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Environmental Conditions and the Site

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A building's form, scale, and spatial organization are the designer's response to a number of conditions—functional planning requirements, technical aspects of structure and construction, economic realities, and expressive qualities of image and style. In addition, the architecture of a building should address the physical context of its site and the exterior space. (Francis D.K. Ching and Corky Binggeli, *Interior Design Illustrated* [3rd ed.], Wiley 2012, page 4)

We depend on the building's site to provide clean air and to help control thermal radiation, air temperature, humidity, and airflow. Building structures rely on site conditions for support and to help keep out water and control fire. The site can also play a role in providing clean water, removing and recycling wastes, and providing concentrated energy.

Once these basic physical needs are met, we turn to creating conditions for sensory comfort, efficiency, and privacy. We need illumination to see, and barriers that create visual privacy. We seek spaces where we can hear others speak clearly, but which offer acoustic privacy. The building's structure gives stable support for all the people, objects, and architectural features of the building.

The next group of functions supports social needs. We try to control the entry or exit of other people and of animals. Buildings facilitate communication and connection with the world outside through windows, telephones, mailboxes, and computer and video networks. Our buildings support our activities by distributing concentrated energy to convenient locations, primarily through electrical systems.

Finally, a building capable of accomplishing all of these complex functions must be built without excessive expense or difficulty. Once built, it must be able to be operated, maintained and, changed in a useful and economical manner. The building should be flexible enough to adapt to changing uses and priorities. Eventually, the building's components may be disassembled and returned to use in other construction.

The design of a building that incorporates all these functions requires coordination between building systems' designers, builders, and users. The building's environmental conditions and its site generate complex factors for architects, engineers, and other design professionals. They, along with landscape architects, examine the site's subsoil, surface water levels, topsoil, and rocks with regard to excavations, foundations, and landscaping. Hills, valleys, and slopes affect stormwater drainage and soil erosion, as well as the location of roads and paths. Shelter from the wind or exposure to sunlight help determine where the building can be built and the type of landscaping. Nearby buildings create shade, divert wind, and change the natural drainage patterns; they can also result in a lack of acoustic and/or visual privacy.

Building Systems for Interior Designers, Fourth Edition. Corky Binggeli and Taylor Lucas.
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INTRODUCTION

In Chapter 1, we begin to examine the design of the building and its site. Interior designers benefit from a general understanding of both **passive systems** and mechanical systems that meet the environmental requirements of buildings. Passive systems regulate the building interior without requiring electricity. Awareness of building systems provides interior designers with the terminology and basic requirements to ask intelligent questions of architects, engineers, and contractors.

This awareness starts with a basic understanding of environmental and site conditions. Climate affects how buildings are designed in different places and how they relate to their sites. An understanding of energy sources and their history helps put their use in buildings in perspective. As interior designers seek to open building interiors to their surroundings, it is important that they understand what opportunities and challenges are involved.

History

Throughout history, buildings have looked both out towards the surrounding site and environment, and in towards the people, activities, and objects they contain (see Figure 1.1). Although interior designers are primarily concerned with the building's interior, their work is often influenced by the building's exterior construction and site.

The building's form and orientation on the site are major concerns of the building's architect. A building's climate and surrounding natural and built features are priorities for the architect, landscape architect, and engineers. During the final decades of the twentieth century, architects began to expand their view of architecture to include areas of social concern, including accessibility and sustainable design, both of which are important to interior designers.

The design of the building, including its massing, configuration, and orientation, generate the relationship between the interior space and the exterior environment. In order to be active and responsible members of the building design team, interior designers must understand the roles and concerns of the architects, engineers, and other consultants who make up the design team. In turn, the rest of the design team will benefit from an awareness of the concerns they share with interior designers.

The interior designer's concern about climate change and renewable energy sources leads to caring about how a building responds to its site and climate and how it fuels its operation. Although they are not directly responsible for deciding on the site and building energy sources, interior designers can play a major role in selecting interior materials that support the conservation of energy and the use of energy sources available on-site.

The interior layout can support or block solar radiation to help keep the interior warm or cool. Selecting thermally massive interior materials can aid passive solar design. In many instances, the project is in an existing building, and most of the work is interior design. In addition, interior designers may be involved in the design of outdoor spaces such as patios adjacent to the building.

CLIMATE CHANGE

Interior designers need to fully understand how a building responds to its site and climate. This will allow the designer to create a solution that best utilizes passive systems, and works with the site, not against it. Designers need to source materials that do not contribute to greenhouse gases and that support the conservation of energy. This small piece of the building project's carbon footprint is the sole responsibility of the designer, and that needs to weigh heavily on your choices and design decisions.

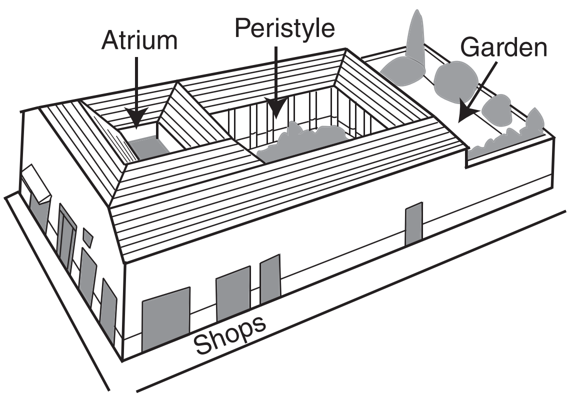

Figure 1.1 Roman residence

According to the 2022 report of the Intergovernmental Panel on Climate Change[1] (IPCC), the warming of the climate is unequivocal, and mostly caused by human-created greenhouse gases. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.

Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems. The number of climate related natural catastrophe events worldwide has increased dramatically (see Figure 1.2). Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions that, together with adaptation, can limit climate change risks (IPCC Sixth Assessment Synthesis Report, Climate Change 2022 Synthesis Report Summary for Policymakers, www.ipcc.ch/).[2]

Small increases in global temperatures are already resulting in hotter summers, changes in precipitation patterns, and rising sea levels. More droughts are occurring in some areas, with floods in others. Warm climate diseases such as malaria are likely to spread and species extinction is imminent.

Damaging results include the melting of permafrost in northern Canada, Alaska, and Russia, which can cause huge amounts of organic material to decompose, giving off **carbon dioxide (CO_2)** and methane. According to the US **Environmental Protection Agency (EPA)**, permafrost melting is already causing sinking land that can damage buildings and infrastructure.

