data at multiple levels and quickly develop sophisticated performance models will no doubt far exceed today's standards and lead to rating systems beyond our current ability to envision. Overall, there will be an increased reliance on scientific evidence to support decisions for built environment sustainability.

Context specificity of rating systems

As with project type, the sustainability of a given solution will vary dramatically based on the context of a given project or solution. For example, incinerating toilets may be tremendously unsustainable where energy is scarce or difficult to produce, but an excellent solution where energy is abundant and water is scarce. Context is a function not only of physical location and constraints, but also socio-economic, political and other factors that can be difficult to define. How can a measurement system incorporate context of use in weighting the relative importance of attributes or variables, without falling prey to the biases and self-interests of the raters?

The newest version of the US LEED rating system, released in 2009, attempts to accomplish this goal via a system of region-specific credit requirements applied to buildings based on location. Table 4.2 shows the evolution of approach to this issue over the multiple versions of the LEED rating system. The LEED 2009 rating system assigns 'bonus points' to existing credits that have been determined by local USGBC chapters to be of particular importance in each location. For example, projects in many parts of the southwestern United States receive regional priority credits for achieving higher levels of water efficiency, since water is an increasingly scarce resource in this region. Which credits should receive extra emphasis in a particular area is determined by the collective input of volunteers serving on regional committees.

By 2020, better integration of existing data and real-time monitoring of local conditions will allow regional credits to be determined using objective algorithms rather than subjective weightings developed by

Table 4.2 Context specificity and the LEED rating system*

Version	Launch	Approach to Context Specificity
LEED v1	1998	Somewhat prescriptive; limited building types – application guides proposed as mechanism for customization
LEED v 2.0, 2.1, and 2.2	2001ff	More performance-based; most credits converted; additional application guides developed; additional core rating systems developed for homes, neighbourhood development, existing buildings, core & shell, and commercial interiors
LEED 2009	2009	Regional priority credits introduced; credit point values changed to reflect new weightings for relative importance of environmental issues (USGBC 2008)

** See www.usgbc.org for the history and details of previous, current, and future versions of LEED rating systems* local interests. Weightings may be able to be integrated as part of rating systems dynamically over time, as conditions change. Coupled with trends toward dynamic, environmentally responsive buildings that monitor and self-adjust to changing conditions, measurement systems will be able to monitor the ongoing relationship between built facilities and their environmental contexts, and reward those facilities that best align with their contextual constraints.

Ongoing accountability based on information accessibility and transparency

The ability to have ratings downgraded or revoked is also a growing trend across rating systems at all scales. For instance, British Petroleum was formally removed in 2010 from the Dow Jones Sustainability Index following the massive oil spill in the Gulf of Mexico for which it was responsible early in that year.

There is also a strong movement in the United States. to revoke LEED ratings for facilities that fail to perform to specified design goals. The USGBC and its founders are presently facing a class action lawsuit claiming that they are fraudulently misleading consumers and fraudulently misrepresenting energy performance of buildings certified under the LEED rating systems, and that LEED is harming the environment by leading consumers away from using proven energy-saving strategies (EBN 2010). Specifically, the suit alleges that USGBC's claim that it verifies efficient design and construction is 'false and intended to mislead the consumer and monopolize the market for energy-efficient building design' (EBN 2010).

> [T]ransparency management has become the cornerstone to which all organizations must build in order to guarantee their continued existence.
>
> Global Reporting Initiative, *Future Trends in Sustainability Reporting*

These examples show a greater awareness and involvement of the market in sustainability-related issues, which is especially acute in response to the first ten years of the twenty-first century and the lack of trust it promulgated (GRI 2010b). In the future, better approaches to data tracking, along with improved systems for transparency and accountability, will ensure that public pressure can be brought to bear in a variety of ways against poor sustainability performers.

> [The new social technologies, media and networks promise – or threaten, depending on your viewpoint – to transform the reporting landscape. They will simultaneously accelerate and deepen market conversations between business and its current stakeholders, and, potentially, bring totally new people and interests into the conversation – with dramatically more powerful information and intelligence resources at their disposal.
>
> Global Reporting Initiative, *The Transparent Economy*

By the year 2020, advances in sensing and control technologies will bring performance data to the forefront of every decision and make it easy to analyse, track and interpret. Building information modelling will no longer be the domain of well-educated domain experts but will instead be ubiquitous, integrating seamlessly with portable devices such as smart phones to provide moment-to-moment performance data to users of built facilities. Individual components and products will be traceable through their entire life-cycles, with information being immediately available via embedded chips or devices. In addition to more up-to-date, rich data from a variety of new sources, the use of Web 2.0 and 3.0 technologies for social networks will also change who accesses that information and what they do with it (GRI 2010c). Ultimately, real time information will become a basis for adapting human behaviours to improve facility sustainability, even as facilities themselves gain the ability to self-adapt to those behaviours.

Case Study: London 2012 Olympic and Paralympic Games Venues

As part of its selection to host the 2012 Olympic Games, the city of London committed to the International Organizing Committee of the Olympics that it would conduct the first sustainable Olympic and Paralympic Games to be held. London promised to be the first summer host city to embed sustainability in its planning from the very beginning and to set the standard for all subsequent Games. The guiding principles for the games have been to:

- use venues already existing in the United Kingdom wherever possible
- only make permanent structures that will have a long-term use after the Games
- build temporary structures for everything else.

Ten principles of sustainability

- Zero carbon – making buildings more energy-efficient and delivering all energy with renewable technologies.
- Zero waste – reducing waste, reusing where possible, and ultimately sending zero waste to landfill.
- Sustainable transport – encouraging low carbon modes of transport to reduce emissions, reducing the need to travel.
- Sustainable materials – using sustainable and healthy products, such as those with low embodied energy, sourced locally, made from renewable or waste resources.
- Local and sustainable food – choosing low-impact, local, seasonal, and organic diets and reducing food waste.
- Sustainable water – using water more efficiently in buildings and in the products we buy; tackling local flooding and water course pollution.
- Land and wildlife – protecting and restoring existing biodiversity and natural habitats through appropriate land use and integration into the built environment.
- Culture and heritage – reviving local identity and wisdom; supporting and participating in the arts.
- Equity and local economy – creating bioregional economies that support fair employment, inclusive communities, and international fair trade.
- Health and happiness – encouraging active, sociable, meaningful lives to promote good health and well-being.

Source: WWF/BioRegional Development.

The hope is to use the Games to help to regenerate East London and improve quality of life in that part of the city while encouraging more sustainable living across the whole of the United Kingdom. The vision that has since guided the development of all venues for the game is to use the power of the Games to inspire change. The hope of London 2012 is to inspire change in everyone from athletes to spectators to supporters and organizers of the games, not only with respect to ecological sustainability, but with respect to other critical sustainability factors as well, such as accessibility and attitudes toward disability.

The Games are being developed under the approach of 'One Planet Living®', developed by the World Wildlife Federation (WWF) and BioRegional Development Group (see box). The British Standard for Sustainable Events (BS 8901) is also being used as a tool to ensure that the games are hosted sustainably, and London 2012 has even developed its own guidelines for corporate and public events (2010) and sustainable procurement and sourcing (2011). With these principles in mind, the Sustainability Plan for the games focuses on five key themes (2009):

- Climate change – minimizing greenhouse gas emissions and ensuring legacy facilities are able to cope with the impacts of climate change.
- Waste – minimizing waste at every stage of the project, ensuring no waste is sent to landfill during Games-time, and encouraging the development of new waste processing infrastructure in East London.
- Biodiversity – minimizing the impact of the Games on wildlife and their habitats in and around Games venues, leaving a legacy of enhanced habitats where we can.
- Inclusion – promoting access for all and celebrating the diversity of London and the United Kingdom, creating new employment, training and business opportunities.
- Healthy living – inspiring people across the country to take up sport and develop active, healthy, and sustainable lifestyles.

The sustainability plan focuses on three core phases of delivery – building the stage for the Games, staging the Games, and building a lasting and sustainable legacy after the Games. As a result of these goals and objectives, the design and construction of venues for the Games are incorporating a variety of strategies and practices to move toward greater sustainability:

- Environmental monitoring – regular monitoring and surveys are being undertaken to manage the effects of construction on the local environment and the people who live and work around the Olympic Park. Issues include air quality, noise, ecology, water quality, flooding and transport impacts.
- Certification by a third party to ISO14001 standards for the Olympic Development Authority's Environment and Sustainability Management System.
- Third-party rating and certification of development: all Olympic Park venues are on track to achieve a BREEAM rating of 'Excellent', the Athlete's Village is on track to achieve the Code for Sustainable Homes Level 4, and all registered development sites are targeting CEEQUAL 'Very Good' rating.
- Aggressive measures for carbon reduction, including a 31 per cent reduction in carbon emissions for the recently completed Velodrome over 2006 building regulations, and use of combined heat/power and biomass systems for energy needs. The Velodrome uses compact design, natural lighting, natural ventilation for passive cooling, and other strategies to achieve these goals. It also incorporates a rainwater harvesting and supply system and water-efficient fixtures, and the design team was able to optimize both the foundation system and cable net system to save 1,000 tonnes of steel in the construction of the facility.
- A new water recycling treatment works to be commissioned in September 2011 to treat and repurpose reclaimed wastewater or black water treated to a level that will exceed bathing water standards. Water from this plant will be used for irrigation and toilet flushing.
- Energy retrofits in surrounding communities to meet carbon-reduction goals, after initial efforts to achieve reduction through renewable energy proved to be technologically infeasible.
- Delivery of at least 50 per cent by weight of construction materials to the Olympic Park using sustainable transport such as barges. As of 2011, the current level is 67 per cent.
- A targeted 100 per cent use of public transport during the Games. Significant improvements are being made to local Underground facilities to support this goal, including a new lighting system dubbed 'spectator-powered lighting' that uses electricity generated by human footfalls on surfaces in the station.

- Use of recycled aggregate in precast concrete units used in the Olympic Stadium and Aquatics Centre seating terraces, temporary bridge decks and Handball Arena.
- Remediation of contaminated soil in some venues such as the Aquatics Centre site.
- Dismantling of old industrial buildings on site and recovery of 98.5 per cent of materials for reuse or recycling.
- Design of all temporary venues to use bolted steel tress systems that can be reused when the Games are over.
- Use of non-phthalate PVC wraps in building construction that can be recycled or reused after the Games.
- Creation of over 45 hectares of new wildlife habitat as part of the 250 hectare site, with the potential to become sites of importance for nature conservation (SINC).
- Collection of seed stock from the site prior to redevelopment for subsequent use in creating habitat, and use of local plantings and native species.
- Eradication of invasive species such as Japanese knotweed and giant hogweed on site.
- Addition of 675 new bird and bat boxes to improve habitat for wildlife on site.
- Promotion of diversity and equity in workforce hiring and contracting, including programmes such as the Women into Construction project, training programmes through the National Skills Academy for Construction, and hiring unemployed people from the local borough as part of the project.
- Targeting zero fatalities during all Games-related construction. At present, the accident rate is well below the industry average, and there have been 17 periods of a million worker-hours without reportable incidents over the total 55 million worker-hours worked so far.
- Installation of 3,000 smart meters in the Athletes' Village to inform athletes of their impacts on carbon emissions and help provide an incentive for behavioural change.

Sources

London 2012. (2009). *London 2012 Sustainability Plan: Towards a one planet 2012*. <www.london2012.com/documents/locog-publications/london-2012-sustainability-plan.pdf> (accessed 12 August 2011).

London 2012. (2010). *Sustainability Guidelines – Corporate and Public Events*, 2nd edn. <www.london2012.com/documents/locog-publications/london-2012-sustainability-events-guidelines.pdf> (accessed 12 August 2011).

London 2012. (2011). *London 2012 Sustainability Report: A blueprint for change*. <www.london2012.com/documents/sustainability/london-2012-sustainability-report-a-blueprint-for-change.pdf> (accessed 12 August 2011).

London 2012. (2011). 'London 2012: Sustainability.' <www.london2012.com/sustainability> (accessed date?).

London Organising Committee of the Olympic Games and Paralympic Games. (2011). *LOCOG Sustainable Sourcing Guide*, 3rd edn. www.london2012.com/documents/locog-publications/sustainable-sourcing-code.pdf (accessed 12 August 2011).

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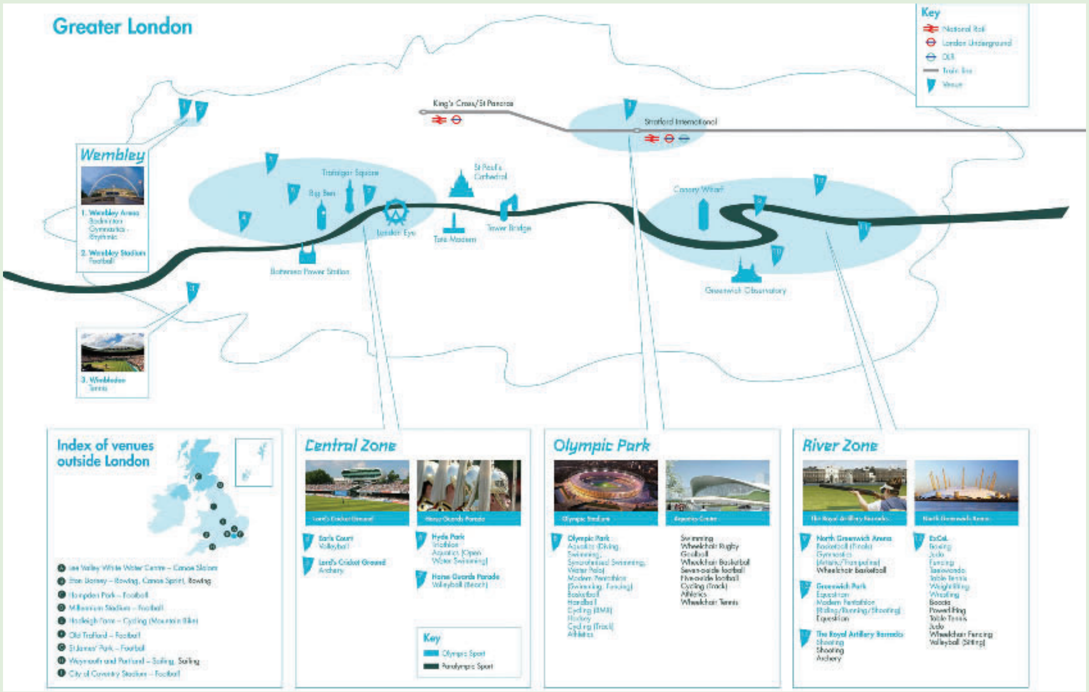


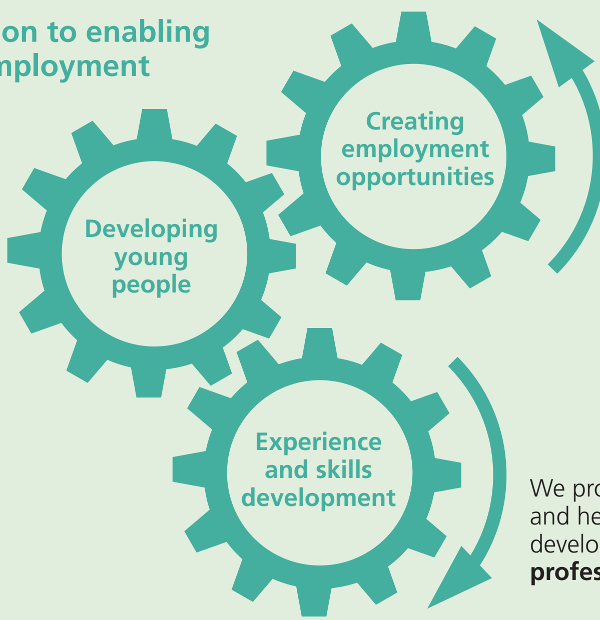
The London 2012 Olympic Site

The Velodrome cycling facility incorporated significant material savings in its construction and is the most energy-efficient building on site. Rainwater is harvested from its iconic roof surface.

Aerial view of the Olympic Park looking East showing the newly developed Parklands alongside the River Lee.

Our contribution to enabling sustainable employment

We provide individuals with **experience** that they can use to enhance their personal and professional lives



We strive to deliver educational programmes, with a particular **focus on young people**

We provide opportunities and help individuals to develop and enhance their **professional skills**

Social sustainability is a strong component of the London 2012 Sustainability Plan. Significant contributions to employment and local business practices have been made as a result of these efforts.

Note

1. The case study of the Duke Energy Center was adapted by the authors based on the content in the Duke Energy Center at Wells Fargo Cultural Campus Case Study. The images in the case study were received from Wells Fargo & Co. and used with permission under a licensing agreement between the authors and the company in this book.

Discussion questions and exercises

4.1 Which green rating systems are presently in use by your organization? For what purpose(s) are they used – baselining, benchmarking, prioritization or documentation? Classify each rating system in terms of its scale and whether it is a threshold or profile tool.

4.2 What green product labelling systems are applicable in your country or region? Visit the online Ecolabel Index (http://www.ecolabelindex.com) and review the labels that apply to your country. How many of these labels appear on products with which you are familiar?

4.3 Visit a local building material supply store. Inventory product labels to identify any ecolabels shown on product packaging. Which of these labels is based on a recognized third-party standard? Do any product labels contain obvious greenwash?

4.4 Perform an Internet search to identify examples of each of the major types of greenwash discussed in the chapter. Which types are most common? How could you modify the claims made to ensure that they are correct? What additional information would be needed to support each claim?

4.5 Conduct an ecological footprint analysis of yourself (search for one of the calculators freely available online). How many Earths would it take if everyone on the planet lived like you? Compare your results with your peers. What single action could you take to make the biggest change in your ecological footprint?

4.6 Find an example of a type of building product where the options have very different service lives. For example, lamps or light bulbs have vastly different service lives depending on the type of technology employed. How many times must the shortest-lived option be replaced to equal the service life of the longest-lived option? How do the costs compare?

4.7 Choose a building material from a specific manufacturer and obtain the information contained in the Checklist of Questions for Product Manufacturers. How much of this information is available on the manufacturer's website? Call the manufacturer and obtain the remaining information. How difficult is the information to obtain?

4.8 Which building- or infrastructure-scale rating systems are in use in your country or region? Which buildings have been certified or rated in your area? Locate the online database of projects for the relevant rating system or contact the rating system administrator and identify the closest projects to your location. Visit the project if possible and identify or document the major green features of the project.

4.9 What are the steps necessary to rate or certify a building using your locally applicable rating system(s)? What costs are involved? Do local, regional or national policies require facilities to be rated using this system? If more than one rating system is used in your country or region, which one is most prevalent? Why?

4.10 What rating has your country achieved according to the Environmental Sustainability Index? Locate the most recent rankings online. Which countries do better than yours? Which do worse? Are you surprised by any of the rankings?

4.11 Does your organization produce a corporate or organizational sustainability report? If yes, locate the most recent report and review the initiatives documented there. Are there any initiatives of which you are unaware? If no report is presently produced, what initiatives within the firm would you recommend including in a future report?

References

American Institute of Architects (AIA). (1990). *Environmental Resource Guide*. Wiley, New York.

Anink, D., Boonstra, C. and Mak, J. (1996). *Handbook of Sustainable Building: An environmental preference method for selection of materials for use in construction and refurbishment*. James & James, London.

Athena Institute. (2010). 'Athena Impact Estimator for Buildings' <www.athenasmi.org> (accessed 21 December 2010).

Austin Energy. (2010). 'Austin Energy Green Builder Program.' <www.austinenergy.com> (accessed 10 December 2010).

Australian Green Infrastructure Council (AGIC) (2010). 'AGIC Rating Scheme.' <www.agic.net.au/AGICscheme.htm> (accessed 21 December 2010).

BuildingGreen. (2010). 'GreenSpec-listed Green Building Products.' <www.buildinggreen.com> (accessed 21 December 2010).

Built Green. (2010). 'Colorado Built Green Program.' <www.builtgreen.org> (accessed 21 December 2010).

Dow Jones Sustainability Index (DJSI) (2010). 'Dow Jones Sustainability Index.' <www.sustainability-index.com> (accessed 21 December 2010).

Earthcraft. (2010). 'Earthcraft House Rating System.' < www.earthcrafthouse.com> (accessed 21 December 2010).

Environmental Building News (EBN). (2010). 'USGBC, LEED targeted by class-action suit.' <www.building-green.com/auth/article.cfm/2010/10/14/USGBC-LEED-Targeted-by-Class-Action-Suit/> (accessed 12 November 2010).

Global Reporting Initiative (GRI) (2010a). 'The Amsterdam Declaration on Transparency and Reporting.' <www.globalreporting.org/CurrentPriorities/AmsterdamDeclaration/> (accessed 12 November 2010).

GRI (2010b). 'Future trends in sustainability reporting.' <www.globalreporting.org/CurrentPriorities/FutureTrends/> (accessed 12 November 2010).

GRI (2010c). 'The transparent economy.' <www.globalreporting.org/LearningAndSupport/GRIPublications/LearningPublications/Explorations/Explorations.htm> (accessed 12 November 2010).

Green Building Alliance. (2009). 'Green building product certification and labeling systems.' <www.pa-green-buildingproducts.org/pdf/GBA_Green_Building_Product_Certification_&_Labeling_Systems.pdf> (accessed 27 September 2011).

Holmes, D., Strain, L., Wilson, A. and Leibowitz, S. (1999). *GreenSpec: The environmental building news product directory and guideline specifications.* E Build, Brattleboro, VT.

Howard, N., Shiers, D. and Sinclair, M. (1998). *The Green Guide to Specification: An environmental profiling system for building materials and components* (BRE Report 351). BRE, Garston, Watford.

Lawson, B. (1996). *Building Materials, Energy and the Environment: Towards ecologically sustainable development*. Royal Australian Institute of Architects. Sydney, Australia.

Leonardo Academy. (2010). 'ANSI standard for sustainable organizations.' <www.leonardoacademy.org/programs/standards/sustainable-organizations.html> (accessed 19 December 2010).

National Institute of Standards and Technology (NIST) (2010). 'Building for economic and environmental sustainability.' <www.bfrl.nist.gov/oae/software/bees> (accessed 21 December 2010).

R.S. Means, Inc. (2010). *Green Building: Project planning and cost estimating*, 3rd edn. Reed Construction Data, Kingston, MA.

SAM Sustainability Investing. (2010). 'Corporate sustainability assessment questionnaire', SAM Sustainability Investing. <www.sam-group.com> (accessed 12 November 2010).

SAM Sustainability Investing. (2010). 'SAM kicks off this year's corporate sustainability investment', SAM Sustainability Investing, 14 April. <www.sustainability-index.com/djsi_pdf/news/PressReleases/SAM_PressRelease_100414_DJSI_CSA.pdf> (accessed 12 November 2010).

SAM Sustainability Investing. (2010). *SAM Sustainability Yearbook 2010*. <www.sam-group.com/htmle/year-book/> (accessed 12 November 2010).

Spiegel, R. and Meadows, D. (2006). *Green Building Materials: A guide to product selection and specification*, 2nd edn. John Wiley, New York.

TerraChoice. (2009). *The Seven Sins of Greenwashing: Environmental claims in consumer markets*. <http://sinsof-greenwashing.org/> (accessed 12 November 2010).

US Green Building Council (USGBC). (2009). *LEED Reference Guide for Green Building Design and Construction*. Available from the Green Building Certification Institute (http://www.gbci.org).

Urban Environmental Management (UEM) (2010). 'Urban and ecological footprints.' <www.gdrc.org/uem/footprints/index.html> (accessed 21 December 2010).

Woolley, T., Kimmins, S., Harrison, P. and Harrison, R. (1997). *Green Building Handbook: A guide to building products and their impact on the environment*. E & FN Spon. London.

World Business Council for Sustainable Development (WBCSD) (2010). 'New greenhouse gas protocol accounting standards available for public comment – WRI and WBCSD unveil new product and supply chain standards.' <www.wbcsd.org/> (accessed 12 November 2010).

5

Project delivery and pre-design sustainability opportunities

The built environment life-cycle: stakeholders, processes and opportunities

In most environmental contexts found on Earth, the built environment is an essential part of the infrastructure necessary for human survival. Buildings provide shelter from adverse climate conditions such as rain and snow, ambient temperature ranges outside human comfort levels and threatening weather conditions. They also afford privacy and security from a variety of dangers, including predatory and pest animals and malevolent humans (Allen 1980). In addition to these roles that contribute to basic human survival, built facilities serve other purposes which help to expand the quality of human life beyond mere biotic survival, including their role as infrastructure for activities such as collection, treatment and/or storage of solid, liquid and gaseous waste, provision and distribution of pure water, processing and distribution of agricultural products into food, and manufacturing and distribution of other products used by humans.

The life-cycle of built facilities typically ranges from 30 to over 100 years (Yeang 1995), and typically consists of the five phases shown in Figure 5.1. External stakeholders are those entities that are based external to the boundary of the facility system, such as contractors, designers, government agencies and others. For these stakeholders, the built facility under consideration represents one of many systems in which they may be involved at any given time. For internal stakeholders, on the other hand, the system under consideration represents a major interest in which they are vested, and may be the only system affecting them at any point in time. These stakeholders, such as owners, tenants, users and clients, have a direct stake and involvement in the facility and the functions it serves: it is their needs the facility is designed and constructed to meet.

Direct stakeholders, either internal or external to the system, are those entities whose actions directly bear upon the facility system, who are directly impacted by the behaviour of the facility system, or whose needs are met directly by virtue of their interaction with the facility. Direct stakeholders include users, constructors, designers, owners and surrounding communities. Indirect stakeholders, on the other hand, have no direct impacts on the facility and may have no direct interaction with the facility at all, but nonetheless are indirectly impacted by the existence of the facility system. Indirect stakeholders include the entities that manufacture materials and supplies used to construct the facility, handle waste materials emitted by the facility, invest money in the potential of the facility, and create codes and regulations which must be observed by the facility system. In some phases of the facility life-cycle, stakeholders that were indirectly represented by other stakeholders in earlier phases of the life-cycle become direct stakeholders as their participation in the interactions of the system becomes integral. For example, future users and tenants of the facility system often do not participate directly in the development process, but are represented by the owner and/or developer of the facility during early project phases. After the facility reaches completion and begins operation, these parties become direct stakeholders due to their direct participation in the system operation. The following subsections describe the activities during each of these phases of the life-cycle.

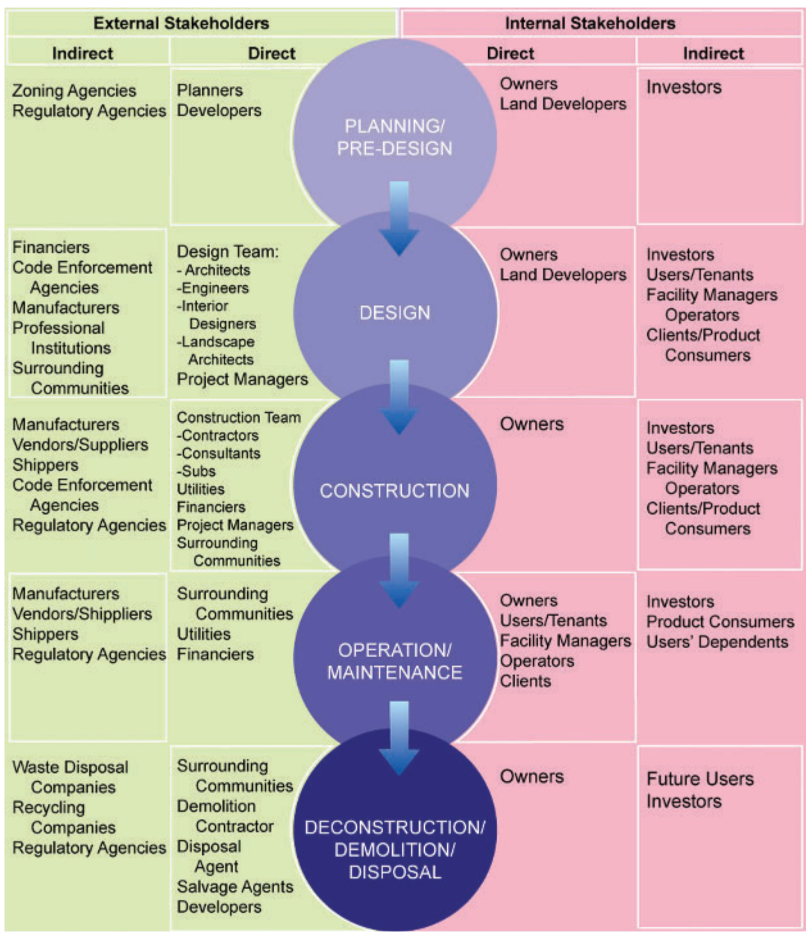


Figure 5.1 Facility life-cycle phases and their stakeholders

Source: Pearce (1999).

Case Study: The People's Place Library, Antigonish, Nova Scotia, Canada

Opened in June 2011, The People's Place is a green and socially sustainable regional library serving the Pictou-Antigonish Region of Nova Scotia, Canada. This new facility, designed using a community-initiated placemaking process, functions as a civic centre that is an integral part of the community, going beyond the traditional functions of a conventional town library. The place-making process – developed by Project for Public Spaces (PPS), a non-profit planning, design, and educational organization headquartered in New York City – was used to involve members of the community in the development and design of the facility and creation of a vision for what the facility should be.

The resulting facility hosts not only a public library but also other key community functions such as a Community Access Program site, an adult learning association, and Health Connections, a local health resource centre that provides a variety of health education and wellness programmes to the local community. Multi-purpose spaces, meeting rooms, and even a community kitchen are available for use by non-profit organizations at no cost. The library also provides a venue for public art, including sculptures, woodworking, visual art and textiles. An outdoor patio provides seating and shade for local residents to relax and interact, and a neighbourhood café is also planned to enhance the patio space. Green features of the building include:

- Adaptive reuse of an existing facility – a former grocery store – in the downtown area instead of constructing a new building on a greenfield site.
- Remediation of environmental contamination found on site, including underground storage tank and fire debris from an adjacent building.
- A closed-loop ground source heat pump system using twelve 500 ft vertical wells located under the parking area.
- Heat recovery ventilation, thermal mass, and in-floor radiant heating to reduce heating energy required.
- Upgraded roof insulation along with a high albedo roof coating to reduce cooling loads.
- Envelope with high-performance barrier membrane to reduce infiltration.
- Evacuated tube solar hot water heating and photovoltaic power generation.
- High-efficiency LED lighting and low-energy lighting, much of which is controlled by occupancy sensors.
- Natural daylighting via skylights on the building's roof.
- High-performance glazing, including a special translucent glazing which is manufactured locally and incorporates a fibrous material that gives it similar insulating value to solid walls while blocking unwanted heat gain and glare during the day.
- Energy Star rated appliances and equipment.
- Rainwater harvesting system used for toilet flushing and watering lawns and plantings.
- 'Stormceptor' catchment drain system to remove oils and sediment from stormwater before it enters local waterways.
- Special 'hydration station' located in the facility to encourage the use of refillable bottles.
- Main skylight operates to provide natural ventilation.
- Landscaping using local, drought-tolerant species to reduce irrigation requirements.
- Use of recycled content or local materials to the extent practicable.

In addition to being a green building that reflected the local community's needs and desires, the library also emphasizes its role as a provider of green knowledge in a green way. Offering free library cards to community members allows the library to offer its books to many different users, thus distributing these resources over many uses. It also offers a special collection called the 'Green Room' that features a variety of materials on sustainable living and green construction. The Library has also developed a Green Guide to illustrate green features of the building and an Artisan Walking Guide to showcase the artwork incorporated in the building.

Sources

MacIver, M. (2011). 'The People's Place: How Placemaking can build today's best libraries.' <www.pps.org/blog/the-peoples-place-how-placemaking-can-build-todays-best-libraries/> (accessed 10 October 2011).

People's Place (2011). 'The People's Place project.' <www.peoplesplace.ca/> (accessed 10 October 2011).

Pictou-Antigonish Regional Library (2011). 'People's Place Green Guide.' <www.parl.ns.ca> (accessed 10 October 2011).

Green technologies employed in the Antigonish library include photovoltaic and solar hot water heating arrays on the roof, Solera energy-efficient glazing which controls heat gain/loss and glare, indigenous planting, a trellis for shading, and Nanawall folding walls that allow inside activities to flow outside to patios when weather is suitable

The main entrance to the library features a bicycle rack and dog waterer for thirsty pets, along with exterior artwork to welcome building users. Energy efficient windows and photovoltaic panels are also visible.

Exterior plantings, a sunbreak trellis, a fully-opening Nanawall, and an artist's bench provide a smooth integration from indoors to outdoors. Photovoltaic panels are visible on the roof.

Pre-design phase

The facility life-cycle starts with an idea or concept during the planning or pre-design phase (Halliday 1994, Hendrickson and Au 1989). This phase focuses on defining aesthetic, functional and physical requirements and constraints for the final building. It also involves identifying any budget, schedule, legal or regulatory constraints that should be taken into account during design (Vanegas 1987). The outcome of the pre-design phase is typically a set of requirements describing the functional expectations the owner has for the facility, also known as a 'programme of requirements' (see box).

Programme of requirements

Major elements

- Vision and large-scale development goals and objectives for the project.
- Performance criteria by which the resulting project will be evaluated.
- Description of major activities to take place within and around the facility.
- Guiding principles for design and construction.
- Project definition and scope description.
- Design question, issues and restrictions to be resolved prior to or during the design process.
- Summary of referenced standards (if any) and preliminary analysis of applicable codes.
- Design goals and architectural philosophy for the project.
- Functional spaces and square footage summary.
- Description of functional space areas in terms of capacities, activities to take place in each area, general description, relationships to other functional spaces, required equipment and services, and special considerations and other needs.
- Conceptual layout of each functional space area, if known.
- Photos, descriptions, sketches, or other information from comparable or similar facilities to show desired outcomes.
- References to site or development master plan elements that will affect design.
- Budget review and analysis.
- Proposed project schedule and constraints.
- Conceptual site and building plans, if available.

The purpose of the programme of requirements document is to consolidate and provide all information needed by the design agent to develop a design solution that meets all stakeholder requirements. It is provided to the design firm that is contracted during the design phase to complete the design for the project.

Design phase

The second major phase of the facility life-cycle is design, where the facility is transformed from an idea to a set of buildable construction documents. Design is often divided into four major phases corresponding to the evolution of level of detail in the resulting documents:

- conceptual design
- schematic design
- design development
- construction documents.

Conceptual design includes developing basic layouts for how the project will be situated on site, plus concepts for building volumes and functional areas within each planned facility. It is followed by schematic design, where scaled drawings are produced along with general specifications and relevant perspective and section drawings. Selection of major systems is also part of schematic design. In design development, the architectural design of the facility is undertaken, and engineered systems in the facility are further modelled, sized and specified. Coordination between the design of these systems is also undertaken. The final phase of design, construction documents, involves production of documents that can be used during construction to actually build the facility, including coordinated architectural and technical drawings, details and construction specifications. These are then used as the basis for project procurement that leads to the construction phase.

Construction phase

The design phase of the life-cycle is followed by construction, in which workers follow the set of construction documents to build a real building in physical space that meets all of the owner's requirements (Vanegas et al 1998). Depending on the procurement strategy employed for the project, a construction team may be selected by low bid, best value, or some other selection process. The team then works together to deliver the project and hand it off to the facility owner. The outcome of the construction phase is a completely functional building ready to be occupied and used.

Post-occupancy phase

After construction, the post-occupancy phase of the life-cycle begins, during which the building is used to meet the needs for which it was designed. This phase is typically the longest phase of the life-cycle, and is also known as the operations and maintenance (O&M) phase. Operations is the process during which the facility performs its intended functions of use, while maintenance consists of all actions performed on the facility necessary to keep it in proper condition to perform its intended function. Maintenance includes activities such as changing lamps as they burn out, cleaning the facility, and minor repairs or replacement of building components that break down (Vanegas et al 1998).

End-of-life cycle phase

When a facility no longer meets the requirements of its owners or occupants, one possible choice is to rehabilitate or reconstruct the facility to improve its performance. This process can be even more challenging than the original construction of the building! A second possible fate is to end the life-cycle of the facility. Deconstruction, demolition and disposal are three options for terminating the life-cycle of a facility, ranging from planned, careful disassembly of the facility to destructive, less careful processes and subsequent removal of materials from the site.

Opportunities for improving sustainability during the facility life-cycle

Built facilities are not independent of other systems; they could not exist without complementary technological and ecological systems to provide sources of matter and energy as inputs, and sinks, consumers, or storage for system outputs. As such, built facility systems are open systems: that is, systems that exchange matter or energy with their environment (von Bertalanffy 1968, Churchman 1979). The primary links between built facility systems and other technological and ecological systems are via the flows of matter, information, and energy across the boundaries of the system. Figure 5.2 shows examples of flows into and out of a built facility, and how they relate to its technological and ecological context.

The imports and exports of materials, energy and waste from a building during its life-cycle contribute to the effects that building has on the natural environment, and the greatest opportunity to influence those ultimate impacts is during the pre-design phase of the project, before the facility has begun to take shape as an idea or ultimate product.

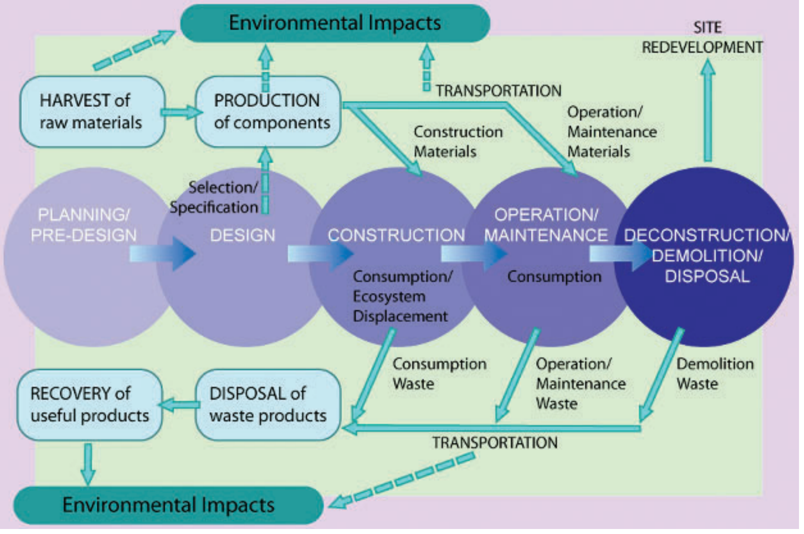


Figure 5.2 The influence of a built facility on the natural environment

Source: Pearce (1999).

Pre-design opportunities

The pre-design process offers significant opportunity to influence the whole later life of the facility, since decisions made during this phase ultimately constrain subsequent decisions later in the life-cycle. The key steps involved in this activity include definition of the requirements for the facility being constructed, development of the formal programme of requirements, and concurrent coordination of these activities with other owner requirements such as master plans to ensure that the facility being constructed is compatible with the development goals for the owner overall.

In this phase, programmers will work closely with owner representatives who will ultimately occupy and use the facility to define objectives, constraints and functional requirements for the resulting facility. These may be based upon the owner's business case for the facility, and may be enhanced and further developed by interviews, charrettes (a collaborative session in which a group of designers drafts a solution to a design problem), working meetings, document review and other sources of information involving facility stakeholders. Interim steps of the process may include visioning and vision development, analysis of activities, benchmarking against other owners with similar or competitive facilities and other steps involved in setting appropriate goals and objectives for the project to be a success.

Identifying facility options

The first opportunity to consider sustainability in the pre-design process is during the fundamental identification of facility needs. This process can be improved by embedding it in the context of sustainability needs analysis, where facility needs are forecast based on long-term sustainability of the organization and its physical resources as a whole. For large, institutional owners, systematic identification of likely long-term facility needs often takes place on a periodic basis to support long-term financial planning. However, it may not always consider the potential impacts of possible future events such as stricter legislation and regulations; resource shortages; rising energy, water and other infrastructure costs, along with potentially diminished capacity; and external development encroachment and/or synergies.

Such long-term thinking can result in capital investments that benefit the organization both financially and in terms of its ability to conduct business, and prevent costly disruption of operations or service failures. The level of risk associated with the ability to conduct sustained operations for some programmes can be extremely high, with severe penalties being imposed if operations cannot continue on a sustained basis. Investing in robust facilities that can survive likely future threats, even if they are not abrupt and catastrophic but instead gradual, is part of a long-term sustainable capital projects programme to support the organization's mission.

Case Study: Freedom Park, Naples, Florida

Collier County Stormwater Management Division

Completed in 2009, Freedom Park is 50-acre natural stormwater management facility constructed by Collier County in Naples, Florida on the Gordon River. Flood control, water quality improvement, habitat restoration, public recreational use and environmental education are all achieved in a beautiful park setting designed as a community asset. The project is the culmination of years of planning to conserve, restore and protect the adjacent Naples Bay and its tributary ecosystem from adverse effects of urbanization. The objectives of the park were to:

- Detain stormwater before it is discharged to the Gordon River and lessen chronic flooding concerns in the Gordon River Extension Basin.
- Improve river water quality by wetland treatment of stormwater and base flow.
- Restore and rehydrate the rare subtropical bald cypress floodplain swamp wetlands.
- Create an attractive facility that is well-suited for a range of passive and active recreational uses, including a public centre for environmental education and nature study.
- Conserve upland and wetland habitats for public open space in a developed urban area.
- Commemorate the events occurring during the 9/11 terrorist attack in the United States.

The total project cost was US$30.2 million, including land acquisition, design costs and facility construction. Value engineering was used to identify US $600,000 in cost savings that could be used as a buffer for contractor needs during construction, resulting in no change orders during the project.

The project combines ponds, wetlands, habitat restoration, trails, boardwalks, educational facilities, and natural landscaping within a passive park setting designed to build and sustain public use and interest. The treatment system consists of a 5-acre pond for stormwater storage, followed by constructed marshes designed to enhance stormwater polishing by submerged aquatic vegetation and native herbaceous marshes that remove harmful pollutants from the stormwater and river water prior to discharge to the on-site natural wetlands. A passive periphyton marsh treatment system included in the park is modelled after natural chemical processes from the nearby Florida Everglades and removes phosphorus from stormwater in the park.

More than 10,000 new native plants and trees were planted during construction. Shallow marshes are populated with native emergent marsh species, including pickerelweed, spikerush, sawgrass, duck-potato and fireflag. Deep marshes in the park include white water lily as well as native species of submersed aquatic vegetation. Extensive infestations of non-native vegetation were removed and the area was replanted with native subtropical cypress floodplain species during construction. Approximately 20 acres of native upland habitat was restored from use as citrus groves and is preserved as an upland preserve area designed for gopher tortoise conservation.

The sustainably designed 2500 sq ft educational centre provides a center of activity to the park and both an origin and destination to site visitors. It includes restrooms, six lookout pavilions, water fountains and walking trails. Educational and informational signage is available throughout the park. There are 3800 feet of boardwalks throughout the park and over two miles of walking trails. In its first year of use, over 18,000 people visited the park for recreation as well as educational programmes such as summer camps, natural history lectures, site walks, silent guided tours and home schooling support.

Workshops were conducted with the public during the design process to capture community input and build support. A variety of visualization techniques including Google Sketchup and traditional renderings were used during the process, resulting in better public understanding and acceptance of the proposed project.

Freedom Park serves multiple purposes, including stormwater management and treatment, education and recreation

Boardwalks and walking trails provide access to the many ecologically restored habitats throughout the park

During design, innovative visualization techniques such as Google Sketchup models and renderings were used during community meetings to obtain public input and increase understanding and acceptance of the project

Portfolio management and resource allocation

A second opportunity is associated with developing a sustainable business case for the project being considered as part of an argument for allocation of resources to this project as opposed to others in the owner's portfolio. The quality of investments in terms of their proactive contribution to the mission of the organization is likely to improve when links are made to formal investment criteria and the strategic plan of the organization.

Considerations for prioritizing project sustainability improvement opportunities

- Impact on the environment.
- Human health and welfare.
- Occupant satisfaction and productivity.
- Resource requirements and costs.
- Risks over the life-cycle.

Projects often exist within a larger organizational context where a finite set of resources must be allocated across multiple opportunities relevant to the organization's mission. During project prioritization, formal consideration of sustainability criteria can help to ensure that projects with sustainability benefits are given proper weighting in the prioritization process. Sustainability prioritization criteria should all be considered from a long-term organizational perspective. Examples of such criteria include project impact on the environment, human health and welfare, occupant satisfaction and productivity, resource requirements and associated costs and risks over the life-cycle. In light of criteria such as these that are often considered externalities to the process, the true benefits of green or sustainable projects can be examined accurately in comparison with traditional alternatives and their advantages adequately given credit in the prioritization process.

Elements of a sustainable business case that should be developed by project advocates include considerations beyond the basic economic investment criteria that are traditionally considered. For instance, what are the environmental liabilities and risks associated with the project as opposed to not doing the project? What are human health and welfare risks and benefits? How will the project be adaptable for presently unforeseen future needs on a 25–30-year time frame? How can investing in higher efficiency or more adaptable technologies now reduce long term risk for the organization? A growing body of evidence exists to support the business case for sustainable facilities, and arguments can easily be made based on precedents set for other projects of many types.

Establishing functional requirements and sustainability goals

During the development of the programme of requirements for a facility, opportunities exist to incorporate sustainability considerations and goals to guide the project. During requirements definition, a clear set of project sustainability goals should be developed that will guide the thinking of the project team throughout the project. At the requirements definition stage, sustainability goals should address major issues such as resource consumption, stakeholder involvement and outcomes, and ecological impacts that will be affected by the project, but they should not propose specific solutions or approaches. Instead, sustainability goals should reflect measurable outcomes toward which the design and construction teams will strive in developing specific project solutions. These goals should also fit within the larger sustainability goals of the institution for which the project is being built.

Formal operationalization of project sustainability objectives is also necessary as part of the final programme of requirements for the project. This process involves specific articulation of how the project sustainability goals are relevant for each component of the programme, including implications by functional space areas, any known sustainability-related constraints that must be observed, and photos, descriptions, sketches or other information from comparable or similar facilities to show desired sustainability-related outcomes. The overall project sustainability goals should also be included as part of the programme of requirements.

Planning project delivery

The project delivery strategy significantly influences the outcome of the project, because it establishes the framework of responsibilities and risk allocation for the execution of all tasks required by the project. The project delivery strategy has three elements. The first element is the delivery system to be used on the project, which defines the contractual relationships between or among project team members, and also establishes the relationships and sequences among the design, procurement and construction phases of a project. Types of project delivery systems include design–bid–build, design–build and fast-track delivery. The second element is the construction contract type, which defines the primary compensation approach within a specific contractual relationship between two parties and allocates risk among them. Types of construction contracts include firm fixed price, cost plus fixed fee and many others. Finally, the third element refers to the method by which members of the project team are selected. Typical selection methods include low bid selection, best value selection, and qualifications-based selection.

Key elements of a sustainable project procurement strategy

- Phasing strategy.
- Delivery system.
- Contract type.
- Selection mechanisms.

A sustainable project procurement strategy should address several key issues. First, based on scheduling constraints, fundraising progress and other considerations, a *phasing strategy* for a capital project should seek to promote an integrated design and construction process while maximizing flexibility of delivery. Although a project may need to be phased to deliver functionality while funds are still being raised, special attention must be given to coordinating the phases of the project in terms of functionality and design, and to coordinating stakeholders to ensure that all information is properly transferred between parties. All parties must also be involved in project alignment process to ensure that everyone understands and can deliver on the sustainability goals and objectives for the project.

Second, the *delivery system* for the project should be selected based on maximizing effective communication among parties while minimizing temptations to cut costs on design. While many advocates of design–build delivery systems argue that design–build promotes sustainable construction due to greater integration and better communication among disciplines and reduction of adversarial relationships, others point out that this delivery system can incentivize teams to cut costs on design to maximize profit. When properly executed, design–build can enhance the constructability and sustainability of the design, but careful measures should be taken to ensure that the design meets all objectives as the process proceeds.

Third, the project *contract type* can also be an entry point for sustainability based on the nature of the project itself. For instance, contractual incentives such as revenue sharing can be built into the agreement between parties to motivate sustainable outcomes such as recycling construction waste. For all contracts, the party playing the construction management role should be an educated advocate with the authority to enforce sustainability objectives and ensure coordination among other team members.

Finally, all *selection mechanisms* employed on the project, from selection of programming and design agents, to contractor and subcontractor selection, to selection of vendors and products for the project, should be aligned with sustainability goals and objectives wherever possible. While owners do not traditionally have the authority to specify specific vendors or subcontractors inside the overall construction contract, they can include performance criteria and documentation requirements as part of all contracts to ensure that these decisions made by their agents fall within larger sustainability goals. For instance, the US federal government has a broad variety of contracting requirements that must be met by all vendors, ranging from use of recycled content and bio-based products, to required demonstration of experience on green building projects. These requirements can serve as precedents for other organizations seeking to develop green procurement programmes.

With these tactics in mind, the remainder of this chapter introduces a case study of the LEED Platinum-rated Trees Atlanta Kendeda Center, located in Atlanta, Georgia, USA. In this chapter, the case is presented and the primary players are introduced. The chapter concludes with a look ahead at possibilities for pre-design in the year 2020.

Case Study: Trees Atlanta Kendeda Center

Trees Atlanta is a non-profit organization dedicated to the protection and improvement of the urban environment through the conserving and planting of trees (see Figure 5.3). After more than 20 years of operating, Trees Atlanta recently decided to construct a new office space by renovating an existing facility donated by Chip Robert & Company. Using resources generated from a three-year capital campaign, Trees Atlanta developed a new office, the Trees Atlanta Kendeda Center (here called the Trees Atlanta building), with tremendous support from the local community. Since Trees Atlanta's mission is to 'protect and improve Atlanta's urban forest by planting, conserving, and educating', the Trees Atlanta building has implemented many sustainable design and construction features along with providing comfortable spaces including staff offices, support spaces, a working exterior yard for tree planting and maintenance work, and an education centre.

Figure 5.3 Trees Atlanta mission

Project site and description

The project site is located in the Reynoldstown neighbourhood of Atlanta (Figure 5.4) – just north of Interstate Route 20 and a few miles east of I-75/85. The Trees Atlanta project is on the periphery of the Cabbagetown and Reynoldstown neighbourhoods, and adds to the exciting changes that are occurring in the adjacent Memorial Drive corridor. This urban location allows the organization to reside in the heart of the city, adjacent to the future beltline development and as part of an emerging mixed-use zone. The existing site is just under an acre and includes an existing vacant manufacturing building built in the 1940s with some additional miscellaneous structures (Figure 5.5). Since one of the first goals for sustainability is reuse, the existing vacant building has been renovated and updated to provide a state-of-the-art sustainable building housing both the non-profit's headquarters and meeting and event spaces used by the community. In addition, the Trees Atlanta building also includes the Bartlett Tree Experts Urban Forestry Demonstration Site and the Home Depot Program Operations Center, where volunteers meet each Saturday before planting and maintaining trees throughout the community.

Figure 5.5 Front view of the existing building prior to construction and a rendering of the same perspective for the final Trees Atlanta building

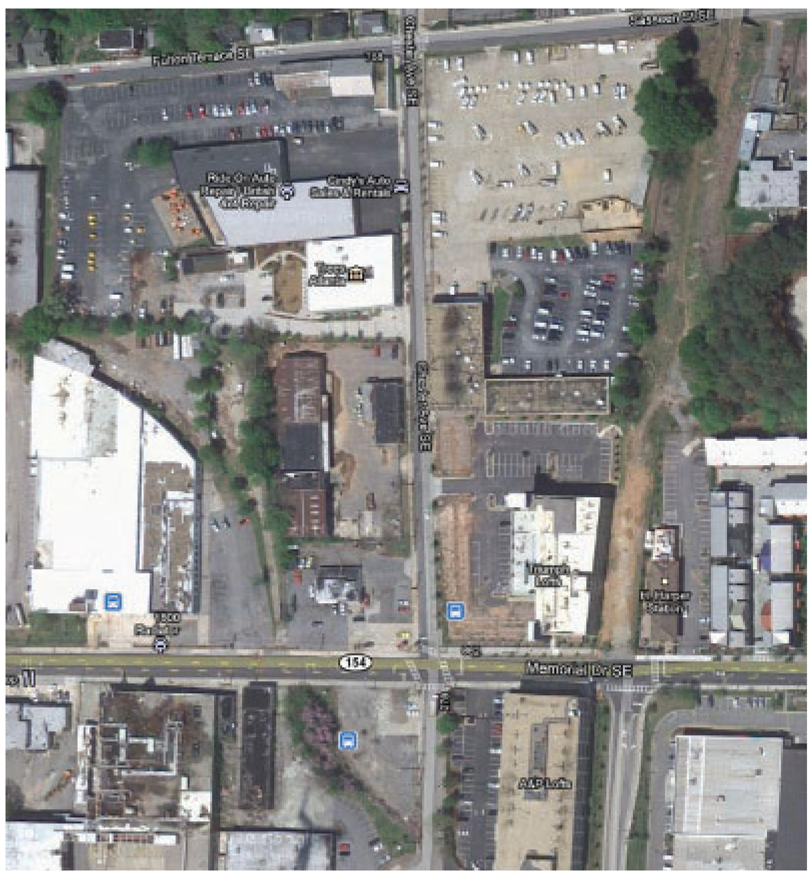


Figure 5.4 Existing location of the Trees Atlanta building within a previously developed industrial district

Building overview

The aim of the Trees Atlanta project was to remodel and upgrade the existing warehouse building into a state-of-the-art office and education building incorporating many sustainable design and construction strategies in order to achieve the goals of sustainability. The key parameters of the Trees Atlanta project are summarized in Table 5.1. Table 5.2 shows the key stakeholders involved in the project. Figure 5.6 shows the site plan and floor plan for the Trees Atlanta building.

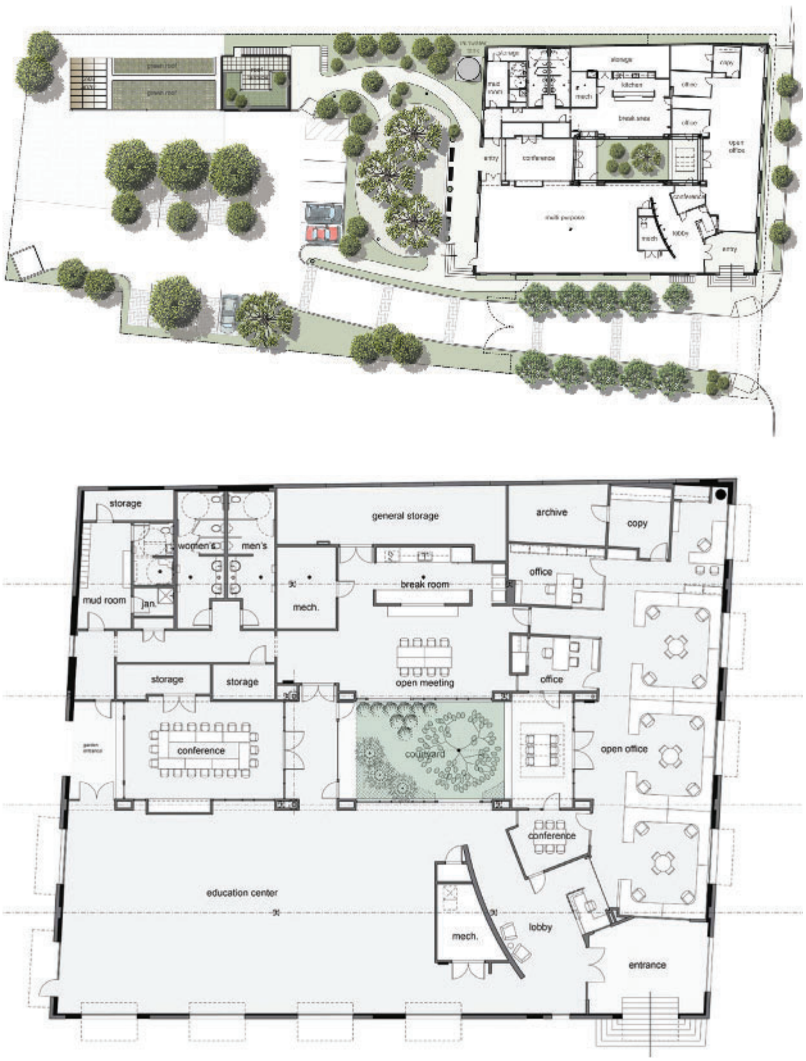


Figure 5.6 Site plan and floor plan of the Trees Atlanta building

Table 5.1 Trees Atlanta building overview

Basics		Building use	
Project name	Trees Atlanta Building	Owner type	Non-profit organization
Project location	Atlanta, Ga., USA	Occupant type	Non-profit corporation
Building type	Office and community centre	Date of occupancy	January 2008
Project cost	$2.5 million	**Project information**	
Project site		Construction type	New construction: 18% Renovation: 82%
Site conditions	Previously developed	Project scope	Single building
Total area	44,321 SF	Total building footprint	13,442 sq ft

Table 5.2 Project participants

Stakeholder	Name of firm
Owner	Trees Atlanta
Architect	Smith Dalia Architects
Civil engineer	Eberly and Associates
Structural engineering	Palmer Engineering
Mec./elec./ plumbing engineering	Moinar Jordan
General contractor	Gay Construction

Pre-design of the Trees Atlanta building

The pre-design stage is the first step in the building development process. This stage includes the development of the facility's functional and operational requirements as well as sustainable design and construction goals. Since decisions made during pre-design not only set the project direction and sustainability of the project, but also have to prove cost-effective over the life of the project, the project team for the Trees Atlanta building faced a significant challenge to establish sustainable project goals, define the process with which to achieve these goals, and develop a clear understanding of the expected results. Integrated design is also a cornerstone for developing a sustainable building, and results in efficiently combined systems for coordinated and environmentally sound products, systems, and design elements. The project team, including Smith Dalia Architects and Gay Construction, also intended to use an integrated building design approach, which was launched during the pre-design phase. The project also included a team approach to achieve the goals of sustainability in the project. As a key part of these processes, the Trees Atlanta building project implemented the following practices at the pre-design stage:

- Have a kick-off meeting.
- Establish a vision statement that embraces sustainable principles and an integrated design team approach.
- Establish the project's sustainable design and construction goals.

- Establish sustainable design and construction criteria.
- Set priorities for the project design criteria.

The first step at the pre-design stage was to have a kick-off meeting among three key parties including owner Trees Atlanta, Smith Dalia Architects and Gay Construction which would serve as the general contractor, in order to develop functional requirements and sustainability goals for the building. At the first meeting, the project team developed the vision statement for the Trees Atlanta building (see box).

Vision statement for the Trees Atlanta building

Since Trees Atlanta is a nationally recognized citizen group that protects and improves Atlanta's urban forest by planting, conserving and education, the Trees Atlanta building has to not only provide comfort spaces but also must achieve the goals of sustainability through the implementation of sustainable design and construction strategies.

Based on the vision statement, the project team established the project's sustainable design and construction goals. The sustainable design and construction goals (see box) were organized into five areas: sustainable sites, water efficiency, energy efficiency, materials and resources, and indoor environmental quality.

Sustainable design and construction goals: Trees Atlanta building

Sustainable sites:
- Minimize stormwater run-off.
- Use native/adaptive planting.
- Achieve site light pollution reduction.
- Install green roof for demonstration purposes.

Water efficiency:
- Collect rainwater for onsite (and possible off site) uses.
- Minimize water consumption in the building by waterless fixtures.

Energy efficiency:
- Achieve 50 per cent reduction in energy consumption.
- Utilize solar energy (photovoltaic and thermal).
- Keep the systems simple.

Materials and resources:
- Use 100 per cent FSC certified wood products.
- Install recycled/refurbished furniture.
- Use locally harvested building materials.
- Install recycled content materials.

Indoor environmental quality:
- Access to daylight and public amenities.
- Use non-volatile organic compound materials.

Case Study: The Visionaire – New York, United States

Completed in 2008, the Visionaire is a green mixed-use, high-rise residential condominium and headquarters for the Battery Park City Parks Conservancy located in Battery Park in New York. The Visionaire was developed as a public–private partnership between the Battery Park City Authority and Albaness Organization, Inc. and incorporated many green building strategies and technologies for enhancing energy efficiency, indoor air quality and water conservation. Due to incorporating green building strategies and technologies, the Visionaire has been certified LEED Platinum for New Construction in 2009 by the US Green Building Council.

Internal environment

- A high efficiency air filtration system continually replenishes and cleanses the air in all residences.
- Twice-filtered fresh air is heated and humidified in dry winter months, and cooled and dehumidified in summer months, for optimal resident comfort.
- Programmable digital thermostats provide year-round climate control.
- Eco-friendly paints, adhesives and sealants emit no or low VOCs, helping to maintain the integrity of indoor air quality.
- The kitchen exhaust system allows residents to increase air exhaust rates on demand for improved air quality and energy efficiency.

Building systems

- A 24-hour indoor air quality (IAQ) monitoring system ensures optimal filtration.
- The building's central heating and cooling system in powered by natural gas, contains no demand, compared to a typical New York City building.
- Environmentally responsible operating and maintenance practices.
- Carbon monoxide monitoring and ventilation control system in parking garage.

Interior finishes and fit-out

- Warm-toned natural materials were selected for their intrinsic beauty, texture and environmental integrity:
  - Floors – quarter sawn/rift cut oak floors sustainably harvested from Forest Stewardship Council (FSC)-certified forests.
  - Kitchen cabinetry – bamboo.
  - Kitchen countertops – river-washed absolute black granite.
  - Backsplashes – bricks of art glass.
  - Bathroom floors and walls – rich limestone with glass mosaic accents.
  - Bathroom cabinetry – teak.

Landscaping

- Rooftop gardens provide beautifully landscaped vistas and open-air entertainment patios.
- Rapidly renewable plantings, such as bamboo trees in the indoor pool area, are carefully nurtured with pesticide-free nutrients.

- Rooftop landscaping provides an extra layer of natural insulation for the building, reducing the urban heat island effect.

Recycling

- Over 85 per cent of site construction waste materials are collected and processed for recycling.
- Construction materials contain a minimum of 20 per cent recycled content.

Residences

- To minimize energy consumption, all residences feature Energy Star® appliances.
- A single master switch at the entrance of each residence allows bedroom, living room and hallway lights to be turned off simultaneously when exiting.
- A four-pipe fan coil heating and air conditioning system provides optimal comfort and energy savings.
- Residences are prewired for automated internal solar window treatments by each resident.

Energy sources

- A 48 kW photovoltaic solar power system integrated into the building façade generates electricity for the building.
- Geothermal systems provide heating and cooling for the Battery Park City Parks Conservancy section of the building.
- 35 per cent of the building's base electricity load is provided through Green-e certified renewable energy sources.
- Natural gas fuels the heating and cooling systems for the building contributing to a substantially lower peak demand on New York City's electric grid.

Building systems

- High-efficiency natural gas-fired heaters and microturbine simultaneously generate electric and hot water.
- The ventilation systems utilize energy recovery technology for substantial energy savings.
- The heating and air conditioning systems utilize high-efficiency pumps and motors.
- The humidification systems utilize high-efficiency natural gas fired equipment.
- Occupancy light sensors minimize electric use in common areas including corridors, stairs, garage and mechanical control rooms.

Building envelope

- High-performance exterior terracotta and glass curtain wall system.
- High-performance radiant low-E insulated glazing provides superior performance in solar energy control and reducing energy costs.

Materials transport

- A 500-mile resource boundary for 50 per cent of building materials minimizes transportation energy consumption and pollution.

Living environment

- Light is utilized as a central feature of the Visionaire to enhance the living environment for residents at every level.
- Generous, open floor plans integrate a flood of natural light into every residence.
- Floor-to-ceiling windows in living rooms provide an abundance of natural light.
- A sky-lit indoor swimming pool and hot tub overlook on of two beautifully landscaped roof gardens offering panoramic views of the city and New York Harbor.

Building design

- The building's streamlined curved façade optimizes natural light and allows generous river and city views from all exposures.
- The building's radiant low-E glass delivers superior performance in maximizing natural light transmittance, and reducing harmful UV rays.
- PV panels integrated into the building's façade harvest solar power to generate a portion of the building's electric load, while reducing greenhouse gases and the use of fossil fuels.
- Public areas feature occupancy sensor controls that automatically raise and lower lights, to conserve electricity when areas are not in use.

Filtered water

- Centrally filtered water is supplied to all residence baths, showers, taps and icemakers.

Conservation

- Plumbing fixtures and appliances, including front-loaded clothes washers, minimize water conservation.
- Toilets by Toto provide a dual flush feature for added water savings.
- A 25,000 gallon per day waste water treatment plant located in the basement recycles water to resupply toilets and provide make-up water for the HVAC system cooling tower.
- A roof garden catchment system harvests up to 12,000 gallons of rainwater for irrigation, helping to reduce the effects of storm surges that can overwhelm municipal water treatment facilities and flush sewage into local water supplies.

A 25,000-gallon per day waste water treatment plant located in the basement recycles water to resupply to toilets and provide make-up water for the HVAC system cooling tower.

Daylighting and fresh filtered air delivered to each living space provide an optimal indoor environment to residents

After setting sustainable design and construction goals at the kick-off meeting, the project team prepared two different charrettes for the project. The first charrette was to focus on developing detailed sustainable design and construction criteria and setting priorities for the project design criteria. The second charrette was specifically related to native and adaptive planting, since Trees Atlanta is dedicated to planting trees and securing a green belt in the City of Atlanta. From the sustainable design charrette, the project team was able to achieve the following goals:

- Develop early consensus on project design priority.
- Generate early expectations for final energy and environmental outcomes.
- Provide early understanding of the potential impact of various sustainable design strategies.
- Develop a checklist of sustainable strategies (LEED credit checklist).
- Initiate a design process to reduce project costs and schedules, and obtain the best energy and environmental performance.
- Identify project strategies for exploration with their associated costs, time constraints and the needed expertise to eliminate costly 'surprises' later in the design and construction processes.
- Identify partners, available grants and potential collaborations that can provide expertise, funding, creditability and support to the project.
- Set a project schedule and budget with which all team members feel comfortable.

The first charrette was comprised of two sessions (morning and afternoon – see box). At the end of the first charrette, the participants developed a charrette report that included objectives, sustainable strategies to achieve the objectives and strategies for measurement, and concerns. Figure 5.7 shows the sustainable development strategies for energy, and Table 5.3 describes the part of the charrette result report pertaining to energy and sustainable sites.

Structure of a one-day charrette

In the morning session, tasks include:

- introduction, ground rules, goals of the day, overview of the charrette process
- project description
- introduction to sustainable design and construction
- why sustainable design and construction for Trees Atlanta building?
- integrated and sustainable design process.

The afternoon session includes:

- Small group meetings
  - brainstorming: develop strategies to reach the goals
  - facilitated session: what are the objectives, strategies, measurement needed?
  - outcome: cost premium and schedule effect.
- Whole group meeting – Summarize the small group meetings
- Closing the charrette – Where will the project go from today?

Table 5.3 Charrette result report from the Trees Atlanta building

Priority	LEED credit	Objectives	Strategies	Measures	Concerns
1	EA	• Energy efficiency (reduce 50% energy consumption in the building)	• Daylighting • Passive design (Insulation) • Glazing (low-e glass) • Highly efficient fixtures (T-5 lighting) • Task lighting • Geothermal heat pump • Solar hot water heater • Occupancy sensor technology • Energy Star rated equipment and appliance • Carbon offsets through purchase of green power credits	• Energy modelling by the design team • Energy Star rated equipment and appliance	• Additional cost premiums • Government incentives and grants investigation
2	SS	• Restore native and adapted vegetation • Plant trees • Provide habitat for vegetation and wildlife	• Plant various types of native and adapted vegetation and trees • Possibly adopt Silva Cell technology • Green roof technologies • Rainwater harvesting system for irrigation • Courtyard at the middle of the building • Permeable concrete for parking spaces • Bioswales (vegetated water retention)		• Second charrette for planting and landscaping by Trees Atlanta volunteers • LEED credit points (integrated approach)

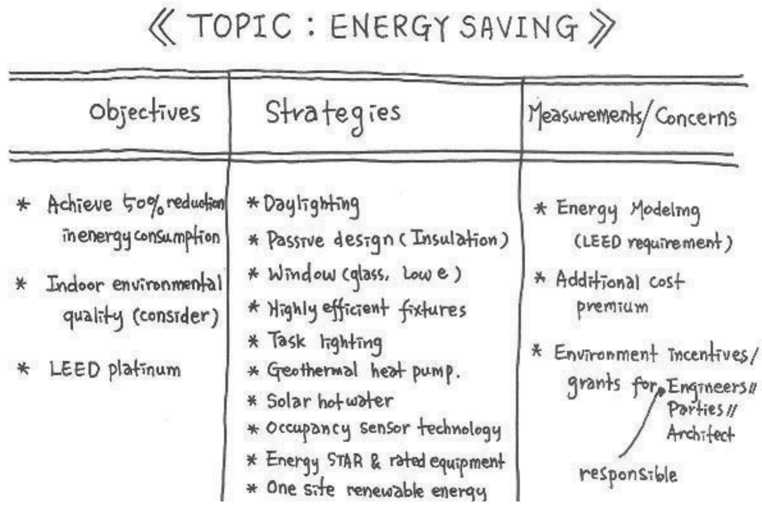


Figure 5.7 Development sustainable strategies for energy saving

Opportunities and challenges

Opportunities:

- soil condition
- paved and open ratio
- budget for landscaping and planting trees and vegetation.

Challenges:

- power lines on the site
- building schedule
- approval process.

The second charrette was specifically related to landscaping and planting trees and vegetation at the project site. At the second charrette, the Trees Atlanta project team set up the following objectives based on the first charrette:

- types of native and adaptive plants and trees
- innovative site details and products
- innovative planting technologies
- viable site technologies
- irrigation system including the rainwater harvesting system
- schedule of Trees Atlanta building
- interactive plan for education at the site.

Figure 5.8 The second charrette for the Trees Atlanta project

In addition, the second charrette (Figure 5.8) defined potential opportunities and challenges associated with planting trees at the project site. From the charrette, the project team identified the following opportunities and challenges related to landscaping and planting trees and vegetation. Through the in-depth charrette, the project team achieved the goals set forth for the event and solved challenges associated with the project.

After completing two charrettes in the Trees Atlanta building project, the design team led by Smith Dalia Architects moved forward into the design phase, incorporating as many of the objectives and strategies (mainly sustainable design and construction strategies) presented at the charrettes as could be incorporated in an integrated manner. In addition, the design team also began to investigate the potential grants and incentives related to sustainable design and strategies that could be integrated into the project. With the completion of these background tasks, the pre-design phase concluded and the design phase began.

Pre-design in 2020

What can we expect of the pre-design process in 2020 and beyond? Almost certainly new types of project delivery approaches will exist based on new ways of thinking about project teams and risk sharing. However, the most significant changes are likely to be driven by new ways of collecting, analysing and using data.

Improved understanding of the life-cycle behaviour of buildings constructed using sustainable design and construction strategies will lead to a greater confidence in planning for the costs associated with these projects. Especially for owners of large capital facility portfolios, better tracking of building performance will enable real-time management to optimize investment in improving existing buildings and balancing facility needs with resources. This information will play a key role in pre-design because it will enable owners to better predict costs as they define facility needs and set sustainability goals. New models of building life-cycle performance that incorporate human and environmental factors will improve the accuracy of long-term forecasting.

With regard to collaborative processes such as charrettes, innovations in social networking, virtual collaboration and virtual reality will enable new stakeholders to be more actively involved in the pre-design process in new ways. At present, much of the creativity resulting from charrettes comes from the energy and enthusiasm of participants interacting together during intense work sessions. Quality facilitation is also key to making the most of these sessions. Emerging information technology will make this type of interaction easier without everyone needing to be located centrally. Rapid retrieval of information from information systems such as Google Earth about the project site will be immediately available to answer questions that arise. Indeed, the skeleton of a building information model may be developed as part of the charrette process instead of later in the process as it occurs today.

A larger body of historical data from existing high-performance buildings, coupled with interactive pre-design models, will enable quick trade-off analysis of options without intensive effort. This body of knowledge will enable quick visualization of alternatives, increasing the ability laypeople and non-experts as part of the process. Ultimately, better access to historical data, increased participation of a broader range of stakeholders, and better ability to predict future performance will be the foundations of pre-design in 2020.

Case Study: Bardessono Hotel

The Bardessono hotel is a boutique luxury hotel located in Yountville, California in the heart of Napa Valley (Figure 1). The hotel includes 62 luxury rooms, a spa, four treatment rooms, a 75-foot-long rooftop infinity pool, a fine dining restaurant and a meeting space. Bardessono was developed by MTM Luxury Lodging (MTM) of Kirkland, Washington and opened in February 2009. Recognizing the value of sustainability and environmental issues as well as the importance of providing a luxurious guest experience, the MTM development team was guided by the following mission statement: 'A hotel can provide a fully luxurious guest experience and be very sustainable at the same time, and environmental initiatives can be implemented in a manner that is practical, economic and aesthetic.' To achieve those goals, Bardessono has implemented sustainable practices not only during the design and construction phase of the development but also at the operation stage of the hotel. The hotel was awarded the LEED Platinum certification by USGBC in January 2010.

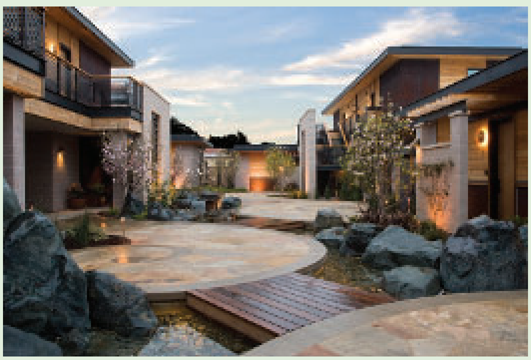


Figure 1 The Bardessono Hotel

Bardessono Hotel

- Project size: 55,159 sq ft, with 62 rooms and a restaurant
- Project cost: $46 million
- Sustainable features: second LEED Platinum hotel in the USA
- Developer: MTM Luxury Lodging
- Architect: WATG
- Contractor: Cello & Maudru Construction

Pre-design in the Bardessono Hotel

During the project delivery of the Bardessono Hotel, the project team fully recognized the value of an integrated design process including a collaborative multidisciplinary approach among all project team members. The major team members consisted of MTM Lodging (Developer), WATG (architect), O'Brien & Company (sustainable consultant) and Cello & Maudru Construction Company (general contractor). These organizations committed to share specialized expertise and coordinate their individual design efforts to achieve a well-functioning, sustainable hotel.

One of the first integrated design processes was the development of sustainable hotel guidelines that set both general goals for the project and specific parameters for hotel design, products, systems and siting. To guide this process, the integrated project team established a 'Project mission statement' (see box). Based on this mission statement, the integrated project team established sustainable hotel goals, defined the process to achieve those established goals, and developed a clear understanding of the expected results from sustainable practices at the pre-design phase. One of the first processes was to have a four-hour sustainable practice charrette with members of the project team (Table 1) to identify and evaluate the project's sustainable design features using the LEED for New Construction (LEED NC) rating system.

Project mission statement

- To make environmental responsibility one of the key design criteria for the hotel's design, development, and sustainability
- To commit, in as many steps, to minimize the environmental cost of the hotel's construction operation
- To recommend all practical environmental actions in regards to this project and research further methods to reduce the impact of the hotel on the environment.

Table 1 Charrette for the Bardessono Hotel

Role	Company
Electrical engineering CAD support	Travis Fitzmaurice
Client/developer	MTM
Lighting designer	Luminae Souter
Project architect	WATG
Interior designer	Inside Out Design
Architect	WATG
Landscape architect	George Girvin Associates
Principal architect	WATG
Principal resort management	MTM Management
LEED project manager	O'Briend & Co.
LEED principal	O'Briend & Co.
LEED research associate	O'Briend & Co.
Mechanical engineer	Ecotope
Civil engineer	Bartelt Engineering
Contractor	
Cello & Maudru Construction	

At the design charrette, the developer demonstrated the vision of the Bardessono Hotel, 'Luxurious Environmental Hospitality' to enhance the guest experience and satisfaction and conserve energy and resources through integrating sustainable practices. Based on the developer's vision and mission statement, the project team members identified the following sustainable strategies:

- Air – Noticeably fresh air in rooms, ceiling fans, operable windows, hard surfaces, minimal carpets, vacuums with highly effective filters to minimize dust and allergens, bedding and linens with no toxins or allergens and low or no-VOC interior flooring, furniture, finishes, etc.
- Food – Emphasize local and organic food and wine on hotel's menu.

- Lighting – Energy efficiency and beautiful aesthetics.
- Connection to the outdoors – Maintain lushness in the landscape design, compost kitchen waste, and look for opportunities for dual-purpose systems in landscaping.
- Aesthetics – Demonstrate sustainability in an elegant way, not overt.
- Stewardship in operation – Natural cleaning products, kitchen waste composting, organic landscaping, high-tech systems controls, dispensers versus bottles for shampoos, etc., earth-friendly linens such as Beech wood linens.
- Education – See things in action – practice 'apparent' sustainability; provide LEED features for others to incorporate in their designs and be a leader in the hospitality industry for sustainable design.

In addition, the project team also discussed additional considerations for LEED certification including prerequisites, LEED implementation, USGBC fees and a disclaimer.

After the first charrette, O'Brien & Co., a sustainability consultant, performed a detailed LEED analysis of the project based on conversations with team members and independent research. A report was developed to deliver the results of the LEED analysis, including an updated LEED scorecard, a detailed explanation of the project's approach and required actions for each credit, and next steps to ensure success in pursuing LEED certification. This first charrette and the report created an integrated collaborative environment among project members to establish sustainable design, construction criteria and guidelines, and also to set priorities for the project design criteria. This integrated design process at the pre-design phase actually enhanced the project team in its quest to successfully move to the design and construction phases of the project.

Sustainability features in the Bardessono Hotel

During construction and operations, the Bardessono Hotel project implemented and continued to use sustainable building practices to not only minimize negative environmental impacts, but also enhance guests' satisfaction and comfort. In addition, the hotel also wanted to achieve cost savings by using less energy, water and natural resources over the building life. Toward this end, the project team of the Bardessono Hotel addressed the following criteria: site sustainability, efficiency with water, energy, atmosphere, materials, resources, indoor environmental quality, design innovation and operation. The Bardessono Hotel started with adopting an integrated design approach and an integrated team process among all project participants at the design phase to achieve the goals of sustainability and luxury while eliminating or minimizing the first cost premiums. The sustainable building practices employed at the Bardessono Hotel are as follows. First, several strategies were implemented related to sustainable sites, including construction activity prevention strategies (Figure 2), public transportation access, bicycle storage and changing rooms, low-emitting and fuel efficient vehicles, storm water management, and measures to reduce the urban heat island effect.

The Bardessono also adopted multiple strategies to reduce water consumption, including dual-flush toilets and low-flow fixtures, thereby reducing 34 per cent of projected water consumption, from 603,618 gallons/year to 398,400 gallons/year. In addition, drought-resistant landscaping using native California species and underground emitters for irrigation are expected to reduce 64 per cent of projected potable water use for landscaping, from 1,4663,452 gallons/year to 526,876 gallons/year. Planting native trees and flowers at the Bardessono is beneficial, as it not only enhances the authentic experience, but also helps save water because native plants will be most suited to the climate.

Figure 2 Erosion control practices at the job site

Figure 3 Solar panels on the roof to generate electricity

The Bardessono also incorporated multiple energy-saving strategies, including passive solar design, low-e glass, sensor technologies, geothermal heat pumps combined with 72 300 ft deep geothermal wells, LED and fluorescent lamps, and 940 solar panels (Figure 3). Passive design strategies in the Bardessono included building orientation, daylighting using natural light, and shading devices to mitigate solar heat gain and increase the overall energy efficiency. With these strategies, it is possible to reduce energy consumption by 31.5 per cent (2980 MBtu/year) along with solar panels that generate 889 MBtu/year. In addition, the Bardessono also purchased Green-e accredited Tradable Renewable Certificate (Bardessono-70%) to encourage the development and use of renewable energy technologies.

The Bardessono salvaged multiple building materials including tufa, or local limestone, and various kinds of trees including walnut, cypress and redwood to reuse in the exterior and interior of the hotel. In addition, the project team implemented a construction waste management plan to recycle construction waste (Figure 4), resulting in a diversion rate of 92 per cent or 1,053 tons.

