SUSTAINABLE DEVELOPMENT

History, Definition & The Role of the Engineer

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This textbook is the third and revised edition of Sustainable Development: History, Definition & the Role of the Engineer*. Chapters 1 and 2 introduce the standard definition of sustainable development, based on the Brundtland Commission's report of 1987, and can be read as a standalone text. The same goes for Chapter 6, which explores the responsibilities of engineers with respect to sustainable development. Chapters 3-5 are geared toward readers who want to find out more about the nuances of sustainable development discourse.*

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The authors

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Contents:

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1.

SUSTAINABLE DEVELOPMENT: THROUGH THE LENS OF ENVIRONMENTAL HISTORY

Key issues in this chapter:

- *Humans have always had an impact on nature; however, current environmental degradation is more severe than in the past because of population growth and the great impact of current technologies.*
- *Sustainable development came about as a compromise between the environmental movement and the development movement.*

Climate change, rainforest destruction, depletion of fisheries, hormone-impacting chemicals: the list of environmental problems humanity is currently facing is long. Is our negative impact on the environment a new phenomenon or have we always struggled with some kind of environmental problems? More than two millennia ago, Plato expressed disappointment over the bare mountains of Greece, which we now know had been eroded by deforestation and grazing. But if environmental degradation is not a new phenomenon, then what is special about what is happening today? We will try to answer these questions by briefly reviewing human history and our relationship with nature, in order to gain perspective on what makes current environmental problems different from earlier ones.

Environmental impact of hunter-gatherers

For more than 90% of the time humans have existed, we have been hunter-gatherers. We may think of our ancestors as uncivilized, malnourished savages whose lives were very challenging, but this is not fully accurate. They often travelled together in small mobile groups, had a varied diet, and enjoyed some leisure time. Studies of present-day hunter-gatherer societies have shown that they spend about one to three hours per day gathering food, while the rest of the day is free and is spent on social life, including time by the fire, telling stories and singing. For comparison, consider the daily schedule for the modern man, with its eight or so hours of work.

Hunter-gatherers often treated nature with special respect, but this did not mean they did not have an impact on their environment. For instance, some groups set large fires in order to hunt and capture prey, which had a significant impact on the ecosystems they lived in. Consider the role of humans in the extinction of several large mammals in history. The loss of large mammals in North America has been attributed to climate change, but even if this is accurate, humans contributed to their extinction through intensive hunting. The large mammals of Australia survived until humans started inhabiting the continent, and their subsequent extinctions don't coincide with other phenomena such as climate change.

The extinction of some large mammals notwithstanding, the environmental impact of hunter-gatherers was fairly small. One reason for this is low human population density. Global population is estimated to have been between 5 and 10 million 10,000 years ago. This number stayed fairly constant for most of human history. There are two main reasons for this: many children died from disease at an early age, and the population was controlled by such measures as infanticide. Warfare also kept populations from growing by reducing the number of men of reproductive age.

The rise of agriculture – and its environmental impact

Hunter-gatherers did not have many tools with which they could impact their environment. With the advent of agriculture, however, that changed, and we humans began to alter our environment at an increasing scale, sometimes with disastrous consequences.

Today, when we think of the Middle East, we might think of a spare desert landscape. The idea that this once was a fertile area where humans first started to put down roots, build cities, and develop agriculture seems incomprehensible. In the 3000s BCE, this development led to the first civilizations, such as Sumer. But the same agricultural development was also to blame for the environmental destruction that led to the landscape looking the way it does today. Mesopotamia was fertile then, but dry, so the rivers were used to make irrigation systems in order to expand the land area that could be cultivated. The surrounding forests were cut down, which led to more erosion and increased the quantity of soil and clay particles transported by the river, resulting in clogged canals and flooding. Evaporation of surface moisture in the hot summer climate left salts behind in the soil. The demand for crops grew, and land was left fallow for decreasing periods of time, further increasing salinity and decreasing fertility. In the end, agriculture brought about a salt desert that has not been able to recuperate for over 4,000 years.

Other areas have suffered a similar course of events, even if the consequences have not always been as dramatic. The human impact on the environment in agricultural societies has sometimes been intentional, via deforestation, irrigation systems, and road construction, but these have often had unintended consequences, including soil erosion, lower water table, and increased soil salinity.

From Womb to Machine: Nature in metaphors and thought during the Middle Ages & Enlightenment

Explanations for the environmental degradation we see today are sometimes sought in Western ways of thinking about, and relating to, nature. Some see mainstream Christianity as the root of the problem. In contrast to many earlier religions, the

BOX 1.1: JAPAN IN THE 1700S, A SUCCESSFUL NATURAL ECONOMY THAT WORKED

There are many examples of resource mismanagement contributing to the downfall of a society, although the extent to which other factors also played a role is controversial in some cases. Researcher Jared Diamond describes some of these cases in his book with the somewhat depressing title, *Collapse – How Societies Choose to Fail or Succeed*.

Diamond considers societies that have succeeded as well as ones that have failed in sustaining their natural resources, thereby blossoming or collapsing as a result. Eighteenth century Japan is an example of the former. After 150 years of civil war, Japan saw a period of peace and political stability under the rule of a so-called Shogun. That stability allowed the population to increase, which led to increased demand for natural resources and resulting deforestation. However, in contrast to many other societies, Japan managed to change course. Today, 80% of the surface area of Japan is covered by forest, despite the country's high population density.

How did this come about? The Shogun recognized the risks of deforestation and implemented two principal measures to change course: limits on population growth and the introduction of forest management systems. Deforestation was arrested in part by reducing the demand for wood—for example, new construction methods requiring less wood were adopted, more efficient stoves were used, and the use of charcoal instead of fuel wood was encouraged—and in part by requiring forests to be replanted after harvest. Firewood imports from neighboring Hokkaido also grew, a perfect example of the kind of export of environmental problems that grew more common during the period of European colonialism. Diets shifted from being based on agriculture to more dependent on fishing and hunting whales and other marine mammals. The Shogun's long-term interest, stable power, and a hierarchical society where laws and rules were followed were necessary for these changes.

Christian God is not part of nature. This means that humans, too, are separate from a nature over which they have dominion. A well-known passage from Genesis is often cited as an example: "Be fruitful and multiply, and fill the earth, and subdue it; and rule over the fish of the sea and over the birds of the sky and over every living thing that moves on the earth." However, other strains of Christianity instead choose to emphasize the human role of caring for, as well as using, the land.

Blaming it all on Christianity is probably a bit too simplistic. Europe underwent great change during the Middle Ages, changes that culminated during the Enlightenment and the Industrial Revolution and led to our modern concept of nature. The predominant metaphor for nature – women, motherhood, the womb – was transformed into a more instrumental view, with the machine as the main metaphor. In the 17th century, the philosopher Descartes – famous for the quote "Cogito, Ergo Sum" – divided the world into material and nonmaterial objects, a system of thinking called “dualism.” The material world is made up of objects we can see and touch, finite objects. Human bodies are material objects. Immaterial, or intangible, objects are not visible – our thoughts and souls are immaterial. But only humans have souls. Nature and all the animals lack souls and may therefore be used by humans for our needs. Some think this conceptual scheme is in part to blame for the environmental degradation we see today.

What impact have these ideas had on our actions? Would environmental problems be less severe if we had different conceptual schemes for understanding reality and nature? Of course, it is impossible to offer definitive answers. But even if these ideas have indeed had some impact on technological and scientific developments, which in turn have aided the exploitation of nature, we should not forget that environmental destruction has also taken place in societies with much more nature-friendly ideologies.

From the Industrial Revolution to the Anthropocene

The next major change in the relationship between humans and nature, after the rise of agriculture, was the Industrial Revolution, which gave us additional technologies for impacting our environment. The bad air quality in urban England – from burning coal to run the steam engines that propelled the growing textile industry – is an early example of the environmental problems these technologies can cause. Colonialism created a more connected world, where exploitation of resources beyond a nation’s borders can fuel economic development independent of local constraints on natural resources. Progressivism, the belief that technology, science, and social organization work in concert and will continually improve human welfare, picked up speed, and faith in opportunities replaced limits. Increased economic activity and new technology were seen as solutions to most problems. The cornerstones of the current world were set in place.

Technological developments and more efficient use of resources allowed population to grow faster, and the rate of the increase did not start to drop until in recent decades. By the mid 19th century, there were about one billion people. One hundred years later, the human population had doubled; the next doubling took 30 years. Now there are more than seven billion people, and global population is estimated to be nine to twelve billion by the end of the 21st century.

The combination of new technology and the scale of resources demanded by the growing population has caused our impact on the environment to reach geological scale. One single company, Syncrude, the largest producer of oil from the Athabasca tar sands in northern Canada, moves 30 billion tons of rock, sand, and soil each year, to extract fossil fuels. That is twice as much as all the rivers in the world move per year. Since 1700, we have transformed 70 percent of the planet’s grassland, half the area covered by savanna, and almost half the temperate forest land to croplands and pasture. Three-fourths of the ice-free surface of the Earth is farmed. Synthetic fertilizer has more than doubled the amount of nitrogen fixated from the air in the soil; 40% of the nitrogen in the proteins we eat comes from synthetic fertilizer. We use half the globally available freshwater, most of it in agriculture. These are just a few examples illustrating why some researchers believe the scale of our impact on global flows and resources merits defining a new geological epoch, the Anthropocene.

A brief history of the concept Sustainable Development

As we have seen, human history is littered with environmental problems, from the extinction of large mammals during the hunter-gatherer periods to urban pollution from the 1800s through today. Often, these problems came with warnings from individuals who highlighted negative consequences. The wilderness movement in the 1800s helped create national parks in Europe and the U.S. However, we had to wait until the second half of the twentieth century for the birth of an environmental movement focused on issues beyond conservation of wilderness. What follows here is a brief history of the modern environmental movement, including an explanation of how the concept "sustainable development" came about and how it has been used in the context of large organizations and international cooperation.

In 1962, Rachel Carson's *Silent Spring*, generally considered the first real wake-up call for environmental issues, was published and received unprecedented attention. Basing her writing on research from various disciplines, Carson, a biologist, described the negative consequences of pesticide use. The "silence" in her title refers to a lack of bird song, the result of egg shells having been thinned by pesticides to the point that baby birds no longer hatch. This was a concrete example of the negative impact of industrialization and the limits of the environment's capacity to absorb pollutants.

In 1970, a U.S. Senator founded the first Earth Day to call attention to environmental issues. The event included a huge rally and is considered the birth of the modern environmental movement with broad grassroots support. Since then, Earth Day has been celebrated annually, recently in as many as 192 countries worldwide. The many different international environmental organizations that sprang up in the early 70s is another sign of broad engagement on environmental issues. For example, Greenpeace and Friends of the Earth were both founded in **1971**.

In 1972, the Club of Rome, an international group with members from academia, civil society, diplomacy, and industry, published *Limits to Growth*. The book reported on scenarios of continued economic and population growth leading to resource constraints, and of increased pollution leading to population collapse. It ignited a major debate and was criticized from many sides. Economists complained that it seemed that the authors had barely considered that scarce resources would mean higher prices and therefore more economic use of resources, or that technology developments can lead to more efficient use of resources. Poorer nations, which had in many cases only recently gained independence, saw the report as an attempt to limit their opportunities to attain the same standards of living enjoyed by industrialized nations. However, the report managed to initiate a discussion about whether a new growth model was needed, one that takes into account resource constraints and the capacity of the environment to absorb pollution. The first international conference on the environment was held that same year, in Stockholm, establishing the UN Environment Programme (UNEP). As was the case with *Limits to Growth*, this conference was met with great skepticism from poorer nations, who saw the environmental agenda as a clear threat to their growth ambitions. Given this great resistance, it became clear that the discussion and agenda needed to consider environmental constraints in conjunction with the rights of poor nations to develop.

