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Introduction

In the span of a few years, the planning, design, and construction fields have been swept up in a dynamic discussion of sustainability and green buildings. In design studios and on construction sites, we are learning to share new goals and new standards and even a new language. For many, our professional lives have been greatly enriched as we learn the meanings and means of this new language. For others, questions swirl: How did this all come about? What is it all about?

Sustainability is about the promises of things that will last—buildings with long and useful lives, forms of energy that are renewable, communities that endure. Green building is about turning the promises of sustainability into reality.

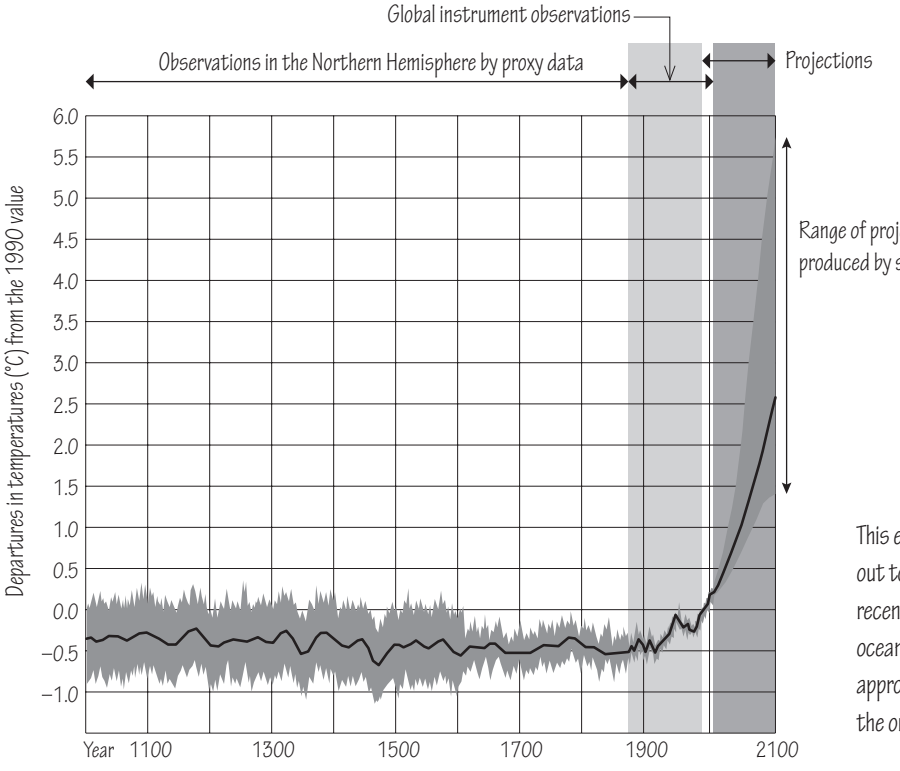
Parallel to the promises of sustainability, and even calling for their fulfillment, is the insistent reminder of scientists who caution about environmental hazards, hazards that are increasingly affirmed by our own observations. However, there is something deeply empowering in not shying away from these hazards, in turning and facing them, in weighing them collectively, and in developing strategies for addressing them. Ultimately, this may be the greatest promise of sustainability—the impetus to consider the environmental challenges we face and to find ways to overcome them.

1.01 The fragility of life on Earth has been emphasized through views of the planet from space, such as the 1990 photograph from the *Voyager 1* spacecraft. The astronomer Carl Sagan described Earth as the pale blue dot, "the only home we've ever known." (Source: NASA)

Facing Environmental Challenges

Several environmental crises are motivating us to reevaluate how we plan, design, and construct buildings. Air and water pollution resulting from fossil fuel use, fallout from nuclear power plant accidents, and the incipient and potential devastation of climate change all point to a critical need to reduce energy use. Human illness resulting from exposure to toxic chemicals compels us to reexamine their intensive use, especially in building materials.

Of particular concern is climate change. The Intergovernmental Panel on Climate Change (IPCC), which includes more than 1,300 scientists from the United States and other countries, reports that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." According to the IPCC, the impacts of climate change have already begun and are expected only to get worse. The consequences of climate change also include such extreme weather events as increased cyclone activity and longer, more frequent, and more intense heat waves; reduced snow cover and greater incidence of coastal and inland flooding; shifting plant and animal ranges and loss of biodiversity; and reduced water availability for human consumption, agriculture, and energy generation.