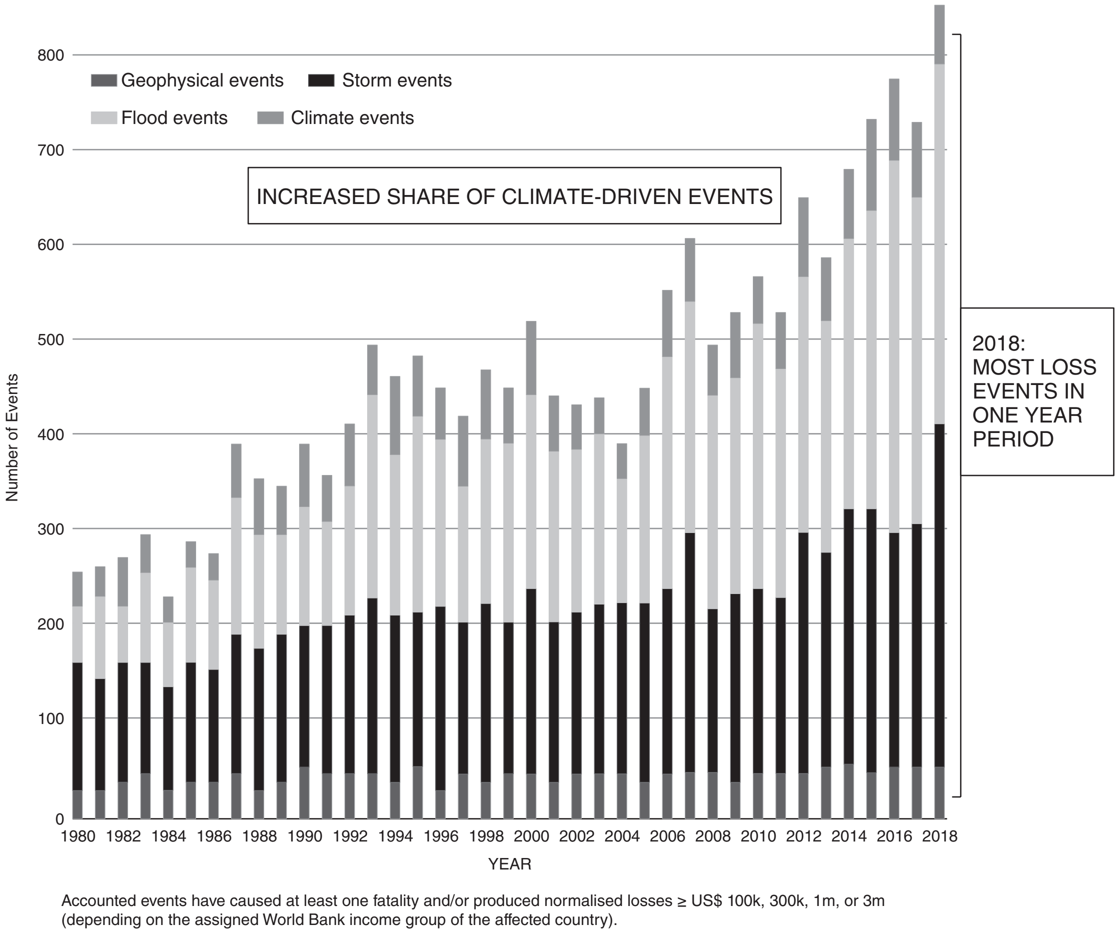

Figure 1.2 Natural catastrophe events worldwide 1980–2018

Source: Redrawn from H. Taubenböck, M. Wurm, M. Netzband, H. Zwenzner, A. Roth, A. Rahman, and S. Dech, 2011. Flood risks in urbanized areas: multi-sensoral approaches using remotely sensed data for risk assessment, *Natural Hazards and Earth System Sciences*, 11, 431–444, page 432. https://doi.org/10.5194/nhess-11-431-2011

[1]https://www.ipcc.ch/report/ar6/wg2/about/how-to-cite-this-report (accessed 8 November 2023).

[2]IPCC, 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.). Cambridge University Press, Cambridge, UK and New York. doi:10.1017/9781009325844.

ENERGY SOURCES

According to the EPA, US buildings account for 40% of total energy use and 65% of all electricity consumption. The source of the energy used to construct and operate buildings is important to interior designers concerned with global climate change and energy conservation. As part of the building design team, interior designers can support the use of sustainable energy sources as well as efforts toward passive design. Conserving energy and using clean and renewable energy sources in buildings reduces the amount of air pollution produced by electric power plants and by burning fuels in buildings.

Energy sources are often categorized as renewable or nonrenewable. **Renewable energy** is energy that comes from naturally occurring resources such as sunlight, wind, or geothermal heat that are naturally replenished on a human timescale.

All of our energy sources are derived from the sun, with the exception of geothermal, nuclear, and tidal power. Before 1800, solar energy was the dominant source for heat and light, with wood used for fuel. Wind was used for transportation and processing of grain. Early industries located along rivers and streams utilized waterpower. In the 1830s, the earth's population of about one billion people depended on wood for heat and animals for transportation and work. Oil or gas were burned to light interiors. By the 1900s, coal was the dominant fuel, along with hydropower and natural gas. Around the beginning of the nineteenth century, mineral discoveries led to the introduction of portable, convenient, and reliable coal, petroleum, and natural gas fuels to power the industrial revolution.

Fossil fuels such as coal, petroleum, and natural gas were formed from decaying plant and animal matter over vast periods of time beneath the earth's surface. Although fossil fuels continue to be formed, their timeframes are such that they are not replaceable at anything like the rates that they are being used, and they are not considered to be sustainable materials. Remaining world fossil fuel reserves are limited, with much of it expensive and environmentally objectionable to remove. Buildings being built today could outlive fossil fuel supplies used at current rates.

As the world's supply of fossil fuels diminishes, buildings must use nonrenewable fuels conservatively if at all, and look to on-site resources such as daylighting, passive solar heating, passive cooling, solar water heating, and **photovoltaic (PV)** electricity.

Some types of energy, such as solar energy, can be used directly by a building for heating and cooling. Others, such as electricity, are produced from another fuel source.

Electricity

Today's buildings are heavily reliant on electricity due to its convenience of use and versatility. Electricity is considered a high-quality energy source; however, only one third of the source energy (often coal) used to produce electricity actually reaches its end use, with most of the rest wasted during production and transmission. As of 2009, consumption of electricity has begun to decline for the first time since World War II, with reductions in all world regions except Asia and the Middle East.

Electric lighting produces heat, which in turn increases air conditioning electrical energy use in warm weather. The use of daylight is an important sustainable design technique. However, daylight is dependent on weather and time of day, so electric lighting continues to have an important role.

For more information on daylighting and electric lighting, see Chapter 17, "Lighting Systems."

The use of electricity for space heating employs a high-quality source for a low-quality task. Passive or active solar heating design uses this unlimited, free source of energy to heat building interiors.

See Chapter 14, "Heating and Cooling," for more information on solar heating design.

Renewable Energy Sources

Renewable sources include solar (heat, light, and electricity), wind, hydroelectric, geothermal, and biomass. Electricity produced by solar or wind energy can in turn be used to generate hydrogen, a high-grade fuel, from water. These are all considered to be renewable resources because they can be constantly replenished, but our demand for energy may exceed the rate of replenishment. Some, such as hydroelectric power, can have negative impacts on the environment.

SOLAR ENERGY

The sun acts on the earth's atmosphere to create climate and weather conditions. The earth's rotation determines which part of the earth faces the sun, controlling day and night. Plant life depends on the sun's energy for growth, and humans and other animals depend on plants for food and shelter. Solar energy is the source of almost all of our energy resources. It does not produce air, water, land, or thermal pollution, and is decentralized and very safe to use. It is used for space heating, hot-water heating, and PV electrical energy.

During the day, the sun's energy heats the atmosphere, the land, and the sea. At night, much of this heat is released back into space. The warmth of the sun moves air and moisture across the earth's surface and generates seasonal and daily weather patterns.

SOLAR ENERGY HISTORY

The sun has long been used to heat and illuminate buildings. The Romans incorporated glass windows into their buildings around 50 BCE to bring in daylight and solar heat, and wealthier Romans often added sunrooms to their villas.

In *The Ten Books on Architecture*, Roman architect and engineer Marcus Vitruvius Pollio wrote:

> If our designs for private houses are to be correct, we must at the outset take note of the countries and climates in which they are built. This is because one part of the earth is directly under the sun's course, another is far away from it, while another lies midway between these two. (Translated by Morris Hickey Morgan, Harvard University Press 1914, republished by Dover Publications, Inc., 1960, page 170)

Italian Renaissance architect Andrea Palladio (1508–1580), author of *The Four Books of Architecture*, was influenced by Vitruvius. Palladio placed summer rooms on the north side and winter rooms on the south side of his buildings to take advantage of the sun.

In the seventeenth century, solar heating was revived in Northern Europe for growing exotic plants in greenhouses. Improved glassmaking techniques led to the popularity of greenhouses (conservatories) attached to upper-class residences.

US modernist architect George Frederick Keck (1895–1980) designed the "House of Tomorrow" for the Century of Progress exhibition in Chicago in 1933. His realization that the all-glass house was warm on sunny winter days, even without a furnace led to his designing solar houses in the 1930s and 1940s. (See Figure 1.3)

SOLAR RADIATION

Solar radiation drops with the distance from the sun, as solar rays spread out. The path of solar rays through the atmosphere is longer in the morning and evening than at noon, and longer at noon at the poles than at noon at the equator (see Figure 1.4).

The **electromagnetic spectrum** of radiation emitted by the sun includes wavelengths ranging from extremely short x-rays to very long radio waves (see Figure 1.5). Radiation is reflected, scattered, and absorbed by dust, smoke, gas molecules, ozone, carbon dioxide, and water vapor in the earth's atmosphere. Radiation that has been scattered or re-emitted is called diffuse radiation. The portion of the radiation that reaches the earth's surface without being scattered or absorbed is referred to as direct radiation.

Ultraviolet (UV) wavelengths make up only a small percentage of the sun's rays that reach sea level, and are too short to be visible by the human eye. UV radiation triggers **photosynthesis** in green plants, producing the oxygen we breathe, the plants we eat, and the fuels we use for heat and power. During photosynthesis, plants take carbon dioxide from the air and give back oxygen.

