CHAPTER 34

ENERGY RESOURCES

BECAUSE energy used in buildings and facilities composes a significant amount of the total energy used for all purposes, and thus affects energy resources, ASHRAE recognizes the "effect of its technology on the environment and natural resources to protect the welfare of posterity" (ASHRAE 2003).

Many governmental agencies regulate energy conservation, often through the procedures to obtain building permits. Required efficiency values for building energy use strongly influence selection of HVAC&R systems and equipment and how they are applied.

More information on sustainable design is available in the *ASHRAE GreenGuide* (2006) and in Chapter 35.

CHARACTERISTICS OF ENERGY AND ENERGY RESOURCE FORMS

The HVAC&R industry deals with energy forms as they occur on or arrive at a building site. Generally, these forms are fossil fuels (natural gas, oil, and coal) and electricity. Solar and wind energy are also available at most sites, as is low-level geothermal energy (an energy source for heat pumps). Direct-use (high-temperature) geothermal energy is available at some locations.

Forms of On-Site Energy

Fossil fuels and electricity are commodities that are usually metered or measured for payment at the facility's location. Solar or wind energy is freely available but does incur cost for the means to use it. High-temperature geothermal energy, which is not universally available, may or may not be a sold commodity, depending on the particular locale and local regulations. Chapter 32 of the 2007 *ASHRAE Handbook—HVAC Applications* has more information on geothermal energy.

Some on-site energy forms require further processing or conversion into more suitable forms for the particular systems and equipment in a building or facility. For instance, natural gas or oil is burned in a boiler to produce steam or hot water, which is then distributed to various use points (e.g., heating coils in air-handling systems, unit heaters, convectors, fin-tube elements, steam-powered cooling units, humidifiers, kitchen equipment) throughout the building. Although the methods and efficiencies of these processes fall within the scope of the HVAC&R designer, *how* an energy source arrives at a given facility site is not under direct control. On-site energy choices, if available, may be controlled by the designer based in part on the present and projected future availability of the resources.

The basic energy source for heating may be natural gas, oil, coal, or electricity. Cooling may be produced by electricity, thermal energy, or natural gas. If electricity is generated on site, the generator may be driven by an engine or fuel cell that consumes fossil fuels or hydrogen on site, or by a turbine using steam or gas directly.

The preparation of this chapter is assigned to TC 2.8, Building Environmental Impacts and Sustainability.

The term **energy source** refers to on-site energy in the form in which it arrives at or occurs on a site (e.g., electricity, gas, oil, coal). **Energy resource** refers to the raw energy that (1) is extracted from the earth (wellhead or mine-mouth), (2) is used to generate the energy source delivered to a building site (e.g., coal used to generate electricity), or (3) occurs naturally and is available at a site (solar, wind, or geothermal energy).

Nonrenewable and Renewable Energy Resources

From the standpoint of energy conservation, energy resources can be classified as either (1) nonrenewable resources, which have definite, although sometimes unknown, limitations; or (2) renewable resources, which have the potential to regenerate in a reasonable period. Resources used most in industrialized countries are nonrenewable (ASHRAE 2003).

Note that *renewable* does not mean an infinite supply. For instance, hydropower is limited by rainfall and appropriate sites, usable geothermal energy is available only in limited areas, and crops are limited by the available farm area and competing nonenergy land uses. Other forms of renewable energy also have supply limitations.

Nonrenewable resources of energy include

- Coal
- Crude oil
- Natural gas
- Uranium or plutonium (nuclear energy)

Renewable resources of energy include

- Hydropower
- Solar
- Wind
- Earth heat (geothermal)
- Biomass (wood, wood wastes, and municipal solid waste, landfill methane, etc.)
- Tidal power
- Ocean thermal
- Atmosphere or large body of water (as used by the heat pump)
- Crops (for alcohol production or as boiler fuel)

Characteristics of Fossil Fuels and Electricity

Most on-site energy for buildings in developed countries involves electricity and fossil fuels as primary on-site energy sources. Both fossil fuels and electricity can be described by their energy content (Btu). This implies that energy forms are comparable and that an equivalence can be established. In reality, however, they are only comparable in energy terms when they are used to generate heat. Fossil fuels, for example, cannot directly drive motors or energize light bulbs. Conversely, electricity gives off heat as a byproduct regardless of whether it is used for running a motor or lighting a light bulb, and regardless of whether that heat is needed. Thus, electricity and fossil fuels have different characteristics, uses, and capabilities aside from any differences in their derivation.

Other differences between energy forms include methods of extraction, transformation, transportation, and delivery, and characteristics of the resource itself. Natural gas arrives at the site in virtually the same form in which it was extracted from the earth. Oil is processed (distilled) before arriving at the site; having been extracted as crude oil, it arrives at a given site as, for example, No. 2 oil or diesel fuel. Electricity is created (converted) from a different energy form, often a fossil fuel, which itself may first be converted to a thermal form. The total electricity conversion, or generation, process includes energy losses governed largely by the laws of thermodynamics.

Fuel cells, which are used only on a small scale, convert a fossil fuel to electricity by chemical means.