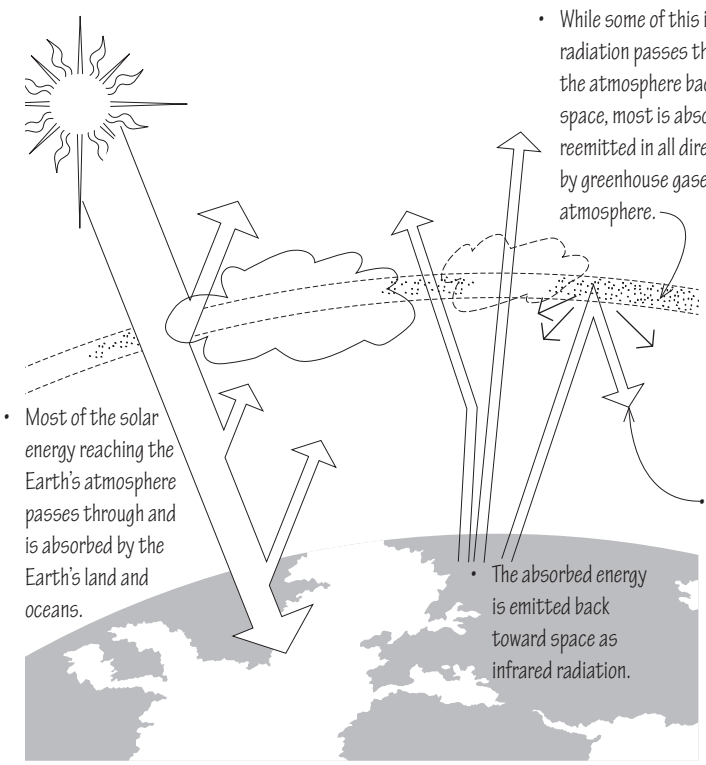


1.02 Variations in the Earth's surface temperature from the year 1000 to 2100. (Source: IPCC)

This early IPCC projection of temperature increases has turned out to be accurate and even on the low side. From the most recent IPCC report, the globally averaged combined land and ocean surface temperature data show an actual warming of approximately 0.40 °C over the period 1990 to 2010, exceeding the originally projected warming of 0.25°C over that period.

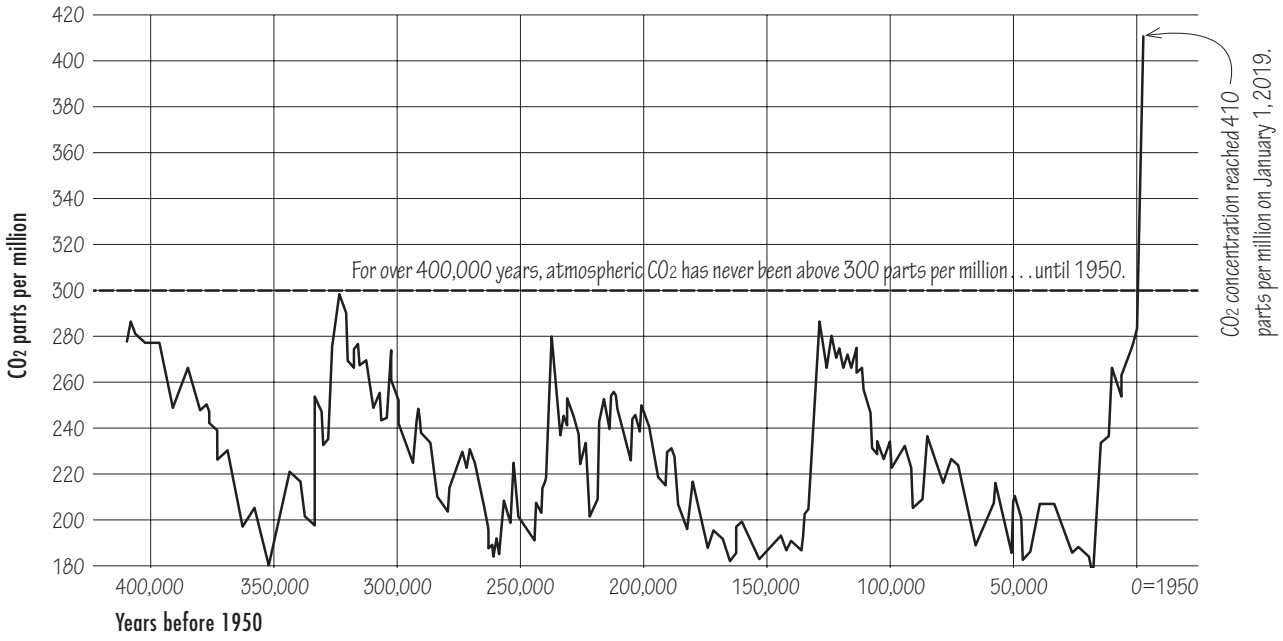
The major cause of climate change is the increasing concentrations of greenhouse gases (GHG) produced by human activities, such as deforestation, changes in land use, and especially the burning of fossil fuels. This finding is recognized by the national science academies of all major industrialized nations.

Greenhouse gases, primarily water vapor but including smaller amounts of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), are emissions that rise into the atmosphere and act as a thermal blanket, absorbing heat and reemitting it in all directions. The downward portion of this reradiation is known as the greenhouse effect and serves to warm the Earth's surface and lower atmosphere to a life-supporting average of 59°F (15°C). Without this natural greenhouse effect, life on Earth as we know it would not be possible.