The World Commission on Environment and development (WCED), led by the former Norwegian prime minister, Gro Harlem Brundtland, was founded in **1983**. The group consisted of secretaries of state, civil servants, and decision makers from 21 nations who were tasked with finding solutions to the growing environmental and development problems. Public surveys were conducted around the world to gain as broad a perspective as possible. In **1987**, the group reported its findings in *Our Common Future*, also known as the Brundtland Report.

Unlike most prior environmental reports and assessments, the Brundtland Report focused on issues of equality rather than natural science. Because ending poverty was a key goal, growth was not seen as a bad thing but rather a means to a valuable end. The concept of *sustainable development* had been used earlier, but the Brundtland Report brought it into mainstream discourse. The most common definition of sustainable development stems from the report's premise that sustainable development requires taking into account the needs of both current and future generations. We will return to the exact definition and interpretations thereof in the next chapter.

The Brundtland Report has been criticized for not engaging with the problem of international power structures preventing the economic development of poor countries, for placing too much blame on those countries, and for suggesting that industrialized nations have “all the solutions”. However, the report managed to highlight the links among a number of issues that previously had been treated separately, including development, global environmental issues, population, peace, and security. The report also brought about a discussion of two kinds of justice – justice within a generation (e.g., questions of distribution and growth) and justice between generations (e.g., environmental and resource issues).

Sustainable development can therefore be seen as a compromise between two different movements – the environmental movement and the development movement – and a recognition of the need to address these side by side. Although the balance between environmental concerns and development has varied, the concept of sustainable development continues to guide international collaboration, particularly within the UN system.

In 1992, the UN Conference on Environment and Development was held in Rio de Janeiro, Brazil. This conference has sometimes been described as the apex of the environmental movement and global engagement with environmental issues. The following figures provide a sense of the impressive scale of the conference: 172 countries were represented; 116 heads of state, 8,000 delegates, 9,000 members of the press, and 3,000 accredited organizations participated. Even though the resulting documents and agreements were not legally binding, the ideas and principles the conference highlighted have subsequently shaped sustainable development work at the national, regional, and local level. Agenda 21, which included 120 initiatives for actual actions and which has been used in cities and regions around the world is but one example. The Rio Declaration emphasized the precautionary principle[1] and environmental impact assessments[2] as tools. The UN Convention on Biodiversity and the Framework Convention on Climate Change were also created in Rio. The latter led to negotiations that resulted in a protocol with binding commitments to reduce greenhouse gas emissions in developed countries five years later (the Kyoto Protocol), and global framework for setting and updating targets for greenhouse gas emissions and climate adaptation globally (the Paris Agreement) 23 years later.

At the turn of the millennium (**2000**), The UN Millennium Declaration was adopted, with eight goals to be reached by 2015. All 189 members of the UN and 23 international organizations agreed on these goals.

The eight Millennium Development Goals are:

1. Cut extreme hunger and poverty by half
2. Achieve universal primary education
3. Promote gender equality
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

The Millennium Development Goals demonstrated a greater focus on development compared to prior discussions; only one goal (#7) had a direct connection to environmental issues. Instead, issues with more of an environmental focus were addressed through other fora, such as the international climate negotiations under the UN Framework Convention on Climate Change and major environment and development conventions like the one held in Johannesburg, South Africa, in **2002**. The latter came to be called “Rio+10” but did not receive as much attention as the 1992 conference and is considered less important. However, agreements on water and fisheries did come out of Johannesburg.

As is the case with other declarations, the Millennium Declaration and the eight goals have been seen as pretty, but empty, words that are not binding. However, a key difference from other declarations lies in the work done to identify quantifiable goals that are easy to track and assess. The goals have made a difference in how

[1] In technical contexts, the precautionary principle means considering a substance dangerous if it is unknown whether it is dangerous.
[2] Environmental impact assessments provide a comprehensive perspective on the environmental impacts of a planned activity.

international and national aid are handled. The results have been mixed. Certain goals, such as reducing by half the number of the world's poor, have been achieved at the global aggregate level, while others, such as increasing equality between women and men, have not been achieved and still seem to be a long way off.

In **2012**, the time had come for the next large global sustainability convention, once again in Rio de Janeiro, "Rio+20." The occasion also marked the beginning of negotiations on new goals to replace those of the Millennium Declaration after 2015. Based on the statement that "poverty is the greatest global challenge" and Agenda 21, work got underway on new sustainable development goals. In September 2015 the UN adopted the 17 sustainable development goals (SDGs) spanning a wide array of subject areas and bringing environmental issues back to the fore. Unlike the eight goals of the Millennium Declaration, the new goals include specific targets for cities, sustainable consumption, climate impact, marine resources, and land-based ecosystems. While the Millennium Declaration goals were mainly focused on the poorest nations, this time the purpose was to include goals that engage and encourage all nations to act.

Of course we should not forget that perhaps the most important work on sustainable development takes place outside these major arenas. Development work takes place at the local and national level, and in collaborations among nations. Environmental organizations continue to inform and work to change opinions and attitudes. In the business world, sustainability issues have gone from a mere marketing question to a strategic one, both because of more stringent regulation but also because of increased awareness among consumers and employees. The road ahead is undoubtedly long, but the journey has begun.

Suggested reading:

Jared Diamond. *Collapse – How societies choose to fail or succeed*. Penguin Group, 2004 (revised ed. 2011).

Sverker Sörlin. *Naturkontraktet*. Carlssons Bokförlag, 1991.

Clive Ponting. *A new green history of the world: the environment and the collapse of great civilizations.* Penguin Books, 2007.

2.

SUSTAINABLE DEVELOPMENT – DEFINITION AND INTERPRETATIONS

Key points in this chapter:

- *Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.*
- *Sustainable development has three dimensions: ecological, economic, and social.*
- *The ecological dimension involves sustaining the environment's production capacity and not exceeding the environment's assimilative capacity.*
- *The economic dimension involves efficiently managing finite natural resources and capital for the long term.*
- *The social dimension involves societal institutions that are important for human needs, such as democracy, trust, law, and international organizations.*

How is sustainable development defined?

The most common definition of sustainable development, also called the Brundtland definition, can be found in the report *Our Common Future* from 1987:

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

First of all, note that the concept *sustainable development* is normative. It tells us how we *ought to* behave in our interactions with others, our contemporaries but also towards future generations. How we ought to behave is a not a scientific question, though scientific knowledge is important in determining what actions have what consequences relative to our normative goals. For example, science helps us determine what kind of medical treatment is most effective or what the impact will be of an increase in the average surface temperature of the planet. But if we do not consider having any moral obligation to care about future generations, the specific impacts of longer-term climate change become irrelevant.

As we saw in the previous chapter, sustainable development emerged as a compromise between the environmental and development movements. The development movement focused on poverty among those of us alive today, while the environmental movement focused on the environmental considerations in managing limited natural resources and maintaining natural ecosystems so that future generations also can provide for themselves and maintain well-being. Ever since the Brundtland Report, the concept of sustainable development and how to interpret it has been hotly debated. Some have focused on environmentally sustainable development and obligations toward nature, while others have emphasized human needs and economic development. Below, we present an interpretation pretty close to that of the Brundtland Report, according to which nature has no intrinsic value. This does not mean that nature is insignificant or lacks value, but that what value it has derives from the value it brings humans. However, sustainable development can also be interpreted based on nature having intrinsic value, irrespective of how it can be used by humans (see Chapter 4).

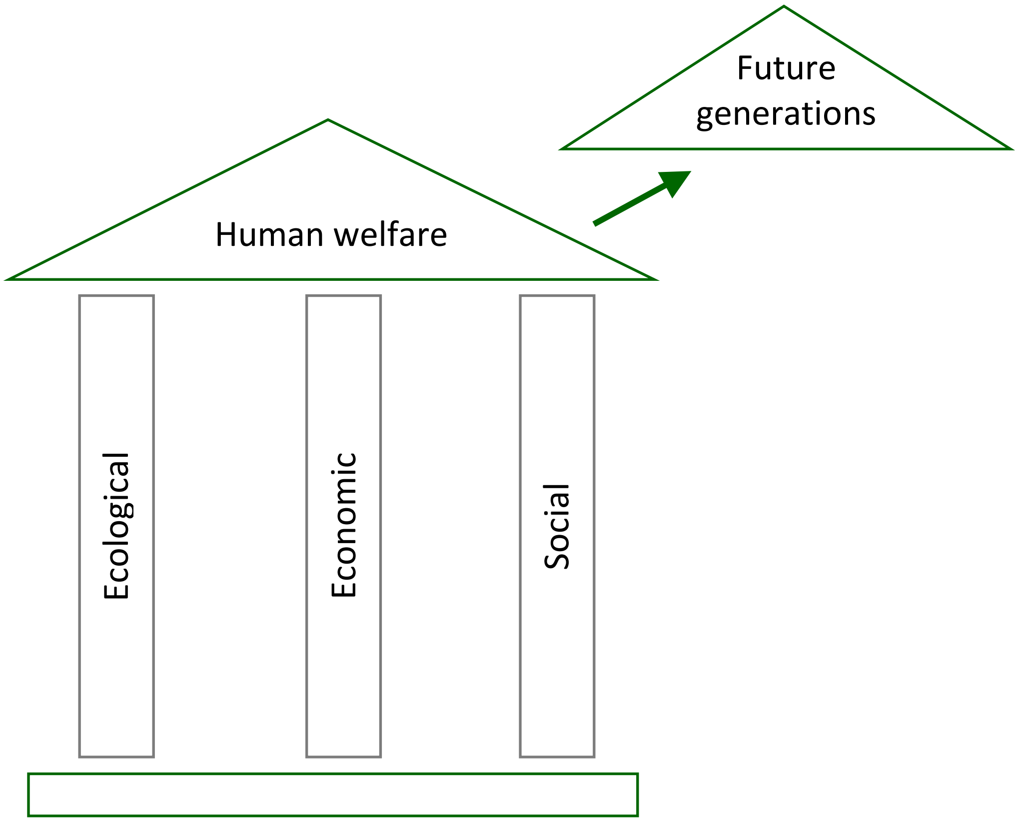
Human well-being and the limits of nature

The Brundtland definition of sustainable development is forceful but vague and therefore requires clarification. The first part of the definition is "to meet the needs of the present..." But what are those needs, and are they all equally important? Is a rich person's need for a new computer as important as a poor person's need for clean water? The Brundtland Report takes a clear stand: Basic needs – clothing, food, shelter, energy, and work – take priority.

However, even if our basic needs are satisfied, we may lack education, influence, means of communication, etc., and the gap between the rich and the poor on these matters if often very wide. Perhaps 'needs' should be conceived more broadly to include what many consider to be the key elements of a good life. If so, perhaps more emphasis should be placed on human welfare rather than merely basic needs. That is not to say, however, that the top priority should not be to address basic needs and the lack of resources afflicting many of the world's poor.

