7.9 World Energy Use

Learning Objectives

By the end of this section, you will be able to:

- Describe the distinction between renewable and nonrenewable energy sources.
- Explain why the inevitable conversion of energy to less useful forms makes it necessary to conserve energy resources.

Energy is an important ingredient in all phases of society. We live in a very interdependent world, and access to adequate and reliable energy resources is crucial for economic growth and for maintaining the quality of our lives. But current levels of energy consumption and production are not sustainable. Depending on the data source, estimates indicate that about 31–35% of the world's energy comes from oil, and much of that goes to transportation uses. This is a reduction by a few percentage points from ten years ago. Oil prices are dependent as much upon new (or foreseen) discoveries as they are upon political events and situations around the world. The U.S., with 4.25% of the world's population, consumes 21% of the world's oil production per year.

Renewable and Nonrenewable Energy Sources

The principal energy resources used in the world are shown in Figure 7.26. The fuel mix has changed over the years but now is dominated by oil, although natural gas and solar contributions are increasing. Renewable forms of energy are those sources that cannot be used up, such as water, wind, solar, and biomass. About 85% of our energy comes from nonrenewable fossil fuels—oil, natural gas, coal. The likelihood of a link between global warming and fossil fuel use, with its production of carbon dioxide through combustion, has made, in the eyes of many scientists, a shift to non-fossil fuels of utmost importance—but it will not be easy.

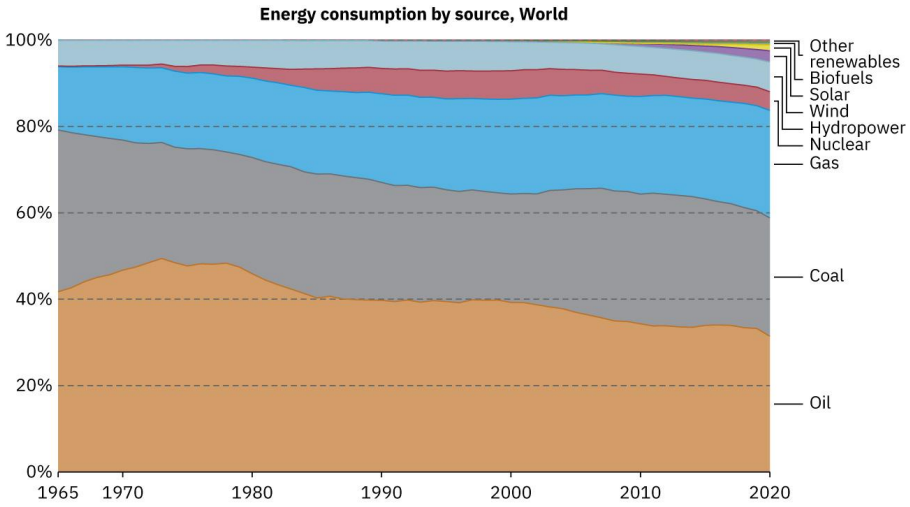

Figure 