Since the Bardessono is a high-end boutique hotel, the hotel implemented multiple strategies related to indoor environment, including daylighting with shading devices, LED and fluorescent lamps, and low-VOC building materials including all glues, adhesives, finishes, paints, carpets and fabrics used in the project. The high quality of the indoor environment (Figure 5) provides a benefit to occupants' health, comfort and well-being. Daylight and views also provide hotel occupants and guests with a connection between indoor spaces and the outdoors.

Figure 4 Construction waste management

Figure 5 Indoor environment of the Bardessono Hotel

The Bardessono also uses sustainable practices as part of hotel operations, including:

- planted areas that are managed organically
- vegetable waste composted in an 'Earth Tub' and reused in planted areas as fertilizer
- organic and locally produced food, including fruit, vegetables and meats
- two culinary gardens to supply food to its own dining facilities, including one on-site and one off-site
- organic bath and cleaning products
- electronic and bio-diesel vehicles used by the hotel to minimize air pollution.

By implementing sustainable practices over the building life-cycle, the Bardessono can not only achieve its goals for sustainability, but also improve guests' satisfaction with the recognition as being the most sustainable luxury hotel in the world.

Discussion questions and exercises

5.1 Consider the building in which you are presently located. When was it built? What was its design life or projected service life? What do you expect will be its actual service life, given trends in development in your area?

5.2 Who are the external and internal stakeholders for the building in which you are presently located? Identify the major stakeholders for earlier phases of the building life-cycle. For example, what firm(s) designed the building? Who built it? What developers were involved? What public agencies played a role?

5.3 Contact an owner organization or design firm and obtain a copy of a programme of requirements for one of their projects. Public agencies such as local schools or governments are likely to have such documents and may be willing to make them available. What elements are included in the programme of requirements? Is sustainability specifically addressed? If not, how could it be incorporated as part of the programme?

5.4 Obtain a copy of the construction documents for a local project. If possible, obtain the documents for the same project for which you reviewed the initial programme of requirements. What are the major sections of the construction documents? Is sustainability specifically addressed? If not, how could it be incorporated as part of the construction documents? How does the final set of construction documents measure up in terms of the original programme of requirements?

5.5 Identify a local public sector project in the planning or design phases of its life-cycle. Contact project representatives and determine the schedule for any upcoming public review meetings. If no meetings are presently scheduled, ask to be contacted when a date has been determined. Attend the public meeting if possible. What opportunities are there for input to the project? How could sustainability issues be raised and addressed in these meetings?

5.6 How will major trends such as stricter legislation and regulations, resource shortages, rising energy and water costs, competition for infrastructure capacity, and projected future development influence projects in your community? What is likely to be the most significant influence in the next five to ten years?

5.7 For the project identified earlier, contact the owner to determine what project delivery strategy has been selected for the project, and why. What delivery system, contract type and selection methods will be used? Is the project typical in this regard? Is a phasing strategy planned for the project? If so, what major phases are planned? Has sustainability been implicitly or explicitly taken into account in developing the project delivery strategy? If so, how?

5.8 Contact the local chapter of professional design associations (such as the American Institute of Architects in the United States) and ask about charrettes that are planned for any upcoming projects. Search the Internet to identify any organizations in your area that offer charrette facilitation services.

5.9 Plan to attend a charrette for a local project as an observer if your schedule allows. How is the charrette organized? How is sustainability taken into account? What is the dynamic among charrette participants? What is the outcome of the event?

References

Allen, E. (1980). *How Buildings Work: The natural order of architecture*. Oxford University Press, New York.

Churchman, C. W. (1979). *The Systems Approach and Its Enemies*. Basic Books, New York.

Halliday, S. P. (1994). *Environmental Code of Practice for Buildings and their Services*. Building Services Research and Information Association, Bracknell, Berkshire, UK.

Hendrickson, C. T. and Au, T. (1989). *Project Management for Construction*. Prentice-Hall, Englewood Cliffs, N.J.

National Renewable Energy Laboratory (NREL). (2010). 'A handbook for planning and conducting charrettes for high-performance projects.' <www.nrel.gov/docs/fy09osti/44051.pdf> (accessed 20 July 2010).

Pearce, A. R. (1999). *Sustainability and the Built Environment: A process and metric for prioritizing improvement opportunities*. PhD dissertation, School of Civil & Environmental Engineering, Georgia Institute of Technology, Atlanta, GA.

Vanegas, J. A. (1987). *A Model for Design/Construction Integration During the Initial Phases of Design for Building Construction Processes*. PhD dissertation, Civil & Environmental Engineering, Stanford University, Palo Alto, CA.

Vanegas, J. A., Hastak, M., Pearce, A. R. and Maldonado, F. (1998). *A Framework and Practices for Cost-Effective Engineering in Capital Projects in the A/E/C Industry*. RT 112, Construction Industry Institute, Austin, Tex.

Von Bertalanffy, L. (1968). *General System Theory*. George Braziller, New York.

Yeang, K. P. (1995). *Designing With Nature*. McGraw Hill, New York.

6

Sustainable Design Opportunities and Best Practices

In the design phase of project delivery, many opportunities exist to influence the sustainability of the resulting facility project. This chapter describes the integrated design process that is key to developing sustainable projects, and presents a range of strategies that can be incorporated in design to improve project sustainability. It concludes with two case studies to illustrate these strategies in practice.

The integrated design process

Integrated design of all facets of the project with each other is a key element of capital project sustainability. Figure 6.1 shows a schematic of

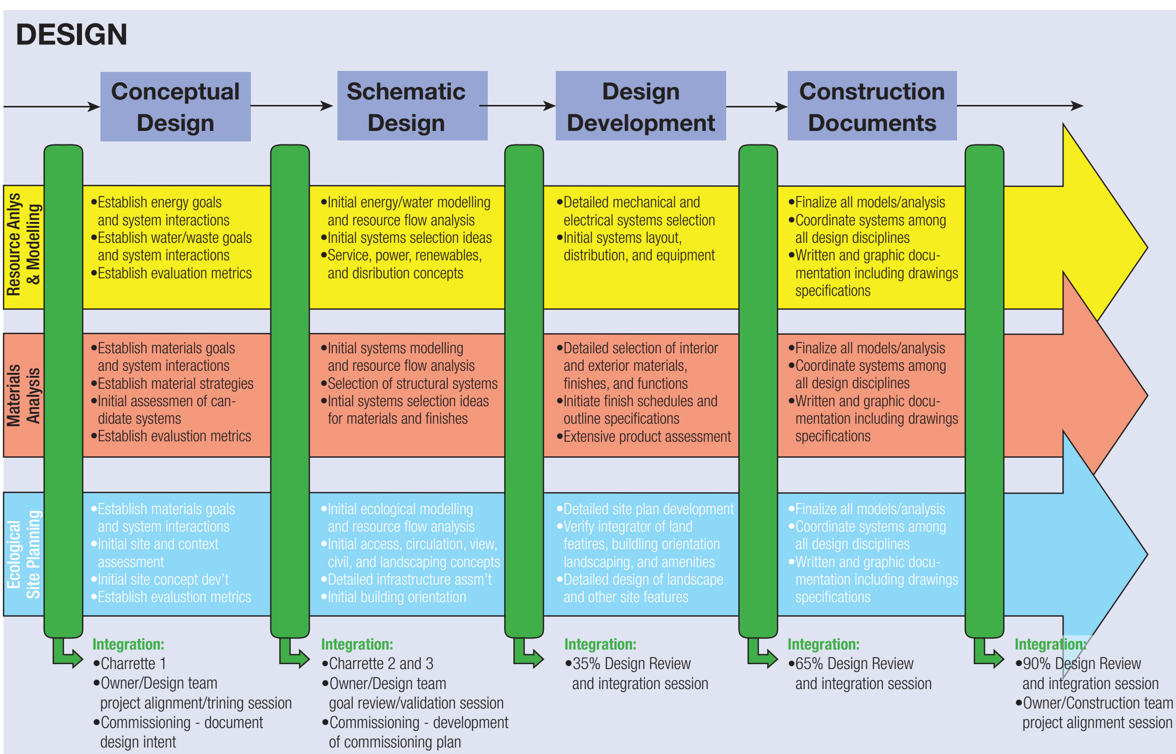


Figure 6.1 Integrated sustainable design process for buildings

Source: Pearce et al (2005).

a sustainable design process for buildings with details of key sustainability-related processes that can be undertaken to ensure a sustainable design outcome. Selected steps in each of three tracks (resource analysis and modelling, materials analysis, and ecological site planning) are associated with each of the four phases of the design process. Cross-cutting all of these processes are integration milestones, indicated by the green bars, that involve activities such as interdisciplinary charrettes, facilitated design reviews, and project alignment sessions to ensure that all sustainability strategies are being developed in complementary ways throughout the process. A similar process can also be applied for integrated design of infrastructure systems, with a focus on the types of resources employed for each specific type of project.

Best practices for sustainable design

In conjunction with a more integrated design process, a number of options exist to adapt the design elements of a built facility to make its life-cycle more sustainable. The following subsections describe best practices in six major categories, as follows:

- **Sustainable sites** – this category includes choosing a good site for a facility, placing the facility on the site, avoiding damage to the site, and restoring the quality of the site. It applies to both buildings and infrastructure systems.
- **Energy optimization** – this category includes eliminating unnecessary use of energy, using energy more efficiently, balancing energy demands, and seeking alternative sources for energy. It applies primarily to buildings.
- **Water and wastewater performance** – this category includes eliminating unnecessary use of water, using water more efficiently, and seeking alternative sources and sinks for water and wastewater. It applies primarily to buildings.
- **Materials optimization** – this category includes eliminating unnecessary use of materials, using abundant renewable materials, using multifunctional materials, and seeking alternative sources of materials. It also includes eliminating or preventing waste, reusing waste within the facility system, sharing it with other systems, and storing it for future use. It applies to both buildings and infrastructure systems.
- **Indoor environmental quality** – this category includes preventing problems at the source, segregating polluters, taking advantage of natural forces, and giving users control over their environment. It applies primarily to buildings.
- **Integrated strategies** – this category includes practices that result in multiple benefits from one action. It includes capitalizing on construction means and methods, making technologies do more than one thing, and exploiting relationships between systems. It applies to both buildings and infrastructure systems.

Together, these practices represent the spectrum of actions that can be taken to reduce negative impacts of the built environment on the natural environment.

Sustainable sites

The first area of best practice deals with facility site and landscape. The most important decision for a project is the selection of a good site. After the best site has been chosen, the next most important decision is where to put the buildings on the site. These two decisions will affect the building's ongoing performance over its life-cycle. Next, the development of the site itself should use low-impact principles and features. Lastly, restoring ecosystems on the site to their best quality will help to keep the site functioning well.

Priorities for sustainable sites

- Choose the best site for the project.
- Choose the best location for the project on the site.
- Develop the site using low-impact principles and features.
- Restore ecosystems on and off the site.

Quite possibly the most important decision when constructing a facility is to choose a good site. The choice of site will not only affect the performance of the facility itself in terms of energy and environmental impact, it will also govern how much and via what mode people travel to and from the facility. For infrastructure projects especially, choosing the best site can strongly influence the ability of the project to perform efficiently and effectively over its life-cycle. For example, locating power and water/wastewater plants centrally within a service area can reduce pumping or transmission requirements and line losses. The terrain, existing development and other considerations will also strongly influence the best choice of site for an infrastructure project. In all cases, the life-cycle performance of the project should be taken into account when siting infrastructure projects, as should social equity and other important considerations. Siting to avoid damaging high-quality ecosystems and to reduce the threat of damage from natural forces such as flooding is also key. When siting infrastructure projects with very long service lives, possible impacts of climate change and population growth and migration should also be taken into account, including sea-level rise, expansion and evolution of neighbourhoods, and changes in temperature.

For buildings, choosing a site in an already developed area will provide building occupants with access to existing amenities, and might allow them to take advantage of walking, cycling or using public transport to access the building instead of having to drive a car. It also can provide a positive contribution to an existing neighbourhood. Choosing a site that is a brownfield (with real or perceived environmental contamination) and cleaning it up not only represents a positive step for the community, it might also offer a tax credit or development incentive for the developer. Avoiding sites that either have valuable ecological resources or higher levels of risk from environmental damage is also wise. For instance, avoiding sites with wetlands or habitats of threatened or endangered species not only preserves these valuable ecological resources, but also avoids the need to mitigate any impacts to these habitats, saving considerable expense. Finally, the choice should consider the long-term risks of resource depletion that might make development difficult in the long run. Water supply in some areas, for example, is becoming more scarce and may mean restrictions on future facility development and use.

Considerations for facility siting

- Location with respect to demand.
- Terrain.
- Potential damage to high-quality ecosystems.
- Vulnerability to natural disasters.
- Proximity to amenities/amenity sharing.
- Opportunities to remediate environmental damage.

Wherever possible, seek sites that will allow amenity sharing with other sites. Siting projects next to facilities that have complementary hours allows them to share common resources like parking lots – a bank that is only open during the day might share parking with a nightclub or restaurant district that operates at night, thereby reducing the need to have two separate parking lots. Choosing sites in already developed areas provide the project with access to existing infrastructure such as streets, water, power and sewers, and can save project time and budget while minimizing impact in the long term. Some sites such as areas under elevated freeways offer overlooked areas with significant possibility (see Figure 6.2).

Figure 6.2 This park area in Sydney, Australia creates a connection between neighbourhoods in an otherwise unusable space

After selecting the best site possible for the project, the next step is to determine where on the site to place buildings or built-up areas. Wisely locating a building and orienting it with respect to the sun can save considerable development costs and 30–40 per cent in heating and cooling costs over the life-cycle of the building. Passive solar design takes advantage of the sun's energy to provide for a building's lighting and space conditioning requirements without using electrical or combustion energy. For instance, orienting a building with its long axis running from east to west and most of its windows on the south side of the building is a passive design strategy in the northern hemisphere. In the summer when the sun passes higher in the sky, overhangs shade the windows from receiving too much sunlight and overheating the building. In the winter when the sun passes lower in the sky, sunlight can enter the windows under the overhangs, providing free heat to the building during the seasons when it is most needed (see Figure 6.3).

A complementary action is to preserve existing trees that may surround the building site. Deciduous trees on the south side of a building in the northern hemisphere can provide valuable shade in the summer, reducing cooling costs (see Figure 6.4). In the winter, they lose their leaves and allow solar energy to reach the building, providing warmth and heat gain. Trees on the north, east and west can also provide shelter from prevailing winds to reduce the heating and cooling loads of the building. Trees can also have positive effects on water retention, air quality and property values.

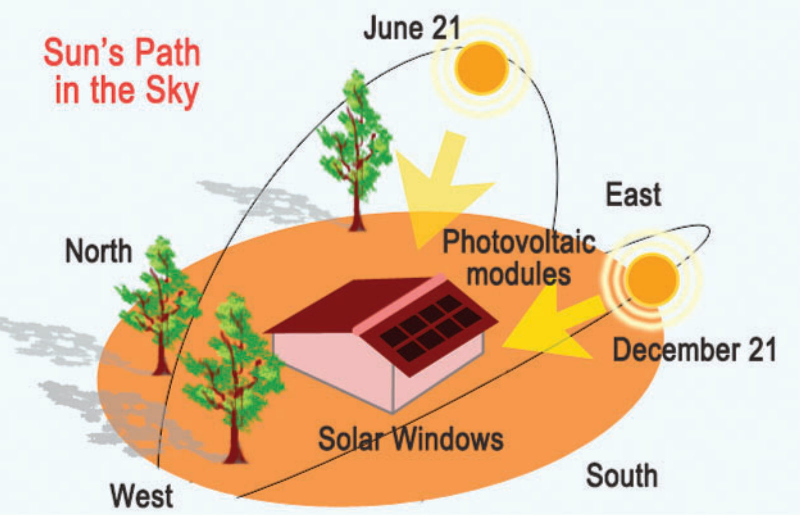


Figure 6.3 Careful orientation can provide significant energy to a building, in this case, in the northern hemisphere. Solar hot water heating can also be provided on the southern exposure. Windows should be minimized on the east and west sides of the building.

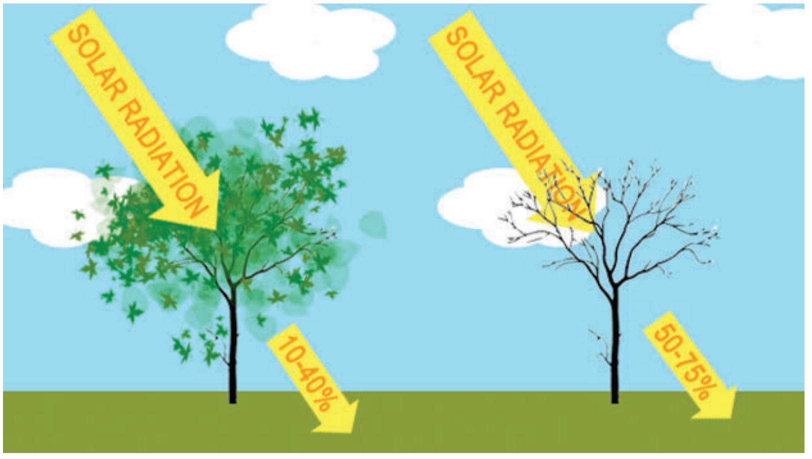


Figure 6.4 Deciduous trees provide shade in summer and allow sunlight through in winter. Only use on the east and west sides of buildings to avoid shading photovoltaic systems on the south side.

After arranging buildings and developed areas on the site, another opportunity applicable both to infrastructure and building projects is to develop low-impact site amenities. These include softscape – the vegetated parts of the site – and hardscape – the parts of the site that are paved or otherwise developed. From a softscape standpoint, native species require little or no irrigation, fertilizer or pesticides once established, since they are well adapted to the climate and can survive typical conditions. Avoid exotic species from other parts of the world – they often out-compete natives and can become invasive in the landscape. Group plants with like needs together in the landscape. This 'zoning' of landscape areas permits focusing irrigation, fertilizer and pesticides only on the plants that require it. Zoned landscaping can also help reduce the risk of wildfire around buildings by keeping areas near buildings clear of flammable vegetation and debris. Use mulch – organic plant matter such as bark or pine straw – to suppress weeds and help retain moisture around landscape plantings. Not only does mulch improve the appearance of many landscapes, it also helps to reduce the need for irrigation and pesticides, and helps to stabilize new plantings until they can become established. Xeriscaping is a series of strategies involving design of landscaped areas that require no irrigation, including use of native plants that can survive without additional water after they have been established.

Low-impact site amenities

Softscape:
- native species
- zoned landscaping
- mulching
- xeriscaping
- bioswales and rain gardens.

Hardscape:
- pervious pavement
- high albedo pavement
- transportation amenities.

Figure 6.5 This bioswale collects and treats stormwater from surrounding paved areas

Bioswales and rain gardens are vegetated areas that absorb and treat stormwater runoff from paved areas and allow it to percolate slowly back into the soil (see Figure 6.5). Plants within a bioswale also help to remove contaminants from runoff that would otherwise have to be treated at a wastewater treatment plant or contaminate local rivers and streams. They are often used in conjunction with alternative pavement configurations to direct runoff to the appropriate areas.

Alternative pavement materials such as pervious concrete, stabilized soil, or grid systems that allow stormwater to infiltrate the site instead of being collected and requiring special treatment are also an option (see Figure 6.6). Stormwater that comes into contact with pavement, particularly areas where vehicles drive or park, becomes contaminated with engine drippings, rubber and asbestos particles, and other automotive residuals. These contaminants, when concentrated in runoff, can pollute local streams and rivers. Stormwater runoff also causes stream damage because there is an increase in water temperature when it contacts the pavement, leading to thermal pollution of local streams. Permeable pavements capture stormwater and allow it to percolate back into the soil rather than running off. High albedo pavement that is light in colour and reflective helps to minimize the urban heat island effect. Urban heat islands are areas with higher temperature than surrounding areas because of dark pavements and buildings absorbing

Figure 6.6 This pervious pavement consists of decorative gravel bonded with a liquid bonding agent. It can be poured around site features and allows water to percolate to the subsoil.

more heat from the sun. Using light-coloured concrete, for instance, can reduce overall temperatures during summer months and lower air-conditioning bills in surrounding buildings.

Amenities to promote the use of alternative transportation, such as sheltered public transport stops, bicycle storage facilities and bike paths, sidewalks or pedestrian trails, and alternative fuel vehicle refuelling stations, are also a key sustainable site strategy. Setting aside special parking for carpools or alternative fuel vehicles also rewards drivers who use these greener transportation options.

After developing the site using green amenities, look for opportunities to restore natural ecosystems on the site to the extent possible. Native species require little or no maintenance and provide landscape beauty as well as habitat for birds, butterflies and other local creatures. Set aside areas of the site to remain undeveloped, or designate areas as open space that can serve the needs of both humans and local fauna. Work with adjoining sites to create common undeveloped areas to increase the size of habitat available to local fauna. Work with owners in the area to restore local ecosystems that benefit everyone, such as local streams and waterways.

Energy optimization

Priorities for energy optimization

- Avoid unnecessary energy use.
- Increase energy efficiency.
- Balance electrical loads.
- Seek alternative energy sources.

The energy used in homes and buildings is significant, and has considerable impact on the natural environment. The best way to reduce impact is by avoiding the use of energy where possible in the first place. Increasing the efficiency with which energy is used is a second way to reduce system demands, followed by balancing electrical loads, since centralized power systems are dynamic and cannot efficiently store electrical energy. The final way to increase the sustainability of energy use in buildings is to seek alternative energy sources based on renewable energy technologies.

One approach to reducing demand for energy in buildings is using timers or occupancy sensors to reduce operating hours for equipment such as water heaters that are not needed during hours when a facility is not occupied, or by switching off lights or reducing ventilation in spaces that are not in use. Other strategies may contribute to demand reduction with no changes required in occupant behaviour. Passive heating, cooling and daylighting all represent ways to provide required performance to building occupants while reducing or eliminating the use of electrical power to provide these services. Energy recovery ventilation systems also help to reduce demand by capturing waste heat from exhaust air in the winter or incoming air in the summer, and using it to preheat incoming air in the winter or exhausting it with outgoing air in the summer. Some systems also equalize humidity in the same way by using a desiccant wheel to transfer humidity to its desired location.

Demand reduction strategies

- Timers/occupancy sensors.
- Passive heating and cooling.
- Daylighting.
- Energy recovery ventilation.
- High-albedo surfaces.
- High-performance building envelopes.
- Dual switching/labelling.
- Thermal mass.

Another simple yet under-utilized technology is high-albedo surfaces. These reflective roof or pavement materials and coatings reduce heat gain by reflecting solar energy rather than absorbing it (see Figure 6.7). These surfaces need not be white and shiny – new coatings are available that reduce heat gain even with darker-coloured roofs. In many cases, the albedo (or reflectivity) of a roof can be increased at no cost simply by choosing a different colour for roof finishes during design. High-performance building envelopes can also eliminate unnecessary uses of energy for heating and cooling. Ways to improve the building's envelope include increasing insulation in wall cavities and attics, sealing cracks and using air/vapour barriers to reduce infiltration, installing high-efficiency windows and doors, and using low-emissivity paint or radiant barriers in attics to reduce heat gain. All of these envelope enhancements can reduce the demands on facility space conditioning equipment and increase occupant comfort during all seasons of facility operation.

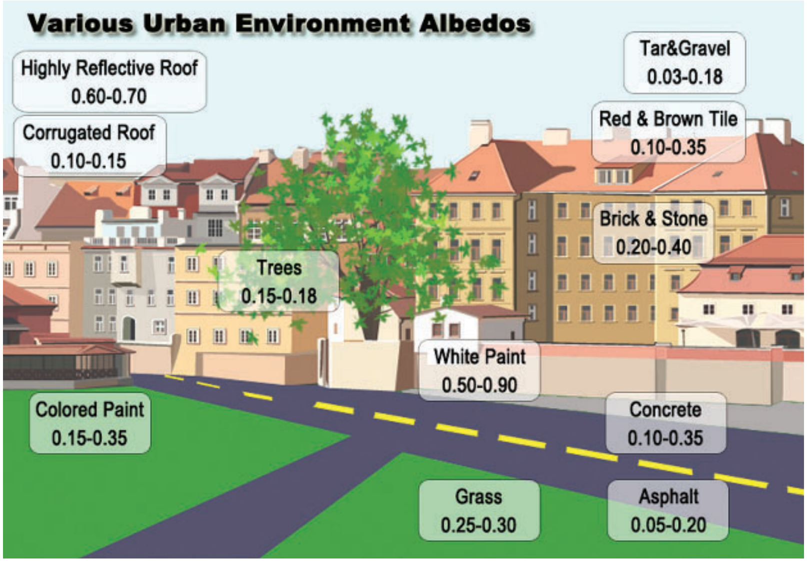


Figure 6.7 Albedo of various materials in the urban environment (0 = perfectly absorptive; 1 = perfectly reflective.)

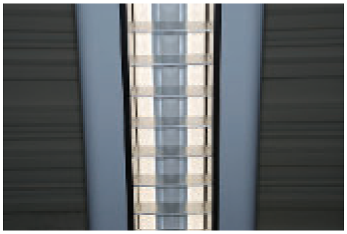


Figure 6.8 This dual-switched light fixture allows the outer lamps to be used alone, the inner lamp to be used alone, or all three to be used at once

Figure 6.9 Especially with systems such as geothermal, proper sizing is critical to keep installation costs low. Oversized systems mean longer trenches for burying geothermal loops, resulting in significant additional installation costs

Effective control systems for lighting can help to eliminate the use of energy during hours when daylight provides enough light. Dual switching – wiring light switches so that combinations of lamps can be switched on or off depending on how much light is needed – helps users to adjust light levels to appropriate levels (see Figure 6.8). Labelling switches also helps users to make more effective decisions about how to operate lighting systems.

A second set of strategies focuses on optimizing the efficiency of energy use within a facility. One way to save considerable energy is by paying attention to proper sizing of building heating, cooling and ventilation equipment (see Figure 6.9). Proper sizing can greatly enhance the efficiency with which mechanical systems use electrical power to meet occupant needs. With mechanical systems, oversizing equipment means these systems operate at peak efficiency only a few days of the year. To achieve peak performance, it is far better to use two parallel systems where both systems are used concurrently to meet peak demands. Under normal conditions, only one system is required, and it operates at peak capacity. The investment in additional capital equipment is offset by operational savings in energy.

Replacing tank-type hot water heaters in buildings with tankless models is another way to save energy in some applications. Although tankless models cost more initially, they last longer than tank-type models if properly maintained. They also eliminate standing heat loss since water is only heated as needed. High-performance heating, ventilation and air conditioning (HVAC) systems also save energy. The use of variable speed fans, pumps and motors enables HVAC to operate at optimum levels rather than cycling on and off. This increases user comfort as well as saving energy. Optimized distribution systems also help to reduce heating, cooling and ventilation costs. Sealing and insulating ducts is an important way to ensure that the energy expended to condition air actually benefits the users of the building.

Load balancing is a way to limit the loads placed on the power grid so they are more reasonably sized and the need for new power plants might be reduced. The electrical grid is a complex system of power plants, distribution networks and end users that consume the power being generated. To keep the system functioning, energy supply must remain exactly balanced with energy demand, or the system becomes unstable. When demand exceeds supply, additional generators are brought online to meet the additional need. If these peak generators cannot meet demand, the system may experience brownouts because there is insufficient power to meet everyone's needs. In the worst case, the system becomes so unstable that safety mechanisms activate to take parts of the grid offline. This is known as a blackout.

The highest demand for energy is typically during mid-afternoon in the hottest part of summer, when industry is operating at maximum output and commercial buildings are operating air conditioning at maximum capacity. Shutting down unnecessary equipment during these periods is one way to reduce the need to bring peak generators online. Peak shaving means shaving demand from peak times during the day, and shifting that demand to off-peak times. Utilities often charge lower rates during off-peak times, providing an incentive for users to shift the timing of their demands to these periods. Thermal storage systems can exploit this opportunity very effectively: energy is used at night to super-cool a thermal storage medium, which then absorbs heat to provide cooling during the day.

Building energy management systems use electronic controls to balance loads during peak times by reducing the amount of power sent to equipment that is tolerant of voltage variability (like some air conditioners, pumps, fans and motors) while maintaining a steady stream of power to equipment that cannot tolerate this variability (like plug loads from computers). Depending on the local or regional climate for power production, the price for electricity during peak hours can be quite high. In many areas, investments in equipment and controls to balance loads can pay back rapidly. Often, utility companies will finance or invest in these systems for built facilities. They may also provide technical assistance to support implementation.

After reducing demand, optimizing efficiency and balancing loads, a final strategy is to explore alternative sources of energy. Two primary ways exist to obtain alternative energy: buying energy from a green power provider, or generating power on site. The first approach, buying from a green power provider, depends on whether a provider exists in the area. Green power providers generate electricity from renewable energy sources such as wind power and solar power, while avoiding non-renewable power sources such as fossil fuels. Even if local power companies do not sell green power, offsets can be purchased from firms that specialize in brokering ‘green tags’ that represent carbon saved by other organizations.

Energy-efficiency strategies

- Optimal equipment sizing.
- Tankless hot water heaters.
- Optimized distribution systems for heating, ventilation and air conditioning (HVAC) and hot water.
- High-performance lighting.

An alternative is to explore the possibility of on-site renewable energy generation such as photovoltaics, wind turbines (see Figure 6.10), gas-fired microturbines, fuel cells or micro-hydro generation. If you have previously explored options for reducing, optimizing and balancing energy demands, it is possible to minimize the size of this investment. Given the difficulty of storing electrical energy, the most effective way to use on-site alternative power systems is with a grid inter-tie, which allows for selling excess power back to the electrical utility when a surplus is generated. Power can also be purchased from the utility when the on-site system does not meet demand. It also avoids the need for costly and high-maintenance battery storage systems as part of the generation system. With photovoltaic systems in particular,

Figure 6.10 Small-scale, vertical-axis wind turbines can be used to provide renewable energy

peak capacity falls at the same time of day as peak demand (during the afternoon), possibly resulting in higher rates being paid for excess power during this time. In parts of the country where there is not much excess generating capacity, utilities may provide financing and technical assistance to help pay for renewable energy systems for interested customers.

Alternative energy sources

Off-site:

- green power provider contracts
- green tags.

On-site:

- photovoltaics
- wind turbines
- gas-fired microturbines
- fuel cells
- micro-hydro.

With demand for energy only likely to grow in the future, designers need to be aware of opportunities to manage consumption of electrical power in built facilities. Energy investments save money over the life-cycle of a facility. They can also increase the ability of the facility to withstand fluctuations in power supply. This reduces vulnerability to natural disasters and other threats. As the world's need for and dependence on power grows, the vulnerability of power systems will increase as well. Facilities with well-managed, minimal energy requirements that include passive systems for lighting, heating and cooling, and on-site power generation capabilities, will be the least vulnerable to fluctuations in power (and prices) from utility suppliers.

Water and wastewater performance

Priorities for water and wastewater

- Eliminate unnecessary uses of water.
- Increase efficiency of water use.
- Develop alternative water sources.
- Develop alternative wastewater sinks.

The next category of best practice deals with sources and uses of water for a facility and sinks for its wastewater. Nearly all facilities require a source of water to meet the needs of occupants such as drinking, washing and waste disposal. Sometimes this water must be drinkable, but other times drinking-water-quality water is used for purposes where it is not really needed. While water appears to be abundant on our planet, less than 3 per cent of all water on Earth is fresh water. The remaining 97 per cent is salt water, which is mostly unusable for human purposes. Of the small percentage of fresh water available, 69 per cent is trapped as ice and snow cover, 30 per cent is stored as groundwater, and less than 1 per cent is available on the surface as fresh water lakes and rivers (UNEP 2002). While it is true that the hydrologic cycle continues to recharge sources of fresh water supply through precipitation, runoff and groundwater infiltration, in many areas the rate of use exceeds the recharge rate, leading to aquifer depletion.

To conserve this precious resource, the most important tactic is to eliminate unnecessary uses of water, followed by increasing efficiency of the water usage. For existing facilities, a careful water audit is critical to identify opportunities for improvement and find and repair leaks that waste water. For new facilities, proper commissioning of water systems will ensure that all such systems are installed properly and function according to their design intent.

Another way to eliminate water use is to install water-free toilets and urinals. Waterless urinals exploit the fact that urine is a liquid itself and does not require water to be conveyed through wastewater pipes. Waterless urinals use a special trap with a low-density fluid or gel to provide a seal that allows urine to pass through but prevents sewer gases from escaping (see Figure 6.11).

Alternative toilets are also available that require no water to flush. Composting and incinerating toilets function without the use of water, and collect and dispose of human waste. Composting toilets function most effectively with either a passive or powered ventilation fan, depending on use. These toilets convert human waste into harmless compost that can be used as a soil amendment on-site. Incinerating toilets use electrical energy or other fuel to literally burn away human waste, leaving an ash residue that can be disposed of more easily. The energy required to power an incinerating toilet is considerable, though, and should be taken into account as a tradeoff against the water savings offered by these toilets.

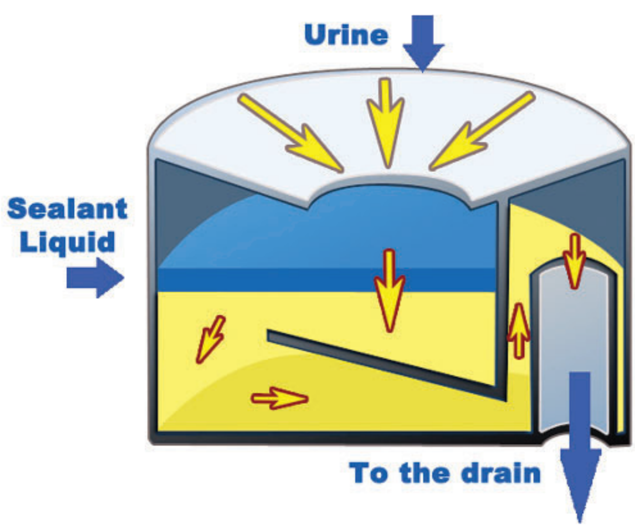


Figure 6.11 The design of a waterless urinal trap uses gravity and a viscous fluid instead of water to convey liquid waste

Water efficiency tactics

- Water-efficient fixtures.
- High-efficiency toilets/alternative flush mechanisms.
- Water-efficient landscaping.
- High-efficiency appliances.

The second tactic is to increase the efficiency of water uses that cannot be eliminated. A wide variety of fixtures are now available on the market to increase the efficiency of water use in showers and sinks. Aeration, the introduction of air into the water flow, is a common technique to reduce the actual flow of water in taps and shower heads while maintaining the perception of high volume flow. While this is a useful tactic for washing, it can be frustrating when the aim is to fill a container with water for cooking, cleaning or other purposes. Many aerated kitchen faucets provide a lever that allows the user to control the degree of aeration and restore full flow when needed. Other types of alternative controls include foot-operated sinks, which allow precise control of flow timing while leaving hands free. More precise automated flow controls are also becoming available for sinks and toilets.

Figure 6.12 This flushometer valve can provide either a half-volume flush or full-volume flush, depending on what is needed

Toilet technology has improved considerably over the last decade, with multiple options available to improve the efficiency of water use. In addition to conventional low-flow toilets, several manufacturers now offer dual-flush toilets that allow a full-volume flush for solid waste and a half-volume flush for liquids. On the commercial level, dual-flush flushometer valves are available that are indicated by a green plunger on the unit. Moving the plunger up results in a half-volume flush, and pushing it down produces a full-volume flush (see Figure 6.12). The manufacturer of this technology has also released an automated dual-flush control unit which dispenses either a regular or low-volume flush based on how long the user is within range of the flush sensor. Manual controls are also included with this unit to allow users to control the flush level if desired. An interesting addition to tank-type toilets is the tank-top handwashing unit. This unit directs potable water through a tap fixture incorporated on the tank lid. Users can wash their hands following use of the toilet, then the wastewater from handwashing is collected in the tank and used for the next toilet flush. These units are available both as retrofits.

For landscaping uses of water, drip irrigation provides a slow release of water directly to the root zone of the plant, avoiding much of the evaporative losses from more common sprinkler systems. Moisture sensors and timers control the operating periods of irrigation systems, ensuring that water is only dispensed when needed and during the early morning when it has time to reach plant roots before evaporating. With both types of system, it is critical to properly locate and maintain all components of the system.

Water-efficient appliances also present an opportunity to increase the efficiency of water use. High-efficiency dishwashers and washing machines are now available that reduce water use by up to 50 per cent over conventional units. Since these units use less hot water, they also save energy.

A third option for increasing sustainability of water use is to seek alternative sources of water, particularly for uses that do not require water to be treated to drinking-water standards. Much of the water used in homes and businesses does not require this high level of water quality, offering the potential to save considerable amounts of energy presently used for water treatment and conveyance.

Alternative water sources

- Rainwater harvesting.
- Greywater recycling.
- Water reuse.

With water scarcity becoming a more serious issue worldwide, rainwater harvesting systems are becoming increasingly common. These systems require a collection surface, typically a roof, that is relatively debris-free and made from a chemically stable substance. Older metal roofs often used lead-based solder at the joints, and are not suitable candidates for rainwater harvesting because of the potential for lead contamination of the water source. Asphalt shingles are also not recommended since they tend to shed particles of sand as they age. Metal, slate and synthetic roofs are all good candidates as collection surfaces. In addition to the collection surface, rainwater systems also require filtration, storage, overflow, and piping to connect components (see Figure 6.13). Most existing roof drainage systems can be easily retrofitted to accommodate rainwater harvesting, provided the collection surface is suitable.

Figure 6.13 This residential rainwater collection system has three underground storage tanks

Another alternative source of water is greywater – the water from sinks, showers and laundry facilities that has been used but does not contain human pathogens. Water from toilets and dishwashers is considered to be blackwater, since it contains pathogens either from human waste or from animal fats associated with dishwashing. Unlike greywater, blackwater requires additional levels of treatment before it is suitable for reuse. Full-building greywater systems can be designed to capture greywater for use in irrigation or for toilet flushing. Separate waste piping is required for greywater and blackwater, in addition to storage receptacles, filtration and piping. The design of greywater systems to meet code requirements often requires special attention, since greywater is an excellent harbour for bacterial growth if it is stored for any length of time. Provisions must be made to balance supply with demand and to ensure that greywater does not remain in the system for a significant length of time before it is reused or disposed. Small-scale greywater systems are also available that can capture water from one fixture such as a shower and divert it for use in an adjacent fixture such as a toilet. These small systems can often be designed to fit under a bathroom sink, and work well for retrofit situations where the opportunity to install dual piping is limited.

A third option to be explored at the infrastructure scale is water reuse – the direct recovery of water following wastewater treatment and repurposing for landscaping or non-potable uses. In some cultures, water reuse faces a significant psychological barrier, even though most treated potable water is ultimately derived from the wastewater of upstream communities. However, water reuse is receiving increased attention in areas such as the southwestern United States, where existing reserves of water are dwindling and climate change threatens ongoing supply. Reused water is recovered directly from municipal or local treatment facilities and provided through separate piping for non-potable use in buildings. It is essentially the same approach as greywater recycling, but on a municipal scale.

A final opportunity to increase the sustainability of a building's water systems involves finding alternative uses or treatments for the wastewater generated. In addition to greywater and blackwater, a building's wastewater stream also typically includes stormwater, which may be contaminated with particulates or drips from parking lots and roofs, and is likely to also be at a much higher temperature than local streams. Alternative treatment systems are available to treat all of these types of wastewater streams. For instance, greywater systems can capture water that has not been heavily contaminated and redirect it for certain uses without treatment as permitted by code. These systems can also be the first step in a more comprehensive system, where lightly contaminated water is recycled for heavier use, then treated on site using a separate system.

One type of alternative wastewater technology that can handle all levels of contamination is plant-based constructed wetlands (Figure 6.14). Constructed wetlands have been used in a variety of climates and for a variety of applications, both small and large. The series of ponds is filled with plants that provide increasing levels of treatment to water as it cycles through. The system is preceded by a primary treatment step that removes solids from the water stream. Following treatment, wastewater is discharged to a local stream. Smaller scale plant-based wastewater treatment systems are also available, and can be sized to treat the wastewater from a single building or multiple buildings. Living Machines are one such technology; they include plants, bacteria and other organisms as part of a simulated ecosystem that uses wastewater as a nutrient source.

Figure 6.14 Constructed wetlands can handle multiple types of wastewater

Materials optimization

Priorities for materials optimization

- Eliminate unnecessary use of materials.
- Increase the efficiency of materials use.
- Seek better sources for material supplies.
- Find better sinks for material waste.

The materials used to construct facilities and to operate and maintain them over their life-cycle are one of the biggest contributors to their impact on the natural environment. For infrastructure projects such as highways and bridges, materials represent the largest impact these facilities have over their life-cycle. In addition to the raw materials used to build, operate and maintain a facility, solid waste also contributes to a facility's impact on the natural environment. Increasing the sustainability of materials use and solid waste generation starts by eliminating the unnecessary use of new materials. This includes using materials that come from waste, salvage or recycled sources. It also includes reusing and adapting existing buildings instead of building new, or deciding that a new building is unnecessary.

Pollution prevention is the careful design of products and processes to eliminate the use or waste of materials in the first place. One example in building construction is to eliminate finishes and expose structural materials instead. For example, concrete floors can be stained, polished or textured to create beautiful surfaces that do not require additional finishes. Exposed ceilings and structure eliminate the need for extensive dropped ceiling systems, and can provide visual interest while saving costs (see Figure 6.15).

Figure 6.15 Exposed ceilings eliminate the need for materials in a dropped ceiling

Salvaged materials can also be a very environmentally friendly contribution to projects. If an existing building is being demolished, there may be ways to reuse materials in the new building. Often, concrete and masonry rubble can be reused for fill, subbase for pavements, or drainage. Sometimes, materials from demolished buildings are higher quality than those that are available new. Timber in good enough condition can be reused for structure, or remilled for flooring or siding. Masonry units may be reused as well. Materials that cannot be reused on new projects may be valuable for salvage in other projects.

Green materials strategies

- Reuse existing facilities and materials.
- Employ pollution prevention.
- Use salvaged materials.
- Use materials with recycled content.

New materials with recycled content also reduce the use of virgin materials. Recycled content materials range from steel to concrete to a wide variety of finishes, structural materials and landscaping materials (see Figure 6.16). Recycled materials like steel and concrete may be impossible to distinguish from virgin materials. Other products may include recycled content as composites. Recycled plastic lumber (RPL) is one such product. RPL combines post-consumer or post-industrial plastic waste with wood fibres or other materials to produce an extremely durable wood substitute.

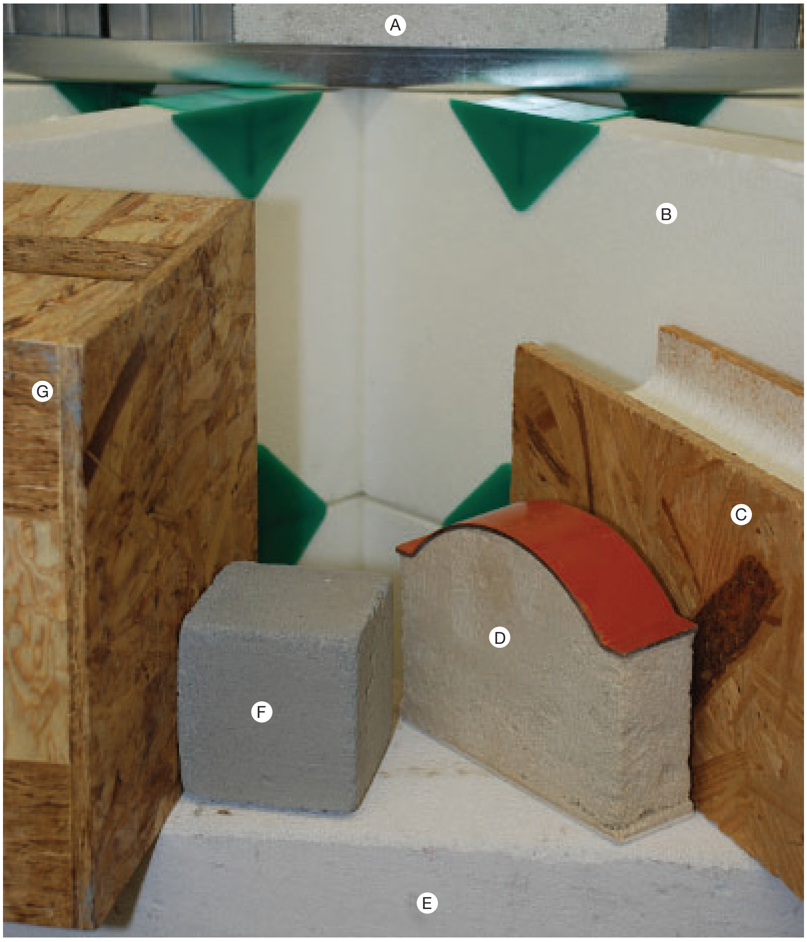
Recycled content can come from a variety of sources. Some recycled content such as flyash is produced as a by-product of manufacturing processes. This material is called post-industrial or pre-consumer recycled

A. Recycled plastic lumber
B. Insulating concrete form material with recycled polystyrene pellets
C. Recycled rubber turf stabilizer
D. Recycled paper fibre board
E. Recycled paper fibre countertop
F. Recycled rubber shingles
G. Recycled content carpet (face fibre and backing)
H. Salvaged lumber
I. Recycled paper and glass cement tiles
J. Recycled glass countertops
K. Recycled rubber flooring

Figure 6.16 Recycled content construction materials

content. It can be recovered and reused as feedstock for other manufacturing processes. Other recycled content comes from products that have been produced and used by consumers, then recovered for recycling. This material is called post-consumer recycled content, and it is preferable to post-industrial recycled content because it truly closes the material loop. Post-industrial recycled content represents waste or inefficiency in manufacturing. Rather than recycling this material, it would be better to improve the manufacturing process to eliminate the waste in the first place.

A second tactic for increasing material sustainability is to make more efficient use of materials. This means getting more benefit from the materials that are used, or using fewer materials to achieve the same benefit. One way to do this is to use multi-function materials. Multi-function materials do more than one thing as part of a building. They can considerably speed up construction along with saving building materials and reducing waste. Every system and technology used in a project comes with overhead – the extra packaging, transportation and other costs that do not add value to the product itself. When one product serves multiple purposes, the amount of overhead for the system is a fraction of the overhead associated with the multiple systems it replaces. Many multi-function materials serve as the primary structure of the building, such as insulating concrete forms (ICFs), structural insulated panels (SIPs) and aerated autoclaved concrete (AAC) (Figure 6.17). Each of these structural systems also serves as the building enclosure, insulation system, and mounting surface for interior and exterior



A. Embedded steel stud SIP
B. Polystyrene insulating concrete form
C. Polystyrene stress skin SIP
D. Aerated glass stress skin SIP
E. Aerated autoclaved concrete
F. Fibre-reinforced aerated concrete
G. Straw core stress skin SIP

Figure 6.17 Multi-function construction materials

finishes. When these products are used, the construction of one system achieves as much as three or four traditional building systems. This saves time, labour, packaging, transportation and ultimately money.

An energy-related example of multi-function materials is building-integrated photovoltaics (BIPVs). These solar panels are built into components that play other roles in a building. For instance, some are incorporated as coatings on windows and can generate electricity whenever the sun shines on the window. Other BIPVs are manufactured as solar shingles – they generate power while acting as the roof itself. Still others are used as shading devices for windows or parking lots.

Green roofs are a second example (see Figure 6.18). These vegetated roofs have been used in Europe for many years, and are recently

Figure 6.18 Green roofs provide a number of functions to serve the building, including thermal buffering, stormwater management and aesthetics

becoming more popular in the United States, as the energy benefits and benefits for roof life are demonstrated. Green roofs provide enclosure, stormwater management and thermal control while cleaning the air and providing a habitat for birds and insects. Green roofs are typically installed on top of a roof membrane, and can be of varying complexity. They help to ballast the roof itself. They also protect the membrane from solar radiation, which causes the material to break down. They stabilize temperatures on the roof, which also reduces stress on the roof membrane and keeps the building cooler. They help to absorb rainfall, reducing the rate at which stormwater runs off the site. Finally, they are a microhabitat for birds, insects and plants. They help to clean the air. This single system, although it may cost more than a traditional roof, provides significant benefits that can make it a good investment. All benefits and costs must be considered together when making a decision on what kinds of system to use.

Another approach is to use smart materials, which work by changing in response to environmental conditions. For instance, smart windows may automatically increase their level of tint in response to higher levels of sunlight. Smart window blinds or mounts for solar panels may automatically adjust to follow the sun's path. Some materials are under development that can change colour or other properties as well.

New generations of lightweight modularized construction systems are now available that can also do more with less. Prefabricated, factory-assembled building components reduce waste and use materials more efficiently since they are manufactured in a controlled environment. Production of multiple runs allows manufacturers to optimize the use of materials and produce the most efficient components possible. Modular construction components include carpet tiles, raised floor systems and demountable furniture systems. These systems allow rapid reconfiguration to meet changing user needs. They also permit replacement on a unit-by-unit basis in the case of damage, avoiding the need to replace entire rooms of carpet when there is one stained or worn area (Figure 6.19).

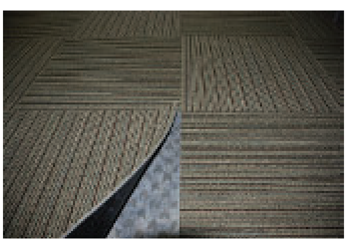


Figure 6.19 Carpet tile is a modular material that reduces waste and speeds installation

Seeking better sources for materials can help to ensure an ongoing supply of products to meet the needs of future generations. Substituting abundant, renewable materials helps to preserve the limited supply of non-renewable resources. Ensuring that materials are sustainably harvested means that the supply of those materials can continue indefinitely. Using local materials also helps to reduce the impacts of transportation of raw materials while supporting local economies.

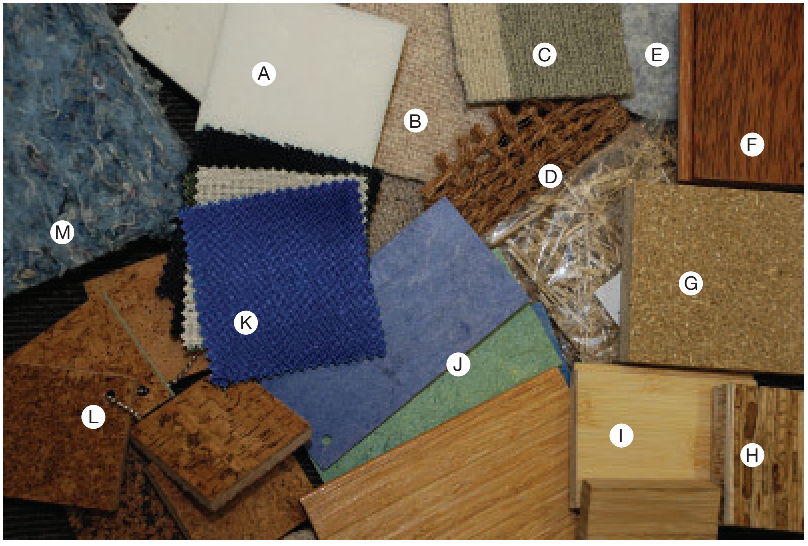
Properties of green materials

- Abundant.
- Renewable/rapidly renewable.
- Sustainably harvested.
- Local/regional.
- Bio-based.
- Recyclable.
- Recycled-content/waste-based.
- Non-toxic.

Rapidly renewable materials are a special class of materials that can be regrown quickly (see Figure 6.20). According to the US Green Building Council, a rapidly renewable material is any material that can be sustainably harvested on a less than ten-year cycle. Examples of rapidly renewable materials are bamboo, cellulose fibre, wool, cotton insulation, corn-based carpet, blown soy insulation, agrifibre, linoleum, wheatboard, strawboard and cork. Each of these materials is also bio-based – they are made from plant products.

Other materials can be considered green because they are abundant. Buildings made from soil – rammed earth, adobe or cobb construction – fall into this category. Some earth-based construction methods include small quantities of cement or lime to provide additional strength. An innovative material in this category is Papercrete, a fibre cement product that uses waste paper for fibre.

Strawbale construction uses abundant bio-based materials. Straw bales used for this purpose are typically three to five times more densely packed than agricultural bales. Strawbale construction can be either structural or used as infill with a wood frame or other structure. Bales are stabilized by hammering rebar or bamboo spikes through the layers. Bond beams are used to ensure a load-bearing surface along the tops of walls. Proper detailing to prevent moisture intrusion is critical for success. Deep overhangs and moisture barriers between bales and foundations are common. Straw bales can have very high insulating value and a two-hour or greater fire rating depending on the exterior and interior finishes.



A. Soy-based foam insulation
B. Wool carpet
C. Corn-based carpet fibre
D. Coir/straw soil stabilization mats
E. Corn-based carpet backing
F. Coconut wood flooring
G. Wheat straw fibreboard
H. Sorghum board
I. Bamboo flooring/plywood
J. Linoleum
K. Hemp fibre fabric
L. Cork flooring
M. Cotton fibre batt insulation

Figure 6.20 Rapidly renewable construction materials

Case Study: Living Wall - Hotel InterContinental, Santiago, Chile

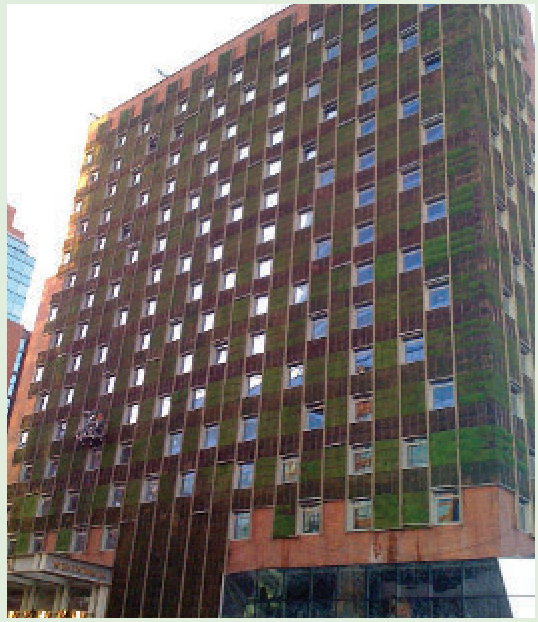
Located in Santiago's Financial Center, the InterContinental Hotel recently installed one of the largest living wall systems in the world as part of a new 16-storey addition to the existing hotel. The 17,000 sq ft modular green wall was installed on the southern and western elevations by local contractors, and features four different types of plants: ophiopogon, ajuga reptans, and ceratostigma mixed with musgo. Automated irrigation is installed to facilitate the health of the plantings, and water sensors control the amount of irrigation to minimize wasted water.

The exterior wall system is anticipated to provide a variety of benefits, including:

- savings of between 40 and 60 per cent on cooling costs due to shading and evapotranspiration
- sound dampening of noise from adjacent streets
- removal of pollutants from surrounding air.

An interior living wall is also installed in an atrium off the lobby of the club tower, providing a welcome quiet space for guests to relax and enjoy the ambience.

Source: Greenroof Projects Database (2011). 'Hotel InterContinental, Santiago, Chile.' <www.greenroofs.com/projects/pview.php?id=1205> (accessed 28 September 2011).



Living wall modules cover the western and southern façade of the club tower

An interior atrium features a living wall that provides a quiet and peaceful venue for hotel guests

Automated irrigation with water sensors provides water to the variety of plants in the interior and exterior living wall systems

Sustainably harvested materials offer another more sustainable option. The Forest Stewardship Council (FSC) is an organization that evaluates wood products to determine whether their harvest is sustainable. Sustainable harvest means that wood is harvested in such a way that it could continue to be harvested indefinitely without degrading the forest source.

Wherever possible, local sources of materials should be sought out for projects. Using locally produced materials reduces one of the biggest impacts of building materials – the energy required to transport them. Often, locally harvested materials can be obtained at less cost than imported materials. Using local materials can save time for procurement, and also helps support the local economy. Finally, finding better sinks for waste materials generated by facilities reduces environmental impact. On- and off-site recycling and using biodegradable or reusable packaging are some of the ways to improve performance in this area.

As the world population continues to grow and people demand a higher quality of life, demand for raw materials will only increase over time. Smart use of materials for construction can help to ensure an ongoing supply of materials to meet human needs both now and in the future.

Indoor environmental quality

Contemporary humans spend over 90 per cent of their time indoors in some countries, often in climate-controlled buildings that are sealed against leakage to maximize energy efficiency. At the same time, the materials used to build those structures have become largely composite and/or synthetic. From carpets to engineered wood products, the indoor environment now consists of products that are made from and emit chemicals over their life span.

Priorities for indoor air quality

- Prevent problems at their source – avoid toxins in buildings.
- Segregate contaminants from occupied areas.
- Increase ventilation to dilute contaminants.
- Ensure proper building maintenance.

Together, these factors have led to a sharp increase in building-related symptoms of ill-health. Sick building syndrome is a disease associated with symptoms that occur whenever people occupy a particular building. These symptoms include headaches, fatigue, and other more severe problems that increase with continued exposure. With increased concerns for energy conservation, building operators often reduce ventilation rates in unoccupied spaces or during nights and weekends. Reduced ventilation rates plus more airtight buildings plus more chemical emissions from building products inevitably leads to problems. On top of all this, many products in modern buildings such as drywall, carpet and ceiling tiles serve as excellent food sources for mould. Inadequate ventilation, moisture and food sources have led to explosions of mould growth in some construction projects, with disastrous results for building occupants. Humans also contribute to the problem by virtue of their activities. The basic act of breathing increases carbon dioxide levels in a room. Higher concentrations of carbon dioxide can lead to drowsiness, reduced productivity, or even headaches and discomfort. Activities like smoking, cooking or operating printers and photocopiers contribute pollutants to the indoor air.

The indoor environment is critical for a building to do what it was designed to do. Keeping occupants happy, healthy and productive is essential for good business and stakeholder satisfaction. The first tactic is to prevent potential problems at their source, before they have a chance to create a problem. Often, decisions made during the design of a building can have a huge impact on indoor environmental quality. For instance, locating buildings upwind of major pollution sources such as power plants and away from noise sources like highways can eliminate the need to try to mitigate these problems later. Careful placement of air intakes for ventilation systems can also prevent problems. All vents and exhaust areas should be located downwind from air intakes, and the features of neighbouring buildings should be considered when deciding where to locate air intakes and exhausts.

Figure 6.21 Composite products can offgas VOCs

The materials used to construct the facility have the potential to create problems as well if they are not carefully selected. Many modern finishes such as paints, sealants, carpets and composites contain solvents and adhesives that release volatile organic compounds (VOCs) as they age (Figure 6.21). If occupants can smell an odour, the product that caused it is already on its way to their lungs. Products should be specified that contain minimum or no VOCs to avoid this problem. Most major paint producers now have lines of low-VOC paints that perform just as well and cost about the same as traditional paints. Carpets can also be certified for indoor air quality.

Proper drainage, exterior detailing and landscaping can help to prevent water intrusion into the building envelope. Whenever water or moisture exists at moderate or warm temperatures with an available food source, mould or mildew is likely to grow. Careful detailing and maintenance can help to prevent this problem, along with proper and adequate ventilation. In particular, the areas surrounding the facility must be graded to properly drain water away from the building to prevent moisture problems in basements and crawl spaces.

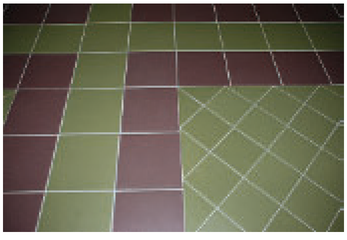


Figure 6.22 Non-absorptive finishes such as this recycled glass tile floor are easy to clean and do not trap particulates and vapours

Careful selection of landscape plants can also help to prevent problems. Many ornamental trees and shrubs produce considerable pollen, as do species such as olive, acacia, oaks, maples and pines. Pollen produced by these trees can aggravate allergies as well as contaminating air intakes and rainwater harvesting systems.

Indoor air quality can be improved by specifying finishes that are non-absorptive such as stained/polished concrete, tiled floors and painted walls (Figure 6.22). Not only are these finishes easier to clean, they do not trap particulates and vapours that can later be released to cause occupant discomfort. Choosing finishes with biocides or mould-resistant coatings can also help to prevent problems. Natural linoleum, for instance, has biocidal properties and is a good choice for flooring for this reason.

A second major category of tactics in achieving good indoor environmental quality is to segregate activities and materials that create pollution from other parts of the building. This also applies to segregating the building itself from polluters in surrounding areas. Activities often occur within buildings that have the potential to introduce contaminants into the indoor environment. These include but are not limited to kitchens, office equipment rooms, housekeeping areas, and chemical mixing and storage areas. Research has shown that the primary sources of indoor chemical pollutants are ordinary consumer products like paint, cleaning compounds, personal care products and building materials. Everyday tasks such as bathing, laundering, cooking and heating can all contribute to poor indoor air quality.

Separate ventilation should be provided for areas where these activities take place to minimize the risk of pollutants spreading to other parts of the building. In addition, these areas may be isolated from other spaces in the building through full deck-to-deck partitions and sealed entryways, depending on the risk level of contamination. Indoor smoking areas are special cases that require careful design and construction to ensure that non-smokers do not receive exposure to environmental tobacco smoke.

Entrance control is important to keep dirt and pollutants outside the building from getting inside. Air lock entryways and vestibules are one approach that can also save energy by keeping conditioned air inside the building and unconditioned air out (Figure 6.23). These and other entry areas can benefit from the use of walk-off mats and dirt collectors, particularly in areas where inclement weather may lead to snow and ice being tracked into the building. Walk-off mats are also available for use outside construction areas to help prevent contamination of other areas of the building.

Figure 6.23 Vestibules both save energy and improve indoor air quality

Additional strategies for indoor air quality include increased ventilation rates and proper maintenance. Increased ventilation rates can help to ensure that any contaminants within occupied areas are exhausted and replaced with fresh air. The American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) specifies recommended ventilation rates by type of occupied space that should be considered minimums for design. Increasing ventilation in mechanically conditioned spaces also can increase energy use and introduce problems with humidity if not carefully controlled, so these issues must also be considered in developing an effective ventilation strategy. Proper maintenance is also critical for indoor air quality, and green housekeeping plans are discussed further in Chapter 8 as a means to achieve this requirement.

Other aspects of the indoor environment extend beyond air quality. A variety of natural forces, from psychology to physics, can affect the indoor environment. Paint colours influence the user's experience of a space. They can be employed to create different perceptions in different ways. The laws of physical science can also be used to provide natural lighting, ventilation, heating and cooling in a space. This not only saves energy, it can provide better indoor environmental quality for occupants.

Natural daylight can be used to enhance the indoor environment in many ways. It can also cause problems if not managed well, like excessive heat gain, fading and glare. Light shelves are one way to incorporate daylight into a space without overheating spaces along the building perimeter. Light shelves bounce sunlight onto the ceiling of a room and reflect it further back into the building space. In combination with reflective or light-coloured ceilings, light shelves spread the benefits of natural light throughout a space. Natural ventilation, when carefully designed, can also create a comfortable indoor environment with minimal energy, but its success is often a function of ambient humidity levels.

Giving users control over their environment is an effective way to improve indoor environmental quality from the standpoint of building occupants. A variety of technologies old and new are available to provide this function, and the effects on building users can be significant. Studies have suggested that occupants who can control their spaces are happier, have greater job satisfaction, take fewer sick days and are more productive.

Figure 6.24 Operable windows give building occupants control over their environment and enhance the building's ability to survive power outages

Operable windows (Figure 6.24) have gone in and out of vogue in architectural design over the past decades. Traditional buildings without mechanical heating and cooling had operable windows to allow users to control the indoor climate. Many contemporary buildings, however, have mechanical systems whose operation can be impeded with uncontrolled introduction of outside air. For this reason, many commercial and institutional buildings do not include operable windows, which can create a threat to passive survivability if the power supply to run mechanical equipment becomes unavailable. In many climates, operable windows can be used in lieu of mechanical ventilation during the swing seasons (fall and spring) when outdoor temperatures are mild. This can save considerable energy for operations. It also contributes to user satisfaction with the space.

Lighting, temperature, humidity and ventilation controls are also becoming more sophisticated in modern buildings. Many commercial buildings rely on elaborate sensor and control systems to control these variables. However, each individual user of a building is different. Not all users are comfortable with the same environmental conditions. Providing individual controls at each workstation or office can help users adjust conditions to meet their individual needs and increase their satisfaction with the space.

Under floor air distribution systems (UFADs) increase the level of control users have over their individual workspaces. UFADs provide the ability to control ventilation rates and perceived temperatures at each individual workspace. These systems also increase ventilation effectiveness and promote a more uniform flow of conditioned air through the workspace. UFADs used in office environments can be combined with modular office furniture to allow rapid reconfiguration of space to meet changing user needs. They maximize the ability to make adjustments to space while maintaining proper ventilation and space conditioning in each work area. Modular control units can be moved around the space to provide airflow wherever users are located. This level of flexibility and control means that users are happier in their workspace and less likely to need supplemental space heaters or fans to be comfortable.

Integrated strategies

Many of the tactics and technologies described in the previous subsections offer multiple benefits for the natural environment. The challenge for the designer is to find integrated green solutions that meet the owner's needs for a facility, do not damage natural ecosystems or deplete resource bases, and do not exceed the project budget. Building systems are inherently related to each other. The design of one system affects the design of another. For instance, increasing the weight of the structure means that the foundations have to be increased as well. Sometimes these relationships can be exploited to pay for investments in one system through savings in another.

Integrated strategies for sustainable buildings and infrastructure systems

- Integrated systems design.
- Dematerialization.

For instance, integrated design means that larger areas of high-performance windows might be included as part of the building envelope design to provide for daylighting (raising total project cost), but the benefits of better envelope performance and reduced heat load from light fixtures are recouped by reducing the capacity of the building cooling system (lowering total project cost). Additionally, a smaller HVAC system might mean smaller pumps, fans and motors, reduced duct sizes, smaller plenums and reduced floor-to-floor height, also reducing the cost of the facility. Reduced floor-to-floor height means less surface area of the building envelope, which means lower material costs for the system. It also means that the overall weight of the building is reduced, meaning that foundations can be smaller and more efficient as well.

In the end, the overall increase in the total first cost of the project may be negligible if the benefits of improving one system are captured in the design of related systems. More importantly, life-cycle cost savings can be even bigger with these more efficiently designed systems. HVAC systems in particular will be much more efficient if they are right-sized for the facility, allowing them to operate at maximum efficiency over the life-cycle of the facility.

Another strategy being used to green construction projects is dematerialization. Dematerialization refers to using services instead of products to meet user needs. Office managers have successfully used this concept for years, for example, in the form of photocopiers that are most likely leased rather than owned. Instead of buying the machine, the user pays a per-copy charge to the company that owns and maintains the machine. Rather than take ownership responsibility (and associated liability) for equipment, the user pays another company to provide the benefits of that equipment. That company, often the manufacturer of the equipment, has an incentive to provide the most efficient equipment possible The company makes its profits based on a profit per unit of service provided. It also has incentive to design products that can be easily repaired, upgraded or disassembled, since it retains responsibility for the ongoing maintenance and eventual disposition of the equipment.

Figure 6.25 A leased fuel cell is an example of a dematerialization strategy

A variety of building systems and components, ranging from roof systems to flooring to mechanical and electrical systems such as fuel cells (Figure 6.25), are available as services from companies that will install appropriate systems to provide a level of performance defined in the contract on a fee or pay-for-performance basis. Some companies also incorporate maintenance services to optimize the performance of their systems. Manufacturers typically know more about maintaining their products than anyone else. Often owners can afford higher performance on a lease basis than they can buy outright.

When considering what actions to take on a project, making smart choices is critical. Every action taken comes with a cost. Recognizing those costs and considering the benefits of those actions can result in actions that achieve their intended results. An important issue to consider is whether users will have to change their behaviour to achieve the desired effects. Some changes are completely transparent to users, whereas others require significant change in habits or procedures. Changes are more likely to have the desired outcomes if they do not require people to change their behaviour. When possible, choose solutions that can get the job done without requiring users to change their habits.

The degree to which the change is compatible with existing infrastructure is also important. Some changes, like lighting retrofits, can be as simple as changing a light bulb. Other changes may not be compatible at all with existing buildings, or may not be possible given the skills and equipment of the construction crew. Look for easy changes that can be undertaken with existing skills and tools wherever possible.

Case Study: Trees Atlanta Kendeda Center

To illustrate sustainable design opportunities and strategies in the design phase of the facility life-cycle, this section examines sustainable design best practices by conducting two in-depth case studies. The main case study for best practices is the Trees Atlanta building located in Atlanta, Georgia, USA. In conjunction with the case study of the Trees Atlanta building, this book also includes a case study of the Bank of America Tower in New York. As these case projects have incorporated many sustainable design strategies to achieve the goals of sustainability in these buildings, they illustrate a wide range of opportunities related to sustainable design practices in buildings. Best sustainable practices for these buildings are described in five categories, as follows:

- sustainable site
- energy optimization
- water and wastewater performance
- materials optimization
- indoor environmental quality.

The first case study starts describing the features of sustainable site at the Trees Atlanta Kendeda Center.

Sustainable site

Since a building significantly affects natural ecosystems and biodiversity, the selection of a building site has to be the first priority to achieve sustainable design opportunities. After the best site has been chosen, the next most important decision is where to put the building on the site. These two decisions will significantly affect the building's ongoing performance over its life-cycle. Thus, in the Trees Atlanta building project, the project firstly considered a building site that had been previously developed to not only minimize negative environment impacts but also preserve a greenfield or previously undeveloped site that might otherwise have been selected for development. By choosing a site that is already developed, it was possible to reduce pressure on undeveloped land and to use existing municipal service infrastructure to prevent the need for expanded utility infrastructure. In addition, the site choice in this case influences public transportation access and allows building visitors and employees to take advantage of walking and cycling instead of driving a car.

Sustainable site considerations in the Trees Atlanta building

Site selection:

- using a previously developed site and building
- locating in an urban setting with existing public infrastructure
- locating in an urban setting with existing public transportation.

Alternative transportation:

- locating the building near public transport routes
- providing secure bicycle racks and storage
- providing preferred parking for low-emitting and fuel-efficient vehicles.

Low-impact site amenities:

- installing porous surfaces to allow for stormwater retention
- installing bioswales (vegetated water retention)
- installing green roof on the shed building.

Site development:
- conserving exiting natural areas
- restoring damaged areas
- maximizing open spaces
- installing advanced exterior lighting fixtures.

Heat island effect:
- installing highly reflective roof on the main building
- planting Georgia native and adapted trees and vegetables
- installing a green roof
- using an open-grid pavement system.

After selecting the best site possible for the project, the project team determined where on the site to place the building. Orientation and location of the building can present the opportunity to save considerable development costs and heating and cooling costs over the life-cycle of the building. In this case, the building orientation was determined based on constraints of the existing development on the site.

The third consideration related to sustainable site is to achieve an opportunity to develop low-impact site amenities. These include softscape – the vegetated parts of the site – and hardscape – the parts of the site that are paved or otherwise developed. The low-impact amenities in the Trees Atlanta building included planting native trees and vegetables, installing bioswales to absorb and treat stormwater runoff from paved areas, and alternative pavements including a grid system.

The Trees Atlanta building has incorporated sustainable strategies to protect or restore habitat through conserving existing natural areas and maximizing open spaces. In addition, the Trees Atlanta building has installed advanced exterior lighting fixtures to reduce light pollution.

Finally, the next consideration is related to heat island effect to minimize impacts on microclimates and human and wildlife habitats. The Trees Atlanta building included the following strategies:

- Use an open-grid pavement system.
- Plant trees at the time of occupancy to shade the building structure and parking lots.
- Install high-albedo and vegetated roof surfaces.

The following section describes more detail about these sustainable site strategies for the Trees Atlanta building.

Sustainable site selection of the Trees Atlanta building

Trees Atlanta is a non-profit organization, dedicated to protecting and improving the urban environment by planting and conserving trees. Therefore, for its new headquarters, Trees Atlanta found a site that had previously been developed in the city of Atlanta (Figure 6.26). In addition, it made a decision to renovate an old and existing warehouse to become a state-of-the-art facility with many sustainable features because this caused less environmental impact than a new building project. Due to the renovation, the Trees Atlanta building was able to save previously undeveloped land and did not affect land that is prime farmland, is subject to flooding, provides a habitat for threatened or endangered species, is near or includes bodies of water or wetlands, or is available as a public park or open space. In addition, since the project site had been previously developed, it also means there is no need for expanded transportation and utility infrastructure, and affords the building occupants more access to alternative transportation, further reducing the overall environmental impact of the development project.

As the Trees Atlanta building involved converting an existing warehouse to a multi-purpose facility with access to existing infrastructure and public transportation, it was very easy to connect the development

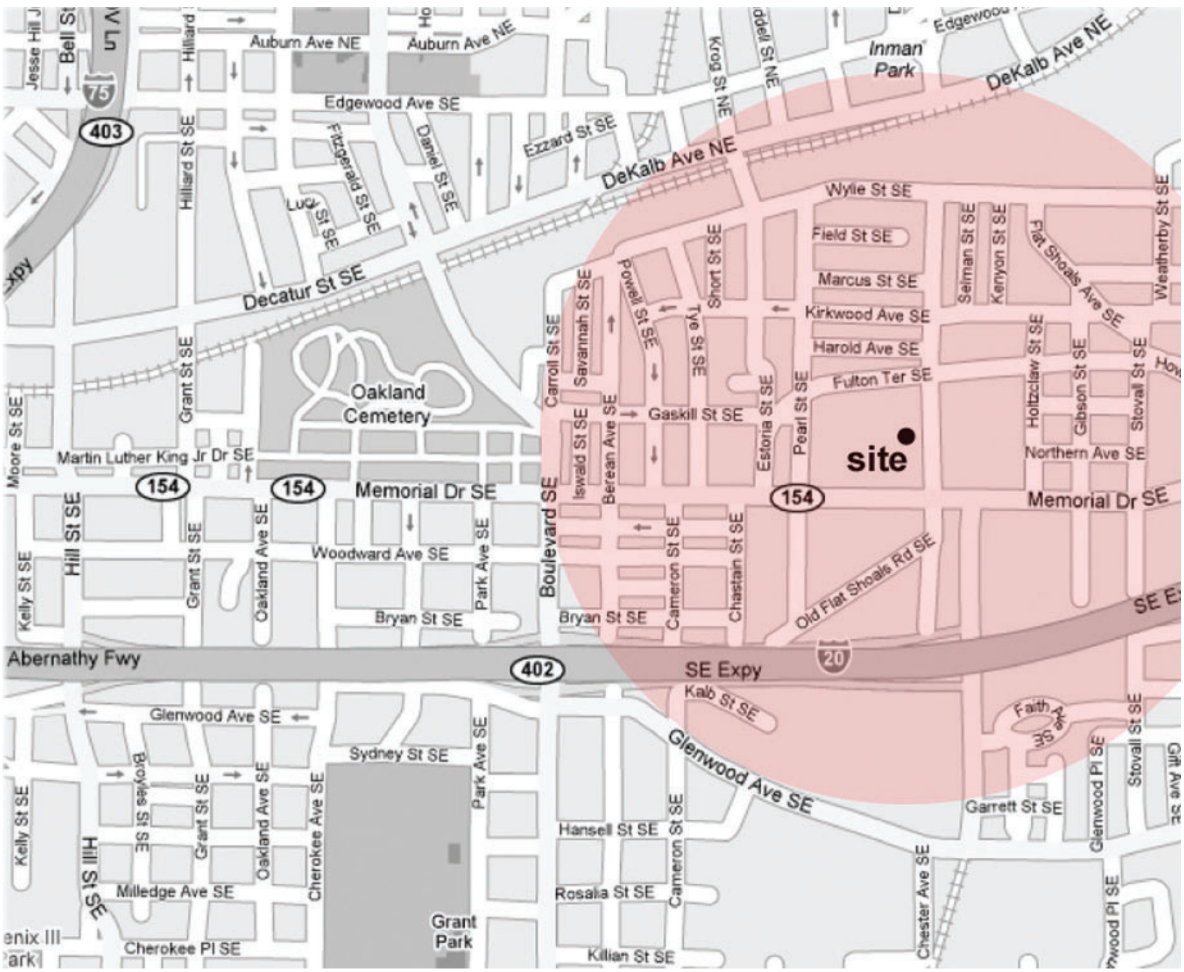


Figure 6.26 The existing facility location near public transport and amenities. Public transport (heavy rail) runs along the train line north of the site, and bus lines run along Memorial Drive just south of the site. Interstate access is available to the west (I-75) and south (I-20). Surface streets provide bicycle and pedestrian access.

with the existing urban community and residential areas and neighbourhoods. In addition, the building is close to basic services such as schools, restaurants, libraries and medical services with good pedestrian facilities, which provides occupants with easy access without cars. This community connectivity also helps to reduce urban sprawl, a growing problem that affects quality of life and requires commuters to spend an increasing amount of time in automobiles. The redevelopment of the Trees Atlanta building in an urban area helped to restore, invigorate and sustain established urban living patterns, and to create a more stable and interactive community. In addition, it reduced the environmental impact from automobile use, minimized the need for installation of basic infrastructure and transportation, and also improved the quality of life of building occupants.

Building location and parking

Even though the building was pre-existing at the site, there were opportunities to incorporate sustainable design strategies. One of the major sustainable strategies was to create a courtyard to provide daylight in the building interior spaces (Figure 6.27). The project team also developed a landscape plan to plant trees that surround the building site with the purpose of providing valuable shade in the summer that can eventually reduce cooling loads. In the winter, these trees lose their leaves and can allow solar energy to reach the building, providing warmth and heat gain.

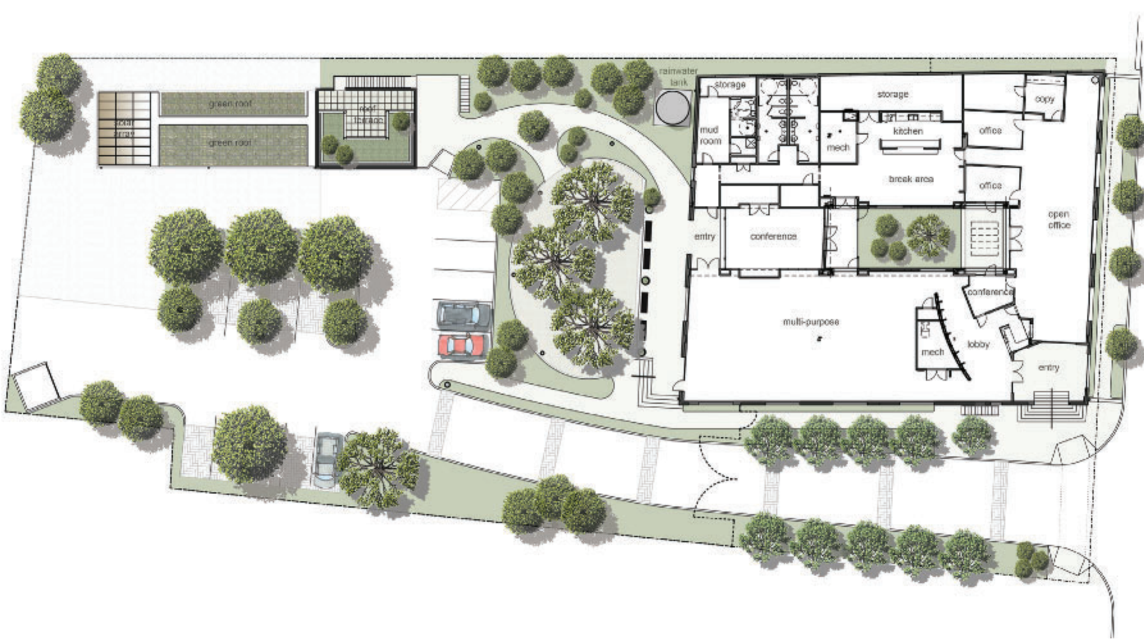


Figure 6.27 Site plan of the Trees Atlanta building

The Trees Atlanta building integrated several sustainable approaches to reduce pollution and land development impacts from automobile use. It was designed to encourage occupants to use alternative transportation with a lower environmental impact. The building is located in an urban area with existing public transportation, and is within a quarter-mile of one or more stops for two or more public bus lines. There are secure bicycle racks/storage with shower/changing facilities inside the building (Figure 6.28). Trees Atlanta maintains several bicycles with safety helmets to lend occupants for relatively short commuting trips.