The second part of the Brundtland definition, not "compromising the ability of future generations to meet their own needs," stems from the idea that our interventions in the environment affect future generations' abilities to meet their own needs. Here, technology becomes central for two reasons. First, technological advances, coupled with population increase, have resulted in humans developing the capacity to seriously endanger the welfare of future generations. On the other hand, the limits imposed by nature are affected by technology to some extent. In a world where wood is the only construction material, preserving forests becomes more important than if buildings can be built from stone and cement. Substitutability of construction materials, or materials in general, is a key question.

If we adopt a concept of sustainable development that focuses on human needs and human welfare, the natural question is: What is required to achieve and maintain welfare now and in the future? One common way of answering this question involves dividing the requirements into three categories: ecological, economic, and social. These dimensions are not ends in themselves but are the means to reach the overall goal of developing and maintaining human welfare now and in the future.



Ecological dimension

The ecological dimension involves sustaining natural systems that can keep providing humans with important goods and services. This dimension can be divided into the *environmental production capacity* and the *environmental assimilative capacity*.

The *environmental production capacity* is the ability to provide humans with natural goods broadly conceived. This means crop land, healthy fisheries, clean water, and forests that can be used for fuel or other products; in short, renewable resources. But the environment also provides ecosystem services (see Box 2.1), including circulating nutrients, or bees pollinating plants. Furthermore, nature does not only produce tangible goods; the environment has recreational value, and, to a varying degree, spiritual or religious value.

The *environmental assimilative capacity* involves the ability to assimilate a variety of emissions and environmental impacts. For instance, the oceans absorb massive amounts of carbon dioxide. Were this not the case, the amount of carbon in the atmosphere would be growing even faster, more of the impacts of warming would already be taking place, and future impacts would be arriving sooner. Similarly, processes in nature break down chemicals to less dangerous forms. When ecosystems are depleted, this can affect the environment's assimilative capacity, and we become more sensitive to our own impacts as well as to natural impacts.

BOX 2.1: ECOSYSTEM SERVICES

Ecosystem services are usually defined as the "direct and indirect contributions ecosystems make to human well-being," i.e., ecosystems' utility for humans, as distinct from their intrinsic value or their value to other species. Even if the concept *ecosystem services* has been in use for a long time, it was popularized following the publication of the 2005 report, *Millennium Ecosystem Assessment.* This report distinguishes four different categories of ecosystem services:

Supporting: Basic ecosystem functions underlying the delivery of all the other services, primary (biomass) production, carbon and nitrogen cycles, top-soil formation, and evolution.

Provisioning: Production of utility for humans, including freshwater, food, fiber, biofuels, and genetics resources for drugs and chemicals.

Regulating: Processes that stabilize the climate system, clean and regulate water flow, decompose toxins, and control disease and pests.

Cultural: Religious and cultural environmental values, as well as purely aesthetic values and use of nature for recreation, eco-tourism, inspiration, or as a source of knowledge.

The extent to which biological diversity contributes to ecosystem services has been debated for a long time, but recent research demonstrates that species-rich environments increase the efficiency of ecosystems' basic functions, i.e., how biomass is produced, materials are broken down, and nutrients re-circulated. Ecosystems with great diversity have a greater likelihood of having species that are very productive as well as species that complement each other and thereby make better use of available resources. More species and greater genetic diversity also mean that if some species or individuals are lost, others can take their place, making these ecosystems more resilient to perturbations. This does not mean that greater biodiversity always leads to better ecosystem services. Consider, for example, monocultures in modern agriculture, which can be very productive. In the ecological dimension, biodiversity should be considered a means toward the ends of production capacity and assimilative capacity, rather than an end in itself.

The ecological dimension can be understood as a boundary we must not cross; after all, if we ruin the Earth, there is nothing to do with our money. However, there is a big difference between cutting down a tree and deforesting the planet. So where do we draw the line? How large impact on the environment can we accept while maintaining sustainable development? After all, impacting natural systems cannot always be wrong: cutting trees or emitting carbon dioxide may be necessary to satisfy our needs. However, it is not consistent with sustainable development to systematically deplete natural resources so that future generations do not have access to them.

In the 90s, John Holmberg at Chalmers came up with four principles of sustainable development, of which three pertain to how humans can avoid harming nature (the ecosphere). The principles were picked up by the organization The Natural Step, among others. The first principle states that substances from the Earth's crust (fossil fuels, metals, etc.) should not systematically accumulate in the ecosphere. The second principle states that human-produced substances should not systematically accumulate in the ecosphere. The third principle states that we should not systematically reduce environmental production capacity and diversity. As you can tell, systematic impacts – i.e., impacts over an extended period of time – are an important part here. For some kinds of impacts problems will arise sooner for others, in terms of production and assimilative capacities. The principles do not explicitly address this, but they certainly give an indication of the direction in which environmental work should strive.

In 2009, Johan Rockström at the Stockholm Resilience Center and a group of well-known international researchers launched the idea of *planetary boundaries*. They went a step beyond Holmberg's principles and pointed out a number of critical areas in which humans are at risk of, or already, causing dangerous changes in the ecosystems, including the amount of carbon dioxide emitted and how much freshwater we are using. Both of these approaches are attempts to describe how to manage the ecological dimension of sustainable development.

Complicating our consideration of ecological systems is the fact that we do not really know what coming generations will need. Historically, animals with fur were an important natural resource in cold parts of the world, in order for humans to stay warm in the winter. Today, we can meet that need in other ways, with better insulation in our homes and with synthetic clothing. In that regard, driving animals with fur to extinction in the 1900s would not have been a problem. Of course, those animals may be important in other ways, for instance in terms of how ecosystems function.

The fact that we do not know what ecological resources future generations may come to need is a good reason to be careful not to make irreversible changes to ecosystems. Some environmental degradation has been repaired: rivers have been cleaned up, and the air in some cities has become much cleaner. Other interventions are much harder to fix. For example, if we emit large amounts of carbon dioxide, it will stay in the atmosphere for thousands of years. Likewise, if species are lost, biological diversity cannot be restored.

What is clear is that we depend on natural systems today, and we will continue to do so in the future. The ecological dimension involves guaranteeing that there is enough left of these natural systems in the future.

Economic dimension

The word *economics* is rooted in the idea of managing household resources. The economic dimension therefore involves managing the resources required to sustain human well-being now and in the future. One can divide the economic dimension of sustainable development into two parts: *finite natural resources* and *monetary capital*.

Finite resources include fossil fuels, metals, and phosphorous. These are substances we extract from the crust of the Earth, which are not part of the ecological system and are not renewed. The basic question concerning these resources is: how should they be allocated among people today, and how should they be allocated among generations to come? Saving all the resources for future generations would presumably not help current generations in meeting their needs, but ruthless exploitation would mean putting future generations at risk of not being able to meet their needs. Future generations may come to have a great need for the oil we burn today, or will they have as little interest in oil as we do in furs to keep us warm? We need to try to manage resources in a reasonable way. We could choose to conserve finite resources by keeping them in the ground, but that is not necessarily the best way to promote human well-being. For example, access to iron is important and has been for many civilizations. One solution, when it comes to materials, is to extract the resources today, but to use closed systems, to commit to re-using the materials in the future. This actually makes the materials more readily available to future generations than if we had kept them in the ground.

By *monetary capital*, we mean assets created by people: roads, buildings, factories, etc. Economic sustainability involves managing this infrastructure. What should we leave behind and in what condition? Perhaps more importantly, what societal structures are we leaving for future generations? One basic question is how we choose to invest in infrastructure. For example, one-sided investments in highways have an impact on future generations' ability to develop new transportation solutions. The challenge is to keep the long term in mind alongside current needs.

The economic dimension of sustainable development is fundamentally about finding an efficient way to manage the economy and financial resources, and to balance current generations' needs against future ones' in a reasonable way.

Social dimension

The social dimension of sustainable development involves creating and sustaining social institutions and structures that are important for human well-being. This includes such fundamental institutions as an efficient and functioning state, a reliable law enforcement and judicial system, and good international cooperation (such as the UN). But it also encompasses less formal concepts, including trust among people in a society.

Well-functioning institutions are known to promote human well-being in a variety of ways. The rule of law and faith and trust among people are important conditions for economic development. A well-run public sector decreases the risk of deep economic crises, but it also promotes collective decision-making and guarantees that public services reach those for whom they were intended. International cooperation can prevent war and conflict.

An institution is much more than the ideas and conceptions associated with it. Consider democracy. The idea has been around for a long time. But the social institution of democracy is much more complicated. Democracy is not simply the idea that all adults should have the right to vote, but also the knowledge of how to conduct general elections, and unwritten norms about how all parties to an election accept the outcome. In young democracies, these kinds of things cannot be taken for granted. Developing and building democratic institutions takes time.

Institutions develop over an extended period of time, in response to intentional plans as well as accidental occurrences. For instance, the modern organization of research and education has evolved over centuries. Universities are obviously important components in meeting current and future challenges, but they are also important keepers of knowledge and ideas that may not seem central today but that may come to be important in the future. The role of the university is not simply to develop environmental technology solutions. Elementary education for women in poor countries has often proved to have other positive consequences for society at large: it serves to improve the status of women, leads to lower child mortality, and slows population growth.

Some social institutions and structures are very resilient but can hardly be considered to enhance human well-being. The caste system in India has existed for thousands of years but leads to some people being considered "untouchable"; the Palestine-Israel conflict has lasted several generations, but neither side seems to benefit from it. Sustainable development raises the question about what we *want* to sustain, what we *should* sustain, not what we *can* sustain.

The social dimension of sustainable development is probably the broadest dimension; it also has the widest variety of definitions. Many different factors can be included in the social dimension of sustainable development beyond those already considered, including human rights, peace, equality, fighting poverty, co-determination, and more.

How to think about the three dimensions

The three dimensions of sustainable development constitute a conceptual framework; the boundaries between the dimensions are not always entirely clear. Economically efficient use of resources often requires well-functioning social institutions. If there is nothing there to prevent us from, say, stealing, it will be hard to develop an economy that works. Ecological threats are often tragedies of the commons – if a common resource can be used at will (e.g., a fishery or the option of simply releasing pollutants into the air) this resource will tend to get overused. These kinds of situations can be resolved, but new social contracts or policy measures are needed, rather than new inventions. The reverse also holds: in societies that suffer intense ecological stress, in which food production is declining, social institutions are at risk of collapsing.

The three dimensions of sustainable development can also come into conflict. If we build a dam for hydropower, we build monetary capital, and we supply people with electricity. However, the dam destroys an ecological resource. One dimension is compromised, while another is enhanced. Deciding what counts as a reasonable balancing of priorities requires deciding the relative values of the dimensions; how much is the electricity generated by the dam, and the economic and social development it may spur, worth, compared to the losses in natural capital, now and in the future. Such decisions are not easy, but the next chapter will consider a few different approaches for thinking about these trade-offs.

The three dimensions illustrate that ensuring good conditions for meeting fundamental needs requires considering several different components. Focusing exclusively on nature, or exclusively on social institutions, leads to major problems. Sustainable development requires us to multi-task mentally and see the importance of all three parts. But our societies also need to be organized so as to appreciate the links between the three dimensions. That is the essence of sustainable development.

Suggested reading:

World Commission on Environment and Development. *Our Common Future*. Vol. 383. Oxford: Oxford University Press, 1987.