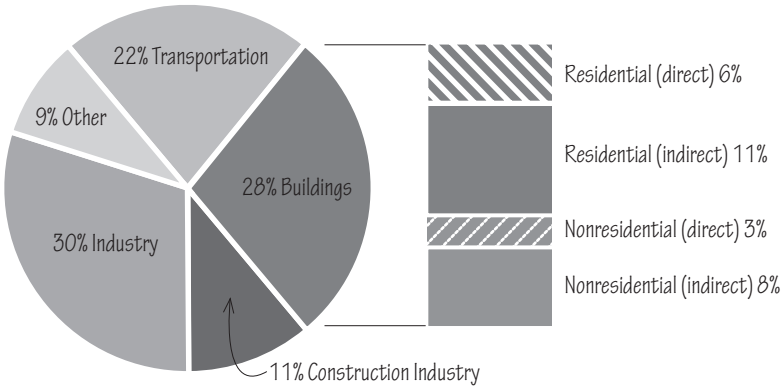


1.03 The greenhouse effect.

Beginning with the Industrial Revolution, however, the burning of fossil fuels in ever-increasing amounts has contributed to higher concentrations of carbon dioxide, methane, and nitrous oxide in the atmosphere, intensifying the natural greenhouse effect and contributing to global warming and climate change.

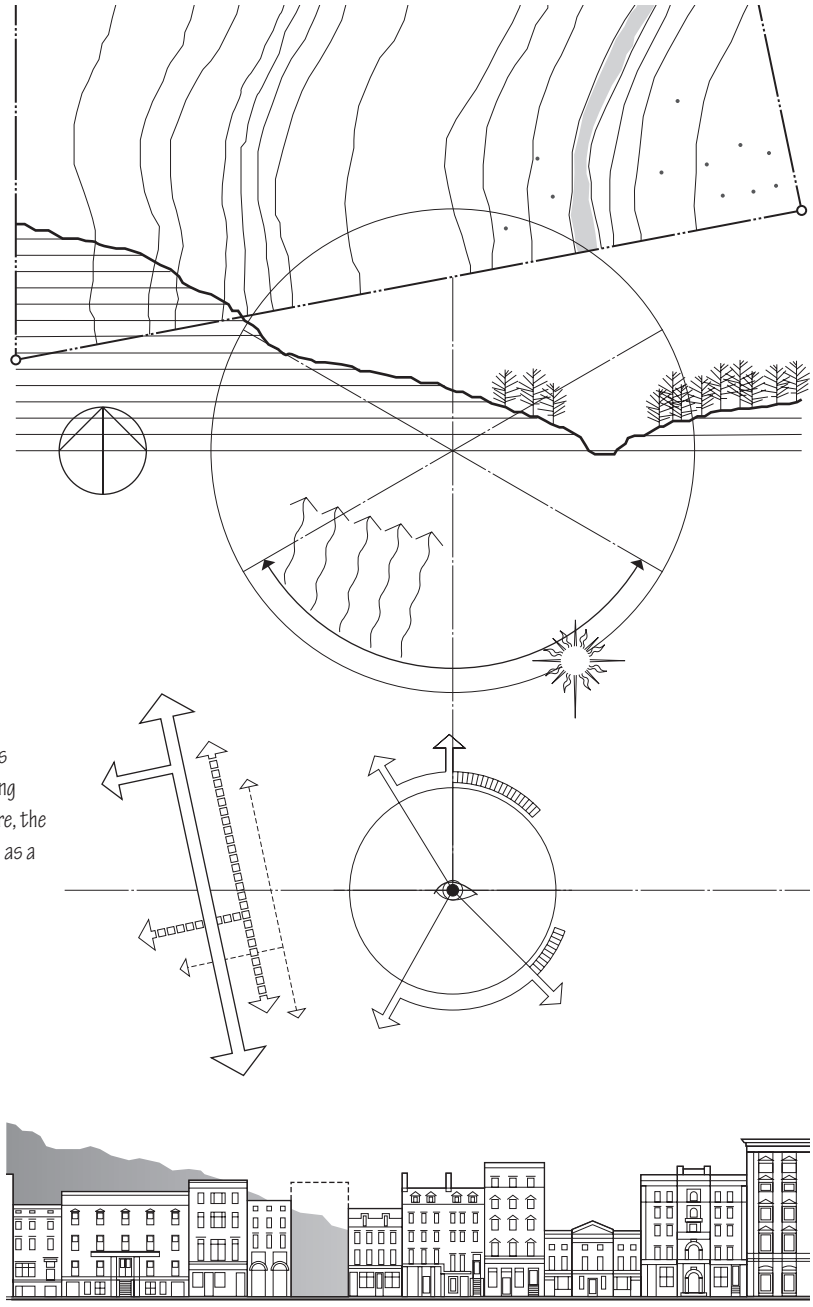


1.04 Atmospheric samples contained in ice cores and more recent direct measurements provide evidence that atmospheric CO_2 has increased since the Industrial Revolution. (Source: NOAA)



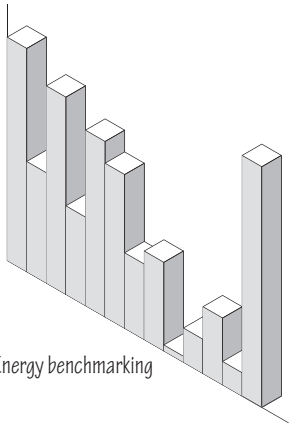
1.05 Share of global energy-related CO_2 emissions by sector. (Source: 2018 Global ABC Report; IEA)

Data from the International Energy Agency indicates that buildings are responsible for almost 40% of global greenhouse gas emissions. Most of the building sector's energy consumption is not attributable to the production of materials or the process of construction, but rather to operational processes, such as the heating, cooling, and lighting of buildings. This means that to reduce the energy consumption and GHG emissions generated by the use and maintenance of buildings over their life span, it is necessary to properly design, site, and shape buildings and incorporate efficient heating, cooling, ventilation, and lighting strategies. However, as operational energy use is reduced, attention will increasingly also need to be directed to reducing the embodied energy of construction materials.