The Trees Atlanta building provides preferred parking for low-emitting and fuel-efficient vehicles, as shown in Figure 6.29. Finally, it has been sized to meet, but not exceed, the minimum local zoning requirements for parking spaces, and provides preferred parking for carpools or vanpools. Those approaches to minimize private automobile use can save energy, specifically petroleum, and can avoid the associated environmental problems such as vehicle emissions that contribute to smog, air pollution and greenhouse gas emissions, as well as environmental impact associated with oil extraction and petroleum refining. The restriction of the size of the parking lots also reduces the negative impacts on the environment such as stormwater runoff and urban heat island effects from the asphalt surface.

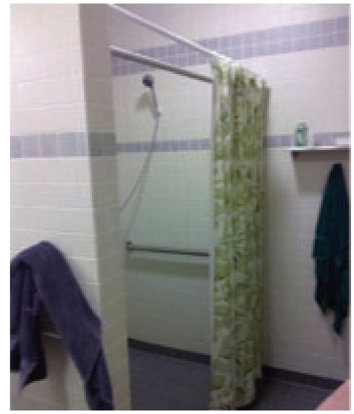


Figure 6.28 Secure bicycle racks and the shower/changing facility

Low-impact site amenities

To develop low-impact site amenities, the project incorporated various sustainable strategies. The first sustainable strategy is to plant native trees and species that require little or no irrigation, fertilizer or pesticides once they are established (see Figure 6.30). Mulch made from ground wood pieces was laid to not only suppress weeds and help retain moisture around landscape planting, but also improve the appearance of landscape and help reduce the need for irrigation and pesticides.

Figure 6.29 Preferred parking for low-emitting and fuel-efficient vehicles is reserved by the sign shown in the photo

These strategies can also reduce the challenges associated with stormwater runoff from the site. Stormwater has been identified as one of the major sources of pollution for all types of water bodies, because large volumes of stormwater runoff can discharge both pollutant loading and excess heat into receiving water, which can seriously damage water quality and harm aquatic life (USEPA 2007). Minimizing stormwater runoff reduces the need for stormwater pipes and infrastructure to convey and treat runoff volumes. The Trees Atlanta building also developed a stormwater management plan to reduce the amount of impervious area and increase infiltration using pervious paving materials, harvesting stormwater for reuse in irrigation and indoor nonpotable water applications, designing infiltration swales and retention ponds, and installing a vegetated roof.

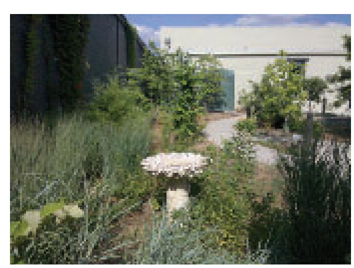


Figure 6.30 Planting native trees and vegetables that require little or no irrigation

To reduce the impervious areas in the parking lots, pervious pavers made of pre-cast brick (see Figure 6.31) were installed to reduce the stormwater runoff flow rate, volume and temperature, and to filter pollutants. This type of pervious paver is one of the less expensive

Figure 6.31 The parking area incorporates pervious pavers to capture stormwater for tree roots and recharge groundwater supplies

Figure 6.32 Rainwater collecting tanks and surface (membrane roof)

strategies from a construction and maintenance standpoint. It also helps recharge groundwater supplies.

Runoff storage capabilities were created by installing rain barrels and cisterns (Figure 6.32) to collect water from the membrane roof. This collected water will be used for irrigation and toilet flushing to reduce potable water consumption.

Vegetated bioswales (Figure 6.33) were installed to treat water quality, attenuate flooding potential, and convey stormwater away from critical infrastructure. Bioswales use a combination of plantings, geofabrics, soil and aggregate to strategically divert and filter stormwater using the roots of the plants installed in the swale. By installing bioswales in the building site, the Trees Atlanta building achieved the following benefits:

- Treat water quality using soil, vegetation and microbes.
- Reduce total volume of stormwater runoff.
- Increase infiltration and groundwater recharge.
- Provide a multifunctional conveyance system.
- Be an aesthetic part of the landscape and improve biodiversity on site.

Finally, a vegetated roof was installed on the building to capture stormwater, which then slowly evaporates from the otherwise impervious roof area. This vegetated roof system can reduce peak stormwater runoff rates and volumes as well as filtering runoff to produce a clear effluent.

By incorporating these sustainable strategies for low-impact site amenities in the Trees Atlanta building, it was possible to limit disruption and pollution of natural water flows and to provide native trees and species that require little or no irrigation, fertilizer or pesticides.

Site development

In congruence with its role as a citizens group that protects and improves Atlanta's urban forests by planting, conserving and educating, Trees Atlanta actively sought to restore native and adapted vegetation and other ecologically appropriate features to the site. Damaged areas were restored using native and or adapted plantings for over 50 species, including three different types of green roofs (Figure 6.34). This also provided a significant open space as habitat for vegetation and wildlife and to promote natural biodiversity. Trees Atlanta installed a subsurface tree protection and stormwater infiltration system that can support traffic loads while providing uncompacted soil volumes for large tree growth and on-site stormwater management. The installed modular framework (Figures 6.35 and 6.36) provides unlimited access to healthy soil, a critical component of tree growth in urban environments. This subsurface tree protection and stormwater infiltration system also provides a receptacle to manage stormwater, potentially reducing the urban heat island effect and reducing stormwater surges to local watercourses. The site's open space with many trees and native and adapted vegetation also reduces the urban heat island effect, increases stormwater infiltration, and provides the users with a connection to the outdoors.

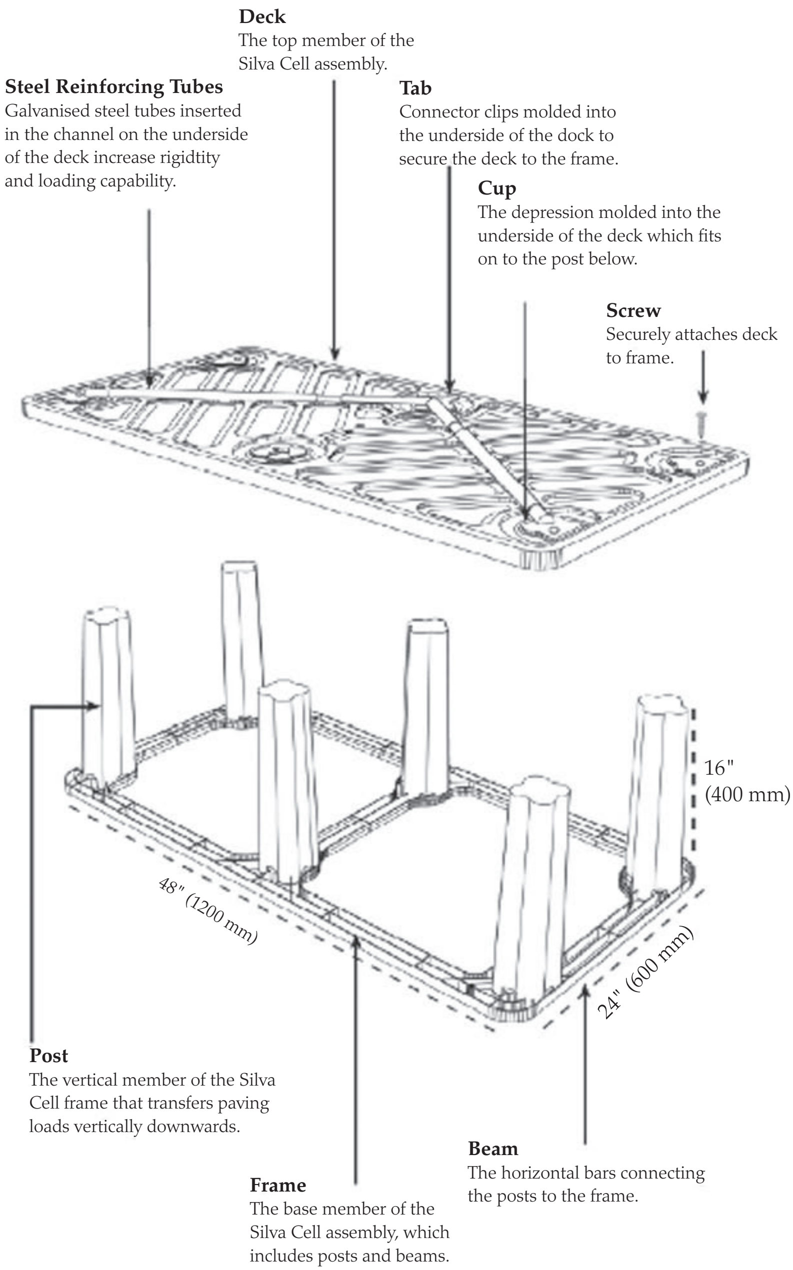


Figure 6.35 Subsurface tree protection and stormwater infiltration system
Source: Deep Root Green Infrastructure, LLC.

Figure 6.33 Installing bioswales to manage stormwater runoff

Figure 6.34 Vegetated roofs for the Trees Atlanta building

Figure 6.36 The subsurface tree protection and stormwater infiltration system being placed

Illumination of the building, site, and supporting facilities such as pavements, parking lots and roadways was designed to limit the light emitted, because excess and obstructive artificial light can affect a site's nocturnal ecosystem and negatively impact on fauna. Light pollution also limits night sky observations by humans and represents an inefficient use of energy. To mitigate those concerns, the Trees Atlanta building implemented several features including:

- Choosing interior building light systems that only provide the necessary light for the use of a space.
- Installing an automatic dimming system that automatically controls the luminance of light and turns off light fixtures when a space is not being used (Figure 6.37).
- Using the minimum amount of light necessary for safety and comfort.
- Installing covers on site lights that do not allow light to project upwards or outside the building boundary (Figure 6.38).

Figure 6.37 Lighting controls

Figure 6.38 Reduction of exterior light pollution by using shields that direct light downward where it is needed, rather than upward into the night sky

The urban heat island effect

The installation of dark, non-reflective surfaces for parking, roofs, pavements and other hardscape contributes to the urban heat island effect, which elevates temperature during the summer. As a result the annual mean air temperature of a city with one million people or more can be 1–3°C (1.8–5.4°F) warmer than its surroundings. In the evening, the difference can be as high as 12°C (22°F). The urban heat island effect can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality. In addition, it can affect site habitat, wildlife, and animal migration corridors. To mitigate this effect, the Trees Atlanta building used materials with higher solar reflectance properties (with a solar reflectance index (SRI) of at least 29) in the site design, provided shaded areas using trees and vegetation, and reduced hardscape surfaces in the large open spaces surrounding the building. The SRI is a measure of how much radiant energy is reflected from a surface and absorbed from it, with 100 being a perfectly reflective surface and 0 being a perfectly absorptive surface. The Trees Atlanta building installed a high-albedo roof surface shown in Figure 6.39, with an SRI of 78. There is also a vegetated roof, a layered system that consists of vegetation, growing medium, filter fabric, drainage, and a waterproof membrane set on top of a conventional roof (Figure 6.34).

Figure 6.39 The high-albedo roof surface reflects sunlight instead of absorbing it

Energy optimization

Buildings account for approximately 40 per cent of the energy and 74 per cent of the electricity consumed annually in the United States (EIA 2010), so it is very important to increase energy efficiency and generate energy using on-site renewable energy systems wherever possible. This reduces the environmental and economic impacts associated with excessive energy use. Table 6.1 lists the energy-related best practices employed in the Trees Atlanta building, resulting in an estimated 70 per cent energy saving over ASHRAE 90.1-2004 (the applicable minimum standard), and Table 6.2 provides an energy analysis.

Table 6.1 Sustainable energy features of the Trees Atlanta building

- Daylighting
- Geothermal heat pumps
- Solar hot water heater
- Highly efficient fluorescent fixtures and ballasts
- Lighting occupancy sensor controls
- Task lighting
- Energy Star rated equipment
- Onsite renewable energy (solar panels on shed building)
- Carbon offsets through purchase of green power credits (discussed further in Chapter 8)

Daylighting

Since a significant portion of all the lighting energy used by the building can be saved through daylighting and daylight also can provide comfort for the indoor environment, the Trees Atlanta building includes several daylighting options. The first architectural decision related to daylighting was to open up the centre of the existing industrial building, creating a new interior courtyard to bring daylight into the space (see Figure 6.40). This new interior courtyard provides an outdoor meeting place

Table 6.2 Energy analysis compared with a conventional building

Building element/item	Unit of measure	Baseline building	Proposed building
Building			
	VLT	0.75	0.58
Type 3	SHGC U-Value VLT	0.76 1.16 0.75	0.23 0.28 0.38
Type 4 (Small side windows)	SHGC U-Value VLT	Code minimum Code minimum Code minimum	0.21 0.28 0.34
Atrium Main Entrance Side Entrance	Glass (New) Glass (New) Glass (New)	Code minimum Code minimum Code minimum	Types, 1, 2 and 3 Types, 1, 2 and 3 Types, 1, 2 and 3
Window / Wall Ratio Zone	Orientation	WWR	WWR
Multipurpose	West South East North North (Atrium)	38% 38% 50% 50% 37%	Same Same Same Same Same
Office	Southwest South East North West (Atrium)	16% 35% 28% 0% 66%	Same Same Same Same Same
Backspace	North West South (Atrium)	0% 8% 37%	Same Same Same
Conference	West East (Atrium)	66% 66%	Same Same
Light Shelves East South West	 Depth (Feet) Depth (Feet) Depth (Feet)	 None None None	 5′-0″ 5′-0″ 5′-0″
Skylights	None	n/a	n/a
HVAC			
Design temp-cool Design temp-heat Supply temp-cool Supply temp-heat	deg F deg F deg F deg F	75 70 55 95	Same Same Same Same
Occupied	Fan operation Fan operation	Continuous On/Off	Same Same

Building element/item	Unit of measure	Baseline building	Proposed building
Dining Locker	W/sq ft W/sq ft	1.40 0.60	0.98 0.42
EXTERIOR LIGHTING POWER			
Connected load Operation	Watts Schedule	7.850 On when dark (Photocell)	1.141 Same
INTERNAL LOADS			
Office equipment Office task lighting Conference rooms Multi-purpose	W/sq ft W/sq ft W/sq ft W/sq ft	1.10 0.20 0.25 0.25	Same Same Same Same
OCCUPANCY			
Occupancy Hours of Operation	Full time FTE Transient Mon–Fri Sat, Sun Holidays	11 50 (2hr stay) 8:00 am to 5:00 pm Closed Closed	Same Same Same Same Same
SPACE VENTILATION RATES			
Entire building	Cfm	ASHRAE plus 30% (min)	Same

and has become a place to plant the symbol of the entire mission of the organization: trees. In addition to the new interior courtyard, the daylighting components include the use of window overhangs for shading (Figure 6.40), interior light shelves for bouncing light into the space (Figure 6.41), light tubes in specific places (Figure 6.42), and detailed selection of fenestration characteristics to optimize daylighting performance.

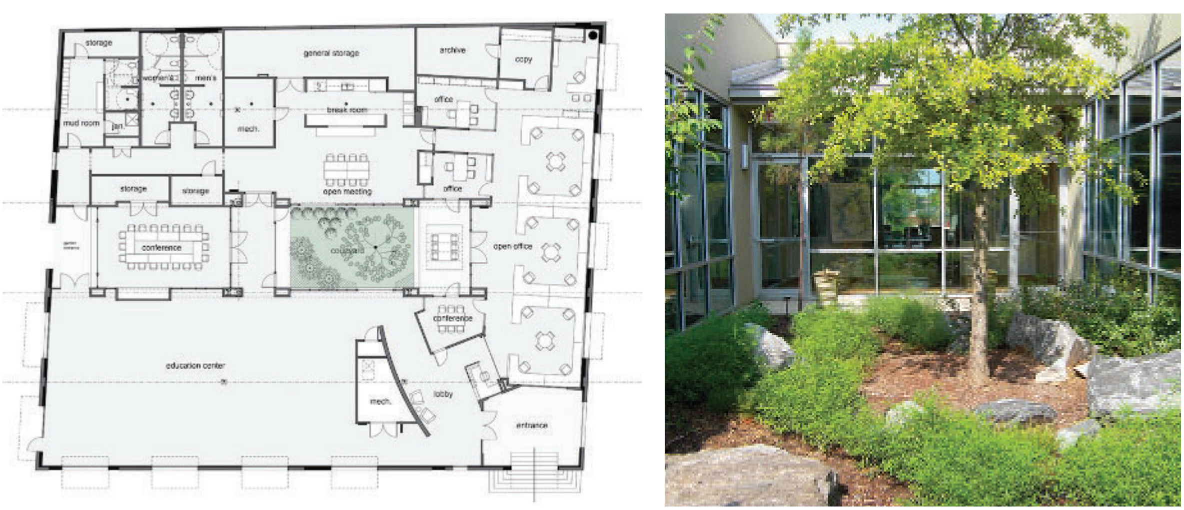


Figure 6.40 The courtyard provides enough daylight and a warm environment

Figure 6.41 Window overhangs for shading and interior light shelves

Figure 6.42 Light tubes to bring daylight into the interior

The HVAC system

HVAC systems can be the largest energy consumer in the building, to provide heating, cooling, humidity control, filtration, fresh air makeup, building pressure control and comfort control. In the Trees Atlanta building, the HVAC system utilizes a ground source geothermal system (Figure 6.43) made up of four indoor units, each serving a unique zone, and a heat recovery unit for the office space unit (Figure 6.44). Since the geothermal system uses pipes to transfer heat from underground for heating and cooling (Figure 6.45), the system retrieves heat during cool months and returns heat to the ground in hot summer months. The units are controlled by programmable thermostats (Figure 6.46) and are strategically located to ensure that the ductwork will run simple, straight, and with minimum bends. The air conditioning design load was established to accurately reflect conditions to prevent oversizing the HVAC systems. Thus, the initial budget load estimate was over 35 tons of cooling, but when the high performance features of the building were incorporated, the final cooling load was about 24 tons.

Figure 6.44 The heat recovery system to recover heat from air

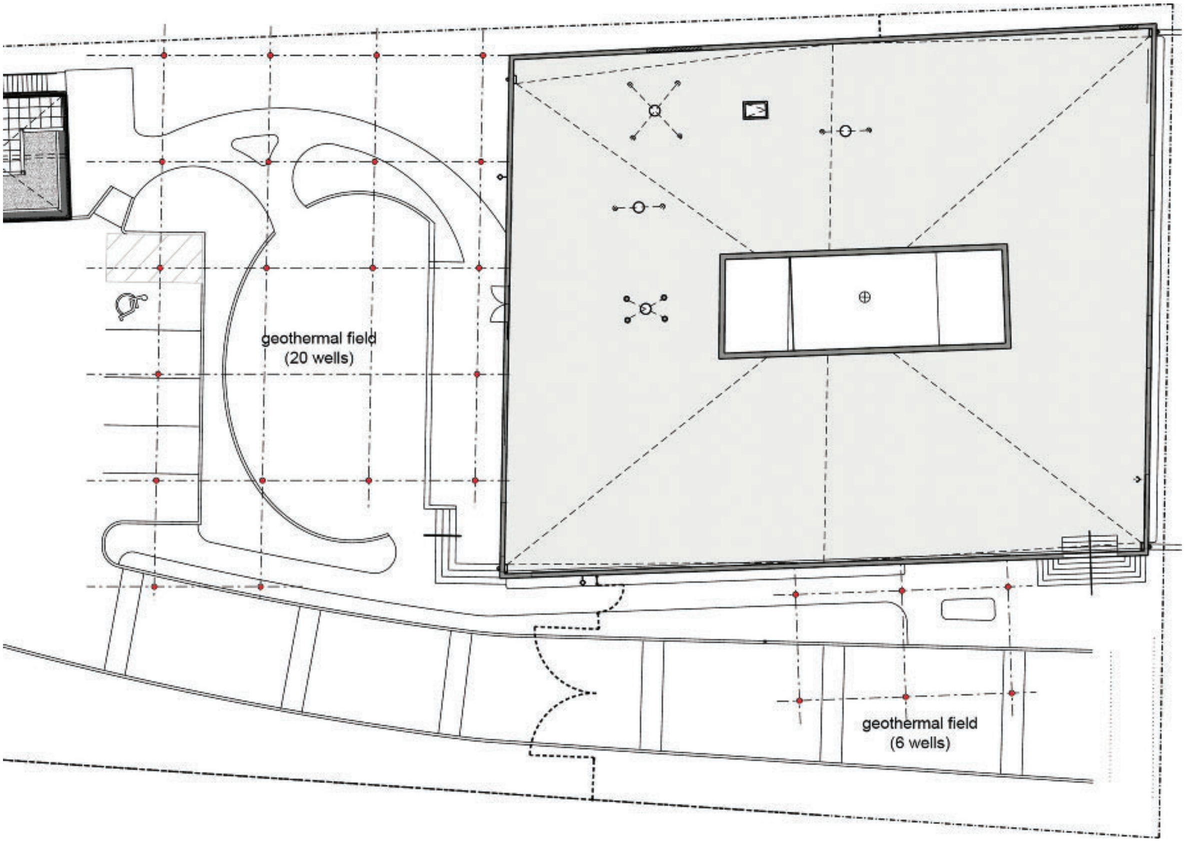


Figure 6.43 Geothermal site plan

Figure 6.45 The geothermal trench and underground piping

Figure 6.46 The geothermal system and programmable thermostats

Building envelope

The building envelope of the Trees Atlanta building was optimized through energy modelling analysis early in the design phase, as shown in Table 6.2. The original building was an existing concrete masonry unit (CMU) structure with a simple built-up roof and no insulation. The final design included furred-out walls with R-13 insulation and additional roof insulation (R-20) as well as the selection of high-performance fenestration products. The new roof is white to reflect summer sun (Figure 6.47). Since the western exposure of the building is often a difficult exposure in the southern US climate, it features a planting of trees that provide shading for this exposure.

Figure 6.47 The white roof and trees shading the west exposure

Domestic hot water system

Domestic hot water is provided by a solar thermal hot water system (Figure 6.48) consisting of rooftop panels, a solar PV powered circulation pump, and well-insulated storage tank of 80 gallons. The system is an indirect type in that a glycol (environmentally friendly) solution is circulated through a heat exchanger located in a tank connected to the city water supply (Figure 6.49). A backup electric element is provided for periods when solar heating is limited. The solar fraction for this installed system is over 70 per cent and the system's estimated energy output is 2,119 kWh per year with system rating at 3.9 kW.

Figure 6.48 Solar hot water system elements

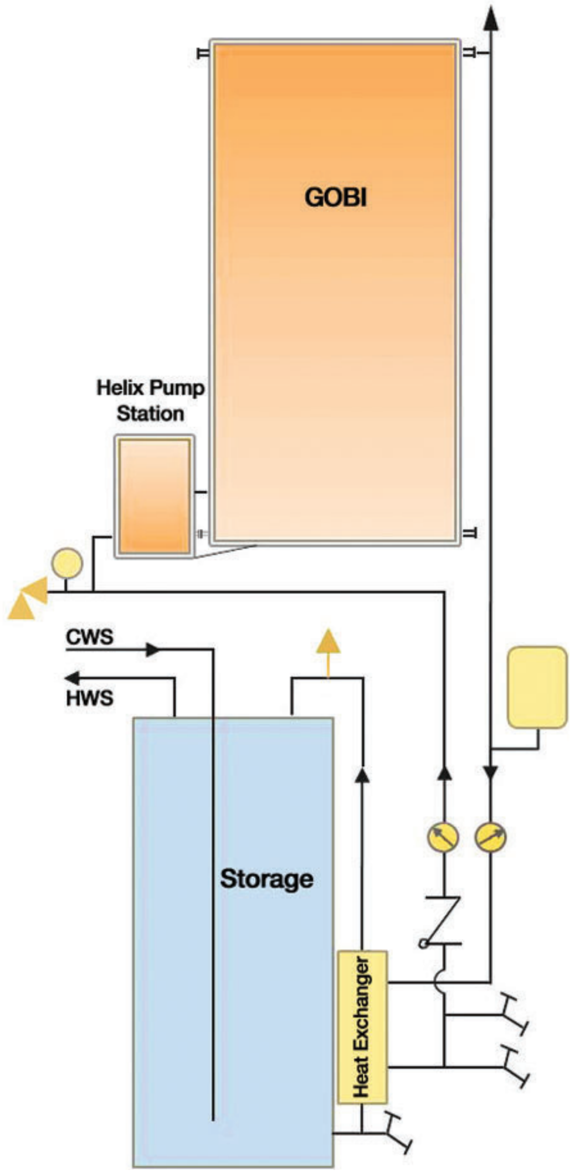


Figure 6.49 Solar hot water system schematic

High efficiency lighting fixtures and ballasts with occupancy sensors

Lighting is one of the major building uses that consumes a lot of electricity and also is very important for people's daily life and health. Thus, the Trees Atlanta building has maximized the use of daylight as a primary lighting source for the building. In addition, high-efficiency lighting fixtures and ballasts were installed (Figure 6.50) that can reduce lighting density in watts per square foot and use 30 per cent less energy than the minimum ASHRAE 90.1 2004 lighting power density. Lighting

Figure 6.50 High-efficiency lighting fixtures and occupancy sensors

occupancy sensors (Figure 6.50) were installed to control indoor light in designated spaces including rest rooms, conference rooms, bicycle storage and the like, which can turn lights on automatically when someone enters a space. These installed occupancy sensors can reduce lighting energy use by turning lights off soon after the last occupant has left the space. In addition, supplemental task lights (Figure 6.51) also have been installed to provide additional light at each workspace for user comfort.

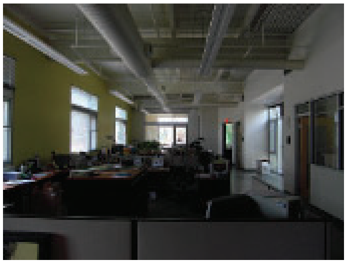


Figure 6.51 A workspace with daylighting, overhead lights and task lights

In addition to those sustainable features to reduce energy consumption in the building, Energy Star rated equipment has been installed to further reduce energy consumption.

Solar PV systems

The Trees Atlanta building has installed a 5-kilowatt solar electric PV system comprising 24 SunPower SPR-210 (210 watt) modules mounted on the roof (Figure 6.52). The installed PV system can annually generate 6,635 kWh based on a DC to AC derate factor of 0.80 and tilt of 8 degrees. The panels face due south to have full sun. In addition, the system has incorporated a SunPower 5000m inverter and net meter for a direct grid intertie system with the local power company (Georgia Power).

Figure 6.52 Roof-mounted solar photovoltaic panels

Since the energy performance of a building mainly depends on its design, the Trees Atlanta building considers both passive design strategies, including the building's massing and orientation, materials, construction methods and building envelope, and active strategies including HVAC and lighting systems. The building also includes on-site renewable energy systems including solar PV panels to reduce the environmental and economic impacts associated with fossil fuel energy use. Finally, the building has adopted an integrated, whole-building approach to optimize energy efficiency.

Water and waste water performance

Since the consumption of public water supply in facilities in the United States increased 12 per cent between 1990 and 2000, to 43.3 billion gallons per day (11 per cent of total withdrawals and slightly less than 40 per cent of groundwater withdrawals), it is vital to increase water efficiency to not only reduce water consumption but also reduce the amount of waste water and energy consumption. As described in Chapter 1, 8 per cent of US energy demand goes to treating, pumping and heating water (USEPA 2010). The Trees Atlanta building has several sustainable features that increase water efficiency to minimize water consumption and wastewater generation. Sustainable water features in the facility also have lowered the life-cycle cost for building operations and the costs for the municipal supply and treatment facilities. The sustainable features in the Trees Atlanta facility include:

- Georgia native and adaptive plants (Figure 6.53)
- rainwater collection for toilet flushing and site irrigation (Figure 6.53)
- low-flow fixtures.

Landscaping irrigation practices consume a significant amount of portable water in the United States. Outdoor uses, mainly irrigation for plants and vegetables, account for 30 per cent of the 26 billion gallons of water consumed daily (USEPA 2010). Planting native and adaptive plants on the project site can reduce water consumption for landscaping, and irrigating using captured rainwater using the three rainwater tanks also eliminates the needs for portable water. The Trees Atlanta building has not installed a permanent irrigation system, and has native and adapted plantings for Georgia's climate, thereby eliminating potable water use for landscaping. The building captures rainwater in three tanks.

Figure 6.53 Native plants and rainwater harvesting tanks

It is very important to increase water efficiency in buildings to reduce the burden on municipal water supply and wastewater systems. The Trees Atlanta building includes several sustainable features for this purpose: low-flow fixtures (1.28 gallons per flush (gpf) toilets, 0.5 gpf urinals, aerated self-generating taps, and low-flow shower heads, some of which are shown in Figure 6.54) and using rainwater for the flushing of toilets and landscaping. There is a 40ft x 40ft catchment area comprising a quarter of the roof area (Figure 6.55). The annual rainfall in Atlanta is 50.1 inches per year. The captured water is collected into two 4,500-gallon aboveground rainwater collection tanks (Figure 6.55) that preserve the water for use in toilet flushing and landscaping. In using these sustainable features for water efficiency, the building is estimated to save 83.3 per cent of typical potable water usage (Table 6.3).

Figure 6.54 Low-flow fixtures including aerated self-generating taps and low-flow urinals

Table 6.3 Water saving in the building

Baseline case: annual water consumption (gal):	34,590	gallons/year
Design case: annual water consumption (gal):	20,425	gallons/year
Total annual non-portable water consumption (gal):	14,660	gallons/year
Total water savings	83.3	%

Figure 6.55 Rainwater catchment and two rainwater collection tanks

Material optimization

A large amount of waste is generated during construction-related activities, including construction, operation and demolition. The construction sector is a major consumer of materials and resources. Sustainable design and construction best practices related to materials and resources include:

- Selecting sustainable materials that have minimal environmental, social, and health impacts during extraction, processing, transportation, use and disposal.
- Practising waste reduction by maintaining occupancy rates in existing buildings to reduce redundant development and the associated environment impact of producing and delivering new materials.
- Minimizing waste at its source, including reducing the overall demand for products.
- Reusing and recycling materials, resources and existing facilities.

Figure 6.56 Existing CMU walls were reused in the new structure

In the Trees Atlanta building, the majority of the existing building's envelope (75 per cent: 31,453SF/41,932SF) was reused to conserve resources, reduce waste and reduce the environmental impact of the materials, manufacturing and transport involved in a new building (Figure 6.56).

The Trees Atlanta building achieved its goals for the project with a construction waste management plan to recycle or salvage for reuse 90 per cent of the waste generated on-site. For example, in an effort to minimize the material waste from the construction effort, all of the demolished concrete was crushed and reused on site. With this and other strategies such as recycling and salvage (Figure 6.57), the project diverted 90 per cent of construction and demolition debris from disposal in landfills and incineration facilities.

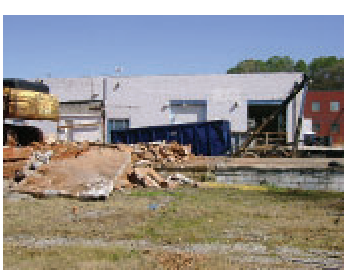


Figure 6.57 Recycling skips help to divert construction waste

Over 10 per cent of the total material cost went on materials that were extracted, processed and manufactured regionally or locally. This strategy reduced transportation impacts even as it stimulated local economies. To increase demand for building products that incorporated recycled content materials, the Trees Atlanta project employed a high level of recycled-content building materials – 13 per cent by total material cost – including structural steel components, metal studs, drywall, carpet, window frames, wood doors, bike racks, toilet partitions, batt insulation materials, and cast concrete countertops (Figure 6.58).

The design team also planned to use as many rapidly renewable materials as possible, including bamboo flooring materials and medium-density fibreboard (MDF), to reduce the use and depletion of finite raw materials and long-cycle renewable materials (Figure 6.59).

Since Trees Atlanta is a non-profit organization dedicated to planting and preserving trees, a major goal for the project was to use sustainably harvested wood products whenever possible. The building project team ensured that 63 per cent of all wood-based materials and products used in the building were certified in accordance with the Forest Stewardship Council's (FSC's) sustainable harvesting criteria (see Chapter 4). The main purpose of using FSC wood-based materials and products is to encourage environmentally responsible forest management.

Figure 6.58 The recycled content included carpet tiles and cast concrete countertops

Figure 6.59 Bamboo flooring and MDF cabinets

Table 6.4 Sustainable indoor environment features of the Trees Atlanta project

Indoor environmental quality	• Improving air ventilation • Managing air contaminants • Using less harmful materials to prevent indoor environmental quality problems • Allowing occupants to control desired settings • Providing daylighting and views

Indoor environmental quality

People spend a significant amount of their time indoors, on average more than 90 per cent in the United States, so the quality of the indoor environment has a significant influence on human well-being, productivity and quality of life (USEPA 2001). Trees Atlanta understands the importance of indoor air quality in creating a good working environment in the building, and their building incorporates many features to ensure this is the case. Table 6.4 shows the sustainable indoor environment features.

To improve occupant comfort, well-being, and productivity, the building manages indoor air quality (IAQ) by mechanical ventilation systems exceeding the minimum requirements of the ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality. Since the building was calculated to need a minimum total of 1,994 cubic feet per minute (cfm) of air exchange, the outside air energy recovery ventilator supplies one of the ground source heat pumps units with 2,400 cfm of outside air and the other three ground source heat pump units serving the facility have 430 cfm each ducted into the facility. This is a total of 3,690 cfm of outside air introduced into the building compared with the minimum ASHRAE Standard 62.1-2004 requirement of 1,994 cfm.

Low-emitting materials

One of the strategies to improve indoor air quality is to reduce the quantity of indoor air contaminants including adhesives, sealants, sealant primer products, paints, coatings and carpets that are odorous, irritating, and/or harmful to the comfort and well-being of installers and occupants. Therefore, all materials that emit contaminants including volatile organic compounds (VOCs) were avoided to the maximum extent possible. Instead, low-emitting materials were used for all adhesives, sealant, sealant primer products, paints, and coatings (Green Seal products). All carpets met the testing and product requirements of the Carpet and Rug Institute Green Label Plus Program, which identifies carpets with very low VOC emissions (Figure 6.58).

Occupant control over systems

One of the significant factors related to IAQ is providing a high level of lighting system control by individual occupants or groups in multi-occupant spaces. There are 15 individual workstations including private offices and cubicles in the building, and each one has an individual lighting control. In addition, Table 6.5 lists the lighting controls that have been installed in the shared multi-occupant spaces within the building.

Table 6.5 Multi-occupant space lighting control

Multi-occupant space	Description of installed lighting controls
Small conference room	Manual light switch with an occupancy sensor
Break-out room	Manual light switch Mostly daylit space – manual shades available at individual window sections for controllability of natural light
Large conference room	Eight-scene controller for specific room uses Electronic shading devices for daylight control
Multi-purpose space	Eight-scene controller for specific room uses Manual shading devices for daylight control

Table 6.6 Trees Atlanta temperature and humidity design criteria

Season	Maximum indoor space design temperature (deg F)	Minimum indoor space design temperature (deg F)	Maximum indoor space design humidity (%)
Spring	78.0	68.0	70.0
Summer	78.0	68.0	70.0
Fall	78.0	68.0	70.0
Winter	72.0	68.0	70.0

Every user of the space also has direct access to natural ventilation: each bay of workstations has access to its own operable windows to provide natural air (see Figure 6.60). The mechanical system is designed for four separate 'work zones' that can be controlled independently, saving energy by not ventilating the zones that are not in use while also providing independent user controllability for each zone. Thermostats were provided in the office area, break-out/kitchen area, large conference room, small conference room and multipurpose space. The majority of the multi-occupant spaces have access to either exterior or interior courtyards.

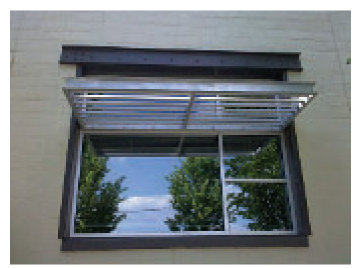


Figure 6.60 Operable windows provide natural air into occupied spaces, and exterior shading devices help control heat gain

The HVAC systems provide typical conditioning for an office-type facility, with temperature and humidity design criteria as shown in Table 6.6.

The multiple daylighting strategies provide occupants with a connection between indoor spaces and the outdoor spaces through the introduction of daylight and views into regularly occupied areas of the building (Figure 6.61). The first approach used was to expand existing window openings at the exterior walls. Second, the large interior courtyard provides ample natural light to virtually all interior spaces, while providing open views through and across the entire building. The glass used for the exterior windows was carefully considered. High-performance glass was used in the areas that receive the most severe solar gains (east/west) and near regular building occupants. Shading devices included canopies and manual blinds to shade extra light (Figure 6.62). Daylighting shelves (Figure 6.62) also were provided at the southern window openings. Due to the importance of daylighting for the Trees Atlanta building, virtually all of the regularly and non-regularly occupied spaces (with the exception of only the storage areas and restrooms) have direct views to an exterior space and to the outside (Figure 6.63). These exceptional views were achieved through the creation of large openings at the exterior walls, and the courtyard, which was planted with native trees and ground cover, affording a serene exterior setting for the occupants of the facility.

If you examine this case study of the Trees Atlanta building, you will notice how many sustainable design strategies have been used to make the building's life-cycle more sustainable. It also demonstrates the integrated sustainable design process. Next, we look at the Bank of America Tower in New York, to identify sustainable design strategies in a high-performance tall building.

Figure 6.61 Daylight in the building and open views across spaces

Figure 6.62 Shading devices and interior light shelves

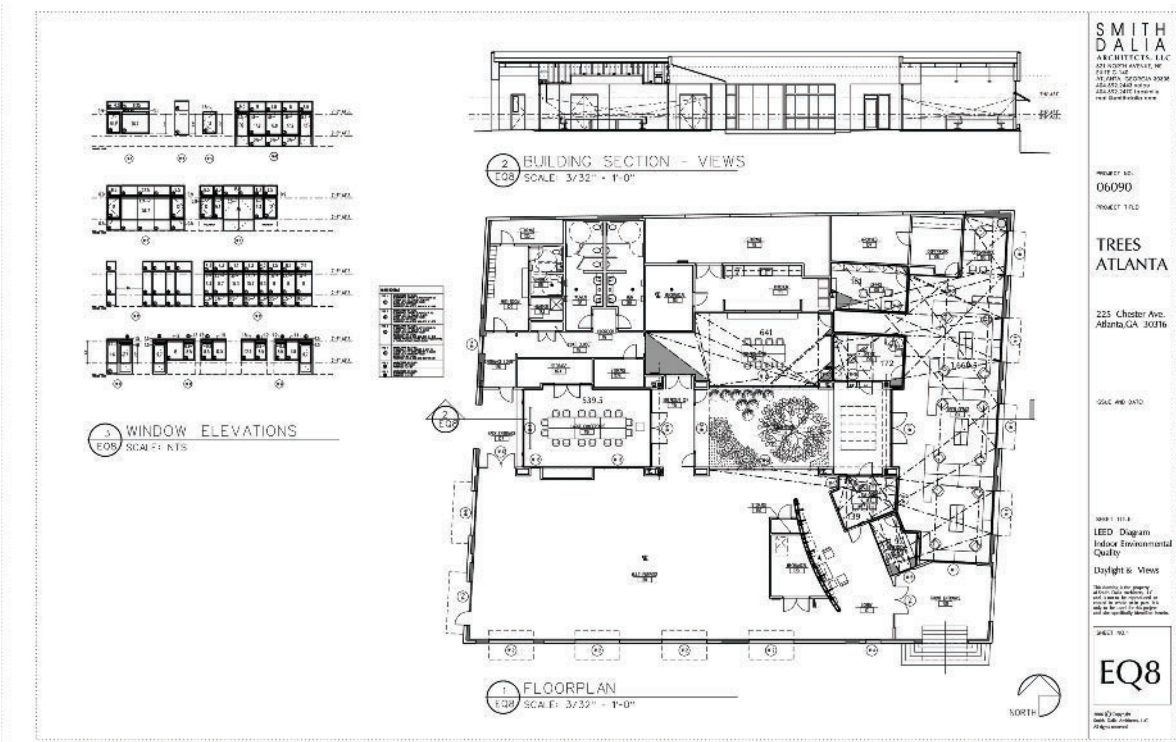


Figure 6.63 Floor plan for daylight and views

Case Study: Bank of America Tower

The Bank of America Tower is second only to the Empire State Building in New York in square footage. It is also the second tallest building (336 m with 55 storeys) in New York, again after the Empire State Building (381 m with 102 storeys), with a mast rising about 46 metres taller than the Chrysler Building's spire (319 m with 77 storeys). The tower is located in the heart of Manhattan, across from Bryant Park at 42nd Street and 6th Avenue, and is a triple landmark for sustainable and energy-saving design, its crystalline form and its sheer size. The tower project commenced in the early 2000s, the ground breaking occurred in 2004, and the tower officially opened in May 2010 (Figure 6.64).

Bank of America, a major world corporation, initiated the Bank of America Tower project early in 2000 so that it could be one of the world's largest financial institutions to provide financial services in New York. Since Bank of America is genuinely interested in corporate sustainability and environmental initiatives including climate change, one of the company's long-standing efforts is to sustainably operate and develop its buildings in ways that can:

- reduce greenhouse gas emissions
- reduce energy consumption

- reduce water consumption
- reduce materials consumption
- provide healthier indoor environments.

The Bank of America Tower is a prime example of this comprehensive commitment to sustainability. At the programming and design stage, the project team included Bank of America, Durst Organization and Cook + Fox Architects. The aim was to create a sustainable world landmark building that would also be the highest-performing building, integrating many sustainable design and construction strategies that would enhance the health and productivity of its tenants, minimize water and energy consumption, reduce waste, and promote environmental sustainability.

Bank of America Tower

- Location: New York City, NY, USA
- Building type: Office
- Date of groundbreaking: 2004
- Date of completion: May 2010
- Total area: 195,000 sq m (2,100,000 sq ft)
- Total height: 336 m (1200 ft)/55 floors
- Cost: $1 billion
- Green Building: LEED Platinum certification
- Owner: Bank of America
- Developer: Durst Organization
- Architect: Cook + Fox Architects LLP
- Structural Engineer: Severud Associates
- Contractor: Tishman Construction Corporation

Figure 6.64 Bank of America Tower in New York
Courtesy of Cook + Fox Architects.

Sustainable sites

Sustainable sites

- Public transportation and parking:
  - Include zero parking spaces.
  - Locate near public transport.
- Urban garden room:
  - Provide a urban garden room to provide green public space, reinforcing the building's street-level interactions as well as its connection to Bryant Park.
  - Public circulation spaces:
- Provide three times more public circulations space than is mandated by as-of-right zoning.
- Heat island effect reduction:
  - Install a green roof.
  - Install highly reflective pavers.

Figure 6.65 Sustainable site features in the Bank of America Tower – a dense urban location

Since the tower is located in the heart of Manhattan, occupants can enjoy the New York public transport systems with zero parking spaces, reducing automobile use and greenhouse gas emissions (Figure 6.65). The tower also includes a mid-block pedestrian passage known as Anita's Way and Urban Grade Room (3,500 sq ft, 330 sq m) at the corner of Sixth Avenue and 43rd Street, which acts as a front porch by providing public space and a sheltered extension of Bryant Park (Figure 6.66). A carbonized bamboo ceiling extends through the curtain wall and hovers 25 ft (7.6 m) out over the sidewalk to provide a natural habitat for pedestrians (Figure 6.65). To reduce the urban heat island effect in the city, the tower incorporates a green roof and highly reflective pavers. Finally, the project also includes the newly opened Stephen Sondheim Theatre to provide social services to the public. The theatre, originally built as Henry Miller's Theatre in 1918, is now the first 'sustainable' theatre on Broadway.

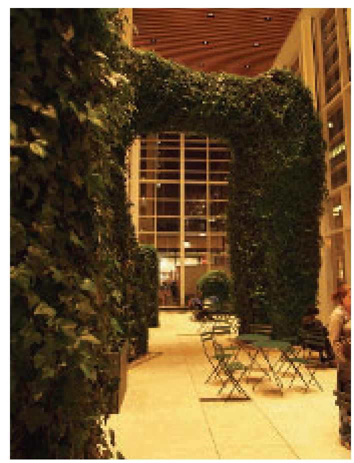


Figure 6.66 Anita's Way and Urban Grade Room at the corner of Sixth Avenue and 43rd Street

Energy optimization

One of the main objectives of sustainability for Bank of America was to reduce energy consumption in its buildings. To achieve this goal, the Bank of America Tower incorporated multiple energy saving strategies. The tower employs high-performance curtain walls to reduce solar heat gain through low-emissivity glass and heat-reflecting ceramic frit as well as minimal air infiltration (see Figures 6.67 and 6.72). The Tower also includes daylighting concepts along with occupancy sensor and automated daylight dimming technologies to reduce energy for lighting (Figure 6.72). A 4.6 mW cogeneration plant provides 65 per cent of the building's electrical energy, and the heat generated by the plant is recovered to run other building systems (Figure 6.68). Efficient generation of the building's own electricity through the natural-gas-fuelled cogeneration plant is cheaper than purchasing electricity from local utilities. The plant also significantly reduces the need for additional electricity grid development in the city.

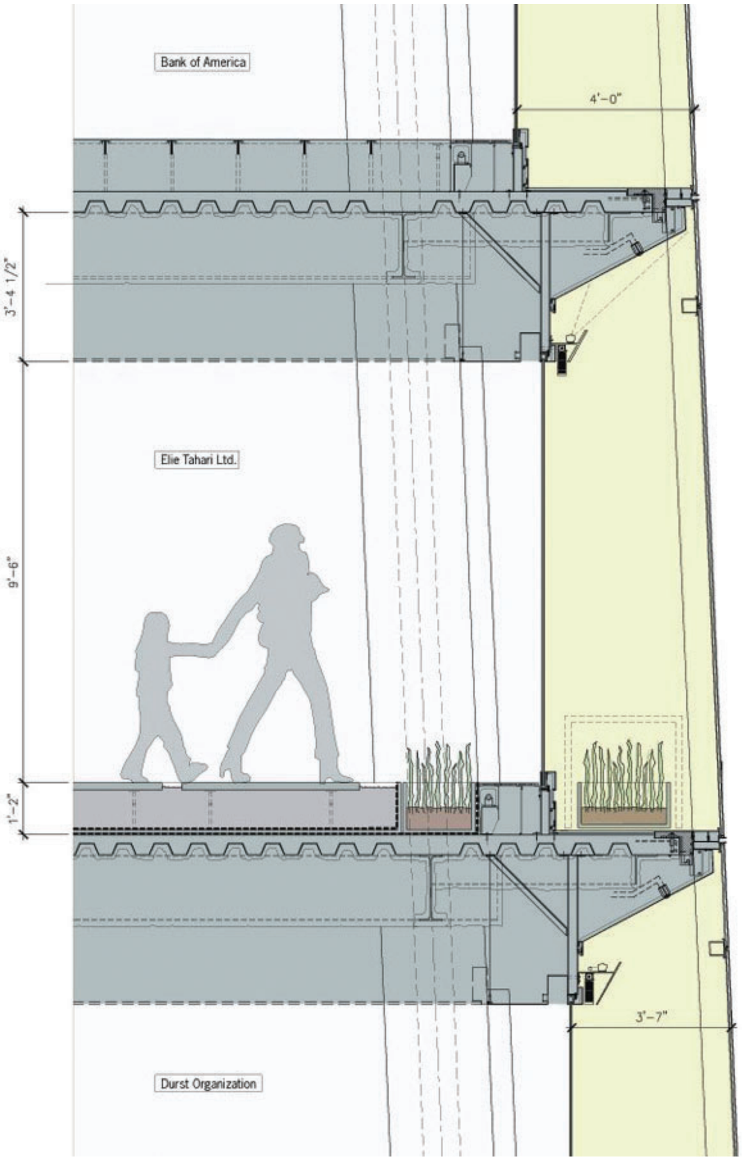


Figure 6.67 Sustainable envelope design and glycol ice storage for energy optimization
Courtesy of Cook + Fox Architects.

Air conditioning (AC) is supplied by chillers in a variety of sizes, ranging from 850 to 1,200 tons (770 to 1,100 medic tons), which provide optimal efficiency. The staggered sizes make it possible to monitor AC demands and adjust chillers usage to get the most efficient use out of each one. The electrical demand also is reduced through the use of a glycol system (Figure 6.67) that creates ice at night (when energy is cheaper), which is then used to help cool the building during the day. Forty-four tanks, each with a capacity of 625 cu ft (17.7 cu m) of glycol, are frozen at night and then melted the next day to shave the building's electrical energy demand for air-conditioning by about 5 per cent.

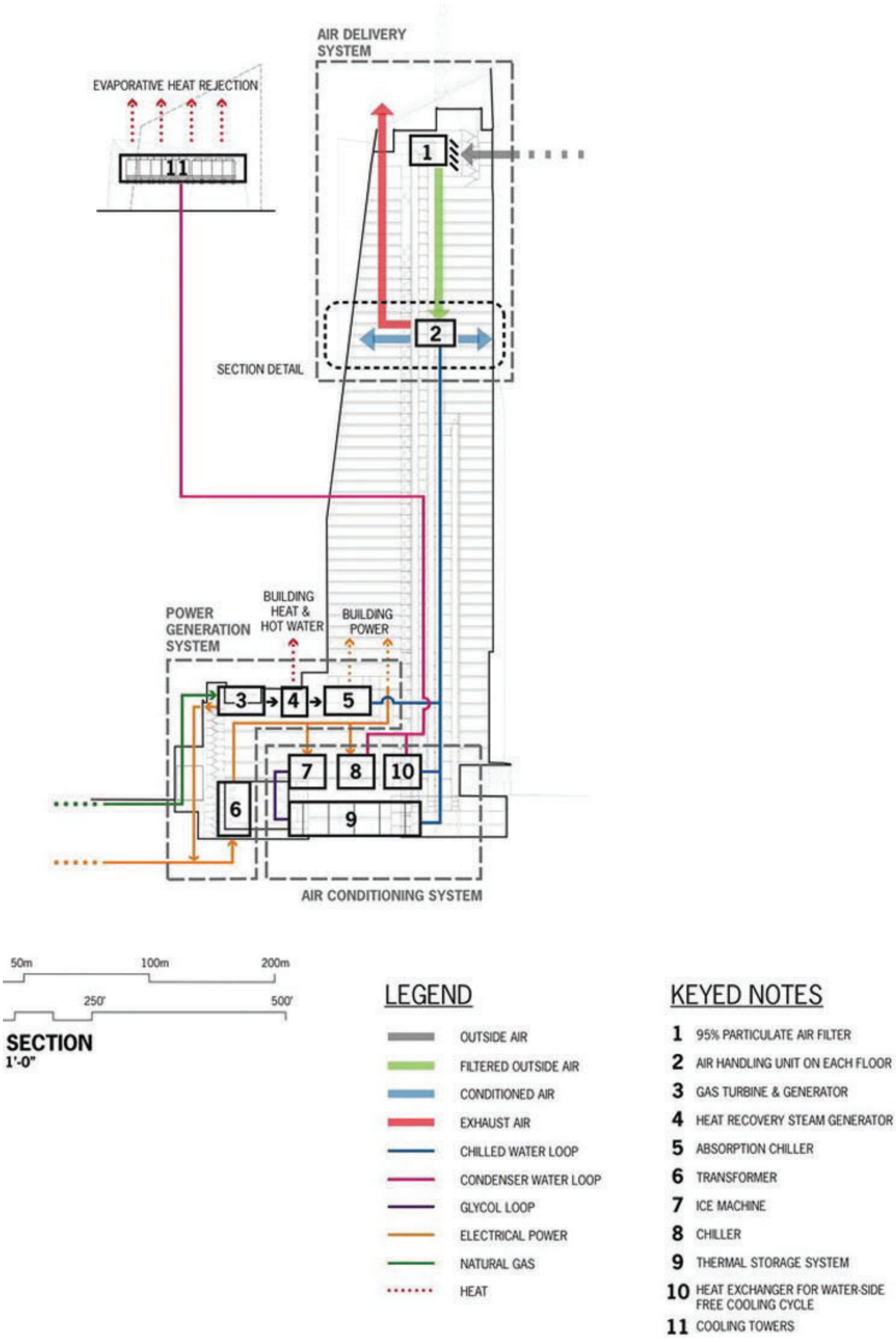


Figure 6.68 Diagram of Tower's HVAC Systems
Courtesy of Cook + Fox Architects.

Energy optimization

- High-performance curtain wall
  - Reduce solar heat gain through low-emissivity glass and heat-reflecting ceramic frit.
  - Reduce air infiltration.
- Daylighting system:
  - Reduce artificial lighting requirements through higher ceilings and highly transparent glass.
  - Install an occupancy sensor system.
  - Install an automated daylight dimming system.
- On-site co-generation plant:
  - Install a 4.6 mW cogeneration system.
  - Provide 65 per cent of building's annual electricity requirements.
  - Reduce daytime peak electricity demand by 30 per cent.
  - Generate most of the heating energy for the building.
- Absorption chiller (see Figure 6.68):
  - Provide heat in winter and cooling in summer.
- Glycol (ice storage) system:
  - Provide approximately 25 per cent of building's annual cooling requirements
  - Reduce daytime peak loads on city's electricity grid (at night, excess electricity from-the co-generation system is used to produce ice, which is melted during the day to supplement the cooling system).

These energy-saving strategies make it possible not only to save significant energy but also to reduce greenhouse gas emissions.

Water and waste water performance

Water and waste water performance

- Rainwater harvesting and greywater system (5,000 gallons (19,000 l) per day:
  - Capture and reuse 48 inches of annual precipitation.
  - Capture and reuse cooling coil condensate and greywater generated on-site.
  - Collect groundwater in the basement of the building (not necessarily a more sustainable water source, but reducing the use of potable water and its resource-intensive treatment).
  - Install four large holding tanks (total about 60,000 gallons) located at four different floors heights to feed toilets and for other greywater uses.
- Water use reduction:
  - Install waterless urinals and low-flow plumbing fixtures.
- Water saving:
  - Save 7.7 million gallons per year (45 per cent reduction in the use of city water).
- Waste water reduction:
  - Reduce 95 per cent of waste water to the city's sewer system.

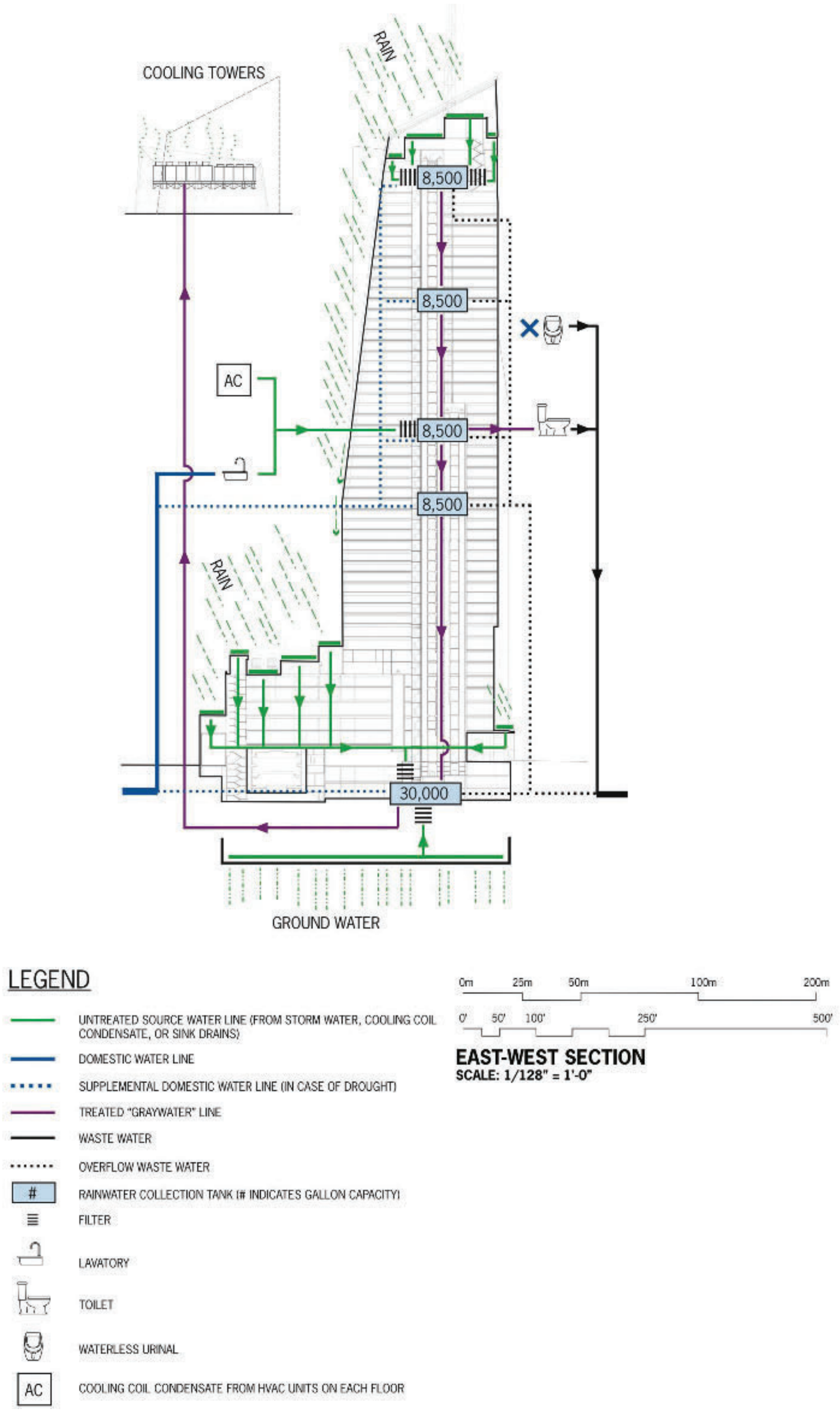


Figure 6.69 Diagram for water and waste water saving strategies
Courtesy of Cook + Fox Architects.

Water conservation was a major consideration in the Tower's design. The project team included a rainwater harvesting system as well as a greywater harvesting system not only to reduce water consumption but also to minimize the generation of wastewater. The conception is to recycle all water in the building except toilet water by treating all collected rainwater and greywater. The Tower can capture about 5,000 gallons (19,000 liters) of rainwater, cooling-coil condensate water and groundwater[2] per day in order to treat and reuse it (Figure 6.69). There are four large holding tanks – totalling about 60,000 gallons (230,000 L) located on different floors in order to feed toilets and for other greywater uses, such as the cooling towers on the roof. These integrated water strategies, coupled with water conservation plumbing fixtures, can reduce water consumption from the conventional level by about 45 per cent. It was possible to cut water sent to the sewers by about 95 per cent, which substantially reduces demands on the city's sewer system.

Material optimization

The Bank of America Tower has used substantial quantities of local or regional building materials, including 1.6 million sq ft of glass in the curtain wall that was harvested and manufactured within 500 miles of New York City (Figure 6.70). In addition, 91 per cent of all construction and demolition debris was recycled or otherwise diverted from disposal in landfills. The Bank of America Tower used as many building materials as possible that contain recycled content, including structural steel (87 per cent recycled content) and concrete (45 per cent recycled

Examples of regional source materials

Red: Manufacturing location
Green: Harvesting location

1. Structural steel (Columbia, SC)
2. Curtain wall (Montreal, CA)
3. Concrete (Port Chester, NY)
4. Bathroom countertops (Brooklyn, NY)
5. Quarried stone (Various Locations in Vermont)
6. Stone fabrication (Patterson, NJ and Bronx, NY)
7. Millwork (Jamaica, NY)
8. Access flooring (Red Lion, PA)
9. Gypsum wallboard (Shippingport, PA)

Figure 6.70 Regionally harvested and manufactured materials
Courtesy of Cook + Fox Architects

content). All building materials were carefully sourced and reviewed before installation to confirm that they were low-VOC, sustainably harvested, manufactured locally, and/or contained recycled content wherever possible. Finally, salvaged artifacts from Henry Miller's Theater were reused in the new Tower (see Figure 6.71).

Figure 6.71 Sustainable features for material optimization – recycled content steel and reuse of materials from the old Henry Miller's Theater. The building façade was reused in its original, intact form
Courtesy of Cook + Fox Architects.

Material optimization

- Recycling:
  - Recycle or divert 91 per cent of all construction and demolition waste from landfill.
- Recycled materials:
  - Use structural steel materials that contain 87 per cent recycled content.
  - Use concrete that contains 45 per cent recycled content (blast furnace slag).
- Regional materials:
  - Use 1.6 million sq ft of glass in the curtain wall that was assembled within 500 miles of the site.
  - Use sustainably harvested wood crating for glass transit.
- Reuse materials:
  - Reuse salvaged artifacts from Henry Miller's Theatre.
- Low-VOC materials:
  - Use low-VOC building materials.

Indoor environmental quality

Indoor environmental quality

- Air ventilation:
  - Remove 95 per cent of particulates by air filtration.
  - Intake outside air at 800 ft.
- Daylight and views:
  - Access natural daylight and views through higher 9 ft 6 in ceilings.
- Under-floor ventilation system:
  - Allow for individual climate control through in-floor air diffusers.
  - Provide more efficient and healthy cooling and fresh air through floor-by-floor air handling units.
- Air monitoring system:
  - Track carbon dioxide, carbon monoxide, VOCs and small particulates.
  - Ensure consistently high quality of ventilation air.

The Tower was designed and constructed to provide a high-quality indoor environment to building occupants, which can improve occupants' health and productivity. An under-floor ventilation system was installed throughout the building to allow for individual climate control through in-floor air diffusers. This raised floor system makes the routing of cables and computer infrastructure much easier (Figure 6.72). The makeup air inside the building is pulled in through intakes at 800 ft (300 m) above the street, cleaned through an air filter that captures about 95 per cent of particulates, and then cleaned again before it is

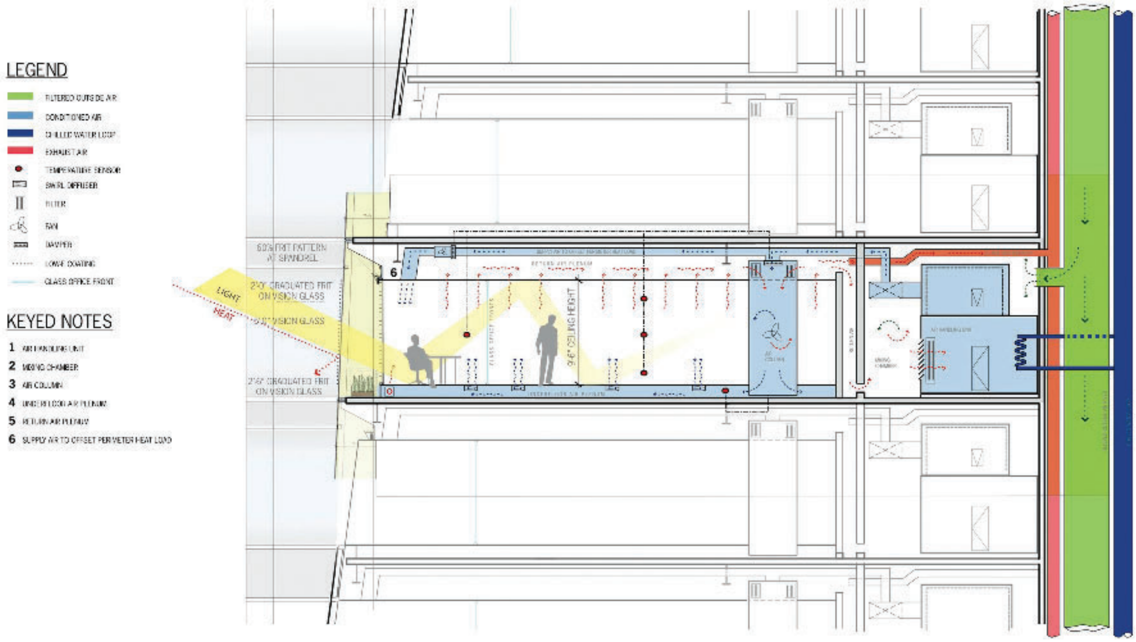


Figure 6.72 Diagram of floor section and air intake and circulation system
Courtesy of Cook + Fox Architects).

distributed throughout the building (Figure 6.72). These systems result in providing very clean hospital-grade air to all building occupants. In addition, there is an air monitoring system that measures air quality throughout the building. This system monitors carbon dioxide, carbon monoxide, VOCs and small particulates. Finally, occupants in the tower enjoy natural daylight and views through higher 9 ft 6 in ceilings and floor-to-ceiling windows glazed with extremely transparent, low-iron glass (Figure 6.72). With these design strategies, the Bank of America Tower can provide an exceptional indoor environment to improve occupants' health and productivity.

Altogether, the sustainable design strategies employed in the Bank of America Tower have resulted in a world-class landmark facility exemplifying the best in sustainable design for high-rise facilities. With the anticipated increase in world population and increasing numbers of people living in cities, there is a real need to develop better ways to design and build structures like this, both now and in the future.

Sustainable design in 2020

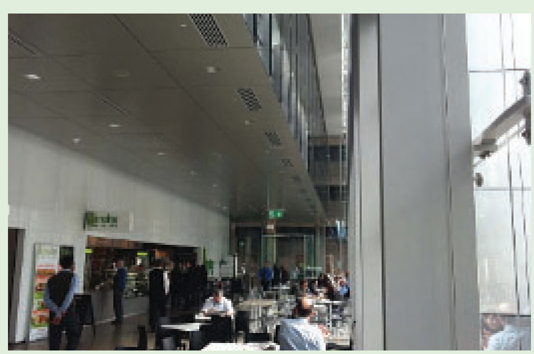
How will we design built facilities and infrastructure systems in the future? What will they look like, and what expectations will their owners have for them? Not only will the technologies and materials we use be different from those of today, the processes we use to determine human needs and develop design solutions will be different. Indeed, the very

Case Study: Sydney Water HQ – New South Wales, Australia

Sydney Water's new head office is located at One Smith Street, in the historical city of Parramatta, west of Sydney's central business district. It has received a Five Star Green Star Office as Built V2 rating, achieving a score of 72 from the Green Building Council Australia. The building, designed by Denton Corker Marshall and owned by Brookfield Multiplex, is a 17-storey, 23,000 sq m office tower, and has incorporated many sustainable strategies and technologies including water and energy efficiency and recycling. Sydney Water's HQ includes green features such as:

- brownfield remediation to clean up asbestos contamination at the site
- an onsite water recycling plant to provide recycled water for toilet flushing, cooling towers, fire testing and irrigation
- rainwater harvesting to provide additional water for toilets and cooling towers
- solar heating panels to supplement hot water requirements
- a high-performance glass façade with shading that can control heat entering the building without limiting natural light
- using construction materials made from renewable sources for a high recycled content
- a rooftop garden for heat island effect and stormwater
- the use of chilled beam cooling instead of conventional air conditioning
- improved air quality and office environment through using products with low volatile organic compounds (VOCs) and continuous fresh air supply.

By implementing these sustainable features, the Sydney Water HQ has cut greenhouse gas emissions by 30 per cent and reduced drinking water use by 75 per cent over a typical office building. In addition, the reduction in water used at the site also can reduce the flow of wastewater to the sewerage system by 90 per cent. The building also utilizes a convective chilled beam system to cool the building and its occupants, which requires fewer refrigerants and is more energy-efficient than conventional cooling systems. Chilled beams work by allowing air to circulate around pipes placed at ceiling level filled with cool fluid. As the air circulates, it becomes cooler and sinks to the occupied area of the rom. The system aims to improve the air quality within the building while its heat absorption from lighting and equipment reduces energy demand and minimizes greenhouse gas emissions. Since the Sydney Water HQ is located next to a major transport interchange, the building contains efficient showers, bicycle racks, and other facilities to encourage staff to commute using healthier and more environmentally sustainable methods.



A high-performance glass façade with shading that can control heat entering the building without limiting natural light nature of the built environment is likely to shift in response to drivers such as higher population density in urban centres, climate change and increased resource scarcity.

We can certainly expect an increase in the numbers of tall buildings and the challenges associated with them as we look for better ways to house ourselves in dense urban settings. New technologies will be developed to take better advantages of resources in place, such as solar and wind energy and natural rainfall. The buildings of 2020 will, by necessity, be far more self-sufficient than their counterparts of today, with systems in place to passively light, ventilate and condition their spaces. Water will be cycled and treated extensively, refreshed primarily by rainfall instead of dependence on local water supplies. They will also be much more mixed-use than buildings of today, integrating nature as part of vast urban gardens that provide food and services to their residents and occupants. They will also support a greater degree of virtual enterprise and commerce based on information technology, with occupants working from home or travelling locally to satellite offices instead of commuting long distances to a central workplace.

The very process of design will continue to evolve and change. New generations of building information models, along with their infrastructure counterparts, will be established very early in design and carry through continuously to operations and the end of the life-cycle of capital projects. These models will be interoperable between and among all stakeholders involved in project delivery, unlike today where they must be awkwardly translated from phase to phase. Information models from existing projects will provide valuable performance data and lessons learned that can be easily tapped to make better design decisions and better understand the integrated performance of building systems.

Stakeholders, both laypeople and professionals, will have access to the design process through social networks and project information systems through which they can contribute their ideas, requirements and aspirations for the project. Just as today's space-conditioning systems are becoming more easily controlled by individual building occupants, so too will the design process of tomorrow be more responsive to the concerns of the whole set of stakeholders, resulting in buildings that better meet the needs of stakeholders over time.

Notes

1 The images of the case study of the Bank of American Tower are from Cook+Fox Architects and are used with permission.

2 The Bank of America Tower collects groundwater from the basement of its building site to eliminate groundwater discharge to the public sewer system.

Discussion questions and exercises

6.1 Identify a local project in the design phase of development. Contact the design team and learn more about the project, including its sustainability goals and objectives. If possible, attend one or more design phase meetings as an observer. How is sustainability taken into account in these meetings?

6.2 Consider the building in which you are presently located. Given its design, how well did it address the major priorities for sustainable sites? What sustainable site features were included? How might it have been better designed to take site sustainability into account?

6.3 Where is your building located with respect to major infrastructure support systems such as power plants, water and wastewater treatment facilities, solid waste facilities and transport networks? Obtain a local or regional map and determine how close your building is located to these critical support facilities. How is your building connected to this critical infrastructure? What options are available?

6.4 Where is your building located with respect to major natural and cultural assets? In what watershed or drainage basin does your building sit? Where does stormwater go when it leaves your site? Where is the nearest functioning natural ecosystem? How do your development and surrounding neighbourhoods interact with that ecosystem? What possibilities exist for synergies with surrounding development? What environmental vulnerabilities exist?

6.5 How is your building oriented on its site? Obtain a site plan and evaluate the building's solar orientation. What could be improved about the building's orientation and geometry to improve its solar performance? How does the current landscape influence the building's performance, and how might it be improved?

6.6 Inventory the amenities and landscape features on your site. How could the site design and amenities be improved to increase the sustainability of your building?

6.7 Consider the building in which you are presently located. Given its design, how well did it address the major priorities for energy optimization? Inventory the energy-optimizing features that were included in the design. How might the building have been better designed to take energy into account? What features or technologies could have been included? Which would have the greatest potential impact?

6.8 Contact the staff responsible for operating your facility, and map the operating schedule for your building. What are the set points and operating hours for your building? How could the operating schedule be adjusted to increase energy efficiency? What, if any, trade-offs would there be for building occupants?

6.9 Obtain a schematic of the mechanical systems of your facility if one exists. What technologies are included to improve the energy and water performance and overall resource efficiency of those systems?

6.10 Contact the organization that provides electrical power to your facility. What is the rate structure and pricing scheme for power? Is any portion of the energy portfolio provided by renewable sources? Are green tags available? Does your facility's design take into account the energy supply scheme and pricing incentives available to it?

6.11 Identify the nearest sources of renewable energy to your location. Some nearby sources may be distributed on local sites rather than produced centrally. Visit one or more of these sources and interview the operators. What are the major challenges to their effective operation?

6.12 Consider the building in which you are presently located. Given its design, how well did it address the major priorities for water efficiency and wastewater performance? Inventory the water-optimizing features that were included in the design. How might the building have been better designed to take water into account? What features or technologies could have been included? Which would have the greatest potential impact?

6.13 Locate a local facility that uses alternative water or wastewater technologies. Interview users of those technologies to determine how well they perceive the technologies to work. Interview operations or maintenance staff and document their perceptions. What, if any, unexpected maintenance issues have arisen? Have any technologies been discontinued or abandoned?

6.14 Consider the building in which you are presently located. Given its design, how well did it address the major priorities for materials optimization? Inventory the material-optimizing features that were included in the design. How might the building have been better designed to take materials into account? What features or technologies could have been included? Which would have the greatest potential impact?

6.15 Locate a local facility that used green or high-performance materials in its construction. Interview users of those technologies to determine how well they perceive the technologies to work. Interview operations or maintenance staff and document their perceptions. What, if any, unexpected maintenance issues have arisen? Have any materials been discontinued or replaced?

6.16 Consider the building in which you are presently located. Given its design, how well did it address the major priorities for indoor environmental quality? Inventory the IEQ-optimizing features that were included in the design. How might the building have been better designed to take IEQ into account? What features or technologies could have been included? Which would have the greatest potential impact?

6.17 Locate a local facility that included high-performance indoor environmental quality in its design. Interview building occupants to determine how well they perceive the technologies to work. Interview operations or maintenance staff and document their perceptions. What, if any, unexpected maintenance issues have arisen? Have any products or systems been discontinued or replaced?

6.18 Perform an Internet search to identify building products and systems that can be purchased with manufacturer service, maintenance or leasing agreements. What are the terms of these agreements? How might they increase the sustainability of a facility on which they are employed?

References and recommended reading

7group, Reed, W. and Fedrizzi, S. R. (2009). *The Integrative Design Guide to Green Building: Redefining the practice of sustainability.* Wiley, New York.

Keeler, M. and Burke, W. (2009). *Fundamentals of Integrated Design for Sustainable Building.* Wiley, New York.

Kibert, C. J. (2007). *Sustainable Construction: Green building design and delivery.* Wiley & Sons, New York.

Kwok, A. and Grondzik, W. (2006). *The Green Studio Handbook: Environmental strategies for schematic design.* Architectural Press, London.

Lechner, N. (2008). *Heating, Cooling, Lighting: Sustainable design methods for architects*, 2nd edn. Wiley & Sons, New York.

Mendler, S. F. and Odell, W. (2005). *The HOK Guidebook to Sustainable Design*, 2nd edn. Wiley & Sons, New York.

Mumovic, D. and Santamouris, M. (eds) (2009). *A Handbook of Sustainable Building Design and Engineering: An integrated approach to energy, health, and operational performance.* Earthscan, London.

Pearce, A. R., Bosch, S. J., DuBose, J. R., Carpenter, A. M., Black, G. L. and Harbert, J. A. (2005). *The Kresge Foundation and GTRI: The far-reaching impacts of green facility planning*. Final Project Report to the Kresge Foundation, Troy, Mich., 30 June.

R. S. Means, Inc. (2010). *Green Building: Project planning and cost estimating, 3rd edn.* Reed Construction Data, Kingston, MA.

United Nations Environment Programme (UNEP) (2002). *UNEP in 2020*, United Nations <www.unep.org/pdf/annualreport/UNEP_Annual_Report_2002.pdf> (accessed 15 July 2010).

US Energy Information Administration (USEIA) (2010). *Annual Energy Outlook*, <www.eia.doe.gov/forecasts/aeo/index.cfm> (accessed 10 November 2010).

US Green Building Council (2009). *LEED Reference Guide for Green Building Design and Construction*. Available from the Green Building Certification Institute (http://www.gbci.org).

US Environment Protection Agency (USEPA) (2001). *An Introduction to Indoor Air Quality* <www.epa.gov/iaq/ia-intro.html> (accessed 15 July 2010).

USEPA (2007). *Developing Your Stormwater Pollution Prevention Plan: A guide for construction sites*, USEPA <http://cfpub.epa.gov/npdes/stormwater/swppp.cfm> (accessed 10 June 2010).

USEPA (2010). *Conserving Water*, USEPA <www.epa.gov/greenhomes/ConserveWater.htm> (accessed 10 June 2010).

7

Sustainable Construction Opportunities and Best Practices

During the construction phase of project delivery, careful attention has to be paid to both design strategies and construction opportunities to ensure that a project is delivered in a sustainable fashion. This chapter describes opportunities in the construction phase of project delivery that apply to infrastructure, building and industrial projects alike. The chapter begins with an overview of the changing nature of construction services, followed by a range of strategies that can be incorporated from pre-construction through to turnover of the project at the end of construction to improve project sustainability. It concludes with two case studies to illustrate these strategies in practice.

Construction opportunities

Construction-phase opportunities for sustainable projects

- Preconstruction services.
- Minimizing site disturbance.
- Erosion and sedimentation control.
- Pollution prevention.
- Sustainable site operations.
- Commissioning.

Managing a project to increase its sustainability requires careful attention to construction operations. Minimizing disturbance to the construction site helps preserve habitat and biodiversity that may exist on the site and makes it easier to restore the site when the project is complete. Careful control of erosion and sedimentation retains valuable soil on site and prevents damage to surrounding sites and waterways. Measures to prevent light, noise and dust pollution during and following construction also preserve a good relationship with those on surrounding sites. Many opportunities exist for environmental stewardship within the project office and in travelling to and from the project site. Finally, all of these measures combined can be part of a sustainable operations and pollution prevention plan for the project.

As with design, a broad variety of opportunities exist to incorporate sustainability tactics during the construction portion of the delivery process. Based on the nature of the owner, its procurement constraints, and the project and its specific needs and requirements, applicable tactics can vary considerably from project to project, so it is difficult to predict at the early stages of a project what specific tactics will apply. Preconstruction services are one opportunity a contractor has to better understand the opportunities offered by a particular project. The range of sustainability opportunities in this part of a project is discussed next.

Preconstruction services

A significant change in recent construction history is the enhanced role being played by contractors in project planning and design. Historically, the role of contractors prior to construction has been limited to providing cost estimates in the form of bids for projects, even if they are not ultimately selected for project delivery through a conventional design–bid–build scenario. However, as project complexity increases and the costs of construction continue to escalate, owners have begun to recognize the incredible value that can be brought to early planning and design by those who will ultimately have to implement the designed facility.

The project delivery methods of construction management–agency, construction management at risk, and design–build are seeing increased use, especially in the public sector, as a means to draw upon the additional value construction knowledge can bring to the facility delivery process while delivering a completed project faster than ever before. These delivery methods involve construction personnel, especially estimators and preconstruction managers, for a much longer time than the traditional bid preparation process. In addition to conventional tasks such as quantity takeoffs, pricing and subcontractor/vendor bid management, these stakeholders are now involved with tasks such as helping to define the scope of work for a project; assessing alternative systems, materials or methods; and assisting the design team and owner team in defining the design intent for the project.

In projects with sustainability goals, these roles are further enhanced. Contractors are involved in the integrated design process from the very beginning, and may be hired only to perform preconstruction services or also later permitted to bid on the project, depending on the owner's limitations and requirements. In addition to information on the cost and schedule impacts of design decisions, construction managers must now assist in providing information on the sustainability impacts of those decisions, including the extent to which materials and systems will contribute to a project's potential rating under one of the many green rating systems (see Chapter 3), or the degree to which selected systems will impact the project's site and surroundings during construction. Providing this level of service requires an increased focus of construction companies on the task of knowledge management, and effective capture of lessons learned from early experiences with green projects.

The relatively new role of preconstruction manager has emerged among construction management firms as a distinct function separate from the traditional construction project manager. This function plays the primary role of shepherding a project through the planning and design phase and assisting in evaluating the implications of potential decisions at every point along the way. One of the most important functions of this individual is to provide a complete picture of the project budget and schedule at any point during this process, including all appropriate contingencies and qualifications at each stage. As the project nears completion of the design phase, the preconstruction manager will systematically work with the design and owner teams to reduce the need for such contingencies and qualifications by identifying areas of risk and aiding in decision making to reduce and manage those risks.