Robert W. Kates, Thomas M. Parris and Anthony A. Leiserowitz. "What is sustainable development? Goals, indicators, values, and practice." Environment 47(3):8-21, 2005.

Christian Azar, John Holmberg, and Kristian Lindgren. "Socio-ecological indicators for sustainability." Ecological Economics 18:89-112, 1996.

Johan Rockström et al. "Planetary boundaries: exploring the safe operating space for humanity." Nature 461:472-475, 2009.

3.

STRONG AND WEAK SUSTAINABILITY

Key points in this chapter:

- *Economic growth and sustainable development are not necessarily in conflict. The impact on the environment of economic growth depends on the nature of that growth.*
- *Weak sustainability is defined as requiring the sum of natural and monetary capital not to decline over time, while strong sustainability is defined as requiring neither natural nor monetary capital to decline.*
- *The main point of contention between strong and weak sustainability is the question of substituting monetary capital for natural capital.*
- *The possibilities for such substitution change over time, as a result of technology developments and changes in people's preferences.*

In this chapter we will pick up where the last one ended, discussing the connections between the different dimensions of sustainable development. In particular, we will focus on balancing the economic and the ecological dimensions. As mentioned in the introductory chapter, sustainable development can be understood as an attempted compromise between two different goals: fighting poverty through economic development and protecting the environment. Therefore, it should come as no surprise that one of the most hotly debated issues in sustainable development is the relation between economic growth and environmental interests. Some will assert that there is a fundamental conflict between a steadily growing economy and sustainability, but others assert the opposite, that economic growth is a pre-condition for sustainability. These discussions make clear that differing conceptions of sustainability are in play; this chapter seeks to clarify those different conceptions and the arguments related to them.

Sustainable development and economic growth

In order to understand the relation between economic growth and sustainability, we first have to understand what economic growth is. Economic growth is a measure of the increase in the total value of the goods and services produced in a country, generally referred to as the gross domestic product or GDP. To simplify, we can think of the causes of economic growth as two-fold: on the one hand increased access to labor, capital, and other inputs, and on the other increased productivity. The former is achieved by saving and investing in, for example, infrastructure, factories, machines, or education, or by increasing inputs of labor, energy, raw materials, natural capital (agricultural land or water), or ecosystem services. Increased productivity is achieved through technology development enabling the more efficient production of goods and services, so that fewer inputs (labor, capital, and resources) are required for each unit produced.

The important conclusion here is that the relation between economic growth and the environment depends on the nature of the economic growth, i.e., on what is driving the growth. If growth is solely driven by an increased use of finite and renewable resources, and an increased demand for nature to supply us with ecosystem services, this will have major negative environmental consequences. If growth is exclusively driven by increased productivity, growth may even be environmentally beneficial. Therefore, there is no inherent conflict between economic growth and sustainable development; if musicians create better music, authors write better books, and directors make better movies that we are all prepared to pay more to hear, read, and watch, we can have exponential economic growth for the foreseeable future, despite the physical limits of our planet.

But even if there in theory is no conflict between growth and sustainability, the important question is what the situation looks like in practical terms. Growth advocates typically promote a transformation of our economies toward *green growth* driven by environmentally friendly technology. Growth critics, however, rightly point to the increased use of and pressure on natural resources resulting from the enormous growth we have experienced since the Industrial Revolution, despite the fact that this growth has mainly been driven by productivity gains. That is, even if increased efficiency results in less resource use per dollar, this improvement tends to be cancelled by the economic growth caused by the same productivity gains. The 19th-century British economist William Stanley Jevons was the first to highlight this relationship, noting that the technological progress that yielded efficiency gains in the use of coal in industry led to an increase in the use of coal, not a decrease.

One major difference in perspectives on economic growth and sustainability thus hinges on the nature of growth and the possibility of de-coupling growth and increased pressure on natural resources in the future. But the different sides in the debate differ on another important matter, too, namely to what extent natural capital and ecosystem services are needed for continued development of human welfare and well-being.

Economic growth and strong versus weak sustainability

Philosopher Bryan Norton asks his readers (see suggested readings):

> *[S]uppose that our generation converts all wilderness areas and natural communities into productive mines, farmlands, production forests, or shopping centres, and suppose that we do so efficiently and that we are careful to save a portion of the benefits, and invest them wisely, leaving the future far more wealthy than we are. Does it not make sense to claim that, in doing so, we harmed future people...?*

From Dobson (ed.), *Fairness* & *Futurity*, 1999 (see Suggested reading below)

Here's the question: Is economic growth that consumes natural resources and replaces them with increased economic well-being sustainable? Let us put this question in terms of how our total capital changes over time: is it possible to replace natural capital (i.e., finite and renewable natural resources, which, in a variety of ways, supply us with raw materials, energy, and other ecosystem services) with monetary capital (i.e., something we have produced ourselves, infrastructure, machines, knowledge)? Those who answer "Yes" are called advocates of *weak sustainability*, while those who answer "No" are advocates of *strong sustainability*.

According to weak sustainability, there is no difference in kind in the utility provided by different kinds of capital. The important thing, from a sustainability perspective, is that the sum total of natural and monetary capital not decline over time. That is, according to weak sustainability, natural capital can be depleted sustainably, if simultaneous investments are made to increase monetary capital sufficient to compensate for that loss. Let us consider the example of the hydropower dam from the previous chapter. A proponent of weak sustainability would consider building the dam sustainable so long as the increase in monetary capital exceeded the loss in natural capital. The two types of capital are fungible or *substitutable*. Strong sustainability instead assumes that natural capital cannot be replaced by monetary capital (substitutability is low). Sustainable development therefore requires that neither natural nor human-made capital decline over time. In the hydropower example, strong sustainability prohibits building the plant no matter how much monetary capital would be gained, since this will inevitably result in a loss of natural capital. The concept of substitutability turns out to be at the core of the conflict between weak and strong sustainability.

Substitutability – technological development and critical natural capital

The fact that some natural capital can be replaced by monetary capital is obvious. This very substitutability is the basis for much of the economic growth we have seen since the Industrial Revolution. Consider agriculture: Modern agriculture replaces work performed by people and animals – whether plowing or sowing or harvesting – with tractors, harvest machines, and other machines; the fertilization that nitrogen-fixing plants or animal manure previously provided now comes from synthetic fertilizers that have fixed nitrogen from the air. Meanwhile, agriculture illustrates our fundamental dependence on some ecosystem services; we are still far from being able to manufacture human nutrition through artificial photosynthesis, which would sever our reliance on biomass and produce provided by plants and crops.

There is a range of substitutability for ecosystem services, some that we can readily replace with current technology (e.g., LEDs rather than camp fires, email rather than carrier pigeons), some that are hard or expensive to replace (e.g., manual pollination of fruit trees, compared with the service bees and other insects provide), to some fundamental ecosystem services that it is hard to imagine replacing (e.g., formation of new top-soil that we can farm, or oxygen for us to breathe). This leads us to two conclusions: (1) the possibility of substituting natural capital for monetary capital depends on the technologies available (or, as we will see, on the preferences we have), but (2) there are some kinds of natural capital that we cannot do without, i.e., *critical natural capital*.

The first conclusion implies that technology development will affect what natural capital is necessary for us to maintain a good standard of living for coming generations. The problem is that it's very hard to predict how future technology developments will affect the possibility of replacing natural capital with monetary capital (see Box 3.1 for an illustrative example). A more optimistic perspective on these opportunities leads to a position aligned with weak sustainability.

Uncertainty about future opportunities for substitution is one of the main arguments put forward by advocates for a stronger version of sustainability. They hold that an important difference between natural and monetary capital is that loss of natural capital is often irreversible; it cannot be recreated. We cannot experience a species that is lost, nor can we resurrect a fishery that has collapsed entirely, but factories, roads, and other monetary capital can be replaced much easier (so long as the knowledge has not been lost). This combination of natural capital that cannot be regenerated and the major uncertainties about how important natural capital may be for our welfare, currently as well as in the future, is what makes advocates of strong sustainability argue that natural capital that may be critical for future generations should be better protected.

BOX 3.1: VISINGSÖ – AN EXAMPLE OF HOW SUBSTITUTABIIITY CHANGES OVER TIME

After the Napoleonic Wars in the first decades of the 1800s, Sweden lost Pomerania in northern Germany. Pomerania had bountiful oak forests, which had supplied the Swedish navy with lumber for war ships. To ensure future access to timber, Sweden organized the planting of a large oak forest, several hundred hectares, on Visingsö, an island in the lake Vättern. From 1830 to 1850, more than 300,000 oaks were planted on the island.

In the 1970s, the oaks were ready for delivery, and the head of the Swedish navy was notified. In the intervening 150 years, a few changes had taken place in ship construction, and the navy understandably declined the offer to use the oaks to build ships.

This illustrates the difficulty in predicting future generations' need for natural capital and how technology developments may change those needs. For what it is worth, while the navy had no need for the oak timber, it has come in handy in restoring the royal warship Wasa, building the East Indiaman Götheborg, and making whiskey barrels for the distillery Mackmyra. The forest is also a popular tourist destination because of the unique landscape, and the rich birdlife attracts ornithologists. Technologies change over time, but so do human interests and preferences.

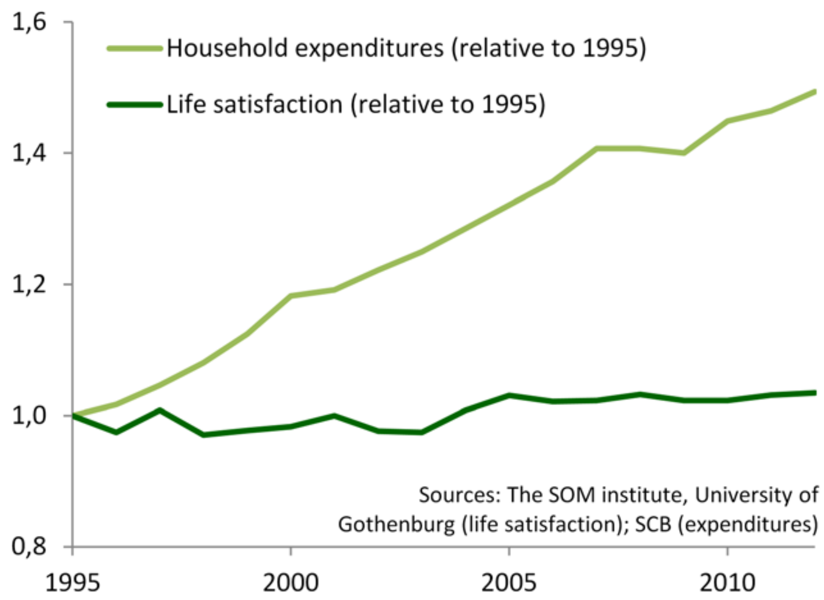
Substitutability and preferences

Thus far, this discussion about substitutability has centered on the extent to which we can replace natural capital with monetary capital in producing goods and services. But nature does not just contribute to human well-being by being a production factor in the economy. We also use nature directly, by being in it. Using nature for pleasure, deriving aesthetic satisfaction from it, and using nature for religious or spiritual experiences or knowledge, constitute cultural or social ecosystem services. To what extent can these be replaced by monetary capital and goods and services that we produce? That is, even if we, as in Bryan Norton's thought experiment, could sustain high economic growth despite (or because of) exploiting natural resources to the point where there is little nature left for future generations, have we deprived them of experiences that reduce their well-being compared to what it would have been?