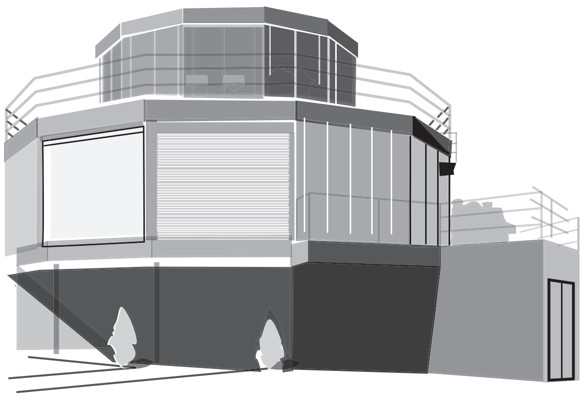

Figure 1.3 George Frederick Keck "House of Tomorrow," 1933

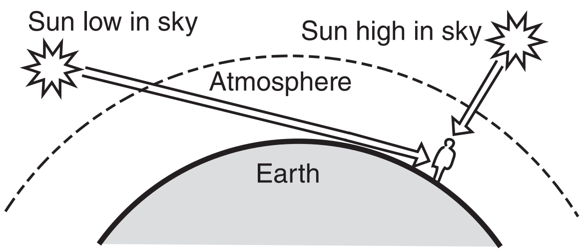

Figure 1.4 Sun's path through the atmosphere

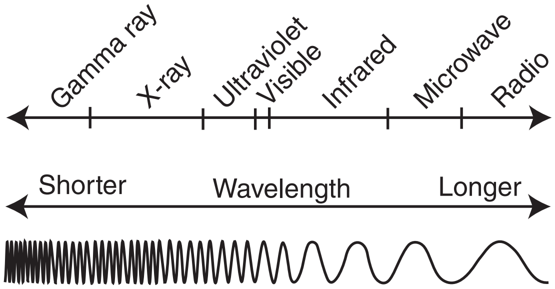

Figure 1.5 Electromagnetic spectrum

Humans and other animals breathe in oxygen and exhale carbon dioxide. Plants transfer the sun's energy to us when we eat them, or when we eat plant-eating animals. That energy goes back into the environment when animal waste decomposes and releases nitrogen, phosphorus, potassium, carbon, and other elements into the air, soil, and water. Animals or microorganisms break down dead animals and plants into basic chemical compounds, which then re-enter the cycle to nourish plant life.

UV radiation kills many harmful microorganisms, purifying the atmosphere and eliminating disease-causing bacteria from sunlit surfaces. It also creates vitamin D in our skin, which we need to utilize calcium. Photosynthesis also produces wood for construction, fibers for fabrics and paper, and landscape plantings for shade and beauty.

Infrared (IR) radiation, with wavelengths longer than visible light, carries the sun's heat. The sun warms our bodies and our buildings both directly and by warming the air around us.

The distance that radiation must travel through the earth's atmosphere, as well as atmospheric conditions, largely determine the amount of solar radiation that reaches the earth's surface. The distance varies with the angle of the earth's tilt toward or away from the sun. The angle is highest in the summer, when direct solar radiation strikes perpendicular to the earth's surface. The angle is lowest in the winter, when solar radiation travels a longer path through the atmosphere. Consequently, the greatest potential solar gain (in the Northern Hemisphere) for a south-facing interior space occurs during the winter (see Figure 1.6). Nearer to the equator, the sun remains more directly overhead throughout the year (see Figure 1.7).

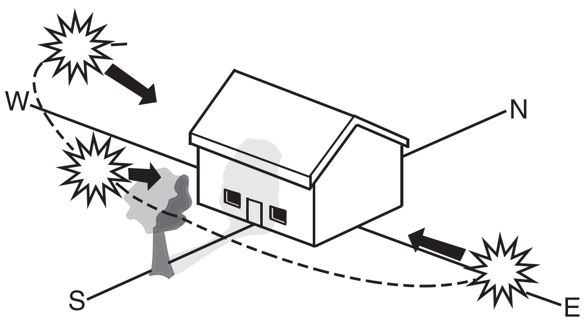

Figure 1.6 Sun angles in northern latitudes

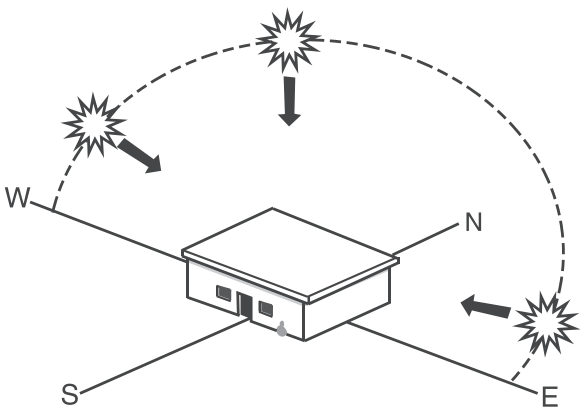

Figure 1.7 Sun angles in tropical latitudes

The sun illuminates the indoors through windows and skylights during the day. Direct sunlight is often too bright for comfortable vision. When daylight is scattered by the atmosphere or blocked by trees or buildings, it offers an even, restful illumination. Under heavy clouds and at night, artificial light provides adequate illumination.

Sunlight can also be destructive. Most UV radiation is intercepted by the high-altitude ozone layer, but enough gets through to burn our skin painfully. Over the long term, exposure to UV radiation may result in skin cancer. Sunlight contributes to the deterioration of paints, roofing, wood, and other building materials.

Fabric dyes may fade, and many plastics decompose when exposed to direct sun. This is an issue for interior designers when specifying materials.

PV technology converts solar energy directly into electricity at a building's site. PV collectors provide energy for heating water or for electrical power. PV cells are made of silicon, the most common material in the earth's crust, are very reliable, and have no moving parts. They produce no noise, smoke, or radiation.

See Chapter 15 Electrical System Basics for more information on photovoltaic (PV) technology.

The use of solar energy for heating requires consideration of shading to avoid overheating. Greek and Roman buildings used porticoes and colonnades for both shade and protection from rain. Following their example, Greek Revival architecture in the southern United States adopted large overhangs supported by columns, as well as large windows for increased ventilation and white exterior colors for maximum solar reflectance.

WIND POWER

Wind power derives from currents created when the sun heats the air and the ground. Wind power uses a turbine to convert the energy of wind flow into mechanical power that a generator can turn into electrical energy.

By 200 BCE, windmills were used in China to pump water. By the eleventh century CE, windmills were used in the Middle East to grind grain. Their use declined as steam engines dominated during the Industrial Revolution. Larger **wind turbines** had been developed in Denmark by 1890 to generate electricity. In the 1930s, wind turbines brought low-cost electrical power to rural areas of the United States (see Figure 1.8).

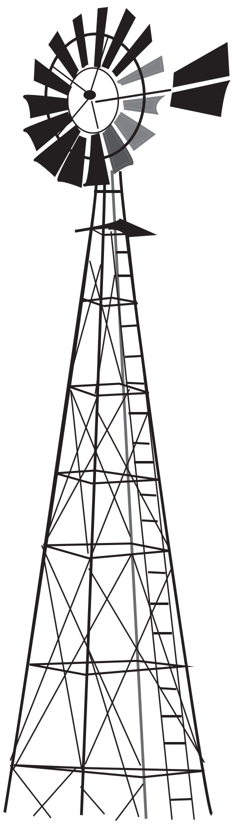

Figure 1.8 Wind turbine, 1930s

Wind energy is plentiful in most of the United States. Wind turbines require a windy site, and raising the turbine as high as possible accesses higher wind speeds (see Figure 1.9). Although wind is an intermittent source, turbines can be connected to the electrical grid for steady power. Stand-alone systems require battery storage. Hybrid systems combine wind with photovoltaics, in which wind power dominates in less sunny, windier winters and solar power provides electricity in summers. The noise produced by small wind turbines is generally not objectionable to most people, and larger turbines are being engineered to reduce noise levels.

HYDROELECTRIC POWER

Hydroelectric power (hydropower) is energy that is produced when water stored behind a dam is released at high pressure. This energy is transformed into mechanical energy, which is used by a turbine to generate electricity. In the United States, about 5% of energy is produced by falling water.

Hydroelectric power has a long history (See Figure 1.10). The world's first hydroelectric power plant began operation on the Fox River in Appleton, Wisconsin, in 1882. By 1907, hydropower was providing 15% of US electrical generation.

Today hydroelectric power is almost exclusively used to generate electricity. The dams needed typically require flooding large areas of land to produce storage lakes. This disturbs the local ecology and can prevent fish from reaching their spawning grounds. Some outdated, dangerous, or ecologically damaging dams in the United States are being demolished.

Micropower systems are very small hydroelectric systems that rely on running river water without a dam. They require at least 3 ft (1 m) of elevation change, but work better with more.

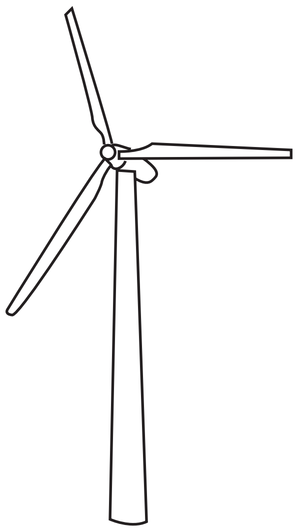

Figure 1.9 Wind turbine today

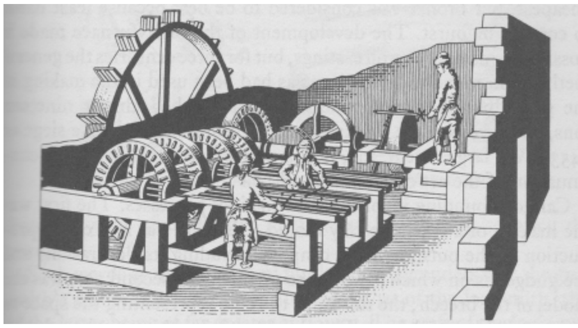

Figure 1.10 Water-powered machinery for boring gun barrels

Source: Reproduced from Diderot's Encyclopedia (1777), in T.K. Derry and Trevor I. Williams, *A Short History of Technology*, Oxford University Press 1960, republished by Dover 1993, page 149

GEOTHERMAL ENERGY

Geothermal energy consists of the earth's internal heat. About 10 ft below the surface, the earth maintains a fairly constant temperature. A geothermal system collects, concentrates, and distributes this energy. There are two common applications of geothermal energy: extraction of heat originating deep within the earth, and geo-exchange of heat near the surface using a heat pump.

