PART

I

THE BUILDING AND ITS ENVIRONMENT

Although interior designers are primarily concerned with the conditions inside buildings, they benefit from observing a building's site, climate, and geography. Interior spaces are increasingly blended with their natural settings. Wise energy use dictates awareness of how sun, wind, and cold affect the building's interior. Interior designers today are working as part of environmentally aware design teams.

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Environmental Conditions and the Site

Like our skins, a building is the interface between our bodies and our environment. The **building envelope** is the point at which the inside comes into contact with the outside; it is the place where energy, materials, and living things pass in and out. The building's interwoven structural, mechanical, electrical, plumbing, and other systems create an interior environment that supports our needs and activities and responds to exterior weather and site conditions. In turn, the building itself and its site are affected by the earth's larger natural patterns.

THE OUTDOOR ENVIRONMENT

The sun acting on the earth's atmosphere creates climate and weather conditions. 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 is the source of almost all of our energy resources. **Ultraviolet (UV) radiation** from the sun triggers photosynthesis in green plants, producing the oxygen we breathe, the plants we eat, and the fuels we use for heat and power. UV wavelengths make up only about 1 percent of the sun's rays that reach sea level and are too short to be visible. About half of the energy in sunlight that reaches the earth arrives as visible wavelengths. The remaining energy is infrared (IR) radiation, with wavelengths longer than visible light that carry the sun's heat.

The distance that radiation must travel through the earth's atmosphere largely determines the amount of radiation that reaches the earth's surface. This distance varies with the angle of the earth's tilt toward or away from the sun; this tilt is responsible for the seasons.

The sun warms our bodies and our buildings both directly and indirectly by warming the air around us. We depend on the sun's heat for comfort, and our buildings are designed to admit sunlight for warmth. Passive and active solar design techniques also protect us from excessive heat and help keep our buildings comfortable in hot weather.

The sun's heat also powers the **hydrologic cycle** by evaporating water into the air and purifying it through distillation. The water vapor condenses as it rises, then precipitates as rain and snow, which clean the air as they fall to the earth. Heavier particles fall out of the air because of gravity, and the wind (driven by the sun's heat) dilutes and distributes any remaining contaminants when it stirs up the air.

The sun illuminates the indoors through windows and skylights during the day. Direct sunlight is often too bright for comfortable vision. When the atmosphere scatters visible light, the resulting shade offers an even, restful illumination. Under heavy clouds and at night, artificial light provides adequate illumination.

Sunlight disinfects surfaces that it touches, which is one reason the old-fashioned clothesline may be superior to the clothes dryer. 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.

However, sunlight can also be destructive. While most UV radiation is blocked by the high-altitude ozone layer, enough UV radiation gets through to burn our skin painfully, sometimes even fatally. Over the long term, exposure to UV radiation may result in skin cancer.

In addition to providing direct solar heat and light, the sun's energy is transferred, stored, and used by plants and animals.

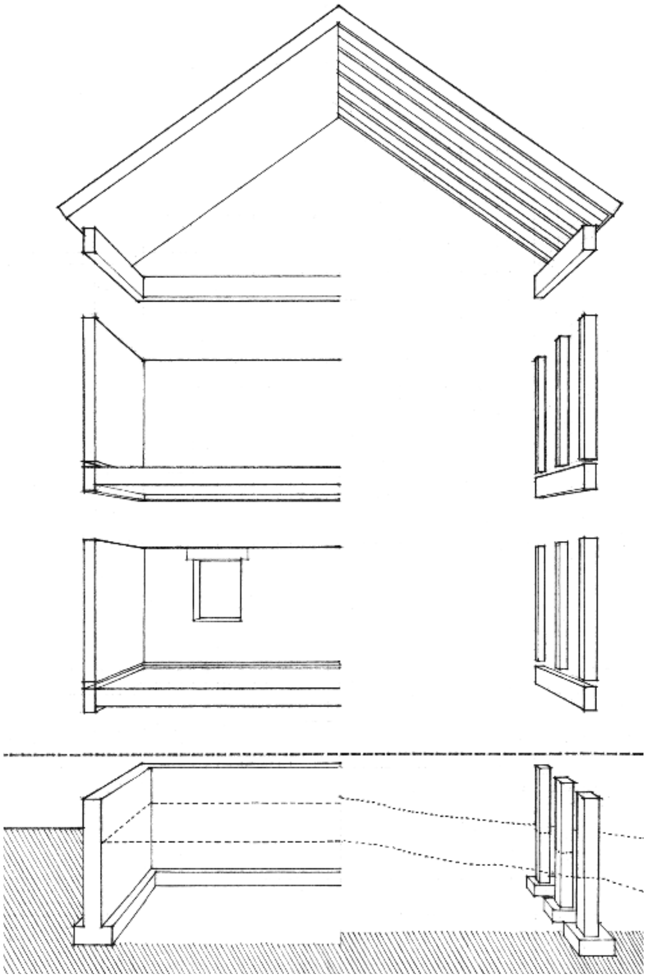

Figure 1-1 Superstructure and foundation. The underground part of the building is in direct contact with soil, rock, and groundwater. The aboveground superstructure is affected by wind, rain, snow, and sun. Building designs can blend into or shut out environmental conditions. Our design choices have a direct impact on our world.

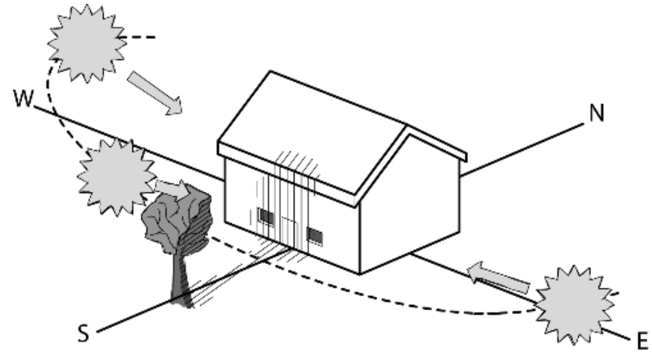

Figure 1-2 Sun angles in northern latitudes. In the northern hemisphere, direct solar radiation in midsummer strikes perpendicular to the earth's surface. In the winter, solar radiation travels a longer, lower-angled path through the atmosphere.