Table 7.1 Selected preconstruction practices and their role in project sustainability

Practice	Description	Sustainability role
Contribute to project sustainability goal setting	Contribute to the development, evaluation and selection of project sustainability goals based on construction knowledge.	Include knowledge of means and methods associated with choices of materials and systems; identify impacts of those means and methods that may not be apparent to other team members.
Track project team decisions	Maintain tracking log of all decisions made by the project team during design, including current status.	Tracking log should include decisions that may be cost-neutral but would otherwise affect sustainability goals for the project.
Prepare variance reports	Develop estimates that will allow easy tracking of changes from previous and future estimates to explain what has changed, and why.	Variance reports should capture not only impact on project cost and schedule, but also impacts on sustainability goals. For example, how might the decision affect the project's score on a green rating system? What credits would be affected?
Prepare bid lists	Working with the owner and design team, develop a list of bidders who should be invited or encouraged to bid on the project.	Assist owner in developing evaluation criteria that include relevant experience with sustainability projects and key qualifications.
Provide scopes of work to bidders	Provide a clear scope of work for all bidders, including a bid manual that incorporates key requirements such as insurance, safety, general provisions.	Include sustainability goals and implications for project delivery as part of the bid manual; highlight key sustainability requirements that may impact the cost, schedule, means or methods of the scope of work.
Pre-qualify bidders	Confirm that all bidders have the resources to perform the work, a history of successful performance, ability to complete the work given current workloads, and can meet insurance and bonding requirements.	Evaluate sustainability-related capabilities such as the number of accredited or certified personnel for relevant rating systems; identify experience with comparable sustainability projects.
Hold pre-bid conference	Conduct a comprehensive pre-bid conference to encourage successful bidders.	Include explicit discussion of project sustainability goals and requirements, and clarify how these may impact project delivery; discuss qualification criteria.

The preconstruction manager also plays the critical role of packaging work and communicating its scope to bidders, which can have a significant impact on the ultimate project cost. This pivotal person is also often in charge of constructability review and value engineering or value analysis, since they possess the most comprehensive perspective on the project and how it will ultimately need to be implemented. Table 7.1 shows some of the key practices that are generally the responsibility of the preconstruction manager, and how they play an important role in a green project in particular.

After the preconstruction phases of the project are complete and a construction provider has been selected, the next important steps in project delivery involve deciding how the project site itself will be managed to meet sustainability objectives. The opportunities inherent in these decisions are discussed next.

Sustainable site management

One of the most important strategies for sustainable site operations is to minimize disturbance to the project site during construction. Except for brownfield sites that require environmental remediation, the less disturbed the construction site, the better. Particularly important are greenfield (previously undisturbed or undeveloped) sites and sites with critical habitat or important ecological features. However, minimizing disturbance even on previously developed sites creates fewer problems that must be fixed at the end of the project. It also reduces environmental and legal liability during construction. This tactic applies equally well to building and infrastructure projects.

Disturbing the site creates potential soil erosion and instability problems. It can also damage tree roots, even if the tree trunk and branches appear to be undisturbed. Careful attention must be paid to limiting or prohibiting vehicle traffic in areas with tree roots. This is especially true for heavy equipment. The weight of the vehicles and equipment compacts the soil and damages the ability of the tree roots to absorb nutrients from the soil. This eventually kills the tree.

The most common means for limiting site disturbance is to erect construction fencing as a boundary for operations. Chain-link or security fencing is often used around the perimeter of the site for security purposes. Lightweight plastic fence is more often used within the site boundaries to mark areas that should be left undisturbed. The fence is placed at least as far from the trunk as the drip line of the widest branch (Figure 7.1). This ensures that heavy equipment will stay off the area in which tree roots exist.

A second important factor in limiting site disturbance is proper selection of construction equipment. Equipment is often selected based on minimizing cost to the project. Since labour has historically been the most expensive aspect of construction projects, equipment is often selected to maximize human productivity and minimize the length of time a task requires.

Figure 7.1 a) Fencing can be used to limit disturbed areas. b) Tree protection fencing should be placed at or beyond the tree's drip line

Figure 7.2 Rubber-tracked equipment does less damage than metal tracks on soft ground

Figure 7.3 Signs remind equipment operators of contract penalties for damaging vegetation

Figure 7.4 Silt fence is an often-used strategy for erosion and sedimentation control

This approach, however, does not take into account the ecological damage heavy equipment can cause. For example, metal-tracked equipment can cause much more serious damage to site soil than rubber-tracked equipment (Figure 7.2), and tyre-based equipment may cause even less damage depending on soil conditions. While ecological damage may not be the only criterion for equipment selection, it should at least be considered as a factor in making more sustainable choices.

Contractual penalties and incentives can also be used to motivate more sustainable behaviour on site. For instance, projects for which preservation of mature trees is important may impose fines for damaging trees targeted to be saved on site. This fine is often a function of tree diameter. In one case, a project manager actually posted large price tags on the trees to be preserved on his project site (Figure 7.3). This visual reminder made the contractual penalties for damaging trees very clear to the excavation subcontractor and its equipment operators. As a result, no trees were damaged during the project.

Erosion and sedimentation control

During project planning, site selection and design, the project sustainability team can take many actions that prevent erosion and sedimentation during construction. These include:

- choosing previously developed sites instead of greenfield sites
- choosing sites with few steep slopes
- locating buildings on areas of the site that require less grading.

After the site has been selected and the building has been designed, managing erosion and sedimentation becomes the responsibility of the general contractor and subcontractors (Figure 7.4).

The project civil engineer or landscape architect typically begins the control process by identifying erosion-prone areas of the site and outlining soil stabilization measures (see Table 7.2). The contractor should develop a specific erosion and sedimentation control (ESC) plan to implement those measures and meet legal requirements.

Table 7.2 Erosion and sedimentation control measures

Control measure	Description
Soil stabilization	
Temporary seeding	Plant fast-growing grasses or 'green manure' species to temporarily stabilize soil in areas where the soil will again be disturbed in the future.
Permanent seeding	After soil has been placed in its final location on site, plant grass, trees, shrubs and other plantings to permanently stabilize soil.
Mulching	Place straw, cut grass, wood chips or gravel on the surface of disturbed soil to hold it in place. Choose an organic mulch that will quickly decompose if the soil will later be moved to another location.
Structural control of soils	
Earth dike	Construct a dam of stabilized soil to divert runoff from disturbed areas into sediment basins or sediment traps. Use seeding or other measures to stabilize the earth dike.
Wattle	Install bundles of straw or straw bales continuously across areas of erosion to remove sediment from stormwater before it leaves the site. Wattles should be staked in place to prevent movement.
Silt fence	Install 2″ x 2″ stakes no greater than 6′ apart to support filter fabric to remove sediment from stormwater before it leaves the site. The base of the filter fabric should be placed in a trench at least 4″ x 4″ and backfilled with native soil or gravel to prevent blow-out.
Sediment trap	Excavate a pond area or construct earth embankments to contain stormwater. This trap will retain stormwater and allow sediment to settle while the water percolates into the soil.
Sediment basin	Construct a pond with a controlled water release structure to allow sediment to settle out of stormwater before it leaves the site.

The best measure for erosion and sedimentation control is to avoid disturbing site vegetation during construction. This can be accomplished through careful planning of site operations to minimize the areas of site that will be disturbed. In areas where site disturbance is unavoidable, construction activities should be carefully planned to minimize potential damage. Areas where disturbance will be frequent should be isolated from the rest of the site by structural controls such as earth dikes, wattles or silt fences. Stormwater falling onto these areas should be diverted to sediment traps or sediment basins to allow soil particles to settle out. Mulching with gravel can be used to stabilize areas where equipment or vehicle traffic will occur. Gravel can also help control airborne dust. A vehicle wash area will ensure that soil accumulating on vehicles is removed before it leaves the site.

Temporary or permanent grading can help to slow and divert stormwater to desired areas. Where possible, grading should be done to encourage sheet flow instead of a concentrated flow of stormwater. Sheet flow involves water running at a low depth across a wide area. Sheet flow tends to slow water velocity, thereby reducing the erosion potential. Lengthening flow paths and reducing gradients also reduces water velocity and minimize erosion.

Priorities for erosion and sedimentation control during construction

- Avoid landscape disturbance.
- Isolate disturbed areas from the rest of the site using earth dikes, wattles or silt fences.
- Divert stormwater from disturbed areas to sediment traps or basins.
- Stabilize disturbed soil and control airborne dust in travel pathways during construction.
- Use permanent landscape features where possible, and temporary features elsewhere, to manage stormwater:
  - Encourage sheet flow of water.
  - Lengthen flow paths.
  - Reduce gradients to reduce velocity.
- Use temporary seeding or mulching in infrequently disturbed areas:
  - Native plantings.
  - Green manure/nitrogen-fixing species.
  - Maximize the restoration potential of the site.

Diverting stormwater into vegetated areas can both slow water velocity and encourage sediment filtering and water percolation. Sediment basins can and should be vegetated using temporary or permanent seeding to promote filtration and absorption of stormwater. More permanent vegetated structures such as infiltration trenches, vegetated swales and bioretention cells are likely to be part of sustainable site design for green projects. The general contractor should work closely with the project design team to determine the potential for incorporating such structures, or at least the grading for them, as part of stormwater management during construction.

Areas with infrequent disturbance, such as spoil piles or soil storage areas, may rely upon temporary seeding or mulching to minimize damage to the soil before it is replaced on site. When choosing a seeding strategy, use native or non-invasive plants to minimize the potential for future landscaping problems. Some plant species are known as ‘green manure’. These species become established quickly after planting and fix nitrogen in the soil in which they are grown. They can be tilled under and mixed into the soil during grading. When this happens, they enrich the soil as compost that helps permanent landscaping become established. Recommended species of green manure that work well for this purpose include legumes (members of the pea family) and various types of clover (see Figure 7.5). Consult a local agricultural school or the county extension office for recommended species for the local climate and conditions.

Figure 7.5 Species such as crimson clover stabilize and provide nutrients to the soil

Pollution prevention

After construction begins, pollution of many types can threaten workers on the site and neighbouring sites. Pollution can be defined as any harmful substance or effect introduced into the environment as a byproduct of another activity. Noise, dust, air pollution and engine drippings from heavy equipment all reduce the sustainability of construction operations

(Figure 7.6). Emissions and off-gassing from materials can contaminate the air. Accidental spills or improper disposal of wastes contaminate the soil. Light pollution during night operations can pollute the environment if it shines beyond the work area. Sediment and eroded soil can pollute neighbouring sites if they are allowed to run off the project site.

Reactive measures can and should be taken on site to protect workers from these threats. Personal protective equipment (PPE) is one way to ensure that workers are protected from hazards such as noise, vibration, chemical exposure and struck-by injuries. Likewise, reactive measures such as perimeter silt fences can be taken to stop sediment before it runs off the site.

However, reactive measures assume that pollution problems are going to happen in the first place. A better approach is to use solutions that prevent problems before they happen. Table 7.3 shows examples of proactive versus reactive solutions to common types of construction pollution.

Figure 7.6 Equipment operating in dry soil generates airborne dust

Table 7.3 Examples of pollution prevention and mitigation measures

Pollutant	Source(s)	Reactive (mitigation) measures	Proactive (prevention) measures
Light	Night operations. Welding or cutting operations.	Shielding or redirecting light fixtures to focus only on the work site.	Revising construction schedules to avoid night operations. Using smaller lights focused directly on task areas.
Noise and vibration	Equipment operation	PPE for workers. Arranging work shifts to allow worker breaks. Perimeter fencing for a noise barrier.	Revising construction schedule to avoid operations during sensitive times. Choosing equipment with lower noise production.
Dust and airborne particulates	Equipment operation. Wind erosion of exposed soils.	PPE for workers. Surface treatment of exposed soils with water or dust suppression chemicals.	Limiting site disturbance. Leaving existing vegetation intact. Covering exposed soil with temporary or permanent seeding.
Airborne chemical emissions	VOCs from the offgassing of new synthetic materials.	PPE for workers. Increased ventilation rates during product installation.	Using low- or no-VOC products. Designing for exposed surfaces. Using pre-finished materials.
Soil and groundwater pollution	Engine drippings. Refuelling. Accidental spills. Improper disposal.	Spill countermeasures such as berms, absorbent mats and barriers. Contained storage for chemicals and hazardous materials. Spill cleanup plans/equipment	Using non-hazardous materials where possible. Spill prevention training for employees. Proper equipment maintenance. Centralized refuelling.
Surface water pollution (heat and contaminants)	Engine drippings. Accidental spills. Exposed soil without erosion control measures. Paved surfaces	Spill countermeasures. Perimeter silt fences. Spill cleanup plans/equipment. Contained storage. Stormwater detention basins	Proper equipment maintenance. Pervious surfaces. Seeding exposed soil. Limiting construction disturbance. Infiltration basins.
'Tracked' soil on neighbouring streets	Vehicle wheels.	Vehicle wash stations.	Limiting construction disturbance. Off-site materials staging. Just-in-time delivery.

Case Study: Center1, Seoul, South Korea

Completed in October 2010, Center1 is an office building located in the downtown Seoul, South Korea. The building has a gross area of 168,000 sq m along with two 32-storey towers 148 m high. The two towers are connected through a podium and the of building substructure. Since the project team had to reduce construction duration, to secure safety during earthwork in the urban area and to reduce noise pollution, the top-down method of bracket supported reinforced concrete downward (BRD) was applied. In addition, the project implemented several green building strategies to achieve the goals of sustainability and LEED silver rating. One of the major green strategies was to reduce energy consumption and carbon emissions. Recommendations were to:

- Improve glass performance. Consider lowering shading coefficient: used low-e glasses with U-value 1.6, shading coefficient 0.32.
- Utilize demand ventilation control system (carbon dioxide sensors).
- Replace the air-cooled multi-system with fan coil units, where possible.
- Add vestibules to the entrances to the building, except for the emergency exits: vestibules were installed where there are swing doors.
- Add daylight sensor controls (dimmers): four sensors were installed on each floor (total 60 floors).
- Add variable frequency drives (VFDs) on the fans applied to air-conditioning systems.
- Utilize air-side economizers if possible.
- Provide VFDs for cooling towers.
- Target lighting power density to 10 per cent less than the ASHRAE 90.1 requirement.

By implementing these energy saving strategies, Center1 is expected to reduce energy consumption by 17.95 per cent from the ASHRAE standard. Other green strategies included:

- A pedestrian- and public transport-friendly location in the centre of Seoul.
- a green roof in order to serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, and helping to lower urban air temperatures and combat the heat island effect.
- Water-saving taps.
- Use of local labour in construction and manufacture of products used in the building.
- Operable windows to allow natural ventilation.
- Daylighting design to provide optimal indoor environments to occupants.
- Use of low-VOC materials including adhesives, sealants, paints and carpets to improve indoor air quality and reduce health-related illnesses.

Center1 is located in downtown Seoul with two 32-storey towers that include many green strategies.

Source: HanmiGlobal Co., Ltd.

Courtesy of HanmiGlobal Co., Ltd.

Perimeter plantings on the roof help to buffer temperatures and mitigate stormwater run-off

A second green roof area is accessible to building occupants as part of an outdoor deck area with a view of the city and its famous river park

Figure 7.7 Recycling containers help to divert consumer waste on the job site

Site business operations

In addition to construction activities to create the building, contractor business operations on site also offer opportunities to contribute to project sustainability. The same practices that will be employed in the final building should also be considered for the site's temporary construction office. For instance, recycling facilities for paper, beverage containers and other types of recyclable waste should be available for workers on site (Figure 7.7). Other containers may be appropriate to collect rechargeable batteries, compostable food waste or other types of waste.

Closing the recycling loop is also important. Using recycled content paper and office products helps to provide a market for recyclable materials. Refurbished office furniture also saves raw materials and reduces waste. Paper goods such as toilet paper can be obtained with recycled content. Recycled content paper towels can be collected and composted if facilities are available.

Opportunities for improving site operation sustainability

- Environmentally friendly job site toilets and products.
- Reusable construction barriers and fencing.
- Building information modelling (BIM) to reduce job site paper.
- Virtual project meetings.
- Digital project documentation.
- Careful management of temporary site utilities.
- Transportation of people and materials to and from the site.
- Alternative fuel vehicles.
- Managing site access to reduce vehicle idling.

Nearly every aspect of site operations has opportunities to improve environmental stewardship. For example, it is possible to rent environmentally friendly portable toilets in some markets. These toilets use non-toxic chemicals that are formaldehyde- and alcohol-free. During servicing, they may be cleaned with biodegradable, non-toxic cleaning products. Paper products may be chlorine-free and made from recycled content. Water used in flushable stalls can also be dispensed through water-conserving fixtures. A web search for 'green portable toilets' will identify what options are available for a particular job site.

Rental of temporary construction barriers and fencing is another way to reduce job site impacts. This reduces the use of virgin materials to construct the fence. It also reduces the need to dispose of temporary materials at the end of the job. Similarly, with the advent of building information modelling (BIM), job sites may become increasingly paperless in the future. Plans, specifications and other project documents may be shared among the project team electronically rather than through paper copies. Virtual project meetings are now possible using widely available, low-cost infrastructure which is available on many projects. Conference calls and video or computer-based conferencing can replace the need to physically travel to the job site. Webcams, remote sensing and other digital technology can provide documentation of project conditions that reduces the need for physical transportation to the site.

Site utilities such as power and water should be carefully managed as well. Temporary water lines are often constructed without the same level of care as permanent lines. This can result in leaks, particularly if flow is not shut off after the water has been used. Site personnel should be aware of the location of all temporary utility lines and should regularly inspect them to locate and repair leaks. Education of subcontractors is also important to ensure that leaks are immediately brought to attention. It should also be emphasized to subcontractors that they must turn off lights that are not required and other equipment such as radios when the site is unoccupied. These provide another way to make the project more environmentally friendly and resource efficient.

Transportation of people and materials to and from the site also has impacts on resource efficiency, air quality and traffic congestion. Especially for congested sites, sustainable construction supervisors should consider the possible impacts of employee parking on site preservation goals. Policies and incentives to encourage employee carpooling or public transport use can help to reduce these problems. Consider providing preferential parking for carpools and alternative fuel vehicles when designing the site layout.

Some firms have converted to alternative fuel vehicles for their fleets (Figure 7.8). Employees may also elect to drive their own alternative fuel vehicles to the project. Increasingly, heavy equipment is run using biodiesel mixtures instead of conventional diesel. This reduces the air emissions resulting from diesel combustion and also reduces dependence on non-renewable resources.

Figure 7.8 Alternative-fuel vehicles, such as this electric truck, have a reduced carbon footprint

Managing site access can also have a significant environmental impact. Sites with security inspection checkpoints can be particularly problematic. Not only do idling vehicles emit pollution as they wait in line for security inspections, the materials they carry can be compromised. For instance, concrete has a limited window of opportunity for placement after it has been placed into Ready-mix trucks. If trucks are delayed in reaching the site, entire batches of concrete can be ruined and must be disposed of.

Even if formal security checkpoints are not an issue, careful planning of material deliveries and equipment mobilization and demobilization can reduce the air quality impacts of vehicle idling. Reducing transportation impacts is an important part of a sustainable site operations plan.

Opportunities to reduce resource consumption, waste generation and other harmful impacts should also be inventoried at the start of the project. These include office practices, project documentation practices, green services and utilities, and transportation.

Sustainable site operations plans should include an inventory of all of these potential impacts. The following checklist describes operational impacts that should be considered as part of the plan. After the impacts have been identified, applicable best practices should be identified that can reduce or eliminate them. Responsibility for monitoring and quality control may be assumed by the sustainable construction supervisor or assigned to others. Responsible parties should be clearly indicated as part of the sustainable site operations plans.

Materials management

Effective materials management not only improves project sustainability, it offers the potential to save project costs. Working with vendors on product procurement and delivery practices can reduce solid waste and increase efficiency. Better product storage helps prevent damage to products and saves the cost of later replacement or disposal of damaged products. Finding alternative things to do with excess materials reduces disposal costs and may also offer benefits in terms of tax credits or vendor credit. All of these tactics can be integrated into a materials management plan that will save money while improving project sustainability.

Product procurement/delivery

Not only is it important to choose green products for use in a sustainable construction project, it is also important how those products arrive on site. Two key elements of this process should be considered on green products: product procurement and product delivery. Product procurement involves identifying and selecting a source for products and communicating product requirements and delivery expectations to that source. It is followed up by ensuring that what is delivered meets those requirements and working with the vendor or supplier to correct any problems. Procuring green products may require using different vendors and suppliers than are customary for a company. New relationships, accounts, and lines of communication may need to be established.

Sustainable materials management:

Product procurement/delivery strategies

- Establish relationships and lines of communication early with new vendors/suppliers.
- Allow for lead time uncertainty in product delivery.
- Review and understand new requirements for product documentation.
- Establish a product documentation file.
- Obtain necessary manufacturer training and certification.
- Specify reusable/returnable packaging and return it to the manufacturer or supplier.
- Use compostable or recyclable packaging and appropriately compost or recycle it.
- Use just-in-time delivery where possible.

These relationships are a good investment for companies working on green projects. However, they represent a risk of the unknown. Lead times for products may be unfamiliar, and more time may need to be built into the schedule. New requirements for product documentation may also require additional attention. Manufacturer training and certification may also be required for some types of products. Building these relationships early on will help companies be more competitive as green projects become the norm. Obtaining the necessary training and building a product documentation file for green products will reduce the learning curve and uncertainty for future projects. Systematic attention to product procurement is worth the effort in the long run.

The second half of the equation is product delivery. An important part of green delivery is the means and methods of transportation used to deliver the product to the site, although this may be difficult to influence. A second important consideration is the packaging that is used to transport and protect the product during delivery.

Adequate packaging is essential to prevent damage to products during and following delivery. However, that packaging need not be an environmental liability. Some manufacturers can provide their products with returnable or reusable packaging. This prevents the packaging from turning into waste, provided that it is properly returned to the source. For instance, delivery of small sizes of sand and aggregate can be arranged using returnable heavy-duty bags that are removed from the delivery truck by crane. These bags allow multiple types of materials to be delivered at once. This has lower transportation impacts than bringing each material separately loose in a truck bed. It also keeps these materials from being contaminated on site or spreading to unwanted areas, and it speeds clean-up.

Other types of packaging may be compostable or biodegradable. For instance, many types of plastic are now being made from plant products such as corn and soybeans. Depending on environmental conditions, these plastics may be compostable, especially in municipal composting facilities where higher temperatures are maintained than in home composting systems. Be sure to check with local composting facilities to verify acceptability of these types of wastes.

Still other construction material packaging can be recycled. Corrugated cardboard is a fairly high-value waste for recycling and can be recycled in most locations. Storing it in a protected location helps keep the material dry and makes it easier to handle for recycling. Wood pallets that are not reusable can be recycled along with clean wood waste, or chipped and used as mulch (Figure 7.9).

Figure 7.9 Wood pallets can be reused, recycled as clean wood waste, or chipped for mulch

Moulded polystyrene is commonly used with cardboard to secure products within packaging, but it is difficult to recycle in all but a few locations. Sheet polystyrene or packing peanuts may be reusable; check local shipping outlets to see if they accept such materials for reuse. Waste paper can be used, either shredded or crumpled, as packaging material that can subsequently be recycled or composted. Packing peanuts may also be made of rapidly renewable, starch-based biodegradable materials. Be sure to verify that this is the case before mixing these items with compostable waste. Sometimes popcorn is even used as an environmentally friendly packing material.

After packaged material arrives on site, it must be stored in a safe, secure location until it is needed. One way to minimize both the need to store material and the risk of damage to the product is just-in-time

Figure 7.10 Just-in-time delivery and placement of products such as precast concrete reduces the need for space on site

delivery. Just-in-time delivery is fairly common for projects involving large components for which on-site storage would be difficult (Figure 7.10). For such projects, it requires considerable planning and coordination since the components are likely to be custom-fabricated.

Just-in-time delivery can also be used for situations where materials are more readily available and scheduling constraints are looser. Commodities such as drywall, drop ceiling panels, carpet, carpet pads and insulation are best delivered as close to installation as possible. These materials are highly absorptive. They pose a high risk of moisture damage and can also be easily damaged while in storage. They also can easily absorb contaminants from other parts of the project. These contaminants can then escape into the building after the materials are installed.

Product storage and staging

Threats to sustainable product storage

- Material security.
- Moisture/humidity.
- Temperature changes.
- Physical damage.
- Chemical spills.
- Absorption of environmental contaminants.
- Ultraviolet radiation.
- Failure to offgas synthetic materials.

The construction schedule dictates when various materials will be needed for a project. Depending on how predictable and reliable the supply chain is, having products arrive on site well before they are needed may be necessary to avoid construction delays. When products arrive before they can be installed, adequate product storage and staging must be provided to ensure their safety.

Material security is one possible threat to stored materials. Other threats result from environmental conditions such as moisture or temperature changes. Still other damage can be caused during construction operations from physical damage (crushing, puncture and so on), chemical spills, or absorption of contaminants from the surrounding environment.

Preventing moisture damage is of paramount importance in material storage, especially for products that are absorptive. Exposure to moisture increases the likelihood of mould in the product itself and can also increase the likelihood of mould in adjacent products after installation. Moisture can also damage adhesives used in composite materials or cause swelling of particles. Careful attention to moisture from all directions is worth the effort, including absorption from the ground and the air. Stacking materials loosely to allow good air circulation is also advised in most situations. In extremely humid climates, however, obtain manufacturer advice on how best to store materials, and consider just-in-time delivery where possible.

Other potential damage can be caused by exposure to ultraviolet (UV) radiation. Products containing plastics especially must be protected from UV exposure or they begin to photodegrade. Rigid plastics become more brittle, while softer plastics may become chalky or otherwise lose their integrity. Colour-critical products may start to fade. Covering or shading materials to prevent UV exposure is a critical part of sustainable material storage.

Preventing outside damage is not the only action necessary for material storage. Materials themselves may require attention prior to installation. For instance, materials containing synthetic components or adhesives may need to be unwrapped and allowed to offgas before installation. This prevents potential indoor air quality problems after the building is complete. Products containing fabrics, foam, composite wood, adhesives and finish materials may all need to offgas (Figure 7.11). During this time, they must also be carefully protected from other types of damage.

Figure 7.11 Furnishings and cabinetry should be allowed to offgas away from the building prior to installation

Excess materials

After products have arrived on site and installed in the building, any remaining excess materials must be addressed. Some materials may remain with the building as attic stock for future repairs or maintenance. Others may not be suitable for subsequent use and must be disposed of. However, some materials may remain in smaller quantities that could still be used for other purposes. Finding good uses for these products is a critical part of both materials management and effective waste management.

Uses for excess materials

- Attic stock for future repairs.
- Avoid via careful procurement.
- Return to vendor, supplier or manufacturer.
- Donation to charity.
- Donation to universities, colleges or trade schools for use in education or training.

Ideally, there should be few leftover materials if there is proper storage and staging plus careful estimating and procurement. Sustainable construction personnel should prevent pollution by not ordering more material than necessary to get the job done. However, especially for unusual or hard-to-get products, this may not be advisable, since getting replacement materials if needed would be difficult and time-consuming.

Leftover or excess materials can sometimes be returned to the vendor, supplier or manufacturer for reuse. Protection of excess materials from potential damage is critical to enable product takeback, especially moisture and UV damage. In other cases, usable leftover materials can be donated to charities such as Habitat for Humanity. Local universities, colleges or trade schools may also be interested in leftovers to use as part of education and training, particularly for innovative new products.

Developing a materials management plan

As with other types of management plans, developing a materials management plan requires an inventory of needs, identification of potential solutions, and a cost/benefit analysis to determine the best course of action. Needs for materials management will correlate closely with the construction schedule. Therefore, the construction schedule is a good starting point for identifying needs and requirements.

Elements of a materials management plan

- Inventory of needs:
  - Materials by task.
  - Procurement requirements.
  - Storage/staging requirements.
  - Special subcontractor requirements.
- Storage requirements vs. schedule:
  - Total space required.
  - Material protection requirements.
  - Schedule dependencies.
  - Access within storage area.
  - Inventory of threats.
- Identification of potential solutions.
- Cost/benefit analysis of options.

A materials management needs inventory should begin by identifying materials associated with each construction task and evaluating the procurement and storage/staging requirements for each type of material. It should be prepared in consultation with subcontractors to ensure that their material storage/staging needs are also met.

After all material storage needs have been inventoried, the next step is to map these needs over time, based on the level of completion of the building and other site needs. This helps to determine the amount of space required, special material protection requirements, and total storage time. Arrangements may be possible for items with long lead times to not take possession of the item until shortly before it is needed on site. This helps minimize the risk of damage. Access to materials within the storage/staging area should also be considered. Heavy items requiring equipment to move should be placed where they can be accessed without damaging other items.

After the materials inventory is complete, each item in the inventory should be assessed in terms of potential threats that should be guarded against. Table 7.4 lists potential threats to be considered for each material in the material inventory, along with mitigation measures.

Provisions should also be made in the schedule to ensure that offgassing materials have adequate time to release chemicals before inspection begins. Excess materials at the conclusion of each task should be considered in the materials management plan and also addressed specifically in the project waste management plan.

Table 7.4 Threats and mitigation measures for material storage

Threats to material integrity	Mitigation measures
Moisture ☐ Exposure to precipitation ☐ Excess humidity ☐ Absorption from ground contact	• Indoor product storage • Placement to allow ventilation • Preventing ground contact • Adequate covering • Active ventilation/heating
Photodegradation ☐ Exposure to UV radiation	• Indoor product storage • Adequate covering
Material security	• Indoor product storage • Protected/locked storage
Temperature fluctuation	• Indoor product storage • Active ventilation/heating
Physical damage ☐ By equipment during moving ☐ By equipment while stored ☐ Improper orientation/support	• Indoor product storage • Adequate support • Following manufacturer stacking/protection recommendations
Contamination ☐ Exposure to spills ☐ Exposure to dust ☐ Absorption of contaminants from surrounding materials	• Separate storage of absorptive items from potential contaminants • Adequate covering • Sealed openings • Active ventilation • Cleaning before installation

Waste management

Managing solid waste on the construction site creates tangible, visible benefits. Psychologically, skip/dumpster contents form a first impression of how green a project is. Although there are more impactful ways to increase project sustainability, effective waste management is a good place to start.

Waste-generating construction processes

Demolition debris and construction cutoffs are the most obvious sources of waste on the construction site. However, significant quantities of waste come from other sources that could be avoided:

- **On-site fabrication of building components** – fabrication on site increases overall waste rates. The likelihood of reusing scrap materials is much smaller on the job site than in a centralized fabricating facility where similar products are made regularly.
- **Inefficient procurement and transport of products to site** – purchasing materials in bulk can often avoid significant packaging waste. However, it may also result in excess product on site that is easier to dispose than return to the manufacturer or reuse.

- **Careless materials management** – poor storage and staging practices result in materials that are wasted through physical damage, exposure to moisture or weather, or other damage.
- **Poor coordination of subcontractors** – failure to coordinate the work of subcontractors can result in damage of installed systems or a need to rework finishes.
- **Poor site layout** – inefficient location of scrap storage, cutting areas or disposal areas makes it easier to pull a new piece of material from the stack instead of searching for a scrap that could be used instead.
- **Poor protection of installed work** – a lack of effort to protect installed systems, especially finishes, can require that damaged systems be torn out and reinstalled. This not only generates waste, but also increases project cost and extends the completion schedule.

Each of these practices increases the quantity of solid waste generated on a project. Some occur because of a desire to save time or labour costs. Others can actually increase installation time, such as poor protection of installed work. Managing these trade-offs is an important function of the sustainable construction supervisor.

Options for waste reduction and diversion

Many opportunities exist for reducing the amount of solid waste from a project. Additional opportunities exist for diverting unavoidable waste to better destinations. When preparing for construction and procuring products and materials, significant waste can be avoided in the first place by:

- **Prefabricating components in the shop instead of on site** – this can optimize raw material use and encourage greater use of scrap material, since it is located where similar products will be made in the future.
- **Designing for modular construction** – this reduces waste by sizing building elements to fit standard material sizes, thus reducing the need to cut and customize parts. This approach can also save significant construction time.
- **Ordering materials cut to size** – as with shop fabrication, this encourages centralized cutting, which increases reuse of scrap for future projects and reduces mistakes.
- **Working with manufacturers to reduce packaging waste** – this includes manufacturer takeback of reusable packaging as well as the use of compostable or biodegradable materials.

During construction, process waste can be reduced by:

- **Managing procurement from vendors** – requesting that products be shipped with returnable packaging eliminates the need to dispose of the packaging as waste. Ask suppliers to take back or buy substandard, rejected or unused items, especially if they are responsible for the problem in the first place.

- **Careful excavation planning** – balancing project cut and fill requirements reduces the need to dispose of soil spoils off site. Stockpiling topsoil for reuse also reduces the need to import new soil at the end of the project.
- **Limiting site disturbance** – this reduces the amount of land-clearing debris generated during the project and also minimizes the cost of re-landscaping at the end of the project.
- **Effective materials management** – this ensures that materials are not damaged while on site before they are installed. A staging plan that reduces material movement also reduces the chance for damage.
- **Careful coordination of subcontractors** – proper sequencing installation of products, especially finishes, can reduce the chance of material damage after installation.
- **Protection of installed work** – taking the time to mask off completed areas or install coverings over installed work reduces the likelihood of damage and need for rework.

Figure 7.12 Many building materials can be recovered for future use. Materials like these plumbing fixtures can be recovered for salvage and donated to charities like Habitat for Humanity

In projects requiring removal of existing buildings or systems, waste can be reduced by:

- **Engaging salvage organizations** – this provides an opportunity for companies with established markets to recover useful products from the building prior to demolition activities.
- **Deconstruction instead of demolition** – this involves carefully taking apart building systems so that they can be reused (Figure 7.12).
- **Protection of installed work** – sealing off areas where demolition is occurring reduces the likelihood of damage to materials and systems that are not part of the project.

Figure 7.13 Metals are easily recycled construction materials

For unavoidable waste generated during demolition, renovation, or construction, waste can be diverted from landfills or incinerators by:

- **Capturing recyclable materials** – this involves diverting recyclable materials from the solid waste stream through either on-site separation or commingling for off-site separation (Figure 7.13). Recycling opportunities differ by location based on availability of facilities, market value and other factors.
- **Composting** – this involves segregating biodegradable wastes such as certain types of packaging or land-clearing debris for diversion to off-site composting facilities (Figure 7.14). The effectiveness of this option depends on the types of waste generated and the availability of local facilities.

Figure 7.14 Municipal composting facilities such as this can accept organic wastes

On-site disposal options may also be available for certain types of waste, including:

- **Biodegradable materials** – certain types of packaging, limited amounts of wood waste, and site-clearing and landscaping debris can be processed on site for use as landscaping mulch.

- **Drywall** – in limited quantities, drywall can also be applied on site as a soil amendment after being processed through a grinder or chipper. Whether this is a good idea depends on soil characteristics.
- **Waste concrete** – can be used as subbase for paved areas or foundations, or also as riprap for stormwater management or soil retention. Can also be processed on site using crushing equipment for reuse as aggregate.

Developing a waste management plan

Although a waste management plan takes time to create, it is a good investment for a construction company. As landfill space decreases, waste disposal costs will continue to rise. Increases in the cost of raw materials will also make recycling more economically attractive. Waste recycling is already economically profitable in some parts of the United States.

Elements of a waste management plan

Waste stream assessment:
- Types and quantities of waste by task.
- Time during schedule of generation.
- Possible disposal mechanisms.

Evaluation of local markets:
- Potential destinations for each stream.
- Value for each type of waste.

Cost/benefit analysis of options:
- Pros and cons for individual project.
- Feasibility of options.

Three fundamental activities are part of waste management planning: waste stream assessment, evaluating the local market, and performing a cost/benefit analysis of options. The first step involves reviewing the project to estimate the likely types and quantities of waste associated with each project task, including items to be salvaged, recycled or composted. Identifying the period in the schedule when these wastes will occur is also necessary. Knowing the timing of each waste stream will help to plan site layout and ensure that no more waste bins are on site than are needed at a particular point in the project. For instance, projects that recycle drywall waste do not need a drywall skip on site until interior construction begins. Likewise, a concrete waste skip is not likely to be needed after demolition is finished. The contractor will be responsible for coordinating waste management activities on site.

The second step is to investigate the local and regional market for recycling and salvage. This will determine potential destinations for each waste stream. It will also establish a value for each type of waste. This evaluation should include waste haulers, recyclers, on-site waste subcontractors, and other market options for handling waste streams such as Habitat for Humanity or nonprofit organizations. The last step is to evaluate the costs and benefits of options for each waste stream. The nuances of the project will also determine what is feasible in terms of space constraints for skips.

Considerations for waste management strategy selection

- Direct costs (disposal/tipping, hauling, etc.).
- Indirect costs (management time, labour costs, etc.).
- Likely diversion rates.
- Project diversion goals.
- Potential liability.
- Schedule constraints.
- Space constraints.

The cost/benefit analysis will suggest the best approach for the individual project conditions. Both direct costs, such as landfill and hauling fees, and indirect costs, such as increased management time and labour costs, should be taken into account. Other considerations, such as likely diversion rates, project waste diversion goals, and potential liabilities and schedule constraints, are also important to consider. Four major categories of options include on-site segregation, commingling for off-site separation, on-site processing and salvage/deconstruction.

On-site separation includes all scenarios where waste is sorted into multiple skips located on site. Most commonly, subcontractors are required to sort their own wastes as part of their scope of work, or the process may include a housekeeping subcontractor that takes care of sorting and housekeeping on site. Bins or skips may be kept in a centralized location, or may involve multiple smaller bins located near work areas. The latter option is likely to result in a higher diversion rate, but also requires additional labour to consolidate and empty the bins.

Commingling is available in areas where centralized construction and demolition waste sorting facilities exist. All on-site wastes are deposited by subcontractors into a common bin or skip, which is periodically removed and sorted in an off-site facility for subsequent recycling. A specialty waste management subcontractor generally provides this arrangement. It often results in higher diversion rates. The cost of this option depends on the types and quantities of wastes to be generated as well as market conditions. Waste management companies offering this service have well-established market connections. They are able to consolidate waste streams to achieve higher value of recycled materials.

Major waste management options

- On-site segregation.
- Commingling for off-site separation.
- On-site processing.
- Salvage/deconstruction.

Case Study: Air Force Weather Agency (AFWA) Headquarters Building, Offutt Air Force Base, Nebraska

US Air Force Air Combat Command and Kenneth Hahn Architects

This award-winning LEED Gold project was one of the first buildings certified under a new green building policy implemented by the US Air Force (USAF). Designed to consume less than half the energy of a typical office building, it sets the standard for future Air Force buildings, both at Offutt Air Force Base and throughout the US Department of Defense.

Sustainable sites

Construction of parking lots was avoided on the project by repurposing an adjacent abandoned runway for parking. Storm water detention ponds keep the storm water discharge rate at predevelopment levels. The detention ponds also contribute to a goal of maintaining more than twice the area of the building footprint as permanent open space adjacent to the facility. Preferred parking areas are provided for eco-friendly vehicles, and bike racks, and shower facilities encourage building users to bike to work. Light pollution is reduced through the use of low-cut-off parking lot light fixtures, which are carefully located to prevent light spill onto adjacent properties. Roofing is a highly reflective white membrane, which reflects the majority of the sun's radiation, instead of absorbing it.

Water efficiency

Outdoor irrigation was eliminated on the project by selecting native plants and plants that are well adapted to the growing conditions of the region. Once established, these plants can survive under normal rainfall conditions. Indoor water use was reduced by 30 per cent through the use of waterless urinals, low-flow shower heads, and ultra-low-flow lavatory taps with automatic sensors set for 12-second duration.

Energy and atmosphere

Data centres are one of the most energy-intensive types of facilities constructed today. As the agency responsible for collecting and storing extensive amounts of weather-related data for the Air Force, the AFWA Headquarters building houses significant data processing and storage facilities. Despite this fact, AFWA has achieved an overall reduction in energy usage of over 50 per cent compared to a typical office building. Careful siting of the building to optimize sun angle, the use of sunshades and light shelves inside the windows, and use of highly efficient window glazing are part of the overall strategy to keep energy usage to a minimum. Energy efficiency is also achieved through the use of an HVAC system designed for flexibility and individual control. Key to this efficiency is the use of an under-floor air distribution system, which delivers tempered air to individual floor diffusers located at each work area. Using this system, occupants have the ability to adjust their own air flow easily at each workstation. Use of this system allows lower speed fans and lower velocity air to actually give more comfort with less energy use. Light fixtures use low-wattage lamps, energy efficient electronic ballasts, and are controlled by occupancy sensors. When daylight is adequate for illumination, the lights are turned off for energy savings.

Materials and resources

Special areas on each floor are set aside for the collection of recyclables, and there are also storage areas for recyclables outdoors. During construction, more than 99 per cent of the waste generated on-site was diverted from landfills, through either recycling efforts or reuse of products on-site. The reuse of the existing 24-inch thick concrete runway for parking contributed greatly to achieving such a high rate of diversion. Products specified for this project contain on average over 10 per cent recycled content. Specific products containing high recycled content include structural steel, concrete and carpet. Over 20 per cent of the products specified were manufactured within 500 miles of the project, including structural steel, metal decking, concrete and face brick.

Indoor environmental quality

During construction, special attention to keeping the site clean and eliminating smoking indoors helped to prevent contaminants from accumulating in the building. Before occupancy, the building was flushed with outside air to remove lingering contaminants from the construction process. Low-emitting (low-VOC) materials used included adhesives, paints, carpets, and wood products throughout the building, in order to minimize offgassing into the indoor environment. Walk-off mats in exterior vestibules keep contaminants on shoes from entering the building. Increased ventilation at copy centers prevents noxious odors from migrating to the work areas. Throughout the facility, carbon dioxide is monitored and ventilation rates are increased to ensure that sufficient air exchange occurs to maintain indoor air quality. High-efficiency filters are installed on all mechanical systems.

Project innovations

Security is of paramount concern for all Department of Defense installations, and Offutt AFB is no exception. Limited access controlled through secure gates is a primary means for ensuring base security, but controlling access also can result in long queues of idling vehicles awaiting inspection. To reduce the carbon impacts resulting from additional idling vehicles during construction, AFWA HQ was constructed ‘off-base’, as if the project were not located on a military base, by temporarily relocating the base perimeter security fence to exclude the project site during construction. All construction traffic and deliveries came on-site without having to go through any security checks. This saved a wait in line, a vehicle search, and a nearly 3-mile-long escorted trip from the other side of Offutt AFB. This innovation greatly simplified the construction process, saving over 400,000 miles of travel and thousands of labour-hours that would have been required if the facility was built on-base.

A second major innovation was employed to reduce future costs and solid waste during the building’s life-cycle. The majority of the work spaces in AFWA are enclosed with modular wall panels that are completely movable and reusable for many future reconfigurations. This will save a great deal of drywall, metal studs, insulation and paint, every time a reorganization creates a need for a different floor plan layout. Use of these demountable walls will keep materials out of the landfill and will prevent construction noise and dust from making an unpleasant work area for the building occupants.

The AFWA Headquarters Building received a LEED Gold certification

Concrete work was an extensive part of the building's construction, although significant work, cost, and material use was avoided by repurposing a runway adjacent to the building for a parking lot

The AFWA building was oriented to take advantage of solar orientation

On-site processing may be appropriate for some waste streams such as land-clearing debris or large-scale concrete waste. It involves contracting specialized equipment to come on site to deal with a single type of waste that will then be reused on site, such as crushed concrete for aggregate, or wood waste for mulch. If the project involves work with existing facilities on site, salvage or deconstruction may be economically desirable to recover useful materials. Specialized firms can be employed to salvage reusable products, often in exchange for the value of those products. Demolition subcontractors often provide this service prior to demolishing the building.

Often, projects will involve a hybrid of these approaches based on local market conditions and the specific nature of waste streams involved. After inventorying the likely waste streams from the project and checking the local market, the last step in developing a waste management plan is to evaluate the costs and benefits of each option. Spreadsheet tools available online (see King County 2010 for one example) can help evaluate the costs of disposing versus recycling different materials for the project. Analysis may also include non-monetary costs and benefits such as likelihood of meeting LEED diversion goals and corporate environmental image.

Indoor air quality management

Actions during construction have a significant influence on air quality in the finished building. Many opportunities exist to prevent potential future problems through careful construction practices. An indoor air quality (IAQ) management plan is essential to ensure that the resulting building does not suffer from easily avoidable problems later.

Construction effects on IAQ

Construction can be responsible for introducing contaminants into the indoor environment. Construction activities such as material cutting, spraying finishes, pouring concrete, painting, and installing adhesives all introduce potential contaminants to the building. Simply moving materials into and out of interior spaces can introduce contamination through offgassing of those materials.

Many opportunities exist to reduce these problems. Reducing contaminants in the indoor environment has a number of benefits. These include improved comfort and performance and reduced health risks, of both construction workers and future building occupants. Health risks can be improved by choosing less harmful materials, and by changing the way they are installed. Many of the measures discussed earlier in for pollution prevention can improve indoor air quality as well. Wet processes instead of dry processes help to suppress dust and particulates. Workers should also wear personal protective equipment and employ dust collection when dust is generated through construction processes such as sanding, finishing and welding.

Careful attention to pollution prevention can have economic benefits as well. Capturing or avoiding contaminants in the first place can reduce the time and cost required to clean them up later. Cleaning up is often required at the end of construction when the schedule is already tight. Reducing cleaning-up requirements can make the difference between a project that ends on time and one that is late.

Options for IAQ management

Multiple options exist for improving IAQ. The Sheet Metal and Air Conditioning Contractors National Association (SMACNA) has developed a standard for managing IAQ during construction, demolition or renovation of occupied spaces. Chapter 3 of this standard focuses on control measures and guidelines to be used during construction. These include HVAC protection, source control, pathway interruption, housekeeping and scheduling.

IAQ control measures during construction

- HVAC protection.
- Source control.
- Pathway interruption.
- Housekeeping.
- Scheduling.

Figure 7.15 All temporary and permanent HVAC components should be protected during construction

The contractor should protect all HVAC equipment, both temporary and permanent, from dust and odours during construction (Figure 7.15). Before installation, all duct and equipment openings should be sealed with plastic. Equipment operated during construction should be protected with filters at all return air openings or on the negative pressure side of the system. Unducted plenums in the construction work zone should leave ceiling tiles in place and seal off return air grilles. The contractor should check for leaks in return ducts and air handlers, and seal them promptly to prevent introduction of contaminants. Mechanical rooms should not be used for storage during construction. All filtration media should be replaced before the building is occupied.

From a source control standpoint, low-emitting materials should be used. Where materials containing VOCs must be used, proper control measures should be employed. For instance, areas where such materials are stored or installed should be isolated from other areas and properly ventilated. Equipment that generates exhaust fumes should also be isolated or avoided if possible. This includes exhaust from idling vehicles near air intakes for the building. Dust collection systems should be used on all equipment used for cutting or sanding.

Construction activities should be physically isolated from clean or occupied areas. This can be accomplished with temporary barriers such as plastic sheeting and duct tape. Isolated areas should be kept under negative pressure to keep contaminants within the space. Ventilation with outside air should be used, especially during construction tasks that generate air pollution. All absorptive materials should be protected both before and after installation to prevent contamination.

Proper maintenance and cleaning should be undertaken regularly during construction, especially after spaces have been enclosed. This provides a safer work environment and also prevents problems for future occupants. Porous materials should be protected or cleaned with dry methods instead of wet methods to prevent exposure to moisture. High-efficiency vacuum cleaners can be used to clean dusty areas without spreading dust further.

Sequencing of construction activities can be used to prevent dirty activities from contaminating previously installed materials. If buildings are occupied during regular business hours, dirty or odorous tasks should be scheduled during off hours to reduce impacts to occupants. Adequate time should be included in the schedule for building flush-out and/or air quality testing after construction is complete. The schedule should also include a reminder to replace all filtration media prior to occupancy.

Commissioning

Commissioning is a systematic process for quality control of building systems. This process covers the quality from inception through project delivery. The aim of commissioning is to ensure that building systems as installed perform according to the design intent and owner's requirements. Since contractors are involved in delivering and installing building systems to create a complete facility, they represent a critical link in the commissioning chain.

Commissioning is typically conducted by a third party not otherwise involved in the project to ensure the objective review and evaluation of the building systems' condition and performance. Results are then reported directly to the owner. In some cases, the commissioning agent can be an employee of one of the companies involved in project delivery. This may be the architect, an engineering firm or contractor. In more complex projects, the agent must be an independent consultant or a qualified employee of the owner. In all cases, the commissioning agent should act independently of the project's design and construction management.

The following systems are typically included as part of the scope of all commissioning efforts:

- HVAC and refrigeration (HVAC&R) systems, both mechanical and passive, plus associated controls.
- Lighting and daylighting controls.
- Domestic hot water systems.
- On-site renewable energy systems such as photovoltaics (PV) or wind turbines.

More extensive commissioning efforts may also include systems such as the building envelope, which behaves dynamically and affects energy performance. Fire suppression, stormwater management systems, water treatment systems, data/IT systems, and other speciality systems are also often part of the commissioning scope. The commissioning process involves, at a minimum, the following steps:

- Designating an individual as the commissioning authority to lead, review, and oversee the completion of commissioning process activities.
- Reviewing owner project requirements (developed by the owner) and basis of design (developed by the design team) to ensure clarity and completeness.
- Developing commissioning requirements and incorporating them into construction documents.
- Developing and implementing a commissioning plan.
- Verifying the installation and performance of systems within the scope of the plan.
- Completing a summary commissioning report to the owner.

To meet LEED requirements for Enhanced Commissioning (EA Credit 3), additional requirements include:

- Conducting a commissioning design review prior to the development of construction documents.
- Reviewing contractor submittals applicable to systems under the scope of commissioning.
- Developing systems manuals for commissioned systems.
- Verifying that requirements for training on commissioned systems are met.
- Reviewing building operation within 10 months after substantial completion.

Many of these requirements should be implemented in conjunction with members of the project team. The commissioning authority is ultimately responsible for reviewing and approving the outcomes developed by the team. Commissioning requirements are most often described in a specific section of the general conditions of the construction specifications. They may also be referenced on the drawings and in bid forms. They may also be a part of specification sections related to the systems being commissioned.

The commissioning process and intent

Depending on the project delivery method being used, the sustainable construction supervisor may be involved in commissioning activities throughout the project delivery process. For instance, in design–build projects, the construction team may be invited to participate as part of pre-construction activities such as project planning or design. In these cases, the sustainable construction supervisor can contribute knowledge and expertise on how construction means and methods will affect system delivery and performance. These may contribute to the owner's project goals and requirements. The commissioning authority (CxA)

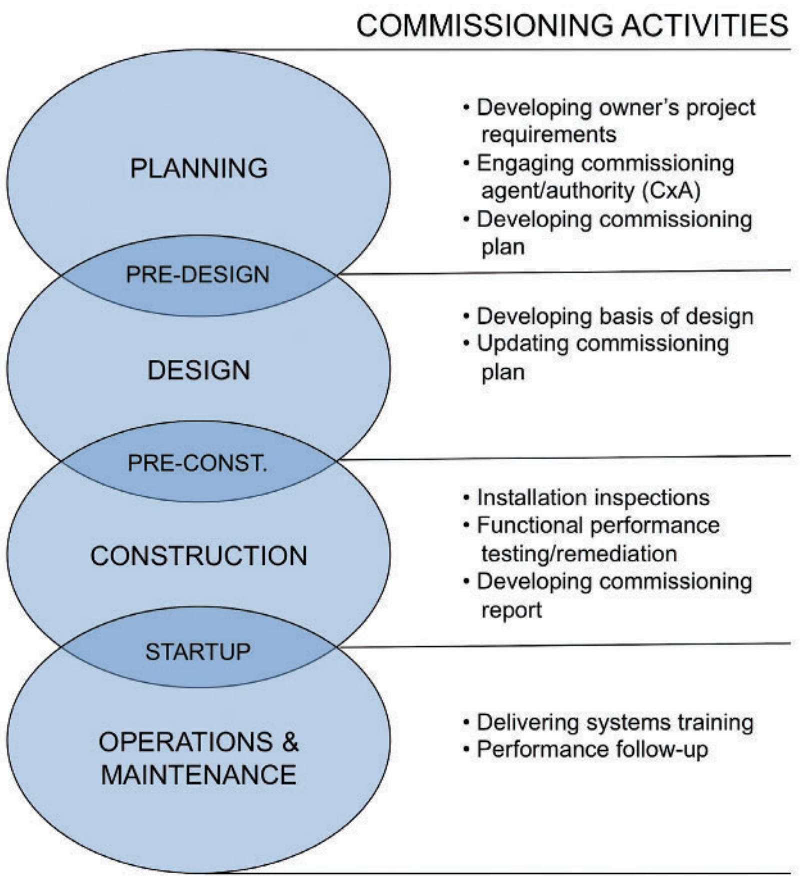


Figure 7.16 Typical commissioning activities by project phase

may also be a member of the contractor's organization, particularly if the project is being delivered by a construction management 'at risk' delivery method.

The overall commissioning process parallels the project delivery process as shown in Figure 7.16.

Construction-related commissioning activities

The primary involvement of the contractor with commissioning activities will occur during planning and implementing the construction process. Specific roles played by the contractor during this time may include:

- Reviewing and understanding commissioning requirements in the construction documents and commissioning plan.
- Preparing a commissioning milestone schedule.
- Undertaking any responsibilities specifically assigned to the construction supervisor in the commissioning plan.
- Informing and coordinating responses of subcontractors to commissioning requirements in the construction documents or commissioning plan.

- Coordinating the presence of the commissioning authority with scheduled construction activities such as system installation and performance testing.
- Notifying the commissioning authority of any relevant changes in the project scope or schedule.
- Verifying that the commissioning authority has met the requirements of the commissioning plan.
- Providing copies of submittals and documentation pertaining to commissioned systems to the commissioning authority for review.
- Coordinating training on commissioned systems as part of project closeout.

Working with the contractor, the commissioning agent will also be involved with installation inspection and performance testing. The purpose of these activities is to ensure that equipment is properly installed and able to perform as desired. Installation inspection of commissioned systems often occurs at the starting-up of individual system components. The commissioning agent will follow prefunctional checklists or start-up and checkout forms to document the start-up process. Depending on the requirements of the commissioning plan, the installing contractor might complete the forms instead of the commissioning agent. The purpose of these inspections is to discover any improperly installed components prior to performance testing.

Elements of system performance testing

- Start-up.
- Shut down.
- Capacity modulation.
- Emergency and failure modes.
- Alarms.
- Interlocks to other equipment.

System performance testing (also called functional performance testing) occurs after all system components have been installed. All components in each system to be commissioned should be fully ready for operation under part- or full-load conditions. Performance testing then involves testing each process in the sequence of operations, including start-up, shut down, capacity modulation, emergency and failure modes, alarms, and interlocks to other equipment. The purpose of the test is to simulate conditions under all modes of operation to be sure the equipment performs as expected. The outcomes of the test will identify performance problems that need to be remedied before the system will be acceptable to the owner. The contractor will work with other members of the project team to develop and implement a plan to fix any identified problems.

Case Study: Trees Atlanta Kendeda Center construction phase best practices

To achieve the goals of sustainability in the construction project, it is necessary to implement sustainable strategies not just during design, but also during the construction phase of the building's life cycle. The Trees Atlanta Building project introduced in Chapter 6 incorporated a number of sustainable strategies at the construction phase. These sustainable strategies included:

- Erosion and sedimentation control through construction activity pollution prevention.
- Construction waste management.
- Construction indoor air quality management during construction and before occupancy.
- Building commissioning.

The following subsections describe these sustainable strategies in more detail.

Construction activity pollution prevention

During the development of the construction site, the removal of existing vegetation can increase erosion, which causes a variety of environmental problems. Erosion of soil from the construction site greatly reduces the soil's ability to support plant life, regulate water flow, and maintain the biodiversity of soil microbes and insects that control disease and pest outbreak. In addition, the off-site consequences of erosion from developed sites include a variety of water quality issues. Water run-off from the construction site carries pollutants, sediments and excess nutrients that disrupt aquatic habitats in the receiving water. Sedimentation also contributes to the degradation of water bodies and aquatic habitats by lessening water flow capacity as well as increasing flooding and turbidity levels. Airborne dust from construction activities can also cause environmental and human health impacts including asthma.

In the Trees Atlanta building, several strategies for controlling erosion, sedimentation and airborne dust generation were implemented as part of an erosion, sedimentation, and pollution control plan (Figure 7.17) to reduce pollution from construction activities. The erosion, sedimentation, and pollution control plan for the Trees Atlanta site was prepared using the same Georgia Department of Natural Resources and City of Atlanta design standards that apply to all construction sites of between 1 to 5 acres. The plans were designed with a three-phase approach to show the demolition, intermediate and final phase best management practices (BMPs). Each phase of the plan demonstrated the use of BMPs such as silt fences, inlet sediment traps, seeding, grassing, dust control, and construction entrances designed to provide at least 67 cu yd per acre of sediment storage within each phase. In addition to the measures proposed in the erosion, sedimentation,

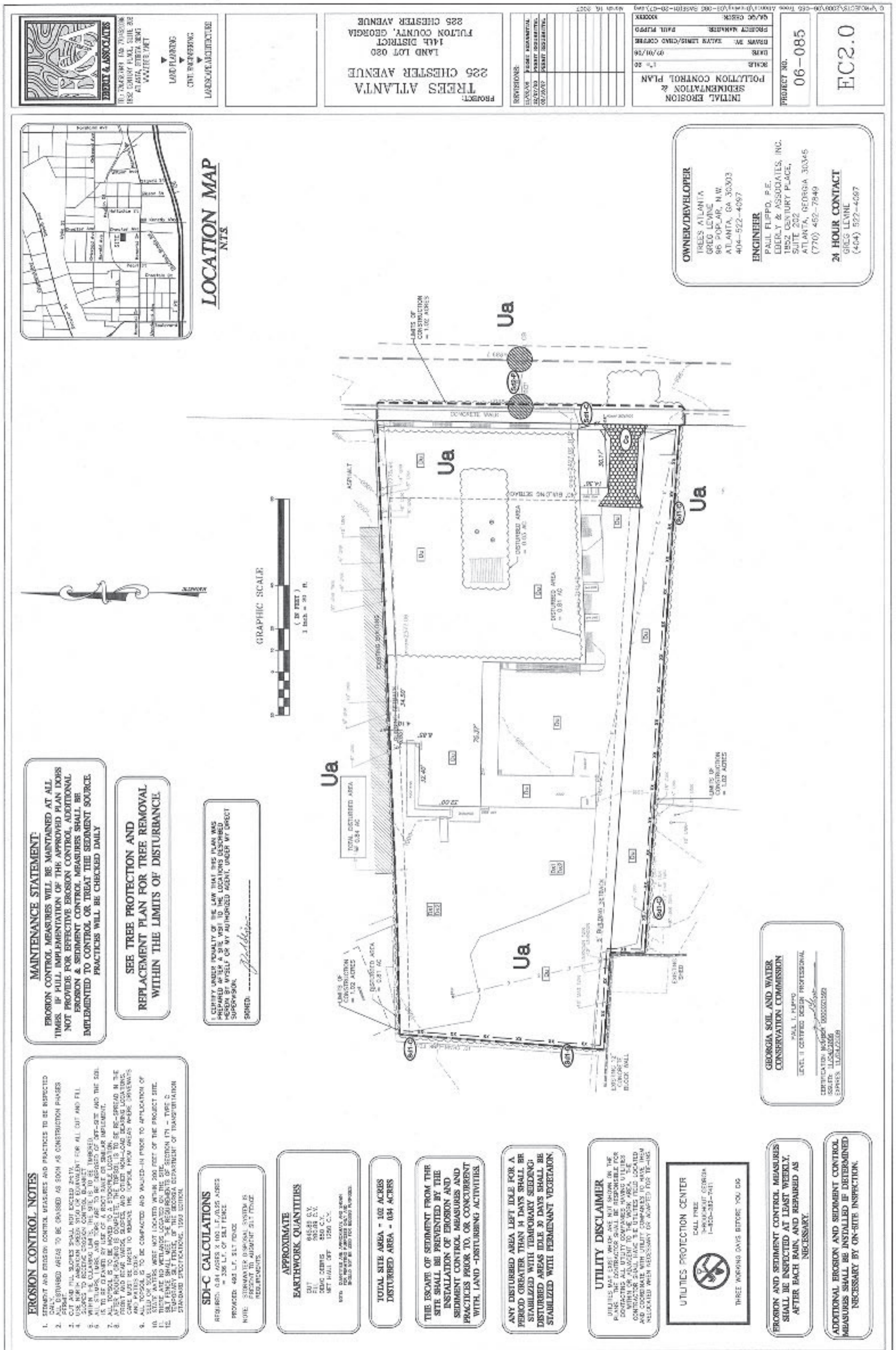


Figure 7.17a Erosion, sedimentation and pollution control plan for the Trees Atlanta site – demolition phase

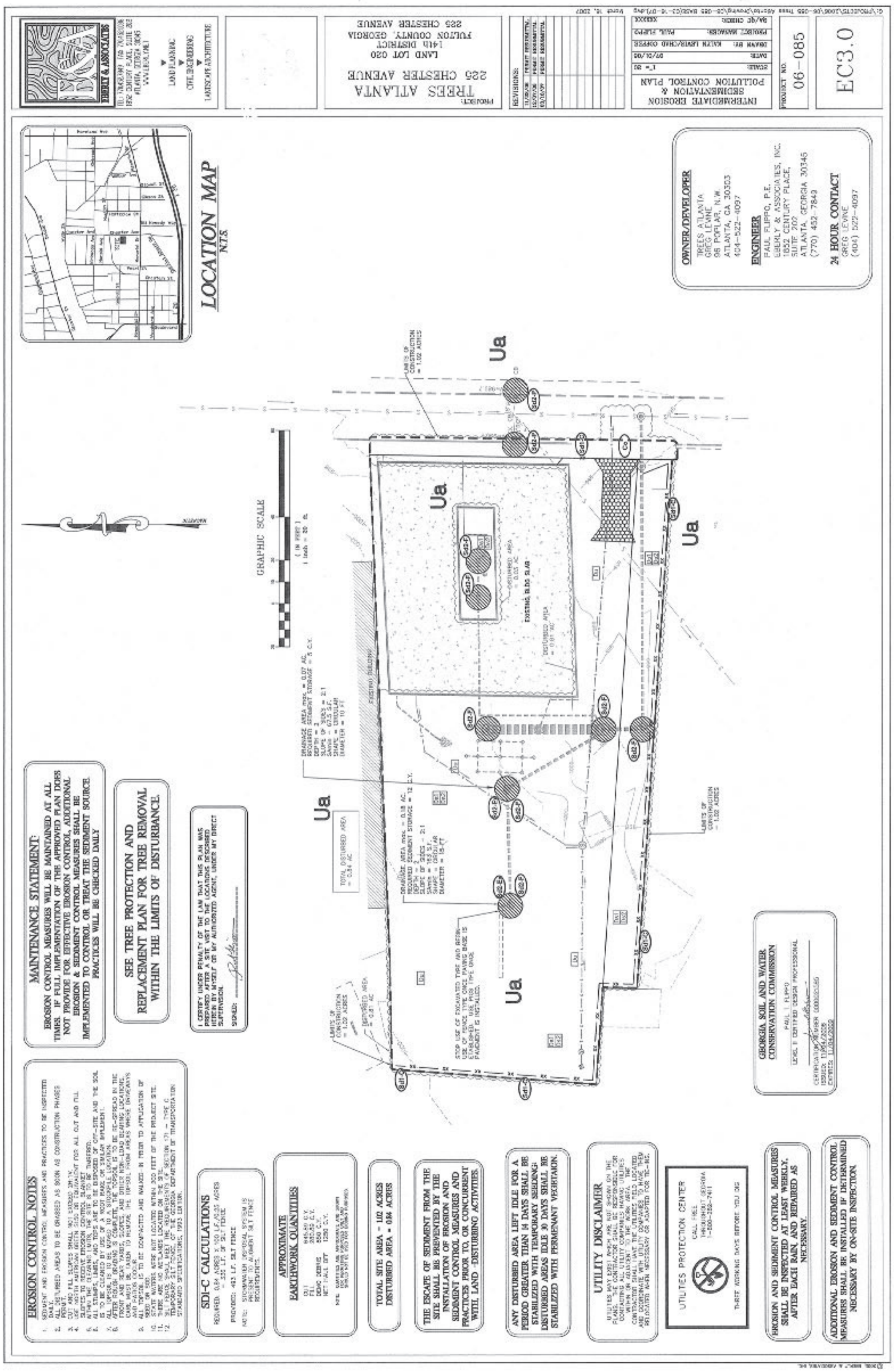


Figure 7.17b Erosion, sedimentation and pollution control plan for the Trees Atlanta site – intermediate phase

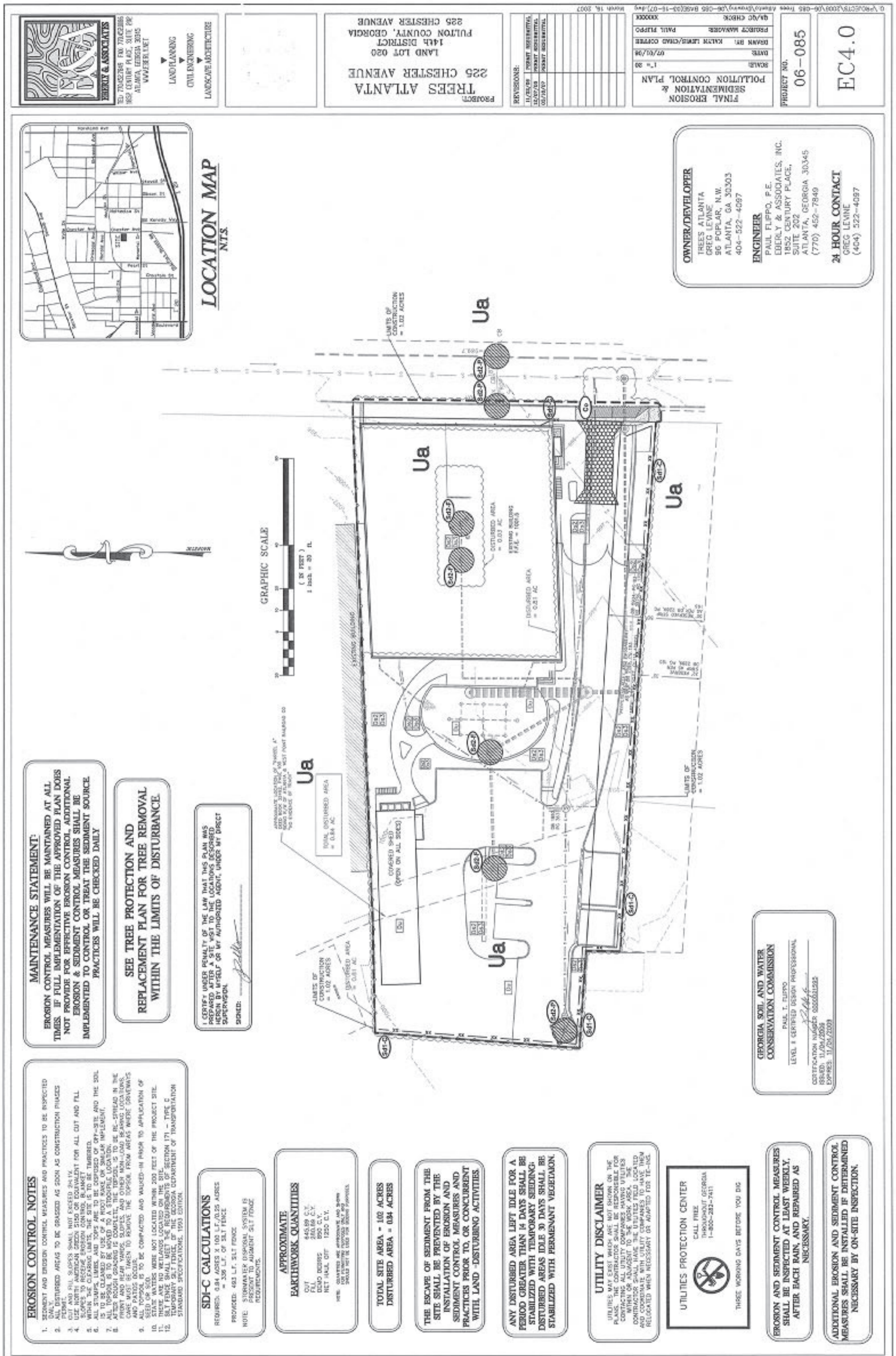


Figure 7.17c Erosion, sedimentation and pollution control plan for the Trees Atlanta site – final phase

and pollution control plan, while the Trees Atlanta parcel is 1.08 acres (net lot size), it was proposed to disturb only 0.84 acres, thus further limiting the need for damage control in the first place.

Construction waste management

Construction activities including both construction and demolition generate significant amounts of solid waste. According to the US Environmental Protection Agency (USEPA), building-related construction and demolition (C&D) debris totals approximately 160 million tons per year, accounting for nearly 16 per cent of total non-industrial waste generation in the United States (USEPA 2008). Because of the significant impacts of construction waste, source control and prevention of construction wastes can achieve the greatest environmental benefits. In addition, recycling of construction and demolition debris reduces demand for virgin resources and reduces the environmental impacts associated with resource extraction, processing and in many cases transportation. For the Trees Atlanta Building project, a construction waste management plan was implemented to divert the maximum amount of on-site construction waste from landfills through recycling and salvage efforts. The box shows the waste management plan for this project.

To achieve the goals of recycling and waste prevention, the general contractor and subcontractors diverted the following amounts of construction waste:

- concrete/masonry (679 tons)
- metal (13 tons)
- asphalt (161 tons)
- green waste (5.77 tons).

Due to its active recycling and waste prevention approach (Figure 7.18), the Trees Atlanta project recycled or salvaged just over 84 per cent of solid waste generated by the project. This equates to a total of 959 tons of construction waste diverted out of a total construction waste generated of 1,139 tons.

Figure 7.18 Recycling of construction waste

Construction waste management plan for Trees Atlanta

Purpose
To establish a procedure for the handling and disposal of construction debris. The plan is a component of the LEED Greed Building Rating System, based on requirements of LEED-NC version 2.2, Credits MR 2.1 and 2.2.

Goal
To divert the maximum amount of on-site construction waste from landfills through recycling or salvage efforts.

Implementation
There will be two phases: demolition and construction.

Demolition
Gay Construction is responsible for ensuring that on-site demolition waste will be recycled or salvaged as much as possible. The materials to be recycled, but not be limited to, are: metals, concrete, concrete masonry block, ceiling tiles, and unpainted wood. Individual containers will be clearly labelled (in English and Spanish) for each material. The demolition contractor will appoint an on-site member of his team to monitor the containers on a daily basis to be sure that the containers are being filled with the correct material. The demolition contractor is responsible for keeping an organized record of waste HAW receipts and reporting the percentages and totals diverted construction waste to Gay Construction while demolition is in progress. These reports/receipts shall include the quantity in volume and weight, hauler, and destination.

Construction
Gay Construction is responsible for all recycling of construction waste and quality control during construction. Individual hauling containers will be provided for concrete, masonry, metals, wood, gypsum board, cardboard and general waste. Recycling containers will be provided for glass, aluminum, paper and plastic. All containers on site will be clearly labelled (in English and Spanish) and will be checked daily to ensure compliance with these terms. All subcontractors will be aware of and participate in this construction recycling effort. Waste haul receipts will be kept in an organized manner by material and month and must relate to the progress spreadsheets. Gay Construction shall submit waste management calculations and documentation on a monthly basis to confine that materials are being diverted by recycling or salvage.

Orientation
Each subcontractor will be required to participate in recycling construction debris. As contractors begin work on-site, their foreman will be given a copy of the subcontractor guidelines and given a tour of the site recycling containers. The foreman will be required to convey this information to their labourers.

Reporting
Gay Construction will be responsible for the keeping a waste management report throughout the demolition and construction process. This report will be organized in the attached format and submitted on a monthly basis. Reports will include the type of material recycled, the recycling hauler and destination and the quantity of waste being diverted, by weight, as well as that waste taken to the landfill.

Daily activities
The Gay Construction site superintendent is responsible for the day-to-day activities on the jobsite. This is expanded to meet the demands of the CWMP. The site superintendent keeps a log of all containers removed from the site to compare to receipts from the container subcontractor. The superintendent also keeps track of waste created by the subcontractors and determines the appropriate means of disposal.

Construction indoor air quality management

Demolition and construction practices often lead to increased exposure to indoor air pollutants through the introduction of synthetic building materials, power equipment and vehicles, and new furnishings and finishes. To reduce air quality problems resulting from construction, the Trees Atlanta building implemented an IAQ management plan based on the recommended design approach of the SMACNA *IAQ Guideline for Occupied Buildings under Construction*. The IAQ management plan (see box) describes the practices undertaken in the building to protect indoor air quality. Figure 7.19 shows some of practices employed to reduce indoor air problems. Although the plan discourages the use of HVAC equipment during construction, it provides for temporary operation if filters with a minimum efficiency reporting value (MERV) of 8 are used to protect the equipment from damage. In this project, the air handling units in the building were operated at various points during construction, but MERV 11 filters were installed and then replaced prior to building flush-out, thereby exceeding the minimum requirements set forth in the IAQ management plan.

In addition, a building flush-out was conducted that supplied a minimum of 3,500 cu ft of outdoor air per sq ft of floor area (at a minimum rate of 0.30 cfm/sq ft of outside air) a minimum of three hours prior to occupancy and during occupancy, until a total of 14,000 cu ft/sq ft of outside air had been delivered to the space. By conducting these practices to improve indoor air quality, it was possible to prevent future indoor air quality problems resulting from construction and to promote the comfort and well-being of both construction workers and building occupants.

Figure 7.19 IAQ protection measures undertaken during construction, including housekeeping, protection of materials from damage, and plastic protection for ductwork and equipment in storage

Indoor air quality management plan for Trees Atlanta

Purpose

The purpose of the IAQ plan is to reduce IAQ problems resulting from demolition and construction phases of this project. While work is being performed on the site, each subcontractor shall adhere to the following responsibilities, requirements, and measures of this document to minimize construction related pollutants throughout the building system and contamination of materials. This plan is a component of the LEED Green Building Rating System, based on the requirements of LEED-NC version 2.2, Credit EQ 3.1 – Indoor Environmental Quality and the control measures of the SMACNA *IAQ Guidelines for Occupied Buildings under Construction*, 1995, Chapter 3.

Goal

The goal of the IAQ plan is to maintain a safe and healthy environment for construction workers while the project is underway and to ensure a healthful and comfortable environment for the building's future occupants.

Plan

The existing building will be partially demolished and the interior build-up will be completely demolished, leaving only a shell and structural members. During demolition and construction prior to dry-in, the building shall be kept open and well ventilated during working hours. Gay Construction will be responsible for making sure the building is swept out at the end of each workday. The existing roof will remain until the exterior walls are built and all added structural members are in place.

Moisture protection

Moisture-absorbent materials will be stored in a dry area inside the building and covered with plastic to keep dry. If these materials shall be installed before dry-in then the materials will be protected from the weather as needed. The general contractor will conduct a walk-through on a daily basis to ensure there is no moisture damage to installed and uninstalled materials. Any problems will be dealt with on a situational basis to decide whether the material can be salvaged or needs to be replaced.

Volatile organic compounds (VOC)

No volatile organic compounds that exceed LEED restrictions will be installed with the building envelope. All low-VOC-emitting materials used within the envelope shall be kept in a closed container unless in immediate use. Any material used on the exterior of the building (i.e. exterior paint, roofing) that exceeds LEED restrictions or VOC content shall never enter the building. These materials shall be stored in ventilated storage outside and away from the building. The general contractor will continuously oversee this throughout construction and make a daily walk-through to ensure materials are stored in the appropriate places.

HVAC protection

The HVAC system will not be used during the construction process. Once the system is installed all openings shall be sealed. The mechanical rooms shall be confined and used only in necessary situations and shall not be used to store construction materials.

Housekeeping

The building shall be kept clean and orderly on a daily basis throughout the construction process. Gay Construction will be responsible for the site in general and each subcontractor will be responsible for their particular work areas. This includes sweeping, mopping or vacuuming of dust, accumulated water and other potential contaminants. All spills shall be cleaned up immediately and reported to the IAQ supervisor. The subcontractors will be responsible for keeping their work areas clean and organized. All subcontractors will be responsible for their on-site equipment, tools, and cleaning supplies and required to keep them contained within their appropriate areas. The IAQ supervisor shall ensure that the subcontractors conform to this act.

Implementation

Responsible parties

The general contractor will appoint a responsible person that will be responsible for implementing and monitoring the IAQ plan. This person will be responsible for but not limited to:

- **Coordinating inspections** – the IAQ supervisor will walk over the site at the end of each work day to ensure compliance with the IAQ Plan. This will include making sure all materials on site are stored in the correct locations and protected from the elements, making sure the building and site are kept in a clean and orderly manner, and checking that the HVAC system is sealed.
- **Maintaining an inspection log** – the IAQ supervisor will keep a log of any non-compliant conditions and on corrective actions taken.
- **Coordinating meetings** – if the IAQ supervisor witnesses reoccurring problems then a meeting with the responsible parties may be scheduled. The general contractor and LEED coordinator may be present.

Orientation

Gay Construction will be responsible for ensuring that each subcontractor participates in the IAQ plan. As contractors begin work on site, their foreman will be given a copy of the subcontractor guidelines. The foreman will be required to convey this information to their labourers. All employees on the site shall understand and abide by the IAQ requirements set out in this plan.

Reporting

Gay Construction will provide documentation as required by LEED Version 2.2 in weekly IAQ reports with photo documentation that emphasize the following points.

HVAC:

- Ensure the installed HVAC system is not being used during construction.
- The system is sealed, and all openings are covered with plastic.

Materials and storage:

- No materials exceeding the VOC limits are present in the building.
- All materials that contain VOCs are in a well-ventilated area.
- Stored materials are covered to protect from dust and moisture.
- All moisture sensitive materials are kept covered and dry.
- Materials are stored orderly and out of the way of walking traffic.

Housekeeping:

- The floor is swept regularly to minimize dust particles.
- No liquid is standing on the slab.
- There are at least two clear means of egress.

HVAC duct protection policy

If the HVAC system is operated during the construction process, temporary filters with MERV 8 will be used to protect all central filtration points and all return air inlets. Once the temporary filters are in place, photographs will be taken at each installed location. These photographs will be included in a filter replacement verification log, listing the date of initial installation, filter locations and filter MERV ratings. The filters will be inspected by the IAQ Supervisor on a weekly basis and changed as needed. Each filter change out will be recorded in the filter replacement verification log, listing date, filter change location, filter MERV rating, and a photograph of the newly installed filter.

Building commissioning

Facilities that do not perform as intended can consume significantly more resources over their lifetimes than they should. Thus, the building commissioning process has to be conducted to verify that the project's energy-related systems are installed, calibrated and performing according to the owner's project requirements, basis of design and construction documents. Major benefits of building commissioning include reduced energy use, lower operating costs, reduced contractor call-backs, better building documentation, improved occupant productivity after construction, and verification that the systems perform in accordance with the owner's project requirements. In the Trees Atlanta Building, the owner hired a commissioning agent to conduct detailed commissioning for the systems listed in Table 7.5.

SITE OBSERVATION REPORT

WORKINGBUILDINGS

Trees Atlanta Office
Trees Atlanta
Project #06090

Site Observation Report 1
Wednesday, September 26, 2007
Report by John McFarland

Present at Site:

Mechanical

Reference No.: SOR-1-1	*Equipment:* GSHP-2	*Responsibility:* Mechanical Contractor
Room No.: 128	*Room Name:* Future Office	*Drawing:*

Mechanical

Description:
A few plenum boxes were not covered with plastic at the time of the survey.

Recommended Action:
Cover plenum boxes with plastic to protect from dust.