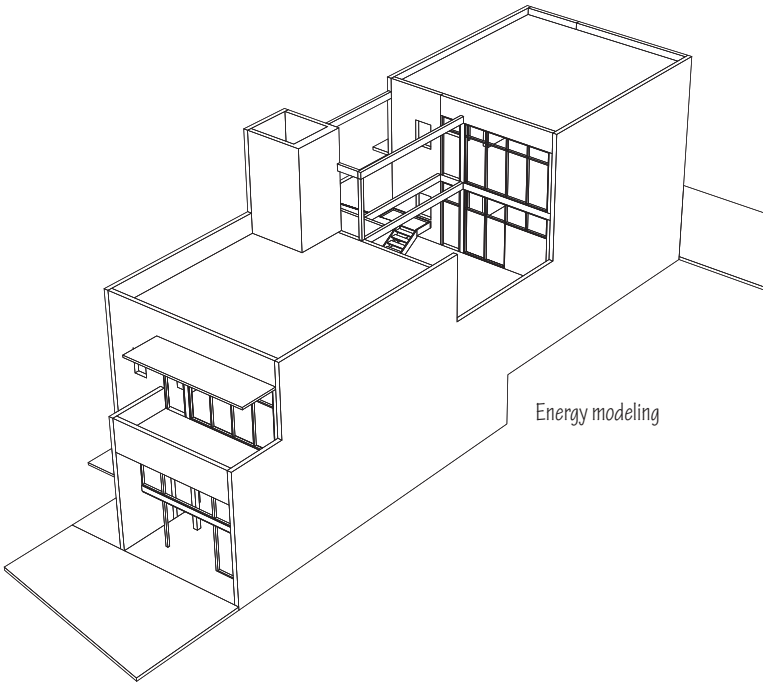


1.06 Well-sited and energy-efficient buildings could reduce carbon emissions in other sectors as well, by using less energy to produce and transport building materials and for people to be transported to and from buildings. Furthermore, the potential benefit of a future stream of reduced energy costs has been viewed as a way to offset the initial investment required to reduce carbon emissions.

Infrared thermography



Energy benchmarking



Energy modeling

1.07 Each year new approaches, new tools, and new products become available, offering ways to reduce energy and material use in buildings.

New Information, New Risks, New Opportunities

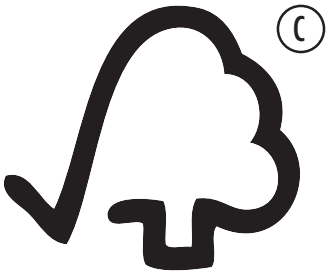
As knowledge of climate change and other environmental risks have been emerging, formal and informal research in buildings during the past few decades has given insights into how buildings work, how they can fail environmentally, and, as importantly, how such failures can be prevented. The converging demands of our multiple environmental crises and the relatively new information about how buildings perform and can be developed more sustainably offer opportunities for approaching the design of buildings in new ways. The field of green buildings is young and infinitely rich. New opportunities abound in design and construction to improve energy and resource efficiencies, to reduce the use of toxic chemicals, and to do so in a more affordable way.

However, there are many potential risks and pitfalls in green building design and construction. It is easy to be drawn to new products or approaches that claim to be green, but are in fact ineffective or are so costly as to prevent balanced investment in other, more cost-effective improvements. Our challenge is to use common sense, to reject token, showy, or ineffective building improvements, all while staying open to new, potentially valid ideas and tools. There is an urgent need both for critical thinking when scrutinizing new ideas and for flexibility when adapting to change that is occurring at a rapid pace.

Green building design need not focus solely on simply adding features to buildings to make them greener. While increasing thermal insulation values will improve the energy efficiency of a building and adding solar photovoltaic systems will reduce the need for electricity derived from nonrenewable sources, there is also much to be gained through judicious design that is not simply additive but rather more integrated and organic in nature. For example, we could select more reflective surfaces for interior finishes that would require fewer artificial light sources while delivering the same interior light levels. We could select building shapes that have less exposed surface area and so use less energy for the same floor area than more complex building shapes.

Being always mindful of the aesthetic nature of what we design and build, we might also ask: What is the effect of green design on the beauty of the built environment? Fortunately, beauty need not be sacrificed in order for buildings to be green. Green buildings may challenge conventional notions of what is beautiful, but the opportunity arises to reevaluate our notions of beauty, to reexamine how we define beauty in buildings, and to explore beauty in new architectural forms.