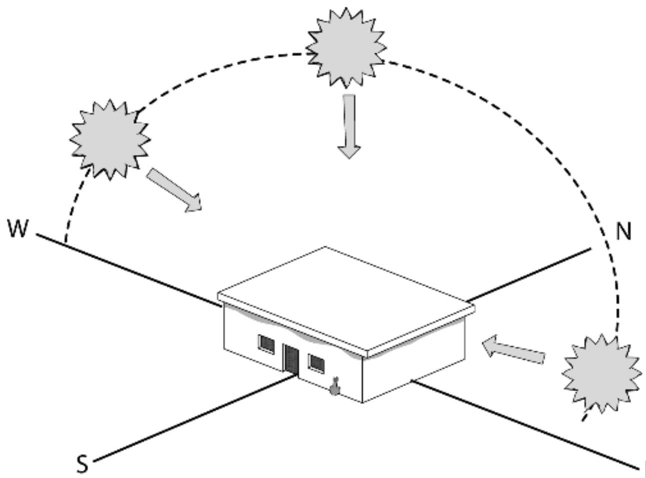

Figure 1-3 Sun angles in tropical latitudes. Closer to the equator, the sun remains more directly overhead throughout the year.

Plants combine the sun's energy with water and turn it into sugars, starches, and proteins through photosynthesis. During this process, plants remove carbon dioxide from the air and return oxygen. Humans and other animals breathe in oxygen and exhale carbon dioxide, thereby completing the cycle.

Besides the roles photosynthesis plays in food supply and oxygen production, it is also instrumental in producing wood for construction, fibers for fabrics and paper, and landscape plantings for shade and beauty.

☑ **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 that interior designers must consider when specifying materials.**

Plants transfer the sun's energy to us when we eat them, as well as when we eat plant-eating animals. This energy goes back into the environment when animal waste decomposes and releases nitrogen,

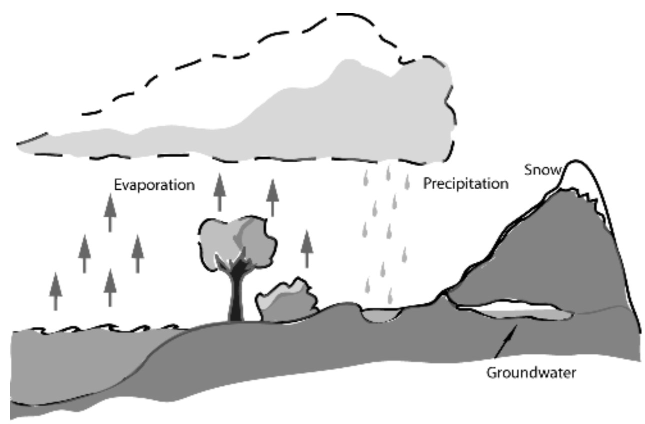

Figure 1-4 Hydrologic cycle. Changing climate conditions affect how much water evaporates from ice, snow, and surface bodies of water. When, where, and how much water precipitates back to the earth are also affected by climate, including wind and storm patterns. Warming temperatures influence how much water is stored as ice and snow.

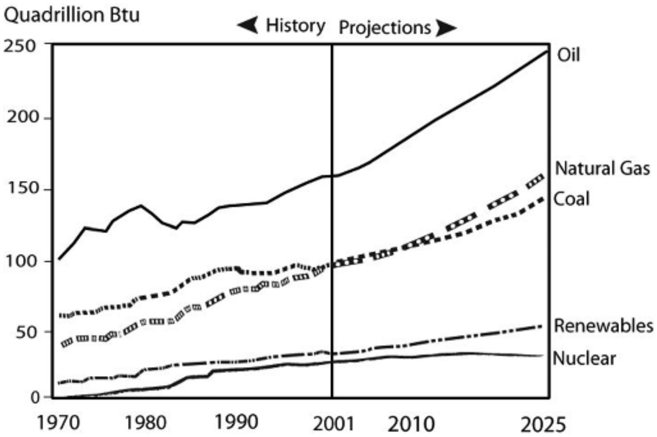

Figure 1-5 Graph of world energy use. This graph shows worldwide energy use.

phosphorus, potassium, carbon, and other elements into the soil and water. Animals or microorganisms break down dead animals and plants into basic chemical compounds, which then reenter the cycle to nourish plant life.

All of our energy sources are derived from the sun, with the exception of geothermal, nuclear, and tidal power.

- **Photovoltaic (PV)** technology converts solar energy directly into electricity at a building's site. PV collectors provide energy for heating water or for electrical power.
- Wind power derives from currents created when the sun heats the air and the ground.
- Hydroelectric power is made possible by the solar-driven cycle of evaporation and precipitation of water.
- Electricity produced by solar or wind energy can in turn be used to generate hydrogen, a high-grade fuel, from water.
- Photosynthesis provides the materials for biomass conversion, which is the combustion of firewood, crop waste, and even animal waste.

All of the above are considered to be renewable resources because they can be continually replenished, but our demand for energy may exceed the rate of replenishment.

Our most commonly used fuels—coal, oil, and gas—are fossil fuels. Huge quantities of decaying vegetation were compressed and subjected to the earth's heat over hundreds of millions of years, creating the fossilized solar energy we use today. Clearly, these resources are not renewable in the short term.

LIMITED ENERGY RESOURCES

According to the Department of Energy (DOE), 85 percent of the energy used in the United States comes from fossil fuels. With only 5 percent of the world's population, the United States consumes roughly 25 percent of the world's fossil fuel resources, of which buildings use 40 percent to operate.

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

Historically, human societies have used a variety of energy sources. Before 1800, solar energy was the dominant source of heat and light, and wood was used for fuel. Wind was used for transportation and processing of grain. Early industries located along rivers and streams utilized waterpower.

Around the beginning of the nineteenth century, mineral discoveries introduced portable, convenient, and reliable coal, petroleum, and natural gas fuels to power the Industrial Revolution.

