CHAPTER 1

Sustainability and Energy

BUILDING ENERGY CONSUMPTION IS A SIGNIFICANT PORTION of the total energy used worldwide. In the United States, buildings use about 40 percent of the total energy consumed and about 68 percent of the electricity produced. Buildings are responsible for 38 percent of carbon emissions.[1] Buildings account for the highest carbon emissions, followed by transportation and industry. Buildings will continue to grow as the population of the world grows. The current world population according to the U.S. Census Bureau is 6.9 billion[2], and is projected to grow from 6.1 billion in 2000 to 8.9 billion in 2015.[3] The growth in population creates demand for new buildings: residential, educational, commercial (office and retail), health-care, and manufacturing. Growth of the buildings is going to happen, whether we like it or not. These new buildings will increase the demand for energy, increasing the cost of energy. Additionally, the growth of buildings will increase the global carbon emissions.

Economic development is essential to the social, political, and economic order of the world, and building construction is a big part of the economic development of all the world's countries. With almost 9 million people employed in construction (per 2008 statistics), it is one of the largest industries. The wages of construction workers are relatively high. The construction industry also creates and promotes small business, as more than 68 percent of construction-related establishments consist of fewer than five people, and a large number of workers in construction are self-employed.[4]

[1] National Institute of Building Sciences, Whole Building Design Guide, 2009.
[2] US and World Population Clock, US Census Bureau, www.census.gov/main/www/popclock.htm.
[3] World Population to 2300, Department of Economic and Social Affairs, United Nations, 2004.
[4] United States Department of Labor, Bureau of Labor Statistics, www.bls.gov/home.htm.

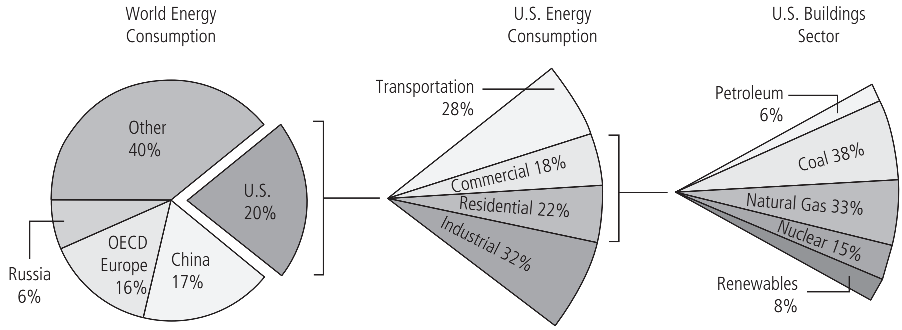

Figure 1-1 Building energy use according to the U.S. Department of Energy. *Buildings Energy Data Book*

Economic development and growth will continue to add new buildings. The new buildings present an opportunity to adopt new technologies and reduce the increase in demand for energy, thus containing the cost of energy. Slowing down the increase in energy consumption through advanced technologies also reduces carbon emissions, reducing the impact of development on the environment.

In the 1300s, Arab historian Ibn Khaldun defined or described economic growth as:

> *When civilization or population increases, the available labor or manpower increases. In turn, luxury increases in correspondence with the increasing profit, and the customs and needs of luxury increase. Crafts are created to obtain luxury products. The value realized from them increases, and, as a result, profits are again multiplied. And so it goes with the second and third increase. All the additional labor serves luxury and wealth, in contrast to the original labor that served the necessity of life.*

Versions or parts of Ibn Khaldun's theory are still valid in modern times, which means that economic development is imminent and ongoing. Construction of new buildings is a big part of economic development and will continue, as a result of:

- Growth due to increase in population
- Higher rate of growth in the developing countries due to globalization
- A very high disparity between the per capita energy consumption and building footprint in developing countries vs. developed countries
- Trying to catch up with developing countries puts additional demand above and beyond normal population growth.

New technologies can contribute to slowing down the growth of energy consumption, without slowing down the economic growth that is essential to maintain the world's social, political, and economic order. The goal of energy savings in buildings is to reduce the rate of growth of energy consumption, while maintaining economic growth. World economic growth is expected to grow 49 percent by 2035, as reported by the United States Energy Information Administration report *International Energy Outlook 2010*.[5]

Continuing at this rate of growth and development with the current practices of using energy, which primarily comes from using fossil fuels, has two diametrically opposite forces. On one side is growing more, traveling more, having more space, and brighter and bigger cities. On the other side, there are limited or declining resources. Effectively utilizing resources is essential or soon it will take more than one earth to meet the growing needs for resources. "Soon" is now, according to the

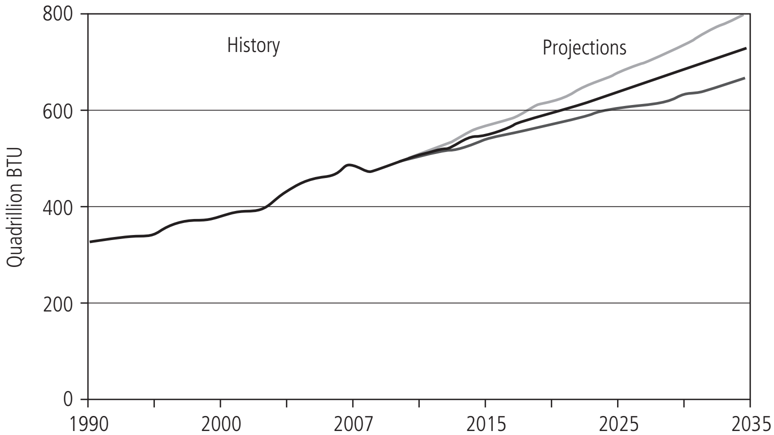

Figure 1-2 World marketed energy consumption in three economic growth cases, 1990–2035. *U.S. Energy Information Administration*