Fossil fuels undergo a conversion process by combustion (oxidation) and heat transfer to thermal energy in the form of steam or hot water. The conversion equipment is a boiler or a furnace in lieu of a generator, and conversion usually occurs on a project site rather than off-site. (District heating or cooling is an exception.) Inefficiencies of the fossil fuel conversion occur on site, whereas inefficiencies of most electricity generation occur off site, before the electricity arrives at the building site. (Cogeneration is an exception.)

Sustainability is an important consideration for energy use. The United Nations' Brundtland Report (UN 1987) stated that the development of the built environment is sustainable if it "meets the needs of the present without compromising the ability of future generations to meet their own needs." More information may be found in Chapter 35.

ON-SITE ENERGY/ENERGY RESOURCE RELATIONSHIPS

An HVAC&R designer must select one or more forms of energy. Most often, these are fossil fuels and electricity, although installations are sometimes designed using a single energy source (e.g., only a fossil fuel or only electricity).

Solar energy normally impinges on the site (and on the facilities to be put there), so it affects the facility's energy consumption. The designer must account for this effect and may have to decide whether to make active use of solar energy. Other naturally occurring and distributed renewable forms such as wind power and earth heat (if available) might also be considered.

The designer should be aware of the relationship between on-site energy sources and raw energy resources, including how these resources are used and what they are used for. The relationship between energy sources and energy resources involves two parts: (1) quantifying the energy resource units expended and (2) considering the societal effect of depletion of one energy resource (caused by on-site energy use) with respect to others.

Quantifiable Relationships

As on-site energy sources are consumed, a corresponding amount of resources are consumed to produce that on-site energy. For instance, for every volume of No. 2 oil consumed by a boiler at a building site, some greater volume of crude oil is extracted from the earth. On leaving the well, the crude oil is transported and processed into its final form, perhaps stored, and then transported to the site where it will be used.

Even though natural gas often requires no significant processing, it is transported, often over long distances, to reach its final destination, which causes some energy loss. Electricity may have as its raw energy resource a fossil fuel, uranium, or an elevated body of water (hydroelectric generating plant).

Data are available to help determine the amount of resource use per delivered on-site energy source unit. In the United States, data are available from entities within the U.S. Department of Energy and from the agencies and associations listed at the end of this chapter.

A **resource utilization factor (RUF)** is the ratio of resources consumed to energy delivered (for each form of energy) to a building site. Specific RUFs may be determined for various energy sources normally consumed on site, including nonrenewable sources such as coal, gas, oil, and electricity, and renewable sources such as solar, geothermal, waste, and wood energy. With electricity, which may derive from several resources depending on the particular fuel mix of the generating stations in the region served, the overall RUF is the weighted combination of individual factors applicable to electricity and a particular energy resource. Grumman (1984) gives specific formulas for calculating RUFs.

There are great differences in the efficiency of equipment used in buildings. Although electricity incurs losses in its production, it is often much more efficient than direct fuel use at the building site, particularly for lighting or heat pump applications. Minimizing both energy cost and the amount of energy resources needed to accomplish a task effectively should be a major design goal, which requires consideration of both RUFs and end-use efficiency of building equipment.

Although a designer is usually not required to determine the amount of energy resources attributable to a given building or building site for its design or operation, this information may be helpful when assessing the long-range availability of energy for a building or the building's effect on energy resources. Fuel-quantity-to-energy resource ratios or factors are often used, which suggests that energy resources are of concern to the HVAC&R industry.

Intangible Relationships

Energy resources should not simply be converted into common energy units [e.g., quadrillion (10^{15}) Btu or quad] because the commonality gives a misleading picture of the equivalence of these resources. Other differences and limitations of each of the resources defy easy quantification. For instance, electricity that arrives and is used on a site can be generated from coal, oil, natural gas, uranium, or hydropower. The end result is the same: electricity at x kV, y Hz. However, the societal impact of a kilowatt-hour of electricity generated by hydropower may not equal that of a kilowatt-hour generated by coal, uranium, domestic oil, or imported oil.

Intangible factors such as safety, environmental acceptability, availability, and national interest also are affected in different ways by the consumption of each resource. Heiman (1984) proposes a procedure for weighting the following intangible factors:

National/Global Considerations

- Balance of trade
- Environmental impacts
- International policy
- Employment
- Minority employment
- Availability
- Alternative uses
- National defense
- Domestic policy
- Effect on capital markets

Local Considerations

- Exterior environmental impact
  - Air
  - Solid waste
  - Water resources
- Local employment
- Local balance of trade
- Use of distribution infrastructure
- Local energy independence
- Land use
- Exterior safety

Site Considerations

- Reliability of supply
- Indoor air quality

- Aesthetics
- Interior safety
- Anticipated changes in energy resource prices

SUMMARY

In HVAC&R system design, the need to address immediate issues such as economics, performance, and space constraints often prevents designers from fully considering the energy resources affected. Today's energy resources are less certain because of issues such as availability, safety, national interest, environmental concerns, and the world political situation. As a result, the reliability, economics, and continuity of many common energy resources over the potential life of a building being designed are unclear. For this reason, the designer of building energy systems must consider the energy resources on which the long-term operation of the building will depend. If the continued viability of those resources is reason for concern, the design should provide for, account for, or address such an eventuality.