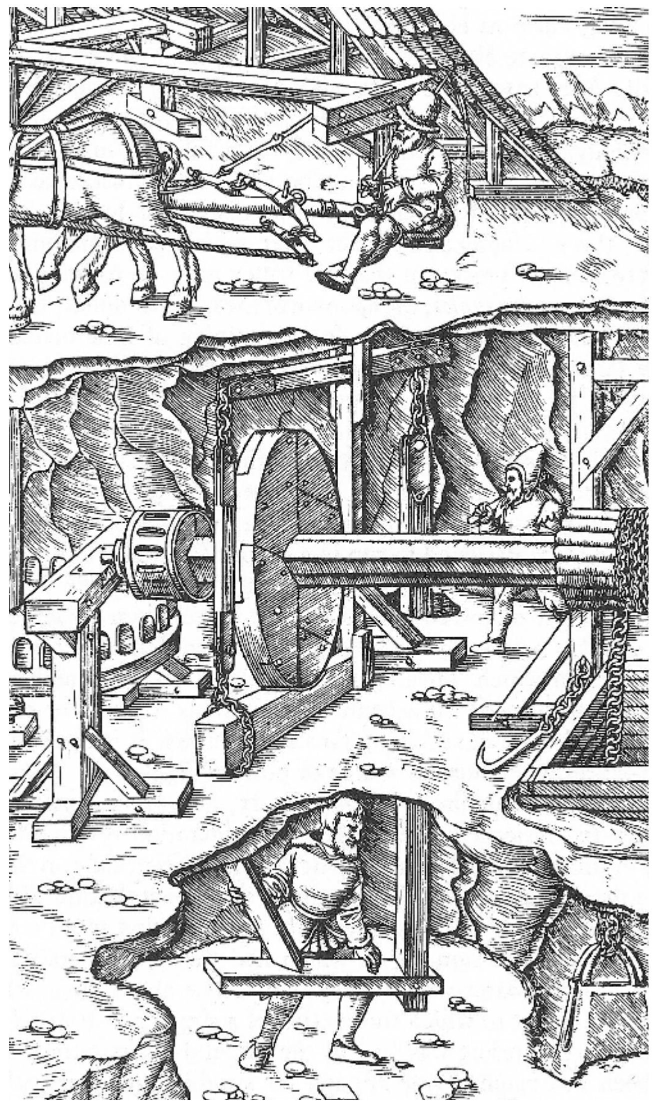

Figure 1-6 Medieval power sources. In 1556, Georg Bauer, known as Agricola, included this image of mining in Bohemia in *De re metallica*. A water wheel is the primary power source for a geared windlass (center) supplemented by horsepower (top) for smaller loads.

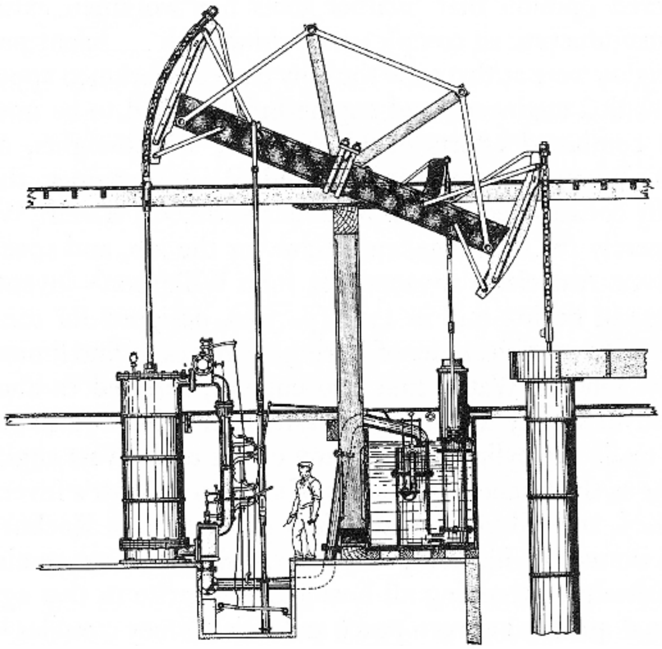

Figure 1-7 Steam engine. This early Boulton & Watt pumping engine was built in 1777 and remained in operation for more than 125 years.

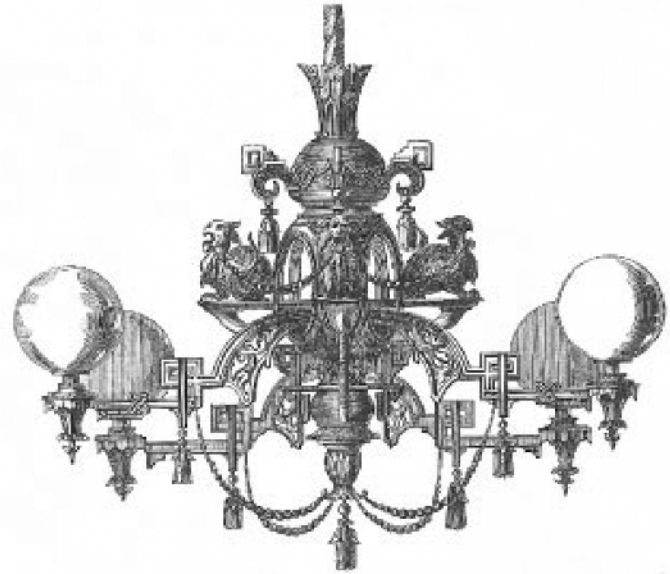

Figure 1-8 Gas chandelier. *The Crystal Palace Exhibition Illustrated Catalog* of 1851 praises this work by Mr. Potts of Burlington as "a beautiful example of metallurgical manufacturing art."

In the 1830s, the earth's population, which was approximately one billion, depended on wood for heat and animals for transportation and work. Oil and gas were burned to illuminate interiors. By the 1900s, coal was the dominant fuel, followed by hydropower and natural gas.

By 1950, petroleum and natural gas split the energy market about evenly. The United States was completely energy self-sufficient because of relatively inexpensive and abundant domestic coal, oil, and natural gas. The introduction of nuclear power promised an energy source that used resources very slowly. Nuclear plants contain high pressures, temperatures, and radioactivity levels during operation and require long and expensive construction periods. The public has serious concerns over the release of low-level radiation over extended periods as well as the risks of high-level