Our answer will depend in part on our preferences; different people simply have different ideas about how important nature and nature experiences are for their well-being. A long-distance skater would presumably not agree that the experience of skating outdoors on lake ice can be replaced by skating indoors; a hockey player or a curling player would presumably much prefer the artificial ice to the rough lake ice. In part it will depend on the purpose. Consider the substitution above: the LED is superior to the campfire for most everyday purposes, but the camp fire can provide an entirely different kind of well-being.

Although the question of whether the social and cultural values nature provides us can be replaced depends on personal preferences, an ever-growing body of research demonstrates that there are real and measurable effects on human health and well-being from time spent in natural environments. A series of studies has shown a positive impact on mental health, stress levels, blood pressure, recovery after disease, and other indicators. For example, patients who have had surgery recover faster if they spend time in, or can see, natural environments; this holds for children exposed to stress, too.

So we have strong support for natural environments contributing directly to human welfare and well-being. Extensive research has also shown that the link between economic prosperity, as measured by GDP, and well-being or happiness is weak when average income (GDP per capita) is above USD 20,000 per year (roughly the current GDP level of countries like Greece and Portugal, whereas Swedish average income is USD 60,000 per year). That is, in poor countries there is a clear link between increased economic prosperity and how people experience their living situations, and consequently clear benefits from economic growth. But in rich nations like Sweden there is little reason to suppose that continued economic growth would lead to an increased quality of life, as shown in the figure on the next page.



Sustainability and the needs of future generations

According to the standard definition of sustainable development, sustainability is a development that satisfies current needs without compromising the opportunities for future generations to satisfy their needs. A key question arises: What needs will future generations have? In this chapter, we have attempted to point out that there are a variety of possible answers to this question and therefore a variety of possible requirements as to how we protect the environment today. The opposing views can be represented by weak and strong sustainability.

The argument for weak sustainability is based on faith in technology developments that largely entail a decoupling of both economic growth and human well-being from demand for natural capital and ecosystem services. Put another way, natural capital does not have any unique properties that make it impossible to replace with monetary capital. The existence of such properties is precisely the main argument for strong sustainability. If we cannot become independent of certain kinds of natural capital, the *critical natural capital*, this entails more stringent requirements regarding protecting natural resources for future generations, if they are to have a chance to have the same well-being we enjoy.

Two final points: First, weak and strong sustainability should not be conceived of as binary opposites, but rather as extremes on a continuous scale. Depending on how unique we consider natural capital to be, or how optimistic we are regarding technological substitutability options going forward, we will end up closer to one extreme or the other. Second, we need to realize that science can only provide part of the answer to substitutability questions. Scientific research will provide information about how unique ecosystem services are in the role they play in economic growth and our well-being, but our values will also help determine the value we place on nature. This is the topic of the next chapter.

Suggested reading:

Thomas Sterner. *Growth and the environment*. SIDA, 2003.

Bryan Norton. "Ecology and opportunity: intergenerational equity and sustainable options" in Andrew Dobson (ed.), *Fairness and Futurity: Essays on Environmental Sustainability and Social Justice*. Oxford University Press, 1999.

Eric Neumayer. *Weak versus strong sustainability: exploring the limits of two opposing paradigms*. Edward Elgar Publishing, 2003.

4.

SUSTAINABLE DEVELOPMENT FROM AN ETHICAL POINT OF VIEW

Key points in this chapter:

- *Entities with intrinsic value have value in and of themselves, while entities with only instrumental value have value to the extent that they support intrinsic values.*
- *Different ethical frameworks grant intrinsic value to different entities. The intrinsic value of an entity is not an empirical question; it is the subject of critical thought.*
- *In anthropocentric ethics, only humans have intrinsic value, while biocentric ethics grant all living individuals intrinsic value.*
- *In ecocentric ethics, the focus shifts from individuals to the whole, granting intrinsic value to entities such as landscapes and ecosystems.*

As noted above, the concept of sustainable development stems from certain ideas about what is valuable and what should be sustained or developed. People often disagree on issues concerning values; this chapter aims to provide the reader with tools to understand why different people have different perspectives on what sustainable development is, based on their differing ethics. The chapter introduces basic concepts and describes a few theories about the value of animals, plants, and nature.

Ethics: intrinsic and instrumental values

For short, ethics – moral reasoning – is about answering the question "What is good?" or "What is the right course of action?" What we consider to be good and right can be tangible things, like human life, or life in general, but also actions, such as telling the truth or acting with virtue, or more abstract concepts like truth or meaning. Later on in the chapter, we will consider different theories for what is good.

In this context, it is important to distinguish between intrinsic values and instrumental values. Intrinsic values do not derive from something else. We are morally obligated to protect, or at least to avoid damaging, whatever has intrinsic value. By contrast, instrumental values derive their value from something beyond themselves, whether something with intrinsic value or from something else with instrumental value. If we think human well-being is intrinsically good, then good friends, for instance, might have instrumental value. Money is another example of something that has instrumental value; it can be useful to achieve other goals, but having a lot of money is hardly a goal in and of itself.

The question of which values are intrinsically good is of fundamental importance in distinguishing among different kinds of morality. According to classic Christian ethics, for example, humans and human life have intrinsic value. According to some interpretations, this means that abortion is always wrong because the fetus is human life. If we instead consider human pleasure to be intrinsically good, and fetuses are not able to experience pleasure, the abortion issue is much less complicated.

The question of what has value is intimately connected to the question of what is the ethical course of action. Broadly speaking, there are two moral theories about good actions: *consequentialism* and *deontology* (duty ethics). Consequentialism judges the rightness of an action by its consequences. Utilitarianism is a form of consequentialism according to which we are to act so as to bring about the greatest happiness for the greatest number. For consequentialists, happiness, or pleasure, has intrinsic value, while the actions that lead to this goal are of instrumental value.

Deontology is typically conceived of as the opposite of consequentialism. According to duty ethics, what's right or wrong is determined by a set of moral principles. The Ten Commandments are a good example of such a set. We ought not kill, steal, lie, commit adultery, etc. In this case, the intrinsic value can be found in the action or the duty, not in the consequences.

Deontological and consequentialist moral systems can readily be seen to reach different conclusions. For example, suppose that you lived in Nazi Germany and that you yourself were not Jewish, but that you had helped a Jewish family hide in the basement. The Gestapo are at the door, asking if there are any Jews hiding nearby. The deontologist would say not to lie, unless the duty not to lie was trumped by a more stringent duty to protect humans against harm. A utilitarian would lie without a second thought, given the obviously better consequences of lying than of telling the truth.

Hume's Law

In the 17th century, Scottish philosopher David Hume conceived of what we refer to today as *Hume's Law*. According to Hume, we cannot derive what we *ought* to do from how the world *is*. Hume's point is that there is a fundamental difference between, on the one hand, phenomena that can be investigated with respect to their physical properties, and, on the other, how we want the world to be. We cannot conclude that slavery should be perpetuated simply because it has existed through the majority of human existence. The fact that ecosystems stabilize following a small perturbation does not entail that it is wrong to disturb a system so much that it cannot regulate itself (nor does it entail that it is *not* wrong to do so).

Goodness is not the kind of thing we can experiment on and discover in the lab. Instead, we can *reason* about what *reasonably* should have intrinsic value and what the consequences of this may be (see Box 4.1). Suppose someone thinks we have a moral duty never to destroy any ecosystem. For clarity, this idea would need to be accompanied by an account of the limit between changing and destroying an ecosystem. If no changes whatsoever are acceptable, then agriculture is immoral, for example. If some changes are acceptable, then how many, or how substantial? Ecosystems exist everywhere on Earth, even on an asphalt lot. If major changes are deemed acceptable, the moral principle would be empty. Even if we cannot determine empirically how large a change is acceptable, we can reason meaningfully about the issue.

But does this mean that empirical knowledge is irrelevant in ethics? No. Once we have decided what has value, we can investigate how to promote this value. If a forest is to be clear-cut, and we consider biological diversity of intrinsic value, it is important to explore how the clear-cut will affect animals and vegetation. On the other hand, if we only consider human pleasure to be of intrinsic value, maybe we only have to ask those who live in the area how they feel about the clear cut. However, the clear cut could affect ecosystem services of which the people there are unaware. That consideration becomes more important if we also take the pleasure and well-being of future generations seriously. What we find intrinsically valuable matters to the kind of information we seek out, and that information is subsequently used to assess various courses of action. In short, information – knowledge – is important in order to determine instrumental values.

BOX 4.1: A SYSTEM OF ETHICS

A system of ethics is a coherent idea about what has value, how different values should be weighed relative to each other, and why something has value. Moral philosophy generally requires that a system of ethics is:

- **Consistent**, i.e., that the parts of the system go together, logically. It would, for instance, be unreasonable to assert that people may marry whom they please while also holding that parents may decide on spouses for their children.
- **Universal**, i.e., the same principles should apply to separate cases if the cases are similar in the ethically relevant respects. For example, it would be unreasonable for people to have to have a certain hair color, in order to have a certain kind of job. However, having a certain kind of education in order to be eligible for the job might be a reasonable ethical principle. That principle would then apply to everyone, i.e., it would be a *universal* principle.
- **Intuitive**, i.e., the system of ethics coincides with what we experience as right. A system of ethics that concludes that it is fine to kill children does not satisfy the requirement of intuitiveness. On the other hand, our moral intuition works best in everyday cases. Counter-intuitive results in extreme cases are not typically considered a strike against a system of ethics. For example, that it could be morally correct to kill in order to save the lives of others may be morally counter-intuitive to some, but this is not the kind of moral choice many face on a regular basis.

What has value? Anthropocentrism, biocentrism and ecocentrism

Human values have shifted over time. Often, killing someone has been deemed less problematic if the victim is from elsewhere, i.e., from some other village or country. In recent centuries, we have come to talk more and more about the equal worth of all humans. This means that all people are considered intrinsically valuable, and that this value is equal for all. More and more individuals are thereby included in what has been called the expanded moral circle. This perspective, which grants humans special status, is called *anthropocentrism*. Sustainable development ties in with this tradition, with the idea that human well-being in the future matters, too, expanding the circle of moral concern to include future generations.

However, it is not clear that only humans have intrinsic value. Current legal traditions often prohibit cruelty to animals, sometimes on the basis of assigning some intrinsic value to animals, although less so than to humans. Some systems of ethics seek to expand the circle of concern to all sentient animals. The idea is that since many animals can experience pain, suffering, and joy, these experiences should be given moral weight. This perspective renders both meat production and animal testing deeply problematic.

In *biocentric* ethics, the circle of moral concern is expanded to cover all life: humans, other animals, and plants. Advocates for biocentrism do not generally assign the same value to all life, which would make it hard for people to eat at all. The ethical implications of biocentrism are mainly that nature should be left alone, and that humans should not hurt or kill animals or plants without good reason.

Anthropocentrism and biocentrism can be conceived of as polar opposites, assigning different values to different individuals. According to stringent anthropocentrism, only humans have intrinsic value. This does not mean that harming animals and nature is unproblematic, since these often have instrumental value for human well-being. Further, if no humans ever came to appreciate a certain forest, but there was a demand for lumber, anthropocentrism would not provide much argument against cutting it down. Moving away from the pole of pure anthropocentrism, some might say that other sentient mammals also have intrinsic value, even if they are not equal to humans. Even farther away, others would find it morally problematic to kill a plant.