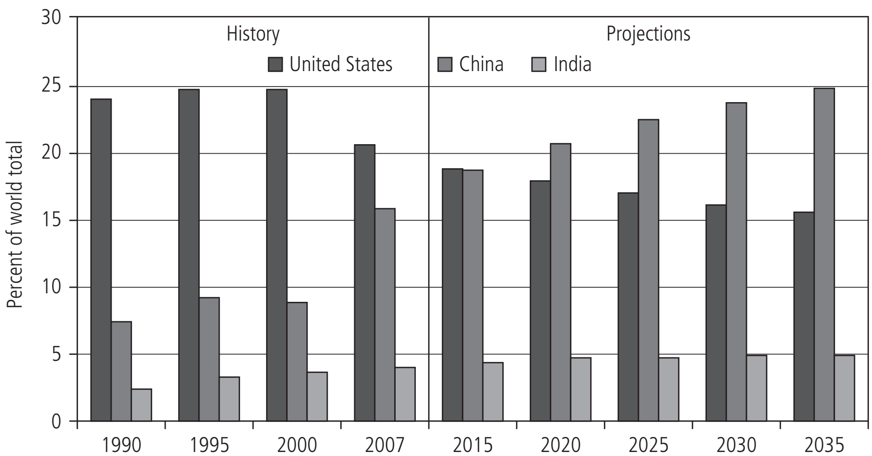

Figure 1-3 Shares of world energy consumption in the United States, China, and India, 1990–2035. *U.S. Energy Information Administration*

[5] United States Energy Information Administration report, *International Energy Outlook 2010,* http://38.96.246.204/forecasts/ieo/".

Global Footprint Network, an alliance of scientists who calculate that in 10 months, humanity will have exhausted nature's yearly budget.[6]

Growth in the developing countries will occur at a much higher rate than in the developed Western world. The U.S. Energy Information Administration has made two forecasts: high economic growth (63%) and low economic growth (37%). With higher growth rates in the developing world or the newly industrialized countries, the median growth of 50 percent is very likely, based on the growth rate and energy consumption growth of India and China. To a certain degree, India's and China's energy consumption growth will not put all the pressure on fossil fuels, given their high level of growth in nuclear power plants. According to the World Nuclear Association,[7] nuclear power generation has the highest growth in Asia. China, Japan, South Korea, and India are the countries with the largest number of nuclear power plants planned; more than eighty-four nuclear power plants are planned in these countries. The recent tsunami in Japan has exposed the vulnerability of nuclear power generation. The damages from the tsunami are evident, and several countries are reevaluating their dependence on nuclear power. Every country is evaluating whether the benefits are worth the risks. It is too soon to predict (1) the pressures that the increase in demand for energy will put on the prices of clean-burning fossil fuels or (2) the huge environmental impact of growth in conventional coal power plants.

The worldwide economic growth will put intense pressure on energy resources and will increase the demand for energy and fossil fuels. In the current methodology of energy production, energy and fossil fuels are almost synonymous, as currently fossil fuel is the major source of energy. Fossil fuels such as oil, coal, and natural gas account for more than 85 percent of the energy used in the United States.[8] The same fossil fuels produce about 70 percent of the electricity. The other 30 percent breaks down as 20 percent from nuclear power plants, 6 percent from hydro power plants, and 4 percent from renewables such as solar and wind power.[9] Making improvements to buildings' energy use and efficiency can generate significant savings in energy and fossil fuel costs. The majority of fossil fuels are a globally fluid commodity that flows to the place of demand or to the highest bidder. The fluidity of the fuel creates a global demand. The increase in demand is much higher in the developing countries.

Potential opportunities exist to make improvements to buildings in the mechanical, electrical, and plumbing (MEP) systems to improve their energy efficiency. There are currently available technologies that are cost effective and can reduce energy

[6] "Global Footprint network," www.footprintnetwork.org/en/index.php/GFN/page/earth_overshoot_day/.
[7] "Asia's Nuclear Energy Growth," World Nuclear Association, April 2010.
[8] United States Department of Energy, www.fe.doe.gov/index.html.
[9] United States Energy Information Administration, Electric Power Monthly report, released Nov 16, 2011. Table 1.1, "Net Energy Generation by Source," 2011, www.eia.gov/electricity/monthly/index.cfm.

consumption by a significant amount. According to guidelines published by the American National Standards Institute (ANSI), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the Illuminating Engineering Society of North America (IESNA), almost 50 percent of energy can be reduced in office buildings.[10] The most common standard used the world over, and adopted by most states in the United States is the ANSI/ASHRAE/IESNA Standard 90.1. The same professional organizations that wrote Standard 90.1 have also written design guides on how to achieve up to 50 percent energy savings over their own standards. Clearly, from these publications, there is evidence that there is significant opportunity to reduce energy in buildings. According to the United States Green Building Council (USGBC), a nonprofit organization that promotes sustainability in the building industry, there are potential technologies for existing and new buildings that can reduce energy use by 25 percent and carbon emissions by 30 percent.[11] Moreover, there are opportunities to continue with growth and its economic benefits, but reduce the impact on energy resources, fossil fuels, and the environment by adopting the efficient technologies.