Geothermal energy can be extracted where sufficient heat is brought near the surface by conduction, bulging magma, or ground water that has circulated to great depths. Geothermal energy is used to heat buildings in Iceland and Japan. In Boise, Idaho, direct geothermal energy heats over 65 downtown businesses.

The second process, **geo-exchange**, uses a heat pump to extract heat from the ground just below the surface in the winter, and uses the ground as a heat sink for summer cooling, so the same heat pump can be used for both heating and cooling. Geo-exchange heat pumps can significantly reduce energy consumption and emission of pollution and greenhouse gases. A ground-source heat pump offers much greater efficiency than an air-source heat pump, is between three and four times as efficient as electric resistance heating, and uses 70% less energy than standard air conditioning equipment.

For more information on heat pumps, see Chapter 14, "Heating and Cooling."

BIOMASS ENERGY

Biomass is the organic matter of plants. Photosynthesis provides the materials for biomass conversion, which includes the combustion of firewood, crop waste, and animal wastes. Biomass can replace chemicals made from fossil fuels to generate electricity and as fuel for transportation vehicles.

Biomass makes use of energy from two types of sources: plants grown for their energy content, and organic waste from agriculture, industry, or garbage. When biomass decomposes, it creates food for new plants; converting it into energy diverts it from this use. Biomass can be considered to be carbon neutral, removing the same amount of carbon dioxide in growth as is returned to the atmosphere when it is burned.

Biofuels derived from biomass include ethanol alcohol, biodiesel, and methane. Biomass conversion into fuel may require more energy than is obtainable from the product itself, in which case it is not a sustainable process.

HYDROGEN

The most abundant element on earth, **hydrogen** is found in many organic compounds as well as water. Although not occurring naturally as a gas, it can be separated from other elements and burned as a fuel. Used in fuel cells, hydrogen combines electrochemically with oxygen to produce electricity and heat, with only water vapor emitted in the process. When used as a fuel, hydrogen is nonpolluting, producing only water when it is burned, and does not contribute to global warming.

Chemical bonds must be broken to free the hydrogen locked within compounds such as water. The most practical method involves production from water by electrolysis, which breaks water into hydrogen and oxygen by passing electrical current through water, using wind or PV-generated electricity.

Hydrogen can be used to generate pollution-free electricity in fuel cells, or to power automobile engines. Hydrogen must be stored in heavy and expensive high-pressure tanks. If stored as a liquid, it must be cooled to –423°F (–253°C).

Storing Renewable Energy

Both wind and solar energy are not easily stored. With any energy storage option, some energy is lost. Batteries lose some of the electrical energy they store as heat, and it takes a large volume of batteries to store a lot of energy.

Wind and hydropower generate electricity by mechanical means, and their energy can be stored before it is converted into electricity. Hydrogen produced by electrolysis can be stored and later recombined with oxygen to recover energy. Hydrogen fuel cells can produce a controlled release of stored energy.

Connecting a photovoltaic system to the existing electrical grid allows the grid to supply electricity when the PV system is inactive at night. Extra PV energy is sent onto the grid. Using a special PV electrical meter, **net metering** only charges the user for electricity used in excess of what they produce.

Nonsustainable Energy Sources

Petroleum and natural gas split the energy market about evenly by 1950. The United States was completely energy self-sufficient, thanks to relatively cheap and abundant domestic coal, oil, and natural gas. These **nonrenewable energy sources** will be consumed at a much faster rate than they can be naturally created. These resources will not be replenished within our lifetime or in some cases, many lifetimes.

Beginning in the 1950s, the United States experienced steadily rising imports of crude oil and petroleum products. In 1973, political conditions in oil-producing countries led to wildly fluctuating oil prices, and high prices encouraged conservation and the development of alternative energy resources. The 1973 oil crisis had a major impact on building construction and operation. Unstable political conditions led to an emphasis on reducing imported oil. Between 2005 and 2011, the amount of oil imported by the United States dropped by 33%, and by 2020 the United States was a net exporter of petroleum. The US Energy Information Administration states that in 2020 and 2021, annual total petroleum net imports were actually negative for the first time since 1949.

Our most commonly used fuels – oil, gas, and coal – are fossil fuels. We started using fossil fuels around 1850. Although limited supplies still remain, it is becoming continually more difficult to access them without causing environmental damage. Burning fossil fuels produces most of the air pollution and smog we experience, plus acid rain and global climate change. These resources are clearly not renewable in the short term, and are not sustainable resources.

OIL

Petroleum is a liquid mixture of hydrocarbons that is present in certain rock strata and can be extracted and refined to produce fuels including gasoline, kerosene, and diesel oil. It is often called "oil," especially when used as a fuel or lubricant. Oil is used to heat buildings and to make lubricants, plastics, and other chemicals, as well as to power vehicles.

The first oil wells were dug in China starting around the fourth century CE. Oil was first distilled into kerosene for lighting in the mid-nineteenth century. In 1859, the first oil well was drilled in Titusville, Pennsylvania. Fuel oil began to replace coal for building heating in the 1920s.

New wells are deeper, underwater, or in almost inaccessible locations. Oil shale is becoming a more common source of oil. It requires huge amounts of energy to extract oil from tar sands, resulting in a high extraction cost and a very high cost to the environment.

GAS

The first well that was intentionally drilled to obtain natural gas was drilled in 1821 in Fredonia, New York. It was originally used as a fuel for streetlights. In 1855, Robert Bunsen invented the Bunsen burner so that gas could be used to provide heat for cooking and warming buildings. However, there were very few pipelines for natural gas prior to the 1940s.

Natural gas is used to generate electricity, and for industrial, residential, and commercial uses. More than half US commercial establishments and residences are heated using gas.

Natural gas is primarily composed of methane, and produces carbon dioxide when burned. It is delivered to most parts of the United States and Europe by an extensive network of pipelines. Most of the easily obtained natural gas in North America has already been taken out of the ground, with limited supplies available from deep wells.

Natural gas recovered from shale now supplies 30% of US natural gas. Supplies of natural gas from shale are relatively clean, compared to the coal used to generate electricity. However, the process of **hydraulic fracturing (fracking)** poses significant environmental risks, including the contamination of well water and the increased possibility of earthquakes. Extraction and transportation can emit methane, a greenhouse gas.

Liquid natural gas (LNG) is odorless, colorless, nontoxic, and noncorrosive. LNG is condensed and shipped in tankers at –260°F (–162°C) over long distances. High costs of production and expensive cryogenic tank storage have limited its widespread commercial use. Concerns about cost and safety have limited development of US terminals.

COAL

Surface mining of coal and its household use is documented by archeological evidence in China from about 3490 BCE. The process of mining coal developed in sixteenth-century Scotland, with advances in the seventeenth century. The Industrial Revolution in eighteenth-century Britain led to extensive use of coal in Britain to drive steam engines (see Figure 1.11).

Since the 1990s, coal use in buildings has declined, with many large cities limiting its application. Coal is the largest source of energy for the generation of electricity worldwide. It is also used for industrial processes such as refining metals. Currently in the United States, most coal is used for electric generation and heavy industry.

Coal is inconvenient to transport, handle, and use. Because it is dirty to burn and may cause acid rain, its use is restricted to large burners, where expensive equipment is installed to reduce air pollution. Modern techniques scrub and filter out sulfur ash from coal combustion emissions, and older coal-burning plants that still contribute significant amounts of airborne pollution are under governmental pressure to improve. Even with this equipment, burning coal still produces CO_2 and contributes to global warming.

The United States has enough coal to last well over a century. However, deep mining exposes miners to the risk of explosions and cave-ins, as well as severe respiratory ailments by exposure to coal dust. Strip mining is damaging to the surface of the land, and reclamation, although possible, is expensive. The western United States, a location where water for reclamation is a scarce resource, is the site of much of the current strip mining.

Figure 1.11 Early nineteenth-century Bradley coal mine, Staffordshire, England
Source: Archivist / Adobe Stock

NUCLEAR ENERGY

Nuclear energy is produced by fission. The introduction of nuclear power promised an energy source that used resources very slowly.

