International Training Institute

For the Sheet Metal and Air Conditioning Industry

Instructor Guide

GREEN/LEED® CONSTRUCTION FOR THE SHEET METAL INDUSTRY

Green/LEED Construction for the Sheet Metal Industry

International Training Institute
for the Sheet Metal and Air Conditioning Industry

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Contents

INTRODUCTION TO GREEN BUILDING

Unit 1: Sustainability and You

Module 1
Introduction to Green Building

Unit Learning Objectives:
After this unit, students will:
- *Be able to define sustainability and the Triple Bottom Line.*
- *Understand the role of green building in addressing current and future environmental needs.*
- *Understand green building as a constantly evolving set of "best practices" and new technologies.*

Time Required: Approximately 2 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 5-20

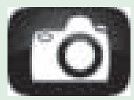
Introduction:
This unit introduces the concept of sustainability and provides a working definition for green building. Students are encouraged to engage this subject matter on a personal level, and then consider how it relates to their jobs. The Triple Bottom Line framework is used to organize environmental, social, and economic concerns associated with buildings.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
Note to Instructor: Ask the students to provide personal definitions of sustainability. You might suggest they begin by asking themselves what they think is worth sustaining.	**Slide 1** **What does Sustainability mean to you?** **SM Page 5** **Notes:**
There are several definitions of sustainability that help guide green building efforts. Three of these are: • **The Brundtland definition** • **The IUCN/UNEP/WWF definition** • **The "Triple Bottom Line" concept**	**Slide 2** **Definitions of Sustainability:** **SM Page 5** **Notes:**
• The Brundtland World Commission on Environment and Development was convened by the United Nations in 1983 to address growing concern "about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development." In defining environmental problems as a global concern, the commission recognized that establishing policies for sustainable development was in the interest of all nations. • The Brundtland definition of sustainable development is **"Development that meets the needs of the present without compromising the needs of future generations to meet their own needs."** In other words, our current quality of life and lifestyle shouldn't prevent future generations from having at least the same quality of life.	**Slide 3** **Brundtland Definition:** **SM Page 5-6** **Notes:**

• Another influential definition of sustainability comes from a report called "Caring for the Earth: A Strategy for Sustainable Living" jointly published in 1991 by three organizations: the World Conservation Union (IUCN), the United Nations Environment Programme (UNEP), and the World Wide Fund for Nature (WWF). • According to this document, sustainability is **"Improving the quality of human life while living within the carrying capacity of supporting ecosystems."** This definition addresses the need to continue to increase standards of living for people around the world while recognizing the limited nature of the resources we have to accomplish that. In other words, the earth's ability to support our lives has natural constraints and our lifestyle must recognize this, so that we're not taking more than it can give back and polluting more than it can naturally manage.	**Slide 4** **IUCN/UNEP/WWF Definition:** **SM Page 6** **Notes:**
• The Triple Bottom Line is a concept for measuring organizational success in achieving sustainability. Traditionally the "bottom line" refers simply to a company's financial performance. When business and **profits** are good, you hear talk of a "healthy bottom line." When a decision is being made, you hear talk of its impact on "the bottom line." • The Triple Bottom Line takes into account not just financial impacts, but also effects on **people** and the **planet**.	**Slide 5** **Triple Bottom Line:** **SM Page 6** **Notes:**

• This concept is often represented in a diagram that conceptually illustrates the interdependent and over-lapping nature of the three categories. Each category—people, planet, and profit—is a circle and the place that they all overlap is where sustainability is achieved. • For example, a manufacturer that produces highly valuable and highly demanded widgets but that also emits pollutants into nearby neighborhoods has a one-dimensional bottom line. Its financial performance may be good, but its impact on people and the planet is bad. So, this manufacturing practice is not, by the definition of the Triple Bottom Line, sustainable. • While noble goals can be achieved by considering any two of these categories—such as **equity (people/profit), livability (people/planet)**, and **viability (profit/planet).** • Sustainability can only be reached by addressing all three.	**Slide 6** **Triple Bottom Line:** **Figure 1: The Triple Bottom Line.** **SM Page 6-7** **Notes:**
• While the goal of green building is to work toward sustainability, it should be noted that "green" is not synonymous with "sustainable." • **Sustainability is an absolute condition**, while the term "green" recognizes the need to make incremental progress toward that ultimate goal. • **"Green" may be thought of as "better" or even "less bad" for the environment**, while "sustainable" implies no net negative impact at all. One might also think of different levels or shades of green as they progress towards sustainability.	**Slide 7** **"Green" vs. "Sustainable":** **SM Page 7** **Notes:**
Note to Instructor: **Discussion:** Ask the class why they think green building is necessary. Why has green building emerged as an important new industry?	**Slide 8** **Why Green Building?** **SM Page 7** **Notes:**

• The U.N. predicts that there will be 9.4 billion people on earth by 2050. More people mean more buildings. • Buildings have **enormous environmental impacts.** • Understanding these impacts leads to the unavoidable conclusion that it is necessary to improve how we **design, construct, operate, and maintain buildings.**	**Slide 9** **Why Green Building?** **SM Page 7-8** **Notes:**
Note to Instructor: **Discussion:** Discuss the idea of a building "life cycle." What impacts do building have at each phase of their life cycle?	**Slide 10** **Building Life Cycle:**  **Figure2: Buildings, and the resources used to create and maintain them, have broad life cycle impacts.** **SM Page 8** **Notes:**
• Green building refers to the set of constantly evolving best practices and technologies applied in the **planning, design, construction, and operations and maintenance** of buildings to address our increased understanding of the **social, economic, and environmental impacts** of the built environment.	**Slide 11** **Green Building Definition:** **SM Page 8** **Notes:**
• Because buildings consume such large amounts of energy and other resources to operate and maintain, there is a correspondingly large opportunity to make environmental performance improvements in this sector. • The work you do can have a direct effect not only on **how a building impacts the environment (planet)**, but also on **how healthy a place it is for occupants (people)** and **how much money a building owner will pay and/or save over the life of the building (profit)**.	**Slide 12** **Opportunity:** **SM Page 8** **Notes:**

• **Buildings are linked to negative environmental impacts in a number of categories** including: ○ Global warming and climate destabilization. ○ Global energy demand. ○ Depletion of natural resources. ○ Habitat disruption and loss. ○ Water quality and scarcity.	**Slide 13** **Environmental Concerns:** **SM Page 8** **Notes:**
Global warming is the phenomenon of increasing surface and ocean temperatures that has been observed over the past more than half century. • Increased temperatures have broad and unpredictable effects on global weather patterns, resulting in **climate change**, or **climate destabilization.** • Global warming might have some isolated positive side effects such as being able to grow tomatoes in Alaska, but overall a climate destabilized future is not one to look forward to.	**Slide 14** **Environmental Concerns:** **SM Page 9** **Notes:**
• **Rising sea levels** endanger wildlife and coastal communities. • **Increased temperatures** damage ecosystems. • **Heat waves** negatively impact human health. • More frequent and powerful **storms** threaten lives and property. • **Drought** threatens food supplies.	**Slide 15** **Climate Destabilization Consequences:** **SM Page 9** **Notes:**

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- Understanding the causes of global warming is helpful in addressing strategies to mitigate its causes and effects.
- Through decades of research, scientists have linked increasing global temperatures with increased concentrations of greenhouse gases in the atmosphere.
- Greenhouse gases are gases that **trap incoming radiation from the sun in the form of heat**, much like the glass in a greenhouse does.

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Slide 16
Greenhouse Gases:

SM Page 9
Notes:

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- There are two types of greenhouse gases:
  - **Naturally occurring.**
  - **Created by human activities (anthropogenic).**
- Naturally occurring greenhouse gases (namely water vapor in the form of clouds and CO_2 released by natural processes) are essential to the Earth's ability to support life as we know it—without them, the planet would be too cold.
- However, human activities since the Industrial Revolution of the 19th Century, such as increased driving and energy production, have resulted in the release of millions of tons of additional greenhouse gases, which is beginning to disrupt the delicate atmospheric balance required to maintain conditions that support humans and other species.

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Slide 17
Greenhouse Gases:

Figure 3: Greenhouse Gas Effect.

SM Page 9-10
Notes:

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Note to Instructor: **Discussion:** Ask the class what they think about the debate over whether or not global warming is caused by human activities. • While there has been some debate about the origin of increased levels of CO_2 in the atmosphere, the fact that greenhouse gas concentrations are escalating is not in question. As you contemplate these issues for yourself, you might consider whether, given the potential consequences, we can afford to waste time arguing over the remote possibility that scientists are wrong about this. If they are wrong, we have nothing to lose (and much to gain) from using energy and resources more efficiently. If they are right, however, then we have no time to lose in taking action.	**Slide 18** **The Debate Over Global Warming:** **SM Page 10** **Notes:**
• **Carbon dioxide** (CO_2) • **Methane** (CH_4) • **Nitrous oxide** (N_2O) • **Hydrofluorocarbons** (HFCs) • **Perfluorocarbons** (PFCs) • **Sulfur hexafluoride** (SF_6)	**Slide 19** **The Six Greenhouses Gases of Greatest Concern:** **SM Page 10** **Notes:**

• Carbon dioxide (CO_2) is the **most prevalent greenhouse gas.** • Concentrations of CO_2 have **increased by almost 40%** since the Industrial Revolution. • CO_2 **naturally flows through the environment** and atmosphere. • The **burning of fossil fuels** is the primary way humans release excess CO_2 into the atmosphere. • Fossil fuels are made of hydrogen and carbon. When they are burned to make energy, the carbon combines with oxygen in the atmosphere to create CO_2. Fossil fuels are considered *non-renewable* because there is a limited supply of them on earth, and it would take millions of years for nature to create more. Fossil fuels are used to not only create energy directly for such applications as industrial processes and transportation, but are also burned to generate electricity for secondary uses.	**Slide 20** **Carbon Dioxide:** **Figure 4: Atmospheric Carbon Dioxide Concentrations, 1759-2004.** **Figure 5: U.S. Greenhouse Gas Emissions by Gas, 2008.** **SM Page 10-11** **Notes:**
• A look at the carbon cycle shows the relative magnitudes of naturally-occurring and human-generated CO_2 emissions. This diagram shows pre-industrial "natural" CO2 fluxes exchanges (shown by the black arrows) and those caused by human activity (shown by the red arrows) worldwide. The ocean, vegetation, and soil components are in almost perfect balance and actually sequester slightly more than they produce. However, fossil-fuel combustion and industrial processes do not show a similar balance, but rather a net positive contribution of CO_2 to the atmosphere. Scientists have determined that the approximate 1 degree Celsius rise is global temperature over the last century is almost certainly connected to these activities.	**Slide 21** **Carbon Dioxide:** **Figure 6: Carbon Cycle.** **SM Page 11-12** **Notes:**

• Because it has such a large and direct impact on the future health of our planet, people sometimes use CO_2 (or even just "carbon") as a shorthand way of referring to all greenhouse gases. • Almost all human activities require an energy input and have corresponding CO_2 emissions. From this, the notion of "carbon footprint" has been developed as a measureable way to determine an individual's impact on climate destabilization and the environment. • Carbon footprint is **the measure of total greenhouse gas emissions generated by a person, activity, or entity.** A carbon footprint can be calculated at a range of scales, from a single human being or a single building to a large corporation, a neighborhood, or even a nation. • Your carbon footprint depends on what kind of car you drive, how often you travel by plane, what kind of energy you use to heat your home and power your appliances, and even what kind of food you eat. • **A building's carbon footprint can be assessed by taking into account the non-renewable energy required to design, build, operate, and maintain it.**	**Slide 22** **Carbon Footprint:** **SM Page 11-12** **Notes:**
• Measuring the impact of an activity or object throughout every stage of its use—from extraction to disposal or reuse—is called lifecycle assessment. • Carbon footprint is **measured using life cycle assessment.** • All of this energy (which might be initially measured in gallons of gasoline, kilowatt hours of electricity or therms of natural gas) can be translated into an equivalent amount of CO_2 emissions, and thus a carbon footprint for each item can be calculated. • Lifecycle impacts as related to materials are described in more detail in Unit 4.	**Slide 23** **Carbon Footprint:** **SM Page 12-13** **Notes:**

Note to Instructor: **Discussion:** What if you wanted to evaluate the relative environmental impact of, say, a piece of lumber and a steel stud? Ask the students how they would go about making this evaluation, comparing the environmental impact of these two items.	**Slide 24** **Comparing Environmental Impact:** **SM Page 13** **Notes:**
• In general, wood has a much smaller carbon footprint than steel due to the incredible amount of energy required to manufacture steel. • The precise carbon footprint for each item would be different. Depends on energy used to: ○ **Harvest** raw material. ○ **Manufacture** each item. ○ **Distribute** each item. ○ **Transport** each item to job site. ○ **Install** each item.	**Slide 25** **Environmental Impact Depends On Energy Used To:** **SM Page 13** **Notes:**
• Carbon footprints **can also be calculated for buildings by assessing their environmental impacts at every stage of the building life cycle.**	**Slide 26** **Carbon Footprint:** **SM Page 13** **Notes:**

- This chart shows the relative amounts of energy used at each stage. It is important to note that the operation of a building over its lifetime consumes significantly more energy than is consumed in the design and construction phases.

- The work you do that directly impacts a building's overall operating efficiency therefore has great potential to reduce the size of the building's carbon footprint. Indeed, greenhouse gas reduction goals are impossible to achieve with improvements in new construction alone. Energy retrofitting existing buildings is a huge part of the global warming solution, and a huge opportunity for the sheet metal industry.

- A building consumes energy at every stage of its life cycle. The first phase, embodied energy, includes the carbon footprints of all the building materials that make up the project.

- Grey energy refers to the amount of energy required to transport those materials to the project site.

- Induced energy is the energy consumed by the actual construction of the building. As you can see, these categories of energy are expended early in the building life cycle. The steepness of the curve through these phases indicates the intensity of energy consumption.

- It is this intensity that makes it easy for green building efforts to focus on the design and construction phases of building projects. However, over the life of the building, the operating energy represents a significantly greater expenditure of energy.

- The vertical sections of the curve represent periodic upgrades to the building, which ideally make the building more efficient, resulting in a less steep subsequent section of curve. The final demolition and recycling phase actually shows a decline in total energy used, which represents components of the building being recycled and reused, thereby transferring their embodied energy to other projects.

Slide 27
Building Life Cycle:

Figure 7: A building consumes energy at every stage of its lifecycle.

SM Page 13-14
Notes:

• In the United States buildings are responsible for: ○ 38% of all **CO_2 emissions.** ○ 72% of **electricity consumption.** ○ 39% of **energy use.** ○ 40% of **raw materials use.** ○ 30% of **waste output** (136 million tons annually). ○ 14% of **potable water consumption** (15 trillion gallons).	**Slide 28** **In the United States, Building Are Responsible For:** **SM Page 13** **Notes:**
• **Non-renewable energy use increases carbon footprint.** • **69% of electricity is generated by burning fossil fuels.** • Non-renewable energy from fossil fuels are used to not only create energy directly for such applications as industrial processes and transportation, but are also burned to generate electricity for secondary uses. • In fact, according to the Energy Information Administration, 69% of U.S. electricity is generated by burning fossil fuels, the major share (51%) by burning coal. • Much of this course is dedicated to helping you understand principles and practices that will lead to greater energy efficiency in buildings, thereby saving money for building owners, reducing reliance on non-renewable fossil fuels and improving environmental performance. • The section on Commissioning in Module 2 describes how working with a Commissioning Agent helps optimize building energy performance. Module 3 is dedicated to energy efficiency and provides a survey of energy efficiency practices and technologies.	**Slide 29** **Other Building Impacts:** **SM Page 13-15** **Notes:**

• **The building sector is responsible for most land use and material extraction impacts.** • Ecosystems disrupted or destroyed. • Creates strain on material resources and waste disposal capacity.	**Slide 30** **Other Building Impacts:** **SM Page 15** **Notes:**
• It is estimated that more than half of original wetlands in the United States have been lost or destroyed by human activities, primarily building. • Benefits of wetlands: ○ **Wildlife habitat.** ○ **Flood control.** ○ **Water filtration.** ○ **Recreation.** • Wetlands are valuable not only for providing habitat to thousands of species of plants and animals, but also for providing vital services to humans such as flood control, water filtration, and recreation. These important ecosytems are threatened by buildings when they are cleared for development or polluted by urban runoff.	**Slide 31** **Benefits of Wetlands:** **Figure 8: Wetlands.** **SM Page 15** **Notes:**
• Low-density, suburban development in particular (often called “suburban sprawl” or just “sprawl”) has many problematic implications. • Problems with low-density development (“sprawl”): ○ **Destruction of wetlands, other ecosystems, or farmland.** ○ **Makes people dependent on cars to get around.** • Sprawl might replace wetlands, other ecosystems, or even prime farmland that exist adjacent or near urbanized areas that are prone to sprawl. • Further, sprawled communities tend to be significantly more dependent on fossil fuel burning vehicles to access services such as the grocery store, pharmacy, church or school and thus have a much bigger carbon footprint.	**Slide 32** **Low-Density Development (“Sprawl”):** **Figure 9: Sprawl.** **SM Page 15-16** **Notes:**

- Impacts of building materials:
  - **Destruction of ecosystems** through clear-cutting and strip mining.
  - Increased **air and water pollution.**
  - **Toxic exposure** to wildlife and humans.
  - **Construction waste**: 170 million tons generated each year.

- Building materials themselves have numerous seen and unseen environmental impacts throughout their lifecycle. As was shown in the example of the 2x6 and the steel stud, the amount of energy required to produce, deliver and install materials can vary greatly.

- The extraction of the elements needed to make building products can completely devastate ecosystems, especially in processes like clear-cutting forests and strip mining. These practices lead to decreased biodiversity, increased air pollution and degraded water supplies through reduced erosion control.

- The manufacture of building products may release toxins into the environment, poisoning fish and wildlife and rendering places unfit for human recreation. In some cases, the people manufacturing the products themselves are at risk for toxic chemical exposure. Some products, once installed, continue to emit toxins into occupied space in the building.

- And finally the disposal of building products contributes to overflowing landfills and highly polluting waste incinerators. The EPA estimates that more than 170 million tons of building-related construction and demolition debris was are generated each year. Construction Waste Management (CWM) practices to help you increase waste diversion rates are covered in Module 2.

Slide 33
Impacts of Building Materials:

Figure 10: Strip Mining.

SM Page 15-16
Notes:

• The construction and operation of buildings also has significant demand on our potable water supply resources. • Water issues: ○ **Water scarcity in some regions.** ○ **Energy used to pump and heat water.** • Water is scarce in many regions. Where there are inadequate water supplies to meet the demands of increasing populations and water resources from water-rich areas are required to meet their needs. Water efficiency is a key priority in these locales. • In addition to the water demand itself, significant energy is required to pump and heat water so an increase in water use means an increase in energy use and energy-based greenhouse gas emissions. So, low-flow, high-efficiency water fixtures can be as much of a *water*-saving technology as they are an *energy*-saving technology.	**Slide 34** **Water Issues:** **SM Page 16-17** **Notes:**

- Stormwater management seeks to eliminate stormwater runoff from construction sites and throughout the life of the building.
- Environmental issues associated with stormwater runoff include:
  - **Erosion**
  - **Pollution of waterways**
  - **Reduced water table**
- Strategies include eliminating impermeable surfaces, diverting runoff to designated vegetated areas, and capturing the runoff for use in the operation of the building.
- In doing so, each building plays a role in supporting the quality of nearby water bodies, reducing the demand for costly public infrastructure and reducing the energy needed to pump and treat water at a treatment plant. Also, such strategies can sometimes make building owners eligible for financial incentives from stormwater utilities or other water quality-focused organizations.
- The Construction Activity Pollution Prevention section in Module 2 provides information specific to best practices in erosion, sedimentation, and dust control during construction.

Slide 35
Stormwater Runoff:

Figure 11: Combined Sewer Overflow (CSO).

SM Page 17-18
Notes:

- It may seem that green building is only concerned with the outside environment, but in fact it addresses interior environmental issues as well. Green building aims to improve the health of the people who construct and occupy buildings as well as the health of the planet.
- According to the USEPA, **people in the U.S. spend approximately 90% of their time indoors.** The quality of the built environments in which we spend that time strongly impacts our health, well-being, and productivity. In fact, **pollutant levels can be 2-100 times higher indoors** due to poor air quality.

Slide 36
Health, Culture, and Community Concerns:

Figure 12: Exposure to even mildly poor indoor air quality.

SM Page 18
Notes:

• Indoor pollutants include: ○ **Particle allergens.** ○ **Chemical pollutants.** ○ **CO_2.** ○ **Temperature.** ○ **Humidity.** ○ **Carbon monoxide.**	**Slide 37** **Indoor Pollutants Include:** **SM Page 18** **Notes:**
• These conditions can be a result of inattentive design and/or construction practices that create insufficient outside air supply, poor ventilation and/or use of inappropriate materials. • Exposure to even mildly poor indoor air quality for a sustained period of time can negatively impact occupants and lead to what is known as *sick building syndrome*. Sick building syndrome (SBS) is a term that describes a range of acute health and comfort symptoms that are linked to time spent in a building. • Sick Building Syndrome (SBS) symptoms include: ○ **Headache.** ○ **Respiratory irritation.** ○ **Dry or itchy skin.** ○ **Dizziness.** ○ **Nausea.** ○ **Difficulty concentrating.** ○ **Fatigue.**	**Slide 38** **Sick Building Syndrome Symptoms:** **SM Page 18** **Notes:**

• Other aspects of buildings that influence human health: ○ **Thermal comfort.** ○ **Lighting conditions.** ○ **Connection to the outdoors.** ○ **Controllability of space.** • Thermal comfort is driven by several variables and can be managed mechanically or passively (i.e., "naturally"). • Occupant control over thermal comfort, task-appropriate lighting and other needs increases ownership of one's space and is connected to higher productivity and worker satisfaction. • Studies also show that the ability to remain connected to the outdoors by access to views, use of daylight and other measures also enhances occupant satisfaction and performance. • Given the choice between a work environment that is well-daylit, has operable windows with views of the sky or vegetation versus a room with no windows and views, what would you choose?	**Slide 39** **Other Influences of Buildings on Human Health:** **SM Page 18-19** **Notes:**
• Before a building's construction is even complete, it poses health risks to the people building it. • Construction workers may be exposed to: ○ **Toxic metals.** ○ Volatile organic compounds (**VOCs**). ○ **Hazardous dusts** such as asbestos and silica ○ High concentrations of **carbon monoxide and other gases.** • Construction Indoor Air Quality (CIAQ) practices will be covered in Module 2 to help you learn to minimize the harmful effects of these hazards.	**Slide 40** **Construction Workers Exposed To:** **SM Page 19** **Notes:**

• In addition to addressing concerns about the impact of the built environment on human health, the "people" aspect of the Triple Bottom Line also refers to the relationship between buildings and the community and culture of the people that inhabit them. • Buildings contribute to community and cultural identity: ○ **Historic buildings.** ○ **Livable neighborhoods.** ○ **Local materials.** • For instance, preserving historic buildings enhances a sense of shared history and pride of place. • Designing neighborhoods to promote walking, social interaction, and community involvement can help contribute to happier, more livable places. • Using locally harvested and manufactured building materials not only strengthens the local economy, but also contributes to regionally meaningful architecture that distinguishes a place and enhances building user experience. • In these ways, buildings are an integral part of the fabric of society.	**Slide 41** **Community and Cultural Identity:** **SM Page 19** **Notes:**
• **"Profit"** is the last aspect of the Triple Bottom Line. • This will be **covered in the next unit.**	**Slide 42** **Financial Concerns:** **SM Page 19** **Notes:**

Unit 1 Summary:
In Unit 1, the students have learned:

- The pursuit of sustainability requires accounting for the impacts of our activities on people, planet, and profit (the Triple Bottom Line).
- Green building is the set of best practices and technologies applied in the planning, design, construction, and operations and maintenance of buildings.
- Lifecycle assessment measures the impact of an object or material through all stages of its use—from extraction of materials to disposal or reuse.
- A majority of U.S. energy comes from the combustion of non-renewable, fossil fuel-based sources that emit heat-trapping greenhouse gases.
- Carbon dioxide is the most prevalent human-caused greenhouse gas and is the most commonly used metric to measure a building's potential influence on climate destabilization.
- A "carbon footprint" is the total amount of carbon generated as a result of an activity or the creation of a product.
- On average, people spend 90% of their time indoors. The productivity, health, and well-being of building occupants are strongly impacted by the quality, comfort, and control of their space.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

INTRODUCTION TO GREEN BUILDING

Unit 2: The Growing Green Building Market

Module 1
Introduction to Green Building

Unit Learning Objectives:
After this unit, students will:

- *Be familiar with current research on the financial costs and benefits of green building.*
- *Understand how building professionals and tradespeople can prepare to work in a growing green building market.*
- *Be able to compare various green building certifications such as LEED, Green Globes, CHPS, GGHC, Energy Star, and the Living Building Challenge.*
- *Understand how government regulation affects the green building market.*

Time Required: Approximately 2 hours

Procedures:

1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:

☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 21-36

Introduction:
This unit describes research on the financial costs and benefits of green building. It also discusses ways that building professionals and tradespeople can take advantage of growth in “green collar” jobs. There are several factors influencing this growth including governmental regulation, an increased emphasis on existing building performance, and green building certification systems. Six green building certification systems are described.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
Note to Instructor: **Discussion**: Ask the class how much extra do they think it costs to build green. • How much does it cost to build green? • Many people assume that, because green building features are relatively new or marketed as fashionable or cutting edge, there must be a large cost premium for building green. • However, while surveys have shown that even building professionals tend to estimate this "green premium" as being on average 16%, current research reports that the cost of green building projects falls into the same range as the cost of conventional building projects. • In other words, there are low and high budget green projects, just as there are low and high budget conventional projects. Indeed, it is safe to say that if green building didn't make sense financially, we would not be seeing the strong growth in the green building market that we are seeing today.	**Slide 1** **Cost and Benefits of Green Building:** **SM Page 21** **Notes:**

• The green building market share in residential and commercial construction has grown rapidly in recent years and is projected to continue doing so. • A 2009 report by the U.S. Green Building Council and Booz Allen Hamilton estimates that the green building industry **added $173 billion to U.S. GDP between 2000 and 2008.** Even in the face of harsh economic pressures, this share is **expected to increase** to $554 billion from 2009 to 2013, including the creation of **7.9 million jobs.** • Even if these projections are high, the tide has definitely turned toward widespread recognition of the economic opportunities—for the sheet metal industry and others—presented by the emergence of the green building industry. A wide-ranging 2005 study concluded that green building projects are quicker to secure tenants, can charge higher rents, have lower turnover, cost less to operate and maintain, and improve business productivity—all of which have a positive impact on the financial bottom line.	**Slide 2** **Cost and Benefits of Green Building:** **SM Page 21-22** **Notes:**

• Part of the misperception about the "green premium" comes from a narrow consideration of the economic profile of a project. • **If only first costs are considered, then green building features can be more expensive** than conventional features. However, when potential savings that the green features provide are factored in ("life cycle cost"), they can pay for themselves many times over. • **Life cycle cost analysis (LCCA) is a method for assessing the total cost of owning a building,** taking into account the costs of acquiring, owning, maintaining and disposing of all building components and systems. • One report claims that a savings of $1.2 trillion could be realized in energy efficiency measures on an investment of less than half that over the next decade. Another study conducted in 2003 showed that an upfront investment of 2% in green building design resulted in an average life cycle savings of 20% of the total construction costs, or ten times the initial investment.	**Slide 3** **Cost and Benefits of Green Building:** **SM Page 22** **Notes:**

- LCCA takes into account:
  - **First costs.**
  - **Lifetime energy use.**
  - **Lifetime operations and maintenance costs.**
  - **Disposal/recycling costs.**
  - Effects on **occupant health and productivity** due to poor IAQ, thermal comfort, lighting, etc.
  - **Marketing advantage.**

- Remember, green building seeks to improve the health and indoor experience of occupants by improving indoor air quality, ensuring thermal comfort, providing proper lighting and connection to the outdoors, and allowing for controllability of space. The magnitude of many of the advantages that can be realized in a green interior environment comes from the fact that a company's investment in personnel is often many times greater than its investment in facilities. For the average employer, staff costs dwarf design, construction, operations and maintenance costs over the long run. Over a 30-year period, initial building costs represent a mere 2% of the total, while operations and maintenance costs account for 6% and staff expenditures equal 92%.

- Therefore building enhancements that improve working conditions and lead to greater employee retention, recruiting power, and/or productivity can have a remarkable economic benefit.

- While it may be difficult to directly link such building features with the behavior of individual employees, studies have been conducted to attempt to quantify these effects across large numbers of people. This research has linked improvements in indoor environments to improved employee health, resulting in reduced absenteeism (resulting in productivity gains of $17-48 billion nationwide) and lower health care costs (at a savings of $20-160 billion).

- Marketing advantage is another way that green building can have a positive impact on profits. Green features appeal to a growing segment of society looking to reduce its overall environmental impact, and people are willing to pay for them.

Slide 4
LCAA Takes Into Account:

Figure 13: Marketing advantage.

SM Page 22-23
Notes:

• In addition to the environmental and financial benefits of green building, three factors are expediting the growth of the green building market: ○ **Government regulation.** ○ **Increased emphasis on existing building performance.** ○ **Green building certifications.**	**Slide 5** **Factors Driving Advancement in the Green Building Market:** **SM Page 23-24** **Notes:**
• Green building started as a grassroots movement, but is fast becoming institutionalized in society through government initiatives including legislation, executive orders, resolutions, ordinances, policies, and incentives. • There are already green building initiatives in at least 45 **states,** 14 **federal agencies** or departments, 17 public **school jurisdictions**, and 41 institutions of higher education. • Most of these initiatives require that new and existing building projects using public funds meet certain green building standards, such as LEED. Because governments are charged with responsibly managing resources over the long term, public agencies have been early adopters of green building practices. In addition to LEED, many government policies also specify energy-specific commitments such as “reduce energy use to 1990 levels by 2020 and 5% more every 5 years thereafter”. • Notably, **30% of all LEED projects are government owned or occupied.**	**Slide 6** **Factors Driving Advancement in the Green Building Market:** **Figure 14: 30% of all LEED projects are governement owned or occupied.** **SM Page 24** **Notes:**

• Besides mandating that publicly owned projects meet green building requirements, governments also fuel the green building market by offering incentives to projects that pursue higher levels of building performance. • Green building incentives: ○ **Cash bonuses.** ○ **Tax credits.** ○ **Expedited permitting.** ○ **Zoning exceptions.** • Availability of incentives varies widely by location. • The Database of State Incentives for Renewables & Efficiency (DSIRE; www.dsireusa.org) is a searchable source of information that can help guide incentives research.	**Slide 7** **Green Building Incentives:** **SM Page 24-25** **Notes:**

• In July of 2009, the House of Representatives passed the **American Clean Energy and Security Act**, which creates a number of programs that, among other things, incentivize green building projects such as energy efficiency retrofits of residential and commercial buildings, the development of standardized energy performance labels for buildings, and the promotion of water efficiency in building products. • In an effort to create a National Retrofit Market, Vice President Joe Biden unveiled the "Recovery through Retrofit" report created by the Middle Class Task Force and the Council on Environmental Equality (CEQ). This proposal focuses on residential weatherization and energy efficiency retrofit on the national level, by providing national training standards, job creation, small business promotion, and long term energy savings (for more information visit www.whitehouse.gov and search **"recovery through retrofit"**). • President Obama issued an executive order in October 2009 calling for focused federal leadership to reduce carbon emissions throughout the federal government. Green building strategies are specifically outlined in this directive as a means to achieve this goal. • Furthermore, funding provided by the American Recovery and Reinvestment Act of 2009 offers opportunities for state and local governments to finance green building projects.	**Slide 8** **Federal Green Building Legislation:** **SM Page 25** **Notes:**

• The federal stimulus funding helps an economic sector that was already growing to return to its pre-recession growth path. This is not to say, however, that the recession has not affected the green building industry. • **Recession caused shift in focus from new construction to existing buildings.** • **Even low-cost improvements in existing buildings can lead to big savings.** • Before credit markets froze in late 2008, new construction was the primary focus of green builders. In many ways it is easier to do things right the first time rather than trying to go back and address performance issues in existing buildings. The housing boom was fueling growth throughout the construction sector, and green builders wanted to make sure that environmental performance was a priority from the earliest phases of planning and design. • Now that new construction starts have slowed considerably, focus has shifted to the performance of existing buildings. While older buildings can present additional challenges to the green builder due to existing constraints, even low-cost interventions can result in significant performance improvements.	**Slide 9** **Greening Existing Buildings:** **SM Page 25** **Notes:**

• Existing building energy retrofits are a **big opportunity for the HVAC industry.** • **Approximately 150 billion sf to be renovated in the next 20 years.** • The volume of potential work in existing buildings for the HVAC industry is substantial and the demand is growing. One estimate states that approximately half of the U.S. building stock will be renovated (approximately 150 billion square feet) in the next 20 years. • There is less risk in existing building retrofits because there is less capital outlay and more "knowns" (systems, materials, etc.) already in place that can be systematically evaluated for the cost-effectiveness of their replacement/upgrading. This is particularly important to owners in a down economy. • An independent research company indicates that major green renovations in the US will grow from $2.1 billion in 2009 to $6 billion by 2013, a nearly 300% increase in just three years. These factors and the changing regulatory climate make all signs point to existing buildings, with particular emphasis on energy, in the near future.	**Slide 10** **Greening Existing Buildings:** **SM Page 25-26** **Notes:**

• There is an argument to be made that **existing buildings are already green** because the environmental impacts of their design and construction have already occurred. If an existing building can replace the function of a proposed new building, then not building the new building avoids numerous environmental impacts. • For example, existing buildings represent a substantial investment in embodied energy (remember the building life cycle energy use chart from unit 1) that can continue to pay dividends throughout the useful life of the building. **Embodied energy** is the amount of energy that was used to create the building and is thus already "embodied" in it. • However, since most of the energy consumed by a building over its lifetime is expended after it is built, environmental performance during the operations phase is of utmost importance. • We've already shown that existing conventional buildings can be energy inefficient, create a disproportionate strain on natural resources, and provide unsatisfactory work or living conditions for occupants. The opportunity to apply green building strategies to existing buildings means that these shortcomings can be addressed, while preserving the embodied energy already invested. • Additionally, existing buildings that employ green features are better equipped to compete with high performance new buildings for buyers and tenants.	**Slide 11** **Greening Existing Buildings:** **SM Page 26-27** **Notes:**

• As the green building market has grown, the need for standards and performance benchmarks has led to the emergence of several green building certification systems. • A representative sample of these systems includes: ○ **LEED** (Leadership in Energy and Environmental Design). ○ **Green Globes.** ○ **Energy Star.** ○ **CHPS** (pronounced "chips", Collaborative for High Performance Schools). ○ **Green Guide for Healthcare.** ○ **Living Building Challenge.**	**Slide 12** **Green Building Certifications:** **SM Page 27** **Notes:**
• Building projects pursue certification for a number of reasons. • Reasons to pursue certification: ○ **Improve environmental performance.** ○ **Regulatory compliance.** ○ **Third-party verification.** ○ **Market differentiation.** • In various ways and to differing degrees, these certification systems validate environmental performance improvements by requiring documented action on the part of the project team. By helping teams commit to a set of goals (such as achieving a certain set of credits or a certain level of certification), certification systems can energize, motivate, and focus project efforts. Each system provides strategies for how to achieve performance objectives and metrics for how to measure success.	**Slide 13** **Reasons to Pursue Certification:** **SM Page 27** **Notes:**

• By far the most widely used and respected of these is Leadership in Energy and Environmental Design (LEED), **developed by the U.S. Green Building Council in 1998**, which addresses environmental performance in buildings in multiple market sectors, including: new and existing commercial buildings including tenant improvements, core and shell projects, and other market sectors such as schools, healthcare facilities, retail, residential, and neighborhood development. • There are currently over 35,000 LEED-registered projects, and more than 4,000 have achieved certification. This represents buildings in all 50 states and 91 countries. • The history, mission, and structure of the USGBC as well as an overview of the various LEED Rating Systems will be covered in the next unit.	**Slide 14** **Leadership in Energy and Environmental Design (LEED):** **SM Page 27-28** **Notes:**

• The Green Globes rating system was originally developed for existing buildings in Canada. • In the US, Green Globes is owned and operated by the Green Building Initiative (GBI), which has emerged in direct competition with LEED and the USGBC. • Certification levels on a scale of one to four globes recognize new and existing buildings that earn at least 350 of a possible 1,000 points across the following categories: energy, indoor environment, site, water, resources, emissions, and project/environmental management. Green Globes administration and certification **costs are significantly less than typical LEED costs**, and the **documentation and compliance requirements are correspondingly less rigorous.** • While the GBI has succeeded in getting Green Globes included as a recognized standard in green building legislation in several states, the green building market as a whole has not embraced it as significantly as LEED. There are currently fewer than 100 Green Globes certified projects in 24 U.S. states. • The GBI has been criticized for its relative lack of rigor and the financial support it receives from the vinyl, chemical, and wood industries.	**Slide 15** **Green Globes:** **SM Page 28** **Notes:**

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- Energy Star:
  - **Joint project of U.S. EPA and Dept. of Energy.**
  - Founded in 1992.
  - **Compares building energy performance with that of thousands of other similar buildings.**
  - Scores of 1-100.
  - Score of 50 is average.
  - Score of 75+ earns Energy Star label.
  - LEED requires Energy Star score of 69+ for existing buildings.
- You may be familiar with the Energy Star label on appliances, computer and office equipment, lighting, and home electronics products. Buildings that fall into one of 13 space type categories can also earn the Energy Star label by using interactive online tools such as “Target Finder” to follow the EPA’s free rating system.