However, these technologies are not commonly known to the construction industry, including most design professionals, contractors, and manufacturers of building construction equipment and materials. Most of these new and advanced technologies or design approaches are basic and simple in nature, and easily understandable and implementable. However, they are different from the current popular practices employed by the building design industry, including design professionals, contractors, and building operators. There are a select few professionals, both architects and engineers, who are familiar with and can confidently design these new technologies or mechanical or electrical systems; however, for the majority of the construction industry, these are technologies they have only heard about or read about. The "unknown technology factor" is the biggest barrier to the use of the more efficient and advanced technologies. To a certain degree, the problem is also the need to break an old habit or to change "business as usual." To successfully implement the new and advanced solutions, there has to be a change in attitude, approach, and practice in the profession. This change is very difficult to bring about in a well-established industry such as the building construction industry, which is a major contributor to the overall economic activity of the United States and the rest of the world. Construction totals to about $800 billion a month, resulting in approximately $9 trillion per year.[12] The construction industry is one of the largest and is well set in its systems, practices,

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[10] *Advanced Energy Design Guide for Small to Medium Office Buildings: Achieving 50% Energy Savings Toward a NetZero Energy Building*, ASHRAE.
[11] United States Green Building Council, www.usgbc.org/.
[12] "Value of Construction Put in Place—Seasonally Adjusted Annual Rate," United States Census Bureau, www.census.gov/const/www/c30index.html.

methods, and approach. Even a small change in this industry is difficult and takes a long time. However, there are positive trends; many projects that have incorporated advanced sustainable technologies are featured in the press and have received positive publicity with their success. Professional organizations such as the American Institute of Architects (AIA) and ASHRAE are promoting these technologies. Government bodies such as the Department of Energy (DOE) are promoting energy efficiency with several programs such as Portfolio Manager, whereby buildings are ranked by their energy consumption compared to similar buildings. Only five to six years back, the universal answer of builders and designers to the question, "Does it cost more to adopt sustainable technologies?" was, "Yes." Now, many builders and designers—if not all—can confidently say, "It does not cost more to employ sustainable technologies." This is a significant shift in position over the last five years. Also, most building owners have voluntarily adopted sustainable technologies to reduce energy use or to be green. Most building owners are designing and operating buildings to USGBC, to obtain LEED certification.

The cost of these new or advanced technologies is not necessarily higher than that of the conventional systems. However, it depends on whom you ask. Professionals who are familiar with the advanced systems will agree that the construction cost is the same, and that if there is an additional cost, it usually is recouped within a reasonable payback period. Professionals who are unfamiliar with these systems will generally believe that advanced technologies cost more, primarily because the "unknown technology factor" raises the cost far higher than the true cost. Some of these technologies do not cost more than conventional systems; they are simply different. Some may cost more for one item, but reduce costs for other items. For example, in underfloor air conditioning systems, the cost of the raised floor is higher, but there is no need to install ductwork and associated accessories such as variable air volume (VAV) boxes and the like. If there are any additional costs, usually they have a very short payback period. The increase in the cost is offset by the energy savings. The payback is calculated with energy analysis and life-cycle cost analysis. Life-cycle cost analysis has not been part of the construction industry; most design professionals are unfamiliar with it. Thus, these professionals are not able to calculate the necessary life-cycle cost or yearly operating cost to demonstrate how payback will justify the expense. Lack of knowledge of or familiarity with new and advanced technologies is limiting. Most in the construction industry tend to stay with what they know and have experience with. This book will demonstrate that the new technologies are basically energy efficient, sound, simple, easy to build, user- and operator-friendly, and cost effective. It will be a small step toward making the entire construction industry familiar with new and different solutions, which will eventually remove the fear of the unknown. This knowledge and awareness in the building construction and operations industry will transform the way buildings are designed, built, and operated.

QUALITY OF LIFE BENEFITS

In addition to their energy and environmental benefits, new technologies improve the quality of life for a building's occupants. Indoor air quality is one of the major factors that affect the quality of life in buildings. People spend 90 percent of their time inside buildings, making it all the more important to focus on the quality of life a building provides for its occupants. Sick building syndrome (SBS) explains why those who spend a lot of time in a building complain of ill health and discomfort, with no apparent cause. The causes of sick building syndrome are generally:

1. The growth of bacteria and molds in the buildings, due to inadequate temperature and humidity control
2. Inadequate ventilation, which is affected by the amount of outside air introduced into the building
3. Ineffective ventilation, which generally results when outside air introduced into the building bypasses the occupants
4. Indoor chemical pollution from off-gassing of building materials and finishes, such as volatile organic compounds (VOC)

Advanced systems, in addition to reducing energy use, have better indoor air quality than conventional systems, leading to better health for the occupants. Indoor air quality is just as important as outdoor air pollution—and in some instances more important. Since people spend 90 percent of their time in buildings, indoor air quality is an important factor in their well-being. Most of the conventional systems that are predominant in the building industry do not improve indoor air quality, and in most instances are detrimental to it. The EPA recommends three basic strategies for improving indoor air quality:[13]

1. Source control
2. Improved ventilation
3. Air cleaners

Two out of the three recommendations are systems-related. Improved ventilation can be achieved by increasing the percent of outside air that is circulating in the building. Only from 15 to 20 percent of the total air circulating in a typical building is outdoor air; 85 percent is recirculating air. LEED certification recognizes this, and in their point-based rating system, the USGBC provides means of increasing ventilation and achieving additional points. However, while implementing this process, careful analysis

[13] "An Introduction to Indoor Air Quality," EPA. www.epa.gov/iaq/ia-intro.html.

has to be made to evaluate the outdoor air quality level. Some areas in the country, especially urban environments, have high levels of outdoor contaminants. Another common way to improve ventilation is by providing operable windows, enabling building occupants to decide the need for more outside air. Improved ventilation may not necessarily result from an increase in outside air, but from the effectiveness with which the outdoor air is delivered to occupants. The conventional systems really fall short in delivering outside air to occupants effectively. The standard overhead air distribution systems mix pollutants in the air delivered to a space, increasing the parts per million (PPM) of contaminant particles at the occupant breathing elevation. Advanced systems such as underfloor air distribution (UFAD) systems reduce the PPM of contaminant particles.