ENERGY RESOURCE PLANNING

The energy supplier (or suppliers) in a particular jurisdiction must plan for that jurisdiction's future energy needs. For competitive energy markets where these decisions do not have high societal costs, these plans are made by energy suppliers and are not revealed to governmental authorities or the public more than is absolutely necessary, because of the advantage competitors could gain by this knowledge. For electricity (and, to a lesser extent, natural gas), significant societal issues are involved in energy resource planning decisions that cannot be made by energy suppliers without approval by many different groups. Issues include

- **Reliability**, which is affected by the diversity of supply sources available. For gas, this includes the number of geographic supply sources and pipelines; for electricity, it includes the percentage of generation from various fuel sources. Consider the projected future supply and reliability of energy resources, including the possibility of supply disruption by natural or political events, and the likelihood of future supply shortages, which could reduce reliability.
- **Reserve margins**, or the ratio of total supply sources to expected peak supply source needs. Reserve levels that are too high result in waste of resources, higher environmental costs, and possibly poor financial health of the energy suppliers. Reserves that are too low result in volatile and very high peak energy prices and reduced reliability.
- **Land use.** Energy production and transmission often require governmental cooperation to condemn private property for energy production and transmission facilities. Construction and maintenance are also regulated to protect wetlands, prevent toxic waste releases, and other environmental issues.

Note that some energy deregulation plans provide no guidance at all on energy supplies, through integrated resource planning (IRP) or other methods. Energy suppliers choose whether to expand their capacity, and what types of fuel those facilities use, based on their own assessment of the future profitability of that investment. In these markets, decisions are made with little societal input other than permitting and pollution control regulations, just as a decision might be made by a manufacturer in an industry such as steel or paper.

INTEGRATED RESOURCE PLANNING (IRP)

In regulated utility markets, integrated resource planning is commonly used for planning significant new energy facilities, especially for electricity. Steps include (1) forecasting the amount of new resources needed and (2) determining the type and provider of this resource. Traditionally, the local utility provider forecasts future needs of a given energy resource, then either builds the necessary facility with the approval of regulators or uses a standard offer bid to determine what nonutility provider (or the utility itself) would provide the new energy resource.

Supplying new energy resources through either a standard bid process by a supplier or traditional utility regulation usually results in selection of the lowest-cost supply option, without regard for environmental costs or other societal needs. IRP allows a greater variety of resource options and allows environmental and other indirect societal costs to be given greater consideration.

IRP addresses a wider population of stakeholders than most other planning processes. Many regulatory agencies involve the public in the formulation and review of integrated resource plans. Customers, environmentalists, and other public interest groups are often prominent in these proceedings.

In deregulated energy markets, supplying markets with new energy resources is typically left up to competitive market forces. This has sometimes resulted in excessive reliance on one form of energy, such as natural gas generation. Another result has been highly volatile prices, when supply is not provided because of insufficient price signals, followed by much higher prices and energy shortages until new supply sources can be obtained (which may not be for several years because of the time required for construction and environmental approval processes). Energy efficiency and demand response programs are increasingly treated as an energy resource on a par with energy production options, with incentives and compensation provided for participants in these programs.

Demand-side management (DSM) is a common option for providing new energy resources, especially for electricity. These are actions taken to reduce the demand for energy, rather than increase the supply of energy. DSM is desirable because its environmental costs are almost always lower than those of building new energy facilities. However, the following factors have caused a decline in the number of DSM programs:

- Building and equipment codes and standards are a highly efficient form of DSM, reducing energy use with much lower administrative costs than programs that reward installation of more efficient equipment at a single site. However, they are more subtle than traditional DSM programs and may not always be recognized as a form of DSM.
- Opening markets to competing suppliers makes it more difficult to administer and implement DSM programs. However, they are still possible if regulators wish to continue them, and set appropriate rules and regulations for the market to allow implementation of DSM programs.

Many IRP participants may be interested in only one aspect of the process. For example, the energy industry's main interest may be cost minimization, whereas environmentalists may want to minimize pollutant emissions and prevent environmental damage from construction of energy facilities. Participation by all affected interest groups helps provide the best overall solution for society, including indirect costs and benefits from these energy resource decisions.

TRADABLE EMISSION CREDITS

Increasingly, quotas and limits apply to emissions of various pollutants. Often, a market-based system of tradable credits is used with these quotas. A company is given the right to produce a given level of emissions, and it earns a credit, which can be sold to others, if it produces fewer emissions than that level. If one company can reduce its emissions at a lower cost than another, it can do so and sell the emissions credit to the second company and earn a profit from its pollution control efforts. In the United States, emissions quota and trading programs currently include sulfur dioxide (SO_2) and nitrogen oxides (NO_x), with plans to implement carbon dioxide (CO_2) trading now under consideration, as well. In Europe, emissions trading for CO_2 began January 1, 2005. To date, this type of activity has largely involved large industrial plants, but it can also involve commercial