The first nuclear power plant started operation in 1957. By 2022, there were 54 commercially operated nuclear plants with 92 reactors, located in 28 US states. Nuclear power produces around 8% of electricity consumed in the United States, according to the EIA.[3]

Despite originally being hailed as the answer to our energy problems, nuclear fission has become one of the most expensive and least desirable ways to produce electricity. The narrowly averted disaster in 1979 at Three Mile Island, Pennsylvania; the 1986 explosion at Chernobyl, Ukraine; and the Fukushima Daiichi nuclear disaster in 2011 in Japan have realized safety fears.

Nuclear plants contain high pressures, temperatures, and radioactivity levels during operation, and have long and expensive construction periods. The public has serious concerns over the release of low-level radiation over long periods of time, the risks of high-level releases, and problems with disposal of radioactive fuel. Nuclear reactors consume huge quantities of cooling water, and heat up rivers. Added to this is the threat of nuclear materials falling into the hands of terrorists or unreliable governments. Civilian use has been limited to research and generation of electricity.

Global Climate Change

Global warming and cooling are part of the earth's natural cycle. However, the global warming that is currently occurring is due in large part to the actions of human beings. The presence of certain gases in the atmosphere allows the sun's UV radiation to pass through, but blocks the infrared (IR) radiation emitted by sources on earth. The increasing production of some gases, most commonly carbon dioxide, is resulting in a warming trend called the greenhouse effect.

GREENHOUSE EFFECT

The greenhouse effect is a natural phenomenon that helps regulate the temperature of our planet, protecting the earth's surface from extreme differences in day and night temperatures. **Greenhouse gases** are pollutants that trap the earth's heat, especially emissions of carbon dioxide from burning fossil fuels. As greenhouse gases accumulate in the atmosphere, they absorb sunlight and IR radiation and prevent some of the heat from radiating back out into space, trapping the sun's heat closer to the earth. If all of these greenhouse gases were to suddenly disappear, our planet would be 60°F (15.5°C) colder than it is, and uninhabitable. Significant increases in the amount of these gases in the atmosphere cause global temperatures to rise.

Human activities contribute substantially to the production of greenhouse gases. Activities including building construction and operation are adding greenhouse gases to the atmosphere at a faster rate than at any time over the past several thousand years, accelerating global climate change. According to the US Department of Commerce National Oceanic and Atmospheric Administration (NOAA) Annual Greenhouse Gas Index for 2016, global warming has increased 40% since 1990.[4]

Greenhouse gases include **carbon dioxide**, **methane** (which is pound for pound over 20 times greater than carbon dioxide over a 100-year period), nitrous oxide, **ozone**, **chlorofluorocarbons** (CFCs), and other gases (see Table 1.1). Most are produced by burning fossil fuels, which include coal, oil, and natural gas. Water vapor can also be considered a greenhouse gas, as it absorbs IR radiation reradiated from the earth.

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[3]https://www.eia.gov/energyexplained/us-energy-facts/
[4]https://www.noaa.gov/news/noaa-s-greenhouse-gas-index-up-40-percent-since-1990 (accessed 17 November 2023).

TABLE 1.1 GREENHOUSE GASES

Greenhouse Gas	Man-made Sources	Comments
Carbon dioxide (CO_2)	Burning fossil fuels, cement production, deforestation	After water vapor, the most common greenhouse gas
Methane (CH_4)	Landfills, rice farming, cattle raising, burning fossil fuels, landfills	Next most common greenhouse gas after CO_2
Nitrous oxide (N_2O)	Nylon production, nitric acid production, agriculture, automobile engines, biomass burning	Third most common greenhouse gas after N_2O
Hydrofluorocarbons (HFCs)	Fire suppressants, refrigerants	Replacement for CFCs, do not affect ozone layer but add carbon dioxide
Perfluorocarbons (PFCs)	Production of aluminum from alumina	Very potent, very long-lived
Sulfur hexafluoride (SF_6)	Electrical equipment manufacturing, window filling inert gas, magnesium casting	Extremely potent but low quantity in the atmosphere

The ten hottest years in recorded human history have occurred since 2010. The polar ice caps are already melting, and as they do, sea levels will rise, leading to coastal flooding. Related changes in climate can affect agricultural production and the habitability of some regions.

We can help control global warming by reducing the use of fossil fuels through energy conservation and alternative fuel sources. Designers can design for energy conservation and the use of clean and renewable energy sources.

Interior designers can specify materials and equipment that avoid fuel combustion and environmentally damaging refrigerants, and select insulation, upholstery, and other products made with environmentally benign materials.

OZONE

A blanket of ozone gas screens the earth from harmful UV radiation from the sun. Depletion of ozone in the stratosphere results in more UV radiation reaching the earth's surface. We need to preserve the high-altitude ozone layer that intercepts most UV radiation before it can reach earth.

The thinning of the ozone layer has been in large measure due to the use of CFC refrigerants in building air conditioning systems. CFCs that had escaped from air conditioners, been released as spray-can propellants, or were released from other refrigerant sources slowly migrated to the upper atmosphere, where they continue to deplete the protective ozone layer for an estimated 50 years.

Production of CFC refrigerants has been banned, but previously released chemicals continue to thin the ozone layer. The US Clean Air Act of 1990 allows the sale of new refrigeration equipment that uses hydrochlorofluorocarbons (HCFCs) until 2020; after that, only service of existing systems will be permitted. In the United States, production levels of HCFCs were frozen in 2015 and banned entirely in 2030. As of 2020, the stratospheric ozone layer is recovering, but complete recovery is not expected until 2050 or later. Refrigerants including CFCs, HCFCs, and hydrofluorocarbons (HFCs) are also greenhouse gases that contribute directly to global warming.

See Chapter 14, "Heating and Cooling Systems," for more information on refrigerants.

Energy Consumption by Buildings

According to the US Energy Information Administration, 60% of the energy used in the United States comes from fossil fuels. With less than 5% of the world's population, the United States consumes nearly 25% of primary energy consumption. In 2021, buildings accounted for 39% of end-use energy consumption.

The sun's energy arrives at the earth at a fixed rate, and the supply of solar energy stored over millions of years in fossil fuels is limited. As the population keeps growing, people continue using more energy. We do not know exactly when we will run out, but we do know that wasting the limited resources we have is a dangerous way to go. Through careful design architects, interior designers, and building engineers can help make these finite resources last longer.

The design of the building's interior can help keep the interior warm or cool. Thermally massive interior materials support **passive solar design**, which relies on the design of the building itself, rather than on fuel-consuming mechanical equipment.

Building designers and owners now strive for energy efficiency to minimize costs and conserve resources. United States building codes include energy conservation standards. The United States is increasingly taking energy use and global climate change seriously. The conservation of resources and use of environmentally friendly energy sources have become standard practice for building designers.

BUILDING SITE CONDITIONS

Early in the design process, site-planning decisions affect the options considered for building lighting and control systems, as well as the amount and type of energy used. The use of on-site resources such as sun, water, wind, and plant life can replace or supplement the building's dependence on nonrenewable fuels. Site planning considers existing site conditions, climatic conditions, and intended building use. It is important for interior designers to be informed and involved in the building design process from the beginning.

Site Analysis

A site analysis is a helpful diagram to understand visually all of the advantages and constraints of a specific project's location. Architects and designers will utilize a site analysis diagram to annotate all aspects of a building site including: wind direction, sun path, greenery and views available, vehicular and pedestrian traffic patterns, building egress points, noise and light pollution, site water flow, existing shade, and building orientation. Considering all these elements when proposing a design solution can become overwhelming without a visual diagram.

Building Placement

Where and how a building is positioned on the earth affects its structure, supply and retention of water, collection and retention of heat from the sun and the earth, cooling and ventilation by winds, exposure to fire, and level of acoustic quiet or noise. Each of these conditions shapes the building's design; the result can reflect and communicate a sense of place.

CONNECTIONS TO SURROUNDINGS

Buildings bring people, vehicles, materials, and sounds of activity to a site. The site is connected to utilities including electricity, water, and natural gas. The building changes how the site is illuminated with electric lighting at night. Heat flows both to and from the building through openings and the building envelope. Landscaping changes the flow of water, and liquid and solid wastes are often moved offsite for treatment or disposal.

When a building fills an entire site, on-site resources are limited, and wind and sunlight may be blocked. Less heat and water are able to be absorbed, and the roof may be the only area capable of nurturing plants.

Climates

Climate study views the weather statistically over long periods of time, including such criteria as temperature, **relative humidity**, solar radiation, and wind speed. Climates vary with the earth's position in relation to the sun, and with latitude and longitude. The characteristics of a climate include the amount of sun, humidity and precipitation, and air temperature, motion, and quality of a specific area.

Relative humidity (RH) is the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature.