- *Target Finder* helps design teams set performance goals for new buildings by correlating estimated annual energy use with national trends for comparable buildings.

- Another tool, *Portfolio Manager,* is used by building owners and operators to manage and track energy and water use in one or more existing buildings.

- Green Globes uses Energy Star to benchmark both new and existing buildings, requiring a score of 50 or above to earn points. LEED requires that buildings earn a score of 69 or above as a prerequisite for participating in the Existing Buildings Operations & Maintenance rating system.

- These tools have been used to gauge and influence the energy performance of over 96,000 buildings since their inception in 2000. They work by comparing a building’s projected or actual energy performance to that of thousands of similar buildings in the Department of Energy’s Commercial Building Energy Consumption Survey (CBECS) database, resulting in a rating of 1-100. An Energy Star score of 50 represents average energy performance. Buildings that achieve a score of 75 or higher (meaning that they are in the top 25%) earn the Energy Star label.

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Slide 16
Energy Star:

SM Page 28-29
Notes:

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• These rating systems change over time as standards increase. Due to overall increases in building quality, older rated buildings may be "rating dated." For example a building may be called "Energy Star 2005." It will still maintain its Energy Star rating, but will not be at the same level as an "Energy Star 2009" building.	

• The remaining three rating systems on the list are used far less frequently and apply to only a very particular part of the market. • **Collaborative for High Performance Schools (CHPS):** ○ Aimed at improving K-12 facilities. • **Green Guide for Healthcare (GGHC):** ○ Aimed at improving hospitals and other healthcare facilities. • **Living Building Challenge:** ○ Certifies sustainable buildings (not just green buildings) ○ All requirements are imperatives (no optional credits). • The Collaborative for High Performance Schools (CHPS, pronounced "chips") publishes a series of best practices manuals and assessment tools to positively influence student experience and performance through better-designed and healthier facilities. LEED for Schools is another rating system focused on the unique issues and priorities of K-12 education buildings. • The Green Guide for Healthcare (GGHC) is a quantifiable green design toolkit emphasizing enhanced environmental and health principles in all phases of the building life cycle. Like schools, healthcare facilities have unique challenges when it comes to implementing green building strategies. These include 24/7 operations, higher energy and water use intensities, and the stringent requirements of health codes and infection control protocols. LEED for Healthcare is being developed in close collaboration with the GGHC. • While each of the rating systems described above guides and recognizes incremental levels of improved environmental performance, the Living Building Challenge sets absolute levels of achievement that must be met in order to participate in the program. The Living Building Challenge includes 20 imperatives such as "Net Zero Energy", which requires that the project produces as much energy as it consumes over the course of the year through on-site renewable energy systems.	**Slide 17** **Other Rating Systems:** **SM Page 29-30** **Notes:**

By holding building projects to such rigorous standards, the Living Building Challenge appeals to that elite sector of the market aiming to create truly sustainable projects, not just green buildings. (Recall the difference between *sustainable* and *green* outlined in Unit 1.) The Living Building Challenge also goes further than other rating systems by more comprehensively addressing the “people” aspect of the Triple Bottom Line. This is achieved by laying out requirements in the categories of Health, Equity, and Beauty in addition to the environmental categories of Site, Water, Energy, and Materials.

• The financial advantages described above largely benefit building owners, but building professionals and tradespeople can also profit from the growth of green building. Surely the promise of “green collar” jobs is at least part of the reason you are taking this course.

• USGBC report: Green construction industry will provide $396 billion in labor earnings between 2009-2013.
• Dept. of Energy report: Every $1 million invested in weatherization projects supports 52 jobs.
• Bureau of Labor statistics: **Growth in green jobs will outpace other sectors through 2016.**

• The 2009 USGBC/Booz Allen Hamilton report referenced earlier predicts that green construction alone will provide $396 billion in labor earnings between 2009 and 2013, up from $123 billion provided from 2000 to 2008.

• The U.S. Department of Energy reports that every $1 million invested in weatherization projects supports 52 direct jobs, and additional jobs are created indirectly for contractors and material suppliers.

• Bureau of Labor statistics suggest that growth in environmental-related occupations will far outpace all other occupations through at least 2016. Green building is part of the solution for getting the U.S. economy back on track, while reaping the benefits of improved environmental performance.

Slide 18
Opportunities for Building Professionals and Tradespeople:

Figure 15: Bureau of Labor statistics.

SM Page 30-31
Notes:

• So how can you take advantage of "green collar" job opportunities and distinguish yourself in a competitive marketplace? • As mentioned earlier, energy is a primary focus in green building. Furthermore, a majority of building-related energy opportunities lie with **existing building retrofits.** That's where HVAC professionals are poised to take greatest advantage. • Regulations and statistics suggest that trades prepared to support energy-related upgrades are well-positioned for work. One professional estimates that 80% of existing U.S. commercial building square footage has cost-effective retrofit potential. An increasing number of U.S. cities now require existing buildings to disclose energy performance, driving owners to get their buildings up to snuff so they can attract tenants and meet increasingly stringent regulations. • Needless to say, that demand for HVAC upgrades, retrofits, energy auditing, commissioning, and other related services is something the sheet metal industry must be prepared to meet.	**Slide 19** **Opportunities for Building Professionals and Tradespeople:** **SM Page 31** **Notes:**
• Personal credentials can help to further distinguish you as a green collar worker. • Possible "green collar" credentials include: ○ **LEED Green Associate and LEED AP.** ○ **Green advantage.** ○ **TABB certification.** ○ **IAQ and Commissioning credentials.** • More information on each of these programs is included in your Student Manual.	**Slide 20** **"Green Collar" Credentials:**  **Figure 16: Personal accreditation and certifications.** **SM Page 32** **Notes:**

• As you can see, there are a number of ways that you can validate your professional achievements and distinguish yourself in the green building market. • In addition to experience, education is one of the most important tools that you need to make sure you are well positioned to thrive in the new green economy. • We have defined green building as a constantly evolving set of best practices and new technologies. Today's best practice is tomorrow's standard operating procedure. This is good because the enormity of the problems we face demands frequent new ideas for solutions, but it also means that there is a constant need for green building practitioners to get informed, gain knowledge, and learn new tools and techniques in order to remain effective and relevant. **The more you know, the more effective you can be as part of a green building team.** • Gaining this expertise will not only differentiate you in the job market, but it will also help ensure that you can do the job right. Hopefully it is clear by now that this is of utmost importance as the stakes are high.	**Slide 21** **"Green" Education:** **SM Page 33** **Notes:**
• There are numerous examples of building projects that have applied green building principles to great effect. It is worthwhile to study these buildings to get ideas of successful strategies and learn from project mistakes. You can find extensive libraries of green building case studies on the websites shown here. **http://www.buildinggreen.com/hpb/index.cfm** **http://zeb.buildinggreen.com/** **http://greensource.construction.com/green_building_projects/default.asp** **http://eere.buildinggreen.com/** **http://www.usgbc.org/LEED/Project/CertifiedProjectList.aspx?CMSPageID=247**	**Slide 22** **High Performance Building Case Studies:** **SM Page 33** **Notes:**

Unit 2 Summary:
In Unit 2, the students have learned:

- Green buildings do not necessarily cost more than conventional buildings.
- Marketability, decreased operating and maintenance costs, access to incentives, and changing consumer preferences contribute to the financial benefits of green buildings.
- Regulation and incentives at all levels of government are playing a strong role in promoting green building market development.
- Several certification systems have evolved to guide and recognize green building products and projects.
- The sheet metal industry is poised to take advantage of “green collar” job opportunities.

Application:
To achieve the learning objectives, engage the students in discussions during class. Assign the case study research exercise* and encourage students to share their findings with each other. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

- Case Study Research Exercise worksheet:

  Project Name:
  Project Description (building size, type, location, users, etc.):
  What strategies does this project employ to address the following categories of environmental concern?
  Site:
  Water:
  Energy:
  Materials:
  Indoor Air Quality:
  How effectively does this project address the Triple Bottom Line concept?
  Is there anything not “green” about this project?

INTRODUCTION TO GREEN BUILDING

Unit 3: The U.S. Green Building Council & LEED

Module 1
Introduction to Green Building

Unit Learning Objectives:
After this unit, students will:
- *Be able to describe the history, mission and structure of the U.S. Green Building Council.*
- *Be able to distinguish between different LEED Rating Systems.*
- *Be familiar with the structure, process and terminology of LEED.*
- *Be aware of criticisms of LEED.*

Time Required: Approximately 1 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
- ☑ **Green LEED CD-ROM, Computer, and Projector**
- ☑ **Pencils**
- ☑ **Paper**
- ☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 37-46

Introduction:
This unit covers the history, mission and structure of the U.S. Green Building Council. The most important project of the USGBC is the development of the LEED green building rating systems. The structure and market sector applications of LEED are discussed along with potential criticisms of LEED.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• **Founded in 1993**, the USGBC is a member-based, non-profit organization that was with the mission "to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy and prosperous environment that improves the quality of life." • Providing tools and expertise to the design and construction industry at large, education to the public, and forums for industry dialogue, the USGBC's most prominent achievement that it **created Leadership in Energy and Environmental Design (LEED) Green Building Rating Systems** (often referred to simply as "LEED"), which is described in more detail later in this unit. • USGBC membership has grown from under 100 members in 1997, to **over 20,000 member companies and organizations**. Local and regional chapters promote USGBC programs, offer education, develop programs, and advocate for green building in their communities.	**Slide 1** **The U.S. Green Building Council (USGBC):** **SM Page 37** **Notes:**
• Until 2009, the USGBC was responsible for the development of LEED rating systems, LEED education, the certification of LEED projects and the accreditation of LEED professionals. Now the latter two functions are handled by the newly-formed Green Building Certification Institute (GBCI). • The GBCI was **created so that the LEED program could comply with ISO requirements for neutral third-party certification bodies.**	**Slide 2** **Green Building Certification Institute (GBCI):** **Figure 17: Until 2009, USGBC was responsible for the development of LEED rating systems, the certification of LEED projects, and the accreditation of LEED professionals.** **SM Page 37-38** **Notes:**

• The LEED for New Construction (LEED-NC) pilot program (version 1.0) was launched in October 1998, with the first version (2.0) available to the public in June 2000. The first LEED-NC Reference Guide was released in April 2001. Other LEED "products" that address the unique challenges and priorities of other market sectors followed starting in 2002. There have been several updates since then. • LEED's **goal is to help promote market transformation marked by the mainstreaming of high performance or green building practices.** • LEED addresses environmental performance at all stages of building life cycle, and for multiple market sectors.	**Slide 3** **LEED Green Building Rating Systems:** **SM Page 38** **Notes:**
• The complete set of LEED rating systems now includes several separate categories: ○ LEED for **New Construction (NC)**. ○ LEED for **Existing Buildings: Operations & Maintenance (EB:O&M).** ○ LEED for **Commercial Interiors (CI)**. ○ LEED for **Core & Shell (CS).** ○ LEED for **Schools.** ○ LEED for **Retail—NC.** ○ LEED for **Retail—CI**. ○ LEED for **Homes**. ○ LEED for **Neighborhood Development (ND)**.	**Slide 4** **LEED Green Building Rating Systems Categories:** **SM Page 38** **Notes:**
• Throughout this course when LEED is discussed, we will use the **LEED-NC** and **LEED-EB:O&M** rating systems to characterize LEED requirements for the vast majority of project types that you may be working on. • In its current version, LEED-NC requirements are similar or identical those for LEED-CS, -CI and Schools.	**Slide 5** **This course focuses on:** **SM Page 38** **Notes:**

- With the exception of LEED for Homes and LEED for Neighborhood Development, all **LEED rating systems are organized around five categories of environmental concern, plus two bonus categories.**

- Categories of concern:
  - Sustainable Sites
  - Water Efficiency
  - Energy & Atmosphere
  - Materials & Resources
  - Indoor Environmental Quality
  - Bonus categories:
  - Innovation & Design Process
  - Regional Priority

Slide 6
LEED Green Building Rating Systems:

Figure 18: Project Checklist: LEED 2009 for New Construction and Major Renovation.

SM Page 38-40
Notes:

- Within each credit category, the rating system contains **prerequisites (not optional)** for certification and **credits (optional)** but the more earned, the higher the certification level.

- Credits may require the implementation of prescriptive measures or set thresholds of performance that can be met in a variety of ways. For example, a prescriptive credit requires that all composite wood in the project contains no added urea formaldehyde while a performance-based credit requires a certain percentage of energy use reduction beyond code.

- The **Innovation & Design Process category** rewards projects for performance achievements not already specified in the rating system, exemplary levels of performance on existing credits and the involvement of a LEED Professional on the project team.

- The **Regional Priority category** awards bonus points for achieving existing credits that have been identified by regional committees as particularly important to a given region. For example, in drought-stressed areas, bonus points may be awarded for achieving water reduction-related credits.

Slide 7
LEED Green Building Rating Systems:

SM Page 40
Notes:

• There are four levels of LEED certification ○ **Certified** ○ **Silver** ○ **Gold** ○ **Platinum** • Correspond to different numbers of points earned on a 110-point scale.	**Slide 8** **Levels of LEED Certification:** **Figure 19: There are four levels of LEED certification- Certified, Silver, Gold and Platinum.** **SM Page 40** **Notes:**
• LEED version 3, **launched in April of 2009,** includes **significant updates to the certification, accreditation and documentation processes,** as well as to the rating systems themselves (referred to collectively as "LEED 2009"). • Understanding these changes will help you appreciate how LEED is evolving in response to market advancements and increasing sophistication in design, construction and building operation practices. • Thousands of projects are currently registered under earlier versions of LEED, so you may well have the opportunity to work on projects pursuing certification under either the old or the new system.	**Slide 9** **LEED version 3:** **SM Page 41** **Notes:**

Major changes in LEED version 3:

- **Credit Alignment.**
- **Point Alignment.**
- **Credit Weighting.**
- **Regionalization.**
- **Minimum Project Requirements.**

- **Credit Alignment:** Previously, different rating systems contained different versions of similar credits. Now credit language is as consistent as possible across rating systems.

- **Point Alignment:** Previously, each rating system contained a different number of points. For instance LEED-NC version 2.2 was measured on a 69 point scale, while LEED-EB version 2.0 had an 85-point scale. Now all rating systems have 100 possible points, with ten additional “bonus points” available in the Innovation & Design Process and Regional Priority categories.

- **Credit Weighting:** Previously, each credit in LEED was worth one point, thus unintentionally lending different strategies the same weight regardless of relative cost or impact. For example, installing solar panels and installing bike racks were each worth one point. Now credits are worth different numbers of points in order to reflect varying degrees of potential environmental benefit.

- **Regionalization:** The Regional Priority credit category did not exist prior to LEED 2009. Now existing credits that are deemed to have particular regional significance are eligible to earn an additional point.

- Minimum Project Requirements: LEED 2009 now stipulates Minimum Project Requirements in addition to credit category prerequisites. These include: compliance with applicable environmental laws; applicability only to permanent structures built on existing land; clarified requirements for defining LEED boundary; minimum floor area (1,000 square feet), occupancy rates (1 FTE) and building area to site ratio (^{3}2%); and mandatory reporting of whole-building energy and water use data.

Slide 10
LEED version 3, Major Changes:

SM Page 41-42
Notes:

• The proper terminology for how LEED recognizes professionals and buildings is: • **"Accreditation" refers to professional credentials.** • **"Certification" refers to building performance.**	**Slide 11** **LEED Terminology:** **SM Page 42** **Notes:**
• Another way that LEED influences the green building market is through the accreditation of LEED professionals. There are now three levels of LEED Professional Accreditation: • **LEED Green Associate (LEED GA)**—for professionals that support LEED and green building but may not directly apply it in their practice. Examples of professions that may pursue the LEED GA credential include marketing, government, students, administration, suppliers, and manufacturers. • **LEED Professional with Specialty (LEED AP+)**—for professionals that directly apply LEED and green building in their daily practice. Examples of professions that may pursue the LEED Professional with Specialty credential include architects, engineers, contractors, consultants, and planners. • **LEED Fellow**—this designation is currently under development to recognize an elite group of highly experienced LEED practitioners.	**Slide 12** **LEED Professional Accreditation:** **SM Page 42-43** **Notes:**

• **LEED professional credentials can lead to job opportunities.** • **Several LEED credits and prerequisites relate directly or indirectly to Sheet Metal Industry work.** • Earning one or more LEED professional credentials (LEED GA or LEED AP+) provides recognizable, third-party validation of your knowledge of green building and LEED. This can lead to job opportunities at firms that are looking to strategically hire staff that will help them win and execute green building projects. • There are several credits and prerequisites in LEED that are directly and indirectly related to your work. In fact, you may already be doing some things that contribute to a project's pursuit of LEED certification without even knowing it. Often, well-planned and executed projects are not too dissimilar from LEED Certified and Silver level projects. If you have ever provided a TAB report to a commissioning agent, disposed of metal in a separate recycling dropbox, fulfilled a specification for recycled content metals and provided a product cut sheet showing recycled content in your submittal to the contractor, or installed high efficiency filters on an air handling system, you have implemented a green building practice, and, if relevant, helped a project pursue LEED certification.	**Slide 13** **LEED and the Sheet Metal Industry:** **SM Page 43** **Notes:**

• USGBC website (www.usgbc.org): ○ **Rating systems and checklists (free).** ○ **Reference Guides (for purchase).** ○ **General green building information.** ○ **Links to USGBC-sponsored and -approved education.** • The USGBC website (www.usgbc.org) is an excellent resource for all things LEED. • It provides a wealth of information about green building in general, links to relevant research, and a portal to green building educational programs offered by USGBC and USGBC-approved providers. • The LEED rating systems and checklists are also available for free. The rating system documents list the intent and requirements for each credit. • Reference guides are also published for each rating system. These contain extensive credit compliance narrative, implementation strategies, and documentation requirements for each credit. The reference guides and other publications can be purchased through the USGBC website.	**Slide 14** **USGBC Website (www.usgbc.org):** **SM Page 44** **Notes:**

• High costs of certification. • Possible to get certified without addressing certain issues (credits are optional). • Projects implement strategies that might not be appropriate just to get points. • LEED rewards *predicted performance* instead of *actual performance.* • Despite its success in getting a large number of building projects to implement green building practices, LEED has been criticized for several reasons. • The administrative, documentation and tracking requirements of LEED certification are not scalable by project size so the relative burden and cost is virtually the same for large and small projects. • Furthermore, because projects do not have to achieve all credits in order to meet certification thresholds, it is possible for a building to be certified "green" without comprehensively addressing significant issues such as energy performance. • On the other hand, some credits might not be appropriate for a project, but are pursued simply to amass points. Examples might be a building in a low-density suburban area that installs bike racks that never get used, or a project that reduces energy use onsite, but is located in such a place that its users must travel long distances by car to reach it thus expending large amounts of energy. • The New Buildings Institute conducted a study in 2008 that compared the actual measured energy performance of LEED buildings to the designed energy performance on which their certification levels were based. The study found that actual performance varied widely from designed performance, with some buildings performing better than expected and some performing much worse. • The most significant criticism of LEED for new construction projects is that certification is awarded for predicted performance as designed, rather than actual performance as verified by operation documents.	**Slide 15** **Criticisms of LEED:** **SM Page 44** **Notes:**

LEED 2009 acknowledges this issue by requiring projects to submit water and energy utility data to the USGBC so that it can study the actual performance across projects. The intent is that this confidential information will inform the ongoing improvement of LEED as a tool that improves actual building performance. Certification is not revoked for projects that fail to perform as designed.	

Unit 3 Summary:
In Unit 3, the students have learned:

- LEED is a tool created by the USGBC to promote market transformation and make green building a standard practice.
- LEED guides projects by providing a set of prescriptive and performance-based standards in five different areas of concern.
- A primary way that LEED version 3 better aligns LEED performance (i.e. certification level) and building performance is by making higher-impact credits worth more points.
- LEED recognizes green buildings through certification. LEED credentials professionals through LEED accreditation. Buildings are certified; people are accredited.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

INTRODUCTION TO GREEN BUILDING

Unit 4: Introduction to Green Building Strategies

Module 1
Introduction to Green Building

Unit Learning Objectives:
After this unit, students will:
- *Understand the importance of an integrated design process in identifying and implementing green building strategies.*
- *Be familiar with green building strategies in five categories of environmental concern.*

Time Required: Approximately 1 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
- ☑ **Green LEED CD-ROM, Computer, and Projector**
- ☑ **Pencils**
- ☑ **Paper**
- ☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 47-64

Introduction:
After introducing the concept of integrated design process, this unit gives a broad overview of green building strategies in five categories of environmental concern: site, water, energy, materials, and indoor environmental quality. Many of these strategies are beyond the scope of work that students will be typically doing. However, the information in this unit will provide context for the more specific applied green building strategies covered in this course, and give students the ability to communicate with others on a green building project team.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
The purpose of the integrated design process is to: • **Encourage collaboration among project team members.** • **Involve everyone early in the project to provide best chance for creative solutions.** • Create an **opportunity for sheet metal workers to provide feedback on costs and benefits.** • Recall from Unit 1 that green building is the constantly evolving set of planning, design, construction and building operations and maintenance best practices and new technologies that has evolved in response to this increased understanding of the social, economic and environmental impacts of development. • The changing nature of the green building industry and the environmental imperative to achieve higher and higher levels of performance means that there is no one right set of strategies for a particular project type or even project. • Highly educated and creative project teams must select the strategies and technologies that make the most sense and work together to yield the best results. The most effective way to ensure that this happens is to use an *integrated design process*. • The purpose of integrated design is to create a collaborative process in which all team members are able to contribute their expertise as it relates to the project goals at every stage of project development. Equally important, it affords the opportunity for the various team members to respond to proposed design and construction strategies in real-time and early in the project while design is still readily impressionable. • For example, if the general contractor and structural engineers aren't involved in early discussions about a proposed rainwater harvesting system, it won't be able to communicate relevant constructability and cost issues that may be optimized with a design modification.	**Slide 1** **Integrated Design Process:** **SM Page 47** **Notes:**

• For sheet metal workers, the opportunity to provide feedback on your experience installing, operating, and maintaining particular architectural features or mechanical systems can help the project team in evaluating related costs and benefits.	
• An integrated design process, unlike conventional design processes, is not linear. Project team members do not pass responsibility from one to the next. Rather, **all relevant team members give input at all points.** • An integrated approach to green building encourages members of the team to think beyond their own scope of work in order to treat the project as a whole rather than a sum of its parts.	**Slide 2** **Integrated Design Process:** **SM Page 47-48** **Notes:**

"Eco-charrette:

- **A kickoff meeting that focuses on green building project goals.**
- Creates team-level commitment.
- Produces a report that **summarizes outcomes, assigns roles, and provides guidance to project.**
- Goal: to create integrated solutions that get the most performance out of the least energy/cost.
- The integrated design process typically starts with an "eco-charrette," which is an all-team project kickoff meeting that focuses exclusively on the green building goals and strategies of the project.
- During the eco-charrette, the owner communicates the green building goals and interest for the project and the team then builds on this to create team-level commitment.
- A report is almost always generated from the eco-charrette that provides a documented summary of the outcome, roles and responsibilities, and guides the project's green building efforts moving forward. In addition, participation in the eco-charrette creates a level of commitment among all team members because they had a stake in the identification of goals and potential strategies. This is very useful during later phases of design and construction when challenges arise and there is a need to evaluate decisions based on the goals established by the team.
- The intent is that the integrated design process yields integrated design strategies in the project, where individual strategies meet multiple objectives.

Slide 3
Eco-Charrette:

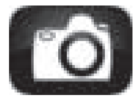


Figure 20: Eco-Charrette.

SM Page 48
Notes:

Note to Instructor: **Class Discussion**: Have a brief discussion with the class that covers the ways in which seemingly unrelated design decisions can affect each other. • How does interior paint color effect energy performance? (Using dark paint colors might mean that more energy has to be used to create adequate light levels in a space.) • How can the rainwater that falls on the site be used? (Rainwater can be captured, stored, and reused for irrigation or toilet flushing. This reduces stormwater discharge costs and also reduces the amount of potable water required by the building.) • How does window design affect energy performance? (If windows are too big, the building won't be energy efficient. If the windows are too small, occupant health and comfort might be compromised.) • Other ideas? (Ask students to come up with their own ideas of integrated design consideration.)	**Slide 4** **Integrated Design Process:** **SM Page 49** **Notes:**
• Some strategies are more relevant to your job than others. • A broad overview of strategies gives you context. • Remember: **the more you know, the more effective you can be as part of a green building project.**	**Slide 5** **Green Building Strategies:** **SM Page 49** **Notes:**
• We will discuss major strategies and technologies that improve building performance in these areas: ○ **Site.** ○ **Water.** ○ **Energy.** ○ **Materials.** ○ **Indoor Environmental Quality.**	**Slide 6** **Major Strategies and Technologies to be Discussed:** **SM Page 49** **Notes:**

• The topics addressed by the Site category of concern are: ○ **Site selection.** ○ **Transportation.** ○ **Site development.** ○ **Stormwater management.** ○ **Heat island effect.** ○ **Light pollution.**	**Slide 7** **Site:** **SM Page 50** **Notes:**
• The overall environmental impact of a building depends largely on its location. When selecting a site for a new project or attempting to improve the site conditions of an existing project, major considerations include: • **Developing only on previously developed land** (i.e. do not build on prime farmland, forest land, wetlands, protected waterfronts or public parkland). Another environmentally beneficial site selection strategy is to remediate and build on a contaminated or "brownfield" site. • **Access to nearby services and amenities.** • **Surrounding development density.**	**Slide 8** **Site Selection, Major Considerations:** **Figure 21: A green building strategy related to site selection.** **SM Page 50** **Notes:**

- The transportation impacts of people coming to and from a building can dwarf the environmental effects of its construction and operation. In addition to locating the building in an existing densely developed area, strategies for reducing transportation impacts include:

- **Ensuring access to and offering incentives for using mass transit** (public transit is twice as fuel efficient as private vehicles based on passenger miles traveled).

- **Pedestrian amenities** such as safe and clearly-marked paths, benches, shade, water fountains, etc.

- **Bicycle amenities** such as secure and accessible parking, showers and changing rooms, workplace incentives for commuting by bicycle, etc.

- **Infrastructure for alternative vehicles and carpools** such as preferred parking, electric car charging stations or alternative fuel fueling stations, cooperation with car-share programs, etc.

Slide 9
Transportation:

Figure 22: If a project is located in close proximity to services and amenities, people are less likely to drive their cars.

Figure 23: Bicycle amenities encourage people to use pollution-free transportation.

SM Page 50-51
Notes:

- Site design not only affects surrounding habitat, but can also preserve or create habitat on site. Strategies for protecting habitat and maximizing open space include:

- **Limited site disturbance:** Minimize use of paving and other site structures. Designate limited areas to be disturbed by construction vehicles, equipment and other activities.

- **Minimizing building footprint:** A taller building with a smaller footprint will allow more space for the preservation or creation of green space that can serve as habitat for local flora and fauna as well as be an amenity for building users. This strategy can also result in a narrower plan, which maximizes daylight penetration in the building and can reduce energy use.

- **Habitat offsets:** Some projects purchase land easements located in ecologically viable areas through a land trust or other conservation organization to offset the undeveloped area lost to the construction of the building.

- **"Bird-safe" design:** Minimize clear and reflective glass to avoid confusing birds; avoid unnecessary light pollution and sun glare to neighboring buildings.

- **Vegetated roofs:** Also known as green roofs or eco-roofs, have many synergistic benefits. In addition to providing habitat for plants, birds and insects, they can absorb stormwater, reduce the heat island effect and reduce heating and cooling loads in a building.

Slide 10
Site Development:

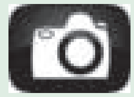


Figure 24: Vegetated roofs.

SM Page 51-52
Notes:

• Stormwater runoff is **a major source of pollution for all types of water bodies** in developed countries. • The prevalence of impervious surfaces in the built environment causes stormwater to **convey a variety of contaminants**—including pesticides, fertilizers, vehicle fluids, and mechanical equipment waste—into municipal sewer systems which often overflow into natural waterways. • In addition to stormwater quality, the velocity and volume of runoff also affect natural water systems due to **erosion impacts.** • The goal of any stormwater management strategy should be to mimic the natural hydrologic cycle and maintain local water tables.	**Slide 11** **Stormwater Management:** **SM Page 52-53** **Notes:**
• Strategies for managing stormwater include: • **Reduction of impervious surfaces:** Minimize impervious pavement, install green roof systems, and maximize vegetation. • **Filtration and infiltration:** These measures treat stormwater before allowing it to pass into the groundwater system: rain gardens, vegetated swales, and pervious pavement. • **Rainwater harvesting:** Collect and store stormwater onsite for use in landscape irrigation, fire suppression, toilet flushing and/or custodial applications. Storage can be handled by rainwater cisterns and/or retention ponds. These strategies can significantly reduce potable water consumption.	**Slide 12** **Stormwater Management Strategies:** **Figure 25: Biowale.** **Figure 26: Harvesting rainwater.** **SM Page 53** **Notes:**

• The proliferation of dark, non-reflective surfaces in the built environment has led to a phenomenon known as the heat island effect, which **leads to increased ambient temperatures (2-10°F)** in developed areas as compared with nearby undeveloped areas. • One way to think of the heat island effect is to think of the feeling of standing in the middle of an asphalt parking lot on a hot, summer day. • This condition creates increased cooling loads in urban buildings, a less pedestrian-friendly environment, and habitat degradation for local plants and animals.	**Slide 13** **Heat Island Effect:** **SM Page 53** **Notes:**
• Strategies for mitigating this effect include: • **Reduction of dark, non-reflective surfaces.** Use light-colored roofing and/or pavement, use open grid paving, avoid asphalt, install vegetated roof systems. • **Shade from trees or structures.** • **Minimize building footprint.** Decrease the volume of surface area (i.e. roof) directly exposed to solar radiation.	**Slide 14** **Heat Island Effect Mitigation Strategies:** **Figure 27: "Cool Roof".** **SM Page 53-54** **Notes:**
• Outdoor lighting and light trespass from interior lights left on at night, though sometimes necessary for human safety, can create light pollution, which **disrupts nocturnal ecosystems, disorients migratory birds and obscures the night sky.**	**Slide 15** **Light Pollution:** **SM Page 54** **Notes:**
• Strategies for reducing light pollution include: • **Automatic shut off controls** for non-emergency interior lights. • **Lamp shielding** to direct light downward and only where needed.	**Slide 16** **Light Pollution Reduction Strategies:** **SM Page 54** **Notes:**

• The Water category of concern deals primarily with potable water use reduction. • This can be accomplished by **using potable water more efficiently or reusing rainwater or domestic waste water** (called graywater) from sinks, tubs, and washers for non-potable applications. • Many of the strategies described below have synergistic benefits with the Energy category, since energy is required to treat, heat, cool and distribute water.	**Slide 17** **Water:** **SM Page 54** **Notes:**
• Potable water use reduction strategies include: • **Water efficient landscaping:** Use drought-resistant and/or adapted plant species, water-efficient irrigation systems or irrigate with harvested rainwater and/or graywater. • **Alternative wastewater technologies:** Such as composting toilets, Living Machines, rainwater or graywater reuse, or constructed wetlands. • **Improved plumbing efficiency:** Install low-flow fixtures including showerheads, low-flow and dual flush toilets, waterless urinals, faucet aerators and/or motion sensors. • **Appliance efficiency:** Look for Energy Star-rated appliances that provide the same service with less water and energy.	**Slide 18** **Potable Water Use Reduction Strategies:** **Figure 28: Native or adopted plants.** **Figure 29: Low-flow plumbing fixtures.** **SM Page 54-55** **Notes:**

• The connection to carbon emissions and climate change makes energy performance the #1 concern of green building. • **Building design has a significant impact on energy performance.** • Strategies for reducing building energy consumption can be applied from the very earliest phases of a project when building location, massing and orientation decisions affect the project's ability to make use of "passive strategies" through free energy sources of solar heat, wind and sunlight. Passive strategies should be prioritized and evaluated as early as possible in the project to minimize the energy denominator before design progresses and systems are specified. • Modules 2 and 3 deal with energy performance in greater detail. As will be discussed at length in Module 3, the imperative to minimize energy consumption continues throughout the occupancy, operations, and maintenance of the building.	**Slide 19** **Energy:** **SM Page 55** **Notes:**
• The Materials category of concern deals with: • The **reduction, reuse, and recycling** of building materials. • The **management of construction waste.** • The selection and purchase of **responsibly manufactured new building materials.** • The **durability of materials** and assemblies.	**Slide 20** **Materials:** **SM Page 55-56** **Notes:**

Note to Instructor:
Discussion: Engage the class in a conversation about potential environmental and human health impacts at every stage of a product's life cycle.

- These impacts include:
- When resources are extracted or harvested to make a material, one must consider the depletion of that resource, whether or not it is renewable, associated habitat loss and the degradation of the surrounding ecosystem, and potential negative health effects of raw materials such as heavy metals.
- During manufacture, large amounts of energy may be required to process raw materials; chemical health hazards may be present; pollution of air, land and water may occur; and irresponsible manufacturers may exploit the workers that produce the material with unfair wages or unhealthy working conditions.
- Packaging and distribution demands even more energy inputs and may involve the wasteful and/or inefficient use of packaging materials. When a material or product is in use, it could potentially present health hazards through off-gassing or chemical exposure.
- If it is poorly made, it will need to be replaced after only a short time. It may also require unnecessarily large amounts of non-renewable energy to operate or maintain.
- Finally, disposal presents a number of environmental problems from limited landfill space to the leaching of toxins from garbage into ecosystems, greenhouse gas emissions of waste incineration, and the energy use associated with the transportation of waste.