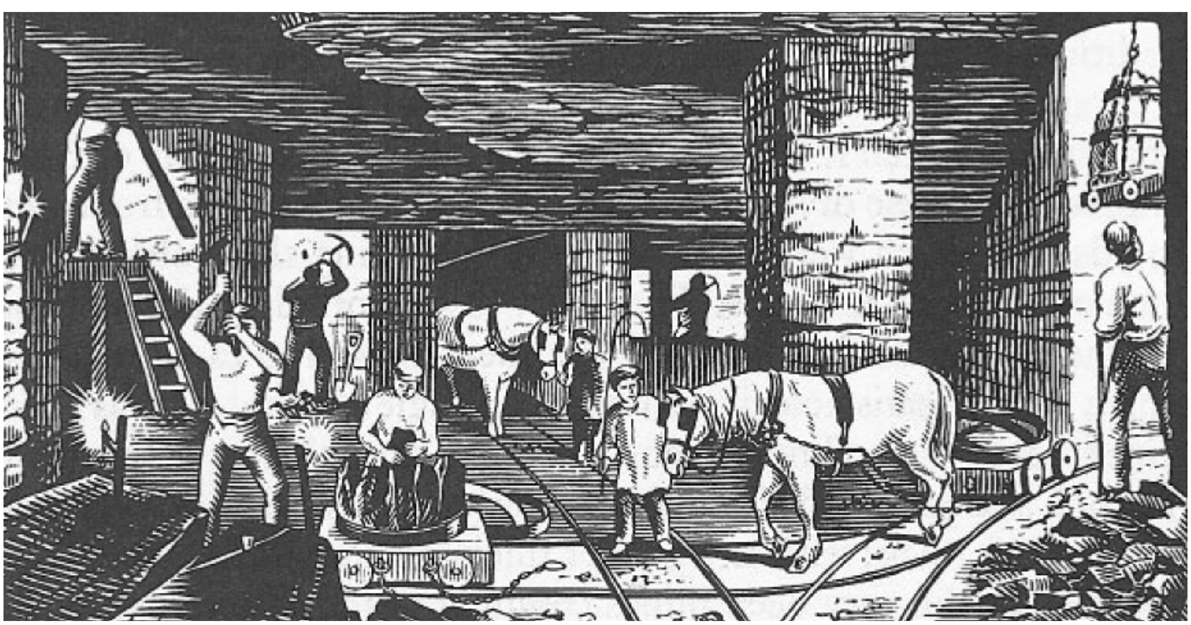

Figure 1-9 Bradley coal mine, Staffordshire. In the early nineteenth century, women carried coal in wicker baskets up 100-foot-tall ladders. Trucks were hauled by women and children who could work in passages too low even for pit ponies. Miners worked in poor ventilation by handpick and crowbar, blasting without a safety fuse until its invention in 1831.

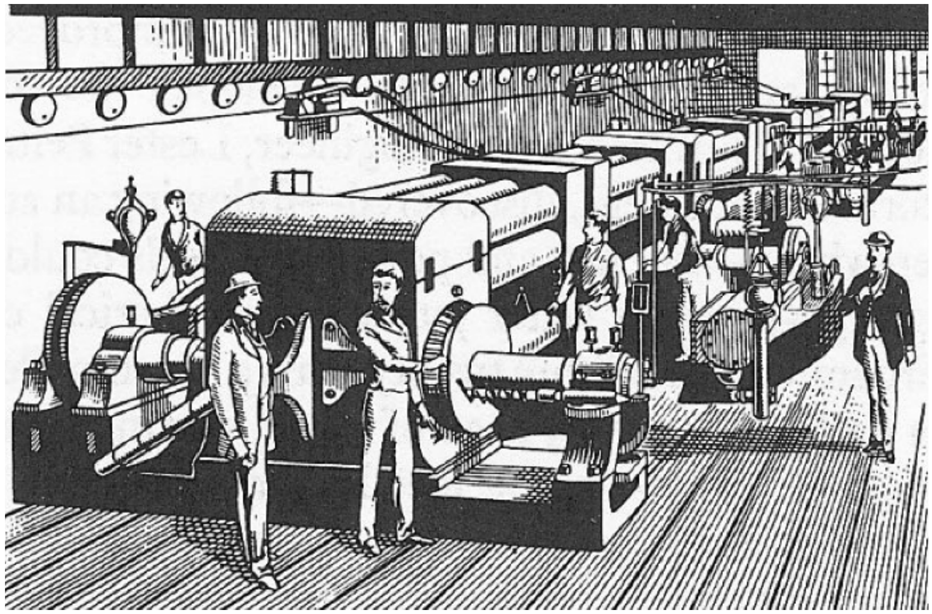

Figure 1-10 Pearl Street generating station, 1882. Thomas Edison's central generating station provided electrical energy for New York; widespread distribution remained a problem.

releases. Civilian use has been limited to research and the generation of electricity.

Since the 1950s, the United States has 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. Between the late 1970s and 1982, the amount of oil imported by the United States dropped from more than 40 percent to 28 percent.

Since the 1990s, coal use in U.S. buildings has declined, with many large cities limiting its application. Currently, most coal is used for the generation of electricity and heavy industry, where fuel storage and air pollution problems can be treated centrally. Modern techniques scrub and filter out sulfur ash from coal combustion emissions, although some older coal-burning plants still contribute significant amounts of airborne pollution.

Today, buildings are heavily reliant on electricity because of its convenience and versatility. Consumption of electricity is expected to continue to rise significantly, especially in the developing economies of Asia.

- Electricity and daylight provide almost all illumination.
- Electric lighting produces heat, which, in turn, increases air conditioning use in warm weather, using even more electricity.
- Only one-third of the energy used to produce electricity for space heating actually becomes heat; most of the remaining energy is wasted at the production source.

World fossil fuel reserves are limited, with much of it expensive and environmentally objectionable to remove. Buildings under construction today could outlive fossil fuel supplies if use continues at current rates. Traditional off-site networks for natural gas and oil and the electric grid will continue to serve many buildings, often in combination with on-site sources.

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 PV electricity. On-site resources take up space locally, can be labor intensive, and sometimes have high initial costs that take years to recover. Owners and designers must look beyond these immediate obstacles and consider a building's impact on its larger environment throughout its life.

Building designers and owners now strive for energy efficiency to minimize costs and conserve resources. U.S. building codes include energy conservation standards, and public awareness of the need to conserve petroleum has risen dramatically. Even so, the quantity of imported oil remains at high levels, according to March 2008 data from the DOE:

- U.S. energy consumption rose 17.5 percent between 2002 and 2006.
- Fossil fuels made up just slightly less than 86 percent of energy consumed in 2006.
- Coal and petroleum use increased, while natural gas use decreased.
- Nuclear electric power increased.
- Renewable energy increased about 17 percent, with increases in biofuels as well as geothermal, hydroelectric, solar, PV, and wind power.

Today, the United States is regarding energy use and global climate change seriously. Time will tell whether the use of environmentally friendly energy sources will become standard practices in the future.

THE GREENHOUSE EFFECT

Human activities, including building construction and operation, are adding greenhouse gases—pollutants that trap the earth's heat—to the atmosphere at a faster rate than at any time over the past several thousand years. Today, we are witnessing global climate change at an unprecedented rate.

The following are some facts about the greenhouse effect:

- It is a natural phenomenon that helps regulate the temperature of the earth, protecting the earth's surface from extreme differences in daytime and nighttime temperatures.
- As greenhouse gases accumulate in the atmosphere, they absorb both sunlight and IR and prevent some of the heat from radiating back out into space, thereby trapping the sun's heat around the earth.
- If all of these greenhouse gases were to disappear suddenly, the earth would be 15.5°C (60°F) colder than it is currently—and uninhabitable.
- Human activities contribute significantly to the production of greenhouse gases, especially emissions of carbon dioxide from burning fossil fuels.
- Significant increases in the amount of these gases in the atmosphere cause global temperatures to rise.