The most effective way to keep the indoor building environment or air clean is to control the source. The source of the contaminants can be indoors or outdoors. Inside source control is accomplished relatively easily by properly selecting the materials and furnishings that make up the indoor environment. Huge strides have been made in this sector, and most indoor materials are rated or labeled with their potential emission of contaminants. Increasing the outdoor air percentage is another way to control indoor source pollution, as the outside air will dilute the contaminants. Increasing the outdoor air percentage of the circulating air has some limitations, however. Depending on the location of the building, the outdoor environment may be too hot or too cold, requiring excessive energy to heat or cool the outside air. Some regions may have harmful levels of outdoor contaminants, limiting the amount of outside air use. Therefore, a good air-cleaning system is essential. Improvement of the efficiency with which the air-cleaning system captures the contaminants from the circulating air is essential in both conventional and advanced systems. LEED building-rating systems recommend a minimum efficiency reporting value of 13, or MERV –13, for permanently installed mechanically ventilated systems, for circulating both building air and outside air. An air-cleaning system can be detrimental to the overall system, however, because a fine filter or air cleaner requires additional energy. Indoor air quality control is a balance of several variables that include: indoor contaminants, outdoor contaminants, ventilation effectiveness, the outdoor environment, filtration, and the delivery system.

FINITE FOSSIL FUEL RESOURCES

Most of the energy we produce and consume comes from finite resources. About 56 percent of the energy produced in the United States comes from finite resources such as coal (22%), natural gas (21%), crude oil (11%), and natural gas liquids (3%). All the resources are finite and will not last forever. Even coal, the largest energy reserve,

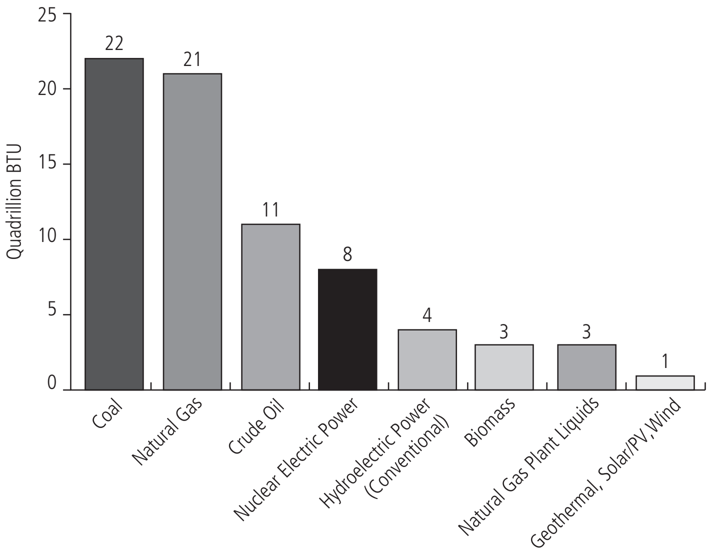


Figure 1-4 U.S. Primary Energy Production by Major Source (2009). *U.S Energy Information Administration, Annual Energy Review, 2009, Table 1.2 (August 2010)*

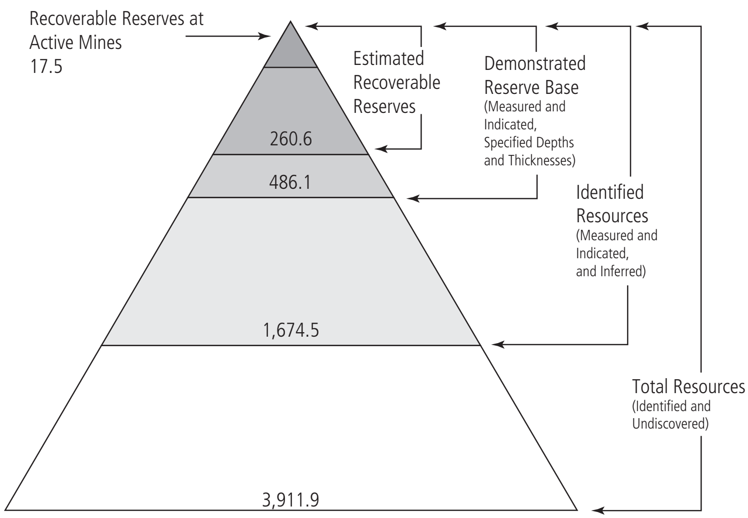


Figure 1-5 U.S. Coal Resources and Reserves (Billion short tons as of January 1, 2010). *U.S. Energy Information Administration, Form EIA-7A, Coal Production Report (February 2011)*

is a finite resource.[14] The very definition of sustainability, "endure without giving way or yielding," conflicts with the use of finite resources such as fossil fuels, which will run out eventually. Until alternate nonyielding resources are tapped into, or technologies are developed to fully utilize renewable resources, it is essential to reduce energy consumption by buildings. A 30 to 50 percent reduction in the energy consumption of buildings can lead to a 12 to 20 percent reduction in overall energy use. The ultimate

[14] U.S. Energy Information Administration, U.S. Coal Resources and Reserves, 2010.

goal is to have all energy come from renewable sources such as wind, geothermal, and solar power. But this will not come about in the immediate or near future. The current focus is on reducing energy consumption by improving the efficiency of building systems, which will accelerate the ultimate goal of relying exclusively on renewable energy.