Slide 21
Environmental and Human Health Impacts:

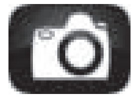


Figure 30: A material or product has an environmental impact at every stage of its lifecycle.

SM Page 55-56
Notes:

- Understanding these life cycle impacts will help you make smart decisions about the relative green merits of building materials and products.
- **Many products claim to be green, but may address only one or a few of the complex issues** described above. Due to the complexity of the extraction/harvesting/manufacturing process, responsible practices at one stage may be offset by irresponsible practices at another stage.
- It is up to you to think critically about such product claims to make sure you don't become a victim of greenwashing. **Greenwash** is an unsubstantiated, false, and/or embellished representation of a building or product's benefits as it relates to sustainability.

Slide 22
Materials:

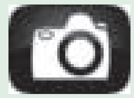


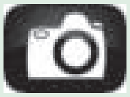
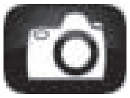
Figure 31: Greenwash.

SM Page 56-57
Notes:

- As we discussed with buildings in Unit 1, a product or material can be thought of as having an *embodied energy* representing all the energy it took to extract/harvest/manufacture, transport, and install it. By reusing or recycling existing materials, we make even better use of energy that has already been spent instead of using new energy.
- Strategies for reducing, reusing and recycling building materials are:
- **Reduce**: The most effective way to manage waste is to reduce it at its source, that is, by using fewer materials in the first place. By designing the building to not require excessive materials, the project team can improve its overall environmental performance. This may involve adopting a minimalist aesthetic that limits interior finishes and exterior adornment. Materials that accomplish two things at once—e.g., structural framing that also acts as interior finish—can be used to great (and green) effect.
- **Reuse**: Building material reuse can be as simple as using salvaged items for parts of buildings or reusing an entire building for a new or upgraded use.
- **Recycle**: Project teams can encourage recycling by providing accessible and easy-to-use recycling facilities as part of the project.

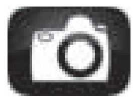
Slide 23
Materials, the Three R's:

SM Page 57-58
Notes:

• Architect William McDonough and chemist Michael Braungart developed the **concept of “cradle to cradle,”** meaning that a material and product should be designed with its entire lifecycle in mind to be **infinitely reusable.** • Our current consumption model is based on the “cradle to grave” model, which depletes resources, both renewable and non-renewable, and creates an unsustainable waste problem. • By maintaining a closed loop, material value is maximized and waste is avoided entirely.	**Slide 24** **Materials, Beyond the Three R’s:**  **Figure 32: “cradle to cradle”.** **SM Page 57** **Notes:**
• High landfill tipping fees make construction waste recycling an economically appealing option. Money can even be earned by recycling metals, concrete, asphalt and cardboard. • This topic will be **covered in depth in Module 2 under Construction Waste Management (CWM).**	**Slide 25** **Materials, Construction Waste Management:**  **Figure 33: Materials with recycled content.** **SM Page 57-58** **Notes:**
• The most important considerations in regard to selecting materials are: • **Embodied energy.** • **Green material certifications.** • **Locally harvested and manufactured materials.**	**Slide 26** **Responsible Material Selection:** **SM Page 58-59** **Notes:**

• In general, a **lower embodied energy** material is preferable, but issues such as **durability and local availability** must also be taken into account. • Materials with recycled content generally have a lower embodied energy. • Many commonly used building products are now available with **recycled content,** including metals, concrete, masonry, gypsum board, acoustic tile, carpet, ceramic tile, rubber flooring and wall base, and insulation. • Materials with post-consumer recycled content are preferable to those with pre-consumer recycled content.	**Slide 27** **Responsible Material Selection:** **SM Page 59** **Notes:**
• Third party certification bodies exist to help sort through advertising claims and evaluate actual environmental performance of building products and materials. Unfortunately, not all so-called “eco-labels” are equally credible to provide objective product evaluation, especially those sponsored by the industries they are supposed to regulate. Reputable “eco-labels” include: • **Forest Stewardship Council (FSC)** certifies forest products, forests, and manufacturers. • **Scientific Certification Services (SCS)** rates materials with recycled content. • Green Seal uses a lifecycle approach to certify paints, coatings, cleaners, and floor care products. • **Greenguard** defines VOC (volatile organic compound) standards for indoor building materials and furnishings. • The **Carpet and Rug Institute (CRI)** certifies green carpet products.	**Slide 28** **Reputable “Eco-Labels” Include:**  **Figure 34: Greenguard defines VOC (Volatile Organic Compound).** **SM Page 58-59** **Notes:**

• Because the environmental impacts associated with transportation (especially automobile and truck transport) are so great, selecting locally extracted/harvested/manufactured materials is an excellent way to **improve environmental performance and support the local economy.** • LEED sets a goal of striving to obtain building material that was extracted, processed, and manufactured within a 500-mile radius of the project.	**Slide 29** **Local Materials Issues:** **SM Page 59** **Notes:**
• Creating and maintaining good Indoor Environmental Quality (IEQ) is **important for the health and productivity of building occupants.** • Topics addressed by this category include: ○ Indoor air quality (IAQ) during construction, pre-occupancy, and occupancy phases. ○ Low-emitting materials. ○ Indoor pollutant source control. ○ Mold prevention. ○ Thermal comfort. ○ Biophilic design.	**Slide 30** **Indoor Environmental Quality (IEQ):** **SM Page 60** **Notes:**
• Making sure outside air delivery rates **meet or exceed ASHRAE Standard 62.1 or the local code** (whichever is more stringent). Though increasing outdoor air delivery rates has been shown to drastically improve indoor air quality, doing so can also increase heating and cooling loads and energy use in a building. Heat exchangers and energy recovery systems (as discussed in Module 3) can help mitigate this effect. • **Installing CO_2 monitors** to ensure that IAQ goals are being met. Calibrate them to set off an alarm when CO_2 levels vary by more than 10%. • **Prohibiting smoking in and around the building.** • Best practices for maintaining good IAQ during and directly after construction are covered in Module 2 under Construction Indoor Air Quality (CIAQ).	**Slide 31** **Strategies for Good Indoor Air Quality (IAQ):** **Figure 35: Installing CO2 monitors.** **SM Page 59-60** **Notes:**

• Many building materials contain **toxic chemicals that harm human health.** • These may be **immediately irritating or contribute to the long-term accumulation of toxins** in a person's body. • This "body burden" of chemicals can be especially harmful to children, whose bodies are still developing.	**Slide 32** **IEQ, Low-Emitting Materials:** **SM Page 61** **Notes:**
• Categories of materials that should be evaluated for their volatile organic compound (VOC) content include: • **Adhesives and sealants.** • **Paints and coatings.** • **Flooring systems** (wood, bamboo, cork, carpet, carpet cushions, laminate sheet flooring and tile). • **Composite wood and agrifiber products** (such as particleboard, MDF, plywood, wheatboard, strawboard, etc.) should not contain any added urea-formaldehyde resins. • **Furniture.** • **Ceiling and wall systems** (including gypsum board, insulation, acoustical ceiling systems, and wall coverings).	**Slide 33** **IEQ, VOC Content:**  **Figure 36: Volatile organic compound (VOC) content.** **SM Page 59-61** **Notes:**
• Strategies for controlling pollutants at their source: • **Reduce or eliminate the use of toxic chemicals** for pest control and/or building maintenance on the building site. • **Install grates, grilles, or track off mats** at all entrances. • Sufficiently **exhaust building spaces** where hazardous gases or chemicals are used. • Properly **contain and dispose of hazardous chemicals.**	**Slide 34** **Indoor Pollutant Source Control:** **SM Page 61** **Notes:**

• Mold growing inside a building can cause serious health problems and expose building owners to liability risks. • Mold prevention strategies include: • Design HVAC systems to **maintain interior conditions** such that relative humidity does not exceed 60%. • Use **redundant exterior construction details** that inhibit moisture incursion.	**Slide 35** **Mold Prevention:** **SM Page 61** **Notes:**
• The notion of thermal comfort is highly personal and affected by numerous variables, some of which are under the project team's control (temperature, thermal radiation, humidity, and air speed) and some of which are not (occupant clothing, activity level, and natural tolerance of hot or cold conditions). • Thermal comfort is important for occupant health and productivity. • Strategies for creating a thermally comfortable environment include: • **Compliance with ASHRAE Standard 55.** • **Giving occupants more control of their thermal comfort** through individual thermal comfort controls. Even allowing people to think they are controlling the HVAC system has been shown to improve satisfaction.	**Slide 36** **Thermal Comfort:**  **Figure 37: Thermal Comfort** **SM Page 62** **Notes:**

• Biophilia is a concept coined by E.O. Wilson, which describes **humans' instinctive tendency to prefer spaces that include natural elements** or even the suggestion of nature. • These elements include: access to daylight and views as well as vegetation, water features, a sense of enclosure or refuge, moderate levels of complexity for mental stimulation, clear pathways, and organic forms. • As described above, daylighting can have a dramatic effect on the quality of an interior space as well as contribute to energy savings. Access to daylight has been shown to improve mood, worker productivity, and student learning. Views further connect occupants with the outdoors. Access to vegetation and water features can be provided in common open spaces and/or indoor courtyards.	**Slide 37** **Biophilic Design:** **SM Page 62** **Notes:**

Unit 4 Summary:
In Unit 4, the students have learned:

- Green building is distinguished by an integrated design process in which all team members work collaboratively throughout the entire project to identify, evaluate, and bring green building goals to fruition.
- An integrated design process seeks to solve multiple problems with a single solution.
- Green building has five primary areas of concern: Site, Water, Energy, Materials, and Indoor Environmental Quality.
- Evaluation of green building strategies should be comprehensive, meaning that you should consider impacts throughout a product's and/or building's anticipated lifetime. Beware of greenwashing.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

INTRODUCTION TO GREEN BUILDING

Unit 5: The Contractor’s Role in Green Building

Module 1
Introduction to Green Building

Unit Learning Objectives:
After this unit, students will:
- *Understand how green building requirements can impact your job.*
- *Be familiar with the primary contractor responsibilities in a green building project.*
- *Be able to develop and reference a list of resources that provide information on new green technologies.*

Time Required: Approximately 30 minutes

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 65-69

Introduction:
Now that students have an understanding of the concept of sustainability; the definition of green building; the environmental, social, and financial impacts of buildings; and a broad overview of green building strategies; they can now fully appreciate their role in a green building project. This unit discusses primary contractor responsibilities in a green building project, and provides tools for developing a personal list of green building resources and references.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• There are several areas of the sheet metal industry—especially for HVAC professionals—that have significant growth potential in the green building market. Not surprisingly, these are all tied closely to **reducing building energy use and carbon emissions.** • New buildings are being designed to meet higher and higher levels of performance. But the drive to **improve the performance** of existing buildings in particular represents a great opportunity for our industry. For instance, **retrocommissioning** and **energy auditing** contracts are becoming more and more common. • In the near future, any field that builds, maintains, and operates energy systems will be increasingly relied upon to meet LEED and green building-related greenhouse gas reduction goals and regulations. Seizing these opportunities requires an understanding of how your work relates to LEED, green building and energy goals, and gaining expertise in closely-related areas to increase your value to projects.	**Slide 1** **Opportunities:** **SM Page 65** **Notes:**

• Green building industry is growing. • Demand for green certifications is increasing. • **"Green collar" jobs require education, flexibility, willingness to learn on the job.** • Contractors provide feedback on cost and feasibility implications of green building strategies. • As the green building market grows and more and more projects seek green building certification, contractors must adapt to changing practices, new responsibilities, and project expectations. • In order to meet both environmental and financial performance objectives, green building projects need the people who are working on them to be up to speed and ready to contribute to achieving project goals. The changing nature of the industry means that there will always be some on-the-job learning. But, the better prepared you are beforehand, the more effective you can be in your "green collar" role. • In a LEED project, the project team will go through a preliminary process (such as an eco-charrette, as described in the previous unit) to determine which credits will be pursued. It is the general contractor's job to provide feedback on the cost and feasibility implications of chosen strategies, as well as to communicate green building requirements to all subcontractors. As mentioned previously, pro-active pursuit of this information can help distinguish your green building and LEED proficiency.	**Slide 2** **Green Building and Your Job:** **SM Page 65-66** **Notes:**

• We've discussed in a general way how an integrated design process demands a broadened awareness of green building principles and practices among all team members. • Now we will take a look at the specific green building activities in which contractors have an important responsibility for LEED compliance and building performance. These include: • Construction Activity Pollution Prevention **(CAPP)** • **Water efficiency** • **Energy** efficiency • Commissioning **(Cx)** activities • Construction Waste Management **(CWM)** • **Local Labor and Materials** (material selection is also the responsibility of the specification writer) • Construction Indoor Air Quality **(CIAQ)**	**Slide 3** **Contractor Responsibilities:** **SM Page 66** **Notes:**
• Construction Activity Pollution Prevention (CAPP) is the **set of practices aimed at reducing pollution generated by construction activities.** • By minimizing disturbance of the site, the negative effects of erosion, sedimentation and airborne dust pollution can be reduced or eliminated. • All contractors and subcontractors engaged in the construction or renovation of a building have a role to play in minimizing pollution during construction. • This strategy and its associated LEED requirements will be covered in Module 2.	**Slide 4** **Construction Activity Pollution Prevention (CAPP):** **SM Page 66** **Notes:**
• The water efficiency of a project is mostly in the hands of building designers, specifiers, and users, but contractors can do their part by verifying that the specifications are accurately followed and fixtures are installed correctly. • **HVAC contractors may be involved in installing, commissioning, and/or maintaining HVAC systems that use water.** Ensuring that these systems are operating to their full potential efficiency will reduce overall water consumption.	**Slide 5** **Water Efficiency:** **SM Page 66** **Notes:**

• **It cannot be overemphasized how important energy efficiency is to the planet and the green economy.** • Module 3 focuses on energy load reduction, efficiency, and onsite renewable energy generation strategies and technologies, as well as LEED requirements for energy performance in buildings. • Once a high performance energy system is designed, commissioning is an essential quality assurance measure to ensure that optimal performance is realized. The contractor must work very closely with the Commissioning Authority to ensure that all responsibilities are clarified and that the commissioning scope is aligned with the master project schedule. Commissioning activities and how they fit into LEED are covered in Module 2.	**Slide 6** **Energy Efficiency:** **SM Page 66-67** **Notes:**
• Construction Waste Management (CWM) planning and administration is a primary responsibility of contractors. CWM implementation is the **responsibility of both the prime contractor and its subcontractors**, but the contractor is ultimately responsible for ensuring that the CWM plan is implemented. • Practices, procedures, and LEED requirements for reducing, reusing, and recycling construction waste are covered in Module 2.	**Slide 7** **Construction Waste Management (CWM):** **SM Page 67** **Notes:**
• Using local workers and materials can have a **positive impact on both the "planet" and "people" aspects of the Triple Bottom Line.** Depending on market conditions, the "profit" aspect may be positively influenced as well. • Involving local workers and subcontractors in a project **strengthens the local economy** and starts to build a critical mass of green building expertise in a community. • As was discussed in Unit 4, the use of local materials can reduce a project's carbon footprint by cutting down the amount of energy required to transport those materials to the project site. LEED rewards projects that source 10% or 20% of their materials (by cost) with 1 or 2 points toward certification.	**Slide 8** **Local Labor and Materials:** **SM Page 67** **Notes:**

• Maintaining good indoor air quality during and immediately following construction is important to **minimize health risks to construction workers and building occupants** alike. • Best practices and LEED requirements for Construction Indoor Air Quality (CIAQ) are described in Module 2.	**Slide 9** **Construction Indoor Air Quality (CIAQ):** **SM Page 67** **Notes:**
Note to Instructor: **Discussion:** Discuss ways to keep informed of new developments in the green building industry, and what barriers might exist to prevent people from keeping current. • Continuing green building education (events, publications, presentations, seminars, courses, etc.) is essential in making sure you have the information you need to perform your job to the highest standard. We've already discussed the value of green building education in this regard. Besides taking courses, you can keep yourself current by taking advantage of numerous publications and online resources. You will have to decide for yourself which of these resources is most useful to the work that you do and the most relevant to your geographic location. • Ask students to consider making a "keeping current" plan for themselves that might entail subscribing to and reading certain publications, attending classes or doing research on their own.	**Slide 10** **How To Keep Informed:** **SM Page 67** **Notes:**

• Good sources of green building information: • The **Energy Information Administration** (www.eia.doe.gov/emeu/efficiency/energy_efficiency_links.htm.) of the U.S. government maintains a list of federal, regional, non-profit, and international energy efficiency organizations at • Building Energy Performance Info™ **(BEPI)** (http://www.bepinfo.com/) is a service that provides current information on energy-related issues relating to commercial real estate. They publish a free daily newsletter as well as maintain a frequently updated blog. • **BetterBricks** (www.betterbricks.com) is a network of information, tools, and resources about energy efficiency sponsored by the Northwest Energy Efficiency Alliance. • The **Whole Building Design Guide** (www.wbdg.org) is a web portal to information on integrated "whole building" design techniques and technologies including design guidance, reference documents, tools, and applied research. • **BuildingGreen** (www.buildinggreen.com) is an independent publishing company that publishes Environmental Building News and maintains a website that offers articles on a wide range of green building topics and products.	**Slide 11** **Green Building Information Sources:** **SM Page 67-68** **Notes:**

Unit 5 Summary:
In Unit 5, the students have learned:

- Retrocommissioning and energy auditing existing buildings is a large "green collar" growth area for HVAC professionals and tradespeople.
- Contractors play a very important role in the green building process and have multiple responsibilities to ensure fulfillment of green building goals.
- There are an array of online and written resources to help you stay current on green building trends and practices.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

PRIMARY GREEN CONSTRUCTION ACTIVITIES

Unit 1: Construction Activity Pollution Prevention (CAPP)

Module 2
Primary Green Construction Activities

Unit Learning Objectives:
After this unit, students will:
- *Understand the importance of Construction Activity Pollution Prevention (CAPP) as it relates to green building.Be aware of national and local standards governing CAPP.*
- *Be able to describe the implementation of CAPP measures.*
- *Be familiar with LEED requirements and documentation associated with CAPP.*

Time Required: Approximately 1.5 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 73-80

Introduction:
Construction Activity Pollution Prevention (CAPP) is a best practice because it helps protect the health and wellness of our communities. This unit provides an overview of the impacts, laws, and strategies related to CAPP as well as its relevance within the LEED rating system.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
What is CAPP? • **Construction Activity Pollution Prevention** (CAPP) reduces pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation. • There are several different measures available to prevent construction activity pollution and each project requires a tailored approach that responds to the site conditions, local requirements and project budget and goals.	**Slide 1** **What is CAPP?** **SM Page 73** **Notes:**
Note to Instructor: **Discussion:** Ask the class: Why do you think Construction Activity Pollution Prevention is important? Write the responses on the board or poster paper. Encourage the students to think about the reasons why CAPP has become an important part of construction procedures today.	**Slide 2** **The "Why" and the "What" of CAPP:** **SM Page 73** **Notes:**
Why CAPP? • **Construction impacts the quality of the earth's surface and air in and around a project site.** • Pollution can harm people, nearby water bodies, and air quality. • Regulations set requirements for on- and off-site cleanup. • Projects can earn credits in LEED for CAPP.	**Slide 3** **Why CAPP?** **SM Page 73** **Notes:**
Construction impacts: • **Erosion.** • **Construction dust pollution.**	**Slide 4** **Construction Impacts:** **SM Page 73** **Notes:**

• Erosion is defined as a combination of processes or events by which **materials of the earth's surface are loosened, dissolved, or worn away** and transported by natural agents such as water, wind or gravity. • The primary cause of erosion on construction sites is the flow of precipitation, or "stormwater runoff," across construction-impacted surfaces which picks up and transports materials on and off the project site. • An example of erosion is the undermining of a streambank caused by high and fast-traveling stream water after a rainstorm. Another example is the slow erosion of a sandbank or dune that is regularly exposed to high winds. • These same conditions can occur at construction sites in more developed or urban contexts where a CAPP Plan can help to minimize and prevent on- and off-site pollution.	**Slide 5** **Erosion:** **SM Page 73-74** **Notes:**

- Erosion pollution **issues on the project site are all based primarily on the loss of top-soil and vegetation.**

- Topsoil is the first several inches of soil and the most biologically-active and nutrient-rich soil layer. So, it is the most important layer for plant and food production and supporting the organisms that maintain soil health and prevent disease and pest outbreaks. Topsoil also helps to control the flow of water through the soil and, the slower the water moves, the less ability it has to cause more erosion.

- All of the issues that stem from topsoil loss also make landscapes more difficult to maintain. Less topsoil means that supplements and amendments such as additional soil, pesticides, fertilizers and water may have to be regularly added to the landscape to maintain plant health.

- Further, replacing a previously vegetated site with built surfaces eliminates any benefits provided by that vegetation to include air quality, shading, water management, habitat and aesthetics to name a few.

- Erosion also has a host of off-site environmental impacts.

- These include: sedimentation of storm sewers and receiving streams, eutrophication of water bodies (a process in which too many nutrients in the water result in an overgrowth of aquatic plants, which in turn crowd out other species), and decreased aquatic species diversity.

- These effects usually pose a greater environmental threat because their impacts are not bound to the project site where they can be more readily managed or remediated.

Slide 6
Erosion:

Figure 1: The primary cause of erosion on construction sites.

SM Page 74-75
Notes:

Note to Instructor: **Discussion:** Ask the students if they have ever experienced dust pollution firsthand and how it might have been handled better onsite. • Construction dust pollution is basically **any form of dust that is created and rendered airborne through construction activities.** It can be caused by material cutting, earth-moving, equipment and vehicle travel, sanding and other construction-related activities.	**Slide 7** **Dust Pollution:** **SM Page 75** **Notes:**

• Construction dust pollution shares some of the same negative on-site and off-site affects as erosion but also more **directly impacts human health.** • The impact of dust pollution is determined by multiple factors such as the conditions of the immediate and surrounding areas, the quality of the dust material, and the rate and concentration of pollution. • For people, the most obvious hazard is dust inhalation and related **respiratory issues** such as coughing, asthma, and decreased lung function. • Dust can also cause problems if it enters your body through your eyes. If the dust is from the cutting of chemically treated lumber or other chemically conditioned material, the body will absorb these chemicals in addition to the dust. This, in addition to exposure to other noxious or toxic substances used in construction can create a “toxic soup” that poses harm to human health for workers, building occupants, and even adjacent communities. • Dust pollution also has similar effects as erosion on the environment. • Dust deposited into water bodies reduces water quality and damages aquatic habitat. • Fish, invertebrates, birds, and other water-dwelling species ingest dust through breathing and eating. Chemicals in the dust can then accumulate in their bodies. As dust dissolves in water over time, these same chemicals change the makeup of the water. This consequently influences the aquatic species that are accustomed to a certain water quality. Think of a fish that is used to healthy lake water suddenly having to respond to cloudy, warmer water with less oxygen. In some cases, the fish may adapt, and in others it may die off.	**Slide 8** **Dust Pollution:** **SM Page 75** **Notes:**
• As we’ve learned, essentially any alteration to land has the potential to generate pollution. • In response to this, regulations have emerged **at multiple levels** of government and to **address different types and scales of projects.**	**Slide 9** **Governing Regulations:** **SM Page 75** **Notes:**

• Typically, construction pollution is regulated through local governments. • Most **local governments have codes, ordinances or other regulatory rules** in place that dictate on-site best practices and measures that prevent pollution during the construction phase. • To comply with these rules and obtain a building permit, projects typically have to show a CAPP Plan and/or erosion and sedimentation control measures in the project drawings and specifications. Photo documentation may be required. • These measures may be inspected by the local permitting authority during construction and fines or, in worst case scenarios, stop-work orders may be issued if the measures are not in-place and/or well-maintained.	**Slide 10** **Governing Regulations:** **SM Page 75-76** **Notes:**
• The US EPA provides a **2003 EPA Construction General Permit** that specifies national erosion and sedimentation requirements for construction projects greater than 1-acre in size. • Specifically, it outlines the rules and provisions required to comply with the **National Pollutant Discharge Elimination System (NPDES)** program, which regulates surface water discharge and pollution.	**Slide 11** **Governing Regulations:** **SM Page 76** **Notes:**
• Sometimes the scale of what's regulated is delineated by a **sensitive natural resource** rather than site, political, or other boundaries. • This might result in multi-agency regulation.	**Slide 12** **Governing Regulations:** **SM Page 76** **Notes:**

• Coast-bordering communities often create **"shoreline management plans" (SMP)** to define the location and quality of future development and to provide a comprehensive framework that identifies and manages environmentally-critical areas within shoreline zone. • SMPs are often developed and implemented through the multiple governmental and non-governmental organizations that have a stake in shoreline protection and management. • Construction activities in shoreline zones may have more stringent requirements due to their close proximity and high potential to impact the nearby water body.	**Slide 13** **Governing Regulations:** **SM Page 76** **Notes:**
• Another example of a multi-agency regulatory mechanism is a **comprehensive aquifer management plan (CAMP).** • Aquifers are underground geologic formations that store water and are recharged by infiltration of surface water. In many parts of the United States, aquifers serve as the primary water resource for drinking, agriculture and all other water-related uses. • CAMPs are intended to ensure that the rate of removal of aquifer water does not exceed its recharge rate and that the quality of the water remains healthy. Construction activities in aquifer zones may have more stringent requirements due to their location above a primary water source and potential to impact local surface water sources that feed the aquifer.	**Slide 14** **Governing Regulations:** **SM Page 76-77** **Notes:**

• Effective prevention of construction activity pollution requires the cooperation of multiple project team members and the appropriate selection, installation, and maintenance of pollution prevention measures. It is important to identify and assign roles early in order to ensure the successful implementation of the CAPP plan, and avoid non-compliance issues. • The CAPP plan is typically **developed by the team's civil engineer, sometimes by the landscape architect, or both.** The role of each of these team members directly influences on-site stormwater management, grading, plant and soil selection, and other site issues that are relevant from construction to building operation. For example, the civil engineer may determine the slope and dimensions of sidewalks or roads, anticipated volume of stormwater runoff, and infrastructure necessary to manage it. The landscape architect may determine necessary soil type and depth, and plant species that are appropriate for a given climate and site. Whoever is responsible for the development of the CAPP plan must ensure that the CAPP plan meets the requirements of the local codes. • Erosion and sediment control measures that are specified in the CAPP plan will also be included in the project drawings and specifications. • The general contractor is responsible for adopting the CAPP plan, and installing and maintaining the CAPP measures throughout the project. • Some jurisdictions may require that the contractor provide photo documentation of the installed and maintained CAPP measures, or the governing authority may perform on-site inspections.	**Slide 15** **CAPP Plan Development:** **SM Page 77-78** **Notes:**

	Slide 16 **Figure 2: This image shows a drainage area protected by straw wattles.** **Figure 3: A designated concrete wash out area prevents concrete from running into storm drains.** **SM Page 77** **Notes:**
• CAPP is **addressed in the Sustainable Sites category of the LEED rating systems** that address new construction and existing buildings. • Local requirements for soil erosion and sedimentation control are often at least equally rigorous as those specified by LEED.	**Slide 17** **CAPP & LEED:** **SM Page 78** **Notes:**
• **LEED NC requires all projects to create and implement an erosion and sedimentation control plan** that conforms to the requirements of the 2003 EPA Construction General Permit or the local standards and codes, whichever is more stringent. This requirement is specified in SSp1. • The plan must address the prevention of soil loss, sedimentation of sewers or receiving streams, and airborne dust pollution. The EPA General Permit legally only applies to projects greater than one acre. But for the purposes of LEED, all projects must comply with the requirements to be eligible for certification. Typically, any relevant plans and drawings created to comply with local codes and standards are sufficient to demonstrate compliance.	**Slide 18** **CAPP & LEED:** **SM Page 78** **Notes:**

• **LEED for Existing Buildings: Operations & Maintenance does not require erosion and sedimentation control,** but addresses it through two optional credits focused on landscape management and site disturbance. • SSc3 offers one point for the creation of an environmentally-sensitive management plan to address the site's natural components. Specific to CAPP, the plan must address erosion and sedimentation control for ongoing landscape operations and any future construction activities. It also must address diversion of landscape waste from the waste stream and fertilizer use. • In order to earn one point under SSc5, projects must put in place native or adapted vegetation that covers a minimum of 25% of the total site area (excluding building footprint) or 5% of the total site area (including building footprint), whichever is greater. The basis for this requirement is that vegetation, in addition to habitat provision and other prospective benefits, naturally prevents erosion and sedimentation.	**Slide 19** **CAPP & LEED:** **SM Page 78-79** **Notes:**
• **It is necessary to provide documentation to verify that the requirements set forth by LEED have been met.** • For new construction projects, these materials include the erosion and sedimentation control plan; erosion and sedimentation control drawings showing the measures in plan; and date-stamped photo documentation of the installed measures. • For existing buildings, a copy of an environmental management plan that specifies measures as relevant to erosion and sedimentation control must be provided.	**Slide 20** **CAPP & LEED:** **SM Page 79** **Notes:**

Unit 1 Summary:

In Unit 1, the students have learned:

- The goal of Construction Activity Pollution Prevention (CAPP) is to prevent soil erosion, waterway sedimentation, eutrophication, and airborne dust generation.
- CAPP is regulated at multiple levels of government. In some cases, a project's CAPP requirements may be dictated by more than one entity.
- LEED addresses CAPP in its new construction and existing building ratings systems. Local CAPP regulations are often at least as stringent as those in LEED.

Application:

To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

PRIMARY GREEN CONSTRUCTION ACTIVITIES

Unit 2: Commissioning

Module 2
Primary Green Construction Activities

Unit Learning Objectives:
After this unit, students will:
- *Understand the benefits and costs associated with Commissioning.*
- *Be able to describe the Commissioning process, including team members' roles and responsibilities.*
- *Gain ideas about how to work successfully with a Commissioning Agent.*
- *Be familiar with LEED requirements and documentation associated with Commissioning.*

Time Required: Approximately 3 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 81-101

Introduction:
This unit defines commissioning as a comprehensive quality assurance process whose purpose is to ensure that building performance goals are met. Building owners benefit from commissioning through cost savings and improved building performance. Contractors benefit through opportunities to teach and learn, and the satisfaction of a job well done. Commissioning roles and procedures are discussed in detail. The unit concludes with information about required and optional commissioning requirements in LEED.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• A building's actual energy performance is determined by many things and influenced by many people. • During the design phase of a project, architects and engineers shape energy performance by designing systems, specifying materials and allocating resources. During construction, contractors construct assemblies and obtain and install equipment. Once the building is occupied, facilities managers operate and maintain the building and building systems, modifying them as time goes by. • With the variety of people and complex processes involved with designing, installing, and operating a building's energy systems it is difficult for an owner to ensure that his or her performance goals are being met. In fact, many buildings do not operate optimally for the design or actual use of the building. • Commissioning is **intended to address, minimize, and correct this margin of potential for error.**	**Slide 1** **What Is Commissioning?** **SM Page 81** **Notes:**
• Commissioning (Cx) is **a comprehensive quality assurance process that provides independent oversight to ensure that energy-related systems perform according to the owner's project requirements.**	**Slide 2** **Commissioning Defined:** **SM Page 81** **Notes:**
• SMACNA defines **commissioning as "the process of advancing systems from a state of static physical completion to a state of full, demonstrated, and documented working order, according to design requirements, during which time the owner's operating staff are instructed in correct systems operations and maintenance."** • Commissioning seeks to bridge gaps in communication and expertise between system designers, installers, and operators.	**Slide 3** **SMACNA Definition:** **Figure 4: Commissioning seeks to bridge gaps in communication and expertise.** **SM Page 81-82** **Notes:**

While the principles of commissioning are largely the same for any kind of project, the process can be referred to by four different names, depending on the type of building and scope of the project. These are: • Commissioning refers specifically to **new construction or major renovation projects.** • **Retrocommissioning** can be applied to an existing building that has not previously been commissioned. • **Recommissioning** is for existing buildings that have previously been commissioned. • **Ongoing commissioning** starts in new construction and continues throughout the life of the building.	**Slide 4** **Commissioning Scopes:** **SM Page 82** **Notes:**
A commissioning scope typically includes the **building's energy systems**, and **may include other systems** listed here. Ideally, it includes all of them: ○ Mechanical ○ Electrical (including lighting) ○ Plumbing ○ Irrigation ○ Control systems ○ Life safety (including fire alarm and protection systems and smoke controls) ○ Elevator control ○ Security ○ Renewable energy systems ○ Building envelope ○ Other specialized systems such as space pressurization or laboratory exhaust systems	**Slide 5** **Scope May Include:** **SM Page 82-83** **Notes:**

• Commissioning activities should begin during the design phase so that the **CxA has the opportunity to review design drawings** for feasibility, logistical, and performance implications. It is not uncommon, however, for the CxA to be engaged only after construction has begun. This limits the potential effectiveness of the commissioning process. Also, a late-starting commissioning process can create a negative dynamic between the CxA and contractors, who may not have known to include commissioning activities in their bids and are reluctant to slow down their work. • A comprehensive commissioning process is better both for the owner (in terms of optimizing performance) as well as contractors.	**Slide 6** **Most effective when integrated early in design phase:** **SM Page 83** **Notes:**
• The most obvious reason to commission a building is to save money over the long term by **reducing energy use**. With volatile energy prices around the country, minimizing utility charges is one way that building owners can maintain control over their investment. • By making certain that the building's energy-related systems are installed according to manufacturers' specifications, commissioning ensures the reliability and maintainability of those systems. This results in **lower operations and maintenance costs.** • Also, since a commissioning scope includes training building staff on proper systems operation, the people charged with running the equipment are better equipped to notice and prevent problems in the future.	**Slide 7** **Owner Benefits:** **SM Page 83-84** **Notes:**

• Once the energy-related systems of the building have been optimized through commissioning efforts, a **building performance baseline is established** against which future performance can be compared. Ongoing commissioning activities can then recognize and address suboptimal performance, adjusting system operation so that the owner's current and future needs can be met. • Commissioning also verifies and organizes building documentation. This further aids owners and building operators in quickly identifying and addressing systems operations issues, and provides renovation designers with useful information from which to base improvements. • Another benefit of comprehensive commissioning is a **reduction in requests for information (RFIs) and change orders.** If a CxA has done a proper design review prior to construction, he or she will have already found any pragmatic or logistical problems that the contractor might face down the line. This means that the contractors can base their bids on more reliable documents, and costly changes and callbacks can be avoided. • Commissioning also leads to **improved occupant health and satisfaction.** This benefits the building owner by reducing complaints and maintaining high tenant retention. By making sure building systems that control the interior environment are operating to the best of their ability, commissioning seeks to reduce negative health effects associated with poor indoor air quality and maximize occupant productivity and well-being.	**Slide 8** **Owner Benefits:** **SM Page 84** **Notes:**
Note to Instructor: **Discussion:** How does a commissioning process benefit contractors and sheet metal workers in particular? What are the challenges for contractors and sheet metal workers in a commissioning process?	**Slide 9** **Contractor and Sheet Metal Worker Benefits:** **SM Page 84** **Notes:**

• Benefits: ○ Job **done right the first time.** ○ **Reduces waste and confusion** on the job. ○ **Reduces callbacks** and warranty work. ○ Ability to take **pride** in your work. ○ **Customer satisfaction.** ○ **Opportunities to teach and learn.** • Potential drawbacks: ○ Seems like extra work. ○ Poor planning can cost contractors money.	**Slide 10** **Contractor and Sheet Metal Worker Benefits:** **SM Page 84** **Notes:**
• For sheet metal workers in particular, commissioning **provides opportunities for career change or advancement.** • Commissioning (along with retrocommissioning and energy auditing) is one of the greatest **potential growth areas in the "green collar" HVAC market.** • HVAC contractors with enough education or experience can qualify for commissioning credentials. • TAB professionals make especially good commissioning authorities because their work is so closely aligned with the goals of commissioning. • Recognizing this, some project owners are now contracting the TAB work directly (instead of indirectly through the general or mechanical contracts) to ensure impartiality.	**Slide 11** **Contractor and Sheet Metal Worker Benefits:** **SM Page 85** **Notes:**