Designing for **local climate** conditions reduces the fuel needed to operate mechanical heating and cooling equipment. Interior shading reduces the need for mechanical cooling, while operable window treatments allow in the sun's warmth when desired.

See Chapter 6, "Windows and Doors," for more information on windows and window treatments.

LOCAL CLIMATES

Local temperatures vary with the time of day and the season of the year. Because the earth stores heat and releases it at a later time, a phenomenon known as **thermal lag** occurs in which afternoon temperatures are generally warmer than mornings. The lowest daily temperature is usually just before sunrise, when most of the previous day's heat has dissipated. Although June experiences the most solar radiation in the Northern Hemisphere, summer temperatures peak in July or August due to the long-term effects of thermal storage. Because of this residual stored heat, January and February – about one month past the winter solstice – are the coldest months. It is usually colder at higher latitudes, both north and south, as a result of shorter days and less solar radiation.

MICROCLIMATES

Sites may have **microclimates**, different from surrounding areas, which result from the interaction of the larger climate with site-specific characteristics such as topography, vegetation, elevation, proximity to large bodies of water, views, and wind patterns. Buildings influence microclimates by redirecting rainwater to nourish plants, blocking or channeling wind, and moderating or maintaining hotter temperatures by storing heat in thermal massive materials. A site should be selected with its microclimate advantages in mind.

HEAT ISLANDS

Cities sometimes create their own microclimate **heat islands** with relatively warm year-round temperatures produced by heat sources such as air conditioners, furnaces, electric lights, car engines, and building machinery. The amount of added heat in a heat island varies widely depending on its location, the season, the time of day, and the buildings it contains.

Cities are often cloudier than surrounding areas, and because of their accumulated heat, tend to have more rain instead of snow. Wind is channeled between closely set buildings. High vertical walls and narrow streets diminish solar radiation. Sun is absorbed and reradiated off massive surfaces, and less is given back to the obscured night sky. Highly reflective glass surfaces intensify glare and add to summer cooling loads of adjacent buildings. The convective updrafts created by the buildings in large cities can also affect the regional climate.

CLIMATE TYPES

Environmentally sensitive buildings are designed in response to the climate type of the site. Indigenous architecture, which has evolved over centuries of trial and error, provides models for building in the four basic climate types: cold, temperate, hot arid, and hot humid.

COLD CLIMATE DESIGN **Cold climates** feature long cold winters with short, very hot periods occurring occasionally during the summer. Cold climates are generally found around 45 degrees latitude north or south: in the United States, North Dakota is an example.

Buildings designed for cold climates emphasize heat retention. Minimizing the surface area of the building reduces exposure to low temperatures. The building is oriented to absorb heat from the winter sun. Passive solar heating is often used to encourage heat retention without mechanical assistance. Cold climate buildings may have fewer windows to limit heat loss. Wind protection may be necessary.

Setting a building into a protective south-facing hillside reduces the amount of heat loss and provides wind protection, as does burying a building in earth (see Figure 1.12).

TEMPERATE CLIMATE DESIGN **Temperate climates** have cold winters and hot summers. Temperate climates are found between 35 degrees and 45 degrees latitude, in Washington, DC, for example.

A temperate climate favors a design that encourages air movement in hot weather while protecting against cold winter winds. Buildings designed for temperate climates employ winter heating and summer cooling, especially where it is humid. In the Northern

Figure 1.12 Pioneer dugout home near McCook, Nebraska, 1890s

Figure 1.13 House for temperate climate, 1930s

Hemisphere, south-facing walls are exposed to winter sun, with summer shade for exposures on the east and west sides and over the roof. Deciduous shade trees that lose their leaves in the winter help to protect the building from sun in hot weather and allow the winter sun through (see Figure 1.13).

Adding materials that retain heat inside a well-insulated building helps even out solar heat gains and losses through windows and internal heat gains from activities; it also moderates high summertime daytime temperatures.

HOT, ARID CLIMATE DESIGN **Hot, arid climates** have long hot summers and short sunny winters, and the daily temperatures that range widely between dawn and the warmest part of the afternoon. They may have very cold winters. Arizona is an example of a hot arid climate in the United States.

Buildings in hot, arid climates feature heat and sun control. They often try to increase cooling and humidity by taking advantage of any wind and rain, and make the most of the cooler winter sun.

Designs for hot, arid climates provide summer shade to the east and west and over the roof. They use massive walls to create a time lag as heat moves slowly from outside to inside (see Figure 1.14). Strategies include shading small windows and outdoor spaces from the sun, with light interior colors to diffuse the limited **daylight**.

Enclosed courtyards offer shade and encourage air movement, and the presence of a fountain or pool and plants increases humidity. In warm climates, sunlit surfaces should be a light color, to reflect as much sun as possible.

HOT, HUMID CLIMATE DESIGN **Hot, humid climates** have very long summers with slight seasonal variations and relatively constant temperatures. The weather is consistently hot and humid, as in New Orleans.

Buildings designed for hot, humid climates take advantage of shading from the sun to reduce heat gain and cooling breezes with many large windows, overhangs, and shutters. They minimize east and west exposures to reduce solar heat gain, although some sun in winter

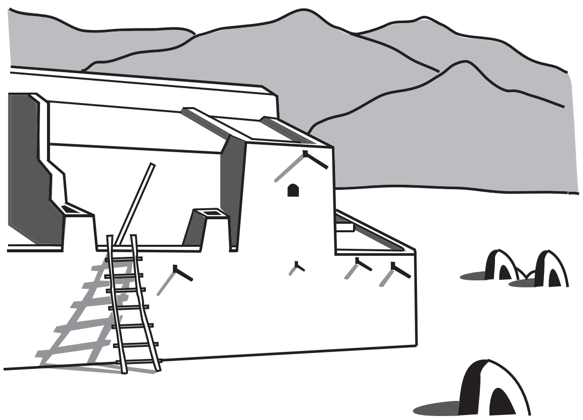

Figure 1.14 Taos Pueblo, New Mexico, 1880

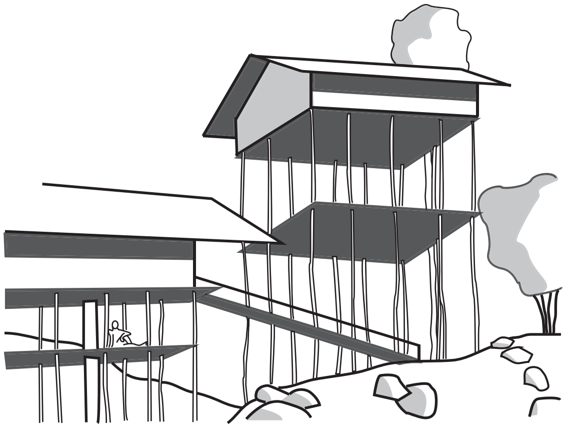

Figure 1.15 Treehouses in Buyay, Mount Clarence, New Guinea

may be desirable. High ceilings can accommodate large windows and to help stratify air, with cooler air at the level of occupants and warmer air exiting the space above. Floors may be raised above ground (see Figure 1.15) with crawl spaces for air circulation.

Additional climate design examples are found in Chapter 2, "Designing for the Environment," and Chapter 12, "Principles of Thermal Comfort."

Site Conditions

Architects analyze the local conditions of the building site, including sun and wind patterns in the summer and winter, water runoff patterns, and microclimate conditions. They look at how privacy and site access, views, sound, heat, light, air motion, and water change with the vertical distance from the surface, and apply this information to design the functions of building spaces to match the horizontal and vertical layers of the building (see Figure 1.16).

The climate of a particular building site is determined by the sun's angle and path, the air temperature, humidity, precipitation, air motion, and air quality. Building designers describe sites by the type of soil, the characteristics of the ground surface, and the topography of the site. The presence of water on the site affects the plants and animals found there. People living on the site are exposed to and alter its views, heat levels, noise, and other characteristics.

Building structures depend on the condition of the soil and rocks on the site. The construction of the building may remove or use earth and stone or other local materials. Alterations destroy, alter, or establish habitats for native plants and animals. Elevating a

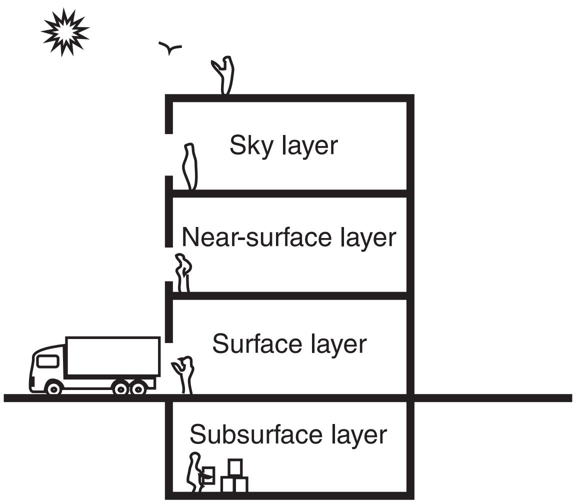

Figure 1.16 Building use layers

structure on poles or piers minimizes disturbance of the natural terrain and existing vegetation. Setbacks provide access to daylight and fresh air, and may be required by code to meet height restrictions (see Figure 1.17).