☑ **Designers can reduce greenhouse gases caused by power plants and building fuel consumption by designing for energy conservation and using clean and renewable energy sources. Designers can specify materials and equipment that avoid fuel combustion and environmentally damaging refrigerants, as well as select insulation, upholstery, and other products made with environmentally benign materials.**

SUSTAINABLE DESIGN STRATEGIES

Sustainable architecture looks at human civilization as an integral part of the natural world and seeks to preserve nature through encouraging conservation in daily life. According to Design Ecology, a project sponsored by Chicago's International Interior Design Association (IIDA) and Collins & Aikman Floorcoverings, "Sustainability is a state or process that can be maintained indefinitely. The principles of sustainability integrate three closely intertwined elements—the environment, the economy, and the social system—into a system that can be maintained in a healthy state indefinitely."

Energy conservation in buildings is a complex issue that involves sensitivity to the building site, construction methods, the use and control of daylight, the selection of finishes and colors, and the design of artificial lighting. The choice of **heating, ventilating, and air conditioning (HVAC)** and other equipment can have a major effect on energy use.

The materials and methods used for building construction and finishing also have an impact on the larger world. The design of a building determines how much energy it will use throughout its life. The materials used in the building's interior are tied to the waste and pollution generated by their manufacture and eventual disposal. Increasing energy efficiency and using clean energy sources can limit greenhouse gases.

Environmentally conscious interior design is a practice that attempts to create indoor spaces that are environmentally sustainable and healthy for their occupants. Sustainable interiors address their impact on the global environment.

TABLE 1-1. GREENHOUSE GASES

Greenhouse Gas	Man-made Sources	Comments
Carbon dioxide (CO_2)	Burning fossil fuels, cement production, deforestation	Most potent greenhouse gas
Methane (CH)	Landfills, rice farming, cattle raising, burning fossil fuels	Second most potent greenhouse gas
Carbon monoxide (CO)	Industrial smokestacks, coal-fired electric utilities, tobacco smoke	Toxic to humans; eventually converts to carbon dioxide in atmosphere
Nitrous oxide (N_2O)	Nylon production, nitric-acid production, agriculture, automobile engines, biomass burning	Third most potent greenhouse gas
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
Chlorofluorocarbons (CFCs)	Refrigeration; air conditioning; blowing agents for foamed plastics for insulation, upholstery padding, packaging; propellants for fire extinguishers, aerosols	Man-made compounds banned by Montreal Protocol in 2000; very stable; last up to 50 years; destroy ozone in upper atmosphere
Sulfur hexafluoride (SF_6)	Electrical-equipment manufacturing, window-filling inert gas, magnesium casting	Extremely potent but low amount in atmosphere

☑ **To achieve sustainable design, interior designers must collaborate with architects, developers, engineers, environmental consultants, facilities and building managers, and contractors. The professional ethics and responsibilities of the interior designer include the creation of healthy and safe indoor environments. An interior designer's choices can provide comfort for the building's occupants while benefiting the environment, an effort that often requires initial conceptual creativity rather than additional expense.**

Setting Sustainability Goals

"Setting sustainability goals with your client is a great opportunity to educate them on sustainable design costs and benefits, and it is a great way to establish a trusting relationship with your client as you begin a project," according to Tom Hootman, American Institute of Architects (AIA), LEED AP (*ASID ICON*, January/February 2008, p. 38). He identifies two key types of sustainability goals: resource reduction and performance enhancement.

Resource-reduction goals include:

- Energy-use reductions
- Carbon-emission reductions
- Water-use reductions
- Materials reuse and recycled content
- Waste reduction

Performance-enhancement goals include:

- Air-quality improvements
- Thermal-comfort improvements
- Acoustical-performance enhancements
- Light- and visual-quality enhancements

It is often possible to use techniques that have multiple benefits, spreading the cost over several applications to achieve a better balance between initial costs and benefits. For example, a building designed for daylighting and natural ventilation also offers benefits for solar heating, indoor air quality, and lighting costs. This approach cuts across the usual building system categories and ties the building closely to its site. We will discuss many of these techniques in this book, crossing conventional barriers between building systems in the process.

Sustainable Design Strategy List

Sustainable design strategies include the following:

- Use alternative energy sources, waste control, water recycling, and control of building operations and maintenance.
- Limit greenhouse gas production by specifying energy-efficient lighting and appliances.
- Reduce energy use by employing natural light, natural ventilation, and adequate insulation.
- Specify materials that require less energy to manufacture and transport.
- Use products made of recycled materials that can, in turn, be recycled when they are replaced.
- Reduce energy use while improving conditions for the building's occupants with user-operated controls, such as low-tech shades or operable windows.
- Use natural on-site energy sources to reduce a building's fossil-fuel needs.
- Carefully site buildings to enhance daylighting as well as passive cooling by night ventilation, support opportunities for solar heating, improve indoor air quality, reduce use of electric lights, and add acoustic absorption.
- Employ rainwater retention for irrigation and flushing toilets.
- Use on-site wastewater recycling for irrigation.
- Reduce noise pollution through building siting, space planning, materials selections, and equipment selection.

Building designers can look at the building envelope, HVAC system, lighting, equipment and appliances, and renewable energy systems as a whole. **Energy loads**—the amount of energy a building uses to operate—are reduced by integration with the building site, the use of renewable resources, the design of the building envelope, and the selection of efficient lighting and appliances. Energy load reductions lead to smaller, less expensive, and more efficient HVAC systems that in turn use less energy.

Buildings as well as products can be designed for reuse and recycling. A building designed to easily adapt to changed uses reduces the amount of demolition and new construction and prolongs the building's life. Products that do not combine different materials allow easier separation and reuse or recycling of metals, plastics, and other constituents than products whose diverse materials are bonded together. The use of removable and reusable demountable building parts increases adaptability but may require a heavier structural system because floors are not integral with beams. In addition, mechanical and electrical systems must be well integrated to prevent leaks or cracks.

The LEED System

The U.S. Green Building Council, a nonprofit coalition that represents the building industry, has created a comprehensive system for building green known as **Leadership in Energy and Environmental Design™ (LEED)**. LEED provides investors, architects and designers, construction personnel, and building managers with information on green building techniques and strategies. LEED certifies buildings that meet the highest standards of economic and environmental performance and offers professional education, training, and accreditation. LEED programs cover new and renovation construction, commercial interiors, and residential projects.

☑ **LEED Professional Accreditation recognizes an individual's qualifications in sustainable building. Interior designers are among those who can become LEED-accredited professionals by passing the LEED Professional Accreditation examination, which establishes minimum competency in much the same way as the NCIDQ and other professional exams. Training workshops are available to those who are preparing for the exam.**

The LEED process for designing a green building starts with setting goals. Next, alternative strategies are evaluated. Finally, the design of the whole building is approached in a spirit of integration and inspiration.