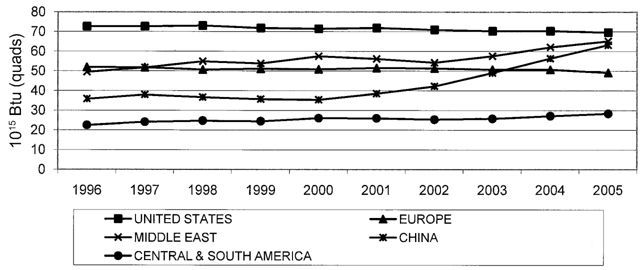

Fig. 1 Energy Production Trends: 1996-2005
(Basis: EIA 2007)

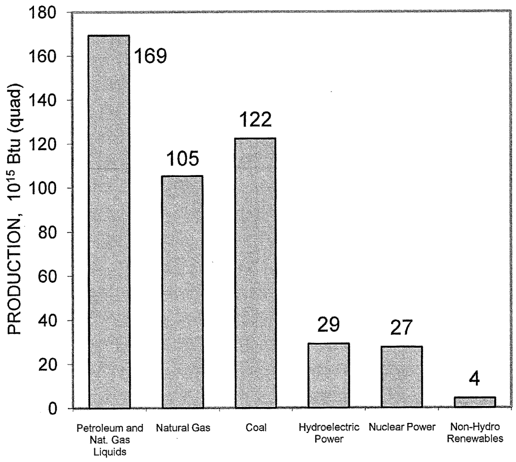

Fig. 2 World Primary Energy Production by Resource: 2005
(Basis: Table 2.9 in EIA 2007)

buildings with on-site emissions, such as generation equipment or gas engine-driven cooling.

Designers must be aware of any regulations concerning pollutant emissions; failure to comply with these regulations may result in civil or criminal penalties for designers or their clients. However, understand the options available under these regulations. The purchase or sale of emissions credits may allow reduced construction or building operations costs if the equipment can overcomply at a lower cost than the cost of another source of emissions to comply, or vice versa. In some cases, documentation of energy savings beyond what codes and regulations require can result in receiving emissions credits that may be sold later.

OVERVIEW OF GLOBAL ENERGY RESOURCES

WORLD ENERGY RESOURCES

Data in this section are from the U.S. Department of Energy's *International Energy Annual 2005* (EIA 2007).

Production

Energy production trends, by leading producers and world regions, from 1996 to 2005 are shown in Figure 1. World primary energy production, which essentially did not increase in the early 1990s, has risen about 2.4% per year from 1996 to 2005, as dramatic economic growth occurred in developing countries such as China. The largest total energy producers in 2005 were the United States (15%), China (14%), Russia (11%), and Saudi Arabia (6%). Together, they produce about 46% of the world's energy production. Total world energy production by resource type is shown in Figure 2.

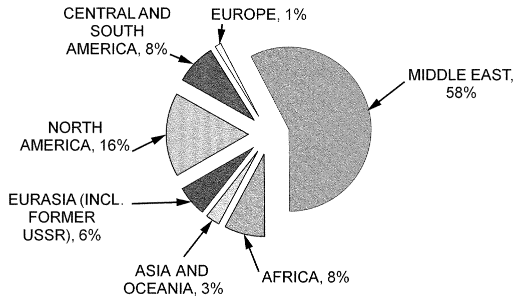

Fig. 3 World Crude Oil Reserves: 2006
(Basis: Table 8.1 in EIA 2007)

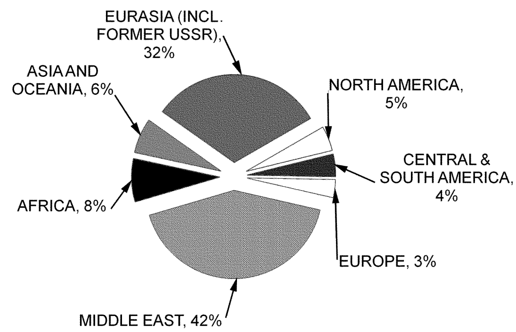

Fig. 4 World Natural Gas Reserves: 2006
(Basis: Table 8.1 in EIA 2007)

Crude Oil. World crude oil production was 73.81 million barrels per day in 2005. The biggest crude oil producers in 2005 were the Middle East (31%), Russia (12%), Central/South America (9%), the United States (7%), and Europe (7%). Since 1996, oil production declined by 25% in the United States, and increased 35% in Russia.

Natural Gas. World production reached 101.5 × 10^{12} ft^3 in 2005, up 64% from the 1996 level. The biggest producers in 2005 were Russia (22%), the United States (18%), Canada (6%), and Iran (4%). Natural gas production in Iran has increased 150% since 1996.

Coal. At 6.49 × 10^9 short tons in 2005, coal production was up 26.5% since 1996. Leading producers of coal were China (37%), the United States (17%), India (7%), and Australia (6%). Since 1996, China, India, and Australia each increased coal production by more than 50%, and the United States increased production by 6%.