Figure 7.20 Example site observation report

Table 7.5 Building systems commissioned in the Trees Atlanta building

- Mechanical systems
  - HVAC systems (ground-source heat pumps and energy recovery ventilation)
  - HVAC control systems (standalone programmable thermostats)
  - mechanical equipment.
- Plumbing system:
  - water heaters (electric and solar)
  - rainwater harvesting system.
- Electrical systems:
  - lighting control systems (time clock)
  - occupancy sensors
  - photovoltaic systems
  - electrical power distribution equipment.

As a result of the commissioning process, approximately 55 issues were identified, and all of them were fixed during the project. In addition, a detailed operation and maintenance manual was developed to help users to properly control all systems as designed, calibrated and installed. Figure 7.20 shows an example of one of the site observation reports generated during building commissioning of the Trees Atlanta Building. These forms were used to identify specific problems with the building where the constructed product did not meet the owner's design intent. The forms also identify recommended actions that should be taken to remediate all identified problems. In this way, commissioning was used to ensure that the owner received the facility for which it has paid.

Case Study: Proximity Hotel and Print Works Bistro

The Proximity Hotel and Print Works Bistro provide a second perspective on greening the construction process. These projects, located in Greensboro, North Carolina, represent one of the world's greenest, most energy-efficient and high-performance developments. The sustainably designed Proximity Hotel features 147 guest rooms and suites, a full service restaurant (Print Works Bistro), and 5,000 sq ft (465 sq m) of meeting and event space. The Proximity Hotel has incorporated many sustainable design and construction features, and the hotel has been recognized as the first hotel in the hospitality industry to obtain the US Green Building Council's top level of certification (LEED Platinum). This environmentally friendly hotel was developed to be a high-performance green building by Quaintance-Waver Restaurant and Hotels because the development team wanted to adopt sustainable construction practices that would not only achieve the benefits of sustainable development but also make sense to the bottom line in the long term. Since the developer had a passion for sustainable practices in its hotel development, the Proximity Hotel incorporated many such sustainability strategies.

Proximity Hotel and Print Works Bistro

- Project type: Hotel and restaurant.
- Project size: 102,000 sq ft with 147 rooms.
- Project cost: $26 million.
- Sustainable features: First LEED Platinum hotel.
- Developer: Quaintance-Waver Restaurant & Hotels.
- Architect: Centerpoint Architecture, LLP.
- Contractor: Weaver Cooke Construction, LLC.

Sustainability features in the Proximity Hotel and Print Works Bistro

The Proximity Hotel project began by assembling a collaborative development team including the developer, architect, contractor, landscape architect, engineer and other consultants. All team members worked in concert to not only maximize water and energy efficiencies in the design and achieve resulting sustainability benefits, but also avoid or surmount the barrier of increased first cost. This multidisciplinary and collaborative integrated design approach resulted in a hotel that is expected to use 39.2 per cent less energy and 33.5 per cent less water than a conventional hotel without reducing comfort or luxury and with minimal additional construction costs.

Figure 7.21 A solar hot water heating system provides 60 per cent of the building's hot water

The facility uses the sun's energy to heat hot water, with 100 solar panels covering the 4000 sq ft of rooftop (enough hot water for 100 homes). This system (Figure 7.21) heats around 60 per cent of the water for both the hotel and restaurant. On the building's site, 700 linear ft of stream were restored by reducing erosion, planting local, adaptable plant species, and rebuilding the buffers and banks. Approximately 700 cu yd of soil were removed to create a floodplain bench, and 376 tons of boulders and 18 logs were used to maintain grade control, dissipate energy, and assist in the creation and maintenance of riffles and pools.

Inside the Print Works Bistro, the bar is made of salvaged, solid walnut trees that were felled because of sickness or storms (Figure 7.22). Room service trays are made of rapidly renewable Plyboo (bamboo plywood). Newly engineered variable speed hoods in the restaurant use a series of sensors to set the power according to the kitchen's needs and adjust to a lower level of operation, typically 25 per cent of their full capacity, when possible. The sensors also detect heat, smoke and other effluents, and increase the fan speed to keep the air fresh. Geothermal energy is used for the restaurant's refrigeration equipment instead of a standard water-cooled system, saving significant amounts of water.

In the hotel itself, North America's first regenerative drive model of the Otis Gen2 elevator reduces net energy usage by capturing the system's energy and feeding it back into the building's internal electrical grid. Abundant natural lighting, including large energy-efficient 7 ft x 4 ft square operable windows in guest rooms (Figure 7.23), connects guests to the outdoors by achieving a direct line of sight to the outdoor environment for more than 97 per cent of all regularly occupied spaces.

In operations, water usage has been reduced by 33 per cent by installing high-efficiency Kohler plumbing fixtures, saving 2 million gallons of water the first year. Air quality is improved by circulating large amounts of outside air into guest rooms (60 cu ft/minute) and doing so in an energy-efficient way by employing energy recovery ventilation (ERV) technology, where the outside air is tempered by the air being exhausted. Regional vendors and artists were used for materials to reduce transportation and packaging while supporting the local economy (Figure 7.24).

From the standpoint of indoor air quality, low-VOC emitting paints, adhesives, carpets (Figure 7.25) and other products were used to reduce indoor air contamination. Guest room shelving and the bistro's tabletops are made of walnut veneer over a substrate of SkyBlend, a particleboard made from 100 per cent post-industrial recycled wood pulp with no added formaldehyde resins. A green, vegetated rooftop will ultimately be planted on the restaurant to reduce the urban heat island effect. This roof reflects heat, thus reducing the amount of energy needed for refrigeration and air conditioning. It also slows stormwater runoff and insulates the rooftop, keeping the building cooler overall. Various types of plants are presently being tried out on the roof in a test area before final planting. Including the green roof as part of the design will also help to improve outdoor air quality.

Now that the hotel has opened its doors, it includes several features to support increased sustainability during operations. Among these is an education centre for sustainable practices that includes tours of the green hotel for visitors and guests, symposia of sustainable practice for local construction professionals, and outreach programmes for students of all ages. In addition, bicycles are available for use by guests to ride on the nearby 5-mile greenway, thus providing a means to improve health and fitness while travelling and reduce transportation impacts. All of these design features contribute significantly to the facility's

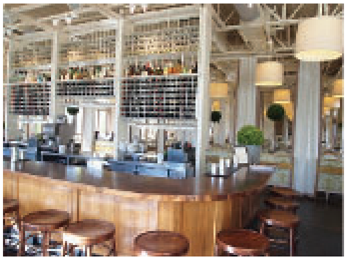


Figure 7.22 The Print Works Bistro bar, made from salvaged walnut

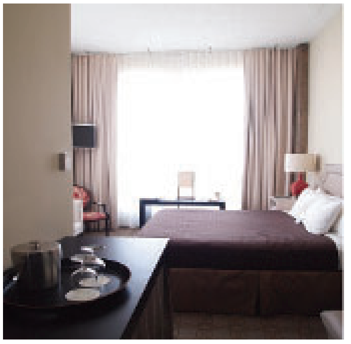


Figure 7.23 Operable windows in hotel rooms provide daylight, views, and connection with nature through natural ventilation

Figure 7.24 Regional vendors and artists were used to reduce transportation impacts and support the local economy

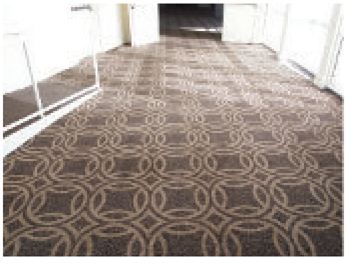


Figure 7.25 Low-VOC finishes improve indoor air quality

sustainability. In addition, featured in this project was the use of a variety of sustainable construction practices, described next.

Sustainable construction practices

The Proximity Hotel implemented a variety of sustainable construction practices to achieve its goals of sustainability for the project. These practices, including sustainable site management with erosion and sedimentation control, waste management, materials management, indoor air quality management and building commissioning, are described in greater detail in the following subsections.

Sustainable site management

The collaborative project team of the Proximity Hotel developed a sustainable site management plan to minimize disturbance to the project site during construction. One of the strategies in the project was to follow local erosion and sedimentation control standards and codes to minimize erosion and sedimentation at the job site. Since the project site was located to next to a local stream, the project team led by the contractor properly implemented several erosion and sedimentation control strategies including silt fences, sediment traps and temporary seeding (Figure 7.26).

Figure 7.26 Silt fences and other strategies were used for erosion and sedimentation control

The project team led by the architect selected architectural precast concrete wall panels as the best cladding system to not only achieve the wall performance of the building but also facilitate sustainability at the construction phase. The hotel's insulated wall panels were made from recycled and recyclable materials only 90 miles (145 km) from the construction site. In addition, the contractor and the precast concrete supplier implemented just-in-time delivery to reduce the need for space on site and to improve productivity (Figure 7.27).

Figure 7.27 Precast concrete wall panel with just-in-time delivery

Waste management

The contractor of the Proximity Hotel developed a construction waste management plan to divert construction debris from disposal in landfills and incineration facilities. Due to the active implementation of the construction waste management plan, the project diverted 1,535 tons (86.9 per cent) of on-site generated construction waste from landfill disposal. In addition, the project made significant use of precast wall panels, which also considerably reduced the generation of construction waste during the project.

Materials management

The Proximity Hotel used 22.4 per cent by cost of the total building materials with recycled content including reinforced steel with 90 per cent post-consumer recycled content, sheetrock with 100 per cent recycled content, asphalt with 25 per cent recycled content, and staircase steel with 50 per cent recycled content. In addition, the concrete used on the project contained 4 per cent fly ash (224,000 pounds), the mineral residue left after the combustion of coal, which was thereby diverted from landfill disposal. By using recycled content materials, it was possible to avoid the impacts resulting from extraction and processing of virgin materials. In addition, 45.95 per cent of the total building material by cost was comprised of building materials and/or products that had been extracted, processed and manufactured within 500 miles of the project site.

Indoor air quality management

The Proximity Hotel project team used a variety of strategies to manage indoor air quality during the project (Figure 7.28). The team developed and implemented a construction IAQ management plan that followed the referenced SMACNA Guidelines. To implement the IAQ management plan, the contractor protected all HVAC equipment, both temporary and permanent, from dust and odours during construction. After completing the construction, the contractor completed a whole building flush-out by supplying a total air volume of 14,000 cu ft of outdoor air per sq ft of floor area while maintaining an internal temperature of at least 60°F and relative humidity no higher than 60 per cent. By completing the flush-out prior to occupancy, the project team was able to reduce contaminants inside the building to result in greater occupant comfort and well-being.

Building commissioning

Given that the Proximity Hotel was a luxury hotel and restaurant project, many key systems required commissioning to ensure proper function after construction was complete, including HVAC systems, kitchen equipment, and the solar hot water heating and geothermal systems. To meet this requirement, the project team along with a consultant conducted an enhanced commissioning process to ensure that building systems as installed could perform according to the design intent and owner's requirement. The building commissioning process of the Proximity Hotel was also similar to the process in the Trees Atlanta project. Requirements for fundamental and enhanced building commissioning are defined by the LEED rating system as shown in Table 7.6.

Figure 7.28 Indoor air quality management via covering of equipment openings

Table 7.6 Requirements for commissioning under LEED

Fundamental commissioning requirements:
- Designating an individual as the commissioning authority to lead, review, and oversee the completion of commissioning process activities.
- Reviewing owner project requirements (developed by the owner) and basis of design (developed by the design team) to ensure clarity and completeness.
- Developing commissioning requirements and incorporating them into construction documents.
- Developing and implementing a commissioning plan.
- Verifying the installation and performance of systems within the scope of the plan.
- Completing a summary commissioning report to the owner.

Enhanced commissioning requirements:
- Conducting a commissioning design review prior to the development of construction documents.
- Reviewing contractor submittals applicable to systems under the scope of commissioning.
- Developing systems manuals for commissioned systems.
- Verifying that requirements for training on commissioned systems are met.
- Reviewing building operation within 10 months after substantial completion.

Sustainable construction in 2020

Given the examples of state-of-the-art sustainable construction practices highlighted in the case studies, what might be the state of construction practice in the year 2020? While a construction site might look the same in ten years to the uninitiated, advances in technologies, materials and processes are likely to significantly change the resource efficiency of construction practice, leading to reduced environmental impacts and improved project economics.

Some technologies are presently under development but will be widely employed by 2020 to improve process efficiency. Automated equipment controls, augmented reality, project information models and improved information technology will make understanding the status of the job site of tomorrow instantaneous for project managers. In particular, four and five-dimensional augmented reality (nDAR) will enable project managers not only to see the current status of a project and compare that with its planned status, but also will enable project stakeholders to visualize other indicators of project sustainability at various points in the project delivery process, such as distance from the job site that a particular component was imported, or other key properties. These technologies will support more effective project planning and status monitoring which will, in turn, reduce waste and other inefficiencies that are presently difficult to identify and manage in a complex project environment.

Evolving equipment technologies are making better use of research and development in the automotive sector, such as hybrid gasoline-electric engines to eliminate idling or equipment run on biodiesel. The energy recovery technologies in use today, such as regenerative drives

Case Study: Gran Torre Costanera, Santiago, Chile

When it is completed in early 2012, the 62- storey Gran Torre Costanera will be the tallest building in South America, with a final spire height of 300 m. Part of a larger commercial development complex that includes office and retail space in the heart of Santiago's Providencia district, the 128,000 sq m tower is seeking LEED Gold certification along with the larger Costanera Center of which it is a part, and is expected to open in November 2012. The overall complex will include four buildings of varying height, including the Torre Costanera, surrounding a central mall with over 300 stores. The expected cost of the development is US$500 million.

Upon completion, the complex will incorporate multiple sustainable design features, including:

- a green roof over the mall complex
- use of recycled steel
- energy-efficient design
- use of water from a nearby canal to provide cooling, which is then treated and returned to the canal.

During construction, special efforts are also being taken to control dust and gas emissions. Noise pollution is also being monitored and controlled.

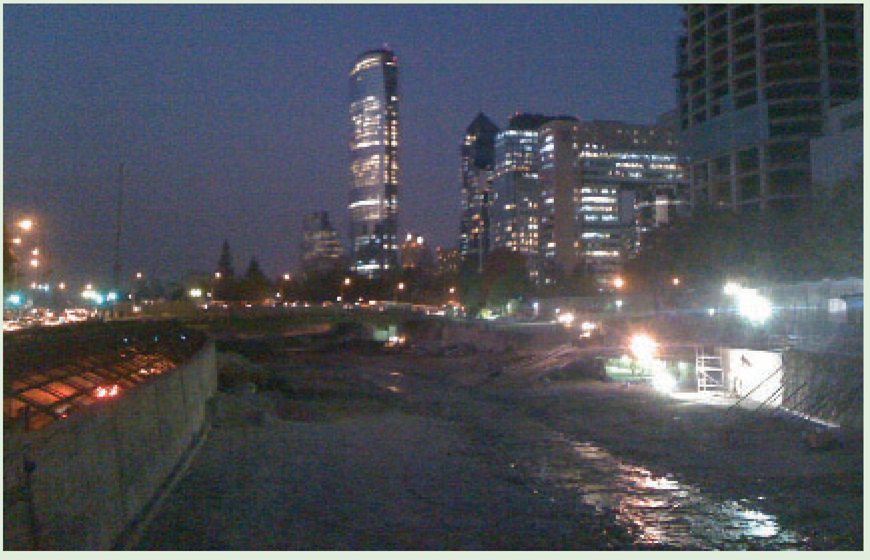
Sources: Cencosud (2011). 'Costanera Center.' <www.cencosud.cl/eng/unidades_costanera.htm> (accessed 28 September 2011).

Meinhold, B. (2010). 'South America's tallest building set to open in 2012.' <inhabitat.com/south-americas-tallest-building-set-to-open-in-2012/> (accessed 28 September 2011).

When completed in 2012, the 62-storey Gran Torre Costanera will be the tallest building in Latin America

The Costanera Center is pursuing LEED Gold certification and includes measures such as recycled content steel throughout the project

During construction, measures are being taken to control negative impacts on the surrounding city, including control of dust, air emissions, and noise



Cooling for the building will be provided using water from a nearby canal. The water will be treated and returned to the canal after use.

on equipment such as elevators, and energy recovery ventilation, will also be more commonly employed as permanent features of buildings, and may also be used to power construction processes.

New approaches to reduced ecosystem impact on the job site will also be in use. Technologies are presently under development that will allow heavy traffic or weight-bearing storage on the job site without disrupting the growth of turf or vegetation on the original soil surface. With the growing awareness of the negative impact construction practices have on soil structure and viability, considerable research is being devoted to finding ways to reduce the literal footprint of a construction project on site. In 2020, a detailed site soil and vegetation inventory will be conducted of every new project site, not just for the purposes of foundation design or stormwater management, but also to carefully design and manage the impacts of the construction process on the site and its biota.

Increased building reuse and adaptation in existing urban areas will also lead to a need for new technologies and approaches to high-resolution condition assessment and building inventorying. Increased use of deconstruction instead of demolition will be coupled with market systems for tagging viable building components before they even come out of a building. Developers may some day base their decisions for demolition based on market demand for building components as much as the future potential a site might have for development.

The construction workforce of 2020 will also look considerably different than it does today. Increasing diversity and social equity, coupled with increased access to education worldwide, means that the workforce of tomorrow will be more heterogeneous. Enhanced technologies for construction mean that sheer physical size and strength will no longer be a requirement for a job in the construction industry. Higher levels of education will be required to understand, install, commission and operate the complex systems that comprise our built environment, leading to greater levels of workforce competency and achievement. These better-educated workers will be directed toward ever greater levels of specialization, leading to a greater need than ever before for an understanding of how their roles fit into the larger picture of the built and natural environments.

Along with the changing workforce, the corporate environment of 2020 will exist in a business environment requiring both greater agility and greater transparency of operations, as discussed in earlier chapters. Construction companies will be expected to understand and meet environmental performance regulations and standards, and to disclose and be accountable for their performance. Environmental and social factors will be key in evaluating corporate performance and will be inextricably linked to business success. Forward-looking firms will begin now to evaluate where they stand with regard to this future business environment, and design a strategy for moving ahead in a world where doing more with less is the norm.

Discussion questions and exercises

7.1 Contact a local construction firm that offers preconstruction services. Interview or shadow a preconstruction services manager to learn more about the role of this stakeholder in project sustainability.

7.2 Locate a project in the construction phase in the local area. Visit the site during the process of site set-up and interview the construction manager or site superintendent. Document strategies used to manage the site sustainably, including pollution prevention and mitigation measures. How well is the project addressing opportunities to minimize disturbance and preserve important site assets? How might the site management be improved to increase sustainability?

7.3 Document the heavy equipment being employed on the site. Obtain a site plan and draw in the limits of site disturbance, material storage and staging areas, waste-tipping areas, and equipment paths. How might the site plan be improved to increase project sustainability? What might be the resulting trade-offs for project productivity?

7.4 Visit the site office and document measures used to increase the sustainability of business operations. How well is the project team addressing opportunities in site business operations? How could the sustainability be improved?

7.5 Visit the areas of the site where materials are stored and staged, talk with the project manager, and document the procurement, storage, packaging and delivery practices being used on the project. Review the project's material management plan if one exists. How well is the project addressing opportunities to manage materials sustainably? Is product information being properly documented to prepare for project certification? How might materials management be improved to increase sustainability?

7.6 Visit the areas of the site where waste is separated, recycled and/or disposed of, talk with the project manager, and document the waste management practices being used on the project. What are the major waste streams that will be generated during the project? Review the project's waste management plan if one exists. How well is the project addressing opportunities to manage waste sustainably? Is waste recycling and/or disposal being properly documented to prepare for project certification? How might waste management be improved to increase sustainability?

7.7 After the project has been 'dried in', visit the enclosed areas of the site, talk with the project manager, and document the indoor air quality management practices being used on the project. What are the major threats to indoor air quality that will be generated during the project? Review the project's indoor air quality management plan if one exists. How well is the project addressing opportunities to manage indoor air quality sustainably? Are activities and controls being properly documented to prepare for project certification? How might indoor air quality management be improved to increase sustainability?

7.8 Contact a local firm that offers commissioning services. Interview or shadow a commissioning agent to learn more about the role of this stakeholder in project sustainability. Review a commissioning report for a project. What types of issues are typically identified and resolved by commissioning a construction project?

References and recommended resources

BuildSmart – Greater Vancouver Regional District. (2004). *Green Construction: Introducing green buildings and LEED to contractors.* <www.infrastructure.alberta.ca/Content/docType486/Production/LEED_PD_Appendix_10.pdf> (accessed 26 September 2011). Contains examples of completed LEED worksheets for construction-related credits.

King County, Washington. (2010). *King County Green Tools: Construction and demolition recycling.* <http://your.kingcounty.gov/solidwaste/greenbuilding/construction-demolition.asp> (accessed 26 September 2011).

Seattle/King County, Washington. (2002). Contractor's Guide: Save money and resources through job-site recycling and waste prevention.<http://your.kingcounty.gov/solidwaste/greenbuilding/jobsite-waste.asp>(accessed 26 September 2011).

Sheet Metal and Air Conditioning Contractors National Association (SMACNA). (2007). *IAQ Guidelines for Occupied Buildings under Construction*, 2nd edn. Available through <www.smacna.org>.

Thompson, J. W. and Sorvig, K. (2007). *Sustainable Landscape Construction: A guide to green building outdoors,* 2nd edn. Island Press, Gabriola Island, WA.

US Environmental Protection Agency (USEPA) (2008). 'Municipal solid waste in the United States.' <www.epa.gov/osw/nonhaz/municipal/pubs/msw2008rpt.pdf> (accessed 12 July 2010).

USEPA. (2011). "State Stormwater BMP Manuals" <yosemite.epa.gov/R10/WATER.NSF/0/17090627a929f2a488256bdc007d8dee?OpenDocument> (accessed 10 October 2011).

US Green Building Council. (2009). *LEED Reference Guide for Green Building Design and Construction.* Available from the Green Building Certification Institute <www.gbci.org>.

8

Post-Occupancy Sustainability Opportunities and Best Practices

After a building has been delivered to the owner at the conclusion of construction, its life is only just beginning. The majority of a facility's impact from an energy and water standpoint occurs during its operational life. Similarly, the majority of its solid waste impact occurs at the conclusion of its service life. Although these phases have not historically been the focus of the architecture, engineering and construction (AEC) industry, they are critical in today's project environment where extended responsibility is becoming more common in the form of design–build–operate–maintain (DBOM) contracts. Even in the absence of such an agreement, the contractor's liability and reputation are contingent upon the continuing performance of a facility. The following sections describe best practices for sustainably operating and maintaining a facility after occupancy and for disposing of the facility at the end of its life-cycle.

Post-occupancy opportunities

Optimizing energy and water performance

Optimizing the performance of an existing facility in terms of energy and water consumption can yield significant benefits, both in operating costs and in user comfort, satisfaction and productivity. Three primary tactics are useful in optimizing energy and water performance: operational adjustments, retrofit of energy- and water-consuming equipment, and working with users to adjust their behaviour.

Opportunities are often overlooked for optimizing efficiency based on proper operations and maintenance. No matter how well it may be designed, equipment will function only as well as it is operated and maintained. Frequently, effective performance is based on not only environmental conditions, but also interactions with other facility systems and occupants. Sometimes, minor adjustments can yield significant results.

Processes such as continuous commissioning can be used for existing buildings to identify ways to improve efficiency with existing equipment. Continuous commissioning is a comprehensive and ongoing process to resolve operating problems, improve comfort, optimize energy use, and identify retrofits for existing commercial and institutional buildings and central plant facilities. In contrast with building commissioning that occurs during the delivery process that focuses on design intent, Continuous commissioning focuses on ensuring that the facility meets current use requirements. Continuous commissioning typically pays for itself in less than three years (FEMP 2002). It involves field metering and performance verification, adjustment of operational control schedules and set points, adjustments to building automation systems, and identification and recommendation of capital upgrades and retrofits that will improve building performance.

Figure 8.1 Lighting retrofits can offer considerable energy savings

Operator training is also essential to ensure that building equipment is used most effectively, particularly in situations with frequent turnover of employees. This training can help to ensure that maintenance schedules and procedures are understood and properly implemented. For example, even simple maintenance practices such as cleaning the transmissive surfaces of lighting fixtures can greatly increase their light output. This reduces the need for supplemental lighting in workspaces, thereby saving energy.

Often, energy audits identify opportunities to retrofit existing systems with more efficient ones. A common retrofit with rapid payback in many buildings is a lighting retrofit (Figure 8.1). Replacing older magnetic ballasts with electronic ballasts in fluorescent lights, along with converting existing fixtures from T-12 lamps to T-8, is a low-cost way to begin. More sophisticated lighting retrofits may include installing solid-state LED lighting fixtures or T-5 fluorescent lighting. These retrofits require replacement not just of lamps but also of fixtures themselves.

Other types of retrofits, including both energy- and water-consuming equipment and devices, may also be appropriate. Advances in the efficiency of building technologies may mean that it makes economic sense to replace building systems or equipment before the end of their service life. In some markets, external incentives such as tax credits, utility rebates and manufacturer rebates are available to encourage such retrofits. In addition to using technical audits to identify retrofit opportunities, external incentives should also be investigated to maximize the return on investment of energy upgrades.

Figure 8.2 Using plantings to shade parking areas and buildings can reduce the urban heat island effect and offer energy savings potential

Landscaping can also offer performance improvement opportunities. In buildings deliberately designed to meet sustainability goals, landscaping is often selected to minimize water requirements. However, temporary irrigation measures are often included during the plant establishment period to ensure healthy initial growth. Discontinuing these measures at the end of the establishment period will help to ensure that water conservation goals are met. For buildings built before sustainability goals were established, replacing existing landscaping with native plants and water-conserving species will also offer significant water conservation potential, and may also help conserve energy if used to shade the building or reduce the urban heat island effect (Figure 8.2).

Clues to building performance problems are often found by looking for occupant adjustments or compensating technologies. For instance, portable heaters, desk fans and occupant-supplied task lighting can

Figure 8.3 Occupant adjustments or compensating technologies are clues that a building may not be performing properly

be signals that a building is uncomfortable for its occupants. These and other adjustments (see for example Figure 8.3) should be noted and explored further as part of energy audits or continuous commissioning.

Information can also be a useful way to balance loads and shave peak demand. Large institutions such as universities often pay commercial rates for power based on time-of-day usage. During the hottest parts of the year, rates can easily triple or more when demand for power is highest. Some institutions send out email reminders (Figure 8.4) to users to shut down unnecessary equipment and lighting during these periods. Not only does this save electrical energy, it also saves considerable cost for the institution through avoided use during high-price periods.

Date: Mon, 19 Aug 2002 17:29:23 -0400 (EDT)
From: [redacted]
Subject: High Energy Cost
Reply-To: [redacted]

Energy Advisory **We Need Your Help!**

Electricity Price Caution is in effect for 8/20/2002 for a time period starting 3 pm to 7 pm
Electricity Price Caution is issued when the electricity prices are 3 to 6 times higher than normal.

Here are some actions you can take to help reduce our electricity consumption

1. Activate the energy saving or "sleep" mode on computers and copiers.
2. Turn off your computer monitor when you are away from your desk for more than 15 minutes.
3. Turn off lights when out of your office or cubicle.
4. Turn off lights in unused common areas such as copy rooms, break rooms, conference rooms, unoccupied rooms and restrooms.
5. If you have control over the thermostat setting for the air conditioner raise it by two degrees during the peak hours. Consider raising the level of the thermostat further when your facilities are unoccupied.
6. Shut off non-essential machinery, computers, and other equipment.
7. Consider reducing number of copiers available for use during peak hours.

Georgia Power Company - Prices for 8/20/2002

Hour	cents/kWh
1:00	2.1203
2:00	2.0594
3:00	2.0235
4:00	2.0263
5:00	2.0278
6:00	2.0213
7:00	2.1258
8:00	2.1257
9:00	2.1637
10:00	2.2745
11:00	2.4378
12:00	3.3367
13:00	4.9845
14:00	8.0461
15:00	11.3748
16:00	12.5938
17:00	12.4085
18:00	11.2554
19:00	8.9338
20:00	7.2654
21:00	6.3741
22:00	4.9265
23:00	3.3319
24:00	2.2695

Average price = 5.0211 per hour at end of interval.

Figure 8.4 Email messages can be used to cue users to change their behaviour to save energy

For buildings designed with energy sustainability in mind, ongoing implementation of efficiency and operations plans is important to ensure that energy goals for the building are met in practice. Some of the efficiency and operations plans that may be included for a green building are:

- **General building operating plan**, including an occupancy schedule, equipment run-time schedules, design set points for heating, ventilation and air conditioning (HVAC) equipment, design lighting levels throughout the building, and seasonal or periodic schedule/set point changes.
- **Sustainable maintenance plan** that describes maintenance strategies and specific requirements for facility systems, including equipment maintenance schedules and procedures, spare parts stock requirements, and other details.
- **Continuous commissioning plan** to adjust the facility for evolving operational requirements.
- **Measurement, monitoring and verification plan** to monitor ongoing building performance and identify performance problems.

In making operational adjustments to existing buildings, operators must be aware of the systems-level impacts that can result from adjustments to operational schedules. For instance, while it might seem to be a good financial decision to reduce or shut down ventilation and air-conditioning systems during unoccupied hours of a building, in humid climates this can result in disastrous impacts on indoor air quality as mould develops in warm, high-humidity interior conditions. Every proposed operational change or system retrofit should be carefully considered in terms of its effects on related systems and likely occupant responses before proceeding. This will help to ensure that high performing buildings continue to perform well over time.

Green product procurement

A second major area of sustainable facility operations is ensuring that all materials, resources and products procured for ongoing facility operations and maintenance meet sustainability goals. Depending on the specific type of facility being considered, there may be significant material or energy flows not directly associated with the facility itself, such as in a manufacturing facility. In these cases, environmental audit procedures such as those covered under the ISO 14000 Environmental Management standard can be used to identify improvement opportunities for material substitution and procurement from more sustainable sources.

For material and energy flows associated with facility operations, it is essential to ensure that products are being procured from the most sustainable source available and delivered to the facility in the most sustainable fashion possible. One key resource required by nearly all facilities is energy. The sustainability of power from outside sources can be improved in two major ways: by purchasing power from green-certified power providers who generate that power from renewable sources; and by purchasing so-called 'green tags' or carbon offsets to offset the negative impacts of power produced from conventional sources. One well-known green power certifying program, Green-e (www.green-e.org), is a programme of the Center for Resource Solutions (Figure 8.5). To be certified under this programme, power producers can apply for renewable energy certification if their power portfolio contains a sufficient proportion of power from certain renewable sources. They can also qualify for green pricing programme certification or for competitive electricity product certification, based on their market structure.

Green-e®

Figure 8.5 The Green-e certified power logo

For other types of products associated with building operations, green procurement practices can help to ensure that products are obtained from the most sustainable source and are as environmentally friendly as possible. As with construction materials, there are a variety of considerations to take into account, including recycled content, recyclability, rapid renewability and non-toxicity. These factors apply primarily to the products themselves. Product packaging and delivery pose another set of considerations, including using products that are local or regional to strengthen local economies and reduce transportation impacts. For instance, key factors in the US Department of Defense's Green Procurement Requirements include:

- products manufactured from recovered/recycled materials
- environmentally preferable products
- energy- and water-efficient products
- biobased products
- alternative fuels and fuel-efficient vehicles
- non-ozone-depleting substances.

Third-party standards such as Energy Star, WaterWise and GreenSeal are available to serve as a basis for green purchasing of products for facility operations. These standards and others are described in more detail in earlier chapters.

Green waste management

At the other end of the product life-cycle, proper recovery and disposal of products at the end of their service life is also critical. Products such as analogue thermostats, fluorescent lamps and ballasts often contain hazardous components that can have significant environmental impact, especially when produced in large quantities. The Universal Waste Rule in the United States governs the proper disposal of these types of products; since they are generally produced in quantities below which laws associated with hazardous waste handling and disposal apply (Figure 8.6).

Figure 8.6 Fluorescent lamps are one common building waste stream covered under Universal Waste Rules

Recycling or otherwise diverting other types of waste is also a priority. Providing appropriate facilities for recycling can help direct user behaviour and result in high-quality recycled material waste streams.

For instance, the containers shown in Figure 8.7 help users place materials in the proper receptacle to prevent cross-contamination. Along with user education programmes, these measures can help to meet operational recycling goals.

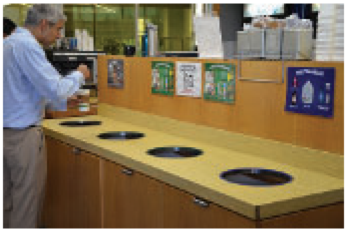


Figure 8.7 Recycling receptacles can be designed to help users correctly segregate waste

Green housekeeping, comfort and environmental quality

After a facility is occupied, green housekeeping practices can help to maintain a healthy indoor environment. The manufacturer's instructions should be followed for maintenance of all finishes. For instance, carpets should be vacuumed or cleaned at the recommended intervals, and can be kept in proper shape by hiring a maintenance contractor to perform this function. It is critical to read labels on cleaning chemicals

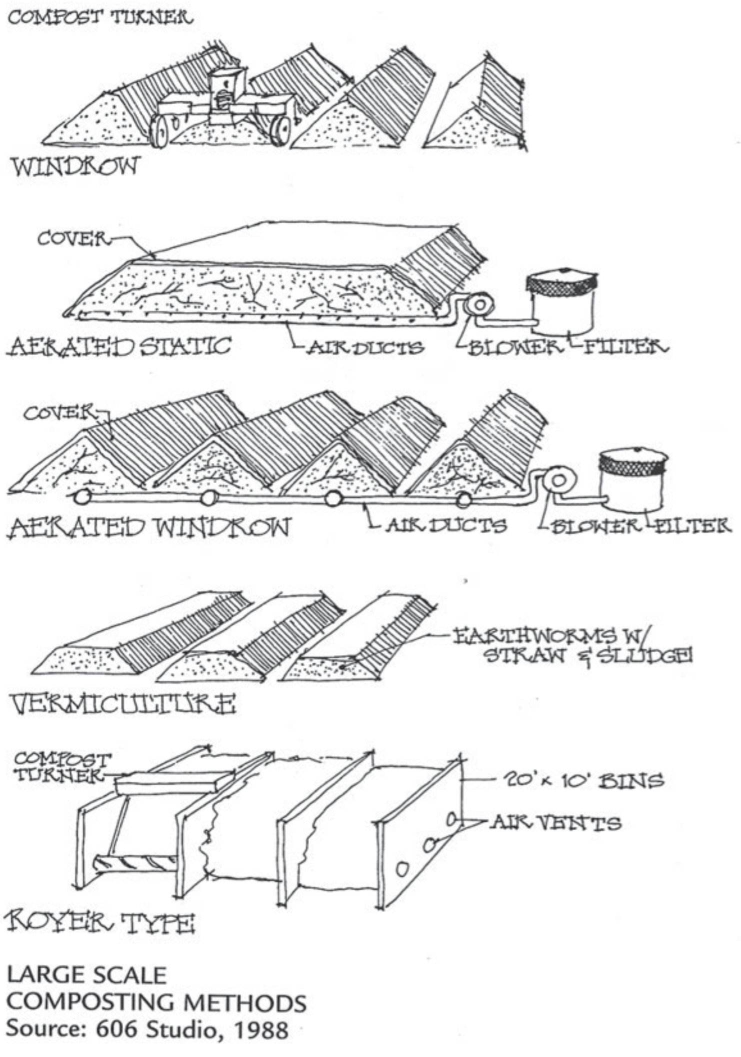


Figure 8.8 Composting on-site can capture organic waste and convert it into useful material for landscaping

and choose non-toxic, water-soluble cleaners wherever possible. GreenSeal (www.greenseal.org) is an organization that has numerous standards for non-toxic cleaning products. Trade associations such as the Carpet and Rug Institute (www.carpet-rug.org) also maintain standards and recommendations associated with green cleaning procedures for related products.

Building humidity levels should be carefully monitored and maintained, with relative humidity levels between 30 per cent and 50 per cent in all occupied spaces of the building. During summer, cooling coils may require maintenance to ensure that they are properly dehumidifying incoming air. All HVAC equipment should be regularly inspected and properly maintained to identify and fix problems before they create unhealthy conditions.

In addition to measures taken inside the facility, low-impact maintenance practices can also be employed for the site and exterior of the building. These practices may include using low-VOC paints and sealers; using non-toxic cleaners; irrigating landscape features only as necessary; minimizing the use of fertilizers and herbicides/pesticides; composting landscape waste (Figure 8.8); creating wildlife habitat in the landscape; using mulching mowers to return nutrients to the landscape, and avoiding or removing invasive plant species.

Green renovations and indoor air quality

Figure 8.9 Proper protection of work areas, unlike the example shown in this photo, can ultimately speed up construction and save both time and money

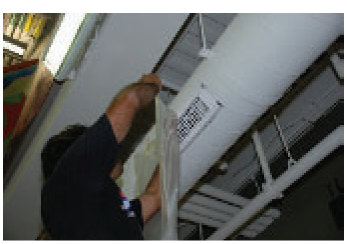


Figure 8.10 Plastic sheeting can be used to isolate ductwork and return air plenums during renovations

Any type of construction or renovation activity in an existing building has the potential to cause indoor air quality problems if not properly managed. Many construction activities produce dust or airborne particulates, such as cutting operations and sanding. Other activities involve installing materials that release VOCs or moisture while they cure – like paint, sealants, adhesives, concrete and new lumber. Even with dust collectors installed on equipment, there is a need to protect building systems from absorbing these pollutants during construction. Proper protective measures can also relieve construction workers from having to constantly worry about dust and pollutants, speeding up construction and saving time and money (Figure 8.9).

At a minimum, construction isolation measures should include protection of all HVAC intakes, grills and registers. Use plastic sheeting and duct tape or ties to ensure that all possible points of entry to building ductworks or plenums are sealed off (Figure 8.10). Be sure to deactivate the HVAC system before you do this. Also isolate entryways to other parts of the building and stairwells or corridors outside the work areas.

When possible, try to sequence the installation of absorptive materials to occur after dust-producing activities will occur. Absorptive materials include but are not limited to carpet, wall coverings, fabrics, ceiling tiles and many types of insulation. If this is not possible, be sure to use plastic or paper sheeting securely taped in place to protect all absorptive surfaces.

Proper ventilation during construction should be maintained to ensure worker health and safety and to exhaust pollutants from the workspace. If possible, continuous negative pressure should be maintained on the workspace to prevent dust and contaminants from migrating to other parts of the building. Ventilation should be provided by a temporary ventilation system to avoid contaminating building ductwork with pollutants.

Regular housekeeping during construction will help to keep contaminants under control and prevent them from becoming airborne (Figure 8.11). Specialty contractors can be retained for this purpose, or work practices can be put in place to require workers to keep their areas clean and free of debris. All construction isolation measures should be regularly inspected for leaks and tears, and should be replaced as needed.

Figure 8.11 Proper housekeeping can help to maintain future indoor air quality

At the completion of construction, all masking and sheeting used to isolate ventilation systems should be removed before restarting HVAC systems to the isolated area. Temporary high-efficiency filters may be used in the HVAC system during some construction activities and before building occupancy to trap remaining contaminants and protect them from entering the system. These filters should be replaced prior to occupancy and properly disposed. The US Environmental Protection Agency (USEPA) recommends a two-week flush-out period for all areas in which construction has occurred prior to occupancy. During the flush-out period, ventilation systems should be run continuously with full outdoor air within a specified humidity and temperature range. While flush-out helps to accelerate the removal of offgassing from building materials, it can also introduce large amounts of humidity into the building depending on the climate and season. This humidity will supplement the already high humidity rates from the curing of materials inside the building itself. If a building flush-out is to be undertaken, operation guidelines for all HVAC systems should be consulted to ensure that humidity controls are able to handle the extra humidity load that may occur.

Other post-occupancy tactics

Ensuring that a green building remains green throughout its lifecycle requires attention not only to the building itself, but also to its occupants and people responsible for its operation and maintenance. Incentive programmes, education and training, and signage and information programmes can all achieve this end.

Figure 8.12 Building signage can be used to explain innovative building features and help building occupants know how to behave

Building owners can provide incentives and amenities that encourage building occupants to use alternative means of transportation for getting to work, such as walking, car-pooling, taking a bus or train, or bicycling. They can also encourage practices such as telecommuting if appropriate for the type of work being done. Signage and information programmes, ranging from email updates discussed earlier in this chapter to the educational signage shown in Figure 8.12, can also alert users not only to what has been done and how they should respond, but also why those measures were taken and why they should care.

Case Study: Homestead Air Reserve Base Fire Station

This renovation/expansion project completed in 2002 is a classic example of turning lemons into lemonade. The original plan involved constructing an entirely new building, but budget constraints during the funding process made this option infeasible. To fit within the lower budget, a decision was made to adapt and expand the existing fire station to better serve the needs of the installation's fire fighters. A general contractor was hired based on willingness to commit to learning about and using sustainability principles, and a major design firm was selected as the architect/engineer due to its prior experience in sustainable design. The overall sustainability goals for the project were communicated during a charrette involving not only installation personnel, but also headquarters personnel including the command civil engineer, who took an active interest in the project.

The goal of lowering utility costs was achieved by using light shelves, low-e glass, clerestory windows, a high-efficiency HVAC system, photoelectric site lighting, and shading the building with landscape plants. Although some of these measures tended to increase the first cost of the project, increases were offset with the savings in other areas, including a smaller HVAC system that could be substituted for the original capacity due to reduced heat loads from lighting. The photovoltaic site lighting was no more expensive overall due to the savings in energy supply lines.

Indigenous plants were used for landscaping to reduce water use, and stormwater is captured and retained through a percolation trench. The existing storm sewer in this area of the installation was already overtaxed, so use of the percolation trench also avoided the expense of having to upgrade the sewer system. Since a major use of water in fire stations is for washing vehicles, a vehicle wash water recirculation system was also included to minimize water demands.

Two other goals were to use recycled materials and to recycle as much waste material from demolition and construction as possible. The contractor was able to recycle nearly 100 per cent of the waste materials from demolition, saving substantial money over landfill tipping fees. As a result of experience on this project, the contractor began recycling waste on other jobs as well. On-site waste separation led to better housekeeping practices on the project, resulting in zero accidents due to a cleaner job site. Savings resulting from avoided waste disposal costs were used to offset the higher costs of using recycled materials in construction.

The existing fire station was renovated and expanded to meet new requirements at Homestead Air Reserve Base

Demolition involved careful preservation of key structural elements

Images courtesy of Bill Cadle, HQ Air Force Reserve Command.

Nearly 100 per cent of demolition waste was recycled through on-site separation, and good housekeeping practices resulted in a project with zero injuries

Mature landscape was carefully preserved to provide passive shading

A high-albedo roof membrane was used to reduce heat gain and lower cooling costs

A percolation trench captures stormwater runoff and avoids overloading a treatment system already nearing capacity

When coupled with a participatory design process, such measures can help building occupants take ownership for the systems in their building and keep them running smoothly. Some facilities even provide occupant manuals or websites to ensure that occupants can find answers to their building-related questions over time.

Regular training for operations and maintenance personnel is also critical to ensure that the facility remains functioning in its optimal state. Especially for facilities where new technologies have been used, proper training and guidance in operations is essential. In some cases, it may make sense to outsource the maintenance function for complex systems such as building automation and controls. Ongoing training, in conjunction with proper manuals and as-built drawings, is also essential, especially in situations where there is high turnover of building maintenance personnel.

Case Study: Trees Atlanta Kendeda Center

As a building with significant sustainability goals during design and construction, the Trees Atlanta building continued to set an example of sustainability best practice during the operations and maintenance phase of the building life-cycle. The following subsections describe practices currently in use in the Trees Atlanta building to optimize energy and water performance, procure green materials, and ensure comfort and a high-quality indoor environment for its occupants.

Optimizing energy and water performance

Optimizing energy and water performance of an existing facility is the single most important strategy to achieve the goals of sustainability in the built environment due to the reduction of energy and water consumption along with minimal annual utility costs. In addition, lower energy and water consumption within the facility can also reduce greenhouse gas emissions that are mainly caused by electricity generation, which accounts for the largest portion of US greenhouse gas emissions. Three primary tactics – operational adjustments, retrofit of energy-and water-consuming equipment and working with users to adjust their behaviour – have been described, and Trees Atlanta has implemented some of the recommendations. First, Trees Atlanta has sustainable building operations and a maintenance meeting every six months to review its monthly utility bills, including water and electricity bills. By comparing their monthly usages and bills with building energy simulation and water-saving calculations, as well as with previous consumptions, it is possible to measure and verify the building's sustainable performance and to monitor occupants' behaviours and attitude. Second, the installed systems and building are continuously evaluated to ensure the performance requirements are being maintained in the Trees Atlanta building. The main approach for continuous commission process is that the owner and a commissioning agent periodically verify proper operation of the equipment to ensure that it is functioning correctly and as efficiently as possible compared to the as-built functional test procedures contained in the system manual. The following clauses describe the commissioning agent's responsibility related to continuous commissioning.

Post occupancy phase

A Coordinate deferred and seasonal functional tests; verify correction of deficiencies.

B On-site review: periodically conduct on-site review with owner's staff.
- Review the current facility operation and condition of outstanding issues related to the original and seasonal commissioning.
- Interview staff to identify problems or concerns they have operating the facility as originally intended.
- Make suggestions for improvements and for recording these changes in the O&M manuals.
- Identify areas of concern that are still under warranty or are the responsibility of the original construction contractor.
- Assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.

Third, the Trees Atlanta building has had several operator training sessions, primarily because the nature of the organization is that it consists of many volunteers. Given that the building has installed sustainable features including a geothermal heat pump system with programmable thermostats, lighting occupancy controls and a solar hot water heater and rainwater collection system for toilet flushing, there is a need to ensure that many people know how to properly operate the building's features (Figure 8.13). Therefore, the contractor of the Trees Atlanta building has developed an operations and maintenance manual that was verified by both an architect and a commissioning agent. In addition, the contractor was required to provide operations and maintenance training for all employees and several volunteers with the fully developed operations and maintenance manual. The commissioning

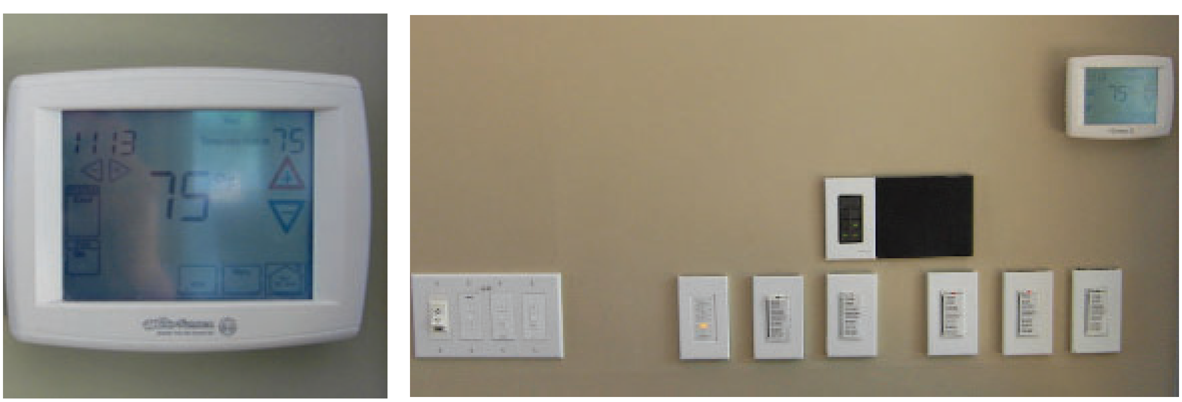


Figure 8.13 Operator training can ensure that building equipment such as these HVAC and lighting controls are used most effectively

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Renewable Energy Certificate Purchase Agreement

Client Name:	Trees Atlanta
Contact Name:	Marcia Bansley
email address:	marcia@treesatlanta.org
Shipping Address:	225 Chester Avenue
	Atlanta, GA 30316
Phone:	404-522-4097
Billing Contact:	Regina Clifton
email address:	regina@treesatlanta.org
Billing Address:	225 Chester Ave.
	Atlanta, GA 30316
Phone:	404-522-4097

Summary of Annual Electric Use (kWh)

Project Name:	Trees Atlanta
Location:	Atlanta, GA
Estimated Annual kWh:	39,790 kWh
Annual Environmental Impact of 100% offset	
Avoided Emissions:	
	55,388 Pounds of CO2
Has the same environmental impact as:	
Not Driving:	60,467 miles in the average car
Planting:	7 acres of fully mature trees

SALESPERSON	PO NUMBER	ORDER DATE
Jason Wykoff		
	PAYMENT TERMS	
	Net 30	

Purchase Details:

Option	Total kWh	Description	PRICE ($/kWh)	TOTAL AMOUNT	Initials
70% offset for 2 years to meet LEED E&A Credit 6 and ID point	79,580	Green-e certified American Wind™	$0.0080	$ 636.64	

The undersigned agrees that he/she is authorized to engage in an agreement on behalf of the company below. By signing, the company agrees to the purchase amount and terms outlined on this page

Confidential and Proprietary Information

American Wind™ is Green-e certified.

MARCIA D. BANSLEY
Printed Name

Marcia D Bansley June 18, 07
Signature / Date

TREES ATLANTA Executive Director
Company Name / Title

Order Acceptance: the undersigned agrees that he/she is authorized to accept this order and the terms outlined on this page on behalf of Renewable Choice Energy.

6/26/07
Aran Rice Director of Operations, Renewable Choice Energy

PRODUCT CONTENT LABEL

This is a renewable certificate product. For every unit of renewable electricity generated, an equivalent amount of renewable certificates is produced. The purchase of renewable certificates supports renewable electricity generation, which can help offset conventional electricity generation in the region where the renewable generator is located. You will continue to receive a separate electricity bill from your utility.

The product will be made up of the following new renewable resources averaged annually.

New[1] Renewable Resources in *American Wind™*		Generation Location
Wind	100%	Nationwide

[1]Includes renewable generators that first started operating after January 1, 1997 or as regionally defined.

For comparison, the current average mix of energy sources supplying the U.S. includes the following: Coal (52%), Nuclear (20%), Oil (3%), Large Hydroelectric (7%), Natural Gas (16%), and Renewables (2%) Source: from USEPA E-Grid). For specific information about this product contact Renewable Choice Energy at 303-468-0405 or on the web at www.renewablechoice.com.

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AMERICAN WIND

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Figure 8.14 Purchasing power from green-certified power providers can reduce environmental problems in the built environment authority also verifies with the owner that the operations and maintenance training is adequate and addresses their needs to properly operate and maintain the building. Finally, the commissioning officer of the project developed an annual operation and maintenance education programme for each member of staff and several volunteers. The education programme provided information on building and building systems operation, maintenance, and achieving sustainable building performance.

Green materials procurement

One of the major areas of sustainable facility operations is ensuring that all materials, resources and products procured for ongoing facility operations and maintenance meet sustainability goals. The first opportunity in green procurement is to purchase green certified power from outside sources. Green power improves sustainability because green electricity products can reduce the air pollution impacts of electricity generation by relying on renewable energy sources such as solar, water, wind, biomass and geothermal sources. Conventional energy production from traditional sources such as coal, natural gas and other fossil fuels, on the other hand, is a significant contributor to air pollution and negative environmental impacts, especially in the United States and other countries heavily relying on coal for energy purposes. The Trees Atlanta building purchased its green power credit of 79,580 kWh from Renewable Choice Energy in Boulder, Colorado (Figure 8.14).

To reduce the environmental and air quality impacts of the materials acquired for use in the operations and maintenance of the Trees Atlanta building, the Trees Atlanta staff attempt to purchase green materials, supplies and equipment for ongoing operations, including:

- paper: buying recycled paper products
- cleaning product: purchase sustainable cleaning products
- toner: purchasing cartridges from a cartridge remanufacturer
- batteries: choosing and using rechargeable batteries
- binders: purchasing recycled binders.

Green waste management including a recycling programme has been strongly implemented within the Trees Atlanta building. The director of Trees Atlanta believes that recycling within the building can change Americans' attitudes and behaviour toward sustainability. Thus, Trees Atlanta has a strong recycling programme under the supervision of the director. Figure 8.15 shows an example of recycling areas inside the building.

Figure 8.15 Active recycling can change people's attitude and behaviour towards sustainability

Comfort and indoor environmental quality

Regular housekeeping is the key to improving indoor environmental air quality within the Trees Atlanta building. Thus, staff and the janitor of the building diligently maintain the building as clean as possible within facility cleaning guidelines and requirements. The copy room has a

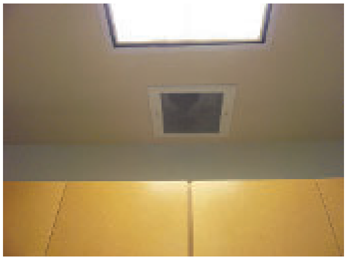


Figure 8.16 This ceiling vent is part of a separate ventilation system used to maintain negative pressure in the copy room to prevent contaminants from entering other parts of the building

different ventilation system to maintain negative pressure that can control dusts and airborne contaminants generated by printing and copying activities. This separate ventilation system contributes to a high-quality environment that helps occupants enjoy working in the building. Figure 8.16 shows the return air vent for the separate ventilation system in the copy room to maintain negative air pressure that can sustain high indoor air quality.

Case Study: the Empire State Building energy-efficiency retrofit

A second example of sustainability activities post-occupancy is the Empire State Building (EBS). The EBS is no ordinary office tower. It is the world's most famous office building, located in the heart of New York City. Each year, it attracts between 3.5 million to 4 million visitors to the Observatory on the 86th floor. As the ESB is the tallest building in New York City, with a height of 1454 feet (443.2 metres), the spire is used for broadcasting by most of region's major television and radio stations. The ESB has 12.8 million sq ft of leasable office space that holds a variety of large and small tenants including Skanska, the Federal Deposit Insurance Corporation, Taylor Communications and Funaro. The building first opened in 1931 and has undergone recent upgrades of lobbies, hallways and other common areas including the just-completed renovation of the observation deck, restoring the building to its original grandeur (Figure 8.17).

Figure 8.17 The Empire State Building

Empire State Building

- Location: 350 Fifth Avenue New York, NY 10118.
- World's tallest building from 1931 to 1973.
- Construction period: 1929 to 1931 (excavation of the site on January 22, 1930).
- Building cost: US$40,948,900 (1931 dollars).
- Project duration: 410 days after construction commenced
- Opening day: 1 May 1931.
- Antenna or spire: 1454 ft (443.2 m).
- Roof: 1250 ft (381.0 m).
- Top floor: 1,224 ft (373.2 m).
- Floors: 102 floors (85 storeys of commercial and office space and 16 storeys of Art Deco Tower, which is capped by a 102nd floor observatory.
- 6500 windows, 73 elevators, and 1860 steps from street level to the 103rd floor.
- Floor area: 2,768,951 sq ft (257.211 sq m).
- 1000 businesses with 21,000 employees work in the building each day.
- Architect(s): William F. Lam at the architectural firm of Shreve, Lamb and Harmon (design period two weeks).
- The building design was based on the Reynolds Building in Winston- Salem, North Carolina.
- Contractor: Starrett Brothers and Eken.
- Project was financed by John J. Raskob and Pierre S. du Pont.
- Management: W&H properties.

Since the ESB is one of the tallest and largest buildings in the world, it has a significant impact on the environment as a result of the process of operating and maintaining the building. According to the building's website,[2] prior to 2008, the performance of the ESB was as follows:

- annual utility costs: US$11 million (US$4/sq ft)
- annual carbon dioxide emissions: 25,000 metric tons (22 lbs/sq ft)
- annual energy use: 88 KBtu/sq ft
- peak electric demand: 9.5 MW (3.8 W/sq ft, including HVAC).

To reduce negative environmental impacts, efforts to make the ESB and similar buildings more environmentally sustainable have resulted in significantly greener office spaces. However, most sustainability-related efforts have been focused on new building construction, while the majority of existing office buildings worldwide have made little or no progress in the areas of energy efficiency and sustainability. Because of this opportunity, Anthony E. Malkin of the Empire State Building Company has committed to establish the ESB as one of the most energy-efficient and sustainable existing buildings in the world, and wants to probe the cost-effectiveness of energy-efficient and sustainable retrofits for existing office buildings. Through this retrofit of the ESB, it will be possible to reduce greenhouse gases and utility costs to demonstrate how to retrofit a large commercial building cost-effectively, and to demonstrate that such work makes good business sense in the commercial office market. Proving the benefits of energy-efficient and sustainable retrofits in the ESB will make it possible not only to create a replicable model for whole-building retrofits for existing offices around the world, and also reduce greenhouse gas emissions and operating costs while providing state-of-the-art indoor environments to office tenants. In addition, the ESB project team anticipates that sustainable retrofits of the ESB will enhance its long-term value based on the opportunity for higher occupancy and rents over time.

Motivation

The goal with ESB has been to define intelligent choices which will either save money, spend the same money more efficiently, or spend an additional sum for which there is reasonable payback through savings. Addressing these investments correctly will create a competitive advantage for ownership through lower costs and better work environments for tenants. Succeeding in these efforts will make a replicable model real for others to follow.

Anthony E. Malkin, Malkin Holdings

Sustainable retrofit of the ESB

The desire to sustainably retrofit the ESB was motivated by the owner's goals to reduce greenhouse gas emissions, to demonstrate a way for sustainable retrofitting of such a large commercial building cost-effectively, and to demonstrate that such work makes good business sense. To achieve these sustainability goals, five dedicated project partners were recruited from several key areas of expertise, including environmental consulting, engineering, project management, and commercial real estate, to develop a proposal for retrofit that would achieve project goals while making good business sense. The five key partners in the ESB project development process are the Clinton Climate Initiative (CCI), Johnson Controls Inc. (JCI), Jones Lang LaSalle (JLL), the Rocky Mountain Institute (RMI) and the Empire State Building Company (ESB), representing both the owner and operations perspectives, shown in Figure 8.18.

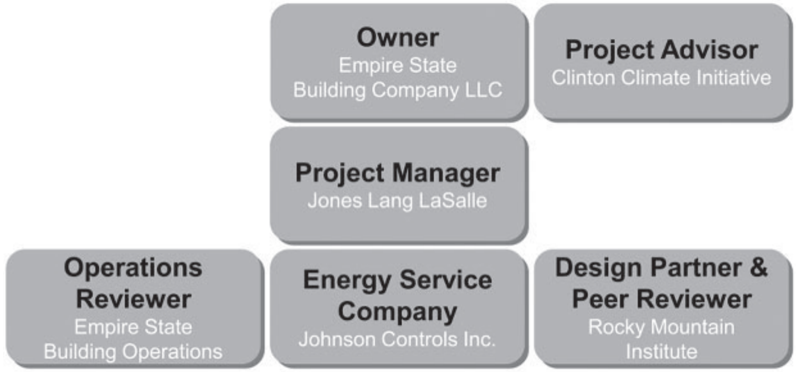


Figure 8.18 Project team members

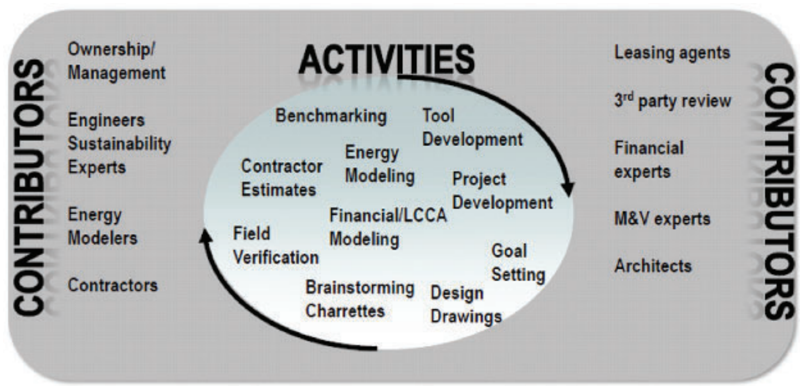


Figure 8.19 Contributors and activities in the ESB project
Courtesy of Empire State Building, LCC.

These core project team members brought the areas of their expertise to achieve the goal of analysing what actions would make the most sense in sustainably retrofitting the ESB. They also closely collaborated in many different activities including goal setting, brainstorming charrettes, tool development, energy modelling and financial/life-cycle cost analysis modelling as shown in Figure 8.19.

After forming a collaborative project team, the project team established action goals to achieve the main sustainability goals for the ESB, including:

- Developing a replicable model for retrofitting the pre-war building in a cost-effective way.
- Developing practices to lower energy consumption costs by as much as 20 per cent.
- Increasing overall environmental benefits of the building retrofit through an integrated sustainability approach to maximize opportunities and market advantage.
- Encouraging the team to be objective, creative and provocative in its approach.

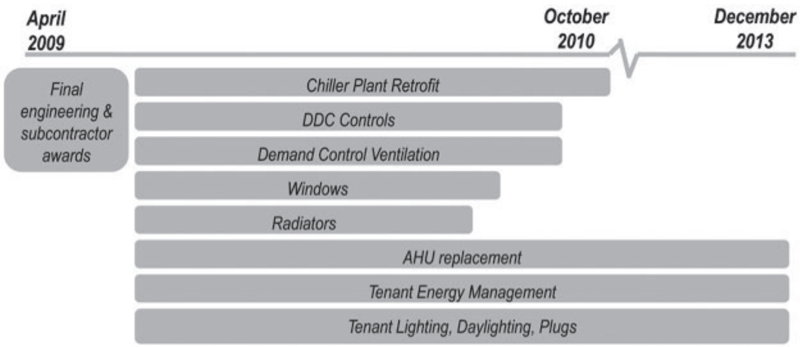


Figure 8.20 Project completion schedule

- Developing a model that is marketable to existing and prospective clients in its approach.
- Coordinating with the ongoing capital projects within the building.
- Developing a financial structure that is efficient and achievable.

To achieve these actionable goals, the collaborative project team developed an optimal proposed solution for sustainable retrofit of the ESB through a rigorous and iterative process that involved experience, energy and financial modelling, rating systems, technical advice and robust debate. The ideas proposed as a result of this project are presently underway as part of an ongoing retrofit process begun in 2010 and expected to continue by the end of 2013 (Figure 8.20), with measurement and verification of impacts continuing through 2025.

Solution development process

The solution development process started with assembling a collaborative team of world-class sustainability and energy specialists as core collaborative team members. The team developed a four-phase iterative process and rigorous cost/benefit analysis to design an optimal solution that would lead to significant reductions in greenhouse gas emissions and promote sustainable design and operations in the existing building. To support the project development process, the project team used various industry standards and newly developed design tools (eQUEST, AGI32 and Google Sketch Up), decision-making tools, and green building rating tools (Energy Star, LEED and Green Globes) to evaluate and benchmark existing and future performance. Figure 8.21 shows the whole four-phase process used to create a replicable model in the ESB.

At the 'identify opportunities' phase, the project team first fully investigated resource use at the existing ESB by examining energy usage between April 2007 and May 2008. They also reviewed tenants' surveys. Second, the project team brainstormed over 60 energy-efficiency ideas and strategies that might be implementable for the project. They also estimated theoretical minimum energy use to address occupant comfort requirements, passive measures and other systems impacts, system design characteristics, technology, controls and changed operating schedules. The identified ideas and strategies were the narrowed to 17 implementable projects (Table 8.1). Next, the project team developed an eQUEST energy model to use for cost/benefit analysis of future improvements, modifications and operational changes (Figure 8.22).

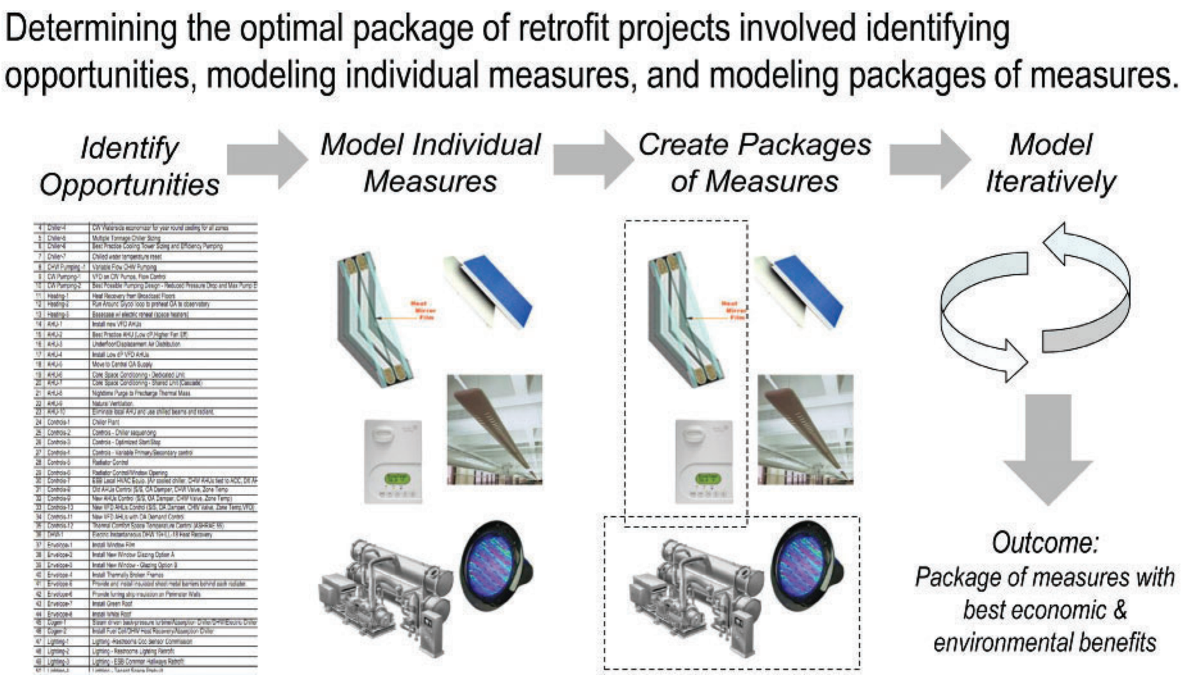


Figure 8.21 Project development process for the ESB
Courtesy of Empire State Building, LCC.

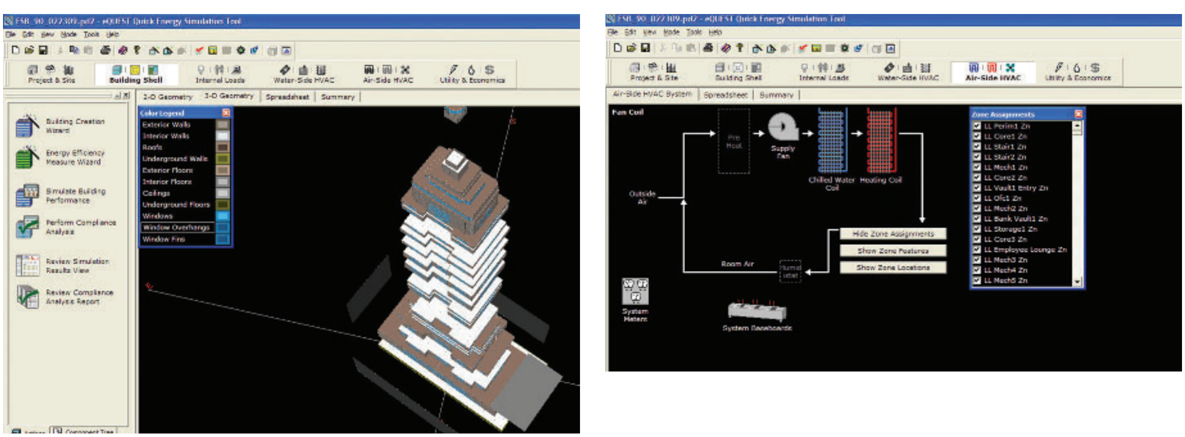


Figure 8.22 Energy modelling tool for energy-efficiency strategies
Courtesy of Empire State Building, LCC.

Table 8.1 Implementable energy-efficiency strategies for the ESB retrofit

Energy efficiency strategies	Description
Building windows (plus t-operative operative temperature transducer and infiltration); SC75/TC88 heat mirror film	Refurbish all existing double-pane windows (6,500 windows). Insert suspended heat mirror film (SC75 or TC88) and krypton/argon gas mix.
102nd floor windows	Add film to existing single-pane windows on 102nd floor event space.
Radiative barrier	Install reflective barrier behind 6,500 steam radiators; seal all gaps with foam and insulate the enclosure pocket in which the radiator sits.
Green roof/cool roof	Add green roof on 5th floor (20,000 sq ft) and 21st floor (10,000 sq tf); add white roof on 25th floor (6000 sq ft) and 30th floor (6000 sq ft).
Balance of direct digital controls	Install mechanical system controls throughout the building (2nd floor, 2-way valves, OA control, exhaust).
Tenant demand control ventilation on existing units (OA)	Add carbon dioxide demand control ventilation for all existing constant volume air handling units (485 total) to reduce outside air conditioning.
Additional direct digital controls	Add controls for all radiator valves and main steam valves.
LED tower lighting	Replace existing metal halide tower lighting with LEDs.
New chiller plant	Install four 1400-ton chillers with primary variable secondary flow using all new pumps.
Retrofit chiller plant	Retrofit existing chillers (keep existing industrial grade shells). Replace refrigerant, new variable speed drives (VSDs), compressors, and motors.
Corridor lighting	New fixtures, lamps, ballast, and digitally addressable lighting interface (DALI) controls for all corridors.
Restroom lighting	New fixtures, lamps, and ballasts for all restrooms.
Variable air volume air handling units	Replace all existing constant volume air handlers with new variable air volume (VAV) units. Install two larger units per floor instead of four units (~240 new units).
Tenant daylighting/lighting and plugs	Install 0.8 W/sq ft with dimmable ballasts and photocells (for daylight dimming on perimeter). Add plug load occupancy controls.
Tenant wall insulation	Add 1″ of R-5 rigid insulation to the inside of all exterior walls in tenant spaces.
Tenant energy management	Provide for end-use sub-metering plus one full time employee (FTE) to manage a tenant energy management program via the Gridlogix website interface.
Aggressive tenant energy management	Provide for an additional FTE to allow additional programming and tenant education/reporting within tenant energy management programme.

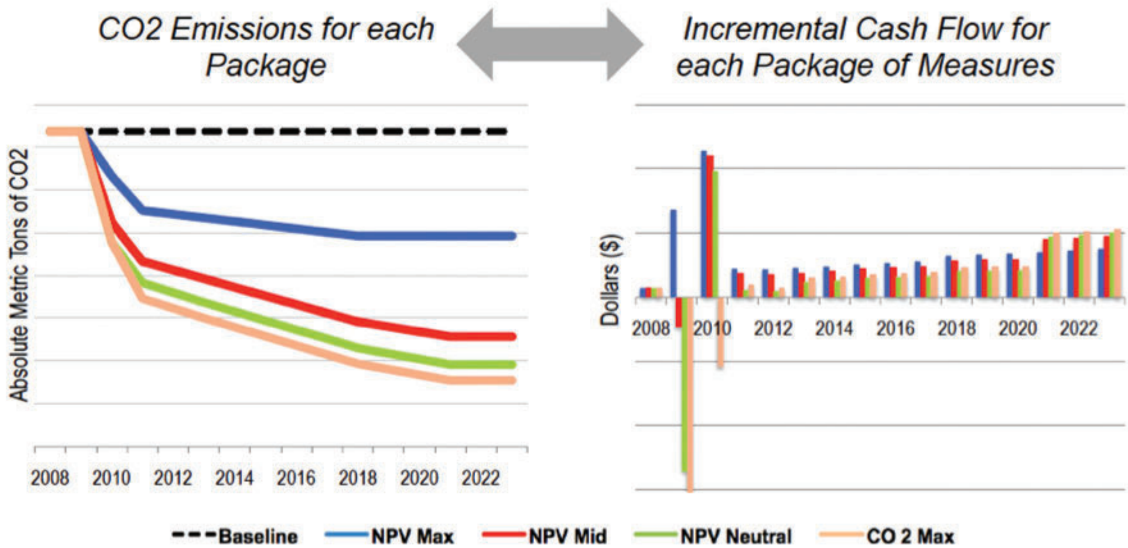


Figure 8.23 Carbon dioxide emissions for each package and incremental cash flow for each package
Courtesy of Empire State Building, LCC.

In the second phase of design development, the project team calculated the net present value (NPV) of selected energy-efficiency strategies and also estimated greenhouse gas emission savings for each strategy (Figure 8.23). In addition, the project team estimated dollars per metric ton of carbon reduced by installing each energy efficiency strategy.

In the third phase of development, the team created different packages or combinations of energy-efficiency strategies with four different goals:

- to maximize NPV
- to balance NPV and carbon dioxide savings
- to maximize carbon dioxide savings for a zero NPV
- to maximize carbon dioxide savings overall.

Figure 8.23 demonstrates the potential carbon dioxide emission reduction for different packages and the incremental cash flow for each package. At this stage, the project team spent significant time to refine energy and financial model inputs to ensure the reliability and accuracy of outputs and to understand the critical relationship between economic investments and carbon dioxide reductions.

In the final phase of design development, the project team iteratively modelled the package measures with the best economic and environmental benefits. By conducting iterative analysis, the project team was able to choose the optimal package of eight energy-efficiency strategies, not only to save energy and reduce carbon dioxide emissions but also to enhance work environments within the building. In addition, these eight sustainable retrofit strategies were also determined to be cost-effective, with an appropriate return on investment (ROI) for the owner.

Optimal energy efficiency strategies

The final eight strategies selected for implementation were:

- building window retrofit
- radiative barrier installation
- tenant demand control ventilation
- tenant daylighting, lighting, and plugs
- direct digital controls (DDC)
- chiller plant retrofit
- variable air volume (VAV) air handling units
- tenant energy management.

These eight strategies will not only reduce energy consumption and carbon dioxide emissions, but will deliver an enhanced environment for tenants, including improved air quality resulting from tenant demand-controlled ventilation; better lighting conditions that coordinated ambient and task lighting; and improved thermal comfort resulting from better windows, the radiative barrier and improved control. Furthermore, these eight strategies are also cost-effective because the additional investment for them will be repaid by a combination of reduced operating expenses, higher rental rates and greater occupancy levels. This payback will occur even though implementation requires investing an incremental cost for retrofitting the building to achieve energy performance. The following subsections describe each of these strategies in greater detail.

Figure 8.24 Building windows refurbishment
Courtesy of Empire State Building, LCC.

Building windows

One of the first energy-efficiency strategies recommended was to refurbish all existing insulated glass units (IGU) consisting of 6500 double-hung windows to include suspended coated heat mirror film (SC75 or TC88) and krypton/argon gas mix (Figure 8.24). By improving the thermal performance of windows, it will be possible not only to reduce energy consumption by about 5 per cent and reduce greenhouse gas emissions correspondingly, but also to improve thermal performance and comfort for occupants in the building.

Radiative barriers

Figure 8.25 Radiative barrier installation between radiators and walls
Courtesy of Empire State Building, LCC.

The second recommended strategy for the project involves the installation of more than 6500 insulated reflective barriers behind radiator units located around the perimeter of the building (Figure 8.25). In addition, all gaps between the radiators and wall will be sealed by foam to insulate the enclosure of the building. Finally, each radiator will be cleaned and its thermostat repositioned to the front side of the radiator. The installed radiative barriers will reduce summer heat gain and winter heat loss, and hence are expected to reduce building heating and cooling energy usage.

Chiller plant retrofit

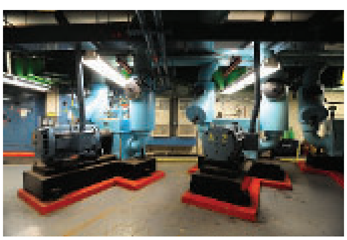


Figure 8.26 Chiller plant retrofit
Courtesy of Empire State Building, LCC.

The recommended chiller plant retrofit project (Figure 8.26) includes the retrofit of four industrial electric chillers (one low-zone unit, two mid-zone units, and one high-zone unit) in addition to upgrades in controls, variable speed drives and primary loop bypasses. All existing pumps and steam chillers will be allowed to remain. For the low-zone chiller, the retrofit involves the installation of a new chiller-mounted variable speed drive (VSD), a new VSD-rated compressor motor, a new IEEE filter in the variable frequency drive (VFD) to reduce harmonic distortion, and a new Optiview Graphic Control Panel with the latest software revisions. For all other chillers, retrofit involves the installation of new drivelines, new evaporator and condenser water tubes, new Optiview Graphic Control Panels with the latest software revisions, chiller water bypasses with two-way disk type valves, new piping in place of backwash reversing valves, new automatic isolation valves on the chilled and hot water supplies to each electric chiller, and temperature and pressure gauges on all supply and return lines. In addition, existing R-500 refrigerant will be removed (per EPA guidelines) and replaced with R134A refrigerant. The existing steam chillers were retained. All electric chillers, condenser water (CW) and chilled water (CHW) pumps, pump VFDs, and zone bypass valves are controlled by the Metasys control system.

Variable air volume (VAV) air handling units

The sustainable retrofit of the ESB also recommended replacing existing constant volume air handlers with a new air handling layout (two

Figure 8.27 VAV air-handling units and controls
Courtesy of Empire State Building, LCC.

floor-mounted units per floor instead of four ceiling-hung units) as well as the use of VAV units instead of existing constant volume units (Figure 8.27). This sustainable retrofit is expected to require little additional capital cost while reducing maintenance costs and significantly improving comfort conditions for tenants by reducing noise and increasing thermal accuracy and control.

Direct digital controls (DDC)

The control system retrofit will involve upgrading existing control systems (Figure 8.28) at the ESB to Johnson Controls Metasys Extended Architecture BACnet controllers that include Ethernet and BACnet risers with all of the necessary devices and equipment, along with an ADX server/workstation, printer, software and web access capability. The retrofit provides an upgrade in controls for the following building systems:

- refrigeration plant building management system
- condenser water system upgrades
- chiller water air handling
- direct exchange (DX) air handling units
- exhaust fans
- stand alone chiller monitoring
- miscellaneous room temperature sensors
- electrical service monitoring.

By upgrading to DDCs, the HVAC system can provide the environmental conditions needed to maximize productivity and indoor environmental quality, lower total energy consumption, improve the reliability of all installed systems, provide access to every aspect of the HVAC system through a secure web browser interface, and monitor and diagnose all HVAC systems installed in the ESB. In conjunction, the DDC upgrade can also reduce maintenance time and costs.

Figure 8.28 System controls
Courtesy of Empire State Building, LCC.

Figure 8.29 Tenant demand control ventilation
Courtesy of Empire State Building, LCC.

Tenant demand control ventilation

Another energy-efficiency strategy recommended for the ESB was the installation of carbon dioxide sensors for control of outside air introduction to chilled water air handling and direct exchange (DX) air handling units (Figure 8.29). One return air carbon dioxide sensor was installed per unit in addition to removing the existing outside air damper and replacing it with a new control damper. Since a tenant demand control ventilation (DCV) system provides just the right amount of outside air for the occupants, it can save energy by not heating or cooling unnecessary quantities of outside air and by providing assurances that sufficient outside air is being supplied to the occupants. In addition, active control of the ventilation system also can provide the opportunity to control indoor air quality, which has been correlated with increased occupant satisfaction.

Tenant daylighting, lighting and plugs

A key recommendation of the sustainable retrofit plan is a tenant daylighting, lighting and plug-in strategy that involves reducing lighting power density in tenant spaces using ambient, direct/indirect and task lighting (Figure 8.30). This strategy also includes installing dimmable ballasts and photosensors for perimeter spaces that can operate with electric lights off or dimmed depending on daylight availability. The strategy also provides occupants with a plug load occupancy sensor for their personal workstations. In the final analysis conducted by the design team, it was not expected that the ESB would provide the capital to ensure that these measures are implemented. Instead, the ESB expects to provide tenants with examples (via pre-builts), the data

Figure 8.30 Tenant daylighting features
Courtesy of Empire State Building, LCC.

(the team analysis) and the tools (the eQUEST model) to help them understand the cost savings of these measures over the term of their lease as a means of encouraging tenants to undertake these projects of their own volition. If the measures are implemented, the ESB will benefit from tenant compliance with these recommendations since it will result in lower overall cooling demand and higher sustainability ratings for the building. Tenants in the ESB will benefit from reduced utility costs and higher-quality, more productive spaces.