Even if the difference between anthropocentrism and biocentrism is great, both ethical systems assign individuals intrinsic value. Not even the biocentric perspective assigns value to species. Species and ecosystems derive value from the use they have for individuals. Without bees, plants are not pollinated, which disadvantages individual animals and plants. So bees as species have *instrumental* value in biocentrism.

In *ecocentric* ethics, the focus shifts from the individual to the whole and to groups. In radical ecocentrism, only the landscape, the ecosystem, the whole have intrinsic value. In this view, individuals only have instrumental value. Ethical systems that assign intrinsic value to individual people and animals often assume that these individuals have consciousness, and that negative emotions should be avoided. In biocentric ethics, the goal is rather to thrive. But ecosystems do not have feelings, and it might not be so simple to determine whether they are thriving. In ecocentric ethics, the foundational idea is instead often that nature be preserved the way it was before humans came along and began to have an impact. Different ethical systems thus do not only differ on what has value, but also on why.

Ecocentric ethics assign intrinsic value to species, not individuals. The distinction might seem uninteresting. If a species of ape has intrinsic value, individuals of the species cannot be killed at will, for instance. But there is room for a lot of conflict here. If only the species has intrinsic value, for chimpanzees, say, we could in principle kill off almost all these apes except for a few, which we lock up in a zoo. The species is preserved. On the other hand, if we merely seek to treat individual chimpanzees well, the species may be lost. Changes to ecosystems may affect their ability to breed, let us say. Shutting some of them away in a zoo simply to preserve the species would seem immoral, would seem to wrong the individuals who were shut away. But in radical ecocentrism, individuals may very well be sacrificed for the good of the species, and individual humans may be sacrificed for the good of a natural ecosystem.

To avoid the poor treatment of individuals, some propose a milder version of ecocentrism, in which individuals, ecosystems, and species all have intrinsic value. This grants humans both intrinsic value and instrumental value to the extent that they contribute to the good of the whole.

Where we fall on the anthropocentric-ecocentric spectrum matters greatly to our perspective on interventions in nature, and to how strong our reasons are for protecting plants, animals, and nature. The concept of sustainable development is traditionally rooted in an anthropocentric perspective, but ecology is often granted a sizeable instrumental value for the well-being of humans. Such a high instrumental value can be tied to a strong sustainable development perspective. In this view, what nature offers us is simply deemed hard to replace with human-created capital. But similar conclusions can be reached starting from a more ecocentric perspective. Obviously, if nature has intrinsic value, it cannot be replaced with human capital. The reasoning is different, but the conclusion is the same, a position that resembles strong sustainability.

Suggested reading:

Mikael Stenmark. *Miljöetik och miljövård*. Studentlitteratur, 2000.

'Environmental Ethics', in Stanford Encyclopedia of Philosophy (http://plato.stanford.edu/entries/ethics-environmental/), 2015.

5.

THE MANY FACES OF SUSTAINABILITY

Key points in this chapter:

- In order to engage constructively with sustainability issues, it is worth understanding the perspective others bring to the table and what underlies differences in opinion.
- There are four sets of opposites in how solutions to sustainability problems are perceived: efficiency – sufficiency; technology solutions – lifestyle changes; individual solution – political solutions; reformism – radicalism.
- Despite the range of definitions, essentially all definitions of sustainable development include the following elements: the concept is driven by normative questions; justice is key; systems-thinking and holistic perspective are required; it is a process.

In previous chapters, we discussed how ideas about sustainable development are affected by what is considered to have value, beliefs in technological development, and how easy or hard it is to replace ecosystem services. Two people could very well have a conversation about sustainable development but be talking about two entirely different things. In order to work constructively on sustainability issues, it is worth trying to understand other perspectives and what underlies differences in opinion. By understanding where people actually disagree, it is easier to find new paths and solutions to the problems we face.

In this chapter, we summarize the pairs of opposites we have come across in previous chapters and describe the pairs of opposites that underlie differences in opinion about what solutions are best for managing the sustainability challenges we face. By framing this in terms of pairs of opposites, we do not mean to suggest that the world is black and white; it is full of gray, of course, and most of us fall somewhere in between the two poles. But most of the time, we fall closer to one end than the other. It is worth reflecting on where you fall and how this relates to the way you see things and why you agree with certain opinions and not others.

Pairs of opposites connected to ideology and values

The first two pairs of opposites have to do with ideologies or philosophies, and conceptions of what has value. They affect ideas about what is sustainable and what is important to prioritize.

Anthropocentrism – Ecocentrism

This pair of opposites has to do with what is believed to have value. Of interest in this context is the kind of value assigned to nature. On one side, we have those who grant intrinsic value exclusively to humans; if nature has value whatsoever, it is instrumental, i.e., contingent on the good it does humans. On the other end of the spectrum we have ecocentrism, which grants intrinsic value to entire ecosystems. Naturally there is a range of views between these two poles (see Chapter 4).

High substitutability – Low substitutability

This pair of opposites addresses the ease with which the goods and services offered by nature can be replaced – substituted for – by economic capital. A belief in high substitutability entails believing that these goods and services are easy to replace; a belief in low substitutability goes hand-in-hand with holding that natural capital should be protected and kept as intact as possible. This framework is connected to perspectives on technological development, as well as what value is assigned to nature. An ecocentrist typically finds it impossible to substitute nature. (For more details, see Chapter 3.)

PAIRS OF OPPOSITES LINKED TO PERSPECTIVES ON SOLUTIONS TO SUSTAINABILITY CHALLENGES

The discussion above addresses differences in approaches to the definition of sustainable development. If we consider solutions to sustainability challenges, we find pairs of opposites that affect perspectives on what actions to take. The point is, even if two parties agree on the definition of sustainable development – what counts as sustainable, what should be preserved and why, they may fundamentally disagree on a course of action. But underlying ideas about the value of technology or nature can also impact perspectives on the right course of action. Let us consider four pairs of opposites that frame perspectives on how to manage sustainability challenges.

Efficiency – sufficiency

The pair of opposites *efficiency – sufficiency* pertains to either reducing the amount of energy and resources used per product or service (e.g., kWh/m^2 to heat a home, amount of fuel per distance travelled) or setting limits as to how much a certain service is needed (e.g., indoor temperature, annual distance driven). Often, the focus is on energy. An unbridled faith in energy efficiency leads some to believe that by simply making household appliances, cars, and other technology more efficient, we will not need to worry about how much we use them or how many we have. At the other end of the spectrum, extreme believers in sufficiency hold that the actual service itself, or the number of products, must be limited in order to make an absolute reduction in energy use. Consider homes: The efficiency perspective holds that if we reduce energy use per unit of living space, we can cut residential energy demand and thereby carbon dioxide emissions. The sufficiency perspective instead holds that the indoor temperature should not be too high or low, but also living areas should not be too large, since this also affects how much energy is needed to heat or cool the home.

Those who mainly emphasize the importance of efficiency often have faith in technological progress and breakthroughs, but also believe that people should not “be told” how to live their lives. People should not have to change their lives; instead of being told how much is enough (for example, a single refrigerator), the idea is that each energy service or activity should have as little environmental impact as possible. If quantity is the only constraint, people may simply use the product or service more, cutting into the effect of the efficiency gains. Consider driving: If your car is fuel-efficient, you may use it more often and drive more, simply because it costs you less to drive. Energy Star appliances in the U.S. are another example. Regulation has made refrigerators much more efficient per unit of volume, but energy use has not been reduced, because now refrigerators are larger and have more added functions (like ice machines).

The difference between making products and services more efficient and limiting their use can also be applied to consumption in general and our entire economy. On the one hand, some believe that as long as the economy becomes more energy efficient (i.e., if energy use per GDP is reduced), we can continue to have economic growth, while others instead believe that growth has to be limited (see Chapter 3 for a more in-depth consideration of economic growth).

Technology – lifestyle changes

This pair of opposites resembles *efficiency – sufficiency* but is broader. Those who believe in technology mainly see technological breakthroughs as solving major global challenges. In the energy and climate arena, fusion is an example. Another is geo-engineering: one geo-engineering scheme envisions sending particles into the stratosphere to have a cooling effect. These believers are optimists when it comes to developing and spreading technology rapidly. Their positions are often, but not always, linked to faith in the substitutability of natural capital (weak sustainability).

At the other end of this spectrum lies a lack of faith in technology to save the day. Many different reasons may underlie this position, for instance, the belief that technology simply will not be enough, that other measures will also be required, that technological development simply will not happen fast enough, or that new technology will create new problems. The alternative is then for people to change their values, either toward a more biocentric ethics or toward less materialistic values. These changes in values are supposed to lead to changes in lifestyles, leading to less environmental impact. Consumption will be cut, air travel reduced, and diets transformed.

The environmental problems associated with eating meat are a good example. If we believe in a technological solution, we might hope that synthetic meat will succeed, that we will be able to continue eating our regular diets but without the negative effects of raising animals. If we instead believe in changes in values, we hope more people will become vegetarians, because they understand that this is the “right” thing, for nature and for the animals.

Individual solutions – political solutions

This pair of opposites is about who is responsible for solving environmental and sustainability problems. Is it the individual? Does the obligation lie with each and every one of us to turn off lights when we leave a room, ride our bikes or use public transport more often, choose energy-efficient appliances, travel less by air, recycle more, etc.? Many contributions to the climate debate focus on precisely this: what individuals can do. In April 2014, Swedish newspaper DN published the story “21 ways to cut your climate pollution.” The article was about how to change your diet, travel, and living. These kinds of lists can be found in other publications and all over the Internet. The underlying idea, ultimately, is that if individuals were to simply live more environmentally-friendly lives, we would solve our common sustainability problems. Some view focusing on the behavior of individuals as the main path to change, because they have lost faith in policy makers' ability or desire to solve the problems.

Others think the responsibility mainly belongs with policy makers. Two principal reasons account for this view. First, the sustainability challenge is considered such a large problem that the solution requires centralized control. It will not help if everyone buys energy-efficient appliances, if coal-fired power plants continue to emit massive quantities of carbon dioxide. The only real solution is strong economic incentives, like a tax on carbon, or simply shutting down the plants. The other reason is that it does not seem fair to blame individuals when all of society bears responsibility. Collective solutions are called for.

These two reasons for believing policy makers bear responsibility do not have to go together. You might think, for example, that individuals have a responsibility but not the means to solve a problem like the climate challenge. Instead, their task is to pressure politicians and support policy makers who are willing to implement the required measures.

An extreme variant of the position that political measures are required to solve sustainability problems is to argue that an enlightened despot should make the required decisions, without having to risk being removed from power by dissatisfied people or business interests. However, few in our democratic society would go so far as to argue for this.

Reformism – radicalism

Overall, this pair of opposites is about whether you believe our sustainability problems are rooted in the very framework of society or not. Can we have an industrialized, capitalistic society or do we need a new way to structure society in order to solve sustainability problems?

Reformism is defined by the belief that only small adjustments are needed to solve the problems a system faces, not fundamental changes to the system. Different degrees of adjustments may be needed. When it comes to climate change, for example, some think a price on carbon is sufficient, while others think additional measures providing direct support for new technologies, including solar power, are needed. But both of these are instances of reformism. The question is only how much to reform the system. The environmental problems caused by agriculture are another example. A reformist would advocate making adjustments to the amount of fertilizer added to the soil, or better regulation of pesticide use.