• A 2009 research report by Lawrence Berkeley National Laboratory investigator Evan Mills, and jointly sponsored by the California Energy Commission, the California Institute for Energy and Environment, and the U.S. Department of Energy, provides the world's largest database of commissioning case studies for new and existing buildings. The sample set includes 643 buildings, representing 99 million square feet of floor area in 26 states. • The findings overwhelmingly support the assertion that **commissioning is a cost-effective process for owners to undertake.** • Median commissioning costs: \$0.30 per square foot for existing buildings and \$1.16 per square foot for new construction (0.4% of total construction costs for new buildings). • Median whole-building energy savings: 16% and 13%. • Median payback times: 1.1 and 4.2 years.	**Slide 12** **Benefits & Cost:** **SM Page 85** **Notes:**
• Additional research findings include: ○ **Considerable reductions in greenhouse-gas emissions** were achieved. ○ Projects employing a comprehensive approach to commissioning attained nearly twice the overall median level of **savings**, and five-times the savings of projects with a constrained approach. ○ **Non-energy benefits** are extensive and often offset part or all of the commissioning cost. *Note to Instructor:* Discussion: Ask the class what some non-energy benefits of commissioning might be. Possible answers include a healthier environment for the building occupants, tenant retention, improved marketability for the building.	**Slide 13** **Additional Research Findings:** **SM Page 85** **Notes:**

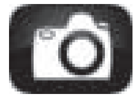
• **Commissioning is a team effort** that requires cooperation, communication, and coordination among all members. • The commissioning authority (CxA) is the individual or organization that leads this team through the commissioning process by communicating goals, coordinating tests and inspections, and clearly defining pass/fail criteria for each component and system. • **The CxA is responsible for establishing the commissioning plan** as well as ensuring that building commissioning is carried out in accordance with the plan.	**Slide 14** **Roles & Responsibilities:** **Figure 5: Summary of Recommended Deliverables by Commissioning Phase.** **Figure 6: Different stages: Commissioning activities.** **SM Page 86-87** **Notes:**
• Each member must expand his or her typical scope of work to play his or her role in the commissioning process. • In addition to the CxA, a typical Cx team includes: ○ **Owner.** ○ **Architect.** ○ Electrical **engineer.** ○ Mechanical engineer. ○ General contractor or construction manager. ○ Electrical **contractor(s).** ○ Mechanical contractor(s). ○ Controls contractor. ○ Sheet metal contractor. ○ Specialty contractors. ○ **TAB agency.** ○ Owner's **O&M staff.** ○ **End user.** • All of these parties have an influence on the building's energy systems during different phases of the project. Collectively, they play a key role in fulfilling the OPR.	**Slide 15** **Other Cx Team Members Include:** **SM Page 86** **Notes:**

• The **owner initiates the commissioning process by hiring the CxA.** This can happen at any stage of a building project, but, again, it is most effective if the CxA is engaged as early as possible. • A document known as the Owner's Project Requirements (OPR) is usually **developed in the pre-design phase of a project to make performance objectives clear** to the team. Examples of variables covered in the OPR include building uses, lighting preferences, building schedule, thermal comfort priorities, energy cost goals, building operation goals, and other variables that the commissioning authority ensures inform how the building is designed, engineered, and operated. • The OPR may be revised during the design process as the owner's objectives and criteria evolve. Because this document is the basis from which the CxA assesses all component and system performance, it is important that the OPR be clear, concise, and comprehensive.	**Slide 16** **Owner's Project Requirements (OPR):** **SM Page 86** **Notes:**
• Once the OPR has been established, the design team uses it to form another foundational document call the Basis of Design (BoD). • The BoD contains the concepts, assumptions, calculations, decisions, and product selections used to **meet the owner's project requirements** and to **meet applicable regulatory requirements**, standards, and guidelines. • It is the CxA's responsibility to ensure that the BoD does in fact support the OPR.	**Slide 17** **Basis of Design (BoD):** **SM Page 86-88** **Notes:**

• Commissioning requirements for contractors are defined in the specifications. • The commissioning specification identifies and describes detailed **roles and responsibilities on the Cx team.** It also lays out **training and documentation requirements.** • Because commissioning can be labor-intensive and time-consuming, it is important that commissioning activities be outlined precisely so that contractors can plan and bid accordingly. • It is the general contractor's responsibility to appropriately define subcontractors' scopes of work to include commissioning activities, ensuring that there are no gaps or overlaps between contracts and subcontracts.	**Slide 18** **Commissioning Specification:** **SM Page 88** **Notes:**
• Whether a project is using the 1995 CSI MasterFormat™ or the 2004 MasterFormat™, commissioning **requirements might be included in a variety of sections.** • In the older MasterFormat™, commissioning requirements might be found under divisions 1 General Requirements, 15 Mechanical or 16 Electrical.	**Slide 19** **MasterFormat:** **SM Page 88** **Notes:**
Note to Instructor: Show tables from MasterFormat, discuss the points that address the Cx function.	**Slide 20** **MasterFormat:** **Table 1. Example: 1995 CSI MasterFormat.** **SM Page 89** **Notes:**
• As the practice of commissioning has gained prominence, the 2004 CSI MasterFormat™ expanded to include **more specific sections that address commissioning.**	**Slide 21** **MasterFormat:** **SM Page 88** **Notes:**

Note to Instructor: Show the relevant sections under Division 01 General Requirements. Equipment- and system-specific commissioning requirements are covered under their respective subdivisions.	**Slide 22** **MasterFormat:** **Table 2. Example: 2004 CSI MasterFormat.** **SM Page 89** **Notes:**
• The types of commissioning activities that contractors are responsible for include: ○ Filing contractor **submittals** ○ Filling out **prefunctional checklists** ○ Facilitating functional **tests** conducted by the CxA ○ Providing **O&M manuals** ○ Facilities **staff training** • These activities and the contractor's role in them are described in the following section.	**Slide 23** **Contractor Responsibilities:** **SM Page 88** **Notes:**
• Because commissioning is a team effort, it is important that you have a good working relationship with the CxA. Here are some tips for getting the most out of your commissioning team experience: ○ **Think holistically.** While maintaining the necessary focus to do your job well, consider how your work fits in to the greater system and integrated group of systems that make a building run. Be curious beyond your task. ○ **Think like an operator.** When doing your work, try to imagine the practical steps that facilities staff will have to take to operate building systems. ○ **Be open to teaching and learning.** Each member of the Cx team has expertise to offer. Be willing to share your knowledge as well as learn from others. ○ **Educate yourself.** The more you know about building systems, the more you can contribute to the commissioning process.	**Slide 24** **Tips for working with a CxA:** **SM Page 88-90** **Notes:**

• These are the primary activities in a commissioning scope of work: ○ Field installation **verification.** ○ Prefunctional equipment **testing.** ○ Control system checkout and testing (including sequence of operations verification). ○ Testing, adjusting, and balancing (TAB). ○ Functional testing. ○ O&M manual and **staff training.** ○ As-built drawing verification. ○ Commissioning outcomes **documentation.** • We will be now go into more detail on each of these scope items in this section.	**Slide 25** **Primary Commissioning Activities:** **SM Page 90** **Notes:**
• The first step in ensuring that a building's energy-consuming systems operate as intended is to make sure that the right equipment is installed in the right location. This is called **Field Installation Verification.** • This may seem more than obvious, but it is surprising how often simple mistakes can occur. • The project drawings and specifications spell out what equipment is to be installed where. It is up to the commissioning authority to verify that the installation contractor has in fact carried out those instructions. • Depending on the particular protocol of the CxA, installation contractors or journeymen may be required to submit field installation verification checklists, or the prefunctional testing checklist (see next section) may include enough information to verify that the correct equipment is installed in the correct location.	**Slide 26** **Primary Commissioning Activities:** **SM Page 90** **Notes:**

Note to Instructor: Show and discuss the sample FIV checklist.	**Slide 27** **Field Installation Verification Checklist:**  **Field Installation Verification (FIV).** **SM Page 91** **Notes:**
• Prefunctional equipment testing involves a three-step process for each piece of equipment: inspection, testing, and startup. • **Inspection** requires that the installing contractor verify that the equipment was installed according to the manufacturer's requirements as well as the plans and specs. As described in the previous section, field installation verification is an obvious but important step to make sure that the right equipment has been installed in the right place. The equipment must be further checked to make sure that shipping materials, bolts, and blocking have been removed. Motor-driven equipment may need to be checked to verify that fluid levels, belt tension, gauges, and calibrations are correct. • The **testing** step involves a static test to verify that equipment is ready for startup. This may include verifying voltage coming to the equipment, checking that connections are properly made for the voltage available and/or checking the motor phase rotation to make sure that the shaft is rotating in the correct direction for the fan. • **Startup** involves turning on the equipment and observing if it is operating properly. Finally, the results of all three prefunctional testing steps must be documented using checklists. These are to be submitted to the CxA for review and approval. The CxA may also back check a sampling of these checklists to gain reasonable confidence that they have been filled out correctly. Any issues that come up during prefunctional testing need to be documented for either immediate or future correction.	**Slide 28** **Prefunctional Equipment Testing:** **SM Page 90-92** **Notes:**

• In order to prepare the necessary inspection, testing, and startup procedures and checklists the **CxA requires equipment and system documentation from installation contractors**, who in turn procure this information from their subcontractors or suppliers. • Keep this in mind when requesting shop drawings or other technical information from those sources. These submittals typically include: ○ Manufacturer instructions. ○ Maintenance requirements. ○ Troubleshooting documents. ○ Factory testing procedures, results, and certifications. ○ Operating characteristics. ○ Warranties and guarantees. ○ Manufacturer field test procedures.	**Slide 29** **Typically Required Equipment and System Documentation:** **SM Page 92** **Notes:**
Note to Instructor: Show sample Prefunctional Assurance Test (PFAT) checklist.	**Slide 30** **Prefunctional Equipment Testing:** **Figure 7: A typical commissioning checklist form.** **SM Page 93** **Notes:**

• Before the TAB contractor can begin his or her work (which is described in the next slide), the HVAC system components must all be in place and the control system must be operational, tested, and documented by the controls system contractor. • The CxA **verifies that the sequence of operations provided to the controls system subcontractor is consistent with the OPR.** If the sequence of operations narrative is insufficient, or if the controls system contractor has had to substantially revise it, the CxA may be involved in reconciling the final version with the OPR. • In addition to the verified sequence of operations, the controls system contractor provides crucial information to the TAB contractor such as temperature and pressure setpoints, and monitoring and control points. The CxA will typically coordinate between the controls contractor and the TAB contractor to identify other specific information that may be needed.	**Slide 31** **System Control Check-Out and Testing:** **SM Page 92** **Notes:**
• The controls system contractor is also responsible for providing: ○ **Technical data** on control system components. ○ **Schematic diagrams** of the entire controls system. ○ Complete **points list.** ○ Written **sequences of controls** for all systems. ○ For direct digital controls systems, a complete set of **system software** must also be provided.	**Slide 32** **Controls System Contractor Responsibilities:** **SM Page 92-94** **Notes:**

• The testing, adjusting, and balancing (TAB) process is highly complementary to commissioning in that its purpose is to ensure that the HVAC system is functioning properly in terms of energy efficiency and providing occupant comfort. • As discussed above, TAB contractors may be engaged independently (like commissioning authorities) or may go on to become commissioning authorities themselves. • Put simply, TAB **examines and finetunes both air and hydronic systems to ensure that flow rates conform to design specifications.** • The documentation of this process provides an invaluable resource for the CxA who can then see that the majority of issues affecting system performance have been resolved.	**Slide 33** **Testing, Adjusting, & Balancing:** **SM Page 94** **Notes:**

• Whereas prefunctional testing dealt with individual pieces of equipment, functional testing (sometimes called functional performance testing) **verifies the operation of building systems** as well as **tests the interaction of multiple systems.** • Functional tests **can either be performed manually or through system monitoring.** • *Manual testing* involves changing a system input or condition on purpose and then observing how the system reacts and whether or not other integrated systems respond properly. • *Systems monitoring* is a more passive approach wherein building systems are monitored to gauge their performance under changing conditions over a period of time. For instance, the CxA may have to wait for the seasons to change in order to observe systems performance under peak heating or cooling loads. Systems monitoring can be achieved using an automated integral Building Management System (BMS) or through the strategic installation of portable data loggers. Data loggers can be programmed to measure and record a wide array of system characteristics including temperature, humidity, flow, pressure, voltage, current, power, and energy. In either case, the description and results of these tests must be documented. • If functional tests reveal problems, the CxA will document them and track them until they are corrected. Contractors are responsible for fixing them, since commissioning authorities don't carry hammers. Once issues have been addressed, the CxA will return to witness re-tests for satisfactory results.	**Slide 34** **Functional Testing:** **SM Page 94** **Notes:**
Note to Instructor Show sample Functional Test (FPT) checklist (Chilled Water System).	**Slide 35** **Functional Testing:** **Figure 8: A typical commissioning checklist form.** **SM Page 96** **Notes:**

• The manuals **inform building personnel as to which models were installed** in their facility and what information applies to their work. In the case of commissioning existing buildings, the CxA works with facilities staff to combine existing and newly obtained O&M documentation and organize it into a concise, indexed manual. • May include: ○ Owner's requirements from OPR. ○ Equipment drawings and specifications. ○ As-built sequences of operations, control drawings, and original setpoints. ○ Etc. • It may also be required to provide condensed **operating instructions** that can be mounted on or near the equipment for quick reference.	**Slide 36** **Operations and Maintenance (O&M) Manuals:** **SM Page 94-95** **Notes:**
• The CxA works with the general contractor (or construction manager), owner, and design team to coordinate facilities staff training. • The GC then communicates the training program requirements to subcontractors, suppliers, and manufacturer's representatives. The actual training program is **developed by the CxA** in cooperation with the building systems designer(s), the installation contractors, and major equipment suppliers. • Typically **tradespeople and/or manufacturer's representatives will deliver the training** sessions in which facilities personnel are shown proper procedures for operating and maintaining equipment.	**Slide 37** **Staff Training:** **SM Page 95** **Notes:**

• Staff training **may include both classroom instruction and hands-on training**, and should cover, at a minimum: ○ Design intent ○ System limitations ○ Overview of information contained in the O&M manual ○ Start-up and shut-down procedures ○ Modes of control and sequences of operation ○ System response to different operating conditions ○ Detailed instruction on the control system ○ Routine maintenance ○ Health and safety provisions ○ Contact information for contractors and manufacturers ○ Recommendations • The CxA may strongly suggest that the trainings be videotaped and documented, allowing current staff to review training material and future staff to receive the information.	**Slide 38** **Staff Training:** **SM Page 95-97** **Notes:**
• As mentioned previously, one of the benefits of a commissioning process is the creation of detailed and reliable building documentation. • Installation contractors may be required to submit mark-ups of construction drawings of the systems they work on, which can then be used to create as-built drawings. • These serve as a useful record from which future equipment or system modifications can be made. They are also an important **reference for building operations staff,** and **essential for training purposes** as a means to transfer construction knowledge to operations staff. • Despite best efforts, it often happens that as-built drawings are not 100% accurate due to oversights or modifications made after the construction drawings have been marked up. • In order to make sure that the as-built drawings are as correct as possible, the operations staff, CxA or system designer may review them in comparison with site observations.	**Slide 39** **As-Built Drawings:** **SM Page 97** **Notes:**

• At the end of the commissioning process, the **CxA delivers a final commissioning report to the owner.** • The report uses the finalized commissioning plan as a template to describe and document in detail procedures, outcomes, corrections and results of re-testing. It also provides an executive summary that correlates performance to stated design intent for all commissioned systems.	**Slide 40** **Outcomes Documentation:** **SM Page 97** **Notes:**
Note to Instructor: **Discussion:** Ask the students what characteristics they think LEED and Commissioning share. • Commissioning is indeed a fundamental aspect of LEED and shares similar intentions and demands for quality. Some examples of shared goals include: ○ Energy efficiency. ○ Greenhouse gas reductions. ○ Reduced energy costs. ○ Quality assurance and quality control.	**Slide 41** **What are the common purposes of Commissioning and LEED?** **SM Page 97** **Notes:**
• LEED's program for new construction projects has **both a requirement and an optional credit available related to commissioning.** These are: ○ EA prerequisite 1: Fundamental Commissioning of Building Energy Systems (required). ○ EA credit 3: Enhanced Commissioning (2 points). • Both are contained in the Energy and Atmosphere (or "EA") LEED category. • The credit is worth 2 points, rather than 1, to recognize the value and effectiveness of commissioning in meeting LEED goals.	**Slide 42** **Cx and LEED-NC:** **SM Page 97** **Notes:**

• EAp1 requires that the project team implement a basic Cx process for these energy-related systems (if present): ○ **HVAC systems.** ○ **Lighting and daylighting control systems.** ○ **Domestic hot water systems.** ○ **Renewable energy systems.** • Other systems may be included at the project team's discretion. The commissioning process required by LEED is similar to the process we've described in this unit: The team must designate a qualified person to act as the CxA who then reviews the OPR and BoD documents for clarity and completeness. The project team then develops a commissioning plan the requirements of which are incorporated into construction documents. The implementation of the commissioning plan involves verifying the installation and performance of the relevant systems. Finally a report is generated to summarize commissioning activities and outcomes.	**Slide 43** **EAp1 Process Requirements:** **SM Page 97-98** **Notes:**

• For all prerequisites and credits, LEED requires documentation that **validates that the project was designed or constructed to meet the performance or prescriptive standards** specified by prerequisite or credit. • For EAp1, there are several scope items that must be documented. The Cx Specification must include: ○ Cx team involvement. ○ Contractor's responsibilities. ○ Submittal review procedures. ○ Required O&M documentation. ○ Meetings. ○ Construction verification procedures. ○ Startup plan development and implementation. ○ Functional performance testing. ○ Acceptance and closeout. ○ Training. ○ Warranty review site visit. • As mentioned previously, these activities largely mirror the scope we've described throughout this unit.	**Slide 44** **EAp1 Cx Specification Requirements:** **SM Page 98** **Notes:**
• EAc3 presents additional "enhanced" commissioning tasks that interlace with the requirements of EAp1. Early engagement of the CxA is rewarded by EAc3, which requires that the CxA conduct a design review. • The **CxA must review contractor submittals**, evaluating them for the following: ○ Conformance with the OPR and BoD ○ Fulfilling operations and maintenance requirements ○ Facilitating performance testing • The credit further requires: ○ Oversight of staff training ○ Walk-through 10 months after building completion ○ Creation of a systems O&M manual.	**Slide 45** **Contractor Submittals Evaluation:** **SM Page 98** **Notes:**

• In this unit, commissioning has been identified as a *proactive* quality assurance process. Because evaluating existing building performance is inherently *reactive,* a slightly different process is required to assess and optimize building performance. • According to the Reference Guide for existing buildings, existing building commissioning or **retrocommissioning** "involves developing a building operation plan that identifies current operating requirements, conducting tests to determine whether building systems are performing optimally in accordance with the plan, and making any necessary repairs or changes." An energy audit "identifies how much energy a building uses and the purposes for which it is used, and identifies efficiency and cost-reduction opportunities." • Both energy auditing and retrocommissioning are addressed in LEED EB:O&M in **1 prerequisite and 3 credits, worth up to six points.** Before we dive into the LEED requirements, it's helpful to review more information on retrocommissioning and energy auditing.	**Slide 46** **Cx and LEED-EB:O&M:** **SM Page 98** **Notes:**
• Retrocommissioning is the investigation, evaluation, optimization and verification of the appropriate **operation and performance of energy systems in an existing building.**	**Slide 47** **Retrocommissioning:** **SM Page 98** **Notes:**
• Energy Auditing is the evaluation, identification, analysis, prioritization, implementation, and verification of **energy improvement measures to an existing building.** • LEED uses the ASHRAE energy audit walk-through assessment protocol in its credit compliance requirements under LEED for Existing Buildings: Operations & Maintenance. • This protocol is defined in Procedures for Commercial Building Energy Audits RP-669, SP-56. • Levels I and II represent increasing levels of rigor in the auditing protocol.	**Slide 48** **Energy Auditing:** **SM Page 98-99** **Notes:**

The following is a summary of the ASHRAE Level I & II Audit Process: 1. **Define the audit focus**. This includes a preliminary review of building documents with the explicit goals of the owner in mind. These documents include utility data, MEP drawings, control system as-builts, TAB reports, and the current capital improvement schedule. 2. **Conduct a site visit**. This is the "walk-through" step wherein the auditor reviews the installation and operation of all major energy-consuming equipment, interviews operations staff, and examines additional building documentation. 3. **Identify energy efficiency measures (EEMs).** Using the information gathered so far, the auditor creates a list of EEMs that could result in potential savings. Once all options are presented, they can be prioritized according to the owner's budget and performance goals. 4. **Analyze utility data**. Utility Data Analysis (UDA) allows the auditor to itemize energy consumption by end use, identify base load and seasonal variation, scrutinize utility rate structures, and compare building performance against established benchmarks. 5. **Conduct cost/benefit analysis**. Once EEMs have been identified for further study, the auditor can use estimates of potential energy and non-energy savings and installed equipment costs to calculate the simple payback for each measure. In a Level I audit, this information provides a general sense of cost and payback issues. 6. **Level I Audit Report**. This basic report includes a description of systems, UDA summary, benchmarking results, a narrative of audit procedures and results, and a discussion of potential benefits associated with chosen EEMs. 7. **Conduct Level II investigation**. A Level II energy audit is distinguished by this phase in which steps 2-5 are repeated in greater detail. By using more direct and detailed measurements, more nuanced logistical considerations, and basing energy calculation variables on directly collected data, the auditor can provide the owner with a more sophisticated picture of current and potential building performance. In a Level II audit, more detailed cost/benefit analysis yields investment-grade information on which to base capital improvement decisions.	**Slide 49** **ASHRAE Level I & II Audit Process:** **SM Page 99-100** **Notes:**

8. Level II Audit Report. A Level II audit report includes the same sections as the Level I audit report, but augments them with the enhanced level of detail applied to the Investigation phase.	
• The intent of EAp1 is to **"promote continuity of information to ensure that energy-efficient operating strategies are maintained** and **provide a foundation for training and system analysis."** • EA prerequisite 1: Energy Efficiency Best Management Practices requires: ○ Documenting the current sequence of operations. ○ Develop a building operating plan. ○ Draft a systems narrative ○ Create a preventative maintenance plan narrative. ○ Carrying out an ASHRAE Level I energy audit. • All five of these steps must be completed in order for a project to be eligible for LEED-EB:O&M certification.	**Slide 50** **EAp1 Energy Efficiency Best Management Practices:** **SM Page 100** **Notes:**
• Under EAc2.1 Existing Building Commissioning—Investigation and Analysis, project teams can earn two points toward certification either by **executing a retrocommissioning process or conducting an ASHRAE Level II energy audit.**	**Slide 51** **EAc2.1 Existing Building Commissioning-Investigation and Analysis:** **SM Page 100** **Notes:**
• An **additional two points** can be earned under EAc2.2 Existing Building Commissioning—Implementation by: ○ Implementing the no- or low-cost EEMs identified by retrocommissioning ○ Or energy auditing efforts and creating a capital plan for major retrofits or upgrades.	**Slide 52** **EAc2.2 Existing Building Commissioning-Implemenation:** **SM Page 100** **Notes:**

• EA c2.3 Existing Building Commissioning—Ongoing Commissioning **awards two more points for the establishment of an ongoing commissioning program** that defines planning, system testing, performance verification, corrective action response, ongoing measurement, and documentation activities to proactively address operating problems.	**Slide 53** **EAc2.3 Existing Building Commissioning-Ongoing Commissioning:** **SM Page 100** **Notes:**

Unit 2 Summary:

In Unit 2, the students have learned:

- Commissioning is a comprehensive quality assurance process that seeks to bridge gaps in communication and expertise between system designers, installers, and operators to optimize building performance.
- Commissioning has energy and cost saving benefits to building owners, and professional benefits to contractors.
- Commissioning is most effective when the CxA is engaged early in the project.
- Commissioning activities include: prefunctional equipment testing, control system testing, TAB, functional testing, O&M manual development, staff training, creating as-built drawings, and documenting Cx outcomes.
- LEED-NC and LEED-EB:O&M both require a basic level of commissioning, and reward additional Cx activities.

Application:

To achieve the learning objectives, engage the students in discussions during class and go over the sample commissioning checklists. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

PRIMARY GREEN CONSTRUCTION ACTIVITIES

Unit 3: Construction Waste Management (CWM)

Module 2
Primary Green Construction Activities

Unit Learning Objectives:
After this unit, students will:
- *Understand the importance of Construction Waste Management (CWM) as it relates to green building.*
- *Understand your role in the successful implementation of a CWM plan.*
- *Identify potential sources of construction waste.*
- *Be able to define the "Three Rs" principle of waste management.*
- *Be familiar with LEED requirements and documentation associated with CWM.*

Time Required: Approximately 1.5 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
- ☑ **Green LEED CD-ROM, Computer, and Projector**
- ☑ **Pencils**
- ☑ **Paper**
- ☑ **Chalkboard, dry-erase board, or poster paper**

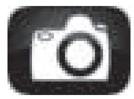
Student Manual Pages: 103-115

Introduction:
This unit begins with a discussion of the environmental impacts of solid waste, explaining why our throw-away society is not sustainable. The "3 Rs" principle of reduce, reuse, recycle is reviewed and discussed in the context of construction waste. Best practices for construction waste management are covered, including the recommended contents of a CWM plan. Both LEED for New Construction and Existing Buildings: Operations & Maintenance reward projects for achieving diversion rates of 50+% and 70+%, respectively.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• Throughout the United States and the rest of the world, **construction activities generate large amounts of waste.** • Construction waste may be generated during: ○ Demolition of existing structures ○ Land clearing in preparation for new projects ○ Construction of new projects, including renovations. • During construction, the demolition phase typically produces the greatest amount of waste.	**Slide 1** **What is CWM and Why Is It Important?** **Figure 9: Construction waste.** **SM Page 103** **Notes:**
Note to Instructor: Show table of typical construction waste types and discuss.	**Slide 2** **Construction Waste Types:** **Table of material category and examples.** **SM Page 104** **Notes:**
• Due to this large amount of construction waste and the range of potential impacts, effective waste management is becoming increasingly important. • The ongoing generation of large amounts of waste from construction sites requires that the waste be put somewhere. Historically, construction waste in the United States was primarily directed to landfills: ○ Located outside of urban areas. ○ **Occupy valuable open space and/or farm & forest land.** ○ **People do not like to locate near a landfill.** ○ **Land requirements are substantial.**	**Slide 3** **Impacts of Solid Waste:** **Figure 10: Landfills.** **SM Page 104-105** **Notes:**

• Substantial space requirements are not the only concerns when considering landfills. • **Landfills can impact the environment by endangering the quality of our water and land resources**. For example, landfills are filled with a wide variety of waste, including hazardous and biological materials. • These materials, if not handled properly, can leach into groundwater and surface water bodies during rain, snow melt, and other events. This leaching of hazardous materials can contaminate drinking water sources. A number of studies have demonstrated the relationship between such groundwater contamination and a variety of adverse health effects, including birth defects and certain types of cancer. • Landfills are also a significant source of methane, a greenhouse gas that contributes to global warming. • According to the USEPA, landfills are the second largest source of human-related methane emissions in the United States. Methane remains in the atmosphere for approximately 9 to 15 years and traps heat at a rate approximately 20 times greater than carbon dioxide (CO_2).	**Slide 4** **Environmental Concerns:** **SM Page 105** **Notes:**
• Large amounts of construction waste can significantly impact on the project's bottom line. • Throughout demolition and construction, the **disposal of waste represents a substantial on-going cost.** • As a result of decreasing landfill capacity and increased regulations of landfill operations, tipping fees (also known as the "gate fee"), the charge for unloading waste at a transfer station facility, have increased significantly. These fees are commonly assessed by weight. Therefore, reducing the amount of waste generated at the project site and diverting waste materials away from the landfill can reasonably reduce project costs.	**Slide 5** **Financial Concerns:** **SM Page 105** **Notes:**

• There are three primary strategies that should be employed to manage construction waste, known as "The Three Rs": **Reduce; Reuse; and Recycle**. • Collectively, these three strategies represent a comprehensive approach to waste management.	**Slide 6** **The "Three R's" Principle:** **SM Page 106** **Notes:**
• The most effective approach to waste management at the construction site is to **reduce the amount of material used in the first place**, also known as "source control." • Source Control: ○ Using simple finishes, and reducing the layering of materials. ○ Multi-use materials. ○ Centralized cutting areas. ○ Ensure accurate orders. ○ Minimizing re-building work.	**Slide 7** **Reducing Through Source Control:**  **Figure 11: A centralized cutting area.** **SM Page 106** **Notes:**

- Materials can be reused either on site or off. Material reuse can be achieved in two ways: (1) the identification of locations within the new or renovated building where materials can be used; or (2) donation of reusable materials to a deconstruction services organization.

- Reuse materials on site:
  - **Requires design consideration.**
  - **Common materials include structural beams, casework, flooring, and furniture.**

- Donate materials for reuse off site. Potential benefits:
  - Reduced cost.
  - Unique character.

- Onsite material reuse requires design consideration. Materials commonly reused in projects include items such as structural beams, casework, flooring, and furniture.

- Incorporating materials from existing structures may, in some cases, require project teams to use additional care during demolition, but the benefits of materials reuse for the project can be substantial, including adding unique character and reducing costs.

- If materials generated during demolition cannot be used in the project, a second approach is to donate materials for reuse off site.

- This can be accomplished by utilizing a deconstruction services organization to dismantle the existing structure. As materials reuse has become increasingly common in the construction industry, a robust deconstruction services industry has developed to meet the demand. A deconstruction services organization crew will dismantle structures on the site with a specific focus on identifying and preparing materials for future reuse. Usable materials are then made available to the public and members of the construction industry for use in future projects, extending the life span of products that would otherwise go to the landfill. In many cases, fees paid to these organizations are tax-deductible, reducing the total cost of service.

Slide 8
Strategies for Reusing:

Figure 12: Mint Dental in Portland.