Tenant energy management

The sustainable retrofit plan builds into each space a web-based tenant energy management system (Figure 8.31) that affords tenants instant feedback to measure, control and lower their energy costs, with actionable recommendations for improving efficiency and sustainability tips. An installed EnNET/Active Energy Management (AEM) platform is provided for collecting 15-minute meter data and for creating a normalized database that can be used to support time series profiling, reporting and integration in the future with property management software for creating a bill based upon a current meter read. In addition, the AEM application can be commissioned and web pages can be created to properly display metering data, time series analysis, real-time metering information, and notifications based on usage parameters. Installing this tenant energy management system will make it possible to reduce energy bills and greenhouse gas emissions, encourage occupants' participation and environmental responsibility, help occupants dispel the misconception that energy-saving measures would result in loss of amenity, boost staff morale and pride as people are enabled to feel part of the solution, and make involvement of key personnel in energy efficiency activities a priority.

Figure 8.31 Tenant energy management interface
Courtesy of Empire State Building, LCC.

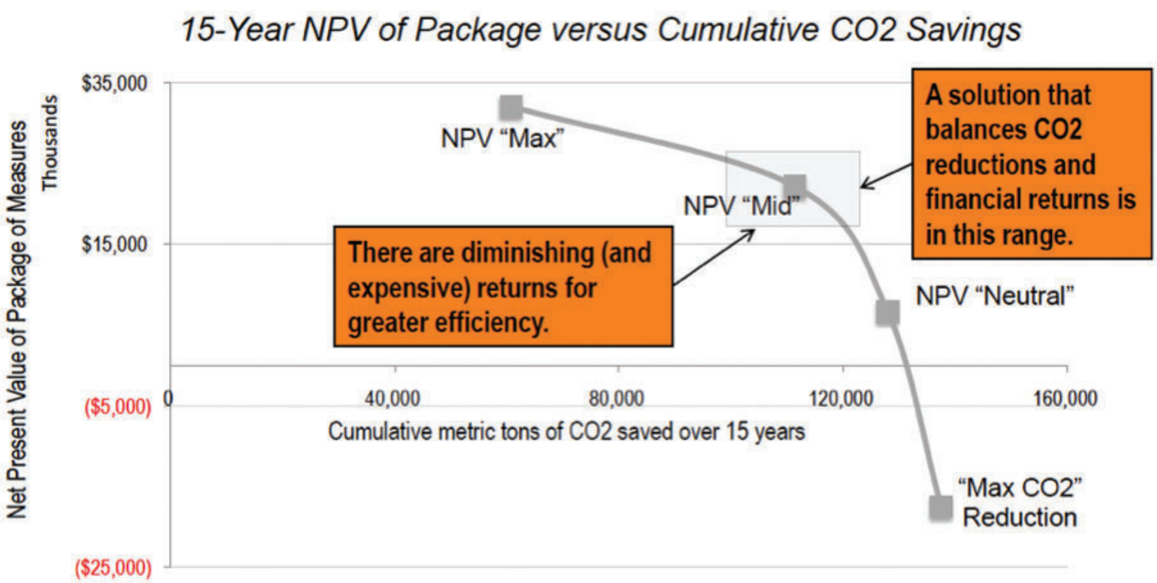


Figure 8.32 The ESB can achieve a high level of energy and carbon dioxide reduction cost-effectively
Courtesy of Empire State Building, LCC.

Expected outcomes from sustainable retrofit

Modelling to pull the project together via iterations between the energy model (eQUEST) and financial models resulted in an analysis (Figure 8.32) that calculates the NPV of the selected package of measures as opposed to cumulative carbon dioxide savings for the four different scenarios considered. In selecting an approach for the retrofit, the project team chose the NPV midpoint' because it included strategies based on a balance of NPV with the amount of carbon dioxide avoided. Based on the analysis, the sustainable retrofit is expected to reduce energy use and greenhouse gas emissions by 38 per cent, saving 105,000 metric tons of carbon dioxide over the next 15 years.

The proposed sustainable retrofit of the ESB can achieve many benefits, but it also requires additional cost premiums for integrating the eight recommended energy-efficiency strategies. In 2008, the capital budget for energy-related projects was about US$93 million, with 0 per cent projected energy savings. Based on the eight energy-efficiency strategies carefully integrated to maximize the benefits of energy and operational savings, the new capital project budget requires an additional initial net cost premium of US$13 million (US$20 million in new expenditure for energy-efficiency strategies minus US$7 million of initial cost savings from downsized systems). However, the anticipated return will include 38 per cent energy savings as a result, or around US$4.4 million annually (Figure 8.33).

Table 8.2 shows the more detailed incremental cost estimate for each strategy compared with the original budget for the retrofit of the ESB in 2008. This analysis shows that the incremental cost of the eight energy-efficiency strategies will be easily offset in just over three years by annual energy savings resulting from the investment.

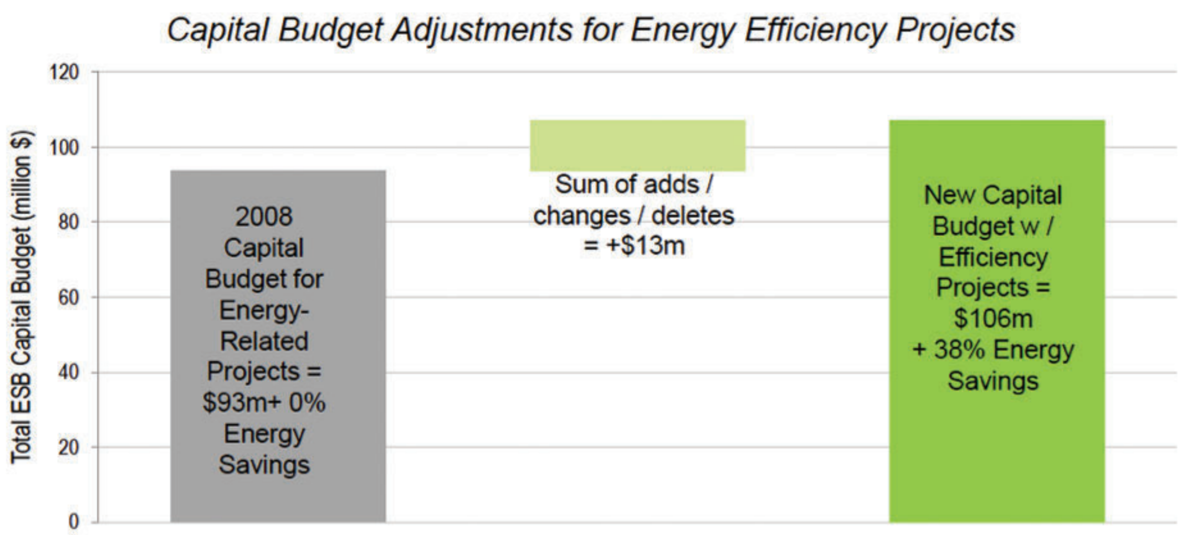


Figure 8.33 Capital budget adjustments for energy-efficiency projects
Courtesy of Empire State Building, LCC.

Table 8.2 Incremental cost for eight energy-efficiency strategies

Project description	Projected capital costs	2008 capital budget	Incremental cost	Estimated annual energy savings
Windows	$4.5 million	$455,000	$4 million	$410,000
Radiative barrier	$2.7 million	$0	$2.7 million	$190,000
DDC controls	$7.6 million	$2 million	$5.6 million	$117,000
Demand control ventilation	Inc. above	$0	Inc. above	$675,000
Chiller plant retrofit	$5.1 million	$22.4 million	-$17.3 million	$702,000
VAV AHUs	$47.2 million	$44.8 million	$2.4 million	$941,000
Tenant daylighting/plugs	$24.5 million	$16.1 million	$8.4 million	$396,000
Tenant energy management	$365,000	$0	$365,000	$320,000
Total	$106.9 million	$93.7 million	$13.2 million	$4.4 million

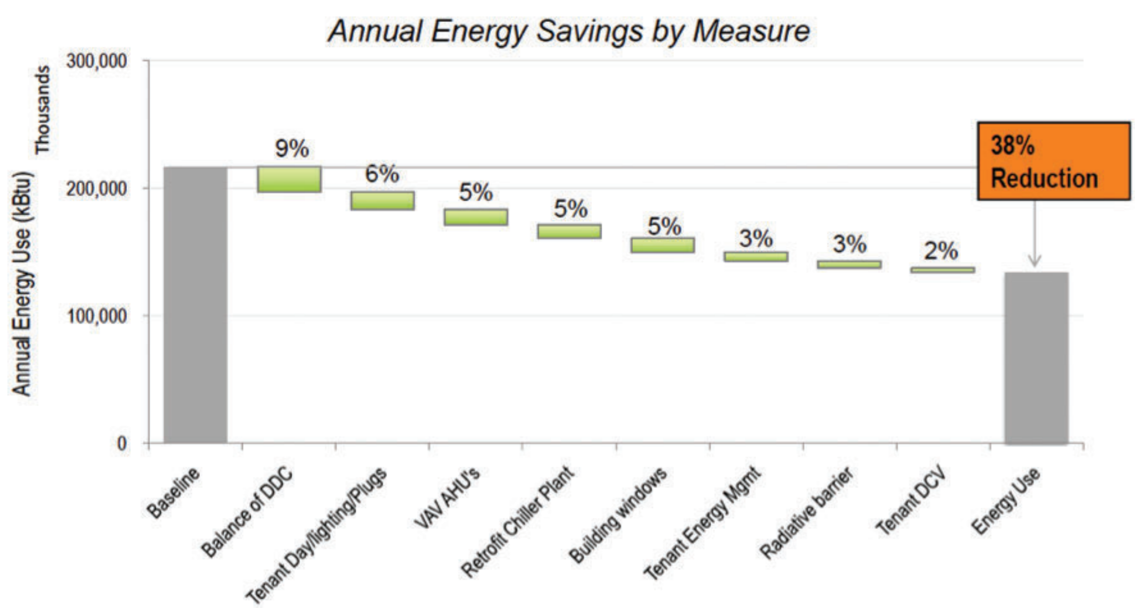


Figure 8.34 Annual energy savings by energy-efficiency strategies
Courtesy of Empire State Building, LCC.

The greatest reduction in annual energy consumption and carbon dioxide from the baseline will result from completing the task of installing DDC control systems (Figure 8.34). The DDC strategy alone would reduce energy use by approximately 9 per cent from the baseline. The tenant daylighting system, along with working with tenants to ensure that layouts maximize the use of natural lighting, would save 6 per cent from the baseline. Three other strategies including replacing constant volume air handling units with VAV units, retrofitting the chiller plant and addressing window glazing would reduce energy consumption and carbon emissions by another 5 per cent. The tenant energy management system and the installation of radiative barriers would save 3 per cent each. The tenant demand control system is also expected to reduce the energy consumption and carbon emissions by about 2 per cent. After all eight strategies are completed; the ESB is expected to be able to achieve an Energy Star score of 90, performing better than 90 per cent of buildings in the United States regardless of age. By implementing all eight strategies, the ESB can achieve annual energy savings of US$4.4 million and reduce carbon emission by 105,000 metric tons over the next 15 years.

The optimal package of eight strategies is also expected to reduce peak electricity demand by 3.5 mW, from 9.6 mW to just over six mW shown as in Figure 8.35. The reduction of peak demand can be beneficial to both the ESB in terms of energy costs, and the utility company that provides electricity to the ESB in releasing capacity to serve other clients.

In addition to reducing energy and carbon dioxide emissions, the sustainable retrofit will deliver an enhanced environment for tenants, including improved air quality resulting from tenant demand-controlled ventilation; better lighting conditions that coordinate ambient and task lighting; and improved thermal comfort resulting from better windows, the radiative barriers and better controls. In addition, these strategies will help to achieve various green certifications including Energy Star, LEED and Green Globes.

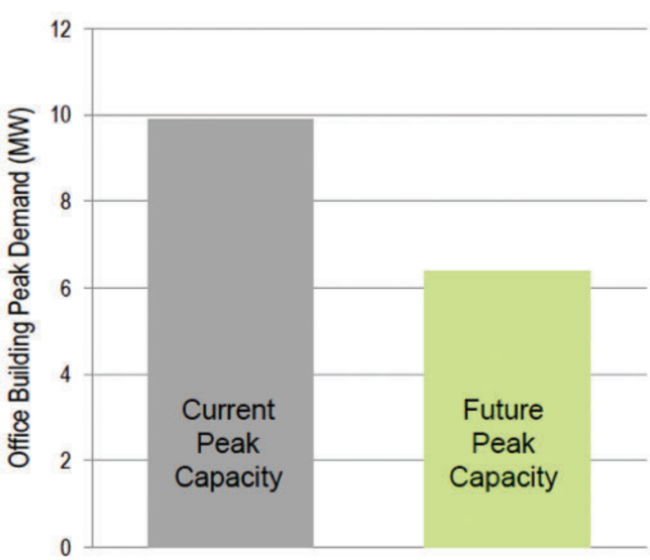


Figure 8.35 Peak demand change
Courtesy of Empire State Building, LCC.

Overall, the sustainable energy retrofit of the ESB is expected to achieve the following results:

- Annual energy cost savings of US$4.4 million.
- Annual energy saving of 38 per cent.
- Reductions in peak cooling and electric loads.
- Payback period of 3.1 years from the incremental cost of US$13.2 million.
- Carbon emission saving of 105,000 metric tons over next 15 years.
- Enhanced work environments.
- Various green certifications including LEED, Green Globes and Energy Star.

Based on this case study of the ESB's sustainable retrofit project, sustainable retrofits for existing building can not only achieve an attractive return on investment but also reduce energy consumption and carbon emissions from the building. In addition, sustainable retrofits such as this also enhance indoor environments for building occupants, which will ultimately enhance the desirability of projects like this in the future.

End-of-life-cycle opportunities

At the end of a facility's useful service life, additional opportunities exist to provide an end to the building's life in a green way. Deconstruction and ecosystem restoration are two major strategies that can be used to ensure the building's life ends as green as it began.

Deconstruction best practices

There are many different fates for built facilities at the end of their service lives. An alternative to the traditional demolition process is gaining popularity as the costs of disposal and raw materials continue to increase. Deconstruction is a process of taking a building apart piece by piece to recover materials in a usable state for use in other buildings. The process of salvaging components in old buildings is not new and has been in practice since construction first began. However, deconstruction takes salvage to a higher level by attempting to recover nearly all the components of a building, not just the most obvious or high-value materials.

The benefits of deconstruction are numerous, including the generation of high-quality, reusable materials at lower cost than virgin materials and reduction of environmental impacts both locally and in landfill. Deconstruction can provide access to building materials that are no longer available in today's market, such as timber and wood products from old-growth forests. It can also provide jobs in urban areas and preserve architectural features that would otherwise be lost (Falk and Guy 2007).

Not all facilities are appropriate candidates for deconstruction. Key to the success of such an approach is finding a good balance between the additional labour required and the reduced costs of disposal versus the value of materials recovered. Assessing the local market for recovered materials is essential to making the business case for deconstruction. Depending on disposal costs, it may be cost-effective to donate materials even though no revenue results. Often, donations can be used for tax deductions by the donating company. Organizations such as Habitat for Humanity or local salvage stores (Figure 8.36) can be good places to donate material.

Figure 8.36 This local store sells salvaged or deconstructed materials for reuse in other projects

During deconstruction, the facility is typically 'soft stripped', where easy-to-remove components such as fixtures, doors, plumbing and electrical components, and flooring are removed and stored for future use. Candidate facilities must also be carefully assessed for environmental hazards, including lead-based paint and other types of contamination. Hazardous components such as thermostats, ballasts and fluorescent lamps should also be removed, and elements such as asbestos or lead-based paint are also mitigated or abated according to applicable laws. Care must be taken during this time to properly capture and store materials and prevent them from being damaged, especially hazardous components (Figure 8.37). After this process, a more intensive approach is used to take apart the building's primary structure, including roof, walls and other components. This process requires careful planning and attention to safety.

Figure 8.37 Careful storage is required to prevent problems with deconstructed building components, especially those containing hazardous substances such as the mercury in these fluorescent tubes

After the building has been deconstructed, additional processing is necessary to render building components suitable for reuse. Wood-based products such as flooring or timbers may need to be remilled to restore their aesthetic surface. Dimensional number will need to be de-nailed before future use, and may also need to be regraded to ensure that it is structurally sound. Some components such as windows and plumbing fixtures should not be reused, since they are likely to be substantially less efficient than contemporary models. After all reusable components have been extracted, the remainder of the building's components are then recycled if possible, or disposed of properly in a landfill. Demolition waste recycling is similar to construction waste recycling, and can be managed using the procedures and resources discussed in Chapter 7.

Ecosystem restoration best practices

In addition to measures taken with built facilities at the end of their life-cycle, the site on which those facilities are located can also be dealt with in a sustainable fashion. This may involve restoring the natural ecosystems that were located on the site before it was originally developed. Ecosystem restoration is a specialized undertaking that requires knowledge of the types of flora and fauna present on the site before development.

The degree to which a site is restored is often dependent on planned future uses. At a minimum, all hazards and environmental contaminants should be removed from the site and/or properly remediated. All exposed soil should be properly graded, stabilized and replanted with proper vegetation. The topography and permeability of the site should also be carefully restored to ensure that erosion and sedimentation do not cause subsequent problems. Beyond these very basic measures, the possibilities for ecosystem restoration are limited only by the level of investment the owner wishes to make.

In some cases, sites may be deliberately rehabilitated to offset damage to other sites. For instance, development of wetland areas in the United States may be permitted if an equivalent wetland is restored or created elsewhere to offset the wetland that was removed. Wetlands can be created only on sites where conditions exist that can sustain the wetland over time. The same is true for other types of restored ecosystems; they must be carefully sited and designed to ensure that environmental conditions support their ongoing sustainability and evolution.

Ecosystem restoration can range from simple reseeding with native plants (Figure 8.38) to more complex development of synergistic natural systems to remediate and enhance a contaminated site or stabilize an unstable area (Figure 8.39). The possibilities for ecosystem restoration are dependent on the local conditions of the site and the types of plants and animals that are native to the area.

Figure 8.38 Ecosystem restoration using reseeding with native plants

Figure 8.39 This constructed wetland is used to treat acid mine drainage from coal mining before it enters the local river

Case Study: Trees Atlanta Kendeda Center building sustainable end-of-life-cycle strategies

As an example of adaptive reuse of an existing building, the new Trees Atlanta headquarters in Atlanta offers some good examples of strategies for minimizing the negative impacts of the end of the building life-cycle and for recovering useful products and materials that can be put to beneficial use. The following subsections describe practices for deconstruction, recycling and waste management employed in the Trees Atlanta building project.

Deconstruction best practices

At the end of a facility's useful service life, it is necessary to deconstruct the facility, which provides additional opportunities to achieve the goals of sustainability in the built environment. Since the Trees Atlanta project included the deconstruction and reuse of parts of an old warehouse, it had the potential to produce much construction waste. To minimize construction waste in the project and eventually reduces the amount of construction waste and debris in landfills, serious waste management and recycling was diverted the maximum amount of on-site construction waste away from landfills through recycling and salvage efforts (Figure 8.40).

To achieve the goals of recycling and waste prevention during the end-of-life-cycle process for the old warehouse, the general contractor and subcontractors diverted the following construction wastes:

- concrete/masonry (679 tons)
- metal (13 tons)

Figure 8.40 Recycling reduced construction waste and debris in the deconstruction phase

- asphalt (161 tons)
- green waste/land clearing debris (5.77 tons).

As discussed in Chapter 7, due to its active recycling and waste prevention approach, Trees Atlanta recycled or salvaged 84.193 per cent (equal to the total construction waste diverted (959 tons)/Total construction waste generated (1,1139 tons)) of its total construction and demolition waste stream.

Post-occupancy sustainability in 2020

How will our post-occupancy facility practices be different in the year 2020? Some of the same drivers that influence design and construction – increasing resource scarcity and better knowledge and information about the built environment – will shape our facility practices over the next ten years.

It has been said that 80 per cent of the buildings that will be present in the year 2020 are already here (Charles Kibert, personal communication). This means that we will have to greatly improve our ability to deal with existing buildings and adapt them to meet changing human needs and environmental requirements. Better technologies for retrofit as well as new approaches and techniques for facility condition assessment and characterization will be common practice in 2020. Technologies presently under development in the laboratory such as augmented reality (AR) will be used to fuse building performance data streams and archival documents and information with current building information models, providing the information necessary to design effective retrofits that optimize facility performance. Nondestructive testing methods and technologies will also improve, and new types of data-mining algorithms will enable better predictive modelling based on historical data.

Resource scarcity will lead to an increase in adaptive reuse of existing facilities as well as safer and more efficient techniques for deconstruction of existing facilities in ways that permit recovery of valuable materials with minimal expenditure of energy. New facilities will have been designed for adaptivity or disassembly, allowing them to be rapidly reconfigured or adapted to changing requirements over time.

Modular materials and systems will be interoperative and upgradable over time as new technologies emerge, without extensive disturbance of related systems or construction time and effort.

Deconstruction of existing facilities will be better coupled with market demand for recovered materials via social network-based technologies for sharing information about the supply and demand of those systems. New occupations and specialities will be created to handle specialized tasks of facility deconstruction and recovery in a way that minimizes waste and maximizes output.

New generations of self-maintaining materials and smart materials that can self-adapt to environmental conditions will reduce the need for human intervention in building maintenance. Artificial-intelligence-based control systems are already in use in many commercial facilities, and their functionality will continue to evolve in conjunction with smart infrastructure systems. These infrastructure systems such as the smart electrical and water grids will balance supply and demand more closely in ways that optimize the performance of the whole system, not just the individual facility.

Summary of sustainable facility practices over the life-cycle

Both now and in the future, many opportunities exist to introduce sustainability throughout the facilities realization process. Some of these opportunities fall at the project level, while others centre on changing the organizational context and processes in which individual projects occur. General themes that exist across all opportunities include:

- Expand consideration in decision making to include the whole life-cycle of the project, not just what it takes to get the project built. This includes building strategic partnerships with internal and external stakeholders to ensure that funding and stewardship exists to sustain the project in the long term.
- Expand consideration in decision making to take into account the context of the project, and how the project will interact with that context over its life-cycle. This includes coordination with larger strategic or master plans, developing business cases and funding plans that consider long-term future trends such as resource scarcity and environmental constraints, and maximizing opportunities to tie the project into multiple organizational sub-units.
- Maximize communication among project stakeholders, and include feedback loops and education to ensure people are aware of and in alignment with project sustainability goals.

These themes permeate all successful sustainable facilities projects, and are necessary to develop facilities that meet stakeholder needs in the present while preserving the organization's long-term capabilities to sustain itself in the community and global context.

Case Study: One Island East – Island East, Hong Kong

Located in the heart of Island East and completed in March 2008, One Island East is a new premium 1.5 million sq ft, 70-storey commercial office tower. From its design and construction through its operations and maintenance to the planning for its ultimate demolition, One Island East incorporated world-class sustainability elements to meet the goals of sustainability in the built environment. During the demolition of the original building, concrete crushers were used instead of typical percussive equipment to not only reduce noise, dust and accidents but also minimize the consumption of water usage for suppressing dust. In addition, this approach allowed for easier recycling.

Swire Properties and Gammon Construction worked together to develop a rigorous waste management plan that reused and recycled 99 per cent of demolition wastes. One Island East also reserved 75 per cent of the project site to provide a green area for leisure and recreational activities. Swire Properties also incorporated numerous sustainable design strategies to reduce the consumption of energy, water and raw materials throughout the life-cycle of the building. One of the major sustainable energy strategies in One Island East was to choose grade 100 high-performance concrete for the columns and core walls, which has the benefits of offering the same reinforcing ratio as grade 60 concrete but with a 26 per cent reduction in volume. The project team incorporated sophisticated energy tools including E20-II, Energy Plus and Computational Fluid Dynamic to improve energy performance. One Island East installed a rainwater recycling system that can collect rainwater and reuse for cleaning and irrigation to reduce water consumption.

Modular and standardized designs, such as movable external pedestal paving, wall panels, light troughs and air handling units, were adopted for One Island East to maximize production and material efficiency as well as to minimize waste generation. Finally, One Island East incorporated an innovative indirect lighting system to allow for dual lighting levels. Carbon dioxide and carbon monoxide sensors have been installed on all the office floors and car parks to optimize indoor air quality. These sustainable strategies were designed to create a built environment that is comfortable and to enhance the productivity of the occupants.

Source: Swire Island East

One Island East incorporated holistic sustainable design strategies to achieve the goals of sustainability in the built environment.
Courtesy of Swire Island East

Sustainable strategies in One Island East's life-cycle
Courtesy of Swire Island East

High-performance concrete reduces the weight of concrete along with associated carbon dioxide CO_2 emissions.
Courtesy of Swire Island East

Notes

1 The case study of the Empire State Building in this chapter was adapted by the authors based on the content in <www.esbsustainability.com/SocMe/?Id=0>. The images in the case study were received from Empire State Building Company, LLC and used with permission under a licensing agreement between the authors and the company in this book.

2 www.esbsustainability.com/

Discussion questions and exercises

8.1 Consider the building in which you are presently located, and review historical utility bills for the facility. You can obtain these bills from the facility's owner or possibly also from the local utility offices. How much energy and water are used by the building to function, and what systems within the building need them to function? What are the biggest users of energy and water within the facility? What upgrades would provide the most significant return on investment? What combinations of upgrades would offer synergistic effects?

8.2 Talk with stakeholders responsible for building operation and maintenance. What measures are in place to ensure proper functioning of the building? How could the building be optimized to improve energy and water performance?

8.3 What evidence can you find in the buildings you occupy to indicate suboptimal performance of the building with respect to meeting its occupants' needs? What compensating actions and technologies have been implemented by occupants to adjust the building to their needs?

8.4 Identify any efficiency and operations plans developed for your building, including general operating plans, sustainable maintenance plans, continuous commissioning plans, and measurement, monitoring and verification plans. How are problems identified and resolved by these plans?

8.5 Does your organization have any provisions for green product procurement? What opportunities are available for green power in your area, both for your organization and your own home? Conduct an inventory of the products used in maintaining your facilities. For which of these are there more sustainable alternatives that could be employed?

8.6 How does your organization presently manage solid waste in its facilities? What opportunities exist to improve its waste management practices? Inventory the waste management options available in your area to determine what can be done to improve solid waste management in your facility.

8.7 Conduct an inventory of the housekeeping practices in your current facility. Review your facility's green housekeeping plan if one exists. What measures are being taken to ensure that housekeeping practices contribute to building sustainability? How could current housekeeping practices be improved?

8.8 Locate a building renovation project in your local area and visit the site to inventory job site practices. What measures are being taken to protect occupied areas during construction? What controls are in place to ensure future indoor air quality? What could be improved to increase the sustainability of the renovation project?

8.9 Identify a green building technology or practice in your facility that is observable by users of the facility. Design a sign to describe how the technology works and educate users on how to interact with it.

8.10 Determine whether your building has a tenant manual or green occupant manual. If yes, review the manual and identify what user measures are recommended to keep the building functioning properly. If not, what recommendations would you make to include in a green occupant manual to help building occupants interact more sustainably with the building's features?

8.11 Visit a local salvage yard or building material reseller if one exists in your community. What types of products are for sale? What cost or quality advantages do they have over comparable new products?

8.12 Consider the building in which you are located and develop an inventory of materials and components that could be recovered through deconstruction. What hazardous materials and components are part of the building that would require special management if the building were to be deconstructed?

8.13 Contact the nearest office of government responsible for ecosystem management and restoration in your region or country. What efforts are underway to restore ecosystems in your area? If possible, visit a restoration site and talk with the people who are managing that site. What are the critical measures being taken to restore environmental quality on the site?

References and resources

Air Force Center for Environmental Excellence (AFCEE) (2000). *C&D Waste Management Guide*. Brooks AFB, TX.

Falk, R. H. and Guy, B. (2007). *Unbuilding: Salvaging the architectural treasures of unwanted houses.* Taunton Press, Newtown, CN.

Fishbein, B. K. (1998). *Building for the Future: Strategies to reduce construction and demolition waste in municipal projects*. <org2.democracyinaction.org/o/5032/t/1507/signUp.jsp?key=41> (accessed 10 October 2011).

Lund, E. and Yost, P. (1997). *Deconstruction–Building Disassembly and Material Salvage: The Riverdale case study*. NAHB Research Center, Upper Marlboro, MD.

Lund, H. F. (1993). T*he McGraw-Hill Recycling Handbook*. McGraw-Hill, New York.

National Association of Home Builders Research Center (2000). *A Guide to Deconstruction*. US Department of Housing and Urban Development, Office of Policy Development and Research, Washington, DC. See www.pathnet.org.

Tchobanoglous, G., Theisen, H. and Vigil, S. (1993). *Integrated Solid Waste Management: Engineering principles and management issues.* McGraw-Hill, New York.

US Federal Energy Management Program (FEMP) (2002). *Continuous Commissioning Guidebook for Federal Energy Managers*. Office of Energy Efficiency and Renewable Energy, US Department of Energy, Gaithersburg, MD.

9

The Business Case for Sustainability

The implementation of sustainability in built facilities has significantly increased over the past ten years. Evidence is growing that considering sustainable strategies in the development of built facilities can provide financial rewards for building owners along with social and environmental benefits for both occupants and society at large. This chapter emphasizes the business case for sustainable design and construction, including a detailed case study on the business case with regard to the energy and water optimization of a building. This is one of the key considerations in implementing sustainable strategies in buildings, because significant opportunities exist to lower annual costs for energy and water. However, the reduction of annual operating utility costs sometimes requires the additional expense of higher first costs. Therefore, it is necessary to identify the relationship between first cost premiums for sustainable strategies versus their life-cycle costs within their payback period. The case study covered in this chapter does just that.

In addition to direct cost saving opportunities, the implementation of sustainable strategies can also provide indirect economic benefits to facility owners, occupants, society and the environment. For example, reducing energy consumption in built facilities can significantly lower greenhouse gas emissions, which reduces the vulnerability of society to climate change at a global level. In addition, energy and water-efficient facilities offer society a range of economic benefits, including cost reduction from lower civil infrastructure costs (including avoided wastewater treatment plant expansions, power plant development, and additional transmission/distribution lines) and preserving nonrenewable resources, including fossil fuels and water aquifers, for the next generation. Furthermore, a number of energy-efficient features including daylighting in buildings can also promote the better health, comfort, safety and well-being of facility occupants, which can reduce levels of absenteeism and increase productivity in the workplace and provide a greater quality of life for facility users in general.

To demonstrate the approach for establishing a business case for sustainability, this chapter focuses on improving energy and water efficiency in a building through an overview of potential strategies to lower or equal the first cost, provide annual energy and water cost saving opportunities, and deliver other economic, social and environmental benefits. To properly explain the business case, the chapter adopts a case study approach using a real case of a building type found everywhere around the world to describe all processes and relationships. The case study employed in this chapter is the planning, design, construction, and operation of Reedy Fork Elementary School located in Greensboro, North Carolina, United States.

Case Study: Reedy Fork Elementary School

Reedy Fork Elementary School (RFES) is an 87,000 sq ft school facility that includes classroom space for 725 students and 70 staff plus dining, gymnasium, auditorium, science, art, music, computer, library and administration facilities (see Figure 9.1). The project started in 2006 and was successfully completed in 2007. Since this school incorporated many sustainable strategies, especially related to energy savings, it was among the top 10 per cent of schools in the United States designed to earn the Energy Star® label. To achieve the project, RFES created a collaborative project team comprising:

- owner: Guilford County Schools
- architect: Innovative Design, Inc.
- civil engineering consultants: B & F Consulting, Inc.
- landscape architects: Landis, Inc.
- structural engineering consultants: Lysaght and Associates, P.A.
- general contractor: Barnhill Contracting, Inc.
- construction management: HiCAPS, Inc.

The RFES project started its pre-design and design based on the G3-Guilford Green Guide that was the School Board's commitment to promoting sustainable design and construction in the school district. As a result, the RFES project incorporated holistic, innovative, sustainable design and construction solutions that were strongly tied to the students' curriculum. The school featured a comprehensive and well-integrated set of sustainable strategies that included:

Figure 9.1 An overview of Reedy Fork Elementary School

Building name: Reedy Fork Elementary School
Location: 4571 Reedy Fork Parkway, Greensboro, NC
Size: 87,000 sq ft
Started: 2006
Completed: 2007
Use: school for 725 students in grades pre-kindergarten through five
Cost: $13.6 million
Distinction: projected to be among the top 10 per cent of schools in the nation designed to earn the Energy Star® label

- Appropriate building orientation.
- A new daylighting design.
- An energy-efficient building shell, with radiant barriers and solar reflective roofs.
- Underfloor air distribution system.
- Indirect lighting with photocells and occupancy sensors.
- Solar water heating and photovoltaic (pv) systems.
- A holistic water cycle approach (rainwater for toilet flushing coupled with bioswales and wetlands).
- Recycled materials and use of local products.
- Indoor environmental quality management.
- Computer based real-time monitoring of sustainable systems.

Facility orientation

RFES was oriented on an east–west axis to maximize the southern solar potential for daylighting, passive solar, solar domestic hot water and PV applications. East and west glazing was minimized to reduce heat gain in summer. Figure 9.2 shows the east–west orientation of the three main wings on the west side of the school. Small courtyards are also provided on the east side of the school to achieve the same effect.

Innovative daylighting design

The use of natural daylighting is a primary strategy to reduce energy consumption as well as a significant factor in improving students' performance, health, comfort and well-being. RFES adopted several daylighting design strategies to achieve potentially significant benefits. The preferred daylighting design features include two south-facing clerestories that use curved, interior, translucent light shelves. These light shelves can filter sunlight down to occupied areas and bounce the remaining light deep into the classroom (Figure 9.3). In addition, highly reflective ceiling tiles also enhance the light being reflected deep into the space. These two strategies resulted in requiring 40 per cent less glass than typical side-lit glazing solutions (Figure 9.4). Furthermore, due to the 20 per cent visible light transmittance of the translucent panel used in the light shelves, glare was also reduced and a soft light was well distributed within the space. The curved translucent light shelves could provide light immediately under each shelf, bounce light back into the space, and diffuse the light. This allowed for glazing at the wall clerestory aperture with maximum visible light transmission. In addition, because the white single ply roofing and the curved translucent light shelves provided adequate daylight by themselves, it could reduce the glass-to-floor ratio over side-lit solutions. To avoid glare, interior dropped soffits were situated to intentionally shade the projection screen area and the television monitors in classroom spaces without blocking views and without the need for operable clerestory window shading devices. These innovative daylighting strategies are the primary lighting source for all education and administrative spaces during two-thirds of the daylight hours, and reduce the need for fluorescent lighting while also diminishing the school's need for air conditioning.

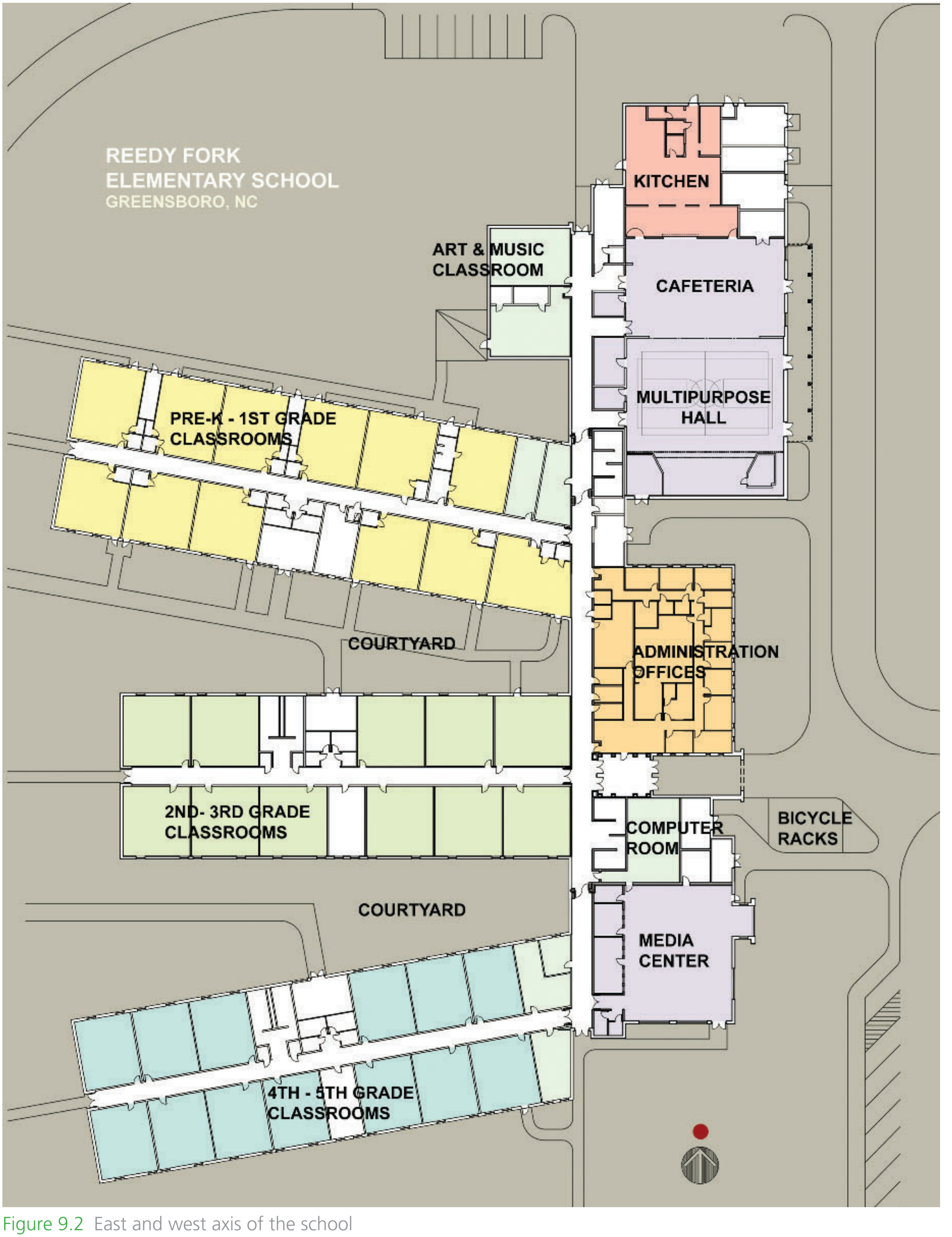


Figure 9.2 East and west axis of the school

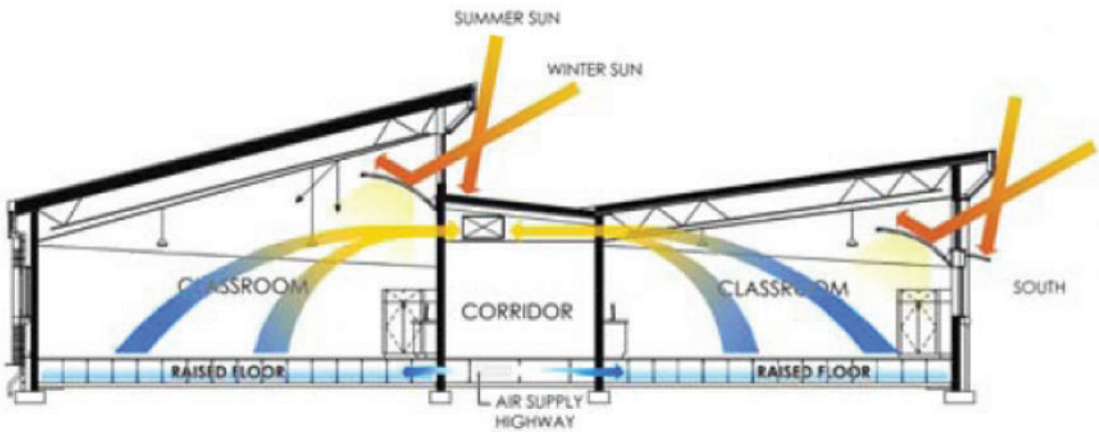


Figure 9.3 Schematic section of classroom showing daylighting

Figure 9.4 Daylighting strategies in RFES

South-facing roof monitors with translucent fabric baffles in the light wells also provided daylighting in the gymnasium, multi-purpose and dining areas of the school (Figure 9.5). These features eliminate direct glare and effectively diffuse light throughout the spaces. Clear double-glazing was also used to maximize visible light transmittance and minimize the glass-to-floor ratio. In addition, adequate overhangs over the monitor windows protect the spaces from direct light during peak cooling periods in the summer. This monitor approach was used because of the large room dimensions and because the ceiling cavity was limited to the thickness of the roofing system, which was shallower than conventional systems using dropped ceilings. Therefore, the reflective losses associated with deep ceiling cavities were eliminated.

Figure 9.5 Daylighting monitors in the gymnasium, multi-purpose room and dining areas

Figure 9.6 Indirect fluorescent lighting with a dimmable lighting system

In addition, to maximize energy savings using daylighting systems, indirect fluorescent lighting was installed through the building (Figure 9.6). The lighting is dimmable and can be controlled by an occupancy sensor and a photocell sensor that work in conjunction with natural daylight to minimize the need for artificial light in the building while there is sufficient daylighting.

Underfloor air distribution

An underfloor air distribution system has been incorporated in classrooms, the media centre and administration offices (Figure 9.7). This raised floor system improves thermal comfort, indoor air quality, flexibility in space usage, and energy consumption. In addition, the system also saved on initial construction costs by reducing the need for expensive steel ductwork at ceiling level. Several courses of masonry were also eliminated because of reducing the ceiling cavity by 2–3 feet throughout. The underfloor strategy also eliminated scaffolding costs and associated safety risks during installation, while simultaneously easing the installation and coordination problems associated with overhead ductwork, plumbing, electrical and control wiring.

Solar energy

A PV system (see Figure 9.8) has been incorporated into the entry canopy to feed 1.75kW of electricity into the computer lab, entrance sign and PV pond aerator. This on-site renewable system reduces the negative environmental and economic impacts associated with fossil fuel energy use while improving outdoor environmental quality.

Figure 9.7 Underfloor air distribution system

Figure 9.8 PV panels used for electricity generation

Figure 9.9 Solar collectors provide hot water for the kitchen

A solar thermal system (Figure 9.9) has also been installed to provide approximately 75 per cent of the hot water for the school, the majority of which is used for the kitchen. These solar systems can also be used as an educational tool to teach students about renewable energy sources.

Rainwater harvesting system

The RFES project incorporated a rainwater harvesting system to reduce consumption of potable water from municipal systems throughout the school. Reedy Fork's unique rainwater harvesting system collects rain from half the roof area of the school and sends it to a 45,000 gallon underground storage tank (Figure 9.10). The collected rainwater is then pumped from the tank to the school, filtered, chlorinated, dyed light blue, and used for flushing each toilet in the school. By using rainwater for toilet flushing, the school can save over 767,000 gallons of water annually that would otherwise be purchased from the City of Greensboro, representing 94 per cent of the water used for toilet flushing. By diverting and treating stormwater that would otherwise be directed from the site's roof into the storm sewer collection system, the rainwater harvesting system also reduces the generation of wastewater. This system also protects the natural water cycle and saves water resources for future generations.

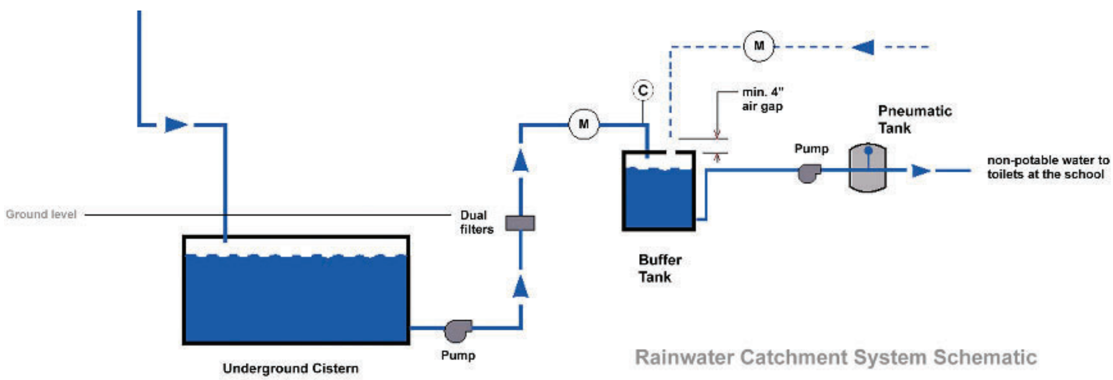


Figure 9.10 Rainwater harvesting system

Figure 9.11 Bioswales and constructed wetland

Bioswales and constructed wetlands

A series of bio-retention swales and constructed wetlands capture all the rainfall not falling onto the roof areas, further minimizing nitrogen runoff in the stormwater before it is absorbed into the soil. No stormwater is discharged into local storm sewers, which significantly reduced infrastructure costs because the existing central sewer line was located miles from the site. Special soils and a variety of aquatic plants such as pickerel weed, soft rush, and spike rush reduce pollutants from the storm water, again returning clean water to the aquifer. PV-driven aerators are also used in the constructed wetland to move surface water and minimize mosquito problems.

Materials recycling and local products

Materials with recycled content used on the project included carpeting, metal roofing and acoustical ceiling tiles. A construction waste management plan was required by the G3-Gulford Green Guide during construction to minimize waste going to landfills. Almost 60 per cent of the total construction waste from the project was diverted for recycling during construction. The school also implemented a programme for daily recycling which continues on an ongoing basis. Locally manufactured masonry products were the predominant structural and finish materials for the school. The specifications for these products were developed to encourage the use of local products and manufacturers, and preference was given to local manufacturers during the bidding process.

Indoor environmental quality management

Poor indoor environmental conditions are well known to affect the health, safety, performance and comfort of students. Therefore, RFES implemented the following strategies as part of the project to improve indoor environmental quality:

- low VOC adhesives used for carpet tiles
- no VOC paints and low-VOC adhesives
- high MERV filters used throughout
- xeriscaping to minimize use of pesticides and irrigation
- indoor air quality management plan required during construction
- air quality testing prior to occupancy
- increased ventilation using outdoor air
- carbon dioxide sensors to determine need for outside air
- 100 per cent daylighting in all classrooms.

Through implementing these strategies to improve indoor environmental quality, RFES was able to increase comfort levels, reduce absenteeism, and increase student productivity and performance.

Experiential learning

Implementing sustainable features at the school was also an opportunity to enhance experiential learning for students. The entry area at the school features a sundial, which allows students to connect the seasonal change with the different positions of the earth and sun (Figure 9.12a). Integrative signage installed throughout the school buildings and site also helps to educate students, staff, the community and visitors about sustainable features of the building and their benefits (Figure 9.12b). RFES also incorporates real-time monitoring of the sustainable design features in the building so that students can use their computer monitoring systems to compare the performance of their system with similar sustainable systems in other schools across the country and around the world (Figure 9.13). With these assets, the school can be used as a case to teach students about the concept of sustainability to influence their attitudes and behaviour toward sustainability.

Breaking through the first cost barrier

Pursuing a higher degree of sustainable design and construction is often challenged by high first costs, even though some sustainable features can lower operational costs from conventional approaches. To achieve the highest level of sustainability within a constrained budget, a project has to use an integrated design approach as described in Chapter 6. The first step of the integrated design approach is to form a collaborative team including the owners, architects and engineers; sustainable design consultants; landscape architects; O&M staff; health, safety and security experts; the general contractor and key subcontractors; cost consultants; value engineers; and occupant representatives. This collaborative team must work together from the start to develop innovative sustainable solutions that meet energy, environmental and social goals while maintaining first costs within budget.

Since adding individual sustainable strategies into a project potentially increases first costs over conventional approaches, the integrated team has to combine many sustainable strategies and optimize them simultaneously to reduce the first costs while achieving the goals of sustainability. One example is that by improving the building envelope, the design team can often eliminate the heating, ventilation, and air conditioning (HVAC) system around the perimeter of the building and also downsize the primary HVAC system. Downsizing the HVAC system can also reduce the size of ducts, which can eventually pay for the envelope improvements. The RFES project is a good example of to achieve sustainability on a budget. The following section describes sustainable design strategies that have been implemented at the RFES project to lower energy and water consumption while reducing or eliminating first cost premiums.

a)

b)

Figure 9.12 Experiential learning opportunities for students

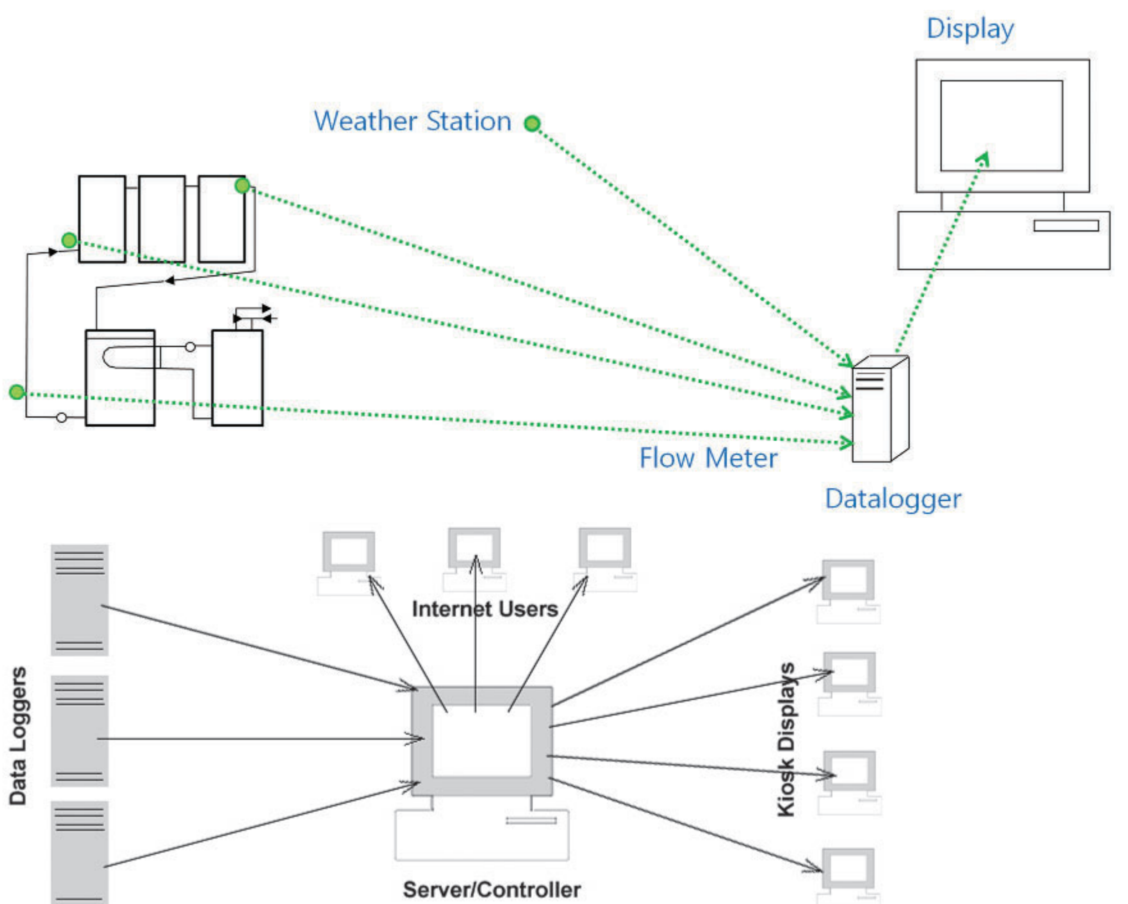


Figure 9.13 Web-based sustainable education

Site design

One obvious strategy to reduce first costs is to take advantage of the site by properly orienting the building to maximize the southern exposure, if the building is located in the northern hemisphere, and minimize east and west glazing. In addition, it is possible to use existing trees, landscaping and natural berms to protect against winter winds and reduce unwanted solar gain to reduce cooling loads. These site design strategies can save operating costs by reducing energy consumption, and may also reduce the first costs for building envelope and HVAC requirements.

The design team chose to retain indigenous vegetation on site to minimize water needs, and adopted xeriscape planting strategies to reduce the first cost from that of non-native plants. In addition, the design team created two functionalities from one system by using the pavement that was part of secondary fire lanes as hard-surface play areas for uses such as basketball courts. This strategy saved the first cost of building two systems instead of one. Finally, the school structure was located on the higher part of the site in order to take advantage of natural slopes for drainage, reducing the need for drainage infrastructure at no additional cost.

Daylighting and underfloor system

Daylighting has many benefits including saving energy, increasing productivity and improving health. Integrated daylighting strategies with adjusting the size of the HVAC system achieved simple dollar paybacks ranging from two or three years in the most expensive scenario, to even having first-cost advantages in the least expensive scenario. On the RFES project, the design team actively used daylighting strategies with south-facing clerestories. This strategy was coupled with underfloor air distribution to improve air quality and to control the first costs of the HVAC system. Since most buildings incorporating daylighting and underfloor system strategies generally add at least $15/sq ft to the cost, the design team adopted a holistic approach to lower the cost premium to $2.73/sq ft. The main mediators of first costs in this case were:

- Daylighting performance was improved, and then glass-to-floor ratio fell below a typical side-lit solution, thus saving on envelope costs since glazing is a significant cost factor.
- The white single-ply roofing further reduced daylighting glass areas by increasing reflected lighting into the clerestory areas of the classrooms on the north side.
- Installing clear double-glazing in the glass areas helped to maximize the visible light transmission and lower the first cost from that of low-E glazing.
- The single sloped ceiling improved reflectance back into the space and eliminated the need for a roof monitor well cavity.
- The elimination of east and west-facing glass except view glass not only lowered the first costs but also reduced peak cooling loads and in turn, reduced the amount of installed cooling equipment.

- Through the incorporation of an optimally sized daylighting strategy, the cooling peak loads are significantly less and chiller capacity could be reduced.
- By implementing indirect lighting, the ceiling cavity was reduced by 6 in to 8 in.
- The underfloor air distribution system reduced the ceiling cavity by 2 ft to 3 ft. This enabled reduced high-end finishes on the exterior of the facility due to shorter floor-to-floor height and also eliminated several masonry courses.
- The underfloor system strategy also eliminated scaffolding costs and associated safety concerns during construction while easing the installation and coordination problems associated with overhead ductwork, plumbing, electrical, and control wiring.
- The simplified construction framing of the roof assembly resulted in materials and installation cost savings.

Figure 9.14 describes the various classroom design options for daylighting and underfloor systems, along with their first cost premiums.

Figure 9.14 Daylighting and underfloor system options considered for RFES

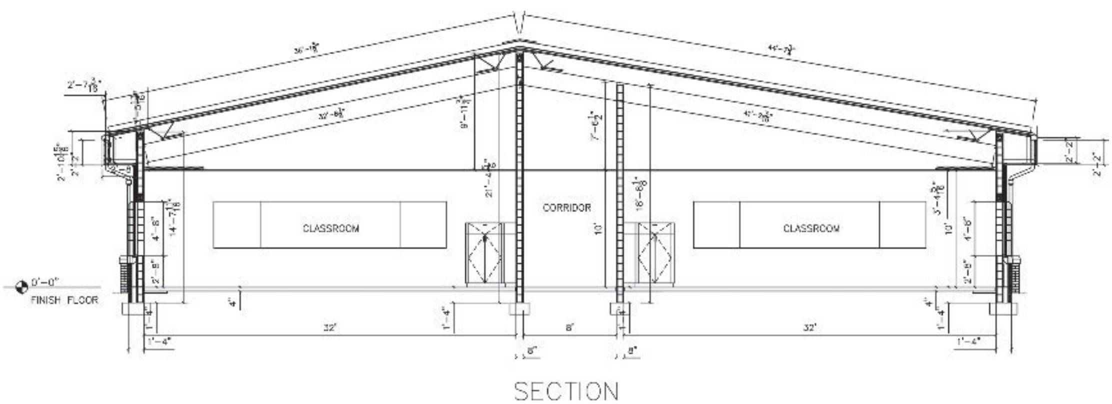


Figure 9.14a No-daylight, flat roof (base design)

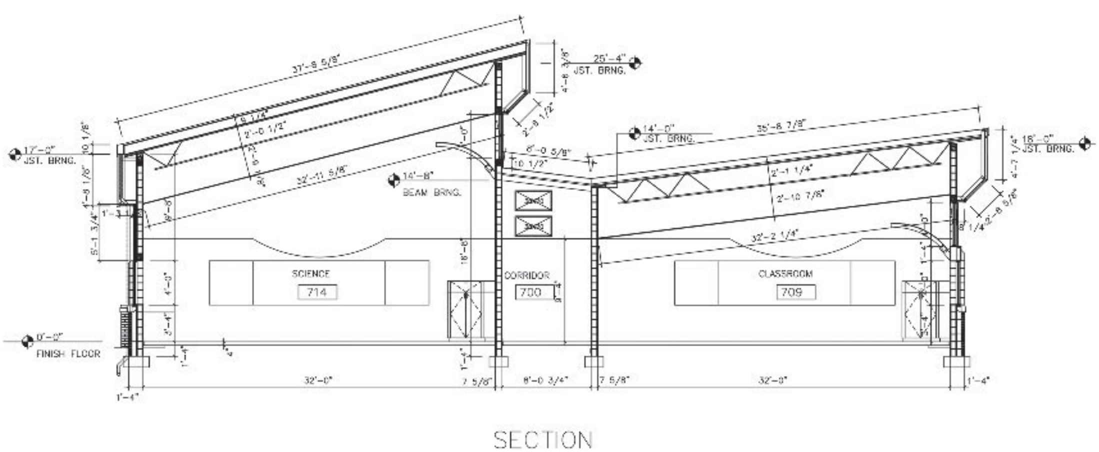
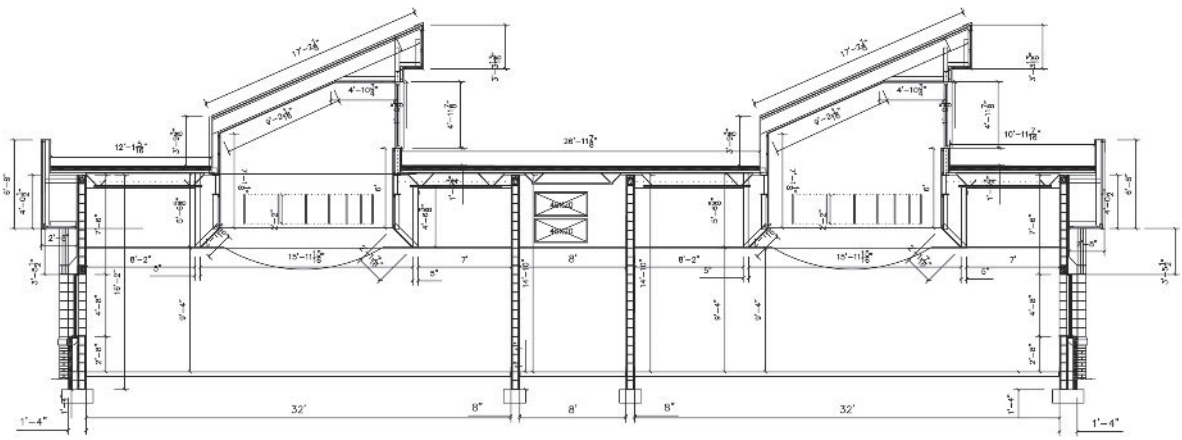
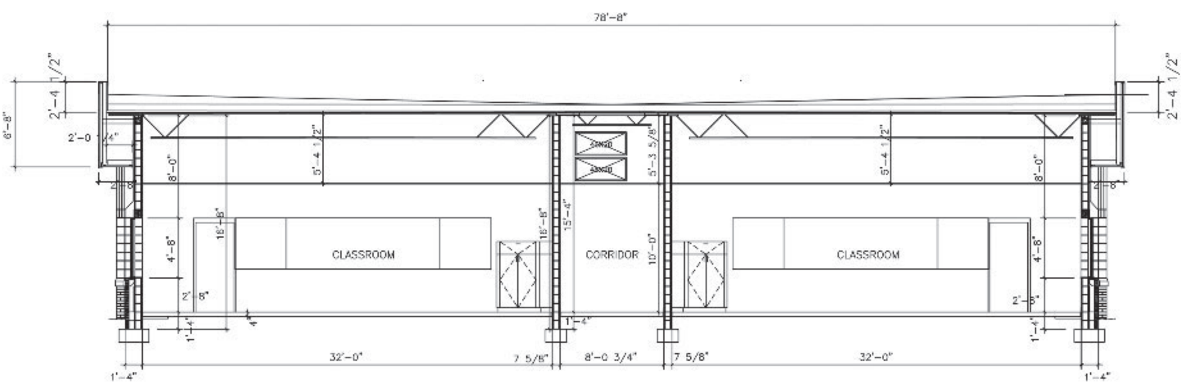


Figure 9.14b No-daylight, standing seam metal roof



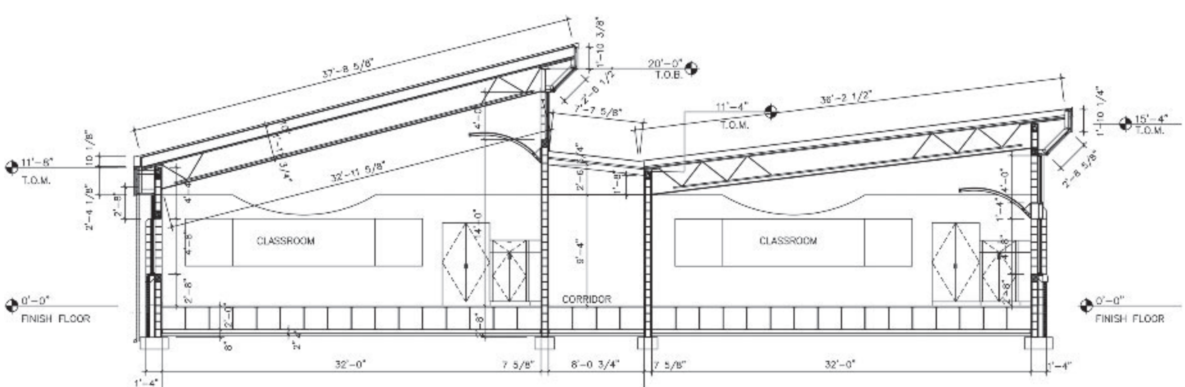
SECTION

Figure 9.14c Daylight with south-facing roof monitors, no underfloor distribution



SECTION

Figure 9.14d Daylight with south-facing clerestories, no underfloor air distribution



SECTION

Figure 9.14e Daylight with south-facing clerestories and underfloor air distribution

Electrical systems for lighting

RFES used PV lighting for remote locations where conduit and trenching cost exceeded the cost of the PV system. Figure 9.8 shows an example of the light for the school sign at the front of the school with its installed PV system, at a reduced first cost. In addition, the school used ganged fluorescent light fixtures in the gymnasium, which costs less and provided an additional advantage by being dimmable. The design team also specified the minimal number of lighting fixtures in hallways to minimize overlighting, which would lower the first costs as well as operating costs.

Building shell

Figure 9.15 Radiant barrier installed beneath a white single-ply roof membrane

RFES used white, single-ply roofing materials and radiant barriers as shown in Figure 9.15. Since 90 per cent of heat gain from the roof was the result of radiant gains, this roof had several advantages: it stayed reflective a long time; it could be utilized to bounce a certain amount of light into daylighting apertures, thereby reducing the size of glazing; and it was also good for rainwater catchment system collection areas. RFES also properly placed radiant barriers that could reduce installed cooling equipment enough to offset the cost of the material. To improve lighting inside rooms, all interior walls were painted light colours, and the rooms were provided with highly reflective ceiling materials and light floor finishes. Lighter-coloured finishes reduced the number of lights that had to be installed in the building. This consideration would not only reduce the initial cost of installing lighting fixtures but also reduce operating costs over the building's life.

Mechanical systems

In RFES, seasonal and hourly space conditioning loads were carefully analysed to determine full-load conditions and fully account for the benefits of daylighting in terms of cooling load reduction. In addition, the design team optimized the mechanical system as a complete entity to allow for the interaction of various building system components, avoiding oversizing of equipment. Finally, the design team carefully investigated the unit sizes of mechanical systems because they wanted to create an opportunity to reduce the overall cooling load to the next smaller chiller unit size by investing in other design elements (Table 9.1). These approaches further reduced the first cost premium and simultaneously reduced future annual operating costs.

First cost comparison

Although RFES included many sustainable features, the actual construction cost was similar to the average bid at the time for an elementary school in the state of North Carolina. This low first cost premium was primarily the result of whole-building, whole-site approaches to the project during the early design process. The final bid for RFES was $151/sq ft in 2006. This bid price was subsequently increased to \$157/sq ft because of the need to have an accelerated schedule to 13 months. The average bid for schools in North Carolina during this time period was \$147/sq ft in 2006. Since RFES incorporated many sustainable features, the school was projected to be among the top 10 per cent of schools in the nation designed to earn the Energy Star® label. Therefore, RFES would enjoy not only lowering annual energy consumption in the building, but also reducing greenhouse gas emissions that would result from energy production.

Annual energy cost savings

Many sustainable features can help effectively minimize a building's energy consumption during its service life. As previously discussed, integrated design (whole building design) considering all architectural and mechanical features at very early stages could minimize a school's annual energy use and reduce energy costs while maintaining comfort and quality. For example, the daylighting strategies coupled with the underfloor system installed in REFS resulted in a slightly higher first cost, but the resulting annual cost savings resulted in a lower life-cycle cost. To illustrate the whole building design approach, energy-efficient strategies that can lower the annual energy costs are discussed in the following section.

To explain this integrated design concept for energy efficiency strategies, the annual energy costs of RFES were analysed. This approach illustrates how an integrated design approach to alter architectural elements and mechanical systems can lower annual energy costs. The base case school, to which the more sustainable school including integrated energy-efficient features was compared, was assumed to meet the levels of energy efficiency in the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 90.1-2001 standard. The total construction cost of this base-case building was estimated and the incremental first costs for sustainable features were also estimated. The annual energy consumption was simulated using DOE 2.1 based on energy simulation models, eQUEST 3.63 and other daylighting simulation tools. After the annual energy uses were simulated using energy modelling, the annual energy requirement was compared with the energy-use estimates of the base-case building, and estimated energy savings and the associated incremental costs were calculated. After these calculations, a life-cycle cost analysis was conducted to calculate the net present value (NPV) and payback periods to compare the base case school building with the actual design that incorporated various energy-efficient features.

Energy simulation for the RFES building

Annual energy consumption was calculated using DOE 2.1-based energy simulations. To support this analysis, it is necessary to identify important parameters used in energy simulations including envelope thermal properties, internal loads and schedules, and HVAC system

Table 9.1 Parameters of energy simulation

Parameter	Value
Weather and Climatic Data	Greensboro, NC, USA (TMY2)
Run period	January 1 – December 31
Cooling Design Day Conditions	Indoor 75°F, 50% RH Outdoor 90°F Dry Bulb 70°F Wet Bulb
Heating Design Day Conditions	Indoor 70°F Outdoor 10°F
Building Area	Building area = 85,000ft^2 (approx)
Construction	Ext. Wall (16") U Value = 0.027 Btu/hr·ft^2·F° Ext. Wall (20") U Value = 0.026 Btu/hr·ft^2·F° Monitor U Value = 0.042 Btu/hr·ft^2·F° Raised Floor U Value = 0.415 Btu/hr·ft^2·F° Slab Floor U Value = 0.709 Btu/hr·ft^2·F° Metal Roof U Value =0.032 Btu/hr·ft^2·F° Membrane Roof U Value = 0.031 Btu/hr·ft^2·F° View Glass U Value = 0.34 Btu/hr·ft^2·F° Daylight Glass U Value = 0.55 Btu/hr·ft^2·F° Ext. door U Value = 0.067 Btu/hr·ft^2·F°
Occupant Schedule	Students 8 am to 4 pm (year round) Admin 8 am to 4 pm (year round) Media 8 am to 4 pm (year round) Gym 8 am to 4 pm (year round) Cafe 8 am to 4 pm (year round) Kitchen 8 am to 4 pm (year round)
Ventiltion (outdoor air)	15 cfm per person (gymnasium) 15 cfm per person (classroom use) 20 cfm per person (office use) 55°F DB Economizer Setting
Natural gas	PSNC Energy
Electricity	Duke Power
Interest Rate	6% Interest Rate

operation schedules (see Table 9.1). Several resources used to assist in the energy modelling include ASHRAE Standard 90.1-2001 and ASHRAE Standard 62-2001 because the base case school design is based on the ASHRAE standards.

Selection of sustainable features

Many sustainable features affecting energy performance were available for use as part of the RFES project. These energy-efficient strategies and technologies included basic building design, use of passive systems, and use of high-performance mechanical systems (Figure 9.16).

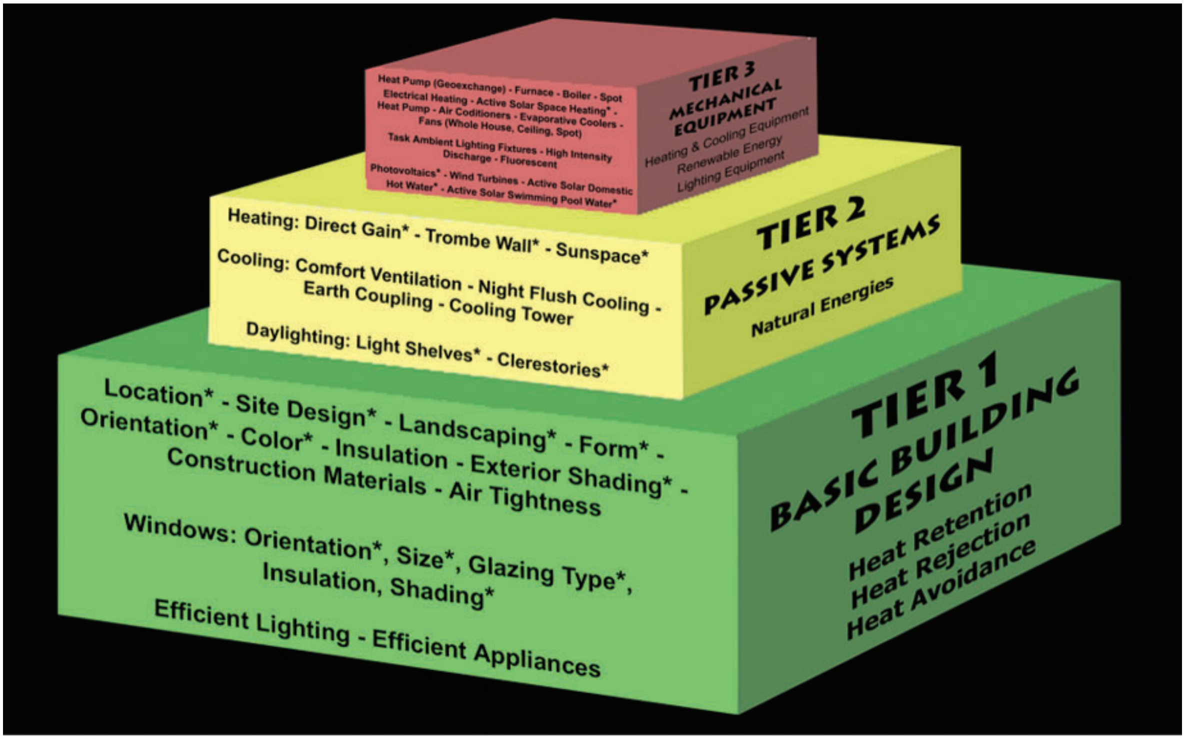


Figure 9.16 Three-tier approach to the design of heating, cooling and lighting
Source: Lechner (2008).

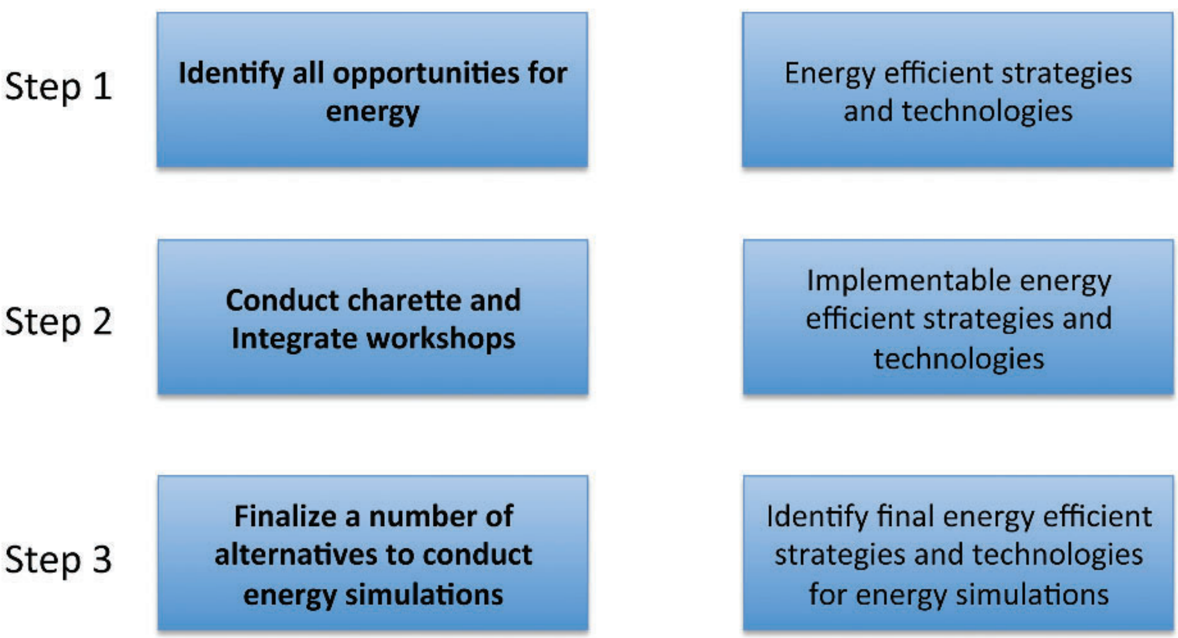


Figure 9.17 Procedure to choose appropriate energy-efficient strategies

However, given the large number of sustainable features related to energy, it was necessary to narrow down to a number of design options to maximize energy efficiency in the building.

Figure 9.17 shows the general procedure to select sustainable features for energy optimization. The initial step was to collect and identify all sustainable design strategies that could improve energy efficiency in the building or that could generate energy using renewable energy sources. The second step was to have an energy charrette/integrated workshop by involving project stakeholders including architects, engineers, users and others in the process of narrowing down the set into implementable sustainable features for this specific building project. The third step was to finalize a number of design options for which energy models were developed and cost studies were conducted.

Using these three steps, a number of alternatives were identified to describe how sustainable features for energy could lower the annual energy consumption in the RFES project compared with the base-case school building that complied with ASHRAE Standard 90.1-2001. The alternatives used in this analysis for the school building are described in the following subsections.

Base case school building

The base-case building was constructed of materials based on the minimum requirements set forth by ASHRAE Standard 90.1. No daylighting glass was included. In this case the building was simulated with the front facing east (Figure 9.18). The central plant in the base-case building consisted of one (1) standard efficiency air-cooled screw chiller using a 10°ΔT and two 80 per cent efficient condensing-type boilers. Classroom wings, the media centre and administration areas were served by variable air volume (VAV) systems. The VAV air handlers were equipped with constant volume fans, chilled water coils for cooling and hot water coils for preheating. Air was distributed overhead (mixing ventilation). Each classroom and major spaces were served by variable air volume terminal boxes equipped with hot water heating. Multipurpose, dining, kitchen and music/art areas would be served by overhead constant volume air systems. Constant volume air handlers were equipped with constant volume fans, chilled water coils for cooling, and hot water coils for preheating and reheating. Ventilation (outside) air was provided through the central air-handling units. An air-side economizer cycle was used to take advantage of free cooling when outside air temperature was at 55°F or lower.

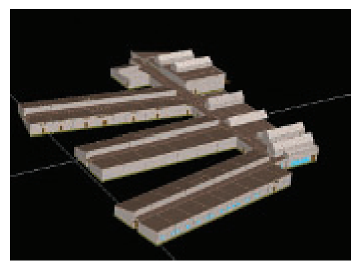


Figure 9.18 Rendering of the base case school building

Alternative 1: daylighting

The 'Daylighting' alternative was one of the most beneficial in that it was very cost effective while at the same time it had the potential to improve both the health and productivity of the students and teachers. As noted above, the daylighting strategies included improving glazing, south-facing clerestories, white single-ply roofing and the curved translucent light shelves, highly reflective ceiling tiles and shading devices.

Alternative 2: improving insulation

Increasing the levels of insulation in wall, roof and floor would reduce energy consumption in the building and improve occupant thermal comfort. The second alternative was to improve wall, roof and floor insulation values from the ASHRAE Standard 90.1 to a wall insulation level of R-38 and the roof insulation level of R-32.

Alternative 3: underfloor air distribution systems

In alternative 3, underfloor air distribution systems were added. The central plant would consist of one standard-efficiency air-cooled screw chiller using a 10°ΔT and two 80 per cent efficient condensing-type boilers. Classroom wings, the media centre and administration areas would be served by standard underfloor air distribution (UFAD) systems. The UFAD air handlers were equipped with variable air volume fans, chilled water coils for cooling, and hot water coils for preheating. Air was distributed underfloor (mixing ventilation). Each classroom and major space would be served by underfloor air terminal boxes equipped with a control damper and hot water heating. Multi-purpose, dining, kitchen and music/art areas were served by overhead constant volume air systems. The constant volume air handlers were equipped with constant volume fans, chilled water coils for cooling, and hot water coils for preheating and reheating. Ventilation (outside) air was provided through the central air-handling units. An air-side economizer cycle was used to take advantage of free cooling when outside air temperature was at 60°F or lower.

Alternative 4: premium underfloor air distribution system

In the fourth alternative, the building would be served by an upgraded underfloor air distribution system. The central plant would consist of one standard-efficiency air-cooled screw chiller using a 10°ΔT and two 80 per cent efficient condensing-type boilers. Classroom wings, media centre and administration areas would be served by premium UFAD systems. UFAD air handlers were equipped with variable air volume fans, chilled water coils for cooling, and hot water coils for preheating. Air was distributed underfloor (mixing ventilation). Each classroom and major space would be served by premium underfloor air terminal boxes equipped with a constant volume fan and hot water heating. Air would be supplied through the floor by varying the geometry of the floor outlets. Multi-purpose, dining, kitchen and music/art areas were served by overhead constant volume air systems. Constant volume air handlers were equipped with constant volume fans, chilled water coils for cooling, and hot water coils for preheating and reheating. Ventilation (outside) air was provided through the central air-handling units. An air-side economizer cycle was used to take advantage of free cooling when outside air temperature is at 60°F or lower.