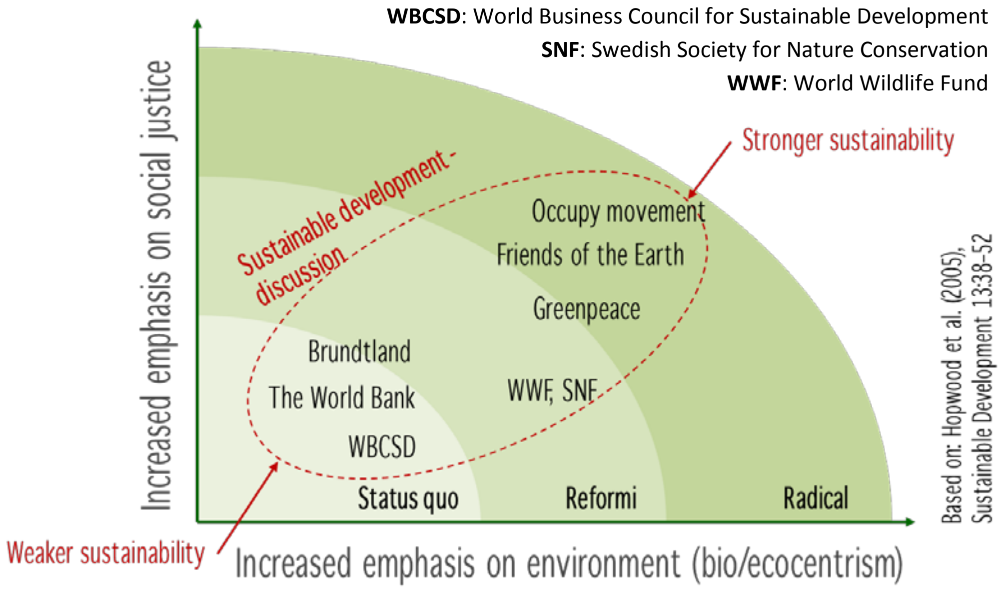
Some also advocate for fewer changes, acting more within the framework of the status quo. They have a strong link to those who believe in technological solutions. These solutions, along with more information provided to consumers, will suffice to solve the sustainability problems. Economic growth and the market economy are key components in developing the necessary technology. For example, according to the free-market think tank Timbro, "[c]apitalism makes it possible for us to adapt and address the environmental problems we have created earlier."

The more radical perspective instead sees the problem as stemming from how society is organized and views that as what needs to be fundamentally changed. The analogy is that we are driving toward an abyss, and small adjustments simply mean that we will get there a bit more slowly instead of avoiding it altogether. Author and activist Naomi Klein highlights the relation between capitalism and climate change in her book *This Changes Everything*: "It's not about carbon, it's about capitalism." Klein asserts that simply introducing a price on carbon will not be sufficient. Instead, if we are going to meet the climate challenge, we need to assume power over corporations, we need local markets, and we need to renew democracy. Let us consider the environmental problems connected to agriculture once again. In that context, someone with a more radical perspective would advocate for self-sufficiency and ecological farming, instead of small adjustments to today's industrial agriculture.

The same line of thinking can be applied on a smaller scale. Take meat consumption, for example. A few years ago, a new hamburger was introduced, 50% beef, 50% beans. The idea was to reduce meat consumption and its related environmental impact. This amounts to a dietary reform, not a fundamental change like switching to a vegan or vegetarian diet.

Is everything sustainable?

We have seen that many different factors determine what counts as sustainable. Among other things, this means that different definitions of sustainable development will have different emphases, such as social factors, or will be more biocentric by not only considering human rights (see Box 5.1 for examples). The image below sketches the sustainability landscape based on emphasis on social justice and transformation. Friends of the Earth are, for instance, representatives of a stronger, more radical perspective. Their mission is to “change the economic world order to build solidarity and ecological sustainability.”[3] WWF has a greater focus on the ecological dimension of sustainable development and works in partnership with large corporations. The Swedish Society for Nature Conservation also focuses primarily on environmental issues. A typical example of their reform-focused work is the certification *Bra miljöval* (“Good environmental choice”), which seeks to shift consumer behavior in a more environmentally friendly direction, by providing information, without radically changing behavior. The Transition Movement has a somewhat more radical approach, focusing more on locally produced goods and services and emphasizing the importance of relationships over material consumption.[4] Large international organizations, such as the World Bank, and others with close ties to the business world, such as the World Business Council for Sustainable Development (WBCSD), are closer to the status quo.



We have painted a picture with a lot of variation. Does this mean that sustainable development can be defined any way we, or you, like? No. Several factors unite essentially all definitions of sustainable development (see Waas et al. in the suggested reading):

1. The concept of sustainable development is used *normatively*, to define what *ought* to be done. It requires us to make decisions based on values.
2. Justice is central to sustainable development, both within and between generations, and may extend to species other than humans.
3. Sustainable development requires a systems approach and a holistic approach.
4. Sustainable development is a process, not a destination.

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[3] Translated from the Swedish Friends of the Earth site, http://www.jordensvanner.se/om-jordens-vanner
[4] https://www.transitionnetwork.org/about/principles

BOX 5.1: EXAMPLES OF *SUSTAINABLE DEVELOPMENT* DEFINITIONS

> *Sustainable development implies using renewable natural resources in a manner which does not eliminate or degrade them, or otherwise diminish their usefulness to future generations... Sustainable development further implies using non-renewable (exhaustible) mineral resources in a manner which does not unnecessarily preclude easy access to them by future generations ... Sustainable development also implies depleting non-renewable energy resources at a slow enough rate so as to ensure the high probability of an orderly societal transition to renewable energy sources.*

Goodland & Ledoc, *Ecological Modeling* (1987)

This definition places very little emphasis on social considerations, instead concentrating solely on resources, although it does take future generations into account. The definition places some faith in substitutability but recognizes that the pace of change matters.

> *[Sustainable development] can also be expressed in the simple terms of an economic golden rule for the restorative economy: Leave the world better than you found it, take no more than you need, try not to harm life or the environment, make amends if you do.*

Hawken, *Ecology of Commerce*

With the phrase, “take no more than you need,” this definition leans toward sufficiency. It can be read as biocentric because it mentions “life” in general, not just human life.

> *[The authors of* Blueprint for a Green Economy *define* sustainability*] in economic terms as ‘non-declining capital.’ [Taking] capital to mean not just monetary and human capital, as economists conventionally consider capital to be, but ‘natural capital’, the value to human beings of the Earth itself.*

Dresner, *Principles of Sustainability,* 2012

This definition represents an anthropocentric perspective, valuing the Earth instrumentally, for the sake of humans, while providing a strong(er) definition of sustainable development, because it emphasizes the need to preserve both monetary and natural capital.

Suggested reading:

Bill Hopwood, Mary Mellor, Geoff O’Brien. "Sustainable Development: Mapping Different Approaches." Sustainable Development 13:38-52, 2005

Tom Waas, Jean Hugé, Aviel Verbruggen, Tarah Wright. "Sustainable Development: A Bird’s Eye View." Sustainability 3:1637-1661, 2011

6.

SUSTAINABLE DEVELOPMENT – ENGINEERS: ROLES & RESPONSIBILITIES

Key points in this chapter:

- *Engineers work in a social context: technology affects and is affected by societal processes, conflict, and values.*
- *Ethical considerations are the rule, not the exception, and a constant part of engineering (although varying in importance).*
- *As a professional group, engineers are responsible for contributing to sustainable development by actively participating in decision-making processes in society, and by clarifying risks and environmental consequences of technologies and projects.*
- *Societies face sustainability problems that demand more of engineers, especially in our ability to analyze complex systems and work in cross-disciplinary teams in which values will differ and will impact technology assessments.*

In Chapter 1, we saw that the explosion of technology gains in the past century has contributed to great improvements for a large share of the global population – less poverty and hunger, lower child mortality, and higher life expectancy – while the environmental consequences have been dire – over-fertilization, loss of biodiversity, increased greenhouse warming, etc. Are engineers and scientists who push technology developments morally required to consider the negative consequences these technologies may have when adopted by society at large? Do engineers and scientists have a *duty* to contribute to sustainable development? If so, what kind of duty? And what does it require of future engineers? This final chapter considers these questions.

Engineers and the social side of technology

Societies have been shaped by technological developments throughout human history, from the first tools to the molding of metal into objects, via the art of writing and the invention of the printing press, and the Haber-Bosch process (with artificial fertilizers bringing far greater yields), to the explosive growth of information technology in recent decades, which is changing how we maintain relationships and engage in political discourse. Society also affects technology development, but this is perhaps not as evident and is therefore not as widely understood. According to the conventional picture of technology development, the process is deterministic, governed by objective facts, with engineers and scientists conducting experiments and tests to find the optimal solution to a technical problem. This picture has gradually been modified as we have come to appreciate technology as in part socially constructed. Interaction among engineers, citizens, and policymakers, who interpret and assess technology in different ways, governs technological development. Of course, the laws of physics (such as the Second Law of Thermodynamics) create boundaries for technological development, but economics, politics, conflicts, norms, and values also shape the end result.

The history of the bicycle provides a classic example. Early on, the asymmetric design with a large front wheel, familiar from old pictures, dominated. This design appealed to young and adventurous men, who conceived of the bicycle as a sport and a pastime, not a mode of transportation. The modern bicycle, with its two equal, medium-sized wheels with inflatable tires, came about because other groups (not the least women) demanded a safer means of transportation. This bicycle was even called "the safety bicycle" at first.

This is a clear example of technology not developing in a vacuum, governed only by the laws of physics and objective criteria for what counts as optimal. Technology is created *by* and *for* people, and the criteria for what solutions count as optimal will therefore always be affected by societal conditions and values. Different groups may therefore have different ideas about how technology ought to be designed and developed, as reflected in the evolution of the bicycle.

Designing benches in public spaces so that it becomes impossible or very uncomfortable to lie down (for example by having an arm-rest in the middle or a slanting seat) is a more controversial and recent example of how design is affected by societal conditions. The point here is not the purpose of the design – sometimes the aim to discourage homeless individuals from sleeping on the benches is conceded, sometimes not – but the consequence: some individuals have a harder time using public space. In the words of social scientist Jane Summerton, technology "is never neutral; technology reflects a plethora of values, considerations, and negotiations."

In their textbook on engineering ethics (see *Suggested reading*), Mike Martin and Roland Schinzinger highlight the idea that engineering is a "social experiment" in order to point out that technology development takes place in a social context. The models and materials engineers use will always be subject to caveats and uncertainties; projects cannot generally wait for complete knowledge or be developed in a lab environment. Rather, knowledge comes from testing and experimenting on new technology in the real world, with unknown and often unexpected results. For example, new research shows that energy efficient LEDs, recently bestowed with the Nobel Prize in Physics, attract insects more than older light sources, which risks affecting their behavior and disrupting ecosystems. Engineers have a responsibility to continually assess their projects and identify possible risks associated with technology and inform consumers and decision makers in a manner that allows them to make informed decisions. In Martin and

Schinzinger's view, ethical considerations and assessments are therefore a natural part of even the simplest engineering projects.

Engineering ethics and sustainable development

Many engineering associations' codes of conduct make clear that engineers have a duty to society (cf. the Wikipedia article, *Engineering Ethics*). The Honor Code of the Swedish Association of Graduate Engineers (Box 6.1) states that engineers are personally responsible for ensuring that technology works to the benefit of humankind, environment, and society, and engineers must provide their technology expertise and inform society of risks associated with their work.