SM Page 106-107
Notes:

• The final approach of effective waste management is recycling, but don't forget that options for reducing and reusing should be exhausted first. • Recycling involves **directing materials away from the waste stream and processing them into raw materials** so that they can be put back into the manufacturing process and incorporated into new products. For a variety of common recyclables, construction waste haulers provide for the storage of recyclable materials on site, as well as their transport and processing to recycling facilities. In many cases, it is necessary to have separate waste and recycling haulers serve the site. • The availability of construction waste recycling resources **varies regionally.**	**Slide 9** **Considerations for Recycling:** **SM Page 107-108** **Notes:**
• However, at minimum, **recycling of metals, concrete, asphalt, glass, and land clearing debris is common.** Generally, recycling **options for paper, corrugated cardboard, plastics, and wood are subject to higher regional variability** and may require some additional coordination with the construction waste hauler to ensure the availability of local recycling resources. • Recycling of drywall, gypsum wallboard, and other materials may be more challenging. • Overall, construction and demolition waste recycling **reduces the demand for virgin resources** and, consequently, **reduces the resource demands of extraction, processing, and, in many cases, transportation.**	**Slide 10** **Considerations for Recycling:** **SM Page 108** **Notes:**

• There are a number of steps that must be taken to ensure that the identified construction waste strategies are implemented on the site: ○ **Develop a CWM plan** (typically done by general contractor). ○ Make **green partnerships** with construction waste haulers and recyclers. ○ Decide between **waste separation vs. commingling.** ○ **Train** jobsite personnel and keeping records. • These approaches ensure that the necessary recycling resources are available for the project team, that jobsite personnel are adequately trained on the project processes and protocols, and that adequate records are kept to clearly demonstrate that the project's recycling targets were met. • Successful construction waste management requires effective coordination at a variety of levels, including the general contractor, the construction team, and the waste and recycling haulers.	**Slide 11** **CWM Strategies:** **Figure 13: Construction waste haulers.** **SM Page 107-108** **Notes:**
• Prior to the start of construction, a construction waste management plan should be prepared for the project. The plan, typically developed by the general contractor, will serve as a road map for how waste and recyclables will be administered throughout the demolition and construction phases. • The plan should **clearly identify the project goal and procedures for recycling** (e.g., 75% of all waste should be recycled), identify specifically how waste and recyclables will be managed on site, list what materials will be recycled during both the demolition and construction phases, identify the relevant haulers and recyclers for each material, and list the specific parties that will be responsible for the successful implementation of the plan. • Development of the plan will **ensure that recycling resources are available, personnel are trained, and adequate records are kept.**	**Slide 12** **CWM Implementation Strategies:** **SM Page 108-109** **Notes:**

• Critical partners for green construction waste management include: ○ **Waste haulers.** ○ **Recyclers.** ○ **General contractor.** ○ **Subcontractors.** • Waste haulers and recyclers, along with the general contractor and subcontractors, ensure that local waste and recycling facilities have been identified and that the necessary agreements are in place so that waste and recyclables generated on site will be directed to the appropriate locations. • The selection of the project's waste hauler and recyclers must be completed with confidence that the hauler and recyclers have the necessary experience with managing, transporting, and processing recycled materials generated at the job site. • Recycling goals should be conveyed to the hauler and recycler early on in project discussions so that there is no misunderstanding of the role and importance of recycling in the project.	**Slide 13** **Critical Partners for CWM:** **SM Page 109** **Notes:**
• An important consideration in the development and implementation of the project's construction waste management plan will be how the construction waste will be handled on site. • There are two options for the management of recycled material on the job site – waste separation and commingling – and the most appropriate choice will depend on a number of factors including: ○ **Site characteristics** (i.e., the amount space available on site) ○ **Resources** provided by the project's waste hauler and recyclers ○ **Experience and knowledge** base of the construction team ○ **Project schedule**	**Slide 14** **Waste Separation vs. Commingling Depends On:** **SM Page 109** **Notes:**

• On-site waste separation, also known as "source separated," is the process of **separating out the various recyclable materials and placing them in clearly-labeled bins** for pick-up and transportation to the appropriate local recycling facility. Bins may be placed on site for the range of materials identified above, including metals, concrete, asphalt, glass, cardboard, etc. • This approach depends heavily on the construction team to ensure that recyclable materials are placed in the correct bins and that the materials are in the necessary condition to meet the requirements of the individual recycling facility (e.g., not mixed with other materials, not soiled in any way that may compromise the ability for reuse, etc.). • Source separation also reduces the amount of processing required at the recycling facility, potentially reducing the fees paid to the recycler.	**Slide 15** **Source Separated:** **SM Page 109** **Notes:**

• An alternative to source separation is commingling. As the name suggests, commingling involves **placing all of the project's demolition and construction waste materials – both recyclables and non-recyclables – into a single container** at the project site. • The container of commingled materials is then transported to a facility for separation of recyclables and non-recyclables off-site. • The use of commingled containers reduces the effort required of the construction team to separate out individual materials types and, generally, requires less space on the jobsite. However, the mixing of various material types can reduce the percentage of material that is recyclable – also known as the "recovery rate" – due to the increased chance of contamination and the potential difficulty in retrieving all of the recyclables in the container. • Once the commingled materials have been sorted at the recycle facility, the recovery rate of each individual load is provided to the general contractor for his or her records. • Generally, having the hauler and/or recycler separate commingled materials off-site can increase the cost of waste management for the project.	**Slide 16** **Commingling:** **SM Page 109-110** **Notes:**

• Successful implementation of the construction waste management plan will depend on the commitment of the construction team to its goals, objectives, and requirements. Consequently, training of all jobsite personnel represents a v**ital step in the success of the construction waste management effort.** • An initial meeting should be held to review the construction waste management plan and its requirements with all personnel prior the start of any work on the project. In the meeting, specific guidance should be given on the project recycling goals and the protocols that will be used throughout the project. This discussion should detail the specific locations of waste and recycling containers, whether demolition and construction waste will be source-separated or commingled, how to document any construction waste management responsibilities (as applicable), and other key information. • A copy of the construction waste management plan should be available at the job trailer and a copy of the plan should be provided to all personnel. This additional effort will clearly convey the importance of construction waste management to the construction team.	**Slide 17** **Personnel Training Considerations:** **SM Page 110** **Notes:**
• Thorough record-keeping of the handling of waste and recyclables generated on site is an essential piece of construction waste management plan implementation. • Throughout the demolition and construction process, **waste and recycling tickets from the relevant facilities should be catalogued** to document the achievement of the project's recycling goals. Documentation of loads received by individual facilities may be provided on a load-by-load basis or on a monthly basis. Waste and recycling facilities and/or haulers commonly provide, at minimum, a monthly summary of materials received and processed. These summary documents will list out the amount and type of material received by weight. • Either the load-by-load tickets or summary document can then be used in the LEED documentation effort.	**Slide 18** **Record-Keeping Considerations:**  **Figure 14: Essential piece of CMW plan implementation.** **SM Page 110-111** **Notes:**

• A range of resources is available to assist the general contractor and construction team in planning for and implementing an effective construction waste management plan. • These resources will provide additional information related to the types of recycling options available within the project area and best practices for utilizing those resources. • Helpful resources include: ○ **Local solid waste authorities.** ○ **Publications & websites.** ○ **Local codes.**	**Slide 19** **CWM Resources:** **SM Page 110-111** **Notes:**
• An excellent starting point when determining the project's construction waste management approach is the local solid waste authority. • Ways that your local solid waste authority can help you: ○ Provide **guidance** on best waste management approaches. ○ **Connect** team with recycling resources. ○ Can **recommend** useful region-specific publications and websites. • As recycling has become increasingly common on both a commercial and residential scale, local jurisdictions have increased the number and types of resources available to construction teams. Representatives from local solid waste authorities will provide specific guidance on the best waste management approaches in the project area and can connect the team with the range of recycling resources available to the construction team, including providing detailed directories and contact information for recyclers in the area. Local solid waste authorities may also be able to recommend useful region-specific publications and website resources to provide additional guidance to the team.	**Slide 20** **Local Solid Waste Authority:** **SM Page 111** **Notes:**

• A variety of national and local publications and websites can provide valuable **guidance on the preparation and implementation of the project's construction waste management plan.** Many of these publications and websites include **case studies** of innovative waste management strategies and provide **links** to information related to both standard and new approaches and resources to waste reduction. • A sampling of publications and websites are listed here: ○ EPA's Resource Conservation website: http://www.epa.gov/osw/conserve/rrr/imr/cdm/reducing.htm ○ Construction Materials Recycling Association: http://www.cdrecycling.org/ ○ California Integrated Waste Management Board Construction and Demolition Debris Recycling website: http://www.ciwmb.ca.gov/ConDemo/ ○ King County's Solid Waste Division Waste Reduction and Recycling website: http://your.kingcounty.gov/solidwaste/greenschools/waste-reduction.asp	**Slide 21** **Websites and Publications:** **SM Page 111-112** **Notes:**
• Finally, the applicable local code for the project site is a necessary resource for the development of the construction waste management plan. • In many areas, the local code includes specific requirements for how waste should be managed on the site, including guidance on the **location and size of waste and recycling containers,** as well as, in some cases, requirements on the **minimum recycling rate** that the project should achieve. • For details on the specific requirements in your area, it is best to discuss them with representatives of the applicable jurisdictions.	**Slide 22** **Local Codes:** **SM Page 112** **Notes:**

• Effective construction waste management and recycling is a critical component of the LEED rating systems. Projects pursuing LEED-NC or LEED-EB:O&M certification can earn points by ensuring that a majority of waste generated during the demolition and construction phases will be diverted away from landfills. In all of the LEED rating systems, construction waste management is **addressed in the Materials & Resources credit category.** • According to the LEED Reference Guides, the intent of CWM credits is to: "Divert construction and demolition debris from disposal in landfills and incinerators. Redirect recyclable recovered resources back to the manufacturing process. Redirect reusable materials to appropriate sites."	**Slide 23** **CWM and LEED:** **SM Page 112** **Notes:**
• The LEED-NC credit related to CWM is: MR credit 2: Construction Waste Management (2 points). • LEED-NC projects **can earn up to three points for effective construction waste management**—two standard points under MRc2 and one point for Innovation in Design. • Projects earn one point if at least 50% (measured by weight or volume) of the demolition and construction waste generated on site is recycled or salvaged. • Two points are earned if that threshold reaches 75%. • The project may earn an additional point for exemplary performance in the Innovation in Design category for recycling or salvaging at least 95% of the project's demolition and construction waste.	**Slide 24** **CWM and LEED-NC:** **SM Page 112** **Notes:**
• To demonstrate LEED-NC credit compliance, project teams must provide: a completed **LEED Submittal Template,** a copy of the **implemented construction waste management plan,** and a **summary log** of all waste that has left the project site and where each material type was diverted.	**Slide 25** **CWM and LEED-NC, Documentation Requirements:** **SM Page 112-113** **Notes:**

• The LEED-EB:O&M credit related to CWM is: MR credit 9: Solid Waste Management—Facility Alterations & Additions (1 point). • LEED-EB:O&M projects **can earn up to two points for effective construction waste management**—one standard point under MRc9 and one point for Innovation in Design. MRc9 addresses alterations and additions to the existing facility that may generate substantial amounts of construction waste. • One point can be earned if at least 70% of demolition and construction waste is recycled or salvaged. In contrast to the LEED-NC credit requirements, the LEED-EB:O&M credit requirements focus solely on base building elements permanently or semi-permanently attached to the building including: components and structures (wall studs, insulation, doors, windows); panels; attached finishes (drywall, trim, ceiling panels); carpet and other flooring materials; and adhesives, sealants, paints and coatings. • In addition to earning the point for MRc9, projects may earn an additional point for exemplary performance in the Innovation in Design category for recycling or salvaging at least 95% of the project's waste.	**Slide 26** **CWM and LEED-EB:OM:** **SM Page 113** **Notes:**
• Documentation requirements for LEED-EB:O&M are the **same as for LEED-NC, except they are not required to submit a construction waste management plan.**	**Slide 27** **CWM and LEED-EB:OM, Documentation Requirements:** **SM Page 113** **Notes:**

Unit 3 Summary:

In Unit 3, the students have learned:

- Construction waste has negative impacts on the environment, community health, and financial viability of a project.
- The "Three Rs" principle (reduce, reuse, recycle) can be applied to construction waste. Recycling should only be a last resort after options for reducing and reusing have been exhausted.
- A CWM plan should contain the diversion rate goal, specific materials to be recycled, and assign responsibilities.
- Projects that have construction waste diversion rates of 50+% and 70+% can earn points toward certification in LEED-NC and LEED-EB:O&M, respectively.

Application:

To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

PRIMARY GREEN CONSTRUCTION ACTIVITIES

Unit 4: Construction Indoor Air Quality (CIAQ)

Module 2
Primary Green Construction Activities

Unit Learning Objectives:
After this unit, students will:
- *Understand the importance of Construction Indoor Air Quality (CIAQ) assurance as it relates to green building.*
- *Understand your role in the successful implementation of a CIAQ plan.*
- *Be able to describe specific CIAQ measures.*
- *Be familiar with SMACNA's "IAQ Guidelines for Occupied Buildings."*
- *Be familiar with LEED requirements and documentation associated with CIAQ.*

Time Required: Approximately 1.5 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 117-125

Introduction:
Maintaining good indoor air quality during and immediately after construction is an important green building priority aimed at protecting the health of construction workers and building occupants alike. This unit presents the SMACNA IAQ Guidelines for Occupied Buildings Under Construction, 1995, Chapter 3, as the set of best practices for achieving good CIAQ. Considerations for CIAQ requirements on both new construction and existing building LEED projects are also covered.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• These four topics will be covered in this unit: • **Environmental health benefits.** • **Financial benefits.** • **CIAQ implementation strategies.** • **CIAQ and LEED.**	**Slide 1** **CIAQ Topics:** **SM Page 117** **Notes:**
• Anyone who has worked on a construction job site knows that the life of a construction worker is not an easy one. Aside from the challenging physical labor, construction workers are faced with all kinds of risks while on the job, some obvious and some not so obvious. • According to the Healthy Building Network, there are four types of **health hazards for construction workers.** These are **chemical, physical, biological, and ergonomic.** • **CIAQ addresses specifically the chemical risks.** Fortunately, many of these health hazards can be avoided, not only for construction workers, but for future building occupants as well by instituting CIAQ plans and best practices.	**Slide 2** **Why Is CIAQ Important?** **SM Page 117** **Notes:**

• It is not always apparent how building materials, products, and practices affect us and our health. The construction site is commonly full of materials and applications containing chemicals to which direct exposure poses potential health issues. • **Chemicals can enter the body by inhalation, ingestion, or absorption.** • That last one mentioned, absorption, is probably the least noticeable. Absorption occurs when chemical-containing materials enter into your body immediately upon skin contact, without you even realizing it. • However, there are many easy ways to avoid such health risks—from simply avoiding the use of toxic materials to taking special precautions to ensure the cleanliness and filtration of the HVAC system—that are described in this unit. *Note to Instructor:* Discussion: Ask the class to relate any incidents of chemical exposure on the job they may have experienced.	**Slide 3** **Why Is CIAQ Important?** **SM Page 117** **Notes:**
• The **primary financial benefit concerns a building's warranty.** If a new building is not to spec, if equipment is malfunctioning, or even if occupants are simply not comfortable and happy with their new space, the contractor is often responsible for addressing these issues. As you are well aware, contractor call-backs can be extremely costly. • The most efficient and financially profitable building projects for both general contractors and subcontractors are those in which a clearly planned, scheduled, and trained team is deployed to achieve project goals. CIAQ plans and practices are an example of this kind of intentional building practice that seeks to create the highest quality building for its human occupants as well as the natural environment.	**Slide 4** **Financial Benefit of CIAQ:** **SM Page 117-118** **Notes:**

• The Sheet Metal and Air Conditioning Contractors National Association **(SMACNA) provides recommended procedures to follow during construction.** These control measures are explained in detail in the IAQ Guidelines for Occupied Buildings under Construction, 1995, Chapter 3.	**Slide 5** **CIAQ Strategies:** **SM Page 118** **Notes:**
• These best practices can be categorized into the following five subjects: 1. **HVAC Protection** 2. **Source Control** 3. **Pathway Interruption** 4. **Housekeeping** 5. **Scheduling**	**Slide 6** **CIAQ Best Practices:** **SM Page 118** **Notes:**

- During the construction process air handling materials and equipment is delivered on-site. In a poorly managed jobsite some of the equipment and materials might be stored in places where they may be exposed to the outdoor elements or construction pollutants. If equipment is then installed and operated, it could compromise the building's air quality by depositing dirt, moisture, or mold into the supply air. Building occupants may suffer reactions to this poor air quality without knowing the cause, making it difficult to readily manage the problem. To avoid this from happening, equipment and materials should be **stored in a clean area** immediately following delivery.

- **Duct openings should be sealed** with plastic both during storage and after installation.

- Ideally, **permanently installed air handlers should not be used during construction** to reduce the chances of contamination. This also makes sense because many manufacturers' warranties begin when the equipment is first used. If the air handling equipment is used before the building is completed, the equipment warranty could expire before the building warranty, leaving a window of time where the contractor may be liable. Temporary heaters should be used whenever possible to avoid starting up permanent air handlers. If, however, permanently installed air handlers are used during construction, project teams should document filter changes to ensure system effectiveness before and after occupancy. Inspections by the commissioning authority or IAQ specialist may further reduce potential problems or oversights.

- When HVAC equipment needs to be operated during construction the return or negative pressure side of the system should be protected. This might apply if the building is occupied in stages as construction is progressively completed. If air returns cannot be closed, temporary filters should be placed over all grilles and openings. To comply with LEED requirements, filtration media must meet certain particle removal efficiency values discussed later in this section.

Slide 7
HVAC Protection:

Figure 15: The most visible strategy for HVAC protection.

SM Page 118-119
Notes:

• Another best practice is to **check for leaks** in all the return ducts and air handlers. • Also, **avoid using the mechanical rooms** for additional construction material storage. • Once the building if ready for occupancy, all the **filtration media should be immediately replaced.**	
• Another important strategy for maintaining good indoor air quality during construction is simply to avoid bringing materials that can negatively affect the air quality, especially finish materials, into the project at all. • The following material types have low or no toxicity alternatives: ○ **Adhesives and sealants.** ○ **Paints and coatings.** ○ **Carpets.** ○ **Composite wood products.**	**Slide 8** **Low or No Toxicity Alternatives:** **SM Page 119** **Notes:**
• Material toxicity can be measured by the amount of **Volatile Organic Compounds (VOCs)** contained in the product or material. • VOCs are chemical compounds that vaporize at room temperature and are thus readily inhaled by people. When you walk into a freshly painted room, the associated "new paint" smell is made possible by such offgassing solvents. Even that "new car smell" that some people like so much is a result of VOCs. • While some people may have a positive association with that new car or that shiny new paint job, these VOCs compromise air quality and can be **harmful to your health.** • Desired VOC performance levels or no-/low-VOC products should be included in the project specifications to help maintain good air quality in the building. In addition to VOCs, air quality on construction sites could be affected by exhaust fumes from equipment such as idling vehicles or gas powered tools. These sources should be eliminated, or at least isolated, whenever possible.	**Slide 9** **Source Control:** **SM Page 119-120** **Notes:**

• Depending on the weather conditions, the exterior environment of a building can become extremely muddy or dusty during construction. Isolating these area can help prevent dirt and other contaminants from entering the building. • By using **temporary barriers, gravel pathways, and walk off mats,** pollutants spread by everyday activity at the jobsite can be minimized. • If air handlers are used during construction and if weather conditions permit, ventilate using 100% outdoor air to exhaust all indoor air which may contain VOCs from finishes applied on site. • Another beneficial strategy is to depressurize the work area to further avoid the spread of dust and odors to adjoining spaces.	**Slide 10** **Pathway Interruption:** **SM Page 120** **Notes:**
• While the concept of housekeeping may be a simple one, maintaining a high quality of cleanliness requires regular **cooperation** from all those working on site. • First, develop a housekeeping plan that identifies responsible parties, activities, and a schedule. This will help provide guidance throughout the project. It is essential that the housekeeping plan is communicated to all contractors and subcontractors so that expectations are clear and agreed upon. • Most importantly, it is essential that a **regular cleaning schedule** is maintained to keep dirt and other contaminants under control.	**Slide 11** **Housekeeping:** **SM Page 120** **Notes:**

• The final recommended best practice for maintaining healthy indoor air quality is scheduling. During the construction process contractors must coordinate a number of activities. All of this coordination requires special attention to the project schedule. • In scheduling these activities, there is an opportunity to sequence tasks so as to **minimize the potential for air quality contamination** on the jobsite. • For example, scheduling the application of a high-VOC content coating (for example, a rust-protecting agent) for which there exists no alternative to take place during off hours or before the weekend will minimize the number of people exposed to toxins and allow time for air out prior to re-occupation of the building.	**Slide 12** **Scheduling:** **SM Page 120** **Notes:**
• In addition to the SMACNA Guidelines, LEED identifies three more CIAQ best practices: ○ **Flush-out.** ○ **Moisture damage prevention.** ○ **Filtration media.** • These strategies overlap to a large extent with the SMACNA guidelines, but are worth talking about separately.	**Slide 13** **LEED CIAQ Best Practices:** **SM Page 120-121** **Notes:**

• In addition to implementing the specific measures described above during construction, a whole building flush-out can accelerate the realization of healthy indoor air conditions. It can also earn a project a LEED point, which is discussed further in the CIAQ and LEED section. • **After all interior finishes are applied,** including any touch-up finishes which may be part of the contractor's punch list, adequate time should be scheduled to allow for a full building flush-out to ensure that any residual solvents which have evaporated into the air are exhausted before building occupancy. • A flush-out is conducted by introducing a certain volume of outside air per area of floor space after all materials are installed. LEED specifies 14,000 cubic feet of outside air per square foot at a minimum of 60°F and maximum of 60% humidity. This can be achieved using the mechanical space conditioning system, fans, or a combination of the two. • As mentioned previously, new air supply and return filters should always be installed immediately prior to occupancy.	**Slide 14** **Flush-Out:** **SM Page 121** **Notes:**

• Material types that are particularly important to protect from moisture: ○ **Drywall** (gypsum board). ○ Oriented Strand Board (**OSB).** ○ Medium Density Fiberboard **(MDF).** ○ **Plywood.** ○ **Metal ductwork.** • An important strategy for ensuring good air quality is to protect all porous building materials stored on site from moisture. All contractors have heard horror stories about the financial liability associated with mold growth in new buildings. The first way to avoid this worst case scenario is to ensure dry conditions and moisture protection for all materials delivered and stored on site from the start. A common example is gypsum board. Almost all buildings today have interior spaces finished with gypsum board. This often means that large amounts of gypsum board are delivered and stored on site. This porous material is highly susceptible to moisture. It should always be stored in the interior of the building and, if moisture is present, it should be elevated from the floor and covered with plastic if necessary. • Other materials susceptible to moisture include composite wood products such as Oriented Strand Board (OSB), Medium Density Fiberboard (MDF), and plywood. • As mentioned earlier, while metal ductwork is not a porous material, it is also important for it to be protected from moisture with the ends bagged off with plastic, and elevated from the floor if necessary.	**Slide 15** **Moisture Prevention:** **SM Page 121** **Notes:**
• One of the first things that comes to mind when thinking of improving indoor air quality is the filters inside the HVAC system. **Filters play a vital role in cleaning any potential particulates and pollutants from being dispersed throughout a building's interior.** If you think of a building like a human body, and the HVAC system like the lungs, then the filters are like the small hairs inside your nose that capture particulates so they don't end up in your lungs, which of course would not be good for your health.	**Slide 16** **Filtration Media:** **SM Page 121-122** **Notes:**

• Filter efficiency is measured by a "MERV" rating, or the Minimum Efficiency Reporting Value. • This efficiency rating is based on two qualities of the filtration media; the ability to capture particulates from the air moving through it and it's resistance to air flow. • **The higher the MERV rating, the higher efficiency of particulate removal and resistance to airflow.** • Therefore, the MERV rating of filters must be compatible with the air handler's ability to move air with a high enough static pressure to be forced through the filter.	**Slide 17** **Filtration Details:** **SM Page 122** **Notes:**
• CIAQ is **addressed in the Indoor Environmental Quality category of the LEED rating systems.** • Here are some important things to note about how LEED treats IAQ: ○ All LEED-NC projects must meet ASHRAE Standard 62.1. ○ Credits awarded for creating and implementing a CIAQ Plan in both LEED-NC & EB:O&M. ○ In LEED-NC, credits awarded for ensuring adequate IAQ pre-occupancy: ○ Building flush-out. ○ IAQ testing.	**Slide 18** **CIAQ & LEED:** **SM Page 122** **Notes:**

• The **LEED-NC credits related to IAQ** are: ○ IEQ prerequisite 1: Minimum Indoor Air Quality Performance (required). ○ IEQ credit 3.1: Construction IAQ Management Plan—During Construction (1 point). ○ IEQ credit 3.2: Construction IAQ Management Plan—Before Occupancy (1 point). ○ IEQ credit 4.1: Low-Emitting Materials—Adhesives and Sealants (1 point). ○ IEQ credit 4.2: Low-Emitting Materials—Paints and Coatings (1 point). ○ IEQ credit 4.3: Low-Emitting Materials—Flooring Systems (1 point). ○ IEQ credit 4.4: Low-Emitting Materials—Composite Wood and Agrifiber Products (1 point).	**Slide 19** **CIAQ & LEED-NC:** **SM Page 122** **Notes:**
• IEQp1 requires that all projects **provide sufficient ventilation rates to support healthy indoor air conditions during occupancy.** Specifically, it requires that all projects meet ASHRAE standard 62.1, and that the mechanical engineer confirm that the ventilation design meets this standard at a minimum.	**Slide 20** **CIAQ & LEED-NC, IEQp1:** **SM Page 122** **Notes:**

• LEED-NC also contains **optional credits that specifically address CIAQ during construction and prior to occupancy.** ○ IEQ credit 3.1: Construction IAQ Management Plan—During Construction (1 point). ○ CIAQ plan that meets or exceeds SMACNA Guidelines. ○ MERV 8+ filters. ○ IEQ credit 3.2: Construction IAQ Management Plan—Before Occupancy (1 point). ○ Flush-out or IAQ testing. • In order to earn one point under IEQc3.1, teams must develop a CIAQ plan that meets or exceeds the recommended control measures of the SMACNA Indoor Air Quality Guidelines for Occupied Buildings under Construction, 2nd Edition 2007, ANSI/SMACNA 008-2008 (Chapter 3), during construction (described above). This plan must also ensure protection of absorptive materials and use filters with a MERV rating of at least 8 on all return grilles. • To earn an additional point under IEQc3.2, prior to occupancy the project must either conduct a flush-out as described earlier in this unit or it must engage a third-party industrial hygienist to conduct IAQ baseline testing that measures concentration levels of specific contaminants. If the latter option is chosen and contaminant levels exceed those allowed by LEED, the project must introduce corrective measures, re-test, and meet the requirements prior to occupancy. A baseline IAQ test double checks the effectiveness of the strategies implemented in accordance with the CIAQ plan, and sets a standard against which future test results can be compared. This test must follow the protocols described in the USEPA's Compendium of Methods for the Determination of Air Pollutants in Indoor Air, specifically to determine levels of the following pollutants: formaldehyde, particulates, volatile organic compounds (VOCs), 4-phenylcyclohexene (4-PCH), and carbon monoxide.	**Slide 21** **CIAQ & LEED-NC, Optional Credits:** **SM Page 122-123** **Notes:**

• IEQ credits 4.1-4.4 reward the **Source Control strategy** by offering up to four points to projects that prioritize the use of low-emitting materials in these categories: adhesives and sealants, paints and coatings, flooring systems, and composite wood and agrifiber products. • Specifically, these credits require that all products in these categories comply with VOC standards established by a variety of agencies. Sheet metal tradespeople working on LEED projects might encounter these requirements, especially as they pertain to adhesives and sealants, and paints and coatings.	**Slide 22** **CIAQ & LEED-NC, Optional Credits:** **SM Page 123** **Notes:**
• The LEED-EB:O&M credit that directly relates to CIAQ is: IEQ credit 1.5: IAQ Best Management Practices—Facility Alterations and Additions (1 point). ○ **IAQ Management Plan that meets or exceeds SMACNA Guidelines.** ○ **Post-construction flush-out for tenant improvements.** ○ **MERV 8+ filters.** • LEED-EB:O&M promotes good CIAQ practices through IEQc1.5, which requires the development and implementation of an IAQ Management Plan for construction activities associated with facility alterations and additions that meets or exceeds the recommended Control Measures of the SMACNA IAQ Guidelines for Occupied Buildings under Construction, 2nd Edition 2007, ANSI/SMACNA 008-2008 (Chapter 3), during construction. For all tenant improvements, it requires implementation of an IAQ plan that includes post-construction flush-out, ensures protection for absorptive materials stored on site, specifies filters with a rating of at least MERV 8 on return grilles, and ensures that HVAC and lighting systems are returned to the intended sequence of operations once construction is complete.	**Slide 23** **CIAQ & LEED-EB:O&M:** **SM Page 123-124** **Notes:**

• In addition to these measures, LEED-EB:O&M also contains several credits that **promote healthy indoor air quality during the occupancy phase of the project.** • IEQp1 requires that projects meet ASHRAE Standard 62.1; IEQc1.3 offers one point for exceeding those requirements by at least 30%. • IEQp2 requires that smoking be either prohibited on site, or limited to restricted areas. • Under IEQc1.1, projects can earn one point for developing and implementing an IAQ management program based on the EPA Indoor Air Quality Building Education and Assessment Model (I-BEAM). • IEQc1.2 offers one point for installing permanent, continuous monitoring systems that provide feedback on ventilation system performance, such as outdoor airflow measurement devices or CO_2 monitors. • Finally, projects can earn one point under IEQc1.4 for installing filtration media with a MERV rating of at least 13 for all outside air intakes and inside air recirculation returns in the building.	**Slide 24** **CIAQ & LEED-EB:O&M:** **SM Page 124** **Notes:**

Unit 4 Summary:

In Unit 4, the students have learned:

- Construction activities generate air contaminants that can compromise air quality during the construction and occupancy of a building.
- A CIAQ management plan identifies strategies, responsibilities, and a schedule by which to reduce air quality pollution potential.
- The SMACNA Chapter 3 Guidelines provide guidance on CIAQ best practices in the areas of HVAC protection, source control, pathway interruption, housekeeping, and scheduling.
- LEED addresses CIAQ for new construction and existing building projects through similar requirements that are based on the SMACNA Guidelines.

Application:

To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 1: Principles of Energy Conservation in High Performance Buildings

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Understand the principles of energy conservation in high performance buildings.*
- *Be familiar with energy efficiency issues and techniques for all types of mechanical systems.*
- *Be familiar with concepts and technologies for building-scale renewable energy generation.*
- *Understand how LEED measures and rewards building energy performance.*

Time Required: Approximately 1 hour

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
- ☑ **Green LEED CD-ROM, Computer, and Projector**
- ☑ **Pencils**
- ☑ **Paper**
- ☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 127-133

Introduction:
This unit emphasizes once again the importance of optimizing the operating energy performance of buildings, making the distinction between "design energy use" and "actual energy use." Four benchmarks that relate to energy performance are described. Energy use in buildings is beginning to be regulated at the state and federal levels. Building owners are motivated to improve the energy performance of their buildings in anticipation of these requirements. A conceptual hierarchy is presented for any comprehensive energy conservation program: 1. Load reduction; 2. Energy efficiency; 3. Onsite renewable energy generation.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• Energy conservation is the **single biggest concern in both new and existing green buildings.** • Represents the **biggest opportunity for the HVAC industry** to take advantage of opportunities in the green building market.	**Slide 1** **Energy Conservation:** **SM Page 127** **Notes:**
• Module 3 is an in-depth review of the hierarchy of priorities in minimizing (and eventually eliminating) non-renewable energy use in buildings. These priorities are: • **1.Energy load reduction.** • **2.Energy efficiency.** • **3.Renewable energy production.** • In other words, reduce the amount of energy that the building needs in the first place, be as efficient as possible in operating the energy-consuming systems in the building, and then produce energy from renewable sources to supplement or eliminate the non-renewable energy demanded by the building. • Sheet metal industry professionals have a significant role to play at each of these steps in the energy optimization process, particularly in terms of energy efficiency.	**Slide 2** **Hierarchy of Priorities:** **SM Page 127** **Notes:**

• As you will recall from Module 1, a building uses a great deal of energy throughout its life cycle, creating a multitude of environmental impacts and long-term financial liability. • While it is important to apply green building practices to design and construction efforts, a much greater **opportunity to save energy exists during the operations phase.** • By optimizing the operating energy performance of a building, project teams can significantly reduce the size of the building's carbon footprint as well as its energy costs. • This fact has created a **large demand for HVAC professionals who can assess and improve building energy performance,** and in doing so, contribute to achieving LEED certification.	**Slide 3** **Energy Conservation:** **Figure 1: Sun shades may optimize a building's energy efficiency performance.** **SM Page 127** **Notes:**
• Energy use is often discussed in terms of either design or actual energy use. • **Design energy** is the quantity of energy that a building is anticipated to consume based on its design, engineering, systems, and building program. This estimate is typically made through a computerized simulation model of the building's operation over the course of a year, or an itemized summation of energy efficiency measures that are assumed to reduce energy consumption compared with a standard code building. • **Actual energy** is true to its name and represents the real energy performance of an occupied, operating building. This can be measured by simply reviewing energy bills for whole building performance or system-level meters to gain a more refined understanding of building energy consumption.	**Slide 4** **Energy Conservation:** **SM Page 127** **Notes:**

• Building energy performance can be expressed in both **absolute and relative** terms. In other words, it can be measured in isolation or compared to similar buildings. • However a building's energy performance is quantified, it is important to understand that the purpose of all of these metrics is to measure and manage energy use. • If you can measure something, you can create performance baselines with which to compare anticipated performance resulting from energy upgrades. This helps prioritize energy upgrade investments by understanding the respective impacts of multiple individual improvements on total building performance.	**Slide 5** **Energy Conservation:** **SM Page 128** **Notes:**

• Absolute building energy performance can be expressed in terms of annual energy use (typically expressed in kBtu) per square foot of building area. • This metric is called the energy use index or energy use intensity, referred to interchangeably as EUI. • **EUI = kBtu/ft^2-yr** • EUI is typically calculated to **create a benchmark of current building energy performance,** and helps the owner and team to set goals for incremental improvement over time. As a sheet metal worker, you may be involved in a building energy audit and/or HVAC-related improvements that are aimed at decreasing the building's EUI. Note that total annual renewable energy that is generated on-site is often subtracted from total building energy use and, consequently, decreases a building's EUI. • A study by the New Buildings Institute compared the EUIs of LEED buildings to that of "typical" buildings in the US Energy Efficiency Administration's Commercial Buildings Energy Consumption Survey (CBECS, pronounced "c-becks") database. The median EUI for LEED buildings was 69 kBtu/ft^2-year, 24% lower than the median EUI for all buildings in the CBECS database (91 kBtu/ft^2-year). An aggressive target for a high performance building might be 25 kBtu/ ft^2-year. Of course the ultimate goal is to create zero net-energy buildings that have an EUI of 0.	**Slide 6** **Energy Use Index (EUI):** **SM Page 129** **Notes:**

• When calculating EUI, you have to **include both natural gas and electricity-based energy use.** In this case, you will have to **convert both therms (natural gas) and kWh (electricity) to a common metric,** Btu (or kBtu, which of course means 1000 Btu). • Conversions: • Natural Gas: 1 therm = 100.043 kBtu • Electricity: 1 kWh = 3.414 kBtu • Example: A 100,000 ft^2 assembly building uses natural gas for heating, and electricity for all other energy loads. A review of the year's monthly natural gas and electric bills shows that the building used 2,500 therms of natural gas for heating and 1,500,000 kWh of electricity for all other energy end uses. We need to put these both in terms of kBtu to determine the EUI. • Natural Gas: Multiply 2,500 therms by 100.043 kBtu/therm = 2,501,075 kBtu • Electricity: Multiply 1,500,000 kWh by 3.414 kBtu/kWh = 5,121,645 kBtu • Total Annual kBtu: Add 2,501,075 kBtu to 5,121,645 kBtu = 7,622,720 kBtu • EUI: Divide 7,622,720 kBtu by 100,000 ft^2 = **76 $kBtu/ft^2$**	**Slide 7** **Calculating Energy Use Index (EUI):** **Calulation Example** **SM Page 128** **Notes:**
• An Energy Star score (see Module 1, Unit 2) is a **relative metric** because it **compares a building's projected or actual energy performance to that of thousands of similar buildings** in the CBECS database, resulting in a rating of 1-100. • Remember that an Energy Star score of 50 represents average performance.	**Slide 8** **Energy Star:** **SM Page 129** **Notes:**

• You may also hear that a building performs "x% better than code (or other benchmark)," which means that its design energy use is x% lower than the minimum requirement. The higher the percentage, the better the building performs. • Examples of common standards against which building energy performance may be compared include: • **ASHRAE Standard 90.1**: The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) publishes standards on a variety of building performance topics. Standard 90.1, entitled Energy Standard for Buildings Except Low-Rise Residential, establishes minimum requirements for the energy-efficient design of buildings, including criteria and mandatory provisions for all major energy-consuming building systems. LEED requires that new construction projects exceed these or applicable local code requirements by a given percentage, whichever is more stringent. • **ASHRAE Standard 62.1**: ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality specifies minimum ventilation rates and IAQ levels so as to reduce potential for ill effects on human health. While it does not deal directly with energy use, ventilation rates do have large implications for heating and cooling loads. The more outside air that is introduced into the building, the more energy has to potentially be expended to convey and condition that air. If fresh air is warmer and/or more humid than acceptable inside conditions, cooling loads are increased. If fresh air is colder than acceptable inside conditions, heating loads are increased. • **California Title 24**: The Title 24 Energy Efficiency Standards for Residential and Nonresidential Buildings were established in 1978 in response to a legislative mandate to reduce California's energy consumption and have been updated several times since. The USGBC considers the 2005 edition of Title 24 to be equivalent to ASHRAE 90.1-2004. The 2007 version of ASHRAE 90.1 does not increase efficiency standards set in 2004; it incorporates the errata and addenda of the previous version and clarifies protocol.	**Slide 9** **Performance Compared to Code:** **SM Page 129-130** **Notes:**

• Therefore Title 24 (2005) is roughly equivalent to ASHRAE 90.1-2007 as well. A 2008 edition of Title 24 went into effect in January 2010. Overall, this update requires approximately 15% greater energy efficiency than the previous standard.	
• In addition to the financial motivation to improve the energy performance of buildings, owners must also respond to governmental regulation. In Module 1 we discussed how government regulation is a strong driving force in the green building market in general. **Laws at the local, state, and federal levels are also more specifically requiring or encouraging building projects to be more energy efficient.** • California, which often leads the US when it comes to environmental standards, has passed stringent legislation that requires owners to report the annual energy use of their buildings. San Francisco now requires businesses to monitor, report, and pay tax on their carbon emissions. The California Energy Commission is moving toward adding net-zero energy performance requirements in Title 24 by 2020 . • Furthermore, the Environmental Protection Agency recently proposed the first national reporting system for major emitters of greenhouse gases under a new rule of the Clean Air Act. Under the proposed requirements, major emitters must report annual greenhouse gas emissions starting in 2011. This rule would provide the federal government national-scale data on greenhouse gas emissions that could be used to develop corresponding regulatory controls, programs, and incentives to reduce greenhouse gas emissions from major sources. Similar reporting requirements are already in place for certain operators, retail providers, and marketers of electricity in the State of California under Assembly Bill 32. If this rule evolves in similar fashion to stormwater regulation under the Clean Water Act, smaller emitters such as building owners and developers may be subject to reporting requirements in the near future. With such a reporting system in place, the way would be cleared for establishing limits on greenhouse gas emissions.	**Slide 10** **Government Regulations:** **SM Page 130-131** **Notes:**

• Proposed federal legislation would establish a "cap and trade" regulatory framework for CO_2 emissions. The Federal American Clean Energy Security Act would require companies to either reduce their greenhouse gas emissions (including that generated by buildings) or buy carbon credits on the open market.	
• Savvy building owners are preparing themselves for these regulations to take effect by improving their buildings now. • But in order to take advantage of short-term incentives and realize long term savings for various energy efficiency measures, **building owners need the help of professionals** that can measure and report performance, meaningfully participate in evaluation of the best energy efficiency opportunities, and effectively implement energy efficiency measures. That's where you come in.	**Slide 11** **Impacts of Regulation:** **SM Page 131** **Notes:**

• A lot goes into optimizing the energy performance of a building, but a successful green process will always follow this hierarchy of three fundamental steps: • **1.Load reduction:** The crucial first step in creating a high performance building is to minimize the amount of energy needed to provide a comfortable, healthy, and productive indoor environment. This is accomplished primarily through building orientation, architectural design strategies, and is also influenced by occupant behavior. Unit 2 provides an overview of load reduction principles. • **2.Energy efficiency**: Once a building's energy requirements have been defined, project teams can go about ensuring that energy-consuming systems are as efficient as possible. In terms of high performance HVAC systems, this means selecting the right system size for the required load, making sure that it is installed and operates correctly, and taking advantage of synergistic opportunities among systems. These issues are covered in depth in Unit 3. The importance of monitoring and managing ongoing building performance in order to ensure continued operating efficiency cannot be overstated. These practices were covered generally in Module 2, Unit 2. • **3.On-site renewable energy generation**: Finally, after loads have been reduced and energy demands can be met efficiently, it is time to consider on-site renewable energy generation. Buildings can further reduce their reliance on non-renewable energy generated off-site by incorporating on-site renewable energy technologies—such as solar and wind—to offset some or all of their energy use. Unit 5 describes the application of these technologies.	**Slide 12** **Priorities for Building Energy Optimization:** **SM Page 131-132** **Notes:**

Unit 1 Summary:
In Unit 1, the students have learned:

- EUI (typically expressed in kBtu/ft^2-yr) is a measure of absolute energy performance.
- Building energy measurement can be used to compare the performance of one building to that of other comparable buildings.
- Green building regulation is strongly focused on energy performance to address climate destabilization and the potential financial benefits of energy use reduction and efficiency.
- The hierarchy of building energy optimization is (1) energy load reduction, (2) energy efficiency, and (3) renewable energy production.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 2: Load Reduction

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Be familiar with the "whole building approach" to building energy demand reduction.*
- *Understand how buildings can make use of "free energy" through passive design strategies.*
- *Be aware of mechanical systems that can help influence occupant behavior and energy consumption.*

Time Required: Approximately 1 hour

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 135-146

Introduction:
This unit covers the first step in a comprehensive energy conservation program: load reduction. Ways of reducing a building's demand for energy (often expressed in terms of heating, cooling, lighting, or other "loads") are divided into two types: architectural design strategies, and technologies to influence occupant behavior. A whole building approach allows project teams to reduce building loads from the earliest stages of design. The design categories that influence building performance most are: passive design and envelope design. Certain mechanical devices are also available to help reduce building energy loads by providing performance feedback to building users, thus encouraging them to modify their behavior.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• **An energy load is a demand for energy.** Occupants of buildings demand energy for things like heating and cooling, lighting, and other powered equipment. Thus heating, cooling, lighting, ventilation, plug, and other loads must be considered when designing a building, and sizing and selecting HVAC equipment.	**Slide 1** **Overview:** **SM Page 135** **Notes:**
• Besides climate, energy loads are influenced by a number of factors including envelope design, ratio of building envelope to floor area, and building program or use. • Because these factors have such a great impact on building energy performance, it is crucial the energy goals are well-communicated to the team members that will influence these variables at the beginning of the project. As the team optimizes building design to meet the many goals of the project, HVAC system requirements, sizing, schedules, and construction approach can change and have a corresponding impact on energy performance.	**Slide 2** **Overview:** **Figure 2: Typical load distribution for office buildings in three different climate zones.** **SM Page 135-136** **Notes:**
• Now that we have discussed energy loads in buildings, let's talk about strategies for reducing them. • There are two main categories of strategies to reduce energy loads in buildings: **architectural design** strategies and strategies that influence **occupant behavior**. First we'll talk about architectural design strategies.	**Slide 3** **Load Reduction Strategies:** **SM Page 136** **Notes:**

- As discussed earlier, green building is a comprehensive or "integrated" process requiring the expertise and cooperation of professionals and tradespeople from a variety of disciplines. In order for a green building project to be successful, all of these people have to keep the "big picture"—namely how buildings impact people and the environment—in mind while simultaneously evaluating each aspect of the building for cost, functionality, aesthetics, and efficiency. This **whole building approach treats the building as a dynamic multi-system organism** instead of a static collection of independent systems that operate in isolation of each other. By considering how building systems interact and analyzing them for synergistic opportunities, project teams can optimize performance by effectively killing two—or sometimes three or more—birds with one stone.