Typically, public utilities connect distribution systems at the building boundary. These include piping for water and gas, and electric service wiring. Buildings contribute to air pollution directly through fuel combustion, and indirectly through the electric power plants that supply energy and the incinerators and landfills that receive waste. The presence of people has a major environmental impact.

The interior of the building responds to these surrounding conditions by opening up to or turning away from views, noises, smells, and other disturbances. Interior spaces connect to existing on-site walks, driveways, parking areas, and gardens (see Figure 1.18). The presence of wells, septic systems, and underground utilities influence the design of residential bathrooms, kitchens, and laundries as well as facilities in commercial buildings.

The hard surfaces and parallel walls in cities intensify noise. Mechanical systems of neighboring buildings may be very noisy, and are hard to mask without reducing air intake, although newer equipment is usually quieter. Plants only slightly reduce the sound level, but the visually softer appearance gives a perception of acoustic softness, and the sound of wind through the leaves may help to mask noise. Fountains also provide helpful masking sounds.

PREVIOUS USES OF SITES

Effective planning can create efficient, environmentally sustainable urban forms while minimizing urban sprawl. Siting buildings near mass transit avoids consumption of fossil fuels and pollution from automobiles.

Reusing land that has already been impacted by human activities rather than undeveloped properties supports land conservation by bringing land back to productive use (see Table 1.2). Land reuse can also promote economic and social revitalization in distressed areas.

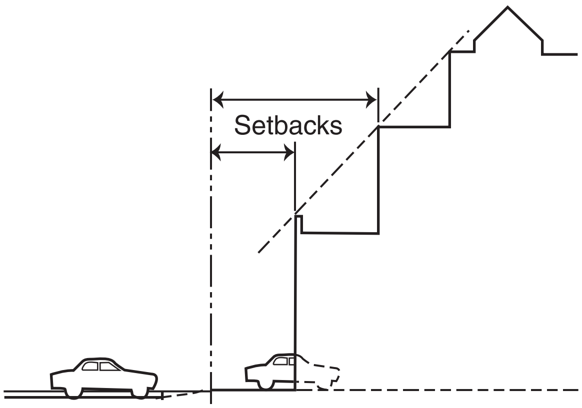

Figure 1.17 Building setbacks

Source: Adapted from Francis, D.K. Ching, *Building Construction Illustrated* (5th ed.), Wiley 2014, page 1.25

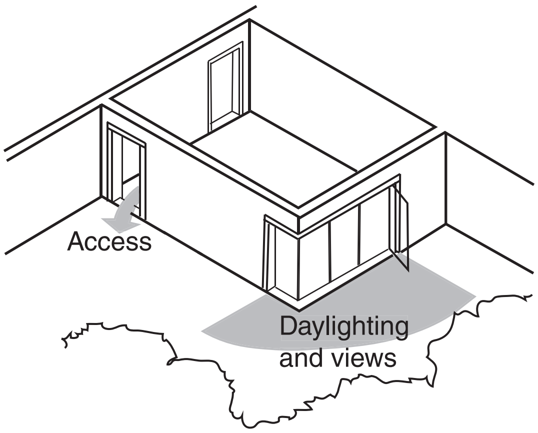

Figure 1.18 Connecting interior to outdoors

Source: Adapted from Francis, D.K. Ching and Corky Binggeli, *Interior Design Illustrated* (3rd ed.), Wiley 2012, page 28

TABLE 1.2 LAND REUSE

Type	Description	Comments
Greenfields	Undeveloped natural properties that have experienced little or no impact from human activities. Can include agricultural land without activities other than farming.	Loss of prime farmland should be avoided. Support biodiversity by siting the building to avoid encroachment on animal habitats.
Brownfields	Abandoned, idle, or underused industrial and commercial facilities for which expansion or redevelopment is complicated by real or perceived environmental contamination.	Hazardous substances, pollution, or contamination may complicate reuse. Brownfields near preexisting infrastructure and a potential workforce can be valuable.
Grayfields	Blighted or obsolete building sites on land that is not necessarily contaminated.	May be valuable due to scarcity of available urban land, preexisting infrastructure, government incentives.
Blackfields	Include properties such as abandoned coal strip mines and subsurface mines.	Surface water may have very low pH levels, may be contaminated with iron, aluminum, manganese, sulfates.

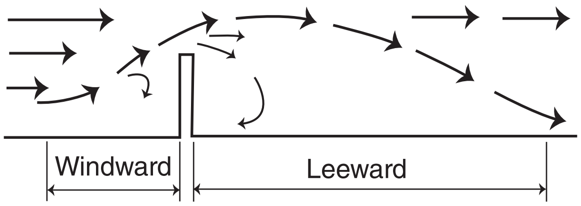

Figure 1.19 Wind barrier

Source: Adapted from Francis, D.K. Ching, *Building Construction Illustrated* (5th ed.), Wiley 2014, p. 1.22

WIND AND THE SITE

Winds are usually weakest in the early morning and strongest in the afternoon, and can change their effects and sometimes their directions with the seasons. Evergreen shrubs, trees, and fences slow and diffuse winds near low-rise buildings.

The wind patterns around buildings are complex, and localized wind conditions between buildings often increase wind speed and turbulence just outside building entryways. The flow of wind typically returns to its original flow pattern after encountering an obstacle (see Figure 1.19). Less-dense windbreaks such as fences and plants tend to reduce the returning velocity more than thicker building materials.

WATER AND THE SITE

Large bodies of water moderate air temperature between day and night and throughout the year. The evaporation of smaller water bodies helps cool summer air temperatures.

Water appears on the site due to precipitation of rainwater or snow, or as groundwater and soil moisture. Some sites offer **potable** (drinkable) water. Treatment or removal of wastewater occurs on some sites.

Fountains, waterfalls, and trees tend to raise the humidity of the site and lower the temperature. Large bodies of water, which are generally cooler than the land during the day and warmer at night, act as heat reservoirs that moderate variations in local temperatures and generate offshore breezes. They are usually warmer than the land in the winter and cooler in the summer.

Rainwater falling on steeply pitched roofs with overhangs is usually collected by gutters and downspouts to be carried away as **surface runoff,** or underground through a storm sewer. Drain leaders are pipes that run vertically within partitions to carry the water down through the structure to the storm drains. Even flat roofs have a slight pitch, with the water collecting into roof drains that pass through the interior of the building.

Sites and buildings should be designed for maximum on-site rainfall retention. Roof ponds and cisterns hold water that falls on the roof, giving the ground below more time to absorb runoff.

See Chapter 9, "Water Supply Systems," for more information on using rainwater.

PLANT AND ANIMAL LIFE

Building sites provide environments for a variety of plant and animal life. Grasses, weeds, flowers, shrubs, and trees trap precipitation, prevent soil erosion, provide shade, and deflect wind. Grassy areas are cooler than paved areas, both day and night. Plants play a major role in food and water cycles, and their growth and change through the seasons help us mark time. They can help keep unwanted solar heat and light out of buildings during the warmest part of the year. Vegetation absorbs moisture during the day for release at night. Plants improve air quality by trapping particles on their leaves, to be washed to the ground by rain; photosynthesis assimilates gases, fumes and other pollutants.

Plants increase our sense of enjoyment and enhance privacy. Plants frame or screen views, moderate noise, and visually connect the building to the site.

Deciduous plants grow and drop their leaves on a schedule that responds more to the cycles of outdoor temperature than to the position of the sun. In the Northern Hemisphere, where the sun reaches its maximum strength from March 21 through September 21, plants provide the most shade from June to October, when the days are warmest (see Figures 1.20 and 1.21). Evergreens provide shade all year and help reduce snow glare in winter.

In the Northern Hemisphere, a deciduous vine on a trellis over a south-facing window grows during the cooler spring, shades the interior during the hottest weather, and loses its leaves in time to welcome the winter sun. Vertical vine-covered trellises work well on east and west façades, while horizontal ones work in any orientation (see Figure 1.22). The vine also cools its immediate area by evaporation.

Bacteria, mold, and fungi break down dead animal and vegetable matter into soil nutrients. Bees, wasps, butterflies, and birds pollinate plants, but are kept out of the building. Termites may attack the building's structure. Building occupants may welcome cats, dogs, and other pets into a building, but want to exclude nuisance animals such as mice, raccoons, squirrels, lizards, and stray dogs.

Termite damage is a problem in warmer climates. It is advisable to recommend an inspection before beginning a remodeling project if there are termites in the area.