Energy Star®

The **Energy Star**® label was created in conjunction with the U.S. Department of Energy and the U.S. Environmental Protection Agency to help consumers quickly and easily identify energy-efficient products, such as homes, appliances, and lighting. Energy Star products are also available in Canada.

Advances in Sustainable Design

An article in *Contract* (January 2008) discusses the plans put forth by the U.S. Green Building Council (USGBC) to revamp LEED into a system that better assesses the environmental impact of the built environment, and the collaboration between USGBC and Autodesk to develop software that could create a more integrated design process via a holistic approach to building systems. Article author Douglas Wittnebel of Gensler (p. 136) predicts that "most, if not all, planned and constructed projects will be ecologically fingerprinted (like a new identification and approval system for appropriating energy and materials for design and construction)." In the same article, Joe Rondinelli of Shepley Bulfinch Richardson Abbott forecasts that "sustainability will be well woven into the building process, eliminating a stand-alone rating system such as LEED."

"Imagine a highly sophisticated **building integrated modeling (BIM)** software capable of calculating real-time energy and water use levels, for example, and USGBC LEED points based upon evolving design decisions, as they're made." So begins an article by Barbara Horwitz-Bennett (*Contract*, January 2008, p. 48).

Conservation of limited resources is good, but it is possible to create beautiful buildings that generate more energy than they use and actually improve the health of their environments. Rather than reducing the amount of damage buildings do to the environment, which results in designs that do less—but still some—damage, designs can have a positive net effect. Buildings can model the abundance of nature, creating more and more riches safely and generating delight in the process.

This work has been pioneered by William McDonough of William McDonough + Partners and McDonough Braungart Design Chemistry, LLC, and Dr. David Orr, chairman of the Oberlin Environmental Studies Program. Their designs employ a myriad of techniques for efficient design.

Creative approaches to environmentally friendly design are in the news daily. In addition, people are looking to techniques used historically and in traditional societies throughout the world for ideas that are responsive to local conditions and respectful of resources.

Figure 1-11 Energy Star® label.

TABLE 1-2. ENERGY STAR® PRODUCTS

Product Category	Energy Star® Products
Appliances	Clothes washers, dishwashers, room air conditioners, room air cleaners, others
Heating and Cooling Equipment	Boilers, fans, central air conditioning, furnaces, thermostats, others
Home Envelope	Insulation, roofing products, windows, doors, skylights
Office Equipment	Computers, copiers, printers, scanners
Lighting	Compact fluorescent light bulbs, residential lighting fixtures, ceiling fans, exit signs
Commercial Equipment	Food-service equipment, vending machines, water coolers, others

BUILDING SITE CONDITIONS

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.

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 sunlight, humidity and precipitation, and air temperature, motion, and quality. In addition, climates change over time; currently, we are experiencing a period of accelerated global climate change.

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**), afternoon temperatures are generally warmer than morning temperatures. Typically, the lowest daily temperature is 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 on December 21—are the coldest months. Temperatures are usually lower at higher latitudes, both north and south, as a result of shorter days and less solar radiation.

Sites may have microclimates, different from surrounding areas, that result from their elevation, proximity to large bodies of water, shading, and wind patterns. Cities sometimes create their own microclimates—heat islands—with relatively warm year-round temperatures produced by such heat sources as air conditioners, furnaces, electric lights, car engines, and building machinery. Energy released by urban vehicles and buildings warms the air 3°C to 6°C (5°F–11°F) above the surrounding countryside. The rain that runs off hard paved surfaces and buildings into storm sewers is not available for evaporative cooling. Wind is channeled between closely set buildings, which also block the sun's warmth in winter. The convective updrafts created by the large cities can affect the regional climate. Sunlight is absorbed and reradiated off massive surfaces, and less is given back to the obscured night sky.

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 CLIMATES

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; North Dakota is an example. Buildings designed for cold climates:

- emphasize heat retention
- offer protection from rain, snow, and winter wind
- often use passive solar heating to encourage heat retention without mechanical assistance

In cool regions, minimizing the surface area of a building reduces exposure to low temperatures. Buildings are oriented so that they absorb heat from the winter sun. Cold air collects in valley bottoms. North slopes get less winter sun and more winter wind, and hilltops lose heat to winter winds. Setting buildings into a protective south-facing hillside reduces the amount of heat loss and provides wind protection, as does setting buildings in earth. In cold climates, dark colors on south-facing surfaces increase the absorption of solar heat. Dark roofs with steep slopes collect heat. This effect is negated when the roofs are covered with snow; however, the snow itself insulates the buildings from heat loss.

TEMPERATE CLIMATES

Temperate climates, which have cold winters and hot summers, are found between 35 degrees and 45 degrees latitude. For example, Washington, DC, is in a temperate climate zone. Buildings in such zones generally require:

- winter heating and summer cooling, especially if it is humid
- south-facing walls exposed to winter sun
- summer shade for exposures on the east and west and over the roof

Deciduous shade trees that lose their leaves in the winter help protect buildings from the sun in hot weather and allow winter sunlight through. Temperate climates favor a design that encourages air movement in hot weather while protecting against cold winter winds.

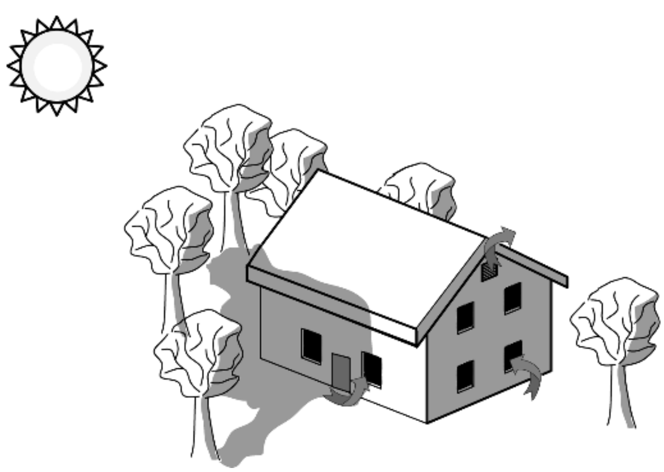

Figure 1-12 Shading and ventilation. Building orientation and landscaping create shade, while window locations aid ventilation.

Figure 1-13 Design for temperate climate. This small 1930s house faces the sun, with shade trees sheltering its east and west sides. When the weather becomes colder and leaves fall, more sunlight warms and illuminates the building's interior.