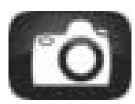
- For example, window placement to facilitate both daylighting and natural cross ventilation reduces the demand for electrical lighting and the need for mechanically-forced ventilation. In this way, the building can be thought of as a collection of interconnected flows (of energy, water, air, etc.) made possible by an assembly of purposefully-designed and installed equipment.

Slide 4
Architectural Design Strategies:

Figure 3: Opportunity for saving energy in a buildingoccurs at the beginning of the design process.

SM Page 136
Notes:

• The **greatest opportunities for saving energy in a building occur at the beginning of the design process** when fundamental issues like building location, program, massing, orientation, and envelope characteristics are resolved. • Building size is one of the earliest determinations that can cut energy loads. All other things being equal, a bigger building will always consume more energy than a smaller building; more area requires greater space conditioning and lighting. Recall that a building's Energy Utilization Index or EUI is measured on a per square foot basis. So if the design team makes smart programming choices and efficient use of space, total square footage and total energy demand can be reduced. The massing, orientation, and envelope characteristics (including glazing area and thermal resistance) of the building will determine how effectively the building can make use of free energy (i.e., solar thermal and wind energy) through passive design strategies.	**Slide 5** **Whole Building Approach:** **SM Page 136-137** **Notes:**
• Though the implementation of many of the strategies described below is the responsibility of the building design team, there are several ways that sheet metal workers may be involved. For instance, in order for daylighting strategies to be effective, light must be let into a building, and also controlled in order to minimize glare and unwanted heat gain. Therefore a daylighting design might include north-facing **skylights, sunscreens or curtain systems, louvers, or other shading devices.** • The work that sheet metal contractors do on the building envelope also contributes to long-term building performance. **Moisture control** is an essential part of ensuring the durability of the structure and the performance of its insulation system. The longer a building lasts, the less energy is required to repair, demolish, and/or rebuild it. • Careful attention to detail in envelope construction is therefore not only a matter of high quality craftsmanship, but also a green building strategy.	**Slide 6** **Sheet Metal Industry Involvement:** **SM Page 137-138** **Notes:**

• Buildings need energy, but that does not mean it has to come from non-renewable, greenhouse gas-emitting sources. The first and best way of reducing dependence on these sources of energy is to make use of the freely-available, non-polluting wind, sunlight, and thermal energy from the sun on the project site. • Passive systems: • **Use renewable on-site energy to heat, cool or light a space.** • **Do not require mechanical equipment to operate.** • Examples of passive design strategies include: Daylighting, passive heating/cooling, natural ventilation.	**Slide 7** **Passive Systems:** **SM Page 138** **Notes:**
• Elements and examples of passive design include: • Bioclimatic Analysis. • **Daylighting.** • **Passive Solar.** • **Natural Ventilation.**	**Slide 8** **Elements of Passive Design:** **SM Page 138** **Notes:**
• Bioclimatic analysis is a detailed study of: • Weather. • Climate. • Solar access. • Wind patterns. • Site conditions. • The information provided by this analysis can be used to **identify appropriate passive design strategies.**	**Slide 9** **Bioclimatic Analysis:**  **Figure 4: Bioclimatic Analysis.** **SM Page 137-138** **Notes:**

• Daylighting is a passive strategy that people use every time they do not turn on the lights in a sunny room. • Daylighting can be accomplished through top- (i.e., **skylights**) or side-lighting (i.e., **windows**), and dramatically affects the quality of light and experience within a space. • A common daylighting strategy is the use of interior or exterior s that are strategically designed to block heat-laden direct solar radiation and bounce sunlight off light colored surfaces (i.e., the ceiling) using a "light shelf" as deep as possible into the building.	**Slide 10** **Daylighting Strategies:** **Figure 5: Daylighting can be accomplished through top or side-lightening.** **SM Page 138-139** **Notes:**
• Daylighting benefits: • **Reduced electric lighting loads** (but can result in increased heating/cooling loads). • High efficiency lighting: • Task/ambient. • Efficient lamps and ballasts. • Controls and sensors. • Increasing glazing area in order to optimize daylighting and reduce electric lighting loads can result in increased heating or cooling loads, depending on building type, location, and use. • Once daylighting has been optimized for a project, high efficiency lighting strategies can be applied. These strategies include: task/ambient lighting design to minimize lighting power density, the use of efficient fluorescent lamps and high performance ballasts, and daylight dimming lighting controls and occupancy sensors.	**Slide 11** **Passive Design:** **Figure 6: Using energy that is passively collected from the sun.** **SM Page 138-139** **Notes:**

• Passive solar: • Can be used for **heating, cooling, or hot water.** • High-performance south-facing windows. • Thermal mass. • Highly-insulated building envelope. • It is possible to partially or completely heat, cool, and/or provide hot water for a building using energy that is passively collected from the sun. (This is in contrast to active solar technologies such as photovoltaic systems). • Again, the ability to utilize passive solar depends on the building type, size, and location. Elements essential to a passively heated building are: large south-facing windows with high-performance glazing, thermal mass, and a highly-insulated building envelope. • Windows must be designed to let in sunlight during the heating season, but be well-shaded during the cooling season. • Thermal mass (any material, e.g., concrete, stone, water, etc., that has a high thermal storage capacity) acts to absorb and store heat from the sun during the day, releasing it slowly back into the space during the night. • A sealed and well-insulated building envelope is important in preventing heat loss via infiltration and thermal conduction.	**Slide 12** **Passive Solar:** **SM Page 139** **Notes:**
• Natural ventilation can be an effective way to **reduce or eliminate the need for mechanical cooling** in climates with tolerable humidity in the summer. • Successful implementation of this strategy requires carefully sized and placed openings that encourage drafts and make use of prevailing wind patterns.	**Slide 13** **Natural Ventilation:** **SM Page 139** **Notes:**

• In addition to providing enclosure, structural integrity, and aesthetic character for a building, the building envelope is the **interface through which energy (in the form of heat) flows** between indoors and outdoors. • It is therefore a vital point of consideration in optimizing the energy performance. Both opaque (walls and roofs) and transparent (windows and skylights) envelope components must work together to meet human needs and minimize energy demand for space conditioning and ventilation.	**Slide 14** **Building Envelope:** **SM Page 139-141** **Notes:**
• Thermal resistance measured by **R-value.** • Thermal conductivity measured by **U-factor.** • The *thermal resistance* of an envelope component or assembly is quantified by *R-value*. Under uniform conditions, R-value is the ratio of the temperature difference across a material and the heat flux (heat flow per unit of area) through it. The larger the number, the more effective the material is as an insulator. • *U-factor* (sometimes also called U-value) is the reciprocal of R-value (U = 1/R), measuring thermal conductivity, or the rate of heat transfer through a medium or material. The smaller the U-factor of a material or assembly, the more slowly heat transfers through it and the greater its ability to temper the influence of outdoor conditions on internal conditions. • R-value and U-factor ratings are designated for all types of envelope components. Opaque components are typically measured for their R-value; transparent components are typically rated with a U-factor. When the energy performance of an assembly is assessed, it is usually done in terms of U-factor.	**Slide 15** **Envelope Design:** **Figure 7: R-values of common building materials.** **SM Page 140-141** **Notes:**

• The overall energy performance of the envelope is much more complicated than the insulating properties of any one component. • For instance, a wall with R-21 insulation might perform as well as a wall with R-38 insulation depending on the **type and density of structural members**, the extent to which the construction allows **thermal bridging** (rapid heat transfer through a building component), the **percentage of the wall that is glazed,** and how well the envelope protects against **air leaks.** • **Infiltration** is another major issue in envelope performance. Leakiness to outside air can substantially negate energy efficiency potential from insulation value. Similarly, if a building's HVAC system is unbalanced, excessive exhaust volume can create a negative pressurization that actually draws outside air into the space, increasing the energy needed to condition that air. • The overall U-factor for assemblies is calculated by adding up the U-factors of each different assembly component and then multiplying their percentage contributions to the total assembly area. Some codes now stipulate maximum assembly U-factors instead of minimum insulation R-values.	**Slide 16** **Envelope Energy Performance Depends On:** **SM Page 141** **Notes:**
• Strategies for improving envelope performance include: • Advanced **framing techniques,** such as staggered studs, to reduce thermal bridging. • Installing **rigid insulation** on the inside or outside face of walls to break thermal bridges. • Using structural insulated panels **(SIPs).** • Using **high performance insulation** such as rigid or spray foam. • **Optimizing placement, sizing, and geometry of openings** to minimize undesirable influence from outdoor conditions. • **High performance glazing.**	**Slide 17** **Strategies for Improving Envelope Performance:** **SM Page 141-142** **Notes:**

- Glazing, though wonderful in terms of passive solar design, daylighting, views, and streetscape, is a weak link in terms of envelope thermal performance. In a mechanically conditioned building, too much heat loss (in the winter) and gain (in the summer) through windows and skylights can create alternately excessive heating and cooling loads and poor thermal comfort for occupants.

- While glass elements will always have a significantly lower insulating value than other components, several **high performance glazing products are available** on the market.

- Depending on the design intent, several advanced features can be incorporated into envelope openings to improve energy performance. These include:
- Multi-pane insulated glazing with low-conductance edge spacers.
- Gas fills such as argon or krypton.
- Low-emittance (low-e) or reflective coatings.
- Low-conductance frame systems.
- Tinted glazing.
- Plastic films.
- Fritted glazing (glazing with a baked-on ceramic coating that can increase heat gain through absorption).
- “Smart windows”

- Emerging “smart window” technology allows the optical properties of glazing to change in response to fluctuations in temperature, light, or voltage conditions. Electrochromic coatings can change glass from clear to a colored transparent state without degrading views in response to low voltage input. Windows utilizing this technology have performed well in tests in terms of energy savings and occupant satisfaction.

Slide 18
Characteristics of High-Performance Glazing:

Figure 8: Sheet metal workers install skylights to decrease lighting energy loads.

SM Page 141-142
Notes:

• High performance roofing strategies that **reduce the heat island effect** (see Module 1) also **reduce building cooling loads** by lowering ambient outdoor temperatures. • Reflective roof or "cool roof" materials or coatings have been shown to provide an average yearly net savings of almost 50 cents/sf, which includes the price premium for cool roofing materials, increased heating costs in winter (when you want to absorb instead of reflect solar radiation), reduced cooling costs in summer, savings from downsizing cooling equipment, and reduced maintenance costs. • High reflectance can be described as **high albedo** (albedo is a measure of solar reflectance on a scale of 0—black—to 1—white) or having a high **solar reflectance index (SRI)** rating (measured on a scale of 0—black—to 100—white).	**Slide 19** **Reflective Roofing or "Cool Roof:"** **Figure 9: Reflective roof or "cool roof".** **SM Page 142-143** **Notes:**
• Vegetated, eco- or "green" roofs are another way to **mitigate the heat island effect and reduce building cooling loads.** • They have been shown to outperform cool roofs in this regard due to the added insulation and shading of the roofing membrane associated with soil and vegetation layers. Green roofs can have the ancillary benefits of **controlling and treating stormwater runoff,** prolonging the service life of roofing substrates, reducing sound reflection and transmission, **creating wildlife habitat, and improving the aesthetic environment.** • There are two major categories of vegetated roofs—intensive, which have soil depths of 6 inches or more, and extensive, which have soil depths less than 6 inches.	**Slide 20** **Vegetated ("Green") Roofs:** **SM Page 143** **Notes:**

Note to Instructor: **Discussion**: Engage the class in a discussion about how occupants can influence building energy loads. • Occupants can also have an effect on building loads by modifying their expectations or behavior. For instance, in Japan formal business dress codes have been loosened in order to reduce the need to cool office buildings in the summer. Or, an office designed for daylighting might require occupants to consider adjusting interior window shades prior to turning on an energy-consuming light.	**Slide 21** **Occupant Behavior:** **SM Page 143** **Notes:**
• Occupant expectations and behavior can be wildcards when it comes to reducing energy loads. No matter how well a building is designed to minimize energy loads, performance can be comprised by unanticipated occupant behaviors such as leaving computers and lights on all night or placing a refrigerator right next to the thermostat. • Occupant education is one way to encourage efficiency by helping people understand how the building is supposed to work and engaging them in energy-saving efforts. • Technologies also exist to help motivate people to improve their energy and water use patterns. These work primarily by monitoring resource consumption and providing occupants with information upon which to base future behavior. In this section we will discuss: • **Submeters.** • **Energy use interface technologies** such as Green Touchscreen and Kill A Watt. • **Building occupancy and HVAC scheduling.**	**Slide 22** **Technologies to Influence Occupant Behavior:** **SM Page 144** **Notes:**

• Building tenants are typically not motivated to manage their energy consumption unless pay their own utility bills. • Installing submeters that correlate energy and water use with each individual tenant space, or even with individual systems within the space, **allows the owner and/or tenants to track and understand building energy use** with a useful level of detail. • Sophisticated submeters can also display energy use in terms of utility costs based on local rates and project future bills based on consumption patterns. Remember: if you can't measure it, you can't manage it! • As a sheet metal worker, you may be involved in installing and/or reading HVAC submeters as part of a building energy audit.	**Slide 23** **Submeters:** **Figure 10: Submeters.** **SM Page 143-144** **Notes:**
• Two examples of currently available energy use interface technology are: **Green Touchscreen** and **Kill A Watt.**	**Slide 24** **Energy Use Interfaces:** **SM Page 144** **Notes:**

• Green Touchscreen is a web-based interactive kiosk software presents general green building information alongside live and historical building performance data to give users a multi-faceted, **"before and after" understanding of building performance.** • The system ties in to the building automation system (BAS) or individual metering devices to monitor energy and water use in real time and create a visual depiction similar to a dashboard in a car. • Used appropriately, this information can **help people understand their impact on building performance** and demonstrate the effect of behavior modifications (such as company-wide efforts to turn off computer monitors at night or the effect of setting the thermostat one degree warmer in the summer) and/or building renovations. • In buildings that incorporate photovoltaic systems or wind turbines, Green Touchscreen can also be designed to report live on-site energy generation in comparison with local weather conditions.	**Slide 25** **Green Touchscreen:** **SM Page 144-145** **Notes:**
• With the goal of managing plug loads on an even smaller scale, Kill A Watt is a product that **measures the electricity consumption of individual appliances.** • A plug load is any non-regulated energy-consuming appliance, system, or other device that requires a plug-in to access its power to operate. The appliance plugs into the palm-sized device, which then plugs directly into an outlet. Kill A Watt provides a readout of daily, weekly, monthly, or annual usage that can be used to evaluate appliance efficiency. • For instance, you can tell if a refrigerator is actually performing as rated or if another appliance is drawing electricity in standby mode. The device also checks the quality of power coming to the outlet by measuring voltage, line frequency, and power factor.	**Slide 26** **Kill A Watt:** **SM Page 145** **Notes:**

• A change in building occupancy can also have an effect on energy loads. • For example, if the use of a space changes from an office that operates only on weekdays to a round-the-clock call center, HVAC set points and scheduling must be adjusted accordingly. • It is important that these adjustments be **based on actual building use patterns rather than generalized assumptions** or outdated information in order to optimize the operation of the mechanical systems.	**Slide 27** **HVAC Scheduling:** **SM Page 145** **Notes:**

Unit 2 Summary:
In Unit 2, the students have learned:

- Whole building energy use is determined by interrelated variables such as climate, building placement and orientation, mechanical systems, and envelope.

- Passive building design strategies minimize building energy demand by taking advantage of natural assets such as solar radiation, sunlight, and prevailing winds.

- The performance of an envelope assembly is determined by the summation of the performance of each individual component multiplied by its proportion of total assembly area.

- Technologies exist to provide occupants and owners with real-time and historical energy consumption data. The intent of these technologies is to provide an accessible means to understand building or component-level energy performance, and enable occupants and operators to respond accordingly.

Application:
To achieve the learning objectives, engage the students in discussions during. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 3: Energy Efficiency: High-Performance Mechanical Systems

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Be familiar with life cycle cost analysis (LCCA) and incentives that exist to promote the use of high performance mechanical systems.*
- *Be aware of high performance solutions for heating, cooling, ventilation, and hot water equipment.*
- *Understand the installation, operation and value of power control devices.*
- *Be aware of potential economies of scale.*

Time Required: Approximately 4 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
- ☑ **Green LEED CD-ROM, Computer, and Projector**
- ☑ **Pencils**
- ☑ **Paper**
- ☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 147-173

Introduction:

Once a green building project has implemented all possible passive design opportunities and occupant behavior modifications, the next imperative is to make its use of non-renewable energy as efficient as possible. In this unit, the energy efficiency implications of a wide variety of HVAC equipment and systems are discussed. The categories of equipment covered are:

- Heating equipment.
- Cooling equipment.
- Air distribution equipment.
- Domestic water heating equipment.
- Power control devices.
- Efficiencies of scale.

The intent of this unit is to provide a sense of the benefits and challenges of this equipment in the context of a comprehensive energy conservation program. Where appropriate, installation and maintenance considerations will be covered. This is by far the longest and most technical unit in the course.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• Once a green building project has implemented all possible load reduction, passive design opportunities, and occupant behavior modifications, the next imperative is to make its use of non-renewable energy as efficient as possible. • An effective energy management program begins with a **senior-level commitment** to building performance goals. • In a new construction project, these goals should be clearly articulated in the **Owner's Project Requirements (OPR) document,** and frequently referenced throughout the design and construction process. The OPR documents the owner's requirements for building program, comfort, design, and other variables that influence building experience and performance. OPR development is typically led by the commissioning authority. The value of implementing a commissioning process to oversee the execution of strategies to meet these goals was discussed in Module 2. • In an existing building, it is also important for the building owner to set clear **performance and financial goals** so that potential improvements are vetted against them. These goals might be contained in a formal corporate **energy policy and/or an energy action plan.**	**Slide 1** **Building Performance Goals:** **SM Page 147** **Notes:**

• Once building performance goals have been set, it is up to the project team to **identify, develop, evaluate, and execute strategies and tactics** to meet them. By bringing the holistic perspective promoted by this course, your capacity to understand and contribute at each phase of this process will be greater. • In this unit we will discuss the energy efficiency implications of a wide variety of HVAC equipment and systems, some of which may be familiar and others which may not be. • An entire textbook could be written on any of these systems. The intent of this unit is to provide a sense of the benefits and challenges of this equipment in the context of a comprehensive energy conservation program. Where appropriate, installation and maintenance considerations will be covered.	**Slide 2** **Building Performance Goals:** **SM Page 147-148** **Notes:**

- Costs:
  - **First cost vs. lifecycle cost.**
  - **Life Cycle Cost Analysis (LCCA)** is useful to compare different systems.
- Values:
  - Lifecycle cost savings.
  - Energy savings.
  - Incentives.

- High performance mechanical systems are a significant capital cost in proportion to other energy-saving opportunities, particularly when only first costs are considered. However, when all the lifecycle costs of acquiring, installing, operating, maintaining, and disposing of a system are taken into account, high performance systems often provide significant net savings.
- Recall from Module 1 that Life Cycle Cost Analysis (LCCA) is the name given to this kind of economic assessment. LCCA is particularly useful when comparing different systems that fulfill the same performance requirements, but have different initial and operating costs. As individual systems and their interactions with other systems become more complex, LCCA provides a straightforward way of comparing cost effectiveness.
- The value of efficiency investments is greater when a building's design energy use has been minimized by exploiting all passive opportunities during design.
- Furthermore, the labor cost for installing high performance HVAC Equipment is not significantly higher than the labor cost for installing standard efficiency equipment.
- The application of high performance HVAC equipment alone can result in substantial life cycle cost and energy savings, in the 10-40% range. If this equipment is incorporated into a project that uses a whole building design approach and benefits from the cooperation of its occupants, savings can amount to up to 70%. A project that achieves a 30% energy cost reduction can typically expect a simple payback period of as little as three to five years. Investing in more expensive equipment that can provide a 40% energy cost reduction could result in a simple payback period of approximately seven years.

Slide 3
Costs and Values of High Performance Mechanical Systems:

Figure 11: Investing in high-performance HVAC equipment reduces energy costs.

SM Page 149
Notes:

• Government and other incentives are one of the ways that first costs can be reduced and payback periods shortened. The availability of state, local, and utility incentives varies throughout the nation, but federal incentives are available to all U.S. projects. These include tax deductions, bonus depreciation, tax credits, grants, and loans. For current information, the Database of State Incentives for Renewable Energy (DSIRE—www.dsireusa.org) maintains a comprehensive list of energy efficiency incentives.	
• This unit covers: • **Heating** equipment. • **Cooling** equipment. • **Air distribution** equipment. • **Domestic water heating** equipment. • **Power control** devices. • **Efficiencies of scale.**	**Slide 4** **High Performance HVAC Equipment:** **SM Page 149** **Notes:**
• In this section we will discuss: • **Boilers.** • **Furnaces.** • **Energy recovery systems.** • **Heat pumps** (air-source and ground-source). • **Solar thermal.** • We'll start with boilers.	**Slide 5** **High Performance HVAC Equipment:** **SM Page 149** **Notes:**
• A boiler is a pressure vessel designed to **produce heat by burning fossil fuels and transferring it to water or steam,** which is then distributed throughout a building. • Boilers are used to heat 32% of U.S. commercial buildings. • Because boilers are generally more complicated than furnaces, there are typically greater opportunities to improve efficiency.	**Slide 6** **Boilers:** **SM Page 149** **Notes:**

• Boilers **can be either condensing or non-condensing.** • Conventional noncondensing boilers are designed to operate at 140°F minimum water temperature to prevent the corrosion of cast-iron, steel or copper parts that can occur when the flue gas condenses in the boiler. • Because boilers can operate more efficiently at lower water temperatures, full condensing boilers made of corrosion-resistant materials are now available. These allow the flue gas water vapor to condense at sub-dew point temperatures when heating demand does not require hotter water. • In order to reduce potable water consumption, the heat from the water that acts as the condensing medium can be reused as domestic hot water preheat, steam condensate, or hot-water return. This water can also be used as a source of heat recovery for another part of the HVAC system.	**Slide 7** **Boilers:** **SM Page 149** **Notes:**
• **Noncondensing boilers generally operate at 75% to 86% combustion efficiency** (taking into account only flue losses). • **High performance boilers with condensing heat exchangers can have efficiencies that surpass 90%.** This number may even be improved with the use of external flue gas-to-water economizers. • Energy Star rates boilers based on their annual fuel utilization efficiency (AFUE) rather than combustion efficiency. AFUE is a more accurate measure of efficiency because it takes into account off-cycle and equipment-jacket losses in addition to flue losses). Boilers with an AFUE of 85% or higher qualify for the Energy Star label. • Due to their superior construction and sophisticated control systems, high performance condensing boilers can cost up to three times more than noncondensing boilers. Given an average life of 25 years, high-efficiency models still generally outperform conventional systems in terms of life cycle cost savings.	**Slide 8** **Boilers:** **SM Page 149-150** **Notes:**

• Grouping **several small boilers in parallel can be more economical and efficient than using a single large boiler.** • Small boilers are more efficient in general and can be less expensive to install because they may not require the use of a crane. • A group of boilers can be more flexible by providing staged heating capacity to respond to different occupancy or seasonal requirements. The redundancy of multiple boilers can also reduce system downtime. • In a building that has an aging but still serviceable boiler, a high efficiency "front-end" boiler might be installed to meet base heating loads while the older equipment is only fired up to meet peak loads.	**Slide 9** **Boilers:** **SM Page 150** **Notes:**
• The following are best practices for boiler system operations and maintenance: • **Establish a total-system water treatment program.** • In the absence of a boiler combustion monitoring system, periodically **check and calibrate** the air-fuel ratio. • In the absence of temperature/pressure reset controls, **periodically reset boiler pressure** to maintain optimum temperatures.	**Slide 10** **Best Practices for Boiler System O&M:** **SM Page 150** **Notes:**
• The following are best practices for boiler system operations and maintenance (continued): • In the absence of an automatic blowdown control system, **assess feedwater and blowdown rates** to minimize dissolved solids that can damage equipment and waste energy. • **Identify and repair steam leaks and steam traps.** • **Remove scale** from heat-exchange surfaces.	**Slide 11** **Best Practices for Boiler System O&M:** **SM Page 150** **Notes:**

• Energy efficient boiler retrofit options include: • **Insulating** hot water distribution lines. • Installing VSD controls on hot water distribution pump motors. • **Installing controls** for: • Combustion monitoring. • Temperature/pressure reset. • Supply temperature setbacks. • Automatic blowdown to remove dissolved solids.	**Slide 12** **Energy Efficient Boiler Retrofit Options:** **SM Page 150** **Notes:**
• Energy efficient boiler retrofit options include (cont'd): • Installing a **stack economizer.** • Installing **baffle inserts.** • Installing **outside air intake vents** for the boiler to reduce or eliminate infiltration caused by boiler operation.	**Slide 13** **Energy Efficient Boiler Retrofit Options:** **SM Page 150** **Notes:**
• For steam systems: • Using the **DoE Steam System Scoping Tool** (www1.eere.energy.gov/industry/bestpractices/software.html) to evaluate and improve system operation. • **Insulating steam distribution and condensate return lines.** • Installing **wide-deadband thermostats** for unbalanced single-pipe steam systems to provide longer on and off cycles, and more even heating.	**Slide 14** **Energy Efficient Boiler Retrofit Options:** **SM Page 150-151** **Notes:**
• Now let's move on to furnaces. • Furnaces are equipment fueled usually by **natural gas or oil** that provide heated air through ductwork to a conditioned space. • Approximately 30% of U.S. commercial buildings are heated this way. • Electric furnaces are generally cost-prohibitive.	**Slide 15** **Furnaces:** **SM Page 151** **Notes:**

• Furnace performance characteristics: • **Average efficiencies** of 76% for existing systems. • **High-efficiency models** up to 92% efficient. • **Energy Star** furnaces have minimum efficiency of 85%. • **Fan-assisted combustion** furnaces more efficient that standard natural-draft furnaces.	**Slide 16** **Furnace Performance Characteristics:** **Figure 12: Fan-assisted combustion furnances.** **SM Page 151** **Notes:**
• Typically furnaces are indirect-fired in that the **heat released by fuel combustion** is **transferred indirectly to the air supply via a heat exchanger.**	**Slide 17** **Indirect-Fired Furnaces:** **SM Page 151** **Notes:**
• Direct-fired furnaces **eliminate the need for (and cost of) a heat exchanger** and its associated efficiency losses by blowing the supply air directly across a gas flame. Designed to operate at a 92% AFUE, these furnaces also **provide ventilation** because they are directly connected to outside air. This type of equipment is **appropriate only for large volume spaces** where there is enough air to sufficiently dilute harmful combustion byproducts.	**Slide 18** **Direct-Fired Furnaces:** **SM Page 151** **Notes:**
• **Besides replacing an older furnace with a more efficient model, AFUE can be improved in a number of ways.** These include: • Replacing a standing pilot light with an intermittent ignition (which is required in some jurisdictions). • Preheat outside combustion air in a direct vent system with exhaust heat (see next section). • Installing automatic vent dampers to close the vent when the furnace is not in operation can improve AFUE 4-10%. • Installing controls to set back supply temperature during unoccupied hours.	**Slide 19** **Improving AFUE:** **SM Page 151-152** **Notes:**

- Now we will discuss energy recovery systems.
- **Heat that is generated by internal sources can be "recovered" and reused to save energy** (e.g., waste heat from HVAC equipment).
- This is typically **done by transferring energy from exhaust air to incoming outdoor air**, thus reducing the need to condition the incoming air. Heat-recovery technologies include: rotary heat wheels (or "enthalpy wheels"), plate-and-frame heat exchangers, runaround coils, and heat pipes.
- Depending on the equipment and application, this type of system can recover 50-80% of the energy used to heat or cool incoming outdoor air.

Slide 20
Energy Recovery Systems:

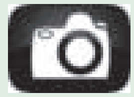


Figure 13: Rotary heat wheel.

SM Page 152
Notes:

- **A larger-scale application of the heat recovery principle** is found in combined heat and power (CHP) systems (also called cogeneration systems) that **generate electric power and then make use of the heat created by that process for HVAC purposes.**
- This heat can be used for space heating, or, with the addition of an absorption chiller, space cooling. For projects that require or benefit from distributed power generation, these systems can be an attractive option with simple paybacks of less than four years and fuel utilization efficiencies of up to 80%.
- Gas engines, microturbines, or fuel cells are used to generate electricity. Gas engines might be fed by fossil fuels or an environmentally preferable biofuel. Microturbines can be driven by water or wind. Fuel cells can be powered by hydrogen produced by electrolyzing water or through an environmentally preferable process involving the anaerobic digestion of methane gas.
- A standard heat exchanger connected to the generator can partially or entirely displace a conventional boiler or chiller.