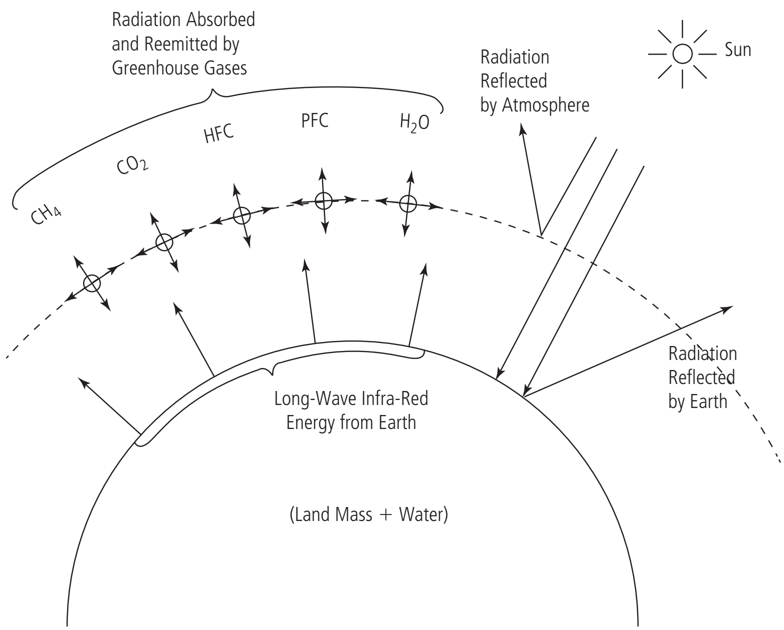
GREENHOUSE GASES

Gases that trap heat from the sun are called greenhouse gases. These gases are essential to life on the Earth in its current form. It is the greenhouse gases that maintain the temperature on the Earth that sustains life. In the absence of the greenhouse gas effect, the temperature of the Earth would be lower by 60°F.

There are several greenhouse gases—the six identified by the U.S. Energy Information Administration and the Kyoto Protocol are:

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous oxide (N_2O)
4. Hydrofluorocarbons (HFCs)
5. Perfluorocarbons (PFCs)
6. Sulfur hexafluoride (SF_6)

Figure 1-6 Greenhouse gas effect. *Asif Syed*



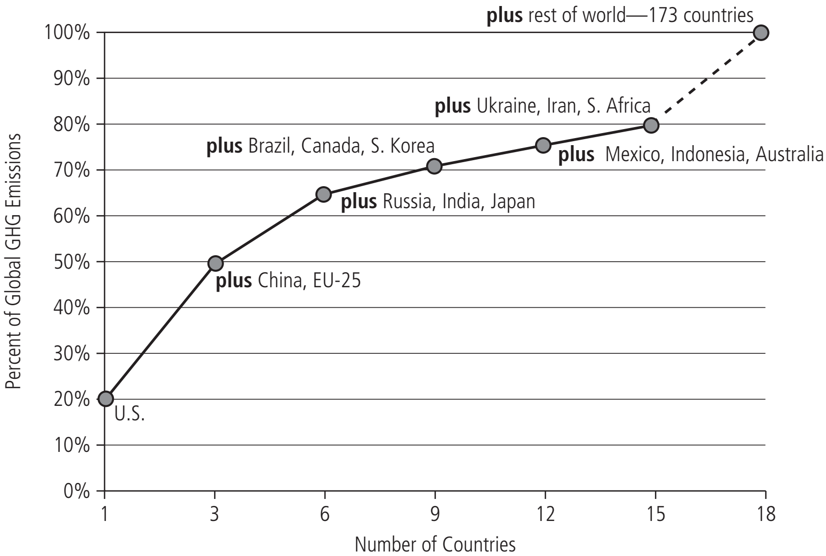


Figure 1-7 Aggregate Contributions of Major GHG Emitting Countries. *U.S. Energy Information Administration*

When sunlight strikes the Earth, some of the energy is re-radiated back into space as infrared energy. All greenhouse gases absorb this re-radiated energy as infrared radiation (heat). The absorbed energy of the greenhouse gases causes heat to be trapped in the atmosphere. Burning fossil fuels leads to the production of carbon dioxide (also referred to as CO_2) emissions. Of the listed greenhouse gases, carbon dioxide is the largest contributor to the greenhouse gas effect. Advanced systems reduce the consumption or burning of fossil fuel for energy, thus reducing the production of carbon dioxide. This leads to the reduction of greenhouse gases.

PROFITS AND SAVINGS FROM ENERGY EFFICIENCY

Energy savings have a direct impact on the bottom line of businesses and building owners. Energy saved through conservation measures and efficiency is energy not consumed. The unconsumed or saved energy does not have to be paid for. The savings from energy efficiency are not commonly discussed. Because of the low cost of energy in the past, compared to the overall or total cost of operating a building and business, the energy budget was small compared to the overall budget of business operation. The cost of energy was so small that it did not stand out or constitute an important factor. This is similar to the cost of gasoline for cars—it was not common to calculate the cost of gasoline while using a car. However, the state of the economy after 2007—with a recession second only to the Great Depression of the 1930s—has caused scrutiny on these aspects of business costs. The higher cost of energy prior to the recession and the apparent waste of energy have put the focus on energy savings and the costs associated with energy use. Savings from energy conservation and efficiency are directly related and proportional to energy saved and greenhouse gases reduced. This has been demonstrated at St. John's University, in New York City, which saved $1,100,000 in operating costs while reducing greenhouse gases by 9,270 metric tons' equivalents of carbon dioxide.[15] St. John's University has an energy efficiency improvement program and participates in the carbon footprint reduction program called the 3010 challenge. The 3010 challenge is for the educational institutions in New York City who voluntarily participate in the program, to reduce their carbon footprint by 30 percent in 10 years. The 3010 challenge is part of New York City Mayor Michael Bloomberg's program to reduce the carbon footprint of New York City, called "Plan NYC."

SITE-TO-SOURCE EFFECT

The amount of energy used in buildings as measured by electric utility meters, natural gas meters, or the measure of fuel oil delivered is not a true representation of the energy consumed by the building. The amount of energy generated at the power plant is much higher. This is especially significant for electricity and is about three times that used at site or in the building. For a 100 watt LED TV, about 300 watts of equivalent fossil fuels has to be burned in the power plant. Site energy is the amount of energy consumption reflected in the utility bills, but it is not the true representation of energy use. The primary form of energy bought at the building site, such as natural gas, comes from a distant location, and losses are associated with it. The most common form of energy used in buildings is electricity, which is considered a secondary form. Electricity is produced by burning a fossil fuel or by a hydro or nuclear power plant, but the most common form of fuel for electricity is fossil fuel. The secondary form of energy electricity is produced in a power plant. Most thermal power plants have only about 30 percent efficiency. So the energy equivalency is much larger at source than at site. In the case of electricity—the most common form of energy—the site energy equivalency is about 3.34.[16] The site-to-source factor includes the thermal efficiency losses and transmission losses. For the most common energy uses, the EPA methodology for calculating site-to-source conversion factors is as follows:

[15] St. John's University, Environmental Assessment Statement: Memorandum of Understanding, Semi-annual Report, July 2011.