Reserves

On January 1, 2006, estimated world reserves of crude oil and gas were distributed by world region as shown in Figures 3 and 4. Countries with the largest reported crude oil reserves are Saudi Arabia (21%), Canada (14%), Iran (10%), and Iraq (9%). Most of Canada's crude oil reserves are in the form of tar sands, which have only recently been included as proven reserves. The largest gas reserves are in Russia (27%), Iran (16%), and Qatar (15%).

World coal reserves as of January 1, 2006, are shown by region in Figure 5. The most plentiful reserves, as a percent of total, were in the United States (27%), Russia (17%), China (13%), India (9%), and Australia (9%).

An important factor is the relative amount of these energy resources that has not yet been consumed. A standard measure is called **proved energy reserves**, which is the remaining known deposits that could be recovered economically given current economic and operating conditions. Dividing proved reserves by the

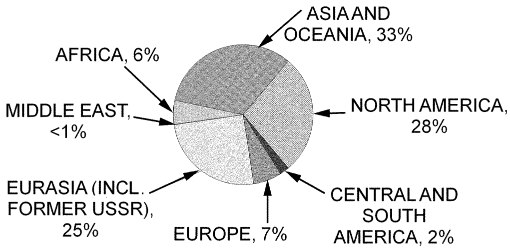

Fig. 5 World Recoverable Coal Reserves: 2006
(Basis: Table 8.2 in EIA 2007)

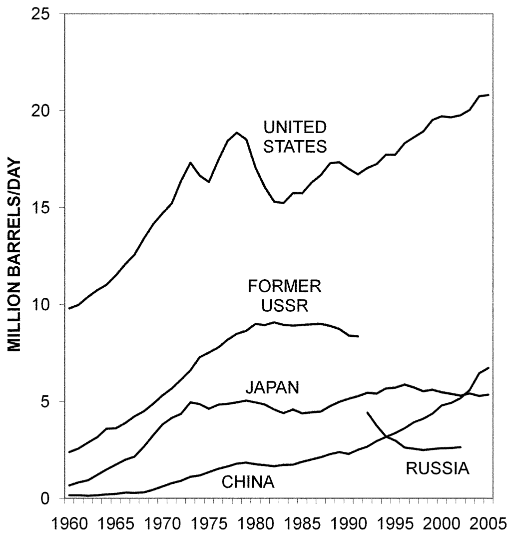

Fig. 6 World Petroleum Consumption: 2005
[Basis: Table 11.9 (EIA 2001) and Table 2.1 (EIA 2007)]

current production rate gives the number of years of the resource remaining. Using this measure, the reserve-to-production ratio at the end of 2005 for crude oil was 48.0 years; for natural gas, 60.3 years; and for coal, more than 153.7 years.

This does not mean that these resources will be depleted in that length of time: additional resources may be discovered in new areas, and improved technology may increase the amount of a resource that may be economically extracted. Also, the future rate of production and consumption may be higher or lower than current levels, which would decrease or increase the remaining years of a resource. However, reserve-to-production ratios provide insights into the limited nature of nonrenewable energy resources and the need to find alternatives, especially for resources with fewer years of remaining reserves.

Also note that, particularly for nations with nationalized energy production, there are limited opportunities to verify energy reserve data, and very large upward or downward revisions have occurred. This is independent of upward revisions that occur when new resources are discovered, or downward revisions as energy reserves are depleted. In recent years, some energy industry sources in particular have questioned the oil reserves of Saudi Arabia (Simmons 2006.)

Consumption

Data on world energy consumption are available only by type of resource rather than by total energy consumed.

Petroleum. Consumption trends of the leading consumers from 1960 to 2005 are depicted in Figure 6. In 2005, the United States consumed far more petroleum than any other country: 24.9% of the world total. Other major petroleum-consuming countries were China (8.0%), Japan (6.4%), Russia (3.3%), and Germany (3.1%).

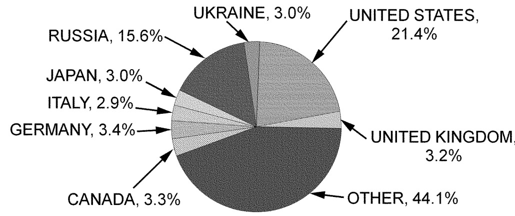

Fig. 7 World Natural Gas Consumption: 2005
(Basis: Table 1.3 in EIA 2007)

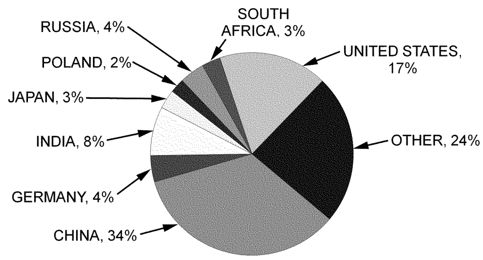

Fig. 8 World Coal Consumption: 2005
(Basis: Table 1.4 in EIA 2007)

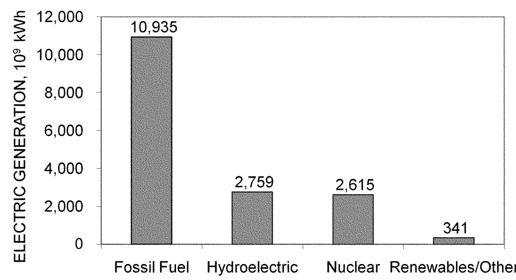

Fig. 9 World Electricity Generation by Resource: 2004
(Basis: Table 6.3 in EIA 2007)

Natural Gas. In 2005, the two biggest natural gas producers (the United States and Russia) were also the two biggest consumers. Figure 7 depicts natural gas consumption by the leading consumer countries as a percentage of world consumption. Of the major consumers, the United States consumed more than it produced (123%), and Russia consumed less (71%), as did Canada (52%). Germany produced very little, and consumption in the United Kingdom was slightly more than production (108%). World consumption of natural gas increased 26.1% between 1996 and 2005. After the United States and Russia, no single country consumed more than 5% of the world total.