Slide 21
Combined Heat & Power (CHP) Systems:

SM Page 152
Notes:

• Now we will discuss heat pump systems. • A heat pump **moves heat from one location to another, without directly burning fossil fuels.** • It does this by extracting heat from a source and transferring it to a sink, thereby raising the temperature of the sink. • Heat pumps can provide heating and/or cooling to a space. • We will discuss two types of heat pumps: air-source and ground-source.	**Slide 22** **Heat Pumps:** **Figure 14: Heat pump.** **SM Page 152-153** **Notes:**
• Air-source heat pumps **range in size from about 1.5 to 25 tons**, and come **packaged either complete or as split systems.** • High-efficiency equipment can have an energy efficiency ratio (EER) up to 11.5 and a coefficient of performance (COP) as high as 3.6. • Air-source heat pumps compare favorably with packaged rooftop air conditioners that incorporate electric resistance heating coils. Where gas prices are high, air-source heat pumps also outperform gas-fueled systems. • In climates where heat pump performance is compromised in the winter, supplemental heat (from either electric resistance or more efficient natural gas) may be required.	**Slide 23** **Air-Source Heat Pumps:** **SM Page 153** **Notes:**

• Ground-source heat pumps (also called geothermal heat pumps or geoexchange systems) **can provide domestic hot water in addition to heating and cooling.** • Especially appropriate for applications in buildings that require heating and cooling over extended operating hours, ground-source heat pumps are more efficient than conventional air-source heat pumps, and can reduce energy costs by as much as 50%, with EERs as high as 30 and COPs as high as 5. • Energy Star qualified equipment has an EER of at least 14.1 and a COP of at least 3.3. • An EPA study found that ground-source heat pumps generally have the lowest life cycle cost and lowest environmental impact of any heating/cooling system.	**Slide 24** **Ground-Source Heat Pumps:** **Figure 15: Today, installation of ground-source heat pumps are being installed by Sheet Metal workers.** **SM Page 153** **Notes:**
• There are three primary types of ground-source heat pumps: • **Groundwater systems** use water-to-refrigerant heat exchangers submerged in ponds, lakes, streams, or wells. • **Direct expansion systems** use a ground-to-refrigerant heat exchanger buried underground. • **Ground-coupled (or closed-loop) systems** utilize a secondary loop filled with brine that connects the ground-to-water and water-to-refrigerant heat exchangers. • All of these take advantage of the fact that subsurface soil temperatures are relatively stable year round (ranging from 45°F in northern latitudes to about 70°F in the deep south), allowing the soil to act as a heat source or sink depending on conditioning requirements and outdoor temperatures.	**Slide 25** **Ground-Source Heat Pumps:** **SM Page 153-154** **Notes:**

• **Buried or submerged coils circulate an environmentally friendly refrigerant to absorb heat from or reject heat to the ground.** The heat pump itself, ground loop pump, and distribution fan or pump are all electric. • Coils may be buried horizontally or vertically. In horizontal configurations, trenches 3-6 feet deep are required. For each ton of heating or cooling required, approximately 400-650 feet of coil is needed. To maximize coil length in available trench space, "slinky" coils are sometimes used. Where site area is limited, vertical bore installations of 150-450 feet can be appropriate. Bore spacing of 15 to 25 feet is required, depending on the water table and the cooling loads of the building. Groundwater systems can be less expensive due to the reduced cost of submerging coils in water and the fact that water conducts heat faster than soil. A sufficiently large nearby body of water with a depth of at least eight feet deep is required.	**Slide 26** **Ground-Source Heat Pumps:** **SM Page 154** **Notes:**

• Now we will discuss solar thermal systems. • The most efficient way to heat space using solar energy is through the passive strategies described in the previous unit. • **Active solar technologies include photovoltaic (PV) systems**, and solar thermal systems that use pumps to circulate water or a heat-transfer liquid through heat-absorbing solar collectors. It is not effective to use PV panels to generate electricity for space heating. • In the U.S., solar thermal systems are used **primarily for domestic hot water and swimming pool heating**. Very rarely, they can also provide space heating by using solar-heated air, liquid, or phase change medium in a radiant heating application, for boiler or furnace preheat, or in an air-heating system. Such a system generally requires a heat pump or furnace backup to provide heat when there is not enough solar radiation to meet demand (such as on cloudy days in the winter). • Also rare, solar generated heat can also be used in absorption cooling processes. • Solar thermal systems will be discussed in more detail in the Domestic Hot Water section.	**Slide 27** **Solar Thermal:** **SM Page 154** **Notes:**
• In this section we will cover: • **Chiller plants.** • **Chilled beam technology.** • **Heat pumps (air-source and ground-source).**	**Slide 28** **High Performance Cooling Equipment:** **SM Page 154-155** **Notes:**
• According to the EPA, chilled-water systems are used in **18% of all U.S. commercial buildings**, and 39% of buildings larger than 100,000 sf.	**Slide 29** **Chiller Plants:** **SM Page 155** **Notes:**
• In very basic terms, a chiller plant is comprised of two components: the **refrigeration system** and the **external heat rejection system.**	**Slide 30** **Chiller Plant Components:** **SM Page 155** **Notes:**

• **Refrigeration:** ○ Chiller. • **External heat rejection:** ○ Heat rejected directly from condenser to outside air (air-cooled or direct expansion (DX) system). ○ Heat rejected via cooling towers (water-cooled system). • Pumps move water between external heat rejecter and chiller, and between the chiller and the air-handling system. • The refrigeration component includes the chiller itself, which is where water is chilled using a refrigeration cycle. • The external heat rejection component rejects the heat from the building and returns cooled water or refrigerant back to the chiller. • In an air-cooled system, also known as a direct expansion (DX) system, heat is rejected directly from the condenser to the outside air. A window air-conditioning unit is an example of a DX system. • In a water-cooled application, one or more cooling towers use either a heat exchanger coil to reject heat to an evaporative water spray and then to the atmosphere (closed circuit), or the condensing water is distributed evenly over the surface of the tower "wet deck" where it is cooled and its heat rejected directly to the atmosphere (open circuit). • Pumps are needed to move water between the external heat rejecter and the chiller (condenser water pumps), and between the chiller and the air-handling system (chilled water pumps).	**Slide 31** **Chiller Plants:** **SM Page 155** **Notes:**

• There are four types of compression chillers: reciprocating, scroll, screw, and centrifugal. • Of these, **reciprocating** chillers are the least efficient. Reciprocating chillers are usually found in DX condenser systems or in smaller capacity (10-200 ton) chiller plants. • **Scroll** and **screw** compressors can typically meet cooling loads of up to 300 tons. • **Centrifugal** compressors have historically been used in larger capacity applications (up to 7,000 tons). New centrifugal chillers that use magnetic bearings and require no lubrication can also effectively meet demands as low as 100 tons.	**Slide 32** **Types of Compression Chillers:** **SM Page 155** **Notes:**
• Absorption chillers **use heat energy instead of mechanical compression** to produce a cooling effect. • Direct-fired absorption chillers use fuel oil or natural gas. Indirect-fired units use heat from a variety of sources including hot water or steam from a boiler, steam from district heating, or waste heat in the form of warm water, air, or other gas. • Though less common, absorption chillers are very efficient and can be cost-effective, especially in areas where peak electricity demand charges are high. The heat produced by firing can be used to provide simultaneous space heating and/or domestic hot water. This type of equipment can range in size from 3 to 2000 tons, and can be used for cooling only or as part of an integrated heating/cooling system.	**Slide 33** **Absorption Chillers:** **SM Page 155-156** **Notes:**

- Federal minimum efficiency standards do not exist for chillers, but ASHRAE standard 90.1, referenced in many local building codes, provides efficiency specifications.

- Chiller plant efficiency is **determined by a number of factors** besides just the efficiency of the chiller itself. The efficiency of pumps and fans must also be considered as well as the effect of coordinating multiple-chiller systems.

- Due to the complexity of chiller plants, it is difficult to improve efficiency without a holistic, integrated approach. Altering the design or operation of one set of components can affect the performance of other components in the system in sometimes unpredictable ways.

- In fact, such modifications can sometimes unwittingly result in a net increase in the energy consumption of the whole system.

- When considering the design of a new chilled-water system or the retrofit of an old one, it is often necessary to use energy simulation software to account for complex system interactions.

Slide 34
Chiller Plant Efficiency:

Figure 16: Sheet Metal workers ensure that chillers operate at optimal efficiencies.

SM Page 155-156
Notes:

• That being said, common opportunities for improving chilled-water system efficiency include the following: • **Replacing standard valves with low-friction valves.** This reduces flow resistance for the chilled water to reduce pump energy use and return less heat to the chiller. • **Insulating chilled-water pipes.** This helps provide cooling only where intended. • **Replacing standard-efficiency or over-sized pumps with high performance equipment** sized for newly reduced loads. Where possible, size pumps so that as much of their operating time as possible is spent in their most efficient capacity range. • Installing variable-speed drives **(VSDs).** VSDs help pumps perform at maximum efficiency at part-load conditions. A ten percent reduction in motor speed reduces energy consumption by 27%. Control systems are necessary to ensure that flow rates are maintained at safe levels.	**Slide 35** **Improving Chilled-Water System Efficiency:** **SM Page 156** **Notes:**

• Common opportunities (cont'd): • **Upgrading the chiller compressor.** In applications where VSDs are not cost-effective (such as where there are extended periods when chillers are operating with very low loads), consider installing a separate small chiller to satisfy demand under just these conditions. Upgrading reciprocating and screw chillers with new magnetic bearing technology can achieve up to a 38% improvement in integrated part-load value (IPLV). • **Using low-voltage soft starters** in the absence of VSDs. Soft starters do not save energy in and of themselves, but do reduce wear and tear on the motor, thus saving maintenance and replacement costs. • **Chiller plant replacement.** The annual energy cost of operating a chiller can be as much as one-third of its purchase price, so improvements in efficiency can result in short payback periods. This can be an especially effective option if other improvements in the building allow a new chiller to be downsized. Because chillers spend most of their operating time at 40-70% of their design load, VSD chillers with VSD pumps and fans offer the most flexibility and cost effectiveness. • **Connecting multiple cooling towers or multicell towers in parallel and using VSDs to control cooling tower fans.** This allows the chiller plant to use excess cooling tower capacity at part-load conditions and reduce fan energy use. • **Installing water-side economizers.** In cool, dry climates water-side economizers can provide more than 75% of the cooling required when outdoor temperatures are low enough. In warm climates that figure is about 20%. An indirect economizer consisting of controls and a heat exchanger installed between the cooling tower water loop and the chilled water loop is most common. When conditions permit, the economizer can bypass the chiller, transferring heat from the chilled-water circuit to the condenser-water loop to provide "free cooling".	**Slide 36** **Improving Chilled-Water System Efficiency:** **SM Page 156-157** **Notes:**

• Operations and maintenance adjustments can result in energy and cost savings of up to 30%. Best practices for the operation and maintenance of chillers include: • **Use controls to properly sequence chillers.** In multi-chiller plants, ensure that each chiller is loaded enough for efficient operation. When loads are low, shutting down one or more chillers and their accessory equipment can yield savings. • **Reset chilled-water and condenser-water temperatures** according to outdoor conditions. Adjusting chilled-water temperatures helps match chiller output to actual cooling load to prevent excessive cooling. Condenser-water temperatures that create an optimum balance between cooling tower fan power and chiller power vary with outdoor conditions. Adjusting accordingly increases efficiency. • **Make full use of cooling towers.** In multi-chiller systems that are plumbed in parallel and have variable cooling tower fan speeds, running condenser water over as many cooling towers as possible at the lowest possible fan speed can increase efficiency. • **Ensure that tubes and cooling towers are clean.** Implement an annual tube-cleaning protocol or use automatic tube-cleaning equipment to remove scale, algae, or slime from the inside of condenser tubes. These deposits can decrease efficiency and reduce the capacity of the chiller: for each 1°F increase in condenser tube temperature due to deposits, chiller power efficiency and capacity are reduced by 1%. Scaling, corrosion, and biological growth also negatively affect cooling tower efficiency. Chemical and environmentally preferable non-chemical treatments (such as ozone generators, electric field systems, and ultraviolet irradiators) address these issues.	**Slide 37** **Chiller Plants, O&M Practices** **SM Page 157-158** **Notes:**

• Now let's talk about chilled beams. • A chilled beam system is a relatively recent innovation that **separates ventilation and dehumidification functions.** • For this reason, this technology is **most appropriate in climates where cooling is required but ambient humidity is tolerable**, or in applications where dehumidification can be provided separately.	**Slide 38** **Chilled Beams:** **SM Page 158** **Notes:**
• How does a chilled beam work? • **Chilled water runs through beam.** • **Rising warm air hits beam.** • **Cooled air falls back to floor.** • **Cycle repeats.**	**Slide 39** **How a Chilled Beam Works:** **SM Page 158** **Notes:**
• There are three types of chilled beams: passive, active, and integrated/multi-service. • **Passive** chilled beams require a separate air-handling system that delivers ventilation air. • Ventilation air is delivered to **active** chilled beams by a central air system via ductwork. • **Integrated/multi-service** beams incorporate additional features such as lighting, speakers, sprinkler openings, and cable pathways. This strategy minimizes the ceiling height needed to accommodate these services, thus reducing overall floor-to-floor heights. • The associated construction material and time savings can be significant. These savings, of course, contribute to cost-effectiveness. Furthermore, where height restrictions limit development density, a reduced floor-to-floor height can result in greater buildable floor area. This, in turn, can result in more efficient use of environmental resources across the board.	**Slide 40** **Types of Chilled Beams:** **SM Page 158** **Notes:**

• Though they can **cost up to 15% more** than conventional VAV systems, chilled beams **save energy by minimizing fan use and using water**, which is a more efficient cooling medium than air. • **Thermal comfort is also improved** because of a more even air-distribution pattern than conventional VAV systems.	**Slide 41** **Chilled Beams vs. Conventional VAV Systems:** **SM Page 158-159** **Notes:**
• Chilled beams must be designed to **avoid surface temperatures low enough to produce condensation.** • Properly positioning the system is also a concern. For instance, there must be enough space between the beam and the bottom of the ceiling structure to **make sure that air can flow through the system.** • Passive beams can create drafts that cause problems in work areas. • Chilled beams should also be **kept away from heat-producing equipment** that can offset the cool air from the beam.	**Slide 42** **Design Considerations:** **SM Page 159** **Notes:**
• We covered heat pumps earlier when we were talking about heating equipment. And as we discussed, they **can also serve as cooling equipment.**	**Slide 43** **Heat Pumps:** **SM Page 159** **Notes:**

• Before replacement of the heating or cooling systems in a building is considered, the efficiency of the air distribution system should be optimized. This can help maximize savings by lowering required heating or cooling capacity. • One of the primary ways of saving energy in any mechanical air distribution system is by reducing fan power. An EPA study found that fan systems are oversized in 60% of U.S. buildings, so **matching fan capacity to load requirements can yield significant savings.** • Other categories of potential improvement in air distribution system performance include: • Evaluating and adjusting ventilation rates. • Installing an improved controls system. • Taking advantage of free cooling when available. • Optimizing distribution system efficiency.	**Slide 44** **High Performance Air Distribution Equipment:** **SM Page 159** **Notes:**
• In this section we will cover: • **Constant volume (CV) systems.** • **Variable air volume (VAV) systems.** • **Hybrid ventilation.** • **Demand-controlled ventilation.**	**Slide 45** **High Performance Air Distribution Equipment:** **SM Page 159** **Notes:**

• We'll start with constant volume (CV) systems. • Constant volume (CV) systems are common in existing commercial buildings. • Their simple operation involves a **thermostat-controlled fan or fans that supply a constant volume of air to a space**; it's either all or nothing. • CV systems lack power modulation capabilities, discharge dampers, and duct terminal dampers. The system is **sized to provide cooling to the zone with the peak load.** In zones with lower cooling loads, the temperature of the air delivered to the space is usually controlled by a terminal reheat or zone reheat component. This feature uses an electric resistance element, hot water coil or other heat source to raise the temperature of the air just before it enters the room. • If you think this sounds inefficient, you're right. Many energy codes now prohibit basic CV systems. • One way of making the best out of a bad system is to disable reheat systems in summer months and adjust the supply air temperature accordingly.	**Slide 46** **Constant Volume (CV) Systems:** **SM Page 159-160** **Notes:**
• There are a few variations of the basic constant volume system. We will take a look at three of them here: • **Constant-volume, variable-temperature (CVVT) system.** • **Dual-duct systems.** • **Multi-zone systems.**	**Slide 47** **Constant Volume (CV) System Variations:** **SM Page 160** **Notes:**

• A slightly more efficient type of CV system is called a constant-volume, variable-temperature (CVVT) system. • This variation **adjusts or resets the temperature of the supply air at the source in response to changing cooling loads.** The reset can be controlled in response to outdoor conditions or the cooling needs of the warmest zone. • Warmest-zone reset is more efficient because it takes into account internal heat gain when determining cooling loads. In this case, the supply-air temperature is set just low enough to cool the zone with the highest load (i.e., the warmest zone). • If there are large load differences between zones, this can still be a very inefficient system.	**Slide 48** **Constant-Volume, Variable-Temperature (CVVT) System:** **SM Page 160** **Notes:**
• Dual-duct systems are another **antiquated strategy that mixes separate heated and cooled air supplies** to meet thermal comfort demands. • Because both heated and cooled air supplies must be maintained, the overall volume of conditioned air is much greater than the actual volume required. • Duct leakage further reduces efficiency. Leakage is typically estimated at 5% in a well-built application.	**Slide 49** **Dual-Duct System:** **SM Page 160** **Notes:**

• Multizone systems work similarly to dual duct systems, but instead of mixing air in boxes located at each individual space, they **mix air with dampers near the fans.** • In addition to the energy inefficiency associated with simultaneously heating and cooling air, damper leaks can waste energy. • Locating the mixing dampers directly downstream of the main supply fan creates pressure losses associated with the high velocity of the air as it passes through them. This requires the supply fan to compensate with even higher power to ensure that there is adequate air flow to each space downstream. • Though there is a higher capital cost associated with multizone units, these systems require less ductwork and dampering than dual-duct systems, and are easier to inspect and repair than dual-duct systems.	**Slide 50** **Multizone System:** **SM Page 160** **Notes:**
• Now we will move on to another type of air distribution equipment – a variable air volume, or VAV, system. • Variable air volume (VAV) systems **provide thermal comfort by adjusting the amount of conditioned air supplied to a space.** • This **reduces demand for fan power when variable speed drive (VSD) fans are used,** saving energy and money. (Variable speed drives, also called variable frequency drives, are discussed in the Power Controls section.) • Reheat may be required if the minimum outside airflow requirement is greater than what is required to meet the cooling load. Fan-powered terminal units can improve air distribution by establishing a base airflow to the room while allowing the central fan to throttle down at low load conditions.	**Slide 51** **Variable Air Volume (VAV) Systems:** **SM Page 160-161** **Notes:**

• **CV systems can be converted into VAV systems to reduce fan power requirements** by 40-60%. • Cost savings vary widely, but according to the EPA most retrofits cost between $1 and $4/sf. One study reported payback periods of .8 to 4.1 years with incentives. • VAV retrofit conversions that involve modifying the zone dampers might be complicated by existing conditions such as: difficult-to-access zone dampers, hard ceilings, interlocking ceiling tiles, or the presence of asbestos. • A VAV conversion can also be accomplished by installing a VSD to control the supply fan speed. Even a modest reduction in airflow can result in fan power reductions of up to 50%. Energy required for reheat is reduced along with airflow.	**Slide 52** **CV to VAV System Retrofits:** **SM Page 161** **Notes:**
• Like CV systems, VAV systems can also integrate variable temperature reset capability. The resulting variable-volume variable-temperature (VVVT) system can **maximize load responsiveness and minimize energy expended for reheat.** • Because two supply variables are now at play—temperature and air volume—calibrating and commissioning such a system is a complicated task requiring a high degree of expertise.	**Slide 53** **Variable-Volume Variable-Temperature (VVVT) System:** **SM Page 161** **Notes:**
• Regardless of their configuration, each major component of an air-handling system has its own considerations when it comes to energy efficiency. We will discuss these five component types: • **Fans** • **Filters** • **Ducts** • **Dampers** • **Controls**	**Slide 54** **Components of an Air-Handling System:** **SM Page 161** **Notes:**

- There are two main types of fans: centrifugal and axial.
- Centrifugal fans are the most common type in HVAC applications. They are **cheaper and simpler than axial fans**, but axial fans are more efficient. **Centrifugal fans consist of a motor-driven impeller (the rotating wheel), usually connected by a belt drive.**
- **In an axial fan, the impeller is mounted inside a cylindrical housing.** An external motor rotates the impeller blades, drawing air through the axis of the housing. This type of fan is most commonly used in high-pressure applications.
- Making sure that fans are not oversized (a strategy called "rightsizing") for their assigned loads is the key to their energy efficiency.
- There are three methods for determining whether or not a fan is oversized in a VAV system: measuring fan-system static pressure, measuring the current draw (amperage) of the fan motor, and checking the fan-control vanes and dampers. In a CV system, only measuring fan-system static pressure will typically work.
- Rightsizing, in combination with using high efficiency motors, energy-efficient belts, and a VSD will produce the best results in terms of energy use, thermal comfort, and equipment longevity.

Slide 55
Fans:

Figure 17: Axial fan.

SM Page 161-162
Notes:

- Filters are an important way to **improve air quality in buildings.**
- However, because filters **increase the amount of energy required** to draw air through an air handling system, they can have a significant impact on energy efficiency.
- The efficiency rating of a filter doesn't refer to energy efficiency, but rather how well the medium removes particles from the air. The pressure drop rating measures how much energy is needed to move air through the filter.
- Regular filter maintenance is essential for energy efficiency as well as occupant health and comfort. Dirty or otherwise unsuitable filters can result in pressure drops of up to .072 psi. A reasonable pressure drop for HVAC filtration media is .0036 psi—twenty times less! It may not always be possible to determine whether or not a filter needs to be cleaned or replaced simply by looking at it.
- The best way to test filtration performance is to measure the actual pressure drop across the filter bank. Pressure measurement devices can be installed in the air-handling system and connected to a building automation system (BAS) to warn facilities personnel when filter maintenance is needed.

Slide 56
Filters:

Figure 18: Filter.

SM Page 162
Notes:

- Ductwork is found in both round and rectangular shapes. While rectangular duct material used to be cheaper, and thus more common, **spiral duct material is now usually the most cost effective and efficient option.**
- Due to their shape and reduced surface area, **spiral ducts feature lower pressure drop and reduced heat gain or loss** (depending on the application).
- The quality of installation also affects duct performance. Surface roughness due to protrusions into the duct makes it harder for a fan to move air through it. Rigid fiberglass ductwork and acoustic fiber linings both negatively impact fan efficiency compared with smooth sheet metal.

Slide 57
Ducts:

Figure 19: Spiral duct.

SM Page 162-163
Notes:

• **Duct insulation improves performance** by preventing unwanted warming of cooled air and cooling of warmed air moving through the system. • **ASHRAE 90.1 specifies insulation values up to R-8 in some locations.** For this reason, some manufacturers offer ductwork products that are pre-insulated. • When using soft insulation, make sure that there is adequate vertical clearance above the ductwork to prevent compression. • Duct insulation can also reduce the transmission of noise from fans and motors into occupied spaces.	**Slide 58** **Ducts:** **Figure 20: Exterior duct insulation.** **SM Page 163** **Notes:**
• The proper operation of dampers **ensures energy efficiency as well as occupant comfort.** • Due to the potential for dampers to leak and the additional energy required to move air past them, the number of dampers in a system should be minimized. • Fan inlet or discharge dampers can be eliminated by VSD fans. • At branch take-offs, fan power can be reduced by removing dampers or using low-loss dampers, while still allowing for minor balancing adjustments. • In older buildings, dampers may become corroded or frozen in position, compromising system performance. Therefore, a regular schedule of damper inspection and maintenance is important.	**Slide 59** **Dampers:** **Figure 21: Damper.** **SM Page 163-164** **Notes:**
• Air distribution system **efficiency can be optimized using CO_2-based control systems** that monitor the amount of CO_2 in the return air and adjust the outside air damper to provide only the amount of outside air needed to meet demand. • Even when spaces are unoccupied, a minimum amount of outside air may be required to account for contaminants released by off-gassing building materials.	**Slide 60** **Controls:** **Figure 22: Controls.** **SM Page 164** **Notes:**

• Now we will move on to hybrid ventilation. • As we discussed earlier, passive systems are clearly the most energy efficient. However, passive ventilation strategies may not be able to meet all ventilation loads at all times. • A hybrid ventilation system **combines passive and mechanical techniques** to take maximum advantage of free resources and provide reliable and consistent thermal comfort and indoor air quality. • Energy and maintenance cost savings are further realized by reducing equipment size and run time.	**Slide 61** **Hybrid Ventilation:** **SM Page 164** **Notes:**
• Two types of hybrid ventilation systems are: • **Changeover (or complementary),** wherein spaces are ventilated either passively or mechanically, but not both simultaneously. • **Concurrent (or zoned),** in which both methods can operate simultaneously to meet different loads in different zones. • Buildings with atriums are particularly good candidates for hybrid ventilation because the atrium height can be used to stimulate a convective stack effect, but interior pressure differentials and varying weather conditions can create situations that require a fan to move air through the space. • Well-programmed controls are important to set changeover points, and prevent conflicts between the two ventilation strategies.	**Slide 62** **Two Types of Hybrid Ventilation Systems:** **SM Page 164-165** **Notes:**

• The last type of air distribution system that we are going to discuss is a demand controlled ventilation system or DCV. • Demand-controlled ventilation (DCV) **adjusts ventilation rates based on the number of people in a space.** • Large assembly spaces in particular benefit from this strategy because they are frequently only partially occupied. Energy savings are calculated to be as high as 60% in such spaces. • By providing the right amount of outside air for the number of people occupying the space instead of always supplying the amount of outside air required for maximum occupancy, DCV can significantly reduce impact on heating and cooling loads depending on the season and building location.	**Slide 63** **Demand-Controlled Ventilation:** **SM Page 165** **Notes:**
• DCV systems **work by integrating control sensors into existing economizers or air makeup units with modulating dampers.** The control sensors communicate either directly with the economizer or with a direct digital control (DDC) system, and can take the form of CO_2 sensors, occupancy sensors, or turnstile counters. • Depending on the size of the space, multiple sensors may be needed. Programming is a critical element of system operation.	**Slide 64** **Demand-Controlled Ventilation:** **SM Page 165** **Notes:**
• A conventional hot water system uses energy to heat water and store it in a tank for distribution to hot water taps. A high performance system can operate by: • Using **free solar energy.** • Heating water only when it is needed, or **"on-demand."** These systems are tankless. • **Sharing heat loads with the space heating system.** • **Using heat recovered from another source.**	**Slide 65** **High Performance Domestic Hot Water:** **SM Page 166** **Notes:**

• Solar hot water systems **make use of free renewable energy,** and **can provide a reliable means to heat water in residential and commercial applications.** • These systems are most cost effective in projects that have good solar access (un-shaded south-facing surfaces on which to mount collectors), where water heating load is fairly constant throughout the week and year, and/or where the replacement of an electric hot water system is being considered.	**Slide 66** **Solar Hot Water:** **SM Page 166** **Notes:**
• System types range from low-**temperature applications**, such as swimming pool heating, to **medium-temperature applications**, such as domestic water heating or space heating, and **high-temperature applications**, such as absorption cooling or steam production for power generation. • The higher the delivery temperature, the less efficient the system and the more collector area required to meet demand.	**Slide 67** **Solar Hot Water System Types:** **SM Page 166** **Notes:**
• All of these systems operate in the same basic way: **sunlight strikes the heat-absorbent surface** of a solar collector, which in turn either **directly heats the water or heats it indirectly** via a heat-transfer fluid. The **heated water is then stored in a tank.**	**Slide 68** **How a Solar Hot Water System Works:** **SM Page 166** **Notes:**

• In a direct system, the water used by building occupants is heated directly by the sun. • In locations that are subject to extended periods of below-freezing conditions, an indirect approach can be used in which an antifreeze solution is pumped through the solar collector and then through a heat-transfer unit where it warms water on its way to the storage tank. • **Active systems move fluid through the piping with electric pumps.** • **In passive "thermosiphon" systems, natural convection pushes warmed water through the pipes.** This requires the collector to be located lower than the storage tank.	**Slide 69** **Solar Hot Water System:** **SM Page 166** **Notes:**
• For small-scale domestic water heating, flat plate collectors are the preferred type. They can deliver water temperatures of 80-160°F; even under overcast conditions they can deliver 80°F water. • Flat plate collectors consist of a **hydronic coil-covered absorber housed in an insulated box with a glass cover that traps solar radiation as heat.** Heat is removed by the water or heat-transfer fluid running through the coils. • The efficiency of such a collector depends on the absorption properties of the absorber, the effectiveness of the insulation, and the performance of the glass cover.	**Slide 70** **Solar Hot Water System:** **SM Page 166** **Notes:**
• **Industrial or commercial water heating might call for evacuated tube or concentrating collectors.** • Evacuated tube collectors consist of a series of small-diameter copper tubing encased in a clear, cylindrical evacuated tube. • Concentrating collectors use parabolic reflectors to focus solar radiation onto a centrally located absorber. Because they only collect direct sunlight, they must rotate on one or two axes in order to track the position of the sun.	**Slide 71** **Solar Hot Water System:** **SM Page 166-167** **Notes:**

• In addition to a solar collector, **all solar hot water systems require thermal storage, system controls, and a backup system.** • Thermal storage can be in the form of either potable or non-potable water, depending on the application. Generally, one to two gallons of storage per square foot of collector area is needed. • In an active system, controls are needed to tell the pump when to move fluid between the collector and the storage tank. These simple controls can be kept separate from a whole-building control system, but it is a good idea to include an indication of system performance such as Btu output or tank temperature in the building automation system. Solar hot water systems are typically designed to meet 40-70% of water heating demand. • A backup heater is required to provide additional heating when loads can't be met by solar energy alone.	**Slide 72** **Solar Hot Water System:** **SM Page 167** **Notes:**
• Now we'll talk about tankless hot water systems. • Tankless or "on-demand" water heaters **heat water directly when it is needed.** This **avoids standby losses associated with conventional storage tank systems.** • Cold water passes through either a gas burner or an electric element on its way to the tap. Gas heaters are significantly more efficient. • Tankless water heaters come in a range of sizes from single tap applications to commercial central hot water systems. This equipment can be effective either in a standalone system or as backup to a solar thermal or energy recovery system.	**Slide 73** **Tankless Hot Water Systems:** **SM Page 168** **Notes:**

• The next topic is shared hot water. • **In buildings that already use hot water to provide space heating, adding domestic water heating to the same system can be relatively efficient and cost-effective.** • By simply replacing the typical boiler/water heater combo with a larger water heater designed to meet both loads, space and equipment costs can be saved. • Codes may stipulate maximum water temperatures (usually 160°F) or require that heating system water remain potable.	**Slide 74** **Shared Hot Water:** **SM Page 168** **Notes:**
• The last type of high performance domestic hot water heater we will talk about today is one that involves energy recovery. • Air-water heat pumps remove heat from the air. They can be installed in such a way as to **capture waste heat from HVAC equipment or other internal sources** (such as kitchens or machine rooms), which can then be used to fully or partially meet hot-water loads. • Another benefit is that the spaces that contain them will be cooled and dehumidified. To be able to consistently meet hot water demand, it is best to pair such a heat pump with a reliable source of waste heat. Therefore any application that has constant refrigeration loads (either for cooling or food refrigeration) presents a good opportunity for waste heat recovery.	**Slide 75** **Energy Recovery Systems:** **SM Page 168** **Notes:**
• **Water-to-water heat pumps can also perform the same function given a free source of reasonably high temperature water**. Where graywater is collected for reuse on site (such as for irrigation purposes), a heat pump can preheat potable water for domestic uses as it lowers the graywater temperature. • Ground-source heat pumps (as discussed under High Performance Heating Equipment) that use water as the heat transfer medium can act the same way.	**Slide 76** **Energy Recovery Systems:** **SM Page 168** **Notes:**

• If you are wondering whether or not energy recovery is an appropriate strategy for a project, **remember this equation:** ENERGY RECOVERY SYSTEM + RELIABLE SOURCE OF WASTE HEAT (e.g., CONSTANT REFRIGERATION LOAD OR GRAYWATER) = APPROPRIATE APPLICATION	**Slide 77** **Energy Recovery Systems:** **SM Page 168** **Notes:**
• To summarize, potential sources of waste heat include: • **HVAC equipment.** • **Kitchens or machine rooms.** • **Refrigeration rooms.** • **Graywater.** • **Ground water.**	**Slide 78** **Potential Sources of Waste Heat:** **SM Page 168** **Notes:**
• Power control devices can further improve building performance. We will discuss three types here: • Direct digital controls **(DDC)** & Building Automation Systems **(BAS)** • **Variable Speed Drives** • **Premium Efficiency Motors**	**Slide 79** **Power Control Devices:** **SM Page 168** **Notes:**

• First we'll talk about Direct digital controls (DDC) & Building Automation Systems (BAS). • As buildings and their HVAC systems become more complex and their efficient operation more important, optimal performance depends more and more on a sophisticated control system. • Direct digital controls (DDC) **use sensors to direct HVAC devices** (such as valves, fans, switches, etc.) via microprocessors using software to execute the control logic. • Sensor devices can measure almost any change in condition. Sensor types include thermostats, occupancy sensors, carbon monoxide/dioxide meters, air quality sensors, daylight sensors, pressure sensors, humidity sensors, and moisture sensors. • Within a single building, multiple systems (individual HVAC systems, life safety, water, lighting, security, etc.) might have DDCs.	**Slide 80** **Direct Digital Controls (DDC):** **SM Page 168-169** **Notes:**
• The **software that coordinates all these controls and allows operators to graphically monitor and manage building performance** is called the building automation system (BAS). • In modern buildings, all the features of the indoor environment (temperature, humidity, lighting, ventilation, etc.) are managed by these computerized systems. • Since all of these qualities depend on energy, the BAS is essential in achieving optimized energy performance. • Despite this fact, only about 10% of commercial buildings have such a system. However, as green building practices become more common, this number will likely increase. • Through scheduling, unloading, and fault detection, studies have shown that in typical commercial buildings, BASs alone can reduce energy by up to 20%.	**Slide 81** **Building Automation Systems (BAS):** **SM Page 169** **Notes:**

• BASs can also reduce water use by operating landscape irrigation systems based on information from moisture sensors and detecting system leaks. • Besides improving system efficiency, the BAS can also **monitor resource use, predict utility charges, and track building performance** over extended periods. • Thermal comfort and IAQ are improved by a BAS that carefully calibrates equipment to produce perfectly conditioned air and proper ventilation rates. • Lighting controls can use information gathered by photocell sensors to maintain optimal light levels either by modulating electric light output (using dimmable ballasts or tiered switches), or controlling daylight penetration with shades or louvers. • In buildings that give occupants control over their environment in the form of room thermostats, operable windows, dimming switches, and adjustable blinds, the operating characteristics of these features can be integrated into the BAS to further enhance indoor environmental quality and energy performance.	**Slide 82** **Building Automation Systems (BAS):** **SM Page 169** **Notes:**

• Of all building systems, **controls are most susceptible to installation errors.** • For this reason, **a thorough commissioning process is critical** to ensure that the benefits of a BAS are realized. It is the job of the commissioning authority to verify the credibility of the control system design. This usually takes the form of evaluating one-line flow diagrams and detailed sequences of operation for each major controlled system provided by the design team. • For performance verification and ongoing operability, it is important that the following items be present for each system: systems narrative, alarms, start triggers, staging, failure and standby functions, power outage response and reset requirements, interfaces to other systems, and energy efficiency strategies with set points given. • The controls contractor should provide calculations and rationale for the number and layout of the controllers in relation to the total number of points. • Control strategies rely on information gathered from sensors throughout the building. Because sensors can “drift” or become uncalibrated, they must be tested on a regular schedule to ensure their effectiveness.	**Slide 83** **Building Automation Systems (BAS):** **SM Page 169-170** **Notes:**

- Now we will look at variable speed drives, another important control that can cost-effectively save energy in certain applications.

- A variable-speed drive (VSD), also known as a variable-frequency drive (VFD), is an electronic device that allows motor speed to vary by adjusting the frequency of the electrical power between 0 and 60 Hertz.

- Whereas a basic fan operates only in the on or off position, a VSD **allows the fan to spin only as fast as it needs to in order to meet load requirements.**

- Because fan power draw is proportional to the cube of its speed, reducing fan speed can save a lot of energy. Operating a fan at 80% of its maximum speed reduces energy use by almost 50%.

- VSDs make the most economic sense when installed on motors that operate many hours per day and accommodate fluctuating loads.

- The price per horsepower on a VSD declines steeply as power capacity increases.

Slide 84
Variable-Speed Drives:

Figure 23: Because fan power draw is proportional to the cube of its speed, reducing fan speed can save a lot of energy.

SM Page 167-170
Notes:

- The last type of power control devices that we cover are premium efficiency motors. These are not exactly controls but we cover them here.
- Minimum HVAC motor efficiency has been federally regulated since 1997. Older HVAC systems are likely to have inefficient motors.
- Even new or recently installed systems can be made more efficient with the use of motors that perform to the National Electrical Manufacturers Association's (NEMA) Premium specification. NEMA Premium motors **exceed standard-efficiency motors by about 1-3%.** While this does not sound like much, since HVAC motors have very long running hours, savings can add up quickly.
- Some premium-efficiency motors operate at high speeds. As we discussed earlier, since fan speed has an exponential relationship to energy consumption, it is important to fully evaluate potential savings of premium-efficiency motors in systems that do not employ VSDs.
- Voltage balance is also an essential consideration when it comes to motor efficiency. Three-phase induction motors are designed assuming that exactly the same voltage will be fed to each phase. When this does not occur, increased heat generated in the motor severely impairs performance, energy efficiency, and longevity.
- Finally, the proper alignment of motor and fan shafts should be checked in new and retrofit situations to ensure efficiency.

Slide 85
Premium Efficiency Motors:

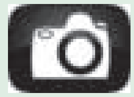


Figure 24: Premium motor.