[16] Energy Star performance ratings, methodology for incorporating source energy use.

TABLE 1-1 SITE-TO-SOURCE CONVERSION TABLE

#	Fuel Type	Site-to-Source Ratio
1	Electricity (grid purchased)	3.34
2	Electricity produced on-site from solar or wind	1.0
3	Natural gas	1.047
4	Fuel oil	1.01

Generation of electricity with fossil fuels is a very inefficient process, with losses as high as 60 to 70 percent. The losses are in the form of heat in the flue gases of the combustion, which are vented into the atmosphere. The heat from the flue gases is not useful in most locations of the power plants, which leads to lower efficiency. Site-to-source conversion is especially important because any reduction in energy at site is almost three times the energy saved at the power plant. The reduction in the greenhouse gases is also three times the amount of energy saved.

NEW LEED VERSION 2009

The new LEED rating system has increased the emphasis on energy. When United States Green Building Council's LEED rating system started, certification—or higher levels such as silver or gold—did not require mandatory points in the energy and atmosphere category. However, in 2007, for basic certification or higher ratings, the emphasis on energy increased, and it became mandatory to obtain two points in energy and atmosphere. Two points meant 14 percent better than the energy code minimum. This has forced architects and engineers to come up with innovative designs. The standard used for energy code minimum is almost universally the American Society of Heating Refrigeration and Air Conditioning Engineers ASHRAE 90.1. The ASHRAE 90.1 standard is becoming more and more efficient as newer versions are introduced every three years. Achieving lower than baseline minimum code was much easier in the past, but with newer versions it is more challenging. Some or most of the advanced technologies are still not the minimum or baseline code requirements, presenting an opportunity to exceed mandated energy efficiency and add more points toward LEED certification.

USGBC's LEED certification process is continuously increasing its emphasis on energy. In the earlier versions of certification, the only energy prerequisite was to comply with code. Additional energy use reduction was optional. Later, in 2007, a mandatory rating of 14.5 percent better than the code became a prerequisite for

TABLE 1-2 LEED RATING SYSTEMS ENERGY OPTIMIZATION POINTS

LEED Rating Version for New Construction	LEED Energy/Total Points	% of Total Points
LEED 2	10/69	14.5%
LEED 2.1	10/69	14.5%
LEED 2.2 (before July 2007)	10/69	14.5%
LEED 2.2 (after July 2007)	10/69 – 2 mandatory	14.5% (2.8% mandatory)
LEED 2009	19/110	18.2%

certification. The LEED 2009 rating system has increased the importance of energy by increasing the points for energy credits. LEED 2009 has 19 points in a 100-point system, with an almost 20 percent emphasis on energy. To achieve higher ratings such as gold and platinum, advanced systems can be used to maximize the points.

PER CAPITA ENERGY CONSUMPTION

The per capita energy consumption of all countries indicates that there is a big gap between the developed countries and the developing countries. The average power consumption[17] of developed countries is 200 MBtu, whereas in the developing countries it is about 20 MBtu. The developing countries have populations that are much larger than those of the developed countries. With the total population of the world at 7 billion, 6 billion people live in the developing world, and only 1 billion in the developed countries.[18] The huge populations of developing countries aspire to the quality of life and the lifestyles of the developed countries. If the populations of developing countries start consuming the same 200 MBtu, the consumption of energy will not be sustainable. Sustainable technologies can help in lowering energy consumption in the developing world. However, most developing countries are using systems that were used in the developed world in the 1970s and 1980s. The technologies of 1970 and 1980 were not energy efficient. Generally, the developing countries emulate what is being done in the developed world. This cycle has to be broken, and new and advanced technologies have to be adopted in the developing world, alongside the developed world, to make a difference in the overall energy consumption of the world.

[17] U.S. Energy Information Administration—International Energy Annual, 2006.
[18] "United Nations Environmental Program—Trends in population, developed and developing countries," http://maps.grida.no/go/graphic/trends-in-population-developed-and-developing-countries-1750-2050-estimates-and-projections.

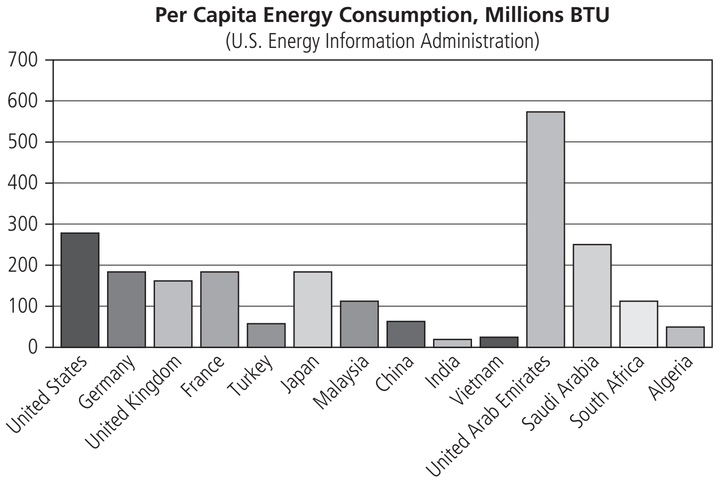


Figure 1-8 Per capita energy consumption of representative countries of the world. *U.S. Energy Information Administration*

BUILDING ENERGY END-USE SPLITS, PEOPLE USE ENERGY

The data collected[19] by the U.S. Department of Energy indicates that almost 50 percent of the energy consumed by buildings goes into serving the occupants' needs, such as water heating (9.6%), electronics (7.6%), refrigeration (5.5%), cooking (3.4%), computers (2.3%), and so on, and that the remaining 50 percent goes into space lighting, heating, and cooling. People use energy whether they are in large commercial buildings, at home, or elsewhere. The space heating, which is 20 percent, provides protection from the elements and is a necessity, whether people are in structured commercial buildings or just at home. Space cooling provides comfort; it was originally considered a luxury, but it has become a universal necessity, and most homes are now air-conditioned.