HOT, ARID CLIMATES

Hot, arid climates have long, hot summers and short, sunny winters, and daily temperatures range widely between dawn and the warmest part of the afternoon. Arizona is an example of a location with such a climate. Buildings designed for hot, arid climates:

- feature heat and sun control
- often try to increase cooling and humidity by taking advantage of wind and rain
- make the most of the cool winter sun
- shade windows and outdoor spaces from the sun
- provide summer shade to the east and west and over the roof

Enclosed courtyards offer shade and encourage air movement, and the presence of a fountain or pool and plants increases humidity. Even small bodies of water produce a psychological and physical evaporative cooling effect. Sites in valleys near a watercourse keep cooler than poorly ventilated locations. In warm climates, sunlit surfaces should be a light color in order to reflect as much sunlight as possible.

HOT, HUMID CLIMATES

Hot, humid climates have very long summers with slight seasonal variations and relatively constant temperatures, as in New Orleans. Buildings designed for hot, humid climates:

- take advantage of cooling breezes and shading from the sun to reduce solar heat gain
- minimize east and west exposures to reduce solar heat gain, although some sun in winter may be desirable

Wall openings are directed away from major noise sources so that they can remain open to take advantage of natural ventilation. If possible, the floor is raised above the ground, with a crawl space under the building for good air circulation.

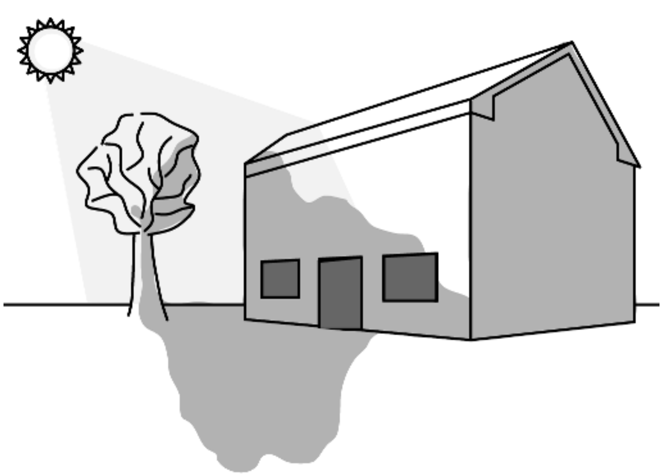

Figure 1-14 Deciduous shade tree in summer. Interior building temperatures benefit from seasonal changes in sun angles and plant growth.

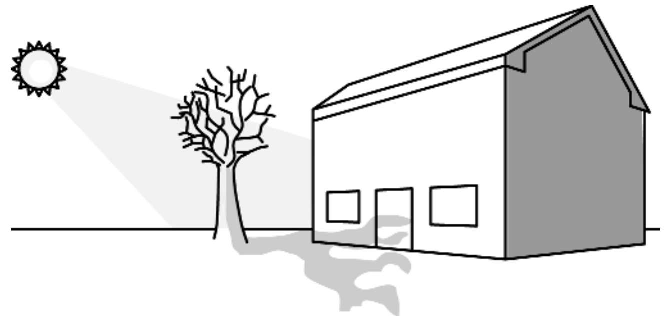

Figure 1-15 Deciduous shade tree in winter. Bare tree branches allow lower lower sun angles to penetrate to the building interior.

The Site

The climate of a particular building site is determined by the sun's angle and path; air temperature, motion, and quality; humidity; and precipitation. Building designers describe sites by type of soil, ground surface characteristics, and topography. 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.

Subsoil and topsoil conditions, subsurface water levels, and rocks affect excavations, foundations, and landscaping of the site. Hills, valleys, and slopes determine how water drains during storms and whether soil erosion occurs. Site contours shape paths and roadway routes, shelter from the wind, and plant locations. Elevating a structure on poles or piers minimizes disturbance of the natural terrain and existing vegetation.

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. Construction can introduce utilities to the site, including water, electricity, and natural gas. Alterations destroy, alter, or establish habitats for native plants and animals.

The presence of people creates a major environmental impact. 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.

- Coal-burning power plants are primary causes of acid rain (which contains sulfur oxides) and smog (which contains nitrogen oxides).
- Industrial smoke, gases, dust, and chemical particles pollute the air.
- Idling motors at drive-up windows and loading docks may introduce gases into building air intakes.
- Sewage and chemical pollutants damage surface water or groundwater.

Built-up areas upset natural drainage patterns. Other nearby buildings shade areas of the site and can divert wind. Close neighbors may limit visual or acoustic privacy. Weeds or soil erosion result from previous land use.

Figure 1-16 On-site sound masking. Plants and water in the Dr. Sun Yat Sen Chinese Garden create a quiet oasis in the center of Vancouver, British Columbia. The placid, contemplative design feels miles away from the busy urban area nearby.

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. The presence of wells, septic systems, and underground utilities influence the design of residential bathrooms, kitchens, and laundries as well as commercial buildings.

Traffic, industry, commerce, recreation, and residential uses all create noise. The hard surfaces and parallel walls in cities intensify noise. Mechanical systems of neighboring buildings may be quite 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 helps to mask noise. Fountains also provide masking sounds.

BUILDING USE LAYERS

As you move up and down a site or within a multistory building, each level lends itself to certain types of uses. The sky layer is usually the most inaccessible and offers the most exposure to wind, sun, daylight, and rain. The near-surface layer is more accessible to people and activities. The surface layer encourages the most frequent public contact and the easiest access. The subsurface layer confers isolation by enclosure and provides privacy and thermal stability, but it may have groundwater problems.

WIND AND THE SITE

Winds are usually weakest in the early morning and strongest in the afternoon, and can change their effects and sometimes even their directions with the seasons. Evergreen shrubs, trees, and fences slow and diffuse winds near low-rise buildings; the more open a windbreak, the farther away its influence will be felt. Although dense windbreaks block wind in their immediate vicinity, the wind whips around them to ultimately cover an even greater area. Wind