Table 9.2 Input parameters and energy consumption

		Base case	Alter. 1	Alter. 2	Alter. 3	Alter. 4	Alter. 5
Shell	Area						
	Wall insulation	R-6.6	R-6.6	R-38	R-38	R-38	R-38
	Roof insulation	R-15.4	R-15.4	R-32	R-32	R-32	R-32
	Glazing	View glass: ASHRAE 90.1 No daylighting	View glass: low-e insulated Daylight: clear insulated	View glass: low-e insulated Daylight: clear insulated	View glass: low-e insulated Daylight: clear insulated	View glass: low-e insulated Daylight: clear insulated	View glass: low-e insulated Daylight: clear insulated
Building system	Cooling plant	Air cooled screw chiller (10° ΔT)	Air cooled screw chiller (10° ΔT)	Air cooled screw chiller (10° ΔT)	Air cooled screw chiller (10° ΔT)	Air cooled screw chiller (10° ΔT)	Air cooled screw chiller (14° ΔT)
	Heating plant	80% efficient hot water boiler	80% efficient hot water boiler	80% efficient hot water boiler	80% efficient hot water boiler	80% efficient hot water boiler	94% efficient hot water boiler
	Air handling units	Variable air volume Air side economizer cycle and constant volume systems	Variable air volume Air side economizer cycle and constant volume systems	Variable air volume Air side economizer cycle and constant volume systems	Standard underfloor air distribution Air side economizer cycle and constant volume systems	Premium underfloor air distribution Air side economizer cycle and constant volume systems	Premium underfloor air distribution Air side economizer cycle and constant volume systems
	Air distribution	Overhead air distribution	Overhead air distribution	Overhead air distribution	Underfloor and overhead air distribution	Underfloor and overhead air distribution	Underfloor and overhead air distribution
Energy	Cooling load peak	257 tons 3,081 kBtu/hr	209 tons 2,510 kBtu/hr	201 tons 2,415 kBtu/hr	200 tons 2,403 kBtu/hr	197 tons 2,364 kBtu/hr	197 tons 2,364 kBtu/hr
	Heating load peak	(2,536) kBtu/hr	(2,509) kBtu/hr	(2,362) kBtu/hr	(2,398) kBtu/hr	(2,398) kBtu/hr	(2,398) kBtu/hr
	Energy performance	46.3 kBtu/sqft/yr	38.9 kBtu/sqft/yr	36.8 kBtu/sqft/yr	36.8 kBtu/sqft/yr	36.5 kBtu/sqft/yr	32.7 kBtu/sqft/yr
	Electric end use	673,835 kWhr	508,371 kWhr	491,206 kWhr	459,487 kWhr	454,562 kWhr	439,961 kWhr
	Natural gas end use	17,420 Therm	16,601 Therm	15,415 Therm	16,413 Therm	16,382 Therm	13,563 Therm
	Lighting end use	258,977 kWhr	131,611 kWhr	131,611 kWhr	131,611 kWhr	131,611 kWhr	131,611 kWhr

Alternative 5: Premium efficiency air cooled screw chiller

The school building was constructed of materials based on the proposed design requirements. The central plant should consist of one premium efficiency air-cooled screw chiller using a 14°ΔT and two 94 per cent efficient condensing-type boilers. Classroom wings, media centre and administration areas would be served by premium UFAD systems. UFAD air handlers were equipped with variable air volume fans, chilled water coils for cooling and hot water coils for preheating. Air was distributed underfloor (mixing ventilation). Each classroom and major space was served by premium underfloor air terminal boxes equipped with a constant volume fan and hot water heating. Air was supplied through the floor by varying the geometry of the floor outlets. Multi-purpose, dining, kitchen and music/art areas would be served by overhead constant volume air systems. Constant volume air handlers were equipped with constant volume fans, chilled water coils for cooling and hot water coils for preheating and reheating. Ventilation (outside) air was provided through the central air-handling units. An air-side economizer cycle was used to take advantage of free cooling when outside air temperature is at 60°F or lower.

Table 9.2 summarizes the detailed input parameters of five alternatives plus the base case. The next step was to simulate energy consumption using the DOE 2.1E-based energy simulation engine to calculate cooling peak load, heating peak load, energy performance and end-use consumption of electricity, natural gas and light. All simulated data is also summarized in Table 9.2.

Incremental first costs for five alternatives based on the base case

Different alternatives that can reduce annual energy consumption have different design and construction costs. Thus, it was necessary to estimate incremental costs of energy efficient features that could enhance energy performance. The cost of each feature was estimated based on drawings and construction documents under the support of the architecture firm and the general contractor. To estimate the incremental first costs of energy efficient features, it was necessary to estimate the first cost adjustments based on the base case because energy efficient features could potentially reduce the size of HVAC systems. Thus, the final incremental first cost for energy efficient features was estimated by combining the change of construction costs and HVAC cost change. The incremental first costs related to energy saving features are summarized in Tables 9.3 and 9.4.

Table 9.3 First cost of HVAC systems for alternatives and base case (in US$)

Economic component	Base	Alter. 1	Alter. 2	Alter. 3	Alter. 4	Alter. 5
Cooling equipment	90,000	80,000	80,000	78,000	78,000	85,000
Heating equipment	20,000	20,000	20,000	15,000	15,000	30,000
Hydronic pumps	28,000	28,000	28,000	25,000	25,000	20,000
Hydronic piping & accessories	220,000	215,000	215,000	215,000	215,000	200,000
Air handling units	200,000	200,000	200,000	225,000	225,000	225,000
VAV boxes w/ HWcoil	85,000	85,000	85,000	100,000	100,000	100,000
Ductwork & accessories (air hwy. incl.)	350,000	350,000	350,000	350,000	300,000	300,000
Air distribution equipment	55,000	55,000	55,000	55,000	90,000	90,000
Exhaust fans	5,000	5,000	5,000	5,000	5,000	5,000
Unit heaters	5,000	5,000	5,000	5,000	5,000	5,000
Breechings and vents	5,000	5,000	5,000	5,000	5,000	5,000
Controls and instrumentation	175,000	175,000	175,000	175,000	200,000	200,000
Test & balancing	25,000	25,000	25,000	25,000	30,000	30,000
Miscellaneous	50,000	50,000	50,000	50,000	50,000	50,000
Architectural cost	0	0	0	0	0	0
Total first cost for HVAC	**1,313,000**	**1,298,000**	**1,298,000**	**1,328,000**	**1,343,000**	**1,345,000**
Incremental first cost	**0**	**(15,000)**	**(15,000)**	**15,000**	**30,000**	**32,000**

Table 9.4 Summary of incremental first costs (US$)

	Incremental first cost ($/sq ft)	Incremental first cost ($)	HVAC cost adjustment ($)	Total accumulated incremental cost ($)
Base case	$0	$0	$0	$0
Alternative 1	$2.77	$240,990	($15,000)	$225,990
Alternative 2	$1.28	$111,765	($15,000)	$337,755
Alternative 3	$1.37	$119,190	$15,000	$486,945
Alternative 4	$1.37	$119,190	$30,000	$501,945
Alternative 5	$1.37	$119,190	$32,000	$503,945

Annual energy cost savings by energy-efficient features

In order to determine the best, most cost-effective energy-saving strategies for the RFES project, the annual energy consumption of the five alternatives as well as the base case building was simulated using the DOE 2.1E-based simulation tool. The unit price of electricity and gas was based on data from electricity and gas providers including Duke Energy and Piedmont Natural Gas. The electricity unit price was $0.09725/kWh and the gas unit price was $1.080130/therm. Total energy cost was equal to the cost of electricity plus the cost of gas.

Table 9.5 shows the total annual energy savings of five alternatives compared with the base case design. The annual energy cost of the base case was $84,346, combining the electricity cost of $65,530 and the gas cost of $18,816 (Figure 9.19 and Table 9.5). The following subsections describe each alternative compared with the base case and the previous alternative. In other words, the alternatives are considered to have a cumulative effect on energy consumption, with each alternative including the features of all previous alternatives.

Alternative 1: daylighting

The implemented daylighting system would reduce annual energy consumption within the building, which ultimately reduced annual energy costs. Since the proposed daylighting strategy reduced electrical lighting use from 258,977kWh to 131,611kWh based on the simulation result, it would be possible to reduce annual electricity cost by $12,386 for lighting, from $65,530 to $49,439. Daylighting strategies also reduced the gas cost by $885, from $18,816 to $17,931 by reducing the building's heating load in winter. Thus, total reduction of energy costs was about $16,976 (Figure 9.19 and Table 9.5).

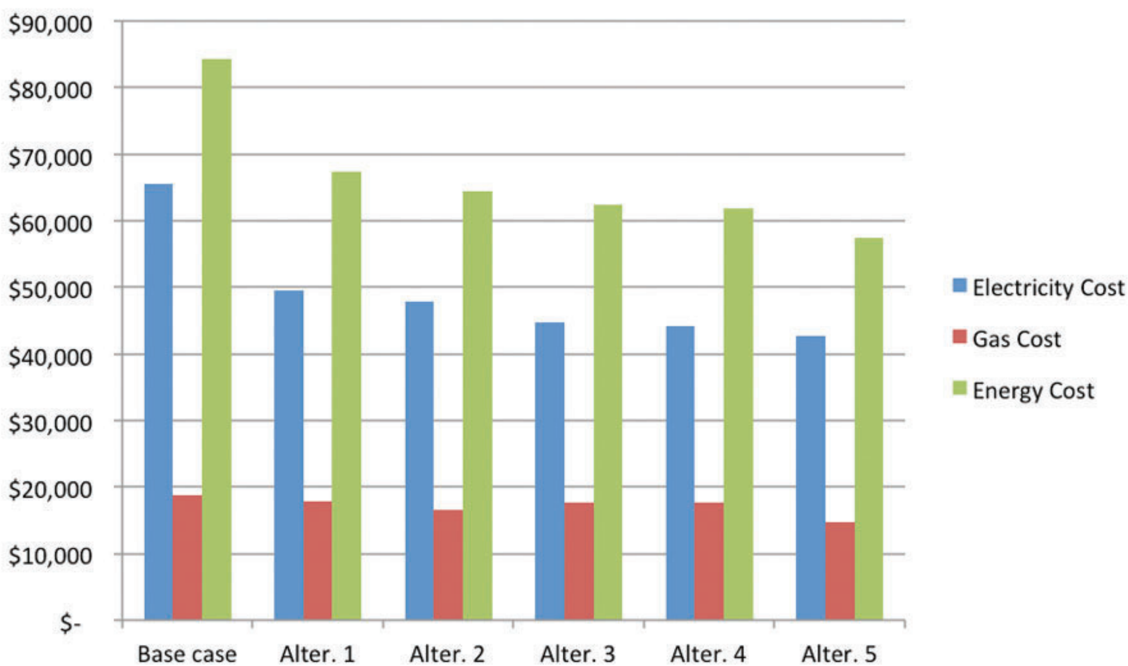


Figure 9.19 Annual energy costs for alternatives

Alternative 2: improving insulation

Improving the level of insulation would reduce both heating and cooling loads of the building. Based on the annual energy consumption simulated by energy modelling, improving insulation could reduce annual electricity cost by $1,670 from Alternative 1 (Table 9.5). In addition, better insulation could also reduce the annual gas cost by $1,281 from Alternative 1. Therefore, improving insulation could reduce the annual energy cost by $19,926 from the base case building, or by $2,950 from Alternative 1 (Figure 9.19 and Table 9.5).

Alternative 3: underfloor air distribution systems

The underfloor air distribution system was estimated to additionally reduce the annual electricity cost by $3,084 from Alternative 2, although the annual gas cost went up by $1,078 (Table 9.5). Since the annual electricity cost saving could exceed the increase of annual gas cost, the underfloor air distribution cost could still save annual energy costs of $21,933 from the base case or $2,007 from Alternative 2 (Figure 9.19 and Table 9.5).

Alternative 4: premium underfloor air distribution system

The premium underfloor air distribution system could further reduce the annual electricity cost by $479 and the gas cost by $33 from Alternative 3. Overall it could reduce the annual energy cost by $22,445 from the base case, and by $512 from Alternative 3 (Figure 9.19 and Table 9.5).

Alternative 5: premium efficiency air-cooled screw chiller

This option could additionally reduce the annual electricity cost by $1,420 and the annual gas cost by $3,045 from Alternative 4. It could lower the annual energy cost to $57,436 compared with the base case of $84,346 (Figure 9.19), resulting in a potential annual energy savings over the base case of $26,910.

Table 9.5 Annual energy cost saving by energy-efficient features

	Measure	Electricity (kWhr)	Elec. cost ($)	Total elec. savings ($)	Gas (therms)	Gas cost ($)	Total $$ngs ($)	Total $$st ($)	Incremental $$ings ($)	Saving ($)
Base case		673,835	65,530		17,420	18,816		84,346		
Alter. 1	Daylighting	508,371	49,439	16,091	16,601	17,931	885	67,370	16,976	16,976
Alter. 2	Insulation	491,206	47,770	17,761	15,415	16,650	2,166	64,420	19,926	2,950
Alter. 3	Underfloor	459,487	44,685	20,845	16,413	17,728	1,088	62,413	21,933	2,007
Alter. 4	Premium air distribution	454,562	44,206	21,324	16,382	17,695	1,121	61,901	22,445	512
Alter. 5	Premium air chiller	439,961	42,786	22,744	13,563	14,650	4,166	57,436	26,910	4,465

Life-cycle cost and payback period

Life-cycle cost is a very important decision-making criterion because it considers all the costs associated with a facility, from construction costs to operation, maintenance, repair and replacement costs throughout the facility's life span. Thus, calculating a net present value (NPV) by life-cycle cost analysis (LCCA) for all alternatives and the base case could help decision makers evaluate the financial effectiveness of energy-efficiency strategies in the RFES project because it could identify the relationship between first cost premiums of energy-efficient strategies and their potential O&M savings during the operation phase. To conduct LCCA, the following assumptions were applied:.

- real discount rate for the analysis: 3.0 per cent (OMB Circular No. A-94)
- length of analysis: 25 years
- energy price escalation: 3 per cent.

Table 9.6 shows both the first cost premium over the base case and the total life-cycle cost for each alternative as a result of this analysis.

Based on the LCCA for all alternatives and the base case, the daylighting strategy (Alternative 1) resulted in the lowest LCC of $1,577,746, which was $101,924 lower than the base case. However, Alternative 5 had the second lowest LCC of $1,581,147 and resulted in the lowest annual energy consumption in the building, even though it required first cost premiums. After estimating all first cost premiums and LCC of energy-efficient alternatives, the project team, mainly the architecture firm and the owner, made a decision to implement Alternative 5 because it would not only minimize annual energy consumption but also save operating cost over the building's life. Therefore, RFES would consume less than half the energy of typical schools and was chosen as one of those in the top 10 per cent of school facilities in the United States designed to earn the Energy Star label. This business case for implementing energy-efficiency strategies illustrates how holistic, innovative and sustainable energy-efficiency strategies can contribute to the goal of sustainability in the building while reducing or eliminating first cost premium barriers.

Table 9.6 First cost premium and life-cycle costs

Alternatives	First cost premium	Life cycle cost
Base case	$0	$1,659,670
Alter. 1	$225,990	$1,557,746
Alter. 2	$337,755	$1,611,390
Alter. 3	$486,945	$1,721,105
Alter. 4	$501,945	$1,726,005
Alter. 5	$503,945	$1,581,147

Annual water cost savings

Water is the other area to consider for the business case. Water efficiency in a capital project can be achieved by a number of technologies that reduce indoor water consumption from that of the standard technologies available on the market. These include ultra-low-flow fixtures and tap aerators, no-water urinals and dual-flush toilets. A building can also reduce potable water consumption by substituting nonpotable water including harvested rainwater or treated wastewater, using recirculation water systems, undertaking leak detection and repair, and employing sustainable landscaping. The reduction of water consumption in the building can also reduce annual water utility bills and minimize needs for municipal infrastructure investments, diminish nitrogen emissions from stormwater and energy use for transporting and treating water, and reduce local erosion and flooding. To achieve annual water cost savings within its building, the RFES design team considered two alternatives: including water-efficient fixtures, and installing a rainwater harvesting system, as well as both together. The decision making for the water saving strategy was based on the preliminary cost benefits study that compared different alternatives.

Design information for water saving

Occupants' estimated water consumption must be determined by calculating full-time equivalent (FTE) and transient occupants and applying appropriate fixture use rates to each. Before calculating FTE and transient occupants, it was necessary to identify the number of students and full-time staff, including a principal, teachers and custodians. Therefore, the design team assumed and estimated that the school operated during a normal school year (175 days) in a co-education session with 750 students, 75 staff and 4 workers with an approximately even gender split (50 per cent male and 50 per cent female). This assumption helped the design team to estimate annual water consumption in the building.

Water-efficient fixtures

The water use within the building was estimated by using the water use program developed by Innovative Design Inc. located in Raleigh, North Carolina. The program calculated the volume of annual water use within the school facility in North Carolina. The reference of water efficient fixtures is summarized in Table 9.7.

Water saving by using water-efficient fixtures

Using the program, RFES annually needed 818,730 gallons of potable water from the city water authority or a well. If water-efficient fixtures were chosen, the annual water consumption was decreased to 409,365 gallons, which saved about 50 per cent of potable water. In addition, this result indicated that 50 per cent of wastewater generation within the building would be eliminated, which could also reduce the need for municipal sewer facilities.

Table 9.7 Water efficiency fixtures – flow rate (gallons/flush)

Fixture type	Advanced fixtures	Baseline fixtures*
Water closet (female)	0.8	1.6
Water closet (male)	0.8	1.6
Urinal (male)	0.5	1.0

* *Set by the Energy Policy Act of 1992.*

Incremental costs for advanced fixtures

Under this scenario, using advanced fixtures that exceed the minimum standards set by the Energy Policy Act may increase the cost of fixtures and installation. Table 9.8 shows the incremental costs of advanced fixtures. Based on a discussion with the architecture firm and construction company, the incremental cost of advanced fixtures was $0.75/sq ft in the RFES project. The total incremental costs were $65,250 (87,000 sf $0.750/sf) in 2006.

Rainwater collection system

Using an integrated rainwater harvesting system was a second technology considered in this project to reduce potable water consumption. A rainwater harvesting system collected rain from half the roof area of the school and sent it to an underground storage tank. The rainwater was then pumped from the tank to the school, filtered, chlorinated, dyed light blue, and used for flushing each toilet in the school. Considering the annual rainfall and volume of water used in the building, a 45,000 gallon water storage tank was designed to store rainwater from 37,000 sq ft of collection area at the roof. The design details of the system are described in Figure 9.20.

Water saving by the rainwater harvesting system

Using rainwater for toilet flushing could significantly reduce potable water use. Based on the rainwater calculation algorithm developed by Innovative Design, Inc., the rainwater storage system would collect 859,063 gallons of rainwater annually that could be used for toilet flushing. This would not only reduce 94 per cent of potable water used (767,565 gallons), but also eliminate 90 per cent of stormwater runoff from the site to the local wastewater treatment system (Figure 9.21).

Incremental first cost for the rainwater harvesting system

Installing the rainwater harvesting system also required additional costs related to excavation, the components of the rainwater collection system, and other infrastructure. According to Figure 9.22, the first cost premium for the rainwater harvesting system was $122,962, including $59,653 for the underground storage cistern, $46,309 for equipment and $17,000 of extra plumbing fixtures.

Rainwater Collection Worksheet

General Information

Guilford Reedy Fork Elementary School August 12, 2011

STATE: NORTH CAROLINA

REGION: 3103 Northern Piedmont | Without Irrigation

Building Data	
Total Roof Area:	86,400 sf
Target rain water supply:	100%
Estimated Water Use Data:	
Fixture Type:	Conventional
Number of Students:	750
Number of Staff:	75
Number of WC groupings:	4
Estimated Water Use Volume	
School Calendar Format	Conventional
Spring term begins:	6-Jan
Summer break begins:	6-Jun
Fall term begins:	11-Aug
Winter break begins:	18-Dec
Special Events per month:	1 /mon.
Average attendance per event:	750
Irrigation Data	
Irrigation area:	0.000 acre
Irrigation Season Begins:	1-May
Irrigation Season Ends:	30-Sep
Data for Yearly Life-Cycle Cost Analysis	
Local Water Cost (per 1,000 gal)	$4.75
Inflation Rate	2.0%
Water Rate Escalation	5.0%
Number of Years for ROI	15 yrs.
Volume of Water Use	
Typical School Day:	3,510 gal
Typical Weekend:	750 gal
Typical Holiday:	162 gal
Holiday Transition:	1,230 gal
Weekly Irrigation Water Load:	0 gal
Environmental Benefits	
Nitrogen reduction from stormwater	18.007 lbs/yr
Less energy used to transport and treat water	
Lessens local erosion and flooding	
Soft water - less impact on pipes, water heater, etc.	
Lessens impact on stormwater infrastructure	

Return on Investment (ROI)		
Estimated Net First Cost	$119,636	
Net ROI after 15 years:	($49,822)	COST
Cistern Size and Optimized Collection Area		
Cistern Size	45,000 gal	
Optimized Collection Area:	37,000 sf	
Override Collection Area:	10,000 sf	
Projected Rainwater Supply:	93.75%	
Estimated Volume of Makeup and Overflow		
With Cistern	Average Year	
Yearly Volume from City/Well:	51,165 gal	
Yearly Volume to Stormwater System:	89,765 gal	
Without Cistern		
Yearly Volume from City/Well:	818,730 gal	
Yearly Volume to Stormwater System:	859,063 gal	
Cost Savings from Water Use		
Water cost (make-up volume):	$243	
Cost with conventional water supply:	$3,889	
First Year Water Cost Savings:	$3,646	
Links on the Web		
North Carolina State Energy Office		
American Rainwater Collection Systems Association		
American Water Works Association		
USGS Water Resources		
Innovative Design		
High Performance Ratings Systems		
NC High Performance Building Guidelines ver 2.0 - Section 3.3: 18-104 points		
USGBC LEED ver 2.0 - Section 3.1/3.2: 1-2 Points		

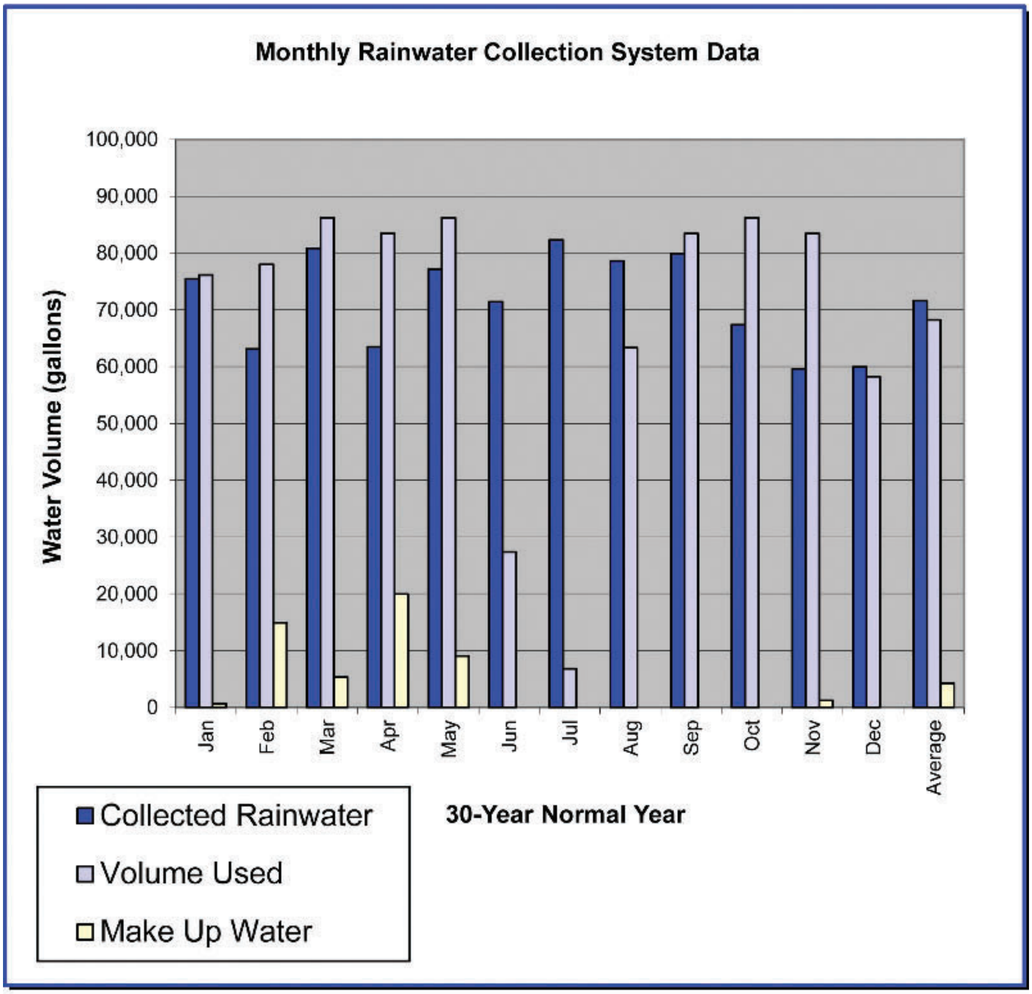
 NC ver 100

Figure 9.20 Rainwater harvesting system

Rainwater Collection Worksheet

Normal Year Chart

Monthly Rainwater Supply and Required Volume



Yearly Data

	Volume (gallons)		
Collected Rainwater:	859,063	gal	
Yearly Volume Required:	818,730	gal	
Make-up Water Required:	51,165	gal	94% reduction
Water to Storm System:	89,765	gal	90% reduction

Figure 9.21 Required water volume and collected rainwater

Table 9.8 Comparison between two water-saving alternatives

Alternatives	Annual water saving	Annual cost saving ($4.75/1000 gallons)	First cost premiums
Advanced fixtures	409,365 gallons	$1,944	$65,250
Rainwater harvesting system	767,565 gallons	$3,646	$122,962

Comparing two water-saving alternatives

For the RFES project, the design team and the school board made a decision to only install the rainwater harvesting system instead of water-efficient fixtures after considering, among other things, first cost premiums and potential water cost savings (Table 9.8). On the surface, this decision may not appear to make economic sense on the basis of an LCCA. However, in this case, decision makers had a perception that high-efficiency fixtures were extraordinarily expensive in 2006 when the decision was being made. Given projected future water shortages in the Atlantic region of the United States, external environmental conditions may also have contributed to the decision to invest in a rainwater harvesting system as a high priority for the RFES project. Upon being interviewed several years after project completion, members of the design team believe that they would definitely make a different choice and incorporate advanced fixtures as part of the project if they had the opportunity to make the choice today.

This example highlights the fact that sometimes, sustainable building decisions take into account factors beyond simple economic analysis. Water-efficient fixtures in particular must consider operating and maintenance requirements and the ability of facility maintenance staff to keep them in proper operating condition during their service life. They should also consider the relative importance of water as an environmental constraint in the specific context of use.

Annual water cost savings and life-cycle costs

In the chosen scenario, the rainwater harvesting system would reduce the estimated annual potable water demand by 767,565 gallons (94 per cent of required water volume). It also was estimated to reduce the stormwater discharge from the site by 89,765 gallons (90 per cent reduction). Even though the break-even point of this investment was about 22 years with assumptions of 2 per cent inflation and 5 per cent water rate escalation, this water saving investment could reduce nitrogen emissions from stormwater runoff, decrease energy consumption, mitigate local erosion and flooding, and reduce the impact of the project on stormwater infrastructure. It could also reduce the risk of future water shortages expected to occur with greater frequency over the coming years. Since the school was projected to operate over a 50-year service life, the NPV over 50 years could bring a financial benefit of $613,242 over the base case.

Rainwater Collection Worksheet

Life-Cycle Costs

Local Cost Data		
Excavation and Grading Costs	Local Cost	
Excavation:	$10	/ cy
Crushed Stone (in place):	$27	/ cy
Backfill:	$27	/ cy
Cost of stormwater piping, trenching and backfill:	$26	/ lf
Approximate cost for stormwater basin	$18	/ cy

Initial Costs for Rainwater Collection System and Infrastructure			
Enter System Cost, If Known:			
Rainwater Collection System Cost (Estimated by Program):			$122,962
Cistern	$59,653		
Equipment	$46,309		
Plumbing infrastructure	$17,000		
On Site Retention			
☐ Retention basin ($ saved by diverting to cistern)			-
Storm Intensity for Design	5	yr.	
Impervious Surface Diverted	37,000	sf	
Approximate intensity of 5 year storm event:	5.00	in	
Approximate volume saved for retention basin:	143	cy	
☐ Reduction of retention basin piping (if basin is eliminated)			-
Distance from building to projected basin site:	0	lf	
Distance from building to cistern:	0	lf	
Public Stormwater System			
☐ Stormwater infrastructure ($ saved by diverting to cistern)			-
Distance from building to city stormwater system:		lf	
Distance from building to cistern:		lf	
☐ Reduction of local stormwater system Tap Fees		/K gal	-
Real Estate			
☐ Land Value			-
Approximate cost per acre	$25,000		
Approximate footprint of basin avoided	0.01	acres	

Environmental Impact Fees			
Downstream nitrogen pollution diverted	18.01	lbs/yr	
	Impact Fee		
☐ Reduction of Nitrogen Impact Fees:	$330	/lb.	$0
•			
•			

Yearly Savings		
Net first year savings		($3,326)
Net first year water cost ($ with cistern - without)	($3,646)	
First year maintenance costs		
Basin maintenance avoided	$20	
Filters/pumps	$250	
Chlorinator	$50	
•		
•		
Net First Year Cost:		**$119,636**

Life-cycle Costs	
Year	ROI
2	($116,134)
3	($112,447)
4	($108,566)
5	($104,481)
6	($100,181)
7	($95,656)
8	($90,893)
9	($85,881)
10	($80,608)
11	($75,059)
12	($69,221)
13	($63,079)
14	($56,618)
15	($49,822)
16	($42,673)
17	($35,153)
18	($27,245)
19	($18,928)
20	($10,181)
21	($983)
22	**$8,690**
23	$18,861
24	$29,554
25	$40,798
26	$52,620
27	$65,048
28	$78,114
29	$91,849
30	$106,288
31	$121,466
32	$137,420
33	$154,190
34	$171,816
35	$190,342
36	$209,813
37	$230,277
38	$251,783
39	$274,385
40	$298,138
41	$323,098
42	$349,328
43	$376,892
44	$405,855
45	$436,289
46	$468,267
47	$501,868
48	$537,173
49	$574,268
50	$613,242

2% average yearly inflation

5.00% water cost escalation per year

Break Even after 22 years

Figure 9.22 Initial cost premiums and net present values

Project planning with the business case in mind

Both immediate and long-term cost savings can be realized by taking into account environmental factors from a performance standpoint when planning and designing a project. Providing performance-based standards, in which the desired performance of the building is specified instead of specific materials or systems, can help to ensure that the desired quality of a school or other facility is obtained while allowing designers the flexibility to take into account the interaction between and among the features. The G3-Guilford Green Guide played such a role in the RFES case study. For example, a common environmental goal is to reduce energy consumption of the building. If this goal is articulated as a performance standard (for instance, 'the facility should exceed Model Energy Code requirements by 30 per cent as demonstrated by whole building simulation'), designers can choose from a whole palette of options that could meet the goal, some of which may be less expensive than a generic design applied to many situations. If the designer is encouraged to optimize the design from a whole-building perspective, the first cost of the building can actually be reduced while also reducing life-cycle operational costs (Weizsacker et al 1998; Pearce, Fischer and Jones 2000).

Design integration across building systems saves money by acknowledging the interdependencies among these systems. The key to achieving synergies in design is to provide design standards that emphasize the desired level of performance for the building, then suggest a variety of high-performing building system types and technologies that can be used to achieve them. The choice of materials and construction techniques used in today's school construction has been a result of several factors.

- First, policies, rules, or standards. For example, in some states, the Department of Education pre-qualifies certain materials for construction. If a school system wants to use materials that are not pre-qualified, they must get approval. If the materials cost more than the standard material, the school system bears the additional cost.
- Second, financial constraints and resources of the local school system.
- Third, competitive market pressures on the design professionals to maintain the owner's construction budget. Design professionals must choose materials and systems with lower initial costs to maintain the owner's budget.
- Fourth, local climate and environmental constraints. Local schools are familiar which products and building systems perform best in their local school environment based on past performance.

Balancing the initial cost against serviceability and continuing operational costs for maintenance and energy is necessary. However, the significance of improvements in energy conservation should not be underestimated. For example, the City of Philadelphia school district found in that the use of performance-based standards for energy-efficient operation of its 260 facilities resulted in an impressive savings of $3.3 million in the first year in energy costs alone (Sender 2000). The cost of energy upgrades can also be supported by grant or incentive programmes such as the US Environmental Protection Agency's (USEPA's) Green Lights program, which provides its partners with connections to financing opportunities and extensive technical assistance to identify 'profitable' lighting upgrade opportunities: those with a rate of return of 20 per cent or more. A school designed to maximize the conservation of energy, minimize environmental impacts, be resource efficient, and be aesthetically compatible with the site is desirable if first costs can be managed, and programs like Green Lights can provide a variety of options for ensuring that they are.

Consideration of other environmental quality factors can provide additional positive benefits as well. By using environmentally sensitive building materials that improve indoor air quality and improving the performance of heating and lighting systems, some schools have reported lower rates of absenteeism and vandalism by 'creating an atmosphere in which students can take pride in their school' (Energy Smart Schools 1997). The USEPA further concluded that by improving indoor air quality in school facilities, it may be possible to reduce the following issues and problems:

- An average of one out of every 13 school-age children has asthma.
- Asthma is a leading cause of school absenteeism.
- 14.7 million school days are missed each year because of asthma.

Researchers at Georgetown University found that achievement scores in school buildings with 'poor' environmental conditions were over five percentage points below scores of students in buildings with 'fair' ratings, and 11 percentage points below those in schools with 'excellent' conditions (Edwards 1991). Another study in North Carolina found that children in daylit (rather than artificially lit) schools score higher on standard performance exams (up to 14 per cent increase over three years) and have better attitudes and attendance rates than their peers in non-daylit facilities (Nicklas and Bailey 1996). Similarly, a Canadian study of the effects of natural light in elementary schools found that students in classrooms with full spectrum light were absent less, grew taller, and had increased concentration levels and more positive moods (Alberta Dept. of Education 1992). Energy savings from daylit schools can also be significant: estimates are that $500,000 on average can be saved over a ten-year period in the average middle school that incorporates daylighting features (English 1997).

Establishing performance-based design standards to achieve environmental quality goals for schools can have significant impacts not only on the first and life-cycle costs of the building, but also on the basic health, achievement and learning of the students. By providing designers with the flexibility to seek innovative and synergistic design solutions for their projects, a variety of high-performance features can be built into the school that will benefit not only the budget of the school district and the state, but also the environment and the students themselves. Schools in the United States and elsewhere have successfully integrated advanced building technologies such as PV arrays, computerized energy management systems and multi-fuel boiler systems. These computer-controlled technologies not only help the school's maintenance staff do a better job of operating the building, they double as a teaching tool, where students can monitor fuel, energy generation and use, and other variables. The final product then becomes a learning laboratory to demonstrate the physical and scientific principles of sustainability and building science for the students and community (Greven 1997; Augenbroe and Pearce 1998, 2009). A variety of organizations in the United States have developed online educational tools including classroom activities, lab experiments and other exercises that use building-related problems and projects to teach math, science, and economics.[1]

Capturing indirect benefits through holistic cost management

Despite commitment to developing sustainable facilities, many organizations still experience difficulty in implementing the concept because of how funding is allocated to projects. Especially in the public sector, personnel responsible for developing project estimates have few resources for accurately estimating the first costs of a sustainable project, let alone potential life-cycle cost impacts of sustainability. In many cases, the only method available for estimating sustainable project costs is to add a contingency factor to the estimate for a traditional project to cover anticipated increases in design costs, material costs and other project costs, particularly for innovative projects in the early planning stages (Pearce 2008; Pearce et al 2010). This approach inhibits the implementation of sustainability for two reasons, particularly in public agencies. First, projects are often funded based on efficiency of first cost, meaning that projects with a higher parametric cost estimate are less likely to get funded; and second, adding a contingency to the project estimate means that even if the project does get funded, there is often no incentive to seek cost savings since the money will be lost if it is not spent, creating a self-fulfilling prophecy of increased costs for sustainable projects.

Figure 9.23 provides a means for examining expectations about sustainable capital project costs. The grid represents a way to plot the relative cost of a sustainable project against its traditional counterpart in terms of both life-cycle and first costs. Figure 9.23(a) shows what many decision makers expect about a sustainable project: it will cost more in the beginning, but will likely save money over the whole life-cycle due to waste reduction, increased durability, reduced operations and maintenance requirements, and other factors. This expectation is illustrated by the red circle in the lower left quadrant of the diagram.

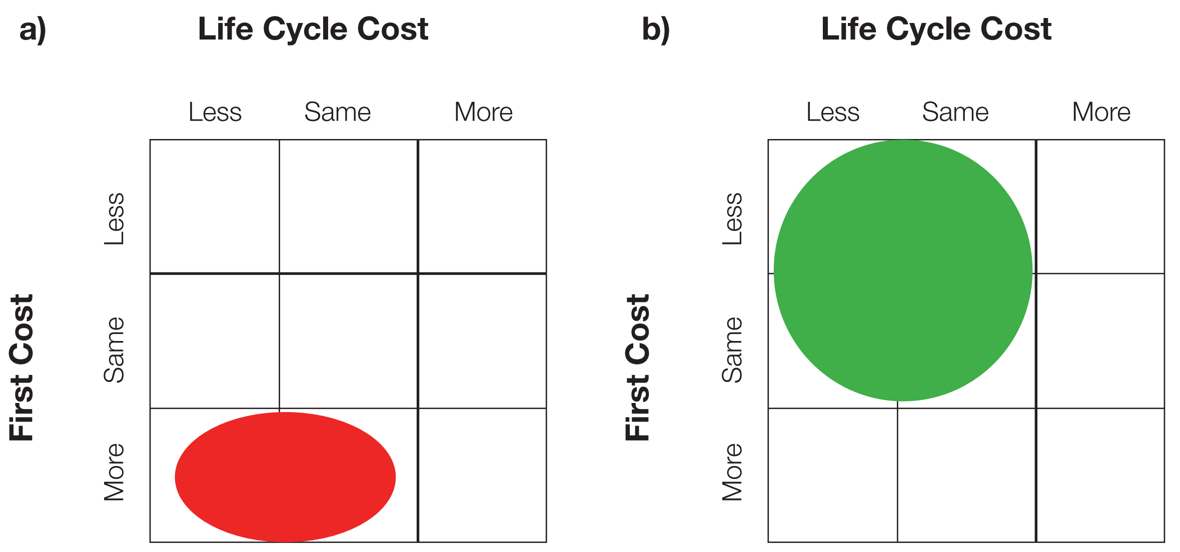


Figure 9.23 Expectations about sustainable project costs (a) Sustainable projects (b) Funded projects
Source: Pearce (2005).

Yet, within contemporary decision environments for funding projects, particularly in the public sector, the projects that will be funded without special intervention lie within the region indicated by green in Figure 9.23(b): those that cost the same or less from a first cost perspective. In many cases, funding constraints mean that minimum first cost is the goal, even though overall life-cycle costs may be greater (the third column in the diagram). This sub-optimal result is possible because the sources of money for first cost and operations/maintenance cost are different and disconnected, especially in public-sector organizations, and may be managed or controlled by entirely different people.

The concept of holistic cost management considers a larger set of questions than traditional project costing from the very beginning of a project. For instance, what will be the impacts of design/construction decisions on life-cycle costs? What opportunities exist to offset increases in first cost for design improvements (as in integrated design)? What externalities should be considered that could result in a better decision about costs?

Instead of the two-dimensional representation of cost shown in Figure 9.23, holistic cost management expands the figure along a third dimension to include additional cost/benefit considerations that are associated with the project. Figure 9.24 illustrates the revised cost model.

The bottom layer of the figure represents the two-dimensional cost comparison shown in Figure 9.23. This layer represents traditionally considered, quantifiable costs such as the costs of material, labour, equipment and cost of money (Table 9.9). Decisions about individual products are sometimes made on a unit cost basis without necessarily considering cost from a systems standpoint. This practice means that some products offering sustainability advantages seem more expensive

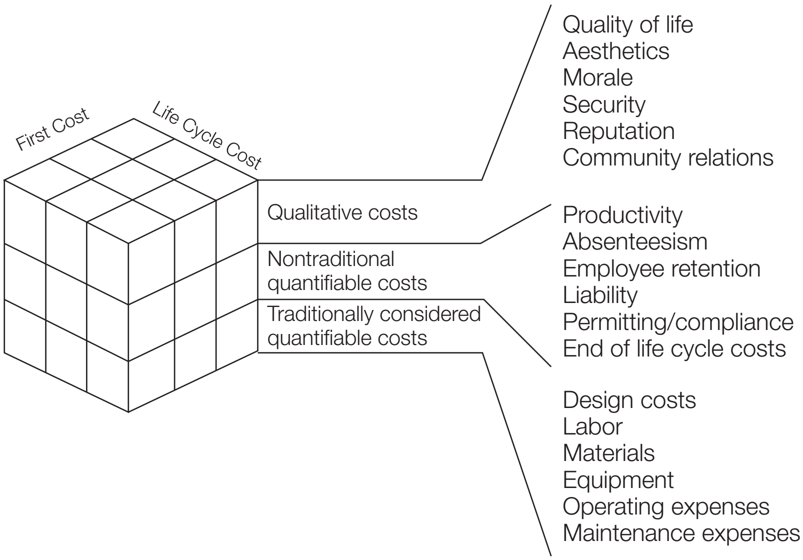


Figure 9.24 Revised whole project cost model
Source: Pearce (2005).

than they really are. For instance, when asked why they don't use integrated building systems such as structural insulating panels or sheathed insulating concrete form blocks, many owners reply that these systems are more expensive than traditional methods such as concrete masonry construction. Yet if savings in labour cost and construction schedule were taken into account, these materials could show an immediate cost advantage to owners. For example, one federal project manager estimated a savings of $3,000 per day due to shortening the construction schedule on his project by using pre-engineered autoclaved aerated concrete systems – all from avoiding the cost of housing personnel in hotels instead of the facility being built as their residence. Similar or even greater savings in opportunity costs can result on many other projects as well.

Table 9.9 Traditionally considered quantifiable costs

First costs	Life-cycle costs
Site acquisition Design costs Project management costs Construction costs: • labour • materials • equipment • contingencies • financing and other costs of money • commissioning/turnover costs	Operation/maintenance costs: • labour • materials • equipment • energy • water Repair/remodel/rehab costs: • design costs • labour • materials • equipment • contingencies • financing • turnover

Other considerations, if taken into account, could more clearly indicate the benefits of sustainability in the built environment. Captured in the second level of the cost model shown in Figure 9.24, these considerations include benefits such as:

- Reduced costs of consumption, waste disposal and noncompliance.
- Reduced liability and environmental risk.
- Improved use of assets, particularly human assets (including increased productivity, reduced absenteeism and building-related health problems, improved morale, and better employee retention).
- Reduced operational and disposal costs.
- Reuse of facilities that otherwise would be disposed of.
- Preparedness for future regulations and requirements.

Each of these benefits reflects a potential cost savings for owners, although many of these kinds of costs are not typically associated with specific projects and the associated decision processes behind their funding. If these potential benefits can be realized, then sustainable projects will truly have an economic advantage over their traditional counterparts. Table 9.10 shows examples of these types of costs that should be considered when making decisions about sustainable projects. The first category, definite costs, includes all costs that will definitely happen as part of the project, but are typically not considered as part of project costs but rather covered as part of overhead or administrative costs. The second category, contingent costs, consists of costs that may or may not occur – their probability of occurrence is less than 1.0. In other words, there is some likelihood that they will occur, and their total costs can be estimated using probabilistic methods such as decision trees. Although the listing is not comprehensive, it illustrates the kinds of costs for which dollar values could be calculated but are typically not included in project decision making.

An additional set of considerations in holistic cost management consists of qualitative costs: costs that have some real impact but are difficult to quantify because of societal values and other measurement challenges. It is at this top level of the holistic cost model that sustainable projects truly dominate traditional projects in their impact reduction; however, the difficulty of assigning actual costs and benefits to specific projects is significant, and therefore these are not typically considered as part of project decision making. Table 9.11 lists some of the cost items in this category.

Costs can be broken into two types at this level: internal costs and external costs. Internal costs are those difficult to quantify costs experienced directly by project stakeholders. Externalities, on the other hand, are generally borne by society as a whole. While projects have some individual contribution to these costs, the net cost is a result of all human activities, and allocating specific responsibilities is difficult. Methods exist to assign costs to these kinds of impacts, and are used frequently in risk analysis and policy development.

Table 9.10 Non-traditional quantifiable costs

Definite costs	Contingent costs
Qualification of suppliers/contractors Reporting and record-keeping Monitoring and testing Spill response readiness Recycling/waste management Facility decommissioning costs Disposal costs	Future compliance costs Future liability/damage costs Remediation costs Responses to future releases or presently unknown hazards Impacted productivity and/or absenteeism Impacted staff retention

Table 9.11 Qualitative costs

Internal costs	Externalities
Impacts on quality of life Value of relationships with surrounding community Value of environmental image	Costs borne by society as a whole, such as: • global warming • ozone depletion • deforestation • resource degradation • ecosystem degradation • species/biodiversity loss • air pollution • water pollution

Indirect methods

The price is inferred from actual choices to which monetary values can be assigned, such as choosing where to live. These methods may examine:

- Averting behaviours – how much people will pay to fix environmental damage; the cost of cleanup.
- Weak complementarity/travel cost, such as where the value of cleaner water is assumed to be connected somehow to visits to a lake.
- Hedonic market methods where the price of a house or a job can be decomposed into attributes, one or some of which are environmental attributes.

Direct methods

This is also known as contingency valuation. These methods involve direct questioning about willingness to pay or willingness to accept compensation in exchange for environmental damage of some sort.

The ultimate outcome of considering the full spectrum of costs associated with a project is a true picture of what costs and benefits will stem from each alternative over the whole building life-cycle. If all costs are considered, then actions that might ordinarily cause problems later (such as endangered species habitat disturbance or use of hazardous

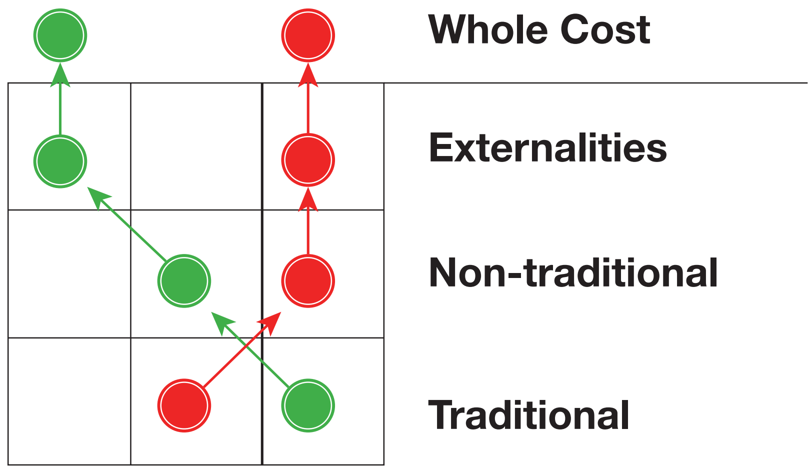


Figure 9.25 Sustainable versus traditional projects from a holistic standpoint
Source: Pearce (2005).

materials) can be adequately considered for the risk they truly represent. Figure 9.25 shows how sustainable projects compare with traditional projects when all these factors are considered. The sustainable project, indicated by the green dots, has lower non-traditional and externality costs than the traditional project, indicated by red. This two-dimensional representation corresponds to looking at the three-dimensional model from the side, and reducing first cost and life-cycle costs to a single metric such as NPV for comparison purposes.

Making the business case in 2020

How will making the business case for sustainability be different in 2020? With current trends, it is likely to be even easier than making the case today. Factors that may result in reduced quantifiable costs for sustainable projects over the next ten years include:

- **Learning curve** – as sustainable products and strategies become more familiar to designers and builders, less effort will be required to use them correctly (arrow A in Figure 9.26).
- **Economies of scale** – as demand increases for sustainable technologies in the marketplace, production and distribution networks will grow and become more efficient (arrow B in Figure 9.26).
- **Resource scarcity** – as many of the materials presently used in building (such as fossil fuels, old growth timber and mineral-derived products) become more scarce, their costs will increase and the cost of using alternatives will become relatively less expensive (arrow C in Figure 9.26).
- **Stricter legislation** – as environmental, safety and occupational health (ESOH) regulations become more restrictive, projects that have lower risk of ESOH threats will become relatively less expensive (arrow D in Figure 9.26).

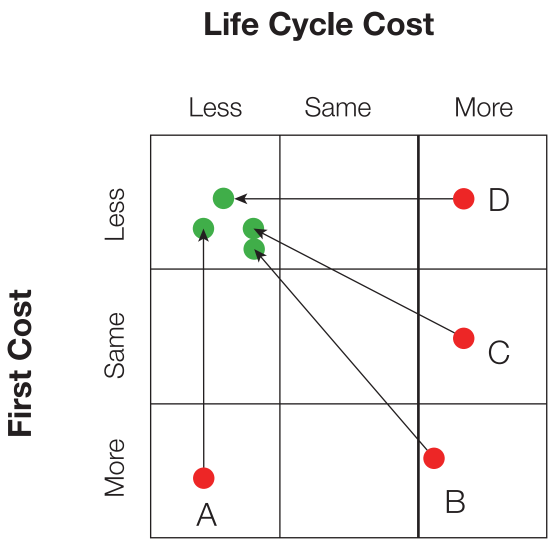


Figure 9.26 Influences on the cost of sustainable projects
Source: Pearce (2005).

All of these external influences will tend to give advantage to sustainable projects from an economic standpoint, at least in the long run. In addition, items presently classified as nontraditional quantifiable costs or externalities are also increasingly likely to be part of any business case evaluation. With the growth in popularity of metrics such as the Dow Jones Sustainability Index (see Chapter 4), companies will be increasingly evaluated based on a triple bottom line of social, environmental and economic performance. Our ability to evaluate the true value of common resources and assets can only improve as well.

The ultimate goal of sustainability is our long-term survival as the human race. The negative impacts of our present methods of construction can no longer be denied. The time has come to seek better ways of building that will maintain our quality of life and ensure that our children and their children can continue to live as well as we do. Thinking strategically about how we go about greening our projects can ensure that we are able to meet sustainability goals without breaking the project budget.

Note

1 See www.engineeringpathways.org for examples.

The business case study of the Reedy Fork Elementary School has been developed by the support of Innovative Design, Inc.

Discussion questions and exercises

9.1 List some of the most promising recommendations you have made in previous chapters for measures to improve the sustainability of the facility in which you are located. What are the first costs associated with implementing those measures? Develop a cost estimate for each of the most promising recommendations. How much more or less expensive is each than the status quo it would replace? Which options cost the least from a first cost standpoint? Do any of the recommendations offer a lower first cost than the status quo?

9.2 For each recommendation considered, how would its life-cycle costs compare with the status quo it would replace? Develop a cash flow profile to show major maintenance and replacement costs. Which recommendations are most preferable in terms of life-cycle costs?

9.3 Do any recommendations offer synergy from a cost standpoint? How might strategies be combined to help break through the first cost barrier? What complementary actions could be undertaken to further reduce costs, such as downsizing related systems?

9.4 Inventory the non-traditional quantifiable costs and benefits associated with each recommendation over its life-cycle, such as increased productivity or user satisfaction, reduced environmental liability, or diminished risk of price fluctuations associated with resource depletion. Which are definite costs, and which are contingent costs?

9.5 What qualitative costs and benefits are associated with each of your recommendations? Which are internal to your organization, and which are externalities that must be borne by society as a whole?

9.6 For the most promising recommendations you have identified, compare the costs and benefits of each option with the status quo. Given this analysis, which alternative(s) would you most highly recommend?

9.7 Which of the external factors influencing cost – learning curve, economies of scale, resource scarcity and stricter legislation – should be most carefully considered by your organization in determining how to manage its facility portfolio, given the context of your operations? Why? What measures can you take to manage that risk?

9.8 Consider the local construction project you visited in earlier chapters. Which of the synergistic design and construction strategies discussed in the chapter could be used to reduce first cost of the project while improving overall project sustainability?

References and recommended reading

Alberta Department of Education. (1992). *Study into the Effects of Light on Children of Elementary School Age: A case of daylight robbery.* Alberta, Canada.

Augenbroe, G. L. M. and Pearce, A. R. (1998). 'Sustainable construction in the USA: a perspective to the year 2010,' in L. Bourdeau, P. Huovila, R. Lanting and A. Gilham (eds), *Sustainable Development and the Future of Construction: A comparison of visions from various countries*. CIB Publications, Rotterdam, Netherlands.

Augenbroe, G. L. M. and Pearce, A. R. (2009). 'Sustainable construction in the USA: a perspective to the year 2010,' in A. K. Pain (ed.), *Construction Industry: Changing paradigm.* Icfai University Press, Hyderabad, India.

Bennett, M. and James, P. (eds) (2000). *The Green Bottom Line: Environmental accounting for management – current practices and future trends*, 2nd edn. Greenleaf Publishing, Sheffield, UK.

Edwards, M. (1991). *Building Conditions, Parental Involvement, and Student Achievement in DC Public Schools.* Georgetown University, Washington, DC.

Energy Ideas (1997) 'Energy smart schools', *Energy Ideas,* 4(3), Winter/Spring.

English, H. (1997). 'Students shine in daylit classrooms', *Energy Ideas,* 4(3), Winter/Spring.

Greven, E. (1997). 'Investments that last a lifetime', *Energy Ideas,* 4(3), Winter/Spring.

Heerwagen, J. (2001). 'Do green buildings enhance the well being of workers?' *Environmental Design+Construction*. <www.edcmag.com/CDA/Archives/fb077b7338697010VgnVCM100000f932a8c0> (accessed 27 September 2011).

Holliday, C. O. Jr., Schmidheiny, S. and Watts, P. (2002). *Walking the Talk: The business case for sustainability.* Greenleaf Publishing, Sheffield, UK.

Kats, G. (2003). *The Costs and Benefits of Green Buildings: A Report to California's Sustainable Building Task Force.* California's Sustainable Building Task Force, Sacramento, CA.

Lechner, N. (2008). *Heating, Cooling, Lighting: Sustainable design methods for architects, 2nd edn*. Wiley & Sons, New York.

Matthiessen, L. F. and Morris, P. (2004). *Costing Green: A comprehensive cost database and budgeting methodology.* Davis Langdon Adamson.

Morton, S. (2002). 'Business case for green design', *Building Operating Management,* November. <www.facilitiesnet.com/bom/article.asp?id=1481> (accessed 27 September 2011).

Nattrass, B. and Altomare, M. (1999). *The Natural Step for Business: Wealth, ecology, and the evolutionary corporation.* New Society Gabriola Island, BC.

Nicklas, M. and Bailey, G. (1996). 'Energy performance of daylit schools in North Carolina'. <www.innovativedesign.net/pdf/energyperformance.pdf> (accessed 10 October 2011).

Pearce, A. R. (2005). 'Leapfrogging the first cost barrier in sustainable construction: a taxonomy and recommendations for the next generation of costing tools', *Proceedings of the 2005 Mascaro Sustainability Initiative Sustainable Engineering Conference*, Pittsburgh, PA, 10–12 April.

Pearce, A. R. (2008). 'Sustainable capital projects: leapfrogging the first cost barrier', *Civil Engineering and Environmental Systems*, 25(4), 291–301.

Pearce, A. R. (2010). 'Costing sustainable capital projects: the human factor', *Proceedings, 2010 Conference, New Zealand Society for Sustainable Engineering and Science*, Auckland, NZ.

Pearce, A. R., Fischer, C. L. F. and Jones, S. J. (2000). *A Primer on Sustainable Facilities and Infrastructure.* Georgia Tech Research Corporation, Atlanta, GA.

Pearce, A. R., Sanford-Bernhardt, K. and Garvin, M. J. (2010). 'Sustainability and socio-enviro-technical systems: modeling total cost of ownership in capital facilities.' Invited paper, Proceedings, 2010 Winter Simulation Conference, Baltimore, Md.

Romm, J. J. and Browning, W. D. (1995). *Greening the Building and the Bottom Line: Increasing productivity through energy-efficient design*. Rocky Mountain Institute, Snowmass, CO.

Sender, M. (2000). Energy Conservation Program Coordinator, School District of Philadelphia, Philadelphia, PA.

US Department of Energy (USDOE). (2003). *The Business Case for Sustainable Design in Federal Facilities.* Energy Efficiency and Renewable Energy Program, Federal Energy Management Program, USDOE, Washington, DC.

Weizsacker, E. et al (1998). *Factor Four: Doubling wealth, halving resource use.* Earthscan, London.

Wilson, A. (2005). 'Making t*he case for green building*', *Environmental Building News*, 14(4), 1 ff.

10

Trends for the Future of Sustainable Design and Construction

What seemed only recently like an insignificant fringe movement in green, sustainable or high-performance facilities has been growing with surprising speed in the commercial and residential construction sectors, and stands to become a driving force for the industrial and heavy sectors by 2020 as well. Not long ago, many building professionals would have classified sustainable design merely as an interesting idea. But awareness of climate change, changes in policy and incentives, and other environmental factors have catapulted it to centre stage, and it is expected to continue to gain prominence in the next ten years. Organizations that consider the potential impacts of this movement will be well prepared for multiple eventualities and can respond with agility to potential threats and opportunities in both the short and long term.

This chapter provides an overview of some of the present and likely future trends that can be anticipated to affect the architecture, engineering and construction (AEC) industry through 2020. The first part of the chapter discusses emerging technologies, including both materials and methods, which will be widely available to firms in the future. The second part covers approaches to process improvement, including lean construction, design for adaptability, DfX and dematerialization, that are presently being pioneered in sustainable construction. The third part of the chapter focuses on the area of sustainable infrastructure, a distinct domain of innovation that is evolving rapidly. The fourth part of the chapter covers broader trends such as biomimicry and industrial ecology, building information modelling (BIM), and climate change and passive survivability, which will shape all sectors of the construction industry in the future and change how firms and individuals interact with one another to get the job done. The chapter concludes by exploring 'over the horizon' predictions for the context in which the construction industry will exist over the near, medium and long term.

Emerging technologies

The construction industry is responsible for designing, assembling, maintaining and decommissioning the built environment on which we all depend. As such, it employs a variety of technologies in both the facilities themselves and the means and methods used to construct those facilities. This first part of the chapter provides an overview of trends in green materials research, nanotechnology, equipment technologies and integrated performance modelling, described in more detail in the following subsections.

Green materials research

While some might argue that the construction industry overall has been slow to change, innovation in materials and methods has permeated the sustainable construction domain. From intelligent buildings that sense and adapt to environmental conditions, to self-healing materials that automatically compensate for damage, to ultra-high-efficiency fixtures and appliances, the 'high tech' end of the industry continues to evolve. There is also a range of improvements to individual materials that have been in use for many years, including ubiquitous materials such as concrete and composite wood.

High-tech green building materials and systems

On the high-tech side, advances in intelligent materials and buildings have included both better, more responsible materials and better performing sensing and control systems for those materials. One such material, aerogel (www.aerogel.com), is seeing considerable growth in the United States. Aerogels encapsulate pockets of air within a gel substance that can be used as an insulating material with extremely high thermal performance, reducing the required thickness of walls and increasing usable space within buildings. Aerogel is also translucent and allows penetration of light through panels that incorporate it. The weight of the product is extremely light, reducing added weight that would otherwise require structural support.

While window performance has consistently increased over time, recent innovations in suspended film technology have enabled new windows to achieve insulating values of up to R-11 while reducing the weight traditionally associated with high-performance windows containing multiple panes of glass (www.seriouswindows.com). With long-lasting, thermally broken fibreglass frames, these windows will significantly reduce one of the most serious sources of energy loss in buildings today – thermal energy escaping through the building envelope. Other technologies such as windows with integrated photovoltaics (PV) or switchable glazing can also improve building function while reducing energy footprint. Window assemblies that incorporate phase-change materials also afford the ability to selectively absorb and re-radiate heat like a wall with thermal mass, while maintaining light transmissivity (Wilson 2010).

Improvements in technologies to support daylighting are also improving the indoor environment while saving energy. For instance, Swedish company Parans (www.parans.com) offers a fibre-optic daylighting system that can be used to provide daylight even in the interior of buildings with very small impact on the building's envelope (and thus thermal performance). Parans's fibre optic system provides precise control over how light is transmitted within a space, and reduces the possibility of unwanted heat gain common with other daylighting strategies.

Together, these technologies can improve the energy performance of a building while maintaining desirable indoor conditions. In addition to these and other new construction products, significant advances are also being made in conventional construction materials, discussed next.

Advances in conventional materials

In terms of improvements to conventional materials such as concrete, significant advances have been made in the formulations and composition of the materials themselves, as well as the equipment and technologies used to place them. For example, California-based company Serious Materials has developed a new type of drywall that can be made with 80 per cent recycled materials, including waste from steel and cement plants (Moresco 2009). Changing the formulation of conventional materials to incorporate waste streams (such as flyash concrete or manufactured wood made from agricultural waste) has also occurred in the concrete and manufactured wood products industries as well. Some firms are also investigating additives to concrete that can improve its water resistance. For instance, New Jersey-based firm Hycrete has developed an additive that can be added to concrete mixes to make them waterproof, thereby eliminating the costs and time associated with secondary waterproofing and drainage products outside subterranean concrete walls (Moresco 2009).

New coatings are also being developed to improve the performance of conventional materials. For example, reflective roof coatings can be applied to manufacture metal roofing panels in a wide range of appealing colours rather than the historically limited palette of light colours. These panels (Figure 10.1) prevent excessive heat gain by reflecting solar radiation during the day rather than absorbing it into the building.

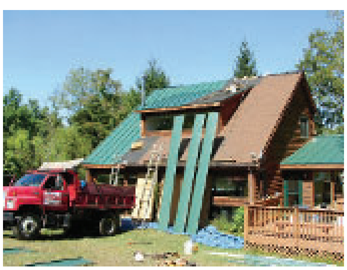


Figure 10.1 Reflective roof coatings can improve energy performance

In addition to new formulations of existing materials, conventional materials are being combined in new ways to both facilitate construction and enhance building performance. For example, structural insulated panels (SIPs) and insulating concrete forms (ICFs) can be prefabricated by manufacturers off-site using commonly available materials such as polystyrene and oriented strandboard or cold-rolled steel, and shipped to the job site where they are quickly installed to reduce the construction schedule (Figure 10.2). Both of these products have significantly improved thermal performance over site-built walls due to the elimination of air or vapour gaps in the wall and the elimination of thermal bridging.

Figure 10.2 Structural insulated panels improve both construction delivery time and thermal performance

Nanotechnology

A special category of evolving materials involves nanotechnology in their development. From the standpoint of construction, nanotechnology can be taken to mean both working with organic or inorganic materials at the nanometre scale, and developing micro and nano tools to operate on that scale. Materials manipulated at the nanometre scale can have a variety of different physical behaviours different from their traditional physical performance. Key areas of nanotechnology application in construction include (BTSC 2006):

- Nano-molecular structures to increase water- or corrosion-resistance of conventional materials.
- Coating materials that can block ultraviolet and infrared radiation, thus increasing durability.
- Glueing applications.
- Nano-lubricants.
- Automatic decontaminators such as self-cleaning materials for windows, mirrors, toilets and other applications.

Nano-materials use extremely small particles to do useful things and add functionality to building materials. For instance, nano-based coatings can be used to make paint repel dirt or concrete absorb air pollution. Nano-coatings are also being used to add mould resistance or biocidal properties to finishes. Nano-machines can be constructed at the atomic level to act as miniature pumps to move materials across barriers or up concentration gradients. Currently under development, a new generation of 'hairy' PV panels are being developed using carbon nanotubes to increase the surface area of the panel exposed to the sun. These new panels will be orders of magnitude more efficient than current panels, and will be inexpensive to produce.

Nanotechnology will ultimately lead to enhancement of the physical properties of conventional materials, and may also lead to the development of entirely new production processes (BTSC 2006). These processes are likely to have greater energy efficiency, better throughput, reduced use of raw materials and less waste (BTSC 2006). Research is continuing worldwide, with significant investment in development of nanotechnology for applications ranging from energy production to drug delivery systems and health monitoring. Applications relevant for the built environment include energy storage, production and conversion; water treatment and remediation; air pollution and remediation; and construction applications as mentioned earlier.

Equipment technology innovations

Just as materials continue to evolve in the construction domain, construction equipment also has the potential to contribute to increased project sustainability as new technologies and ideas are applied. For instance, increased attention is being given to the impacts of construction equipment on air quality. Heavy construction equipment and other tools such as portable generators have significant impacts on local air quality. The burning of diesel fuel for heavy equipment in particular has been linked with human health problems such as asthma and bronchitis. Diesel exhaust contains nitrogen oxides and extremely fine particulates that can lodge in human lungs and cause both short and long-term health problems. Diesel exhaust has been linked to cancer in several studies. Children and adults with respiratory problems are especially vulnerable to health problems from diesel emissions.

As a result of concerns about diesel exhaust, the US Environmental Protection Agency (USEPA) has created the Clean Construction USA program to address this problem. Clean Construction USA provides incentives to reduce the emissions of diesel exhaust on construction sites. Tough new standards have been put into place for engines on new construction equipment, but existing equipment still causes problems. Diesel engines on construction equipment can be in service for as long as 25 to 30 years. Clean Construction USA encourages reducing idling time for heavy equipment where possible. It also encourages installing after-market treatment technologies to reduce emissions from heavy equipment.

New fuel sources for heavy equipment such as biodiesel are also expected to reduce emissions while simultaneously relieving dependencies on non-renewable fuel sources such as oil. Other fuel sources are also being explored for transport in construction as well. In addition to alternative fuel systems based on hydrogen, or electricity, compressed air vehicles are also an area of investigation for construction applications (Nguyen 2008b). Originally invented more than a century ago, vehicles with compressed-air engines are presently in use commercially in Europe and India, but have not been widely diffused beyond these countries. Such vehicles operate using compressed air that is recharged using a relatively small amount of electricity using electrical air compressors. As such, they produce zero pollution while operating. The air expelled from the vehicle during operation is clean and cold, so it can be used as part of an internal air conditioning system. The current high speed of such vehicles is 68 miles per hour, with a range of 200–300 km (Nguyen 2008b). Moteur Development International (MDI) is presently the leading firm in this domain.

An innovation recently entering the marketplace is hybrid diesel-electric heavy equipment. Komatsu now offers a hydraulic excavator with an electric motor to supplement its diesel engine, reducing fuel consumption by 25 per cent on average and over 40 per cent in some cases. The hybrid captures the kinetic energy of the upper structure of the machine (the turning shovel) as it slows down, and then uses that energy to power the accelerating engine. It also manages equipment idling, much like a hybrid car. Other manufacturers are pursuing hybrid technology as well, including Volvo, Hitachi and Sumitomo (http://solveclimate.com).

From the standpoint of construction tools, power supplies represent a historically cumbersome necessity to getting the job done. Power cords to conventional tools limit movement, reduce productivity, and present potential safety hazards that could lead to trips, falls or electrocution if they are severed. Battery technology has improved to a point where many traditionally corded tools have been replaced by cordless models, but these tools do not always provide adequate power to achieve the same performance as their corded counterparts, and the increased use of batteries requires both additional planning to ensure adequate charges and a significant waste stream of hazardous materials as batteries reach the end of their service life and are discarded. An alternative to these power sources is inductive power transfer, also known as wireless power transmission. Nikola Tesla pioneered original work in this area in the early twentieth century, but only recently has it been pushed toward potential commercialization in the construction industry. Passive radio frequency identification (RFID) tags make use of this phenomenon, and as recently as 2009, Bosch demonstrated a toolbox that could be used on the job site to wirelessly charge battery-powered tools stored inside (Goodrum and DeLoach 2009). While these applications rely on short distances to work properly, on the order of several inches, technologies are presently under development to establish longer wireless distance applications using radio waves or lasers. Lasers hold the most promise at present for longer-distance transmission, but they require a clear line of sight to function. There are also concerns about the potential health impacts of high-intensity energy transmissions and limited efficiency of cordless tools in general. However, the ability to transfer power wirelessly may lead to increased productivity and a reduction in the use of temporary power cables that are both costly and dangerous during the construction process (Goodrum and DeLoach 2009).

Process improvement

Several trends in the industry are notable for their contributions toward improving the process of construction project delivery. Lean and green construction, design for adaptability (DFAD), DfX and dematerialization are all ways in which built facilities are becoming more sustainable through process improvements. The following subsections further describe these trends.

Process improvement trends

- Lean construction.
- Design for adaptability (DFAD).
- Design for X (DfX).
- Dematerialization.

Lean and green

During the construction process, lean construction methods can be employed to maximize efficiency. Lean construction is a set of practices that eliminates unneeded steps and materials, eliminating the concept of waste by changing the way projects are built. It is modelled after lean production principles pioneered in the manufacturing industry. For instance, just-in-time delivery of materials to the site means that products are installed right off the truck without being stored or staged. This eliminates the opportunity for materials to become damaged in storage, and minimizes the opportunity for damage as they are moved around the site.

Four key considerations define the philosophy of lean construction (quoted from Lean Construction Institute 2007):

1. The facility and its delivery process are designed together to better reveal and support customer purposes. Positive iteration within the process is supported, and negative iteration is reduced.
2. Work is structured throughout the integrated process to maximize value and to reduce waste at the project delivery level.
3. Efforts to manage and improve performance are aimed at improving total project performance, because it is more important than reducing cost or increasing speed of any single activity (local suboptimization at the expense of global optimization).
4. 'Control' is redefined from 'monitoring results' to 'making things happen'. The performance of planning and control systems are measured and improved.

Ultimately, the focus of a lean construction process is on optimizing the project outcome as a whole rather than optimizing individual pieces and hoping for the best outcome. With the product (facility) and process (delivery) designed together, the attributes of one can be selected to be responsive to the constraints of the other.

The Lean Construction Institute (www.leanconstruction.org) is a non-profit organization that exists to extend lean production principles from manufacturing into the construction domain. Extensive readings on the topic can be found in its online library, along with a discussion of the latest research on the topic and a link to the *Lean Construction Journal.*

Design for adaptability (DFAD)

Design for Adaptability (DFAD) is a design philosophy based on the premise that a product's life-cycle ends because the product itself is unable to adapt to change (Kasarda et al 2007):

A product may be retired for myriad reasons including that it is broken, out of style, or has become inefficient due to technology obsolescence. In these cases, the product was not able to adapt to change – it was unable to self-heal, it could not modify or reconfigure to meet changing fashion needs, or it could not be upgraded, for physical or economic reasons, to utilize new technology.

The DFAD technique uses classical control theory to design and model products as dynamic systems with feedback control strategies to respond or adapt to changes in performance criteria. Extending a product's life-cycle will improve its overall sustainability by reducing the need to employ new resources to replace it. The DFAD approach ensures that products with extended life-cycles are able to maintain desired performance in terms of physical, cultural, environmental, and economic considerations. Under DFAD, products may be remanufactured to meet changing needs, or they may incorporate self-healing materials and designs to undertake changes autonomously. In either

Table 10.1 Types of change in a built facility

Category	Response
Upgrade existing functions	Higher performance levels that require different components/processes
Incorporate new functions	New facility performance objectives that require new components/systems
Modify for different functions	Different objectives from change in usage class that require different components/systems/processes
Change loads/conditions	Higher expected performance under specific load conditions
Change volume	Increased requirements for operable space per usage class
Change in environmental flows	Higher/different performance requirements for internal or surrounding environmental conditions
Change in flow of people/things	Different performance requirements for passage, movement or organization of people/things within/into facility

Source: Slaughter (2001).

case, dynamic stability or equilibrium is maintained over time through the artefact's ability to adjust to changing context and requirements.

From the standpoint of built facilities, buildings have historically been relatively static elements existing within dynamic environments. Facilities must evolve in response to three main types of changes: change in functional use requirements, change in required load capacity, or change in the flows of people, environment, or things within the space (Slaughter 2001 – see Table 10.1).

DfX

Design for X (DfX) is a broader set of ideas of which DFAD is a specific subset. Under DfX, where X is a variable that can represent any of a variety of desirable attributes that the end product might have. From this standpoint, the design process is specifically aimed to result in a product that has those desirable attributes related to the product's lifecycle. Design guidelines under each paradigm help to generate and apply technical knowledge to control, improve or invent characteristics of a product. The acronym DFX is also used in a more general sense to mean 'design for excellence'. A variety of paradigms have been developed under this idea that have been or can be applied to the built environment, some of which are listed in Table 10.2.

DfX is characterized by a systematic procedure that typically includes seven steps (Table 10.3). By following these steps, a project team can systematically identify improvement opportunities and alternatives, and prioritize those alternatives that warrant the most attention.

Table 10.2 DfX paradigms

Strategy	Results in
Design for constructability (DfC)	Buildings that can be easily or efficiently constructed in a variety of possible use environments using existing means and methods; equivalent to design for manufacturability or design for assembly on a product scale
Design for operability/ maintainability (DfOM)	Buildings and systems that can be easily and efficiently operated and maintained; design for operability is equivalent to design for serviceability on a product scale
Design for disassembly/ deconstruction (DfD)	Buildings that can be easily taken apart at the end of their service life with recovery of components in reusable condition
Design for adaptability (DFAD)	Buildings that can change in response to changes in performance requirements or environmental conditions
Design for safety (DfS)	Buildings that can be constructed and used without danger to human stakeholders
Design for quality (DfQ)	Buildings that meet or exceed desired levels of quality and performance
Design for cost (DfC)	Buildings that meet or exceed desired goals for first cost and life-cycle cost
Design for reuse (DfR)	Buildings that can be reused after their first service life, or systems within a building that can be reused in other buildings when they are no longer needed
Design for environment (DfE)	Buildings whose environmental impacts over their life-cycle are better than conventional practice

Table 10.3 Procedure for DfX

Step	Objective
1. Product analysis	Collect and clarify information related to the product being designed.
2. Process analysis	Collect, process and report process-specific data.
3. Measuring performance	Measure product and process performance data as a basis for evaluating performance.
4. Highlight by benchmarking	Establish standards to determine whether or not the product/process is good according to the desired attribute represented by X.
5. Diagnosis for improvement	Determine the causes or reasons for measured performance of the product/process.
6. Advise on change	Explore as many improvement alternatives as possible for each problem area. Many generalized improvement actions have already been identified for each of the types of DfX listed in Table 10.2 (such as 'minimize parts' for DfD).
7. Prioritize	Determine which items can be immediately improved with minor effort, and which of the remaining items are vital and should be pursued with additional resources

Source: adapted from Huang (1996).

Dematerialization

Dematerialization refers to the reduction in the amount of raw materials and energy needed to produce a product or outcome or, in the most general sense, provide an economic function (Ausubel 1996). In the context of built facilities, it can also refer to substitution of services to meet needs that were traditionally met by the purchase of goods. Rather than take ownership responsibility (and associated liability) for equipment, owners pay another company to provide the benefits of that equipment for their project. That company, often the manufacturer of the equipment, has an incentive to provide the most efficient equipment possible, since it reaps its profits based on some profit margin per unit of service provided. It also has incentive to design products that can be easily repaired, upgraded or disassembled, since it retains responsibility for the ongoing maintenance and eventual disposition of the equipment.

A growing number of building systems and components, ranging from roof systems to flooring to mechanical and electrical systems, are available as services from companies that will install appropriate systems to provide a level of performance defined in the contract on a fee or pay-for-performance basis. The Evergreen Lease™ system from Interface FLOR carpet is one example of such a programme that provides carpet tiles. Some companies also incorporate maintenance services to optimize the performance of their systems, since this ensures proper maintenance performed efficiently and on time. The primary advantage of dematerialization with respect to first cost is that the cost of these systems is typically shifted to an operational cost, thereby eliminating those systems from the total installed cost of the project. Often higher-performance systems can be afforded on a lease basis than could be afforded if the system were purchased and included as part of the project's first cost.

Sustainable infrastructure systems

The domain of infrastructure systems warrants special mention as part of the future of sustainable design and construction. Although attention to sustainability trends in this sector lags behind the vertical construction sector, innovations are now beginning to emerge in this domain, many of which stem from the evolution of sustainability in buildings. The following subsections describe specific trends and predictions for sustainable infrastructure in the transportation/mobility, water/wastewater, power and distribution, and telecommunications domains. The section concludes with an overview of upcoming trends now emerging to achieve integrated functionality across multiple infrastructure services.

Transportation and mobility systems

While engineers in the transportation sector have historically focused on the capital project investments such as bridges, highways, ports and airports needed to make society run, in the future, a greater focus will be placed on transportation as a service. The new watchword in sustainable transportation is mobility, the ability to get from one place to another, rather than transportation, the hardware or capital facilities used to get there. In the world of sustainable mobility, focus will be on a diverse mix of alternate modes of transportation, with modes carefully matched to the needs they are meeting (Goble 2009b). Within this mix, human-powered transportation will regain prominence in developed countries as fossil-fuel-based transportation becomes increasingly congested and expensive.

Alternative fuel vehicle development is already growing exponentially in response to awareness of the finite reserves of fossil fuels. To provide venues for these vehicles, infrastructure including roads, bridges, tunnels and streets is continuing to evolve. In 2020, these types of infrastructure systems will uniformly incorporate more sustainable features that are only beginning to be used today such as (HNTB 2010, Danigelis 2010):

- Recycled material, such as pulverized rubber tyres, waste bituminous roofing materials, plastics, glass and broken concrete used for road surface and underlays.
- Habitat preservation including roadside native plantings that also allow for reduced continuing maintenance.
- Vegetative noise barriers as an alternative to concrete noise walls that both absorb unwanted noise pollution and improve air quality.
- Green drainage that diverts water to rain gardens and bioswales, which ultimately filter it back as groundwater.
- Green lanes dedicated to high-density vehicles such as buses, ride-sharing commuters and energy-efficient vehicles.
- Permeable pavement that helps keep stormwater infiltration at pre-construction rates, recharges groundwater, cleans roadway pollutants and strains suspended solids from runoff.
- Road lighting that is self-generated from wind or solar applications and that uses energy efficient led fixtures (see figure 10.3).
- Recycled coal fly ash and other post-industrial recycled materials that serve as additives for paving applications.
- Plastic-fibre reinforced concrete that increases structural integrity and density.

Technologies still on the drawing board or in early prototype today will be actively in use in 2020 to improve transportation infrastructure. These include:

- Vehicle-based sensors to automatically provide condition assessment data for roads, railways, bridges and other structures and surfaces. This data will be collected centrally and used to develop maintenance and replacement plans based on real-time condition data coupled with predictive models.

Figure 10.3 Self-generating light fixtures feature efficient LED lighting powered by PV panels during sunny periods and wind turbines during cloudy periods

- Self-healing and environmentally responsive materials such as concrete with unhydrated cement particles that hydrate when exposed to moisture through cracks, or concrete containing carbon nanotubes that is both stronger and able to detect and report stress conditions based on embedded sensors.
- Trackless elevated trains constructed over existing transportation rights-of-way to reduce space needs while multiplying the capacity of existing corridors.
- Technologies to use existing road or rail infrastructure for the generation of power, through, for example, embedded PV or piezoelectric cells, linking sectors of pavements at different depths with semiconductors to generate thermoelectric power, embedding piping to capture solar thermal energy, or applying flexible PV cells to existing structures such as concrete Jersey barrier (Bright 2010a, Singh 2010a, 2010b).

We can also expect significant growth in the development of multimodal hubs to allow better connectivity between different modes of transport, especially as urban densities continue to increase. Pedestrian and bicycling facilities will also be better integrated into the urban fabric, with human-powered modes taking precedent over fuel-powered modes of transport as part of urban planning. Finally, new approaches to financing, delivery, and ongoing operations and maintenance of these facilities will continue to evolve to better align incentives with functional requirements and allocate risks among stakeholders.

Water and wastewater systems

Despite the beliefs of many that fossil fuels will be the limiting factor to growth in the twenty-first century, water may prove to be an even more valuable, tenuous resource that shapes future development. Already in many parts of the world, water scarcity, uneven distribution, volatility of supply, and pollution and contamination reduce quality of life and endanger public health and prosperity. The need for water where there is insufficient supply has led to some of the most ambitious projects or proposed projects of our times, including the upcoming Yangtze River diversion in China and multiple plans for diversion of rivers in the United States to supply southern California's growing water demands. Removing or barring unwanted water has also been a major civil engineering challenge, such as the Venice tide barrier project in Venice, Italy, and it is likely to become a more frequent type of project as sea levels rise in response to climate change. Flood control and hydroelectric power generation has led to megaprojects such as the Three Gorges Dam in China which have reshaped huge areas of the planet and may lead to unanticipated consequences beyond our imagination. Water is one of the most sensitive political topics in many parts of the world, and it is likely to only become worse as global climate change results in more extreme weather patterns and increasing global temperatures worldwide.

Three key areas are likely to see major innovations over the next ten years in order to meet the world's water needs: new approaches for water distribution and allocation; improved treatment technologies; and new strategies, policies and technologies for water reuse. Examples of technologies that may be in use by 2020 are:

- New biomimetic membranes based on the chemical processes used by tree roots that treat saltwater or contaminated water using drastically less energy than current desalinization or osmosis treatment methods.
- Distributed scale and hybrid distributed-centralized networks of treatment systems that enable water to be treated closer to the point of use. This approach will save pumping energy by reducing the distance water needs to travel between its use and reuse. Such systems may also be more responsive to local water conditions, fine-tuning the treatment approach based on what contaminants are present at a given point in time.
- Self-healing pipes that use a mechanism similar to blood clotting to repair and block leaks, and better approaches to condition assessment such as robotic leak detection.
- Bacteria that react with contaminated or toxic water by glowing, to serve as biosensors for identifying specific water contaminants.
- Simultaneous generation of electricity from wastewater treatment residuals using anaerobic respiration, or sludge/recovered biogas as a biofuel (Bright 2010b, 2010e; Pisutpaisal 2004; Siemens 2010).