Coal. Here, the two largest coal producers (China and the United States) were also the two largest consumers. China is by far the largest coal consumer, with consumption approximately double the United States' in 2005. Figure 8 depicts the percentage of world consumption by the leading consumers during 2005. Since 1980, world coal consumption has increased 57%, mostly in the last five years because of extremely rapid growth in China. Over the same period, consumption by China increased 229%, the United States 60%, and India 290%. Significant drops occurred in Germany, Poland, and Russia.

Electricity. Figure 9 shows the world's electricity generation by energy resource in 2004. Figure 10 shows installed capacity for the same resources at the beginning of 2005. Both net generation and installed capacity were dominated by the United States (23% and 25%, respectively). Comparable figures for the next largest are

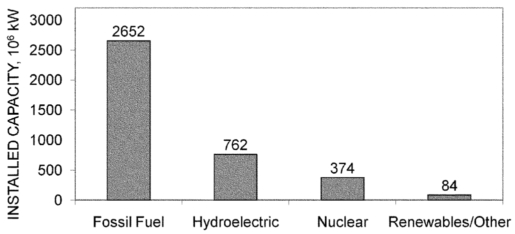

Fig. 10 World Installed Electricity Generation Capacity by Resource: 2005
(Basis: Table 6.4 in EIA 2007)

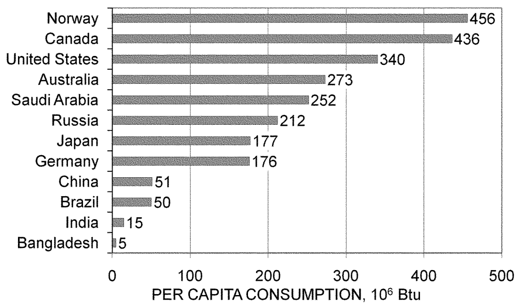

Fig. 11 Per Capita Energy Consumption by Selected Countries: 2005
(Basis: Tables B-1 and E-1 in EIA 2007)

China (14 and 11%, respectively), Japan (6% for both), and Russia (5 and 6%, respectively). In 2005, China had more than five times as much generating capacity as it had in 1980.

Hydroelectric generation increased in the world by 67% between 1980 and 2005, with the largest increases in Central and South America and China. The top countries for hydroelectric generation in 2005 were Canada, Brazil, the United States, and China, collectively accounting for 47% of the world total quantity of hydroelectric generation.

Total world electricity generation from nuclear resources increased 284% between 1980 and 2005, with higher-than-average increases occurring in Asia, Europe, and Africa. The top-generating countries in 2005 were the United States (30% of world total), France (16%), and Japan (11%).

Per Capita. Figure 11 compares the per capita energy consumption of selected countries for 2005. As is apparent, per capita energy consumption in cold-climate countries tends to be highest; also, the level in more developed countries is vastly different from that in less developed countries and differs considerably even among the more developed countries. Note that, although China's total energy use has grown very rapidly in recent years, on a per capita basis it is still far below the levels of more developed countries.

CARBON EMISSIONS

Worldwide carbon emissions from burning and flaring fossil fuels rose 25.1% from 1996 to 2005. Total carbon emissions were 28.193 billion metric tons of carbon dioxide in 2005, up from 22.531 billion metric tons in 1996. Figure 12 shows the changes in carbon emissions from burning fossil fuels from 1996 to 2005 for the total world and for selected countries. Russia, the United States, and Western Europe has small (under 10%) increases in carbon emissions. The developing countries and the Middle East show the largest increases, with extremely rapid carbon emissions growth in China in recent years. Note that although developing countries have the highest growth rates, their per capita carbon emissions are much less than in wealthier nations. A