SHADE

The ability of trees to provide shade depends on their orientation to the sun, their proximity to the building or outdoor space, their shape, height, and spread, and the density of their foliage and branch structure. In the Northern Hemisphere, the most effective shade is on the southeast in the morning and the southwest during late afternoon, when the sun has a low angle and casts long shadows.

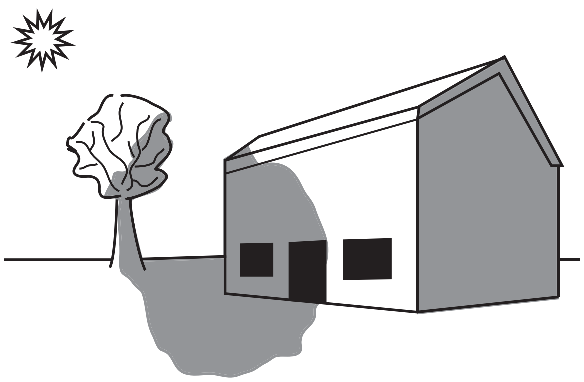

Figure 1.20 Deciduous shade tree in summer

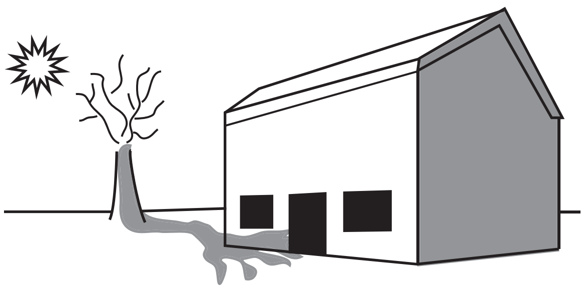

Figure 1.21 Deciduous shade tree in winter

Figure 1.22 Trellis with vine

Air temperatures in the shade of a tree are about 5° to 11°F (3° to 6°C) cooler than in the sun. A wall shaded by a large tree in direct sun may be 20° to 25°F (11° to 14°C) cooler. This temperature drop is due to the shade plus cooling evaporation from the surface area of the leaves. Shrubs right next to a wall produce similar results, trapping cooled air and preventing drafts from infiltrating the building. Neighborhoods with large trees have maximum air temperatures up to 10°F (6°C) lower than those without.

BUILDING SITING AND ORIENTATION

The site location, **building orientation** and geometry, and local climate conditions affect the design of the building and its systems. Site selection and building orientation benefit from the involvement of architects and their consultants as early as possible. By close coordination of an interdisciplinary design team, the architect can optimize the use of the site and its integration with its local environment. Each member of the design team – including the interior designer – can determine how the site affects their particular discipline and how best to further sustainable design goals.

The interaction of building orientation and interior layout has a long history. The Roman architect Vitruvius wrote about the design of public baths that "the warmest possible situation must be selected; that is, one which faces away from the north and northeast. The rooms for the hot and tepid baths should be lighted from the southwest, or, if the nature of the situation prevents this, at all events from the south, because the set time for bathing is principally from midday to evening." (*The Ten Books on Architecture*, Dover Publications, Inc., 1960, page 157)

Building orientation considerations include solar orientation, topography or adjacent structures, prevailing winds, available daylight and shading, views, and landscaping and irrigation needs. The building's orientation, form, and compactness have significant impacts on heating, cooling, and lighting systems, and energy conservation. The orientation of the building and its width and height determine how the building will be shielded from excess heat or cold or open to ventilation or light. For example, the desire to provide daylight and natural ventilation to each room limits the width of multistory hotels.

Buildings that minimize east and west exposures are generally more energy efficient, especially where extensive glazing absorbs heat during summer months. Orienting the main elevations with operable windows perpendicular to prevailing breezes aids natural ventilation. A rectilinear building with its length oriented in an east/west direction will present its longer south façade to the sun for maximum winter solar gain.

When designing a building to take advantage of solar heating, provisions must be made to prevent overheating in warm weather. Roofs provide a barrier to excess summer solar radiation, especially in low latitudes where the sun is directly over-head. The transmission of solar heat from the roof to the interior of the building can result in high ceiling temperatures. High ceiling temperatures can be reduced with thermally resistant materials, materials with high thermal capacity, or ventilated spaces in the roof structure.

Orienting building entrances away from or protected from prevailing cold winter winds, and buffering entries with airlocks, vestibules, or double entry doors dramatically reduces the amount of interior and exterior air change when people enter.

Locating an unheated garage, mudroom, or sunspace between the doors to a conditioned interior space is a very effective way to control air loss in a building.

Interior Layout

To ensure overall compatibility, the layout of a building's interior should be considered while the building is being located on its site, and while its rough shape, shading, and orientation are being established.

In the Northern Hemisphere, spaces with maximum heating and lighting needs should be located on the building's south face. Buffer areas, such as toilet rooms, kitchens, corridors, stairwells, storage, garage, and mechanical and utility spaces need less light and air conditioning, and can be located on a north or west wall. The areas with the greatest illumination level needs should have access to natural lighting. Conference rooms, which need few or no windows for light and views, can be located further away from windows. Spaces that need a lot of cooling due to high internal heat gains from activities or equipment should be located on the north or east sides of the building.

Energy for mechanical heating and cooling can be conserved by locating spaces that accommodate cooler temperatures on the north side of the building. Buffer spaces such as garages on the north or west protect the building interior from winter cold or, for the western exposure, summer sun.

For more information on daylighting and layout, see Chapter 17, "Lighting Systems."

Openings in the building are the source of light, sun, and fresh air. Building openings provide opportunities for wider personal choices of temperature and access to outdoor air. On the other hand, they limit control of humidity, and permit the entry of dust and pollen.

Planning the layout of interior spaces to maximize the use of standard sizes of materials and products minimizes construction waste.

Existing Buildings

Existing buildings are often demolished and replaced with new products in new buildings. Building reuse is a more sustainable practice. **Demolition-by-hand salvage**, in which the building is taken apart and its constituent pieces are reused, is an alternative that is labor intensive (which may provide job training experience) but energy wise.

Historic preservation and adaptive reuse represent the highest form of recycling. Building reuse reduces the demand for new land, recycles existing buildings, uses fewer materials, and reduces the amount of construction demolition and waste going to landfills. By keeping older buildings in usable condition and protecting their original use or finding a new one, communities create a sense of continuity and cultural richness.

Construction work in occupied existing buildings requires separation and protection of occupied areas from construction areas. Noise control measures must be taken. Ducts and airways must be protected from dust, moisture, particulates, chemical pollutants, and microbes during demolition and construction. There should be increased ventilation and exhaust air at the construction site.

Chapter Review

This first chapter has introduced climate change, energy sources, and site conditions. We covered what climate change is, the effect it has had on our planet, and what we as designers can do to fight it. Understanding the different types of energy sources and the differences between the renewable and nonrenewable sources allows designers to make educated decisions and arguments for the most sustainable design solutions. A thorough site analysis ensures an efficient use of building orientation and landscape elements to provide a coordinated interior. Understanding how the exterior and interior environments interact with one another provides the most benefit to the design solution and the occupants of the space. The focus of this chapter helps designers to understand the environment we design within and around. A better understanding of the environment can help us to create energy efficient interiors, and positively affect the site in which we and our occupants live. A solid understanding of energy sources can help designers specify sustainable fixtures finishes and equipment, in Chapter 2 we explore how sustainable design promotes energy efficiency.

Focus words

passive systems
carbon dioxide (CO_2)
Environmental Protection Agency (EPA)
renewable energy
fossil fuels
photovoltaic (PV)
electromagnetic spectrum
ultraviolet (UV)
photosynthesis
infrared (IR)
wind turbines
hydroelectric power
geothermal energy
geo-exchange
biomass
hydrogen
net metering
nonrenewable energy sources
hydraulic fracturing (fracking)
greenhouse gases
carbon dioxide
methane
ozone
chlorofluorocarbon
passive solar design
relative humidity
local climate
thermal lag
microclimates
heat islands
cold climates
temperate climates
hot, arid climates
daylight
hot, humid climates
greenfields
brownfields
grayfields
blackfields
potable
surface runoff
building orientation
demolition-by-hand salvage

Guiding questions

A list of guiding questions to help students and educators digest the chapter's information and lead an open discussion.

1. What is the interior designer's role in terms of site design and energy usage?
2. What are the different design considerations of a building in a hot humid climate verses a building in a cold climate?
3. What are some design strategies that can be used to mitigate a heat island?
4. How do the site conditions affect the space you are in currently? Think about the wind, the view, the sun direction, and site noise.
5. Think about a space that you know that is negatively affected by the site conditions. How could this space be redesigned to serve the occupant better?

Activity

For this activity, choose a building you know and create a site analysis diagram. A site analysis diagram is a plan view that graphically shows the building and the surrounding site conditions. Consider representing the sun movement over the space, wind direction, location of views and light or noise pollution, cardinal directions, pedestrian or vehicle traffic around the building, and any other site considerations. Include a key of your symbols and label your areas.