Water technologies are also likely to be closely integrated in a distributed network with vertical construction to provide local water capture and reuse for purposes such as urban or vertical agriculture or beneficial landscaping. Laws and policy for the allocation of water rights will also continue to evolve in many places as usable water becomes increasingly scarce. Better models of water on an urban systems or regional scale are presently under development in countries such as the United States to better predict water supply and demand issues, and balance water use in a sustainable and equitable way. The notion of a smart water grid, analogous to the smart energy grid (next section) is also being developed as a way to optimize water distribution and balance consumption for non-essential uses with fluctuation in supply over time:

> A Smart Water Grid delivers water from suppliers to consumers using two-way digital technology to control consumption at consumers' homes to save water, reduce cost and increase reliability and transparency. It overlays the water distribution system with an information and net metering system. A Smart Water Grid includes an intelligent monitoring system that keeps track of all water flowing in the system. It also incorporates the use of monitored water mains for less water loss, as well as the capability of integrating renewable water. When water is least expensive the user can allow to the Smart Water Grid to turn on selected water-consuming appliances such as sprinklers or water-boiler pumps that can run at arbitrary hours.
>
> (Horowitz 2010)

Combined with integrated sensing and information systems and smart control algorithms, the smart water grid will allow industry and consumers alike to do more with less water, an essential goal for a more sustainable world.

Energy generation, storage and distribution systems

As with water, energy is an essential part of contemporary society and is necessary for meeting human needs and aspirations. It is the foundation of all other critical infrastructure systems, including water, wastewater treatment, transportation and telecommunications. Historically, the generation of electricity from fossil fuels has been responsible for a large share of the current global climate change problem. At present, considerable research and development is in process to identify new means of generating energy and for more effectively storing, distributing and using the energy that is generated.

From the standpoint of energy generation, research continues into new ways to make electricity at both small and large scales. While many viable technologies exist for large-scale power generation, investment in those technologies has lagged behind demand growth for multiple reasons. By 2020, many of these technologies, including solar thermal, PV, large-scale wind and tidal energy, biomass and geothermal power generation will be brought online worldwide. On a smaller level, localized, distributed power generation will be commonplace, and PV and piezoelectric generators will be integrated with everything from highways to sidewalks to turnstiles in subway stations as a way to generate electricity from every potential source. Net-zero-energy buildings are a reality today, and they will be widespread by 2020 as economies of scale bring down the cost of renewable energy technologies.

A key to more effective use of generated power, particularly from distributed sources, is a smarter electrical grid that can better balance power supply and demand. Smart grid technologies are receiving significant investment as a means to use the power of information to maximize the utility of electrical energy. As with water, the smart grid balances discrepancies in energy demand by reducing power flow to nonessential uses, and can optimize power cost by shifting demand for time-flexible uses to non-peak periods when power is less expensive. The smart grid will also be able to balance many distributed sources of electrical energy and take advantage of such sources as small building-integrated PV arrays to displace centralized power generation when conditions are favourable.

Better systems for energy storage will be a huge component of a sustainable energy infrastructure system. Technologies for flywheel storage, hydraulic head storage and others are presently under development or small-scale deployment and will be an essential part of the smart grid by 2020. Given the likely shift from fossil fuels as energy sources for transport to electric vehicles, there will be significant new demands for energy even as our fundamental sources for that energy dwindle and become less reliable.

In terms of the physical infrastructure that comprises today's electrical grid, significant advances are being made in transmission technology such as self-healing coatings on transmission lines and automated condition assessment systems for those lines. New generations of superconducting lines are also under development and will be a key part of the built environment as existing lines reach the end of their useful service life (Bright 2010c).

Telecommunications systems

Information technology (IT) is at the heart of many of the smart infrastructure systems of tomorrow. As the backbone of today's information-driven society, the telecommunications infrastructure that allows information to flow is dependent upon reliable sources of energy even as the systems that generate that energy depend upon it. While wireless telecommunication is becoming the standard that allows us to be constantly connected to information no matter where we are, it ultimately depends on hard-wired systems that transfer data at high speeds from point to point. Investment in new infrastructure to support this skeleton is growing, and its vulnerability from an energy standpoint is well understood. New approaches to greening data centres and operating them with lower electrical demand are now being pioneered and will become commonplace by 2020. The movement of data from local storage to the cloud as part of the revolution in cloud computing (see Goble 2009a and others) will necessitate ever more attention to the core infrastructure of server farms, data centres and backbone transmission lines as data storage becomes dematerialized, a commodity service that can be outsourced instead of something that exists locally on power-consuming hard drives.

Ultimately, many people envision a world that has access to high-speed data communications no matter where one is on the planet. Technologies presently on the drawing board include, for instance, air-based nodes for data transmission using high-altitude blimps (Bright 2010d). A large part of the planet remains disconnected, especially in developing countries where only low bandwidth is available. Integrated telecommunications will be at the core of the built environment of 2020. Information will allow the world to continue to reduce its carbon footprint and further dematerialize and reduce demands on other types of infrastructure. For example, better bandwidth will facilitate telecommunication, thereby reducing demands for transportation infrastructure. Online billing, banking and tax returns will save megatons of carbon, through reduction in raw materials used and the physical transport of those materials throughout their life-cycle (Scheck 2008). Ultimately, telecommunications will be an integral part of the sustainable world of the future.

Infrastructure systems integration

The question of what is the optimal scale for sustainable infrastructure is now emerging as an area for investigation through research. Historically, trends pointed toward ever more centralized plants to provide infrastructure services, with engineers providing expert knowledge to advance the performance of these systems as technologies evolved. Today, however, there is a greater trend toward distributed infrastructure and self-reliance of buildings. In many parts of the world, centralized infrastructure remains unreliable and poorly functioning, if it exists at all. The trend toward net-zero buildings, which use distributed technologies to provide for their own power and water needs and may even provide excess infrastructure capacity to the surrounding community, is receiving increased attention in the developed world.

Beyond conventional engineering perceptions of infrastructure as a human-designed and managed endeavour, new ideas for sustainable infrastructure often include integration with and support of natural and human-adapted ecological systems as well. Planning development to preserve biodiversity and ecological resources requires careful attention to the needs and requirements of natural ecosystems, such as adequate area and connective corridors to allow for migration of wildlife and other functional requirements. Infrastructure based on natural systems can help to do just that.

Four pillars of sustainable infrastructure

- Better management.
- Full-cost pricing.
- Efficient resource use.
- Whole systems approaches.

Source: US Environmental Protection Agency.

The US Environmental Protection Agency (USEPA) has identified four pillars of sustainable infrastructure in the context of water and wastewater systems, but these pillars can be generalized to apply to multiple types of infrastructure systems as well (USEPA 2010). First, better management of centralized utilities along with smart grid integration of distributed infrastructure can help balance supply with demand and direct resources to where they are most needed within the overall system at any point in time, while pulling from sources that are most sustainable to the greatest extent. Asset management and environmental management systems can contribute to more sustainable operations of centralized utilities, and alternative financing and delivery models such as public–private partnerships can help to stretch limited funding to provide greater services. Coupled with new generations of condition assessment and smart management technology, systematic management can be used to direct resources toward where they will do the most good.

Along with better management of infrastructure systems, rates that reflect full-cost pricing of services and the actual cost to deliver them will be essential to drive behavioural change and business practices to reflect the true value of limited resources. In particular, centralized infrastructure provided by public agencies will need to investigate methods for full cost recovery of these systems to ensure that operations over time is sustainable.

Better methods and technologies for demand-side management and increased efficiency such as those discussed in Chapters 5 to 8 of this book will also be critical for sustainable infrastructure. To keep pace with future population growth and growth in standards of living, behaviour change will have to be coupled with more efficient technologies to achieve desired standards of living, especially in a free market economy where consumers will choose the best-performing alternative they can afford.

Finally, whole systems approaches to management and design will be essential to achieve optimal systems performance. Not only will individual infrastructure systems need to be managed in the context of a larger scope, those systems will need to be integrated and optimized with other types of infrastructure. For example, opportunities exist to generate power from wastewater treatment, solid waste management, and even as part of transportation infrastructure, and integrating these systems in the future will help to exploit such synergies. Likewise, greater dependence on telecommunications may reduce demand for transportation systems during times of peak congestion. Better approaches to integrated whole systems modelling will be critical to ensure that systems are optimized from a holistic perspective to serve the needs of society.

Broader sustainability trends across the construction industry

In addition to the emerging technologies and process improvements already mentioned as being at the leading edge of construction and sustainable infrastructure systems, several broader trends are also influencing the AEC industry. Biomimicry and industrial ecology, BIM, and climate change and passive survivability are all trends that will shape the future of the industry. The following subsections describe each of these trends in more detail.

Biomimicry and industrial ecology

The natural environment is a good source of ideas for making buildings greener. Designers and researchers have begun to look to nature for inspiration as they develop new building materials and systems. This approach is known as biomimicry – imitating nature to create new solutions modelled after natural systems. Nature produces robust solutions with optimum efficiency. Plants and animals that cannot compete simply do not survive. As we head into an age of increasingly scarce resources and a larger population who need them, biomimicry offers valuable lessons for our buildings and technologies alike. There are nine basic attributes of nature that can serve as a core set of biomimicry principles for design and construction of human systems (Benyus 2002 – see box).

Biomimicry principles for sustainable design and construction

- Nature runs on sunlight.
- Nature uses only the energy it needs.
- Nature fits form to function.
- Nature recycles everything.
- Nature rewards cooperation.
- Nature banks on diversity.
- Nature demands local expertise.
- Nature curbs excesses from within.
- Nature taps the power of limits.

Some of the examples from nature that are being considered for potential application in the construction industry are:

- The lotus leaf, where air bubbles trapped under the microscopically rough surface of lotus leaves make water droplets roll off the surface, taking with them dust particles and contaminants. This results in a self-cleaning surface.
- African termite mounds, where the geometry of the mound creates natural convective pathways that encourage ventilation, and the thermal mass of the mound walls buffers temperature changes. Together, these properties maintain temperatures within the mound that are significantly more comfortable than ambient conditions.
- Spider silk, which is as strong as Kevlar but manufactured into extremely durable molecular protein structures on a diet of insects at ambient temperatures instead of using hazardous chemicals at extremely high artificial temperatures and pressures.

- Sheep's feet, which provide even and thorough compaction of clay soils and can be mimicked for soil compaction on the construction site.
- Pine cones, which have a structure that is naturally 'breathable'. This structure can be mimicked to create breathable fibre-reinforced plastic plates that can be used for structural retrofits.
- Self-assembling, self-healing biological organisms – all animals self-assemble their bodies during gestation and are able to self-heal many wounds. Materials such as concrete can be imbued with these qualities to self-repair cracking that would otherwise lead to erosion of reinforcing steel or other damage.
- Natural fibres, which are comparable in terms of stiffness and strength to glass fibres presently employed in building materials, and are more resilient and damage tolerant. They can also be recovered for fuel at the end of their service lives (Nguyen 2008a).

Examples of commercialized building products designed using the principles of biomimicry are:

- I2 Entropy, a carpet tile product by Interface FLOR that contains patterns based on observation of natural landscapes. These tiles are designed in such a way that directional installation is not required. This saves installation time and results in a pattern that looks natural no matter how the product is installed.
- TX Active concrete products, made by Essroc Corporation, contain titanium dioxide that is photocatalytic; in the presence of sunlight, it releases an electrical charge at the surface that oxidizes contaminants on the surface of the material and makes them release easily from the surface, resulting in a self-cleaning material. The Aria line of products is claimed to actually clean the surrounding air by attracting and depositing particulates from it.
- Self-deploying structures, currently under development, that react to changes in their environment such as loads and movements to remain structurally viable. These structures may also be constructed of biomimetic materials themselves in addition to functioning biomimetically.

At a larger scale, industrial ecology involves mimicking the function of entire ecosystems in designing human enterprises. Industrial ecology involves the deliberate design of industrial systems such that the waste from one system can be used as the feedstock to another. Complementary industries may be colocated in so-called industrial 'ecoparks' to minimize the transport requirements for sharing waste streams. Some ecoparks, such as the well-known park in Kalundborg, Denmark, also include non-industrial parts of the community as part of the symbiosis achieved. Figure 10.4 shows the major components included in the Kalundborg network.

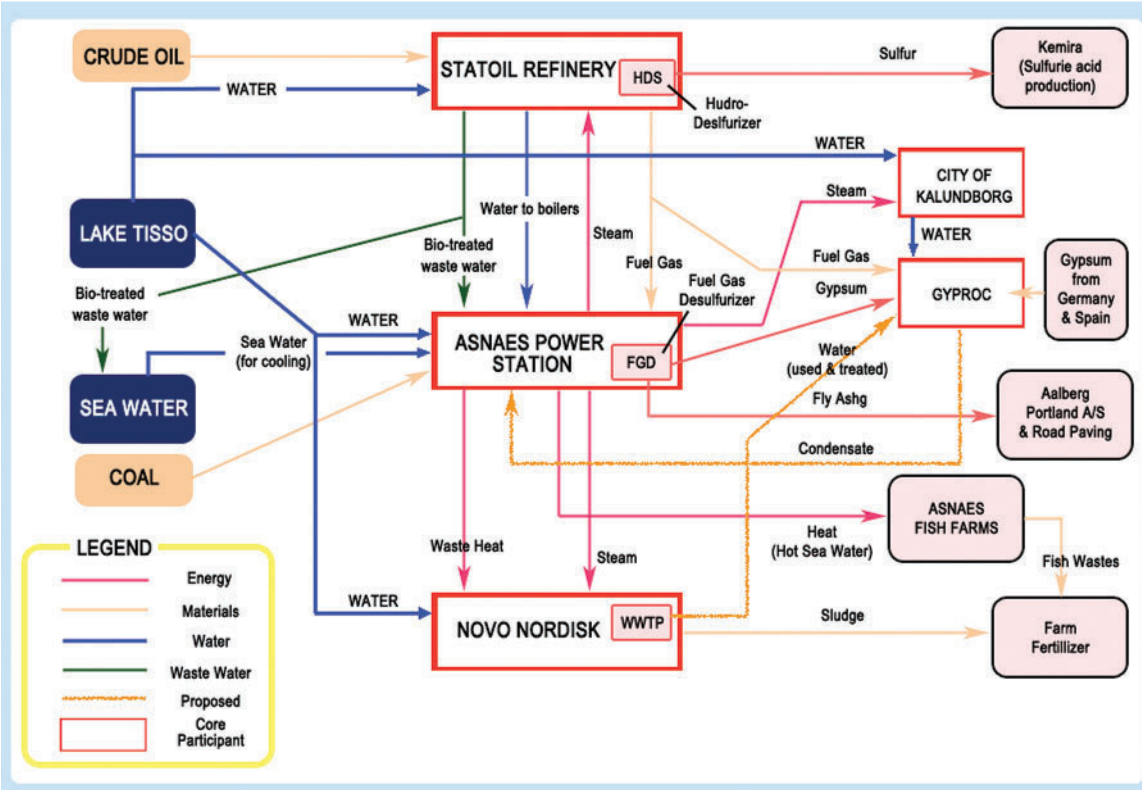


Figure 10.4 Components in the Kalundborg Industrial Ecology Network
Source: www.indigodev.com/images/Kis95.gif

Figure 10.5 A concrete plant is located near Power Plant #3 in Ulan Baatar, Mongolia

Common examples of industrial ecology include the colocation of cement and concrete facilities near coal-fired power plants (Figure 10.5). The flyash produced during combustion of coal to make power can be used in place of Portland cement for making concrete, and waste heat from the power plant can also be used to support the enormous energy requirements for operating the cement kiln itself.

Overall, the principles of industrial ecology and biomimicry allow designers to learn from natural systems that have been evolving since the dawn of life on Earth. They facilitate taking advantage of waste as food, rather than using a linear process of taking resources from the earth, using them, and generating waste that must be distributed back to the natural environment.

Building information modelling (BIM)

Quality sustainable design requires an understanding of how a building will perform after it is built, which in turn requires computer-based simulation software for rigorous building analysis. The advent of BIM offers even greater opportunities for building analysis by pairing the analysis software and BIM for the seamless assessment of building performance. BIM refers to the creation and coordinated use of a collection of digital information about a building project. The information is used for design development and decision making, production of high-quality construction documents, predicting performance, cost estimating and construction planning, and eventually, for managing and operating the facility. BIM has the potential to support life-cycle management and decision making for built facilities, and represents considerable potential for eliminating process waste as part of the facility delivery process. As such, it is well suited to support efforts to increase project sustainability, although opportunities for additional development of BIM tools abound.

A well-populated building information model carries a wealth of information necessary for many aspects of sustainable design and green certification. For instance, schedules of building material quantities can be obtained directly from the model to determine percentages of material reuse, recycling or salvage. Various design options for sustainability can be pursued in parallel and automatically tracked in the model. Advanced visualization techniques can be used for solar studies and to produce 3D renderings and construction animations of a green project.

In order to achieve more comprehensive sustainable solutions, an expansion of traditional thinking is required while making decisions during the design process, including:

- understanding climate, culture and place
- understanding the function of the building
- understanding the needs of the community
- minimizing the consumption of resources
- using locally available resources and natural systems
- using efficient human-made systems
- applying renewable energy generation systems.

A fundamental tenet of sustainable design is the integration of all the building systems among themselves as well as with the external economic, social and environmental context of the project. Therefore, the combination of high-performance sustainable design strategies and BIM technology has the potential to change the profession dramatically and bring a higher-quality design to mainstream architectural practice. Computer technology by itself is not a universal solution, but combined with a comprehensive sustainable design methodology, it can provide powerful support for efficient, expanded and improved services.

Several key challenges still exist with regard to implementing BIM in the pursuit of project sustainability. For example, BIMs have the capability to report areas and quantities from within the model for various parameters that contribute to the sustainability of the project, including water conservation, energy analysis, computational fluid dynamics and daylighting analysis. However, this flow of information at times is so detailed and complex that even specialists avoid using it for decision making because of the considerable effort required in the very beginning of the project to set up the BIM model. Also, the bidirectional flow of information between the architect and design specialists is restricted during design in some cases because of interoperability challenges. BIM has the potential to support a systems-based approach to measuring sustainability, but projects still have vast amounts of segregated data and no single platform that can integrate it. Once this integration of segregated information is achieved on a single platform, BIM will be able to greatly facilitate systems-based sustainability analysis.

One example of this degree of integration is a facility whose orientation is altered during design in order to improve energy efficiency, which may affect daylighting schemes, fenestration, shading, and heating and cooling systems for the building. Changes in the products used for these components could also impact on the tallies of materials, with properties such as recycled or rapidly renewable content. In order to calculate the overall effects of a single change in design process in a holistic fashion, an integration of all the relevant information on a single platform is required, a big obstacle that needs to be overcome. This scenario reflects the fact that a BIM model could be better suited for a systems-based approach where the whole facility is analysed and assessed over its entire lifecycle.

Governments around the globe are implementing new policies and building regulations that mandate sustainable design. However, the design community still lacks widespread experience and understanding of sustainability concepts. For decades, simulation software tools have been available to assist the design of energy-efficient buildings. Unfortunately these tools have historically been difficult to use and thus limited to specialists, so many designers rely instead on simple hand-calculation methods to assess building performance. Structural and mechanical models are being used to interact with architectural models for the purpose of coordination. However, the capacity of software to perform all the aspects of modelling and analysis critical for achieving sustainable design remains unrealized. Versions of BIM models are exported and then imported into separate software packages that produce information that is then translated back to the design team for further adjustments to the design. Further, information regarding the environmental impact of material and system choices is still collected and integrated in the legacy fashion of catalogue and manual referencing.

Perhaps the most interesting connection for sustainable design is the link between BIM and analytic tools that provide insight about the predicted energy or resource use for a proposed design. For example, BIM users can directly link to third-party proprietary suites of building performance management tools, enabling architects and engineers to visualize daylighting, fluid dynamics and energy performance for specific spaces in a proposed project. By quickly revising the model and analysing the impacts of these performance parameters on the building, architects can work in a more fluid but integrated and semi-automated process, while creating increasingly sustainable designs.

However, realizing the true potential of BIM tools to incorporate sustainability requires an understanding of the different types of sustainability measurement systems. While BIM tools offer significant potential to support sustainable design and the data needs of all three approaches to sustainability measurement, there are still considerable needs for further tool development to bring this technology to the point where it can be truly useful for systems-based sustainability analysis. Table 10.4 provides an inventory of current BIM tools in terms of their abilities to measure inputs and outputs to a facility system, a core part of systems-based sustainability analysis. While this flow inventory is not comprehensive, it does highlight the state of the art in current tools in terms of their ability to support systems-based sustainability analysis.

BIM technologies can also be characterized and described by the sustainable design strategies that can be investigated using these capabilities, as follows:

- Parametric modelling: building orientation, massing.
- Simulation and analysis tools: daylighting, water harvesting, energy modelling, renewable energy, materials.
- Integration: combining parametric automation capabilities with simulation tools for design optimization.
- Agent-based modelling: integrated software solutions that track a building's carbon footprint such as embodied energy of materials, emissions from construction, and emissions from the fuel it takes to get work crews to the job site.

With continued evolution of BIM to support project sustainability, the fragmented nature of the construction industry and its reluctance to use sustainable options because of cost and schedule issues may be overcome as green BIM evolves to revolutionize the way the industry functions. More specifically, through a more holistic and comprehensive way to virtually represent and understand buildings, the project delivery team will have better knowledge of the parameters related to sustainability and will be able to examine the implications of trade-offs among project alternatives.

In the future, BIM will hopefully continue to evolve to support sustainability assessment not only at the scale of individual facilities, but also at other scales of analysis. Combining BIM models for individual projects to support portfolio-scale analysis is one such opportunity. Ultimately, green BIM has the potential to lead to more sustainable projects at multiple levels. With better understanding of how facilities perform and how their delivery can be streamlined, green BIM has the potential to reduce the impact of the construction industry and create a better, more sustainable built environment for humans.

Climate change and passive survivability

As the global climate changes, we can expect more severe weather in the future. Severe storms such as Hurricane Katrina in the United States in 2005 will continue to threaten human development, especially as population growth increases the number of people who live in vulnerable areas such as coastal regions or flood plains. For example, an estimated 53 per cent of the population of the United States lives in coastal

Table 10.4 BIM tool capabilities for tracking sustainability-related facility flows

FLOWS IN	FLOWS OUT	TOOL
CASH FLOWS		
Design cost		E, I, R
Construction cost		I
O&M cost		I
Annual maintenance costs		I
	Building-related revenue	
WATER		
Total water demand		G
Potable/nonpotable water demand		G
Indoor/outdoor water demand		G
Rainfall		G
Recycled water		
On-site source		
	Municipal wastewater	
	Groundwater infiltration	
	Stormwater runoff	
ENERGY		
Percent renewable		G
Photovoltaic power		E, G
Fossil fuel		G, I
Nuclear energy		G
Hydroelectric/wind energy		G
Total electricity demand		G, I
Electricity for lighting		E, G, I
Electricity for HVAC		E, G, I
Other electricity use		G, I
Solar heat gain		E, I
Light penetration		E, G, I
	Radiant heat loss	E, I
	Energy produced by building	G, I
MATERIALS & WASTE		
Total material quantity		I, R
Individual material quantity		I, R
Recycled content		I, R
Other material attributes		I, R
	Carbon emissions	G, I
	Total material waste	
	Waste recycled	
	Waste to other sinks	
LEGEND		
E = Ecotect	I = IES Virtual Environment	
G = Green Building Studio	R = Revit Architecture	

zones, making the possibility of rising sea levels and increasingly severe storm events of critical interest there. Other areas are not immune. Tornados, floods, heatwaves, earthquakes and a variety of human-created disasters or errors can cause critical infrastructure and building services to go down at any time. The potential for cyber-terrorism that interrupts control systems for critical infrastructure, and resource shortages and fluctuations exacerbates this problem. How will modern buildings fare when this happens?

Passive survivability is the ability of a building to continue to offer basic function and habitability when its supporting infrastructure, such as power, heating fuel or water supply, fails. There is growing interest in designing buildings around this idea and incorporating passive survivability requirements into the building code. Many contemporary buildings fail miserably when deprived of power. Modern high-rise construction relies on electrical power for everything from ventilation to elevators to pumping water to upper floors. Users may not even be able to open a window for ventilation because of the building design.

Passive survivability is a feature of natural systems that can be modelled in human design. For instance, termite mounds in Australia and Africa are able to control temperature, humidity and ventilation better than most mechanically conditioned buildings designed by humans. Historical vernacular architecture developed before complex analysis methods evolved can also offer key lessons. For instance, the high-mass adobe buildings common in the southwestern United States, Middle East and northern Africa have the ability to absorb and release heat slowly to buffer severe outside temperature swings that occur during a typical diurnal cycle.

The principles of passive survivability align well with sustainable design and construction. Designing buildings to function in the absence of external supplies of energy, water and materials makes them less vulnerable to external threats. It also means that they rely less on the environment for these resources. Passive solar design, natural ventilation, rainwater harvesting, durable materials and greywater reuse are all tactics that both increase passive survivability and increase building sustainability at the same time. Specific areas of consideration in passive survivability design include:

- Natural lighting and incorporation of windows in areas that might be critical during power outages, such as stairwells.
- Building orientation for minimizing cooling and heating requirements.
- Liveable thermal conditions, the design of which depends greatly on climate requirements and local resources; use of local renewable resources for fuel.
- Local renewable energy generation using micro-hydro, photovoltaics, wind and/or others.
- Sanitation, especially in the absence of conventional water supply; waterless urinals and composting toilets are examples of technologies that can provide this function.

- Water collection and reuse, including rainwater harvesting, grey-water recycling systems, and bio-based treatment systems.
- Food production as part of the building structure or landscape and site plan.

Although these features may not be incorporated into every structure, they should be seriously considered as part of a community design strategy, and incorporated into facilities that may be used as emergency shelters during crisis situations, such as schools, hospitals, emergency-service buildings and government buildings. Residential construction can also benefit from these strategies coupled with sustainable landscape designs, thus enabling people to remain in place during crisis situations instead of being displaced to centralized areas where resources may be scarce and conditions are difficult.

Over the horizon: strategic sustainability

One of the most critical trends for the long-term strategic success of business enterprises is an increase in social, resource and environmental constraints imposed by a growing global population with expectations and aspirations for increased standards of living. While concern about the environment and energy resources is not new and has been influencing corporate and institutional policy since the 1970s or before, the need to actively integrate these types of contextual considerations as part of corporate strategy is now and will continue to be essential to the ultimate economic sustainability of these enterprises.

As the nature of corporate enterprises changes in response to contextual constraints, so too must the built environment change which supports and enables those activities. The following subsections highlight ways in which the built environment and industries responsible for delivering and maintaining it and managing its end of life-cycle may change over the short, medium and long terms.

Short-term trends affecting project sustainability

Short-term sustainability trends

- Increasing price volatility for raw materials and energy.
- Reduced reliability of supply for essential commodities.
- Growing consumer awareness and pressure for environmentally and socially responsible products and services.
- Continued population growth.
- Increased vulnerability to natural and human-induced disasters.

Several short-term trends warrant further consideration to establish proactive strategies that can benefit construction companies in the changing global context. These concepts/concerns include:

- Increasing price volatility for raw materials, particularly non-renewable resources and renewables whose harvest or manufacture depends on heavy use of non-renewables (such as fuel costs). This will correspond with increasing volatility and overall costs for energy in all sectors of the economy.
- Reduced supplies/reliability of supplies for essential commodities such as water, coupled with price volatility and overall price increases.
- In developed countries, growing consumer awareness and pressure on the retail and supply sectors for environmentally and socially responsible products and products which maximize resource efficiency over their life-cycles. This trend will correlate with forays into alternative sourcing for products and services by elements in the supply chain closest to ultimate product use.
- In developing countries, continued population growth and increased vulnerability of many of those populations to natural disasters because of the greater density in settlements in vulnerable areas. Increased vying for future stocks of natural resources from developed countries, such as oil reserves.

Mid-term trends in the three-to-ten-year time frame

Issues relevant within three to ten years for the construction industry will influence the mid-term decision horizon for construction companies:

- Increasing volatility in the basic sources of supply for raw materials, due to both increasing scarcity of supply and growing sociopolitical and ecological volatility in regions where raw materials are harvested.
- Increased awareness of traditional modes of transport as a major source of friction in the economic system, as a result of rising fuel costs and increased concern for carbon emissions. Along with this will come a search for alternative transport modes to meet not only personal mobility needs but also needs associated with transportation of goods.
- Increasing savvy among end consumers about the ecological and social impacts of purchasing decisions; this may begin to trickle back to influence overall corporate decision making in the industrial and manufacturing sectors. It will be driven by an increased availability of information and tools to support decision making with respect to these factors that are made widely available on the Web.
- For those companies and institutions that do begin to respond to pressure to improve their triple bottom line, initial forays into sustainability through making changes in their capital facilities. Many organizations elect to begin 'greening' their programmes by starting with changes to capital facilities since it is simultaneously less threatening and more visible to make changes to capital facilities than it is to reengineer industrial processes themselves.

- An increase in demonstrations, both non-violent and violent, against the operations and facilities of corporations that are not socially or environmentally responsible. This trend will lead to increased needs to consider security issues in all capital construction projects, and will lead to the development of new technologies and strategies for hardening industrial facilities in cost-effective ways.
- Increased liability associated with social inequity and ecological destruction. Evolution of legal sophistication in developing countries along with changing consumer expectations will provide both the means and the driver to hold corporations accountable for destructive actions that previously went unnoticed or unpunished.

Mid-term sustainability trends

- Increasing volatility in basic sources of supply for raw materials.
- Increased awareness of the cost and problems of transportation.
- Increased consumer sophistication regarding ecological and social impacts of purchasing decisions.
- Increased attention to sustainability in capital facilities across multiple industries.
- Increase in demonstrations against companies that are not socially or environmentally responsible.
- Increased liability associated with social inequity and ecological destruction.

Long-term trends in the ten+ year horizon

The ten+ year time horizon represents a long-term perspective for the construction industry. Trends and possible changes in the built environment that may be relevant over this time frame are:

- Transformational process changes across multiple industries to address resource supply constraints. These process changes will result in a need to change the types of facilities that support industrial enterprises and dramatically increase both the efficiency of processes and the ability to recover resource streams formerly considered to be waste.
- Colocation of complementary industries to create industrial ecosystems whose inputs and outputs are useful to one another, thereby increasing efficiency and robustness while reducing transportation overhead to achieve useful aims. The construction industry must consider ways in which it can find niches in this industrial ecosystem in order to maximize value to industry.
- Distribution of production capabilities rather than centralization because of the high costs of transportation, and an increase in goods produced locally. Concurrently, the globalization of ideas and services will increase as a means of stimulating the development of emerging countries such as China and India. Effective distribution of production capabilities will require process scalability, flexibility in required operating resources, and new approaches to capital construction that increase cost-effectiveness for multiple small

operations. The AEC industry must respond to this trend with new ways of building and managing projects.

- Increased reliance on distributed instead of centralized infrastructure, especially to meet energy and fuel needs.
- Increasing reliance on locally renewable resources (including energy sources); for instance, tapping of decommissioned landfills to obtain methane for fuel purposes for industries located near such facilities. Overall, industry may begin to view sites formerly considered to be nuisances (such as contaminated brownfields or waste disposal sites) to now be potential assets as new technologies emerge to recover the resources that contaminate these sites.
- Increasing need to develop both facilities and industrial processes that are robust and versatile in terms of raw material supplies and environmental conditions for operation. The uncertain impacts of global climate change will potentially effect raw material sources, reliability of transport and supply chains, and even the physical operation of facilities that house industrial processes. For instance, a rise in sea level might necessitate the relocation of industrial operations currently located near coasts or other bodies of water.

Long-term sustainability trends

- Industry process change to address resource supply constraints.
- Colocation of complementary enterprises to form industrial ecosystems.
- Distribution rather than centralization of production capabilities, and increase in local goods and services.
- Globalization of ideas.
- Increased reliance on distributed as opposed to centralized infrastructure.
- Increased reliance on locally renewable resources and assets.
- Increased development of resilient facilities and processes.

Ultimately, the constraints we are beginning to sense as a society today represent both threat and opportunity to the organizations that comprise the construction industry. Proactively considering these trends will afford those organizations the chance to take a leadership role among their peers and direct their courses of action to be successful and sustainable over time.

Case Study: Masdar City

Masdar City, located in the United Arab Emirates' capital city of Abu Dhabi, is being constructed to be a clean technology research hub that will rival Silicon Valley while being entirely carbon neutral and waste-free. Home to the new Masdar Institute of Science and Technology and commissioned by the Abu Dhabi Future Energy Company, the city's 5.5 sq km will ultimately be home to 50,000 people, 1500 businesses and some 40,000 daily commuters, and will strive to be entirely self-sufficient for all its energy needs. Approximately 80 per cent of water will be recycled and reused. In addition to solar and biomass conversion, other renewable sources of power under consideration include geothermal, hydrogen and wind. Biological waste will be used to create fertilizer, and industrial waste will be recycled or reused.

The project involves thousands of individuals and includes a range of innovative infrastructure system, including a novel system for personal rapid transit that will be the first of its kind. 6D Geographic Information Systems (GIS) models are being used to track costs, project schedules and carbon emissions as part of the collaborative project delivery process, and will be used as the foundation of an automated, paperless asset management system to optimize the performance of the city over its life.

Approximately 5000 workers are being housed on site during the construction phase in a workers' village in harsh desert conditions, and management of worker and material logistics is also being monitored and carefully managed to maintain carbon neutrality (Figure 1). GIS is being used to support this task by:

- Planning construction lay-down areas to be as close to where the work occurs as possible.
- Optimizing utility substation layouts, network routes and facility placement for water and sewage treatment plants, recycling centres, a solar farm, geothermal sells, and plantations of different tree species for production of biofuels.
- Management of the more than 100 different contractors on site.
- Clash detection and alignment at the whole facility scale.
- Management of change orders and tracking environmental impacts, especially compliance with carbon neutrality requirements.
- Combining building information models (BIMs) for individual assets into accurate representation of spatial networks.
- Visualizing energy and water use for the city as a whole during optimization to maintain carbon neutrality.

Masdar City has a variety of innovative infrastructure systems that are designed to be more sustainable than their conventional counterparts. Key sustainable design strategies include:

- Optimal orientation of the city and street grid on a southeast-northwest axis to provide shading at street level throughout the day, minimize thermal gain on building walls, and facilitate the flow of cooling breezes through the city.
- Integrated, mixed uses to keep residential areas close to business, industry, cultural and university/educational facilities.
- Low-rise, high-density urban design to reduce energy use for transportation and reduced heating and cooling loads.

- Incorporation of public spaces as part of the urban fabric to facilitate interaction and engagement among residents, commuters and visitors.
- Pedestrian-friendly design, including overshading to provide a cooler street environment (Figure 2).
- Convenient public transportation through a network of electric buses, a personal rapid transit (PRT) system, and integration with the light rail/metro system of Abu Dhabi.
- Traditional Arabian city design (Figure 3) that takes into account indigenous strategies to deal with the harsh desert climate and reduce energy consumption while promoting socially diverse environments and lively public spaces.

Building design, urban form and infrastructure design were all undertaken using careful prioritization to achieve the biggest environmental gains from the least financial investment, especially the city's orientation and overall form (Figure 4). At the building scale, responsive shading, natural lighting and passive ventilation achieve comfort and performance goals with a minimal infusion of energy. At the very top level of investment, active controls and renewable energy systems are used to achieve the balance of carbon neutrality for the city.

Key infrastructure features of Masdar City include:

- An international photovoltaic (PV) competition testbed begun in 2008 that tests technology from more than 35 suppliers for energy yield, efficiency, ambient temperature effects, sand effects and other factors.
- The Beam Down Project, a new type of concentrated solar power (CSP) plant that uses mirrors to focus the sun's rays onto a receiver where it heats a heat-transfer fluid (such as molten salt, oil or water) that can be used to generate steam to power a turbine and generate electricity. This CSP design is more efficient than conventional designs because the receiver is located at ground level, thus reducing the energy ordinarily used to pump the heat-transfer fluid to the top of an elevated receiver tower.
- Exploratory geothermal testing to locate optimal geothermal resources for thermal heating and cooling, domestic hot water production, power production and desalination. A significant portion of the city's cooling loads will be served using absorption chillers continuously supplied with geothermal heat.
- A 10 MW solar photovoltaic farm comprising over 87,000 polycrystalline and thin-film PV modules on the outer boundary of the city, which is the largest grid-connected solar plant in the Middle East. Cleaning dust from the panels in the desert environment represents a significant cost, especially in terms of water use, so ongoing testing is critical to find improved solutions for this purpose.
- A material recycling centre, which is presently diverting up to 96 per cent of construction waste from the construction of the city for recycling or reuse. Wood is segregated and stockpiled for reuse or processed in a wood shipper. Other materials are separated and sent offsite for recycling. Excavated sand and crushed concrete/masonry are retained on site for fill. Waste that cannot be recycled may be used for fuel in a waste-to-energy plant.
- A joint parking garage and rapid transit station at the gateway to the city, where commuters and visitors can transfer to the city's personal rapid transit (PRT) system. Sustainable design features of the station include an efficient radiant cooling system, backlit recycled glass walls, low-carbon concrete benches, and recharging berths for PRT vehicles waiting in the station.

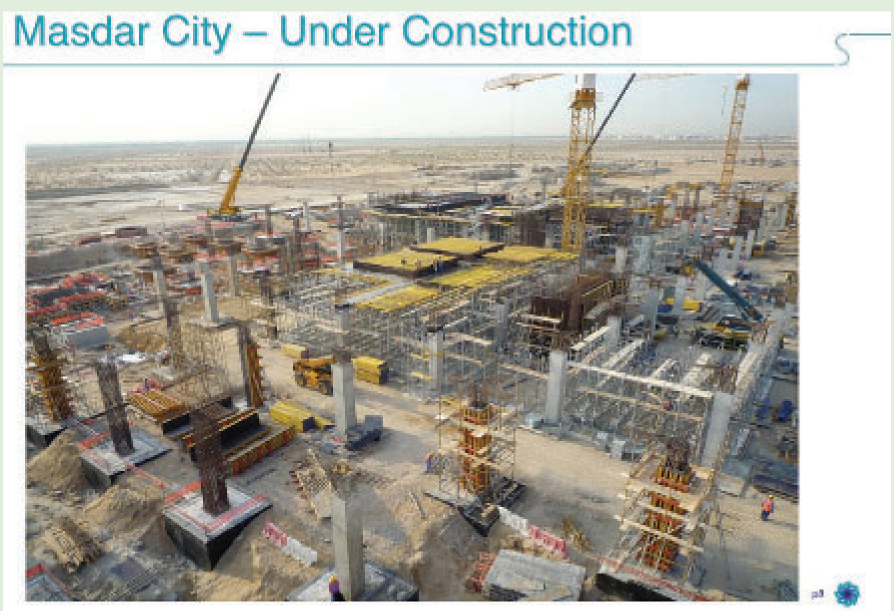
- A personal and freight (FRT) rapid transportation system, which consists of driverless vehicles (Figure 5) controlled by an advanced navigation system using magnets embedded in each corridor to determine position, onboard sensors for obstacle detection, and a wireless connection to a central control system to coordinate operation among all vehicles. Three of the vehicles are flatbeds that are dedicated to transport deliveries throughout the Masdar Institute and transport waste for sorting, reuse or recycling.
- An undercroft area for the PRT system to separate pedestrian traffic from vehicular traffic, and a utility trench below that area to allow for easy access to the city's complex utility infrastructure of power and sewerage lines, piping for potable, grey and black water, wiring for IT and communication systems, waste and recycling networks, and other plant and equipment.
- The Masdar Institute PRT/FRT station, featuring light tubes for natural daylighting, and prominent staircases and hidden elevators to encourage people to make more sustainable choices about vertical conveyance.
- A student reception area featuring a seasonally adaptive system to allow open-air ventilation during cooler months, and closed areas during hot summer months to allow for air conditioning. The master plan for the development dictates that at least as much attention be paid to the spaces between buildings as to the building themselves. Unique fractal patterns constructed from reconstituted stone are used for walkways, and shading, planting and water features lower the perceived temperature from that of open desert or conventional city areas.
- An iconic wind tower to capture prevailing breezes and add moisture to create a low-energy evaporative cooling system for personal comfort.
- A large urban square at the base of the wind tower to take advantage of conditioned air. The square will contain cafés and retail outlets surrounding a public space as well as other services such as a gym, prayer room, organic grocery, and bank. A raised platform beneath the wind tower can serve as a performance stage.
- Building envelopes using best practices such as high insulation levels and strict air-tightness standards, air-filled cushions backed with reflective foil cladding to minimize solar gain and reflect light to the street below. Residential buildings feature red, sand-coloured glass-reinforced concrete screens based on traditional Arab mashrabiya screens that provide shade, reduce solar gain, and provide visual contact with the street while protecting residents' privacy.
- The Masdar Institute Laboratory Building which features active and passive energy management technologies, an open plan, column-free floor plan to facilitate interdisciplinary collaboration, overhead service carriers to provide plug-and-play access for utilities in the labs, and easily reconfigurable furniture to facilitate interaction of researchers.
- The Masdar Institute Residential Building, which contains both men's and women's dormitories with studio apartments, and family dormitories with two-bedroom units. The units were constructed using modular, prefabricated bathrooms to minimize fabrication waste and ensure consistently high quality.
- A Family Square to serve as a meeting place and point of interaction for families, containing cafés, services, and a water featured that uses a thin layer of flowing water to provide efficient cooling during the summer.
- A Knowledge Center that features PV energy harvesting, self-shading overhangs, FSC- and PEFC-certified glulam (glued laminated) timber roof, and a zinc-cladded roof selected for its overall lowest environmental footprint.

- 'Green Finger' linear parks oriented to take advantage of prevailing winds and channel cooling breezes into the heart of the built environment. The parks serve as shaded oases for residents, workers and visitors, and incorporate walking, jogging and bicycle trails for recreation.
- Masdar Institute – Phase 1b, the second phase of the Masdar Institute, which will double the size of the original university campus and add additional capabilities. 'Energy piles' will be incorporated in the substructure of the building to use the water table as a heat sink during the day to assist with air conditioning.
- The Masdar Headquarters Building, designed to be one of the world's first net energy positive buildings that will produce more energy than it consumes, using a PV array that will produce 5.5 GWh annually. The building incorporates a series of wind cones to provide natural ventilation and diffused natural daylight throughout the building. A sawtooth façade allows access to daylight and views while mitigating glare and solar heat gain.
- A ready-mix concrete batch plant used to produce concrete using supplementary cementitious materials such as flyash and blast furnace slag, with a lower concrete footprint than conventional concrete.
- A membrane bioreactor that uses suspended, growth-activated sludge and microporous membranes to separate liquids and solids in stead of secondary clarifiers. This technology performs well in warm climates, has a compact footprint, is easily scalable, and produces an effluent suitable for reuse applications such as toilet flushing, district cooling, and landscape watering.

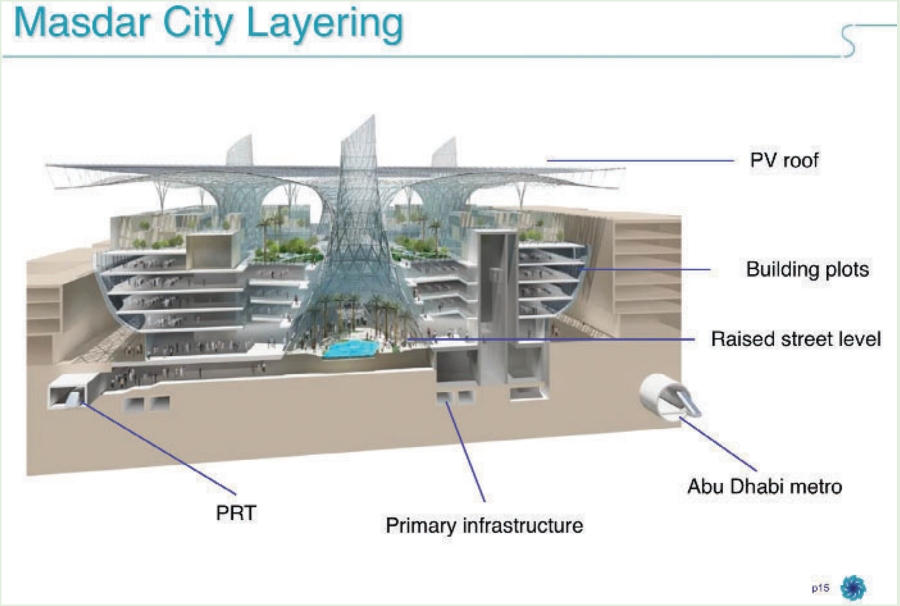
Sources

ESRI (UK) Ltd (2009). *Masdar City: The world's first carbon-neutral city.* <www.esri.com/industries/facilities-management/pdfs/masdar.pdf> (accessed 12 August 2011).

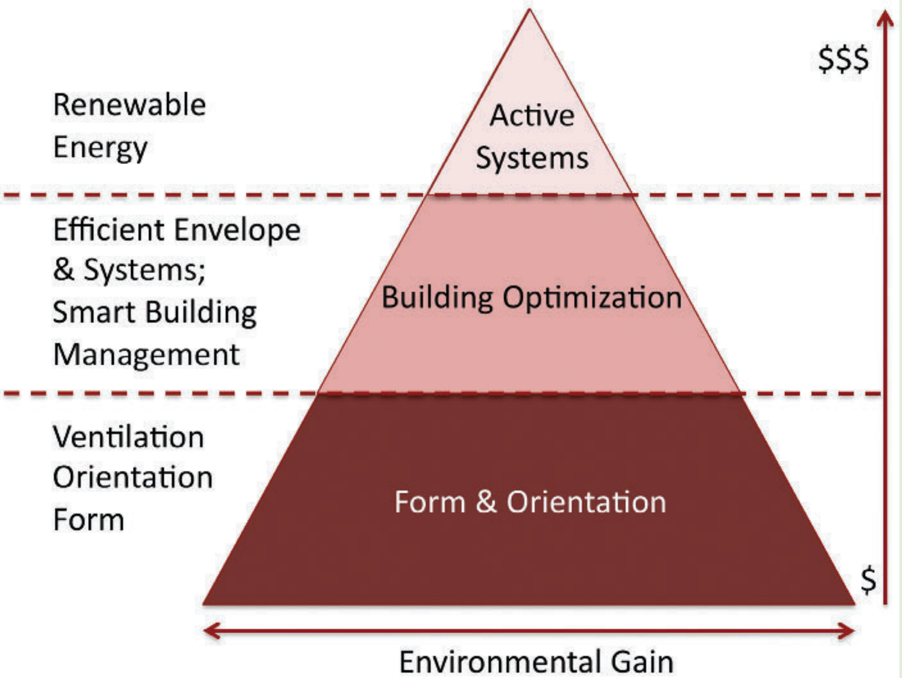
Masdar City (2011). *Exploring Masdar City.* <www.thefuturebuild.com/brochures/page-files/files/Masdar_City_exploring.pdf> (accessed 12 August 2011).



Construction in Masdar City is being carefully managed to ensure carbon neutrality



A layering approach was used in designing the city to provide critical infrastructure and occupied spaces in shaded areas between buildings and beneath photovoltaic canopies



Sustainable design strategies were carefully prioritized to achieve the maximal efficiency for the least investment

Masdar City incorporates the Masdar Institute of Science and Technology as part of a unique, carbon neutral urban environment inspired by indigenous Arabic design strategies

The city's personal rapid transit system transports people, freight and waste in driverless vehicles through parts of the city

Discussion questions and exercises

10.1 Choose one of the high-tech green materials or systems discussed in this chapter to investigate further. What product or products does the high-tech material supersede? How does it compare in terms of first cost with its predecessor? Be sure to include all components necessary for functional equivalence in your analysis. What is the expected payback period for investing in the new technology, given expected savings over its life-cycle? Is the payback period shorter than the service life of the product or system?

10.2 Investigate the availability of biodiesel in your area. How much does it cost compared with conventional diesel? Contact a local project manager to determine how much fuel is used during the course of a typical project. What would be necessary to implement biodiesel on a local construction project? Who would you contact for delivery? What blend would you use between conventional and biodiesel in equipment on your project? What would be the cost implications for a typical project?

10.3 Choose one or more readings from the Lean Construction Institute's website to learn more about the application of lean principles to the construction industry. Identify one component or system on a construction process, and map the value chain leading to the component's installation in a construction project. What extra steps are included in that installation process that do not add value? How might they be eliminated through lean construction planning?

10.4 Identify one aspect of the building in which you are located that could lead to its eventual obsolescence based on the types of change identified in the chapter. How might the building's design be adapted to accommodate that change and still remain functional?

10.5 Identify one or more building products through an Internet search that can be leased instead of purchased as part of a dematerialization strategy. What are the terms of the lease? Compare the cost profile of the leased product with the same product purchased. How are costs distributed over the life-cycle? What is the net benefit to the owner of the leased product?

10.6 Use an Internet search to determine whether any of the sustainable infrastructure technologies mentioned in the chapter exist in your area. Schedule a visit to the site and learn more about the project, or identify a project with case study information online. How is the project more sustainable than the conventional alternative? What challenges exist, both technical and social, in implementing the project? What lessons can be learned for similar projects in the future?

10.7 Visit the online AskNature database at http://www.AskNature.org. Explore the biomimicry taxonomy of functions to identify database entries with applications to the built environment. Choose one or more functions and describe how they could be used as a model for technologies in buildings.

10.8 Choose one of the flows shown in Table 10.4 that are essential to understand in modelling the sustainability of a construction project. How could a BIM model be used to track this information in practice? Explore the websites for some of the mentioned BIM software tools to learn more about these models' capabilities.

10.9 Consider the building in which you are located. What would it be like if all external infrastructure services were suddenly to disappear? What would be the biggest threat to passive survivability in the facility? What retrofit strategies or technologies could be employed to reduce this threat?

10.10 Which of the sustainability trends discussed at the end of the chapter seems to be the most significant to you and your professional or personal life? How could you adjust your current practice to be more resilient to adapt to this trend? What resources would you need? What actions would you need to take? What trend do you believe is most significant for your organization or nation? How can you take action as an individual to increase resilience at a larger scale?

References

Ausubel, J.H. (1996). 'Can technology spare the earth?' *American Scientist Magazine,* 84 (2), 166–78.

Benyus, J. (2002). *Biomimicry: Innovation inspired by nature*. Harper Perennial, New York.

Breakthrough Technology Strategy Committee (BTSC) (2006). 'Nanotechnology and its impacts in the construction industry.' BTSC, Construction Industry Institute, Austin, Tex. <https://www.construction-institute.org/scriptcontent/btsc-pubs/CII-BTSC-00.doc> (accessed 19 September 2010).

Bright, A. M. (2010a). 'Renovating American infrastructure, step 1: transportation.' PopSci Post <www.popsci.com/technology/article/2010-01/renovating-american-infrastructure-mess-1-transportation> (accessed 28 January 2010).

Bright, A. M. (2010b). 'Renovating American infrastructure, step 2: water.' PopSci Post <www.popsci.com/technology/article/2010-01/renovating-american-infrastructure-mess-2-water> (accessed 29 January 2010).

Bright, A. M. (2010c). 'Renovating American infrastructure, step 3: power.' PopSci Post <www.popsci.com/technology/article/2010-01/renovating-american-infrastructure-mess-3-power> (accessed 1 February 2010).

Bright, A. M. (2010d). 'Renovating American infrastructure, step 4: telecom.' PopSci Post <www.popsci.com/technology/article/2010-01/renovating-american-infrastructure-mess-4-telecom> (accessed 2 February 2010).

Bright, A. M. (2010e). 'Renovating American infrastructure, step 5: sewage.' PopSci Post <www.popsci.com/technology/article/2010-01/renovating-american-infrastructure-mess-5-sewage> (accessed 3 February 2010).

Danigelis, A. (2010). '"Chia wall" to muffle highway sound.' *Discovery News*, 19 July <http://news.discovery.com/tech/chia-wall-to-muffle-highway-sound.html> (accessed ??).

Goble, G. (2009a). 'In the year 2020, part i: cloud computing', *Digital Trends*, 22 September <www.digitaltrends.com/computing/in-the-year-2020-part-i-cloud-computing/> (accessed ??).

Goble, G. (2009b). 'In the year 2020, part iii: transportation, urban planning, and energy,' *Digital Trends*, 28 October <http://www.digitaltrends.com/lifestyle/in-the-year-2020-part-iii-transportation-urban-planning-and-energy/> (accessed ??).

Goodrum, P. and DeLoach, S. (2009). 'Inductive power transfer (wireless transmission).' BTSC, Construction Industry Institute, Austin, Tex. <www.construction-institute.org/scriptcontent/btsc-pubs/CII-BTSC-120.doc> (accessed 19 September 2010).

Hannon, J. J. (2007). *Emerging Technologies for Construction Delivery: A synthesis of highway practice.* NCHRP Synthesis 372, National Cooperative Highway Research Program, Transportation Research Board, Washington, DC. <http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_372.pdf> (accessed 29 August 2010).

HNTB (2010). 'THINK5 – sustainable infrastructure: point of view.' <www.hntb.com/point-of-view/think5-sustainable-infrastructure> (accessed 22 December 2010).

Horowitz, G. (2010). 'It's time for the smart water grid.' *Clean Techies blog*, <http://blog.cleantechies.com/2010/06/09/time-for-the-smart-water-grid/>, 9 June (accessed ??).

Huang, G. Q. (1996). *Design for X: Concurrent engineering imperatives*. Chapman & Hall, London.

Kasarda, M. E., Terpenny, J. P., Inman, D., Precoda, K. R., Jelesko, J., Sahin, A. and Park, J. (2007). 'Design for adaptability (DFAD) – a new concept for achieving sustainable design.' *Robotics and Computer-Integrated Manufacturing,* 23(6), 727–34.

Moresco, J. (2009). '4 green building trends to watch in 2010' <gigaom.com/cleantech/4-green-building-trends-to-watch-in-2010/> (accessed 10 October 2011).

Nguyen (2008a). 'Biomimicry in Construction.' BTSC, Construction Industry Institute, Austin, Ted. <https://www.construction-institute.org/scriptcontent/btsc-pubs/CII-BTSC-112.doc> (accessed 19 September 2010).

Nugyen (2008b). 'Compressed-air vehicles in procurement and construction.' BTSC, Construction Industry Institute, Austin, Tex. <https://www.construction-institute.org/scriptcontent/btsc-pubs/CII-BTSC-117.doc> (accessed 19 September 2010).

Pisutpaisal, N. (2004). 'Future wastewater treatment technology: simultaneous treatment of wastewater and electricity generation,' *Proceedings, Joint International Conference on Sustainable Energy and Environment,* Hua Hin, Thailand, 1–3 December.

Scheck, H. O. (2008). 'Power consumption and energy efficiency of fixed and mobile telecom networks.' ITU-T Conference, Kyoto, Japan, April.

Siddiqui, M. Z., Pearce, A. R., Ku, K., Langar, S., Ahn, Y. H. and Jacocks, K. (2009). 'Green BIM approaches to architectural design for increased sustainability'. *Proceedings of the International Conference on Construction Engineering and Management/Project Management (ICCEM-ICCPM 2009).* Jeju, Korea, 27–30 May.

Siemens (2010). *What will the Future of Wastewater Look Like?* <http://aunz.siemens.com/PicFuture/Documents/WaterCasestudy_wastewater.pdf> (accessed 21 December 2010).

Singh, T. (2010a). 'Four solar road designs unveiled by University of Rhode Island.' Inhabitat, 11 November <http://inhabitat.com/four-solar-road-designs-unveiled-by-university-of-rhode-island/> (accessed ??).

Singh, T. (2010b). 'New piezoelectric railways harvest energy from passing trains.' Inhabitat, 9 December <http://inhabitat.com/new-piezoelectric-railways-harvest-energy-from-passing-trains/> (accessed ?).

Slaughter, E. S. (2001). 'Design strategies to increase building flexibility'. *Building Research and Information,* 29(3), 208–17.

US Environmental Protection Agency (USEPA). (2010). 'Sustainable infrastructure: basic information.' <http://water.epa.gov/infrastructure/sustain/basicinformation.cfm> (accessed 21 December 2010).

Wernick, I. K., Herman, R., Govind, S. and Ausubel, J. H. (1996). 'Materialization and dematerialization: measures and trends', *Daedalus*, 125(3), 171–98.

Wilson, A. (2010). 'High-tech glazing with phase-change material', *Environmental Building News*, <www.buildinggreen.com>, 21 June.

Additional resources

Biomimicry Institute. (2010). 'Ask nature.' <http://asknature.org> (accessed 29 August 2010).

Contains a searchable database of over 1200 strategies organized taxonomically to illustrate functions provided by nature and natural structures. Organized to support searching for strategies that can support specific design functions.

Construction Industry Institute (CII) (2010). 'Breakthrough.' <www.construction-institute.org/scriptcontent/break.cfm?section=break> (accessed 19 September 2010).

A listing of ideas from industry members of the CII that are presently being evaluated by the CII's Breakthrough Strategy Committee for possible future research. These ideas are perceived to hold promise for savings of 20 per cent or more of total installed cost in capital projects.

Construction Innovation Forum (2010). 'NOVA Award Index.' <www.cif.org/nova-index.php> (accessed 29 August 2010).

A database of NOVA nominees and award winners. The NOVA Award was instituted in 1989 by the Construction Innovation Foundation to recognize innovations that have had positive, important effects on construction to improve quality and reduce cost.

Environmental Building News (2010). 'Alex's cool product of the week.' <www.buildinggreen.com/live/index.cfm/Alexs-Cool-Product-of-the-Week> (accessed 19 September 2010).

Reviews a new emerging green building technology each week and maintains a database of past reviewed products. Part of BuildingGreen.com, a very reputable source of up-to-date information on green products and processes in the United States. BuildingGreen also has a comprehensive listing of construction materials with green attributes available as part of GreenSpec, an online database available at this site.

National Association of Homebuilders Research Center (NAHRC) (2010). 'PATH technology inventory.' NAHRC, Upper Marlboro, Md. <www.pathnet.org/sp.asp?mc=resources_techinventory> (accessed 29 August 2010).

A searchable database and resource centre of emerging technologies for residential construction. A significant portion of the database focuses on green technologies and practices.

Purdue University (2010). 'Emerging construction technologies.' Division of Construction Engineering and Management, Purdue University, West Lafayette, Ind. <http://rebar.ecn.purdue.edu/ect/Links/technologies/research/default.aspx> (accessed 29 August 2010).

A listing of emerging construction technologies applicable to the industrial and heavy civil sectors.

Glossary

Absorptive finish – A surface finish that will absorb dust, particles, fumes and sound.
Acidification – A process that converts air pollution into acid substances. This leads to acid rain, best known for the damage it causes to forests and lakes. Also refers to the outflow of acidic water from metal and coal mines.
Agricultural land – Property suitable for raising crops or livestock. Includes land cultivated for crops, orchards or vineyards, as well as meadows and pastures used for grazing.
Airborne dust – Particles of soil or other materials that are small enough to be suspended in the air and breathed by organisms.
Albedo – The extent an object reflects light from the sun. It is a ratio with values from 0 to 1. A value of 0 is dark. A value of 1 is light.
Alternative fuel – Any material or substance that can be used as a fuel other than conventional fossil fuels. They typically produce less pollution than fossil fuels and include biodiesel and ethanol.
ANSI – the American National Standards Institute, an organization that sets standards for product performance and testing.
Aquifer – An underground layer of water-bearing rock or soil from which groundwater can usefully be extracted using a water well.
Aquifer depletion – A situation when the withdrawal of water from the aquifer is greater than the rate of natural recharge.
ASTM – the American Society for Testing and Materials, an organization that sets standards for material performance and testing.
Best practice – an action or technology to achieve a desired end that is agreed upon by industry to represent the most effective or efficient way to achieve that end.
Bio-based – A material made from substances derived from living matter. It typically refers to modern materials that have undergone more extensive processing. Linoleum, cork and bamboo are examples.
Biodegradable – Organic material such as plant and animal matter and other substances originating from living organisms and capable of being broken down into innocuous products by the action of micro-organisms.
Biodiversity – A measure of the variety among organisms present in different ecosystems.
Bio-fuel – A solid, liquid or gas fuel consisting of or derived from recently dead biological material. The most common source is plants.
Biophilia – a love or affinity for nature and the natural environment.
Bioretention cells – engineered areas designed to capture and treat stormwater runoff and remove impurities before they percolate into the soil.
Bioswales – constructed watercourses covered in appropriate vegetation to slow and retain stormwater (see also *Vegetated swales)*.
Blackwater – Water or sewage that contains fecal matter.
BMP (best management practice) – A way to accomplish something with the least amount of effort to achieve the best results. This is based on repeatable procedures that have proven themselves over time for large numbers of people.
Brownfield – Property that contains the presence or potential presence of a hazardous substance, pollutant or contaminant. Cleaning up and reinvesting in these properties reduces development pressures on undeveloped open land and improves and protects the environment.
Building envelope – the elements and systems of a building that separate the interior of the building from the outside, including the roof, walls, windows and doors.
Building-integrated photovoltaics (BIPVs) – Photovoltaic systems built into other types of building materials.
Business case – the set of pros and cons, often expressed in economic terms, associated with a proposed

action that defines how that action will contribute to a business's enterprise.

Byproducts – Another product derived from a manufacturing process or a chemical reaction. It is not the primary product or service being produced.

Carbon cycle – The movement of carbon between the biosphere, atmosphere, oceans, and geosphere of the Earth. This biogeochemical cycle has sinks, or stores, of carbon and processes by which the various sinks exchange carbon.

Carbon footprint – A measure of the impact that human activities have on the environment. It is determined by the amount of greenhouse gases produced and is measured in units of pounds or kilograms of carbon dioxide.

Carbon offsets – a donation or other act that aims to remove a certain amount of carbon dioxide from the atmosphere to compensate for the same amount added to the atmosphere by another activity.

Carpool – An arrangement where several people travel together in one vehicle. The people take turns driving and share in the cost.

Ceramic frit – vitreous compounds, not soluble in water, obtained by melting and then rapidly cooling carefully controlled blends of raw materials.

Certified sustainable harvest – the extraction or collection of a natural product in a way that can be continued indefinitely without damage, observed and verified by a third party.

Certified wood – Wood or wood products that have been verified as coming from sustainably harvested sources by a third-party agency.

Charrette – A meeting of project participants that is an intense period of design activity. They are a way of quickly generating a design solution and also integrate the abilities and interests of a diverse group of people.

Chlorofluorocarbons (CFCs) – A set of chemical compounds that deplete ozone. They are widely used as solvents, coolants and propellants in aerosols, and are the main cause of ozone depletion in the stratosphere.

Commissioning – a process of quality assurance undertaken during project delivery to ensure that all building systems function according to their design intent.

Compact fluorescent lamps (CFLs) – A fluorescent lamp that is designed to fit in a normal light fixture. They use less energy and last longer than incandescent lamps.

Composting – purposeful biodegradation of organic matter, such as yard and food waste, into a soil amendment to improve soil quality.

Conservation – Using natural resources wisely and at a slower rate than normal.

Constructed wetland – An artificially made wetland designed for the purposes of treating human-generated wastewater with plants and microorganisms before returning it to the natural environment.

Corporate social responsibility – the practice of managing or operating a company to have an overall positive impact on society.

CRI Green Label – a rating system developed by the Carpet and Rug Institute to evaluate the indoor air quality performance of carpet and flooring products.

Daylighting – the use of windows and reflective surfaces to bring natural light into a space and reduce or eliminate the need for artificial light.

Deconstruction – the careful disassembly of a built facility in a way that enables components to be reused on future projects.

Deforestation – The removal of trees without sufficient replanting.

Desertification – The creation of deserts through degradation of productive land in dry climates by human activities.

Downcycling – Recycling one material into a material of lesser quality. An example is the recycling of plastics, which are turned into lower-grade plastics.

Downstream impacts – effects occurring as a result of the use of a product, or as a result of its disposal at the end of its service life.

Eco-label – a mark or certifying logo that indicates an environmentally friendly attribute of a product.

Ecological footprint – A measure of human demand on the Earth's ecosystems and natural environment. It compares human consumption of natural resources with the Earth's capacity to regenerate them, and is measured in units of area like hectares or acres.

Ecological fragmentation – the division of ecosystems or undeveloped areas into smaller pieces as a result of human development of roads and buildings.

Ecological rucksack – the total quantity of materials moved or used to create a product or service.

Ecosystem – A combination of all plants, animals and micro-organisms in an area that complement each other. These function together with all of the non-living physical factors of the environment.

Embodied energy – the total energy that was used in all the activities associated with producing a product and delivering it to its point of use.

Emissions – a substance discharged into the air or water as a pollutant.

End of life-cycle – the point in time when a product is no longer suitable to be used for its intended purpose .

Endangered species – A population of a species at risk of becoming extinct. A threatened species is any species that is vulnerable to extinction in the near future.

Energy efficiency – The percentage of energy expended to do work that results in a useful work output.
Energy performance credits – a series of credits in the Energy and Atmosphere category of the LEED rating system that reward projects for exceeding the energy code by a certain amount.
EnergyStar – A US government programme to promote energy efficient consumer products. It is a joint program of the US Environmental Protection Agency and the US Department of Energy.
Enhanced commissioning – a process of quality assurance that begins during design and continues throughout and following construction to ensure that all building systems function according to their design intent.
Environmental stewardship – responsibility for environmental quality that is shared by those whose actions affect the environment.
Equipment idling – The operation of equipment while it is not in motion or performing work. Limiting idle times reduces air pollution and greenhouse gas emissions.
Erosion – The displacement of solids by wind, water, ice or gravity or by living organisms. These solids include rocks and soil particles.
Erosion and sediment control plan – a plan developed for a project that identifies risks for erosion and sedimentation during the project and specifies measures for preventing or mitigating them
Externalities – consequences of an action that are experienced by a third party not participating in the action.
Fenestration – pertaining to windows.
Fitness for purpose – the ability of a technology or product to fully meet the intent for which it was designed.
Flush-out – Using fresh air in the building HVAC system to remove contaminants from the building.
Fly ash – fine solid particles of ash that are carried into the air when a fuel is burned.
Footprint – an outline or indention of a foot or shoe on a surface. Also refers to the effect of human activity on the natural environment, as in the phrases ecological footprint and building footprint.
Fossil fuels – hydrocarbon deposits, such as petroleum, coal or natural gas, derived from living matter of a previous geologic time and burned to produce useful work
FSC Certified – wood or wood products that have met the Forest Stewardship Council's tracking process for sustainable harvest.
Fugitive emissions – pollutants released to the air other than from stacks or vents. They are often caused by equipment leaks, evaporative processes and wind disturbances.
Furred out – extended away from a solid wall through the use of a false stud wall to provide insulation and/or attachment points for a finished surface.
Geothermal – heat that comes from within the Earth.
Global climate change – changes in weather patterns and temperatures on a planetary scale. This may lead to a rise in sea levels, melting of polar ice caps, increased droughts and other weather effects.
Green – having some environmental benefit compared to a conventional alternative.
Green Seal Certified – A certification product to indicate its environmental friendliness. GreenSeal is a group that works with manufacturers, industry sectors, purchasing groups, and governments at all levels to 'green' the production and purchasing chain. Founded in 1989, Green Seal provides science-based environmental certification standards.
Green space – the undeveloped areas around built facilities that are covered in landscaping or vegetation.
Greenfield site – a project site that has not been previously developed except for agricultural use.
GreenGuard – a rating and certification system used to evaluate the indoor air quality performance of building products and systems.
Greenhouse gas – a substance in the atmosphere that acts to insulate the earth's surface and retain heat. Examples include carbon dioxide (CO_2) and methane (CH_4).
Greenwash – dissemination of misleading information by an organization to conceal poor environmental practices and present a positive public image.
Greywater – A non-industrial wastewater generated from domestic processes. These include dish washing, laundry and bathing. Greywater comprises 50–80 per cent of residential waste water.
Halons – An ozone-depleting compound consisting of bromine, fluorine and carbon. Halons were commonly used as fire extinguishing agents, in both built-in systems and handheld portable fire extinguishers.
Heat island – an area with a higher temperature than its immediate surroundings caused by greater absorption of solar energy. Often has a different microclimate than its surroundings.
Hybrid vehicle – a vehicle that uses two or more distinct power sources to propel the vehicle.
Hydrochlorofluorocarbons (HCFCs) – A group of human-made compounds containing hydrogen, chlorine, fluorine and carbon that are used for refrigeration, aerosol propellants, foam manufacture and air conditioning. They are broken down in the lowest part of

the atmosphere and pose a smaller risk to the ozone layer than CFCs.

Hydrologic cycle – The circulation and conservation of Earth's water. The process has five phases: condensation, infiltration, runoff, evaporation and precipitation.

IAQ (indoor air quality) – The content of interior air that could affect health and comfort of building occupants.

IAQ management plan – a plan developed for a construction project that inventories possible threats to future indoor air quality arising from the construction process or materials used in a project, then identifies strategies to mitigate or avoid them.

Infiltration trenches – excavated areas filled with plants and vegetation that are designed to allow stormwater to percolate back into the soil.

Innovation credit – a credit under the LEED rating system awarded for actions that greatly exceed the credit requirements defined under LEED.

Insulating concrete form (ICF) – Rigid forms that hold concrete in place during curing and remain in place afterwards. The forms serve as thermal insulation for concrete walls.

Integrated design – a collaborative design methodology. It emphasizes knowledge integration in the development of a complete design.

ISO – the International Standards Organization, a collection of national standards organizations that coordinates international standards.

Just-in-time delivery – the practice of arranging for materials to be delivered to the project site just before they are installed, so that they are not at risk from being damaged during storage.

Leadership in Energy & Environmental Design (LEED) – a family of rating systems developed by the US Green Building Council to rate and certify the environmental performance of built facilities.

LEED Online – the website used by members of a project team to manage the process of applying for LEED certification.

Life-cycle – the useful life of a system, product or building.

Life-cycle analysis – an analytic technique to evaluate the environmental impact of a system, product, or building throughout its life-cycle. This includes the extraction or harvesting of raw materials through processing, manufacture, installation, use, and ultimate disposal or recycling.

Life-cycle cost – The cost of a system or a component over its entire life span.

Life-cycle costing – the process of identifying and tabulating all the costs associated with a product or process over its whole life-cycle, including first costs, operating and maintenance costs, and end-of-life-cycle costs.

Light pollution – excessive or unwanted light from artificial sources.

Light shelf/shelves – horizontal panels located outside or inside windows to reflect light further into interior spaces and provide shading for perimeter areas.

Light tube – a cylinder penetrating the plane of a roof and extending into an occupied area to direct natural daylight to occupied building spaces.

Liquid waste – materials discharged from a process or entity in liquid form as a pollutant.

Lithium ion (LiIon) battery – a type of rechargeable battery in which a lithium ion moves between the anode and cathode; commonly used in consumer electronics.

Local materials – materials that come from within a certain number of miles from the project. Materials produced locally use less energy during transportation to the site.

Long-cycle renewable materials – materials that, while bio-based and renewable, take many years to regrow. Examples include many types of hardwood species.

Low-emission vehicle – Vehicles that produce fewer emissions than the average vehicle on the road.

Low-emitting substance – a material that emits fewer volatile organic compounds than conventional materials of the same type.

Materials management plan – a plan developed for a construction project that inventories materials involved in the project and identifies strategies to protect them until they can be installed, thereby preventing waste.

MERV (minimum efficiency reporting value) – A measurement scale designed in 1987 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to rate the effectiveness of air filters. The scale is designed to represent the worst case performance of a filter when dealing with particles in the range of 0.3 to 10 microns.

Multi-function material – a material that can be used to perform more than one function in a facility.

Nano-material – a material with features smaller than a micron in at least one dimension.

Nickel cadmium (NiCad) – A popular type of rechargeable battery using nickel oxide hydroxide and metallic cadmium as electrodes.

Noise pollution – environmental sound that is annoying, distracting or potentially harmful.

Non-renewable – a material or energy source that cannot be replenished within a reasonable period of time.

Non-toxic – substances that are not poisonous.

NSF – the National Sanitation Foundation, an organization that evaluates and certifies plumbing components and other products.

Occupancy sensor – a sensing and control device that switches on or off depending on the presence of humans in an area. Occupancy sensors rely on changes in heat or motion to detect human presence.

Offgassing – the evaporation of volatile chemicals at normal atmospheric pressure. Building materials release chemicals into the air through evaporation.

Overpopulation – excessive population of an area to the point of overcrowding, depletion of natural resources or environmental deterioration.

Overhang – a horizontal panel or roof protrusion designed to shade and protect the area immediately beneath it.

Ozone depletion – a slow, steady decline in the total amount of ozone in Earth's stratosphere.

Ozone hole – a large, seasonal decrease in stratospheric ozone over Earth's polar regions. The ozone hole does not go all the way through the layer.

Particulate – a small mass of solid or liquid matter that remains suspended in a gas or liquid.

Payback period – the amount of time it takes to recover costs in savings resulting from an investment.

Pervious concrete – a mixture of coarse aggregate, Portland cement, water, and little to no sand. It has a 15–25 per cent void structure and allows 3–8 gallons of water per minute to pass through each square foot. Permeable concrete is also used as a synonym.

Photovoltaics – a technology that converts light directly into electricity.

Pollution prevention – the prevention or reduction of pollution at the source.

Pollution prevention plan – a plan developed for a construction project that inventories potential sources of pollution or waste during construction and identifies strategies to keep them from happening.

Post-consumer – products made out of material that has been used by the end consumer and then is collected for recycling.

Post-consumer recycled content – waste that comes from a product or material after it has served the useful purpose for which it was made.

Post-industrial/ pre-consumer – material diverted from the waste stream during the manufacturing process.

Pre-consumer recycled content – waste that comes from the production process for a product or material.

Preservation – the act and advocacy of the protection of the natural environment.

Rainwater harvesting – the gathering and storing of rainwater. Systems can range from a simple barrel at the bottom of a downspout to multiple tanks with pumps and controls.

Rammed earth – an ancient building technique similar to adobe, using soil that is mostly clay and sand. The difference is that the material is compressed or tamped into place, usually with forms that create very flat vertical surfaces.

Rapidly renewable – a material that is replenished by natural processes at a rate comparable to its rate of consumption by humans or other species. The LEED system of building certification offers points for rapidly renewable materials that regenerate in 10 years or less, such as bamboo, cork, wool and straw.

Raw material – a material that has been harvested or extracted directly from nature, and is in an unprocessed or minimally processed state.

Recyclable – material that still has useful physical or chemical properties after serving its original purpose. It can be reused or remanufactured into additional products. Plastic, paper, glass, used oil and aluminium cans are examples of recyclable materials.

Recycled content – a property of a material meaning that it contains components that have been recycled. Made from materials that would otherwise have been discarded.

Recycled plastic lumber (RPL) – a wood-like product made from recovered plastic or recovered plastic mixed with other materials. It can be used as a substitute for concrete, wood, and metals.

Recycled materials – materials that have been taken from the waste stream and reprocessed for further use.

Recycling – the reprocessing of old materials into new products. A goal is to prevent the waste of potentially useful materials and reduce the consumption of fresh raw materials.

Regionality – the degree to which a material or product is produced locally or within the local region.

Renewable – a resource that may be naturally replenished.

Renewable energy – electricity generated from renewable sources such as photovoltaics or solar thermal, wind, geothermal or small hydroelectric facilities.

Reusable – a material that can be used again without reprocessing. This can be for its original purpose, or for a new purpose.

Salvage – a discarded or damaged material that is saved from destruction or waste and put to further use.

SCS – Scientific Certification Systems, a third-party organization that certifies environmental claims.

Sediment – small particles that settle to the bottom of a liquid, such as soil particles in a body of water.

Sedimentation – a process of depositing a solid material from a state of suspension in a fluid. The fluid is usually air or water.
Service life – the length of time during which a technology or product can be used for its intended purpose.
Site disturbance plan – a plan that indicates the types and limits of disturbance to be allowed during construction on a project site, and identifies strategies for ensuring that disturbance remains within those limits.
Smart material – materials that have one or more properties that can be significantly changed. These changes are driven by external stimuli.
Soil compaction – the compression of soil by heavy weight or pressure, which causes damage to plants and makes it difficult for vegetation to grow.
Solar energy – energy from the sun in the form of heat and light.
Solid waste – products and materials discarded after use in homes, businesses, restaurants, schools, industrial plants, or anywhere.
Solvent-based – a material that consists of particles suspended or dissolved in a solvent. A solvent is any substance which will dissolve another. Solvent-based building materials typically use chemicals other than water as their solvent, including toluene and turpentine, with hazardous health effects.
Source control – deliberate actions taken to prevent waste at the point in a process where pollution or waste is generated.
Sprawl – unplanned development of open land.
Storm water runoff – the unfiltered water that reaches streams, lakes and oceans after a rainstorm by means of flowing across impervious surfaces.
Straw bale construction – a building method that uses straw bales as structural elements, insulation or both. It has advantages over some conventional building systems because of its cost and easy availability.
Structural insulated panel (SIP) – a composite building material used for exterior building envelopes. It consists of a sandwich of two layers of structural board with an insulating layer of foam in between. The board is usually oriented strand board (OSB) and the foam either expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane foam.
Sustainable – able to continue or persist indefinitely without depleting resource bases or damaging natural ecosystems.
Sustainably harvested – a method of harvesting a material from a natural ecosystem without damaging the ability of the ecosystem to continue to produce the material indefinitely.
Takeback – a requirement that waste from packaging or products themselves be recovered by the manufacturer or provider at the end of their life-cycle.
Temporary utilities – services such as electrical power, water and communications that are known in advance to be of limited duration.
Thermal bridge – a condition created when a thermally conductive material bypasses an insulation system, allowing the rapid flow of heat from one side of a building wall to the other. Metal components, including metal studs, nails and window frames, are common culprits.
Thermal mass – a property of a material related to density that allows it to absorb heat from a heat source, and then release it slowly. Common materials used for thermal mass include adobe, mud, stones and even tanks of water.
Triple bottom line – accounting for and reporting on not only the financial profits and losses for a company but also the impacts of that company on the environment and society.
Upstream impacts – the effects of human activity occurring before the activity happens that can be attributed to that activity.
Urban heat island effect – the net rise in temperature in an area resulting from greater absorption of heat by the buildings and paved surfaces in the area.
Urbanization – the removal of the rural characteristics of an area. A redistribution of populations from rural to urban settlements.
Urea formaldehyde – A transparent thermosetting resin or plastic. It is made from urea and formaldehyde heated in the presence of a mild base. Urea formaldehyde has negative effects on human health when allowed to offgas or burn.
Vapour resistance – the ability to a material to resist the flow of water vapour.
Vegetated swales – constructed watercourses covered in appropriate vegetation to slow and retain stormwater (see also *Bioswales)*
Virgin material – a material that has not been previously used or consumed. It also has not been subjected to processing. See also Raw material.
Volatile organic compounds (VOC) – gases that are emitted over time from certain solids or liquids. Concentrations of many VOCs are up to ten times higher indoors than outdoors. Examples of products emitting VOC are paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings.
Walk-off mat – mats in entry areas that capture dirt and other particles.
Waste diversion – preventing solid waste from going to a landfill and directing it instead to recycling, salvage or other beneficial use.

Waste ratio – the proportion of extra material planned for during estimating or ordered during procurement that is expected to go to waste through process inefficiency.

Waste separation – separating waste into recyclable and non-recyclable materials.

Water efficiency – the planned management of potable water to prevent waste, overuse, and exploitation of the resource. Includes using less water to achieve the same benefits.

Water resistant – a material that hinders the penetration of water.

Water-based – materials that use water as a solvent or vehicle of application.

Waterproof – a material that is impervious to or unaffected by water.

WaterSense – a rating and certification system developed by the US Environmental Protection Agency to evaluate the water efficiency of building products.

Wetlands – lands where saturation with water is the dominant factor. This determines the way soil develops and the types of plant and animal communities living in the soil and on its surface.

Wildlife habitat – an environment where an organism or community of organisms typically live or are found.

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