Trademarked Logo of the U.S. Green Building Council



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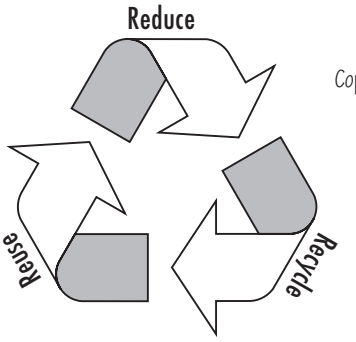


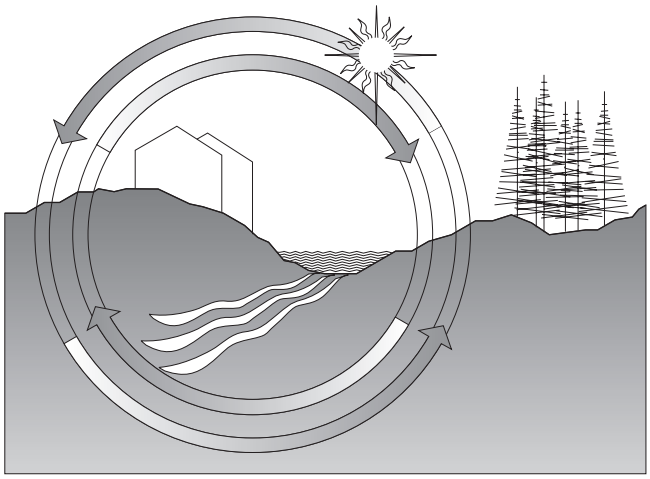
1.08 Symbols for green materials, processes, and practices.

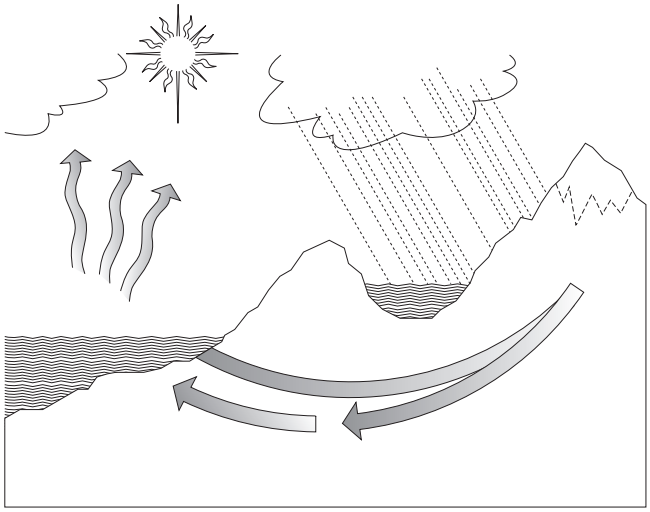
What Is a Green Building?

In this book, the question "What is a green building?" is repeatedly posed. This question takes many forms: Is a green building one that is greener than it could have been? Is a green building one that meets a green building standard? Is a green building one that has low or zero negative impact on the environment and on human health? Should all buildings be green? Are green buildings a passing fad? Do green buildings stay green over time?

The answer to "What is a green building?" is still evolving. Some buildings certified as green according to one of the green building standards have been found to be, in fact, high energy users or in some other way polluting. Conversely, many zero-energy or near-zero-energy buildings have been successfully designed and built but have not been certified as green by any rating system. This is not to question the environmental performance of all certified green buildings. Green building standards and certification systems have contributed immeasurably to the advancement of sustainable design and will continue to do so. However, we may still have a way to go before a green building certification guarantees a high level of energy efficiency or low level of pollution.

Parallel to the question "What is a green building?" is a similar but different question, "What is a greener building?" In many specific areas of building design, the relative merits of different approaches can be weighed by asking which of multiple available options is greener. This is not to advocate for small or incremental improvements in green design. The overall goal of a meaningfully green building remains paramount. However, when facing the many design decisions that need to be made in planning a building, "Is this approach greener?" can be a useful question—one that is often worthwhile asking, regardless of compliance with a specific green building code, standard, or guideline.





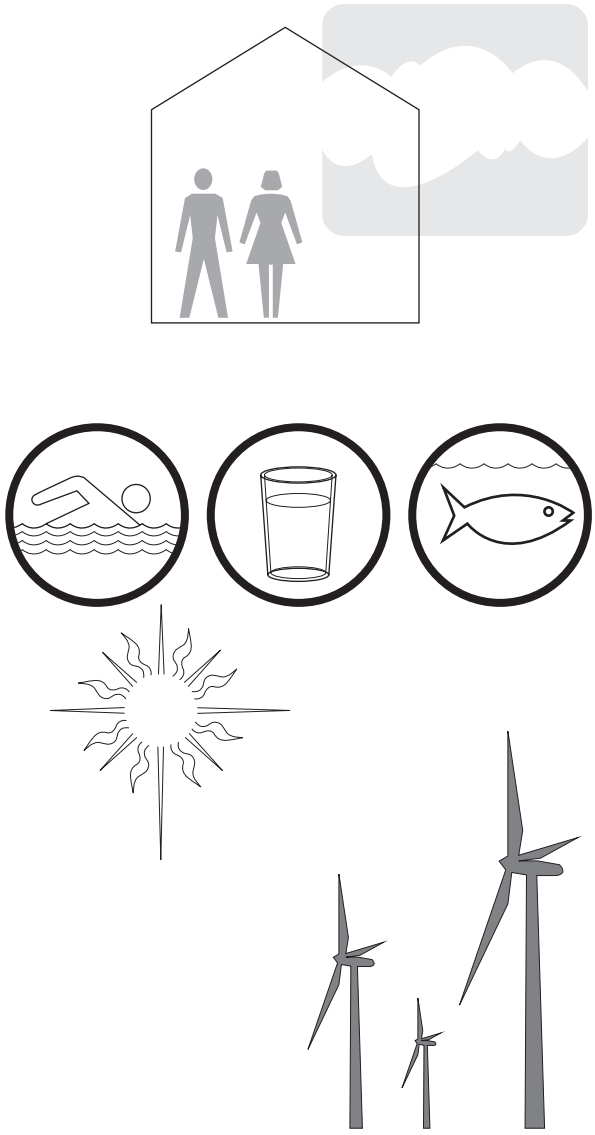
1.09 Mitigating environmental degradation through conservation, reduction of pollutants, and protection of water and natural resources and habitats.