People consume energy, and building systems are a means of delivering the energy. Reducing energy in buildings is a twofold issue: occupants and systems. The ratio of influence of the people and the system is an equal fifty-fifty split. Actions or behaviors of the building users and occupants can make a significant difference in the overall energy consumption. An integrated design approach of advanced systems engages the occupants and brings about the awareness of the entire building design process and the importance of energy and sustainability. Occupants learn how their behavior has an impact on the building's energy and sustainability. This will lead to change in behavior, which will be a benefit.

[19] U.S. Department of Energy—2006 U.S. Buildings Energy End-Use Splits, http://buildingsdatabook.eren.doe.gov/ChartView.aspx?chartID=1.

In the present building design process, the art and science of occupant behavior impact on energy does not exist. Occupant behavior is not considered as a design issue. Integrated design and engaging advanced technologies is a starting point, but soon a new chapter has to be written on this subject. In net-zero buildings, especially the ones when energy is produced on-site with solar photo voltaic cells, occupants understand this. The behavior of occupants can reduce energy, which does not have to be produced in a photo voltaic panel, leading to lowering the capital cost. The initial capital investment associated with solar photo voltaic panels can have an influence on the behavior aspects of the occupants. Some examples of behavior can be using natural light and ventilation.

The efficiency level associated with the systems that deliver the energy to the occupants can be improved with the assistance of the advanced technologies now available. For example: Fans commonly used in buildings are only 65 percent efficient, and air used to transport cooling has extremely low heat-carrying capacity, or specific heat. On the other hand, pumps are 85 percent efficient, and water has very high heat-carrying capacity. Selection of a water-based system can significantly lower the energy consumed. Harvesting daylight by appropriately selecting glazing and lighting control systems, such as dimming, can reduce the lighting energy consumption, which is a significant split. Technologies for glazing include spectrally selective coatings that reduce solar heat gain and maximize light transmission.

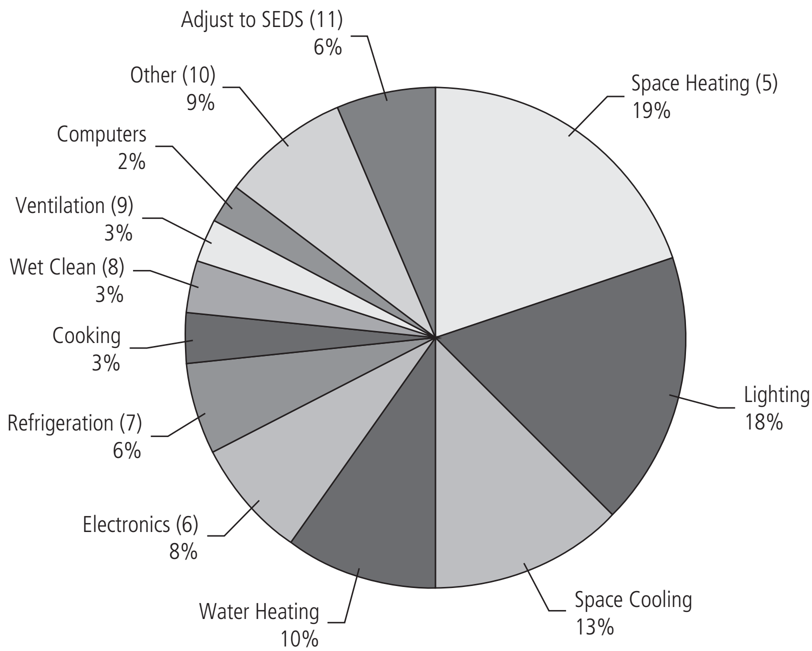


Figure 1-9 U.S. Buildings Energy End-Use Splits.
U.S. Energy Information Administration