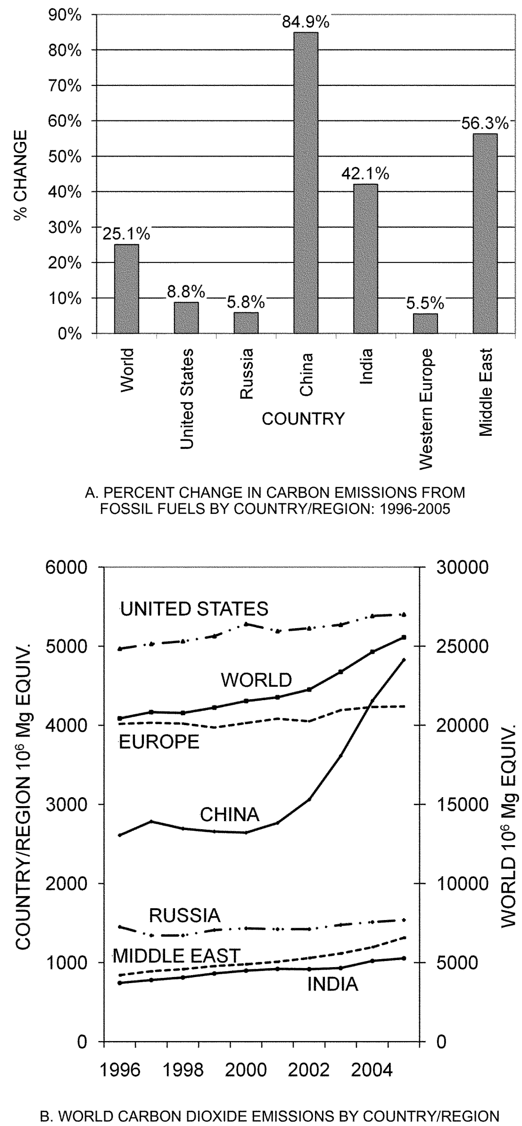

Fig. 12 World Carbon Emissions
(Basis: Table H-1 in EIA 2007)

graph of per capita carbon emissions would look very similar to Figure 11, which shows per capita energy consumption of selected countries.

U.S. ENERGY USE

Per Capita Energy Consumption

Figure 13, based on data from EIA (2006a), shows the growth in per capita energy use since 1950. The 1960s experienced a sharp increase in the per capita energy use growth rate, which leveled off during the 1970s because of higher energy prices and the emphasis on energy conservation. Since the early 1980s, however, per capita energy use growth has been relatively stable as energy efficiency increased. In recent years, per capita energy use has been slowly declining.

The *Annual Energy Outlook* is the basic source of data for projecting energy use in the United States (EIA 2006b). Figures 14 and 15 summarize data from this source.

EIA (2006b) forecasts energy trends based on macroeconomic growth scenarios, which include a variety of energy price and economic growth assumptions. Figures 14 and 15 (the baseline or reference case) assume average annual growth of the real gross domestic

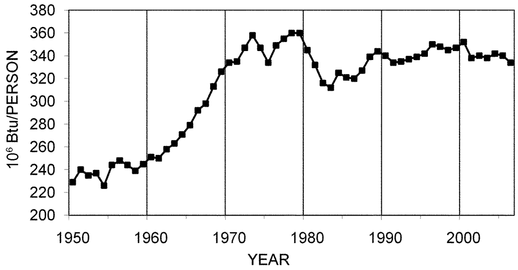

Fig. 13 Per Capita U.S. Energy Consumption
(Basis: Table 1.5 in EIA 2006a)

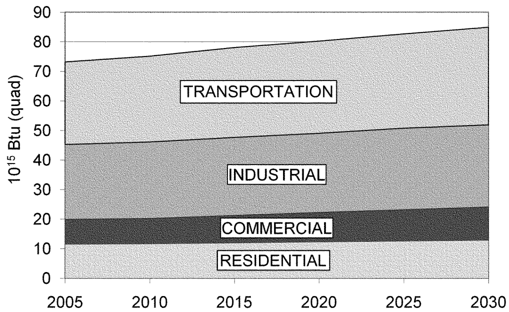

Fig. 14 Projected Total U.S. Energy Consumption by End-Use Sector
(Basis: Table A-2 in EIA 2007)

product (GDP) at 2.4%, of the labor force at 0.9%, and of productivity at 1.9%. The forecast, in order to be policy-neutral, also assumes that all federal, state, and local laws and regulations in effect December 31, 2007, remain unchanged through 2030. Note that this forecast includes the effects of the EISA 2007 energy bill, which included significant energy efficiency and conservation requirements, such as increased use of biofuels and higher fuel economy standards for automobiles and other personal transportation vehicles.

Projected Overall Energy Consumption

Figure 14 shows energy use by major end-use sector (i.e., residential, commercial, industrial, and transportation). HVAC&R engineers are primarily concerned with the first three sectors. Figure 15 shows energy consumption by type of resource. Figure 14 shows less total energy consumption than Figure 15, primarily because it excludes the thermodynamic losses of electricity generation and the processing and delivery burdens of various energy forms.

The following observations apply to the overall picture of projected energy use in the United States over the next two decades (Figures 14 and 15):

- Although a major issue in energy markets is carbon emissions, no specific programs such as cap-and-trade or carbon taxes are reflected in these forecasts, because no specific policies for carbon reductions had been enacted in 2007.
- Carbon emissions from energy use are projected to increase by an average of 0.6% per year through 2030 because of rising energy demand, increasing population, improvements in efficiency, and slow growth in the use of renewable sources. The 2030 level of carbon emissions is projected to be almost 16% higher than the 2006 levels.
- Crude oil prices are expected to rise at an annual rate of 0.3% more than inflation. However, crude oil at any given time may fluctuate substantially because of short-term political or economic events affecting supplies.