Green Building Goals

There are many goals that motivate the planning and design of green buildings.

Perhaps the most widely recognized goals address environmental degradation:

- Mitigate global warming through energy conservation and resulting reduction of GHG emissions.
- Minimize environmental impacts resulting from the extraction of coal, natural gas, and oil, including oil spills; the mountaintop removal mining of coal; and the pollution associated with hydraulic fracturing for natural gas.
- Reduce pollution of air, water, and soil.
- Protect clean water sources.
- Reduce light pollution that can disrupt nocturnal ecosystems.
- Protect natural habitats and biological diversity, with specific concern for threatened and endangered species.
- Prevent unnecessary and irreversible conversion of farmland to nonagricultural uses.
- Protect topsoil and reduce the impacts of flooding.
- Reduce use of landfills.
- Reduce risk of nuclear contamination.



1.10 Improving environmental and economic health.

Goals for green buildings include providing for improved human health and comfort:

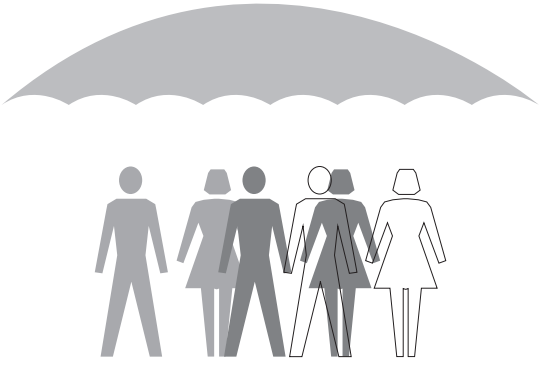
- Improve indoor air quality.
- Improve indoor water quality.
- Increase thermal comfort.
- Reduce noise pollution.
- Improve morale.

Some goals might be considered economic in nature:

- Reduce energy costs.
- Improve productivity.
- Create green jobs.
- Increase marketing appeal.
- Improve public relations.

Some goals might be considered political in nature:

- Reduce dependence on foreign sources of fuel.
- Increase national competitiveness.
- Avoid depletion of nonrenewable fuels, such as oil, coal, and natural gas.
- Reduce strain on electric power grids and risk of power outages.



1.11 Meeting social and societal goals.

Some people broaden the goals of green buildings to include social or societal goals:

- Follow fair labor practices.
- Provide access for the disabled.
- Protect consumers.
- Protect parklands.
- Preserve historic structures.
- Provide affordable housing.

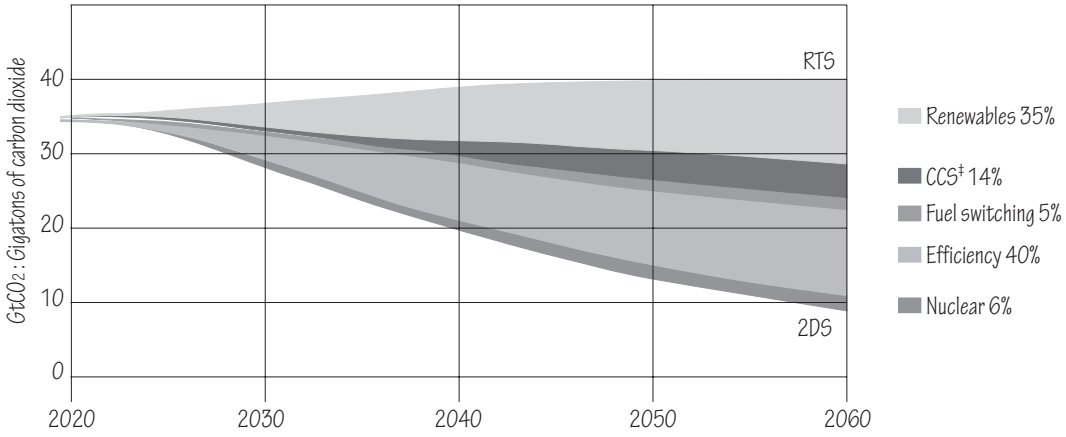
And some goals reflect the unique needs of the human spirit:

- Express deep connection to and love of the Earth and nature.
- Be self-reliant.
- Satisfy the quest for beauty.