CARBON FOOTPRINT

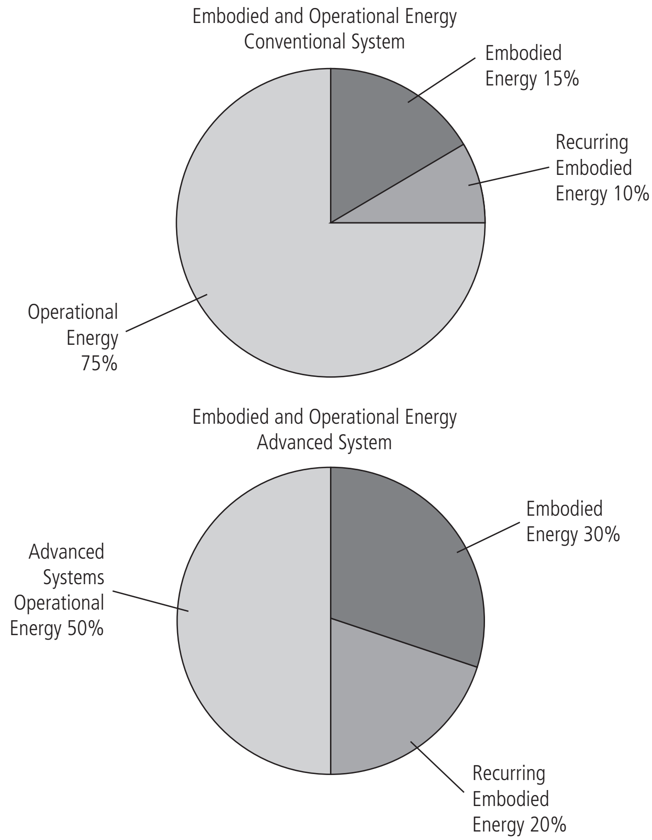
Most organizations, in both the public and private sectors, are becoming carbon footprint conscious. Carbon Disclosure Rating (CDR) is a numerical score based on the level of reporting of a company's climate change initiatives. This is in response to the questionnaire that was developed by the U.K.- based Climate Disclosure Project (CDP) along with PricewaterhouseCoopers. The score is not indicative of the actions taken by the company to mitigate it's climate change issues. The score only indicates the level of disclosure of a company's climate change issues. A high score generally indicates a good understanding and management of issues that impact the climate from a company's activities. Most large companies have a Carbon Disclosure Rating. Carbon disclosure ratings are given for stocks' symbols along with the companies' profit margins, P/E ratios, and return on assets. Companies that are tracking their carbon footprint and their climate change impacting issues need to equip their building systems with advanced technologies that use less energy and thereby leave a lower footprint reducing their impact on climate change. The carbon footprint is a measure of the release of all the six gases identified by the Kyoto Protocol as greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The carbon footprint of an organization or campus or company is the amount of these six gases released directly or indirectly. The measure of the carbon footprint is in tons of carbon dioxide released into the atmosphere. For the other five gases, the measurement used is the effect of these gases on global warming, calculated as carbon dioxide equivalent. Carbon dioxide is used as the baseline.

EMBODIED ENERGY VERSUS OPERATIONAL ENERGY

For working toward carbon neutral or net-zero buildings, understanding operational and embodied energy of buildings is important. Operational energy is the energy consumed annually by the building MEP systems for heating, cooling, appliances, and lighting. The operational energy is based on the type of MEP systems adopted in the building and is easily measured with meters and estimated prior to design with analytical tools such as computer simulation energy software. Embodied energy is the energy used in mining, manufacturing, transporting, installing, and finally demolishing the materials that are used in the building. Operational energy is the majority of the energy consumed in the building over its life cycle. The embodied energy of different materials vary based on the type of materials used such as concrete or steel or wood. The embodied energy also depends on the transportation of building materials from the harvesting site to factories and to the construction site. Wood harvested from renewable forests provides a sequestering effect. While growing wood carbon is captured from the atmosphere and the energy required to produce wood all comes from the sun, a renewable resource. When the wood is used in long-term application such as a building material with a life of fifty years, the carbon is sequestered for that period. The amount of embodied energy and operating energy varies based on the type of building such as retail, residential, commercial, and so forth. Buildings that operate 24/7 like hospitals use far more energy than office buildings that operate only ten hours per day. The embodied energy and operating energy ratio also depends on the life cycle of the building. As the life of the building increases, embodied energy stays the same, while the operating energy goes up. The operating energy is almost three to four times the embodied energy over the life cycle of the building.

Embodied energy is about 20 to 25 percent[20] of the energy over a fifty-year life cycle of the building, while operational energy is 75 to 80 percent. Operational energy is the energy consumed during the building's life once it has been constructed. This energy is consumed by heating and cooling, lighting, and appliances, which

Figure 1-10 Embodied and Operational Energy—Conventional System and Embodied and Operational Energy—Advanced System. *U.S. Energy Information Administration*



[20] http://architecture2030.org/about/design_faq#embodiedenergy.

includes the mechanical and electrical systems delivering this energy to the building. The energy efficiency of the building systems can make a significant impact over the life of the building.

FUNDING OPPORTUNITIES

In order to promote the advanced solutions and technologies for sustainable and energy-efficient operations, several grants and funds are offered by federal and state governments, quasi-government agencies, and public utility companies. While several of the technologies have a relatively low payback or return on investment, this is not always the case. For technologies with higher payback, funding opportunities can help in reducing the payback or the return on investment. The American Recovery and Reinvestment Act of 2009 (Recovery Act), and other grants provide funds to the U.S. Department of Energy and other agencies. The Office of Energy Efficiency and Renewable Energy (EERE) have financial assistance programs for the use of renewable energy and energy efficiency technologies. Most of these programs are based on the funding available, and most of the funds are fixed and are sometimes on a first-come first-serve basis. Very early on during the evaluation of these technologies, such opportunities must be investigated. However, it should not be mistaken that for all advanced technologies such funds or grants are required to make them financially feasible. Some of them can work by themselves, while others require assistance. These programs help reduce the long-term production costs of some technologies, especially solar photo voltaic systems, which are primarily driven by substantial assistance from federal, state, and local utility cash rebates or tax incentives. From 1998 to 2010 the average cost of photo voltaic installations has reduced by more than 50 percent. The current costs are in the range of $5 to $6 per watt compared to $12 to $16 in 1998.

A database of the public funding opportunities is available on the Web. The Database of State Incentives for Renewables and Efficiency (DSIRE) was established in 1995 and funded by the Department of Energy. The website lists all state programs currently providing funding, and also lists federal funding programs. DSIRE is run by the North Carolina Solar Center and the Interstate Renewable Energy Council. Funding opportunities are available for the following and other sustainable energy systems:

1. Solar photo voltaic—roof or building integrated
2. Solar thermal—domestic hot water heating or building heating
3. Wind—on-site urban wind turbines
4. Geothermal, lake, river, or sea cooling

5. Cogeneration—turbines, reciprocating engines, or microturbines
6. High-performance glazing—low E coating
7. Thermal break curtain wall systems
8. Thermal storage
9. Overall building performance
10. Daylight harvesting and dimming
11. High-performance mechanical equipment such as chillers and variable frequency drives
12. Electrical systems—power factor reduction equipment