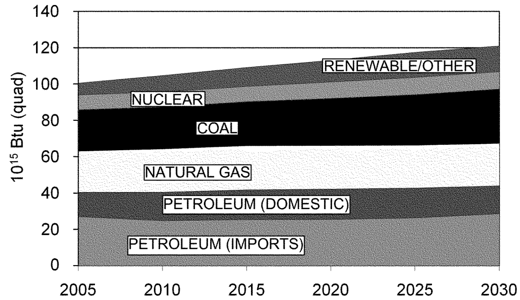

Fig. 15 Projected Total U.S. Energy Consumption by Resource
(Basis: Table A-1 in EIA 2007)

- The wellhead price of natural gas was projected to rise at an annual rate of 0.3% more than inflation from 2006 through 2030. However, the U.S. Department of Energy (DOE) starts from a base price in 2006 that is well below actual market prices experienced in 2007 and 2008. This forecast assumes a long-term slow rise in price as lower-cost natural gas supply sources become less available. In recent years, U.S. natural gas markets have experienced extreme price volatility, making the outlook uncertain.
- The price of coal is expected to decline at an annual rate of 0.2% over the same period as a result of better productivity, more low-cost western coal production, and competitive labor pressures.
- Electricity prices are projected to show no change other than the effects of inflation from 2006 to 2030, because of improved technology and efficiency and the assumed very low increases in fuel costs.

  Nuclear power generation is expected to grow at an annual rate of 0.6% per year, because of construction of new nuclear power plants along with life extensions for existing plants. A total of 17 GW of new nuclear generation units are projected to be completed by 2030, which equates to 11 to 15 new units, depending on facility size and design.
- Electricity generation using renewable sources (which includes cogenerators) will increase by 2.1% per year, but is projected to become the third largest source of electricity after coal and nuclear power by 2025, surpassing natural gas generation between 2020 and 2025.
- Petroleum consumption will grow by 0.4% annually, led by the transportation sector, which is where most of it (74%) is used.
- The share of petroleum consumption met by net imports is projected to be about 64% in 2030, only a fraction of a percent higher than current levels. Over this period, U.S. crude oil production is projected to increase at an annual rate of 0.5%, reversing a multidecade slow decline since the 1970s. Reasons include higher prices encouraging more drilling, enhanced oil recovery projects at existing fields, and production of oil from shale. The forecast is for U.S. oil production to peak in approximately 2020, with declining production through 2030, but with production in 2030 still about 11% above current levels.
- Natural gas consumption will increase by 0.2% per year in all sectors. Natural gas use for electric generation is projected to decline after 2010, and direct use by residential and commercial consumers to increase.
- Coal consumption will increase at an average annual rate of 1.2%. Most of it (90%) will be used for electricity generation.
- Consumption of nonhydroelectric renewable energy will increase by 4.4% per year. This includes ethanol used as a transportation fuel.
- Electricity consumption is projected to grow by 0.9% annually, with efficiency gains offset by increased use of electricity-using equipment and an increasing population.

- Total energy demand in the commercial and residential sectors will grow at 1.4% and 0.8% per year, respectively. This results from increasing population and greater use of computers, telecommunications, and other office appliances, but it is offset by somewhat improved building and equipment efficiencies.
- Energy use by the transportation sector will grow at an average of 0.7% per year, with variations from this average depending heavily on prevailing fuel prices. The growth rate for transportation energy use is much lower than in recent forecasts, reflecting new mandatory fuel economy standards to be implemented during the forecast period.
- Per capita energy use is projected to decline by 0.1% annually, as increases in efficiency more than offset population growth and new energy-consuming products.
- Total energy use per dollar of gross domestic product (energy intensity), however, will continue to fall at an average rate of about 2.4% per year through 2030.

Outlook Summary

In general, the following key issues will dominate energy matters in the next two decades:

- Continued dependency of the United States on imported oil
- Potential increases in use of nuclear power for electric generation
- Role of technology developments, including energy conservation and energy efficiency as alternatives to energy production
- Substantial increases in use of renewable energy, rising from 9.4% of total U.S. production in 2006 to 13.6% in 2030
- Continued growth in total worldwide carbon emissions, and debate over actions to deal with the issue
- Relative merits of various energy alternatives, including nuclear power and different renewable energy options
- Population growth, coupled with the shift of large population segments into retirement

U.S. AGENCIES AND ASSOCIATIONS

American Gas Association (AGA), Washington, D.C.
American Petroleum Institute (API), Washington, D.C.
Bureau of Mines, Department of Interior, Washington, D.C.
Council on Environmental Quality (CEQ), Washington, D.C.
Edison Electric Institute (EEI), Washington, D.C.
Electric Power Research Institute (EPRI), Palo Alto, CA
Energy Information Administration (EIA), Washington, D.C.
Gas Research Institute (GRI), Des Plaines, IL
National Coal Association (NCA), Washington, D.C.
North American Electric Reliability Council (NAERC), Princeton, NJ
Organization of Petroleum Exporting Countries (OPEC), Vienna, Austria
United States Green Building Council (USGBC), Washington, D.C.

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