Some goals may not be explicitly stated but represent some of our less nobler needs, such as the quest for status or prestige.

Regardless of how the stated goals are grouped, there is an ongoing and valid conversation to be had about what the goals are and how to prioritize them. In most instances, constructing green buildings supports one or more of the goals in a harmonious way. However, in some cases, conflicts may occur between two or more goals and the reconciliation of these conflicts represents a vital sorting-out of what is important to us as humans.

In the face of almost unanimous agreement among scientists about the consequences of climate change, and with impacts well under way, such as shifting plant and animal ranges, more frequent flooding of low-lying areas, and receding of polar ice, a major focus of the green building field will remain the reduction of energy consumption and associated carbon emissions.

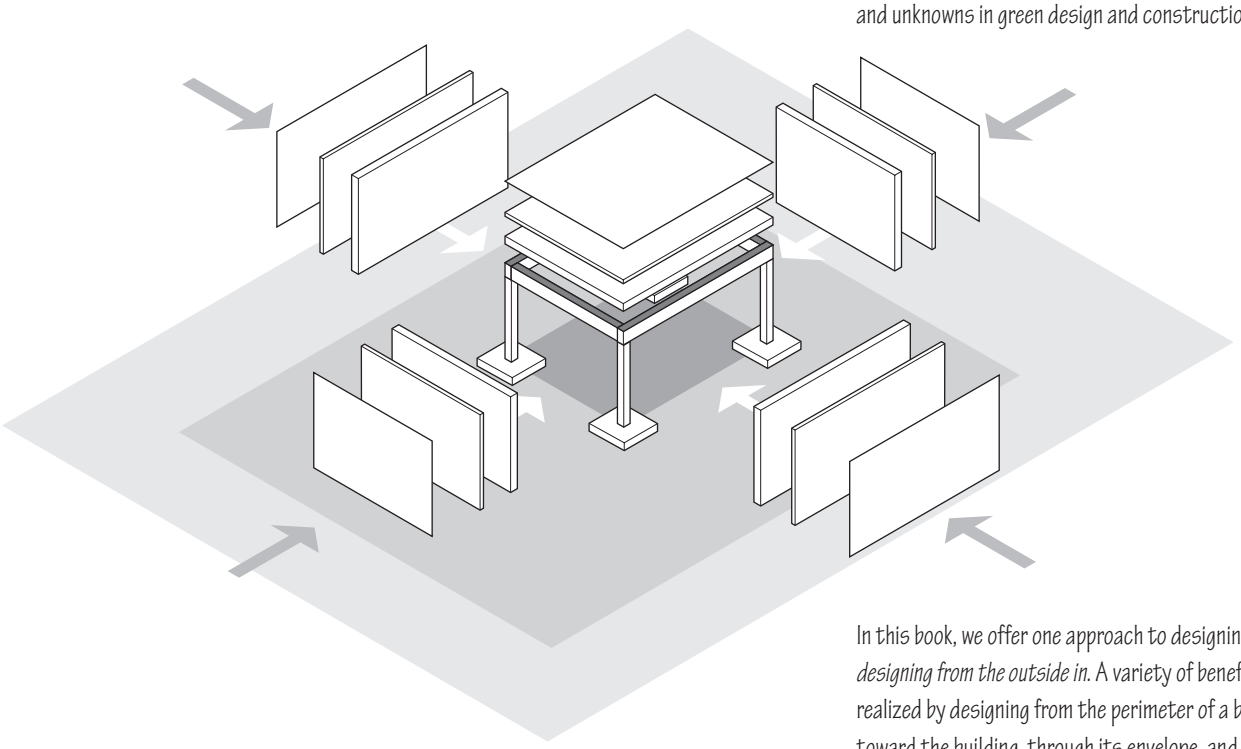


1.12 *Global CO_2 emissions reductions by technology area: RTS* to 2DS†.*
(Source: IAE) Energy-efficient technologies dominate the cumulative CO_2 emissions reductions achieved in the industry, buildings, and transport sectors, reinforcing the importance of efficiency as the "first fuel" for achieving the 2DS vision. Therefore, reducing energy consumption and associated carbon emissions remains of paramount importance in the way we plan, design, and construct buildings.

*RTS: Reference technology scenario ('business as usual')
†2DS: Scenario to reduce carbon emissions to control global warming to 2°C
‡CCS: Carbon capture and sequestration

Approaches to Green Building

In green building design and construction, it often helps to use a commonsense approach. Most of the energy- and water-efficiency trade-offs of different technologies and strategies are readily quantifiable and so can guide decision-making. Hazardous materials are reasonably well-known and identifiable and so can be avoided. Common sense can also be helpful in addressing some of the more complex trade-offs, guiding consideration of new technologies, and preventing design paralysis, which may arise when faced with the many choices and unknowns in green design and construction.