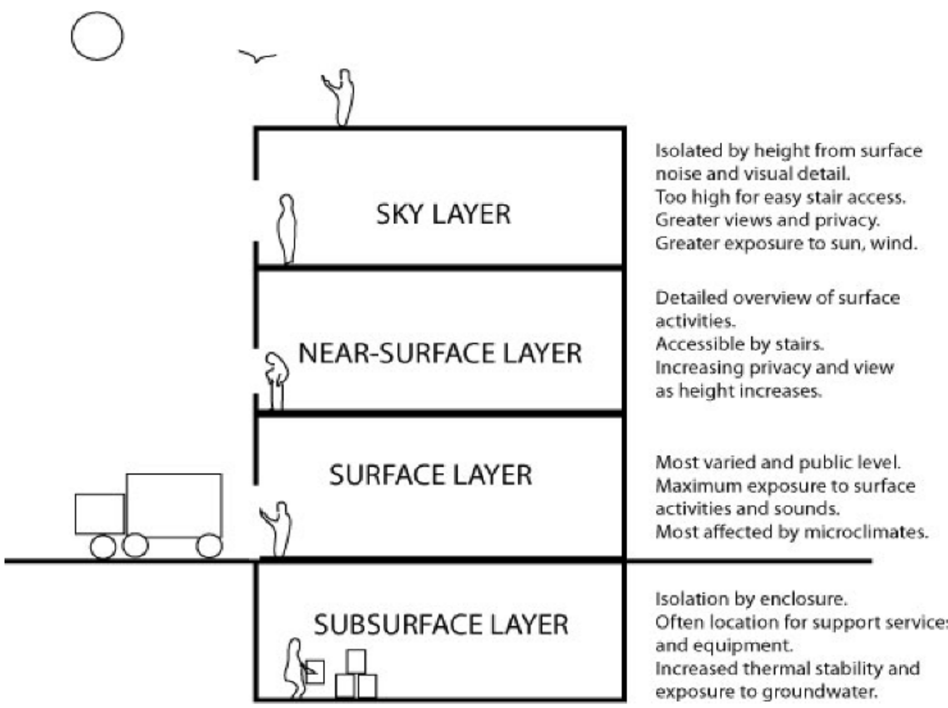

Figure 1-17 Building use layers. Multistory buildings are often layered in ways that reflect the relation to the ground in the placement of building functions.

speed may increase through gaps in a windbreak. Blocking winter winds may sometimes also block desirable summer breezes. Wind patterns around buildings are complex, and localized wind turbulence between buildings often increases wind speed and turbulence just outside building entryways.

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 as well as permit the entry of dust and pollen. The desire for daylight and wind-driven ventilation affects the configuration and location of buildings.

Forests, trees, hills, and other buildings shape local wind patterns. The absorbency of the ground surface determines both how much heat will be retained to be released at night and how much will be reflected onto the building surface. Light-colored surfaces reflect solar radiation, while dark ones absorb and retain radiation. Plowed ground or dark pavement will be warmer than surrounding areas, radiating heat to nearby surfaces and creating small updrafts of air. Grass and other ground covers lower ground temperatures by absorbing solar radiation. They also aid cooling through evaporation.

WATER AND THE SITE

Water appears on the site in four forms:

- precipitation of rainwater or snow
- presence of groundwater and soil moisture
- availability of **potable** (drinkable) water
- treatment or removal of wastewater

Fountains, waterfalls, and trees tend to raise the humidity of a site and lower the temperature. Large bodies of water, which are generally cooler than land during the day and warmer than land at night, act as heat reservoirs that moderate variations in local temperatures and generate offshore breezes. Large water bodies are usually warmer than land in the winter and cooler than land 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. Even flat roofs have a slight pitch, and the water collects into roof drains that pass through the interior of the building. **Drain leaders** are pipes that run vertically within partitions to carry water down through the structure to the storm drains. Interior drains are usually more expensive than exterior gutters and leaders.

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. The evaporation from a roof pond also helps cool the building. Water collected on the roof for later use adds weight and increases structural requirements.

Porous pavement has a water-permeable pavement surface with a stone reservoir underneath. It may look like regular asphalt or concrete, but it is made without fine filler materials; the resulting void spaces allow water to infiltrate.

Incremental paving consists of small concrete or plastic paving units alternating with plants, so that rainwater can drain into the ground. Parking lots can also be made of open-celled pavers that allow grass or groundcover plants to grow in their cavities. Brick paving set on gravel with sand allows water to pass through to the soil below.

In some parts of North America, half of residential water is consumed outdoors, much of it for lawn sprinklers that lose water to evaporation and runoff. Sprinkler timing devices control the length of the watering cycle and the time when it begins, so that watering can be done at night when less water evaporates. Rain sensors shut off the system, and monitors check soil moisture content. Bubblers with very low flow rates lose less water to evaporation. With drip irrigation, which works well for individual shrubs and small trees, a plastic tube network slowly and steadily drips water onto the ground surface near plants, soaking them at a rate they prefer.

The use of recycled or reclaimed water, including **graywater** (wastewater that is not from toilets or urinals) and stored rain, is gradually being allowed by building codes in North America.

Animal and Plant Life

Building sites provide environments for a variety of plant and animal life forms. Grasses, weeds, flowers, shrubs, and trees trap precipitation, prevent soil erosion, provide shade, and deflect wind. They also play a major role in food and water cycles, and their growth and change through the seasons help us mark the passage of time.

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

PLANTS AND BUILDINGS

Plants near buildings foster privacy, provide wind protection, and reduce sun glare and heat. They frame or screen views, moderate noise, and visually connect a building to its site. Plants improve air quality by trapping particles on their leaves. Particles are then washed to the ground by rain; photosynthesis assimilates gases, fumes, and other pollutants.

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, the sun reaches its maximum strength beween March 21 and September 21, while plants provide the most shade between June and October, when the days are warmest. A deciduous vine on a trellis over a south-facing window grows during the cooler spring, shades a building's interior during the hottest weather, and loses its leaves in time to welcome the winter sun. The vine also cools its immediate area through evaporation. Evergreens provide shade all year and help reduce snow glare in winter.

When selecting plants for use in the landscape, designers should consider their structure, shape, and mature height, as well as the spread of their foliage and the speed with which they grow. The density, texture, and color of foliage may change with the seasons. A plant's requirements for soil, water, sunlight, and temperature range as well as the depth and extent of the root structure need to be evaluated. Low-maintenance native or naturalized species have the best chances of success; they also encourage local wildlife. To support plant life, soil must be able to absorb moisture, supply appropriate nutrients, be aerated, and be free of concentrated salts.

Trees' ability to provide shade depends upon their orientation to the sun, proximity to a building or outdoor space, 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 the late afternoon, when the sun has a low angle and casts long shadows.

Air temperatures in the shade of a tree are about 3°C to 6°C (5°F–11°F) cooler than in the sun. A wall shaded by a large tree in direct sun may be between 11°C and 14°C (20°F–25°F) cooler. This temperature drop is caused by the shade plus cooling evaporation from the enormous surface area of the leaves. Shrubs located 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 6°C (10°F) lower than those without such trees.

Remarkably, a moist lawn will be 6°C to 8°C (10°F–14°F) cooler than bare soil and 17°C (31°F) cooler than unshaded asphalt. Low-growing, low-maintenance groundcovers or paving blocks with holes are also cooler than asphalt.

As buildings are increasingly opened up to their sites, building occupants become more aware of their environment. Fresh air and sunlight enter the building and improve the health of those inside. In Chapter 2: Designing Building Functions for Human Health and Safety, we will explore how building codes and standards originally written to protect the health and safety of occupants have expanded to consider energy use and sustainable design.