The current national goals for Swedish engineering programs require students to demonstrate a sufficient "ability to make assessments, taking into account the relevant scientific, societal, and ethical considerations" [our translation]. In engineering programs all over the world, courses and discussions on engineering ethics are standard fare. However, these discussions frequently concern risk-management issues and focus on individual incidents, often spectacular ones, such as the Challenger explosion or the Chernobyl meltdown. The focus is on the individual engineer's responsibility to report mistakes or anomalies, or to stand up for good engineering practices.

This narrow approach to the role of the engineer in contributing to sustainable development is problematic for two main reasons. First of all, the sustainability challenges we face do not consist of, nor are they the result of, isolated incidents or accidents, but reflect structural problems rooted in how our energy, industrial, and agricultural systems have developed. Even if these problems also result in individual environmental catastrophes – such as the gas leak in Bhopal, India, in 1984, which killed more than 10,000 people, or the oil spill in the Gulf of Mexico in conjunction with the explosion of the oil platform Deepwater Horizon in 2010 – it would be wrong to focus exclusively on these spectacular incidents. Also, in order to address structural problems, we cannot simply focus on the responsibility of individual engineers, since they have very little ability to affect the fundamental and overarching framework.

Second, there is a difference between personal and professional ethics. An engineer can very well choose not to work for the weapons industry for personal reasons, without holding that all engineers should refuse to contribute to the weapons industry. In order to discuss the role of the engineer in sustainable development, we need to shift the focus from the moral responsibility of an individual engineer to the collective responsibility and values of the profession.

Professor of Ethics Deborah Johnson points out that engineers as a profession (along with other professional groups) have a duty to contribute to the good of society, but that the interpretation of what this means (what is the *good of society*?) cannot be left exclusively to engineers to determine. Engineers should inform those affected by a given project or technology of the associated risks, but decisions that require

BOX 6.1: HONOR CODE - THE SWEDISH ASSOCIATION OF GRADUATE ENGINEERS

Technology and science are powerful tools in the service of humankind, for better or for worse. These tools have fundamentally changed society and will continue to impact humanity in the future. Engineers carry and keep technological expertise. Engineers therefore have a special duty to ensure that technology is used for the betterment of humankind and society, and that improved technologies are passed down to future generations

Honor Code – Ten Principles

- Engineers should feel a personal responsibility to use technology for the betterment of humankind, environment, and society.
- Engineers should strive to improve technology and technical expertise toward more efficient use of resources without harmful impacts.
- Engineers should make their expertise available in public and private contexts to develop the best basis for decision-making and to highlight the opportunities and risks of technologies.
- Engineers should not work in or with disreputable corporations and organizations or toward goals in conflict with personal values
- Engineers should be completely loyal to employers and colleagues. Obstacles in this context should be addressed openly, starting at work.
- Engineers may not use inappropriate methods to gain employment, assignments, or orders, or try to damage the reputation of a colleague by making unfounded accusations.
- Engineers should respect the confidential nature of information and the rights of others to ideas, inventions, investigations, plans, and blueprints.
- Engineers may not work for unauthorized interests and should openly declare economic and other interests that may affect their credibility as impartial or faith in their judgment.
- Engineers should, whether in private or public, in writing or speech, pursue factual presentations and avoid making incorrect, misleading, or exaggerated claims.
- Engineers should actively support colleagues who face difficulties because of having acted in accordance with this code, and should strive to prevent violations of this code.

Translated from www.sverigesingenjorer.se/Om-forbundet/Sa-tycker-vi/hederskodex

weighing those risks against possible benefits demand more than technical expertise and must be made in consultation with other groups, including politicians and citizens. This situation is reflected in the declaration made by the U.S. engineering community in advance of the Rio+10 Summit in Johannesburg in 2002, which argued that the “engineering community must become engaged earlier in the policy formulation and decision-making process, through its technical and professional societies, to provide knowledge of environmental impacts, costs, and feasibility."

New challenges – from environmental problems to sustainable development

The sustainability challenges society faces are different in kind from the environmental challenges we have faced (and often overcome) in the past. Prior problems, such as water pollution and smog, were local, had clear cause-and-effect chains, and were relatively simple to solve using end-of-the-pipe technologies. Compare this with the climate challenge, a global crisis whereby greenhouse gas emissions contribute to the problem no matter where they occur, and the relation between cause and effect is complex, often invisible, and plays out over centuries.

Some use the concept *wicked problem* to describe the challenge of sustainable development. One factor separating wicked problems from classic engineering problems is that the latter, even if they are complex, have clear goals and well-defined boundary conditions, such as limits on materials or processes. Wicked problems do not have unambiguous objective problem formulations; the characterization of the problem is part of the solution.

Consider climate change once again. Some regard the basic problem to be that coal and oil dominate our energy system, so increasing the price on carbon dioxide emissions and making alternative energy sources more profitable would solve the problem. Others consider climate change to be rooted in our consumer society and a growth paradigm, where a constantly growing economy inevitably leads to increased use of resources and emissions of greenhouse gases, so that as long as this underlying structure is not altered, the climate problem will not be solved. (Compare with the discussion on stronger and weaker sustainability in Chapters 3 and 5.)

Accordingly, wicked problems are characterized by not having unique and objective "optimal" solutions. Differences in values mean that different actors have diverging perspectives on what constitutes a good solution, even if they all have access to the same information and facts. Wicked problems are socially complex, rather than technologically complex. Nuclear power is a good example, where different perspectives on the role nuclear energy can play in reducing emissions depend to a large extent on different values: How should the risks associated with handling radioactive nuclear waste for tens of thousands of years be assessed? How serious is the risk that global deployment of nuclear power will lead to nuclear proliferation?

Finally, wicked problems are dynamic, changing over time – there is no obvious point at which the problem can be considered solved. As opposed to classic engineering problems, every attempt to solve a wicked problem has an impact, often unexpected, that will affect it and future attempts to solve it. A clear example of this can be found in U.S. and European policy measures to increase use of biofuels, including corn ethanol and rapeseed oil biodiesel. Once consumption of these fuels increased rapidly in the early 2000s, critics asserted that this was causing food prices to increase globally, which adversely affected poor people and led to the clearing of rainforests to increase agricultural production. The latter could reduce the climate benefit of the biofuels or even reverse it. Neither politicians nor most researchers had anticipated this, and the EU has since had to revise its goals for biofuels in order to limit these effects.

Sustainable development and “the new engineer”

The difference between classic environmental problems and the wicked sustainability problems outlined above entails new requirements of the engineers tasked with contributing to their solution. Many have written about the need for a “new engineer” with broader expertise than the purely technical expertise that has dominated the profession (cf. Beder and Wiek et al. in the suggested reading). This is also reflected in the requirements of engineering programs (see Box 6.2). Fundamentally, there are three areas in which the new engineer must have deeper expertise: systems thinking, cross-disciplinary work, and insights in ethics.

Understanding sustainability problems and finding solutions requires a systems approach. Many sustainability problems are connected; trade-offs are required among goals and interests, but synergies may also create opportunities. For instance, by increasing agricultural yields, less land area is required to feed the growing (and increasingly wealthy) global population, which reduces the demand for converting forests to fields and pastures (the greatest threat to biological diversity today), poor farmers are better able to make a living, and food costs less, which means fewer poor people go hungry. But higher yields require greater inputs, which leads to increased run-off of over-fertilizing and polluting substances from cropland and higher emissions of the potent greenhouse gas nitrous oxide (from synthetic fertilizers). Other possible effects are further demand for already scarce freshwater supplies for irrigation and, paradoxically, increased deforestation, as lower food prices increases the demand for arable land and higher yields increases the profitability of converting forests to cropland. Understanding these intricate relationships is a necessary condition for finding technical and political solutions to the sustainability challenges facing agriculture, or else new problems will be created, much the way the indirect effects of the biofuel measures took policy makers by surprise.

An ability to work in multidisciplinary settings, working with others from other disciplines and with the end-users of technology, is necessary in order to find sustainable solutions to complex problems. Wicked problems are characterized by different groups having different opinions about what counts as a good solution. Only dialogue among these different groups can create the understanding needed to make the appropriate trade-offs and thereby approach solutions that are acceptable to all parties. This means engineers need to be able to communicate and appreciate other actors’ perspectives and attitudes to technology. Instead of presenting a single optimal solution, engineers are required to know how to present a range of technology alternatives and account for the consequences so that all parties can make well-informed, collaborative decisions.

BOX 6.2: ENGINEERING PROGRAMS AND THE SUSTAINABILITY CHALLENGE

The new demands placed on engineers by current societal challenges are clearly mirrored in requirements and goals in engineering programs in Sweden and abroad. In 1996, ABET, the Accreditation Board for Engineering and Technology for U.S. colleges and universities, adopted new criteria for the expertise a newly minted engineer should have. In addition to training in mathematics and science, and classic engineering problem-solving skills, the requirements list a number of professional areas of expertise, including:

- an ability to function on multidisciplinary teams
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

Similarly, the Swedish national program goals for engineering degrees require students to demonstrate:

- an ability to develop and design products, processes, and systems taking into account the needs and conditions of people and society's goals for economic, social, and ecological sustainable development
- an ability to work in teams with a variety of members
- an ability to verbally and in writing, in national as well as international situations, account for and discuss consultations and the underlying knowledge base and arguments, in exchange with various groups
- an ability to make assessments taking into account the relevant scientific, societal, and ethical factors, and display an awareness of ethical factors in research and development work
- insight into the limits and constraints of technology, its role in society, and the human responsibility for how it is used, including social and economic factors and environmental factors and work conditions

Engineers also need to be able to step back and identify the values and moral criteria shaping our own perspectives and positions on a technology or project, in order to be able to understand the perspectives and positions of others. Actively participating in technology decisions requires understanding a range of ethical concepts central to sustainable development, including inter- and intra-generational justice.

Do all engineers really need all these skills? Do engineers actually encounter sustainability issues out in the real world? In a recent survey of U.S. mechanical engineers by researcher Marc Rosen, two-thirds of respondents reported having worked on sustainability issues or environmental technology in the past year. These technologies pertained to energy efficiency, more efficient use of other resources, or reducing emissions of environmentally harmful substances. Even if this work was motivated by policies or regulations, a majority of respondents reported working on technology that exceeded those requirements. A majority of current engineering students will thus probably face and engage with environmental and sustainability issues in their professional lives. More importantly, an increased understanding of the social and ethical aspects of technology, including improved communication skills and closer collaborations with the actual groups who will end up using the technology we develop, makes us better engineers, no matter what we are working on.

Suggested reading:

Mike W. Martin & Roland Schinzinger. *Ethics in Engineering.* (4:e upplagan), McGraw Hill, 2005.

Deborah G. Johnson. "The Social/Professional Responsibility of Engineers". Annals of the New York Academy of Sciences 577(1): 106-114, 1989.

Sharon Beder. "Beyond Technicalities: Expanding Engineering Thinking". Journal of Professional Issues in Engineering Education and Practice 125(1): 12-18, 1999.

Arnim Wiek, Lauren Withycombe, Charles Redman & Sarah B. Mills. "Moving Forward on Competence in Sustainability Research and Problem Solving". Environment 53(2): 3-13, 2011.