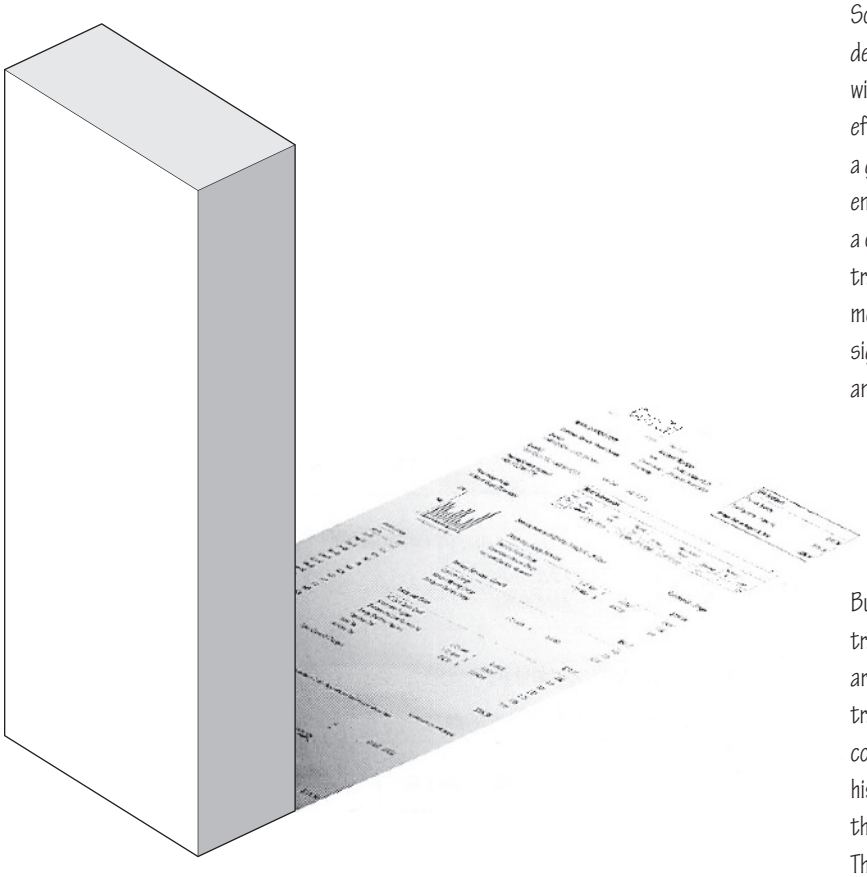
1.13 Designing from the outside by incrementally adding layers of shelter.

In this book, we offer one approach to designing green buildings: *designing from the outside in*. A variety of benefits can be realized by designing from the perimeter of a building site, toward the building, through its envelope, and to its core. By incrementally adding *layers of shelter* and ensuring the integrity and continuity of each of these layers, various energy loads can be substantially reduced. In doing so, the accumulation of green building improvements can actually reduce construction costs, making possible buildings that not only use less energy, less water, and fewer materials, but are more affordable to construct.

Building on some of the notable, recent developments in building science, this book focuses on design strategies for green building rather than on compliance with specific requirements of any particular code, standard, or guideline. However, the principles and approaches presented are intended to be robust enough to meet or exceed the requirements of existing codes, standards, and guidelines, and be applicable to all types of buildings, whether they be wood-frame residences or high-rise structures of steel and concrete.

The various standards for green building design are generally consistent with the approaches suggested by designing from the outside in. However, many existing green building standards calculate energy savings relative to a hypothetical reference building or focus on energy use per unit floor area, and take the building shape as given. Green building standards tend not to question the floor area or the building shape itself. In designing from the outside in, everything is up for questioning, including the floor area and building shape.

Some approaches to green buildings take a particular building design, invest in improved construction (such as thicker walls with more insulation, tighter construction, more energy-efficient windows, or higher-efficiency heating), and have as a goal a building that uses perhaps 10%, 20%, or 30% less energy. While this approach is fully valid, it can be enhanced by a complementary approach, which is to design not an improved traditional building but rather a different type of building that meets the same human needs, for which the goal is to use significantly less energy or preferably net-zero energy and with an eye to affordability throughout.



1.14 We can trace a building's energy use through its utility bills.

Buildings leave a trace of their greenness in their utility bills, a trace that will last for decades to come. Increasingly, buildings are judged by this trace, as online databases in recent years track energy use in individual buildings and perform widespread comparisons of energy use between buildings. The judgment of history has already begun to weigh more heavily on buildings that waste energy, particularly buildings that claim to be green. The good news is that the tools to design and build energy-efficient buildings are increasingly available. The challenge lies in their application.

To architectural form and function, a new dimension in building design is presenting itself: performance. In addition to serving the needs of its occupants and appealing to the eye, mind, and spirit, a building must now perform well, and perform persistently well over time, consuming less energy and fewer resources while providing a high level of comfort and conditions conducive to good health. On one hand, an added set of constraints has been placed on building design. On the other, an opportunity exists to clear a higher bar, do better work, and avoid wasteful and unhealthy buildings.

The reader is invited to join an exploration of the promise of buildings that impact the environment as lightly as possible and use significantly less energy, water, and materials than at present. Let us explore the promise of buildings that could cost less than current buildings while being more comfortable and conducive to human health. Let us explore the promise of buildings that are more strongly integrated into our human communities and the natural world. Let us explore the promise of buildings that we can be proud of.

And then let us try to boldly deliver on these promises.