SM Page 170
Notes:

• District heating and cooling (DHC) systems **save energy by using one central plant to provide space heating, cooling, water heating, and/or process heating to several buildings** in a campus, complex, or neighborhood. • These systems encourage the use of waste heat to drive different HVAC processes at a large scale. • In Europe, entire neighborhoods are heated using energy recovered from electricity generators (see the section on cogeneration under High Performance Heating). This strategy is also employed in the central districts of many U.S. cities (such as New York, San Francisco, Seattle, Minneapolis, Pittsburgh, and San Diego), on U.S. Air Force bases and airports, and on hospital and college campuses. There are over 30,000 district heating systems in the U.S. alone.	**Slide 86** **District Heating and Cooling (DHC) Systems:** **SM Page 171** **Notes:**
• The three basic components of a DHC system are: • **Central plant.** Any type of thermal energy from a boiler, incinerator, geothermal source, solar energy, or waste heat from sewage or another process can be used. Chilled water for cooling can be produced by an absorption refrigeration process, compression chillers, or a combination of both. • **Distribution network.** The piping from the central plant to each serviced building is the most expensive part of the system. In order to reduce distribution energy losses, pipes should be well insulated either before installation or in the field. The density of loads and the efficiency of the pipe system design are critical in establishing the overall performance of the DHC system. • **Consumer system.** This includes the in-building equipment needed to extract and deliver the energy from the thermal distribution medium (steam, high-temperature water, or chilled water) to the building occupants. • District systems that use steam distribution have been in operation for more than a century. Newer designs employ high-temperature high-pressure water or chilled water for distribution.	**Slide 87** **DHC System Components:** **SM Page 171** **Notes:**

• By locating all heating and cooling equipment except the air handlers and ducts in a central plant, all district systems offer these advantages: **reduced space requirements** in the individual served buildings, **eliminated visual impacts** of single-building HVAC equipment, and **eliminated noise and pollution** at the building site. • Emissions from a central plant are generally lower than what would be generated by an equivalent set of smaller plants because of higher equipment quality, seasonal efficiencies, and lower system heat losses. • DHC systems also offer the financial benefits of **reduced insurance costs** for individual buildings (because no boiler poses fire or injury risk), and **reduced maintenance costs** associated with less mechanical equipment.	**Slide 88** **DHC System Advantages:** **SM Page 171-172** **Notes:**

Unit 3 Summary:
In Unit 3, the students have learned:
Improving the energy efficiency of a building is the second step in a comprehensive energy conservation program, after building loads have been minimized, and before renewable energy sources are applied. This unit covered energy efficiency considerations for a wide range of HVAC equipment and system types, including heating, cooling, air distribution, domestic hot water, power controls, and district heating and cooling systems. Once building performance goals have been set, the project team can evaluate the potential of different strategies to meet objectives. Though improving building performance can require additional upfront investment in higher-quality equipment, savings realized over the lifetime of the building can quickly offset initial costs. Life cycle cost analysis provides a straightforward method of comparing the economic impact of different strategies.

Regardless of the particular HVAC application, a number of general principles of efficiency are relevant:

- Use free energy when possible.
- Reuse energy via energy recovery systems, economizers, and waste heat applications.
- Rightsize equipment to meet but not exceed design loads.
- Use equipment that can be modulated to meet changing loads.
- Use controls to program systems to respond to changing conditions, detect equipment failures, and track building performance.
- Commission building systems to make sure they operate at optimal efficiency.
- Implement a preventative maintenance program to keep equipment in good working order.
- Rely on expert professional advice to analyze complex system interactions.
- Take advantage of system synergies and economies of scale where possible.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 4: Energy Efficiency and LEED

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Understand how the LEED rating systems for new construction and existing buildings reward energy performance.*
- *Be familiar with LEED credits pertaining to refrigerant management.*

Time Required: Approximately .5 hour

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
- ☑ **Green LEED CD-ROM, Computer, and Projector**
- ☑ **Pencils**
- ☑ **Paper**
- ☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 175-179

Introduction:
This unit covers:
- How energy performance, refrigerant management, commissioning, and measurement & verification are addressed in the LEED for New Construction rating system.
- How energy efficiency best management practices, energy performance, and ongoing energy performance measurement are addressed in the LEED for Existing Buildings: Operations & Maintenance rating system.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• Reflecting the new greater emphasis on energy-related issues in LEED 2009, credits in the Energy and Atmosphere category of LEED-NC **account for 35% of base points available** (as opposed to 25% in the previous version). • The following is a description of how **LEED-NC rewards energy performance, refrigerant management, commissioning, and measurement & verification.**	**Slide 1** **Energy and LEED-NC:** **Figure 25: LEED Categories and Point Distribution chart.** **SM Page 175** **Notes:**
• The LEED-NC credits pertaining to energy performance are: • **EA prerequisite 2: Minimum Energy Performance (required).** • **EA credit 1: Optimize Energy Performance (1-19 points).**	**Slide 2** **LEED-NC Credits:** **SM Page 175** **Notes:**
• EAp2 is designed to assure that a LEED building will perform marginally better than one built to the ASHRAE 90.1-2007 energy requirements. Simply put, a new LEED building needs to **demonstrate through a digitally simulated energy model that the building's energy costs will be at least 10% less than if it were built to code.** • Instead of an energy model, depending on size and other parameters certain building types, may be eligible to comply with this prerequisite by implementing a set of best practices that are applicable to the specific building type. These include office buildings, retail, schools, warehouses, and self storage facilities.	**Slide 3** **EAp2: Minimum Energy Performance (required):** **SM Page 176** **Notes:**

• EAc1 **allows projects to earn up to 19 points for even better energy performance.** For example, a new building that reduces predicted energy costs by 12%, instead of the minimum 10% required, would earn one point. Additional points can be earned for each subsequent 2% decrease in energy costs up to 19 points (for a total potential energy cost reduction of 48%). • Alternatively, similar to EAp2 requirements, some building types can earn between 1 and 3 points by following certain best practices rather than predicting energy performance through an energy model.	**Slide 4** **EAc1: Optimize Energy Performance (1-19 points):** **SM Page 176** **Notes:**
• The LEED-NC credits related to managing ozone-depleting refrigerants are: • **EA prerequisite 3: Fundamental Refrigerant Management (required).** • **EA credit 4: Enhanced Refrigerant Management (2 points).**	**Slide 5** **Refrigerant Management and LEED-NC:** **SM Page 176** **Notes:**
• EAp3 establishes basic requirements that must be met by all LEED buildings to **eliminate the use of refrigerants that are most destructive to the ozone layer** of the atmosphere, since ozone depletion contributes to global warming. • This prerequisite prohibits the use of refrigerants that include chlorofluorocarbons (CFCs) in new base-building heating, ventilating, air conditioning, and refrigeration systems. • When reusing existing, base-building HVAC equipment, a phase-out plan is required such that all CFC-based refrigerants will eventually be eliminated from the building.	**Slide 6** **EAp3: Fundamental Refrigerant Management (required):** **SM Page 176** **Notes:**
• EAc4 provides two points for **limiting or completely eliminating the use of refrigerants that have excessive ozone depletion potential** (as defined in the Reference Guide).	**Slide 7** **EAc4: Enhanced Refrigerant Management (2 points):** **SM Page 177** **Notes:**

• The LEED-NC credits pertaining to commissioning are: • EA prerequisite 1: Fundamental Commissioning of Building Energy Systems (required). • EA credit 3: Enhanced Commissioning (2 points). • **Covered in Module 2, Unit 2.**	**Slide 8** **Commissioning and LEED-NC:** **SM Page 177** **Notes:**
• The LEED-NC credit pertaining to Measurement & Verification (M&V) is: • EA credit 5: Measurement & Verification (3 points). • LEED addresses energy consumption both **based on the design** (as described above under EAp2 and EAc1), and also **based on actual on-going building energy consumption** as addressed by EAc5. • This credit provides guidance on how to establish a plan for measuring the actual energy consumption of a building over the course of at least one year of operation, and comparing that energy consumption to predicted energy consumption levels. • If the actual energy performance of the building is worse than anticipated, then the M&V plan would establish a process for how to take corrective action so that the predicted energy savings can be achieved.	**Slide 9** **LEED-NC credit, Measurement & Verification (M&V):** **SM Page 177** **Notes:**
• LEED-EB:O&M includes **prerequisites and credits for energy efficiency best management practices, energy performance, and ongoing energy performance measurement.**	**Slide 10** **Energy and LEED-EB:O&M:** **SM Page 177** **Notes:**

• Energy Efficiency Best Management Practices (BMPs) are addressed in LEED-EB:O&M in: • EA prerequisite 1: Energy Efficiency Best Management Practices: Planning, Documentation, and Opportunity Assessment (required). • As detailed in Module 2, Unit 2, **EAp1 aims to ensure that all LEED buildings implement BMPs for energy efficient operations.** These BMPs address the broad goal of reducing energy consumption by ensuring that energy-efficient operating strategies are maintained.	**Slide 11** **Energy Efficiency Best Management Practices and LEED-EB:O&M:** **SM Page 177-178** **Notes:**
• Energy performance related credits in LEED-EB:O&M are: • **EA prerequisite 2: Minimum Energy Efficiency Performance (required).** • **EA credit 1: Optimize Energy Efficiency Performance (1-18 points).** • LEED-EB:O&M, similar to LEED-NC, addresses minimum energy performance through a prerequisite, and awards points for higher levels of energy performance. • EAp2 requires that all buildings that are eligible to use Energy Star's Portfolio Manger tool (see Module 1, Unit 2) must earn an Energy Star score of at least 69 (remember, a score of 50 represents average performance). EAc1 awards from 1 to 18 points to projects with higher Energy Star scores, starting at 71.	**Slide 12** **Energy Performance and LEED-EB:O&M:** **SM Page 178** **Notes:**
• The LEED-EB:O&M credits related to energy performance measurement are: • **EA credit 3.1: Performance Measurement—Building Automation System (1 point).** • **EA credit 3.2: Performance Measurement—System-Level Metering (1-2 points).**	**Slide 13** **Energy Performance Measurement and LEED-EB:O&M:** **SM Page 178** **Notes:**

• There is broad recognition in the energy management field that the ability to measure and manage energy use is closely related to the ability to reduce energy consumption. Because of this, LEED-EB:O&M provides two credits to reward energy performance measurement. • **EAc3.1 provides one point for buildings that use a BAS** (see Unit 3) to monitor and control key building systems, including heating, cooling, ventilation, and lighting. There are also requirements related to ensuring that the BAS is properly maintained and used to inform building upgrade decisions. • **EAc3.2 rewards projects that implement system-level measurement systems.** One or two points are available to projects that provide system-level metering for at least 40% or 80% of the total expected annual energy consumption of the building, respectively. Such system-level metering supports energy management and serves to identify opportunities for additional energy-saving improvements.	**Slide 14** **Energy Performance Measurement and LEED-EB:O&M:** **SM Page 178** **Notes:**

Unit 4 Summary:
In Unit 4, the students have learned:

- LEED-NC contains prerequisites and credits that address: energy performance, refrigerant management, commissioning, and measurement & verification.
- LEED-EB:O&M contains prerequisites and credits related to: energy efficiency best management practices, energy performance, and energy performance measurement.

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 5: On-site Renewable Energy Generation Technologies

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Understand how building-scale renewable energy generation can further reduce a building's carbon footprint.*
- *Be familiar with the theory and practice of photovoltaic power generation.*
- *Be aware of advancing technologies in building-scale wind power generation.*

Time Required: Approximately 1.5 hours

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 181-187

Introduction:
After the project has optimized passive performance and maximized energy efficiency, a high performance green building can employ renewable energy to meet some or all of its remaining energy needs, and reduce its carbon footprint. Renewable energy can be generated on-site or purchased from some utilities. This unit covers solar electric systems, wind energy systems, and biofuel electric systems.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• After the project has optimized passive performance and maximized energy efficiency, **a high performance green building can employ renewable energy to meet some or all of its remaining energy needs, and reduce its carbon footprint.** Renewable energy can be generated on-site or purchased from some utilities. • Onsite renewable energy. For building scale projects, this usually means photovoltaic panels, but wind powered microturbines and biomass generators can also be used. • Green power. Many electricity utilities offer customers the option to purchase “green power,” which comes from renewable energy sources such as wind farms, biomass generators, or large scale solar arrays. • This unit will provide a general description and considerations for on-site renewable energy technologies.	**Slide 1** **Overview:** **Figure 26: On-site renewable energy & green power.** **SM Page 181-182** **Notes:**
• Although there are many types of on-site renewable energy systems, we will discuss three of the most common ones: • **Solar Electric Systems.** • **Wind Energy Systems.** • **Biofuel Electric Systems.** • We’ll start with solar electric systems.	**Slide 2** **Onsite Renewable Energy:** **SM Page 182** **Notes:**

• **A system that converts solar radiation into usable electricity is called a photovoltaic (PV) system.** • *Photo* derives from the Greek word for light; *voltaic* refers to Alessandro Volta, the inventor of the electric battery. The phenomenon of converting light into electricity was first observed in 1839 by nineteen-year-old French physicist Alexandre Becquerel. Einstein explained this phenomenon in a paper published in 1905, and won the Nobel Prize for his theory of the photoelectric effect in 1921. Einstein described the behavior of light as a stream of discrete *quanta* or *photons* instead of simply a continuous wave of energy, as previously thought. • When certain metals absorb light, the photons interact with the atoms in the material to raise the energy of electrons, creating an electric charge. When a large enough number of electrons are excited in this way, an electric current is formed.	**Slide 3** **Solar Electric Systems:** **SM Page 182** **Notes:**
• Photovoltaic technology is constantly evolving in an attempt to make ever more efficient and cost-effective use of free solar energy. • Realizing that PV economics don't yet pencil out for the average consumer, **governments and utilities offer significant incentives to encourage the use of PV systems** to fully or partially provide power to a project. • Efficiencies and installation options vary widely depending on the type of system and individual manufacturer.	**Slide 4** **Photovoltaic Technology:** **SM Page 182** **Notes:**

- **The PV or solar cell is the basis of any PV system.** Individual solar cells are typically small, generating 1-2 watts of power each. **A connected series of solar cells is called a module. Modules can be joined together to form an array** to meet electric demands of various sizes.
- The components that make up the rest of the PV system besides the PV modules themselves are referred to collectively as the balance of system (BOS). This includes the system electronics, support structure, and electricity storage and/or transmission equipment.

Slide 5
System Components:

SM Page 182
Notes:

- Solar cell efficiency is **measured as the amount of electricity that can be generated per incident solar power unit (watt/watt).**
- Commercially-available PV systems operate at efficiencies ranging from about 8-18%. (For comparison, a typical fossil fuel generator operates at about 28% efficiency. However, the “fuel” for a PV system is free, renewable, and non-polluting.)
- As equipment temperatures rise, efficiency decreases. Since sun exposure and high temperatures go hand in hand, these losses can rarely be avoided. Laboratory efficiencies of up to 40% have been achieved, but economic and production factors have limited the performance of commercial systems.
- The PV industry is constantly working to increase efficiency and reduce costs, so these numbers are likely to improve.
- In addition, because PV systems can make a bold visual statement, projects are using them for their marketing value as well their power generating capability.

Slide 6
Solar Cell Efficiency:

Figure 27: The PV or solar cell is the basis of any PV system.

SM Page 182
Notes:

• There are two main types of semiconductors used in solar cells: crystalline silicon and thin-film cells. • **Crystalline silicon (sometimes called "thick crystal") cells are the most common**, and are used in typical glass-covered panels. They deliver approximately 10-12 watts/sf under full sun. • **Thin films of amorphous silicon or other semiconductor materials are lighter and cheaper to produce, but are not as efficient** as crystalline silicon cells (delivering about 4-5 watts/sf under full sun). • Thin-film solar cells do not require glass covers and can be applied directly to glass, ceramic, or other compatible substrates. Building-integrated PVs (BIPVs) can be of either solar cell type. Crystalline silicon cell modules can be used for shading structures, or roof or façade panels. • The shading/PV application makes particularly good sense because the orientation of the panels can be optimized for both purposes. Thin-film cells can be incorporated seamlessly into roof tiles, siding materials, glazing, curtain wall systems, and other building components. Semi-transparent thin-film cells can even be applied to windows to simultaneously moderate daylight and generate electricity. In any BIPV installation, orientation and shading must be carefully assessed.	**Slide 7** **Semiconductors:** **SM Page 182-183** **Notes:**

• **A standalone system requires batteries** to store electricity for use when the sun isn't shining. **A grid-tied system is connected to local utility lines.** When the sun is shining, the PV system contributes electricity to the grid. When electricity demand exceeds what can be supplied by the PV system, the grid can provide backup or supplemental power. • Batteries are required in stand-alone PV systems, and may also be useful in grid-tied systems where peak demand charges can be offset by stored PV power, or uninterrupted power is a priority. • PV batteries must have certain characteristics to meet the unique demands of the system. They must be capable of repeated discharge to almost full capacity without harm, and be able to accept slow recharge.	**Slide 8** **System Types:** **SM Page 183** **Notes:**
• Flat plate systems that use a simple layered panel construction with a glass cover are the most common. • Flat plate panels can either be mounted in a **fixed position**, or on a **one- or two-axis tracking** structure. • One-axis tracking systems track the sun east to west, which can improve solar access by 35-50%. Two-axis trackers trace the sun's daily course from east to west as well as its seasonal course between the northern and southern hemispheres, maximizing the amount of sunlight the system receives. • Concentrating systems use specially designed lenses to concentrate solar energy, thus improving the efficiency of each solar cell. However, most concentrators must use two-axis tracking to be effective. Thus, savings from increased solar cell efficiency might be offset by the cost of expensive tracking mechanisms.	**Slide 9** **System Types:** **SM Page 183-184** **Notes:**

• **PV systems must be designed and installed by experts in order to yield the best performance.** As described above, there is an almost limitless range of ways that a PV system might be installed in a project. • Some general installation considerations for non-building integrated PV systems include: • Coordinate with system manufacturer and (in grid-tied systems) local utility early to identify potential issues prior to installation. • In jurisdictions that use the National Electrical Code (NEC), work with an electrician to ensure that the requirements and specifications of Article 690 are met. Other codes may also apply. • Ensure that the roof or other structure is sufficient to support the array. Augment structure if needed. If space allows, mounting the array on the ground is simpler and less expensive. • Make sure PV modules are not shaded by any adjacent vegetation or structures. • Make sure all roof penetrations are sealed in a way that does not void the roof warranty. • Ground system parts to reduce risk of shock and surges. • Mount system electronics in a shaded and/or well-ventilated area to reduce exposure to high temperatures that shorten the life of the equipment.	**Slide 10** **Installation Considerations:** **SM Page 184-185** **Notes:**

• Material considerations: • All **exposed components should be sunlight/UV resistant,** and able to withstand outdoor temperatures. • **Aluminum should be separated from any concrete** components to avoid corrosion. • **Use only corrosion-resistant steel or aluminum for array support.** Wood and angle iron are not recommended due to deterioration and maintenance issues. Use stainless steel fasteners. • **Different metals (e.g., steel and aluminum) should be separated** to avoid unwanted conduction.	**Slide 11** **Material Considerations:** **SM Page 185** **Notes:**

- The second type of on-site renewable energy systems we are going to discuss is wind energy systems.
- Currently the most efficient way to use wind energy on a project site is to employ **natural ventilation strategies** that reduce or eliminate the need for mechanical cooling.
- Wind energy **can also be converted into emissions-free electrical power** for buildings.
- You may be familiar with the enormous turbines used on wind farms throughout the world for distributed power generation. Building-scale turbines (also called microturbines) also exist to generate electricity for use on site. Of course, the applicability of this strategy depends heavily on the consistency and availability of prevailing breezes. For most building-scale projects, steady winds over 20 mph are usually needed.
- The cost effectiveness of these systems is not yet at a point where on-site wind power generation makes sense for most projects. However, like PV systems, wind turbines are a highly visible indication of a project's green intentions, making them valuable in creating a striking green image.
- Microturbines can be mounted away from the building or integrated into roof ridges or parapets to take advantage of increasing wind speeds as air moves up the face of the building. Blade diameters can be as little as three feet.
- The capacity of a single microturbine typically ranges from 1.5-6 kW.
- Noise and vibration issues must be considered.

Slide 12
Wind Energy Systems:

Figure 28: Building-scale turbines (also called microturbines) to generate electricity for use on site.

SM Page 185-186
Notes:

• Finally, we are going to discuss biofuel electric systems. • Another way to reduce dependence on fossil fuels is to generate electricity using biofueled generators. • A **biofuel is any fuel substance (solid, liquid, or gas) derived from renewable natural resources (or biomass).** Examples include: liquid biodiesel made from used vegetable oil, solid wood chips burned for heat or electricity, and methane gas from municipal or agricultural waste. • The environmental performance of a biofuel depends on the source of the fuel and the amount of energy required to produce it. • For instance, burning virgin wood for electricity creates a host of environmental problems and consumes a resource that could be better used for other things. Similarly, studies have found that it actually requires more than one gallon of petroleum gas to produce a gallon of corn-based ethanol gas. These are inefficient uses of energy, even if they technically are biofuels. From an environmental perspective, the best biofuels are those derived from materials that would otherwise be wasted or, as in the case of methane gas, substances that are generated by the waste itself.	**Slide 13** **Biofuel Electric Systems:** **SM Page 186** **Notes:**
• Biofuels generally **still require combustion to convert them into energy.** • Therefore the use of biofuels still creates air pollution and greenhouse gas emissions. However, in the case of plant-based biofuels, growing the fuel itself sequesters CO_2 from the atmosphere (remember, plants absorb CO_2 in their normal respiration). • Furthermore, because biofuels are renewable, they reduce our dependence on limited supplies of foreign fossil fuels. • Remember from Unit 3, when biofuel generators are combined with space conditioning functions, fuel efficiencies of 80% can be achieved.	**Slide 14** **Biofuel Electric Systems:** **SM Page 186** **Notes:**

Unit 5 Summary:

In Unit 5, the students have learned:

- There are several types of photovoltaic systems, including standard glass-covered panels and building-integrated PVs (BIPVs). In addition to the solar cell(s), a PV system is comprised of its “balance of system” (BOS), which includes the system electronics, support structure, and electricity storage and/or transmission equipment.

- Building-scale wind turbines are uncommon, but under certain conditions, newly-developed micro-turbines can generate pollution-free electricity for individual buildings.

- Biofuels may or may not be environmentally preferable.

Application:

To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 6: Renewable Energy and LEED

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Understand how the LEED rating systems for new construction and existing buildings reward on-site renewable energy generation.*

Time Required: Approximately .5 hour

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 189-190

Introduction:
This unit describes how reducing carbon emissions through the use of renewable energy is addressed in the LEED rating systems for new construction and existing buildings.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• Renewable energy credits in LEED-NC are: • **EA credit 2: On-site Renewable Energy (1-7 points).** • **EA credit 6: Green Power (2 points).**	**Slide 1** **Renewable energy credits in LEED-NC:** **SM Page 189** **Notes:**
• As described in the previous unit, renewable energy systems can reduce a building's carbon footprint. EAc2 and EAc6 are intended to encourage the development of such energy systems. Renewable energy systems can also reduce energy costs, thereby contributing to points earned under EA credit 1: Optimize Energy Performance (see unit 4). • EAc2 focuses on renewable energy systems developed on the building site. In addition to the more common photovoltaic, solar hot water, and wind energy systems, other less common systems include: • **Biofuel-based** electric systems (eligible biofuels include wood waste, agricultural crops, animal waste, and landfill gas). • **Geothermal** electric and heating systems. • Low-impact **hydroelectric** power systems. • **Wave and tidal power** systems. • The points awarded for this credit are dependent on the percentage of the building's energy cost that is met by the renewable energy system(s). Up to seven points are available for LEED buildings that meet at least 1% to 13% of their total energy costs through eligible renewable energy systems.	**Slide 2** **EAc2: On-site Renewable Energy:** **SM Page 189** **Notes:**

• In contrast to EAc2, EAc6 focuses on the use of **grid-source renewable energy** technologies rather than on-site renewable energy systems. • An entire industry has been established to allow electrical consumers to buy their electricity from renewable energy sources, most commonly from utility-scale wind, hydroelectric, and solar sources. • EAc6 stipulates that buildings can earn two points for purchasing at least 35% of their electricity from approved renewable sources.	**Slide 3** **EAc6: Green Power:** **SM Page 189** **Notes:**
• Credit documentation requirements for **EAc2** include providing **calculations of the project energy generation from each on-site renewable energy system**, and providing **proof of installation,** such as records of incentives received. • Credit documentation requirements for EAc6 include a copy of the contract for the purchase of the appropriate number of renewable energy certificates.	**Slide 4** **Documentation:** **SM Page 189-190** **Notes:**

• The LEED-EB:O&M credit related to renewable energy is: • **EA credit 6: Emissions Reduction Reporting (1 point).** • The primary purpose of encouraging renewable energy systems is to reduce emissions associated with fossil-fuel based energy sources. EAc6 indirectly addresses this same purpose as it **requires the tracking and documentation of greenhouse gas emissions** associated with the project. • Such efforts make it easier to assess the emission reductions that would be provided by incorporating renewable energy into the project, either on- or off-site. Although the expectation is that credit compliance will lead to emission reductions, a reduction of emissions is not required for credit achievement. • Credit documentation requirements for EAc6 include a reporting of emission reductions using an independent third-party emissions verification body.	**Slide 5** **Renewable Energy and LEED-EB:O&M:** **SM Page 190** **Notes:**

Unit 6 Summary:

In Unit 6, the students have learned:

- There are numerous LEED credits, including those outlined in Unit 4, that address energy consumption. The credits covered in this unit specifically address carbon emissions by encouraging the use of on- and off-site renewable energy systems, and emissions tracking.

Application:

To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

ENERGY: LOAD REDUCTION, EFFICIENCY, AND ON-SITE GENERATION

Unit 7: Conclusion

Module 3
Energy: Load Reduction, Efficiency and On-site Generation

Unit Learning Objectives:
After this unit, students will:
- *Compare the energy consumption and costs of low, medium, and high performance buildings.*
- *Review the importance of building energy performance with regard to climate destabilization.*
- *Understand your vital role in optimizing building energy performance.*

Time Required: Approximately .5 hour

Procedures:
1. Review each objective with the students.
2. Discuss the slides for this unit.
3. Conduct a review discussion and administer unit quiz.

Equipment and Resources:
☑ **Green LEED CD-ROM, Computer, and Projector**
☑ **Pencils**
☑ **Paper**
☑ **Chalkboard, dry-erase board, or poster paper**

Student Manual Pages: 191-193

Introduction:
This unit emphasizes the role of the sheet metal industry in improving the performance of new and existing buildings. Students are encouraged to use the knowledge gained in this course as a foundation on which to build with further training.

PRESENTATION:

WHAT YOU SAY	WHAT YOU SHOW
• The definition of "high performance" is constantly changing as the green building industry evolves, new technologies are developed, and best practices become standard. • "Performance" refers to a number of different ways that a building works: ○ **Design process.** ○ **Construction practices.** ○ **Indoor environmental quality.** ○ **Resource efficiency.** • While the ultimate goal is to create buildings that have no net negative impact on people and the environment, there are many incremental steps to be taken to reach that eventual point. • As this course and your case study research have hopefully shown you, green building strategies are useful solutions to real problems. • In terms of energy, the basic concept is simple: reduce loads, maximize efficiency, and use renewable energy sources.	**Slide 1** **High Performance Buildings:** **SM Page 191** **Notes:**
• Because buildings represent such a large proportion of total US energy consumption, building energy performance is a high priority. • A standard building meets code requirements and nothing more. For an office building, this might result in an EUI of 75 kBtu/ ft^2-year. • **Smart design and integrated strategies can commonly yield medium performance buildings that perform 30% better than code.** • **High performance buildings are currently achieving energy use reductions of 60-75%.** • An elite but growing group of **zero net energy buildings generate all the energy they need** over the course of a year, boasting an EUI of 0.	**Slide 2** **High Performance Buildings:** **SM Page 191** **Notes:**

• **Existing buildings present the greatest opportunity** to address energy because there are so many relative to new construction, and most perform at a code or "low" level. • Great opportunity for sheet metal industry. ○ Energy system evaluation. ○ Data gathering and communication. ○ HVAC installation. ○ Updating system maintenance protocols. • The opportunity for the sheet metal industry is equally great as HVAC professionals will be called upon to evaluate, upgrade, and track energy consumption in these buildings. Specifically, sheet metal workers are positioned to take on energy system evaluation, data gathering and communication, installations, and updating system maintenance protocols to bring low-performing buildings to a medium or high level. The demand for these services and capabilities will only grow stronger with environmental imperatives, government regulation and incentives, and private sector demand.	**Slide 3** **Opportunity:** **SM Page 191-192** **Notes:**

• The costs associated with achieving different levels of performance vary widely and depend entirely on the unique circumstances of the project. What is clear, however, is that green buildings do not have to cost more, especially when life cycle costs are considered. • Medium-performing buildings can use standard HVAC systems in conjunction with comprehensive load reduction strategies to achieve energy savings at no additional HVAC equipment cost. • **Investment in higher-grade equipment can lead to higher performance,** with typical payback periods of 3-10 years. • **Optimizing existing HVAC performance can create significant improvements with minimal capital investment.** This can be achieved through strategies such as adjusting run times to better match building programs, preventative maintenance, and air balancing. • Studies have shown that the incremental costs of meeting certification requirements in LEED buildings (which may be low, medium, or high in terms of energy performance) range from 0-8%. Soft costs, such as additional design fees, may initially add to green building budgets but pay off as an investment in load-reducing design strategies that reduce operating costs. • High performance buildings can also make use of incentives and grant funding to make project economics more feasible.	**Slide 4** **Cost:** **SM Page 192** **Notes:**

• **The sheet metal industry is at the forefront of professionals positioned to address energy in buildings.** While sustainability encompasses more than just energy, the evidence and demand indicate that this area of concern will remain the leading criterion by which green buildings are evaluated. • Thinking back to Module 1, recall the numerous ways that buildings impact the environment and the health of people. While they are responsible for many negative effects, buildings can also have a positive influence on the way we use resources and the quality of life of the people that inhabit them. • Green buildings do more with less, but that does not mean they don't function as well as conventional buildings or aren't wonderful places to be. • In the future, all buildings will have to be energy-efficient and green. Of all the environmental impacts buildings have, non-renewable energy use is arguably the most critical because it relates directly to greenhouse gas emissions. • As you assess, install, upgrade, and maintain HVAC systems to perform at their peak, you are fulfilling your new green-collar role. The small difference you make on a single building is magnified as the whole sheet metal industry collectively tackles energy in its day-to-day work. The result is financial payback for owners, less impact on the natural environment, and an expanded role and more jobs for sheet metal workers—the Triple Bottom Line of people, planet, and profit.	**Slide 5** **Your Vital Role in Building Energy Performance:** **SM Page 192-193** **Notes:**

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• **By taking this course you have increased your knowledge of green building concerns, principles, and practices.** In doing so, you have created a comprehensive foundation on which to build with more tactical training in green building practices relevant to the sheet metal industry such as: TAB, IAQ, commissioning, and energy auditing.

• On that last point, **ITI has developed full training programs for Total HVAC Systems Audit and Total Building Energy Audit.** These courses will equip you to gather the data required to assess the energy efficiency of a building's HVAC system or, in a broader sense, the overall building envelope and its energy using systems.

• Even if you don't go on to take more green building courses, this foundation allows you to effectively engage in any green or LEED project because you now understand green priorities, principles, practices, and expectations. Take the knowledge that you have gained in this course and use it to take advantage of new job opportunities in the growing green building market, and be assured that in doing so you are doing your part to make the world a better place.

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Slide 6
Your Vital Role in Building Energy Performance:

SM Page 193
Notes:

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Unit 7 Summary:
- N/A

Application:
To achieve the learning objectives, engage the students in discussions during class. Use the Review Worksheet questions to feed a review discussion at the end of the unit. Administer the Unit Quiz to assess that all learning objectives have been successfully met.

Knowledge Check Answer Key

Module One:

Unit 1:

1. b
2. c
3. Green building refers to the set of constantly evolving best practices and technologies applied in the planning, design, construction, and operations and maintenance of buildings to address our increased understanding of the social, economic, and environmental impacts of the built environment.
4. Answers may include: headache, respiratory irritation, dry or itchy skin, dizziness and nausea, difficulty concentrating, and fatigue.

Unit 2:

1. d
2. c
3. b
4. Energy cost savings, reduced maintenance costs, improved occupant productivity.
5. a

Unit 3:

1. a & d
2. Leadership in Energy and Environmental Design.
3. The goal of LEED is market transformation, i.e. to make green building practices mainstream.
4. Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality.
5. Answers may include: high cost of certification; credits don't apply to all projects; projects can earn certification while still ignoring important green building issues; certification for new construction is awarded based on designed performance instead of actual performance.

Unit 4:

1. b
2. c
3. c
4. Answers may include: use water efficient landscaping, employ alternative wastewater technologies, improve plumbing efficiency, improve appliance efficiency.
5. Answers may include: establishes clear performance goals, encourages collaborative work process, creates commitment among team members, leads to creative ways of solving more than one problem with a single strategy.

Unit 5:

1. a & d
2. See examples given under the "Keeping Current" section at the end of this unit. Examples could include the websites listed, printed publications, seminars, additional training courses, etc. Citations could be specific to a given area, depending on what's available locally. The idea is to get students thinking about how they can expand their knowledge of green building practices and stay current as this field continues to evolve.

Module Two:

Unit 1:

1. c
2. a
3. False.

Unit 2:

1. Commissioning is a comprehensive quality assurance process that provides independent oversight to ensure that energy-related systems perform according to the owner's project requirements.
2. e
3. Answers may include: getting a job done right the first time, reduced waste and confusion on the job, reduced callbacks and warranty work, ability to take pride in your work, customer satisfaction, opportunities to teach and learn.
4. A BoD is the document that contains the set of concepts, assumptions, calculations, decisions, and product selections make to meet the owner's goals as stated in the OPR.
5. Inspection, testing, startup.
6. Answers may include: owner's original requirements and corresponding design requirements; drawings and specifications for equipment and systems; system single-line diagrams; any relevant shop drawings and/or as-built drawings; manufacturer technical information and instructions; as-built sequences of operations, control drawings, and original set points; description of equipment or system operation; recommended re-testing, calibration, and maintenance schedules.

Unit 3:

1. Answers may include: dwindling availability of space; land and water pollution; adverse human health effects; contribution of methane gas to global warming.
2. Reduce, Reuse, Recycle.
3. Reduce.
4. e
5. Local solid waste authority, websites and publications, local code.
6. 50%; 75%

Unit 4:

1. a
2. HVAC protection, Pathway interruption, Source control, Housekeeping, and Scheduling.
3. c

Module Three:

Unit 1:

1. b
2. a
3. c
4. 1. Load reduction.
   2. Energy efficiency.
   3. Onsite renewable energy generation.

Unit 2:

1. b
2. a
3. a
4. d

Unit 3:

1. d
2. b
3. An absorption chiller.
4. Optimized equipment operation, system failure detection, tracking of building performance.
5. a

Unit 4:

1. b
2. a

Unit 5:

1. A stand-alone system requires batteries to store electricity for use when the sun isn't shining. A grid-tied system is connected to local utility lines.
2. A good PV battery should be capable of repeated discharge to almost full capacity without harm, able to accept slow recharge, have charge protectors preventing overcharge or complete draining, long-life, able to withstand environment in which they will be used.
3. Cost, steady winds over 20 mph are usually needed, and noise and vibration.
4. While biofuels still require combustion to create power, they produce fewer emissions than fossil fuels. Biofuels can also be produced renewably from domestic sources, reducing reliance on foreign supply.

Unit 6:

5. 1. Biofuel-based electrical systems (eligible biofuels include wood waste, agricultural crops, animal waste, and landfill gas).
   2. Geothermal electric and heating systems.
   3. Low-impact hydroelectric power systems.
   4. Wave and tidal power systems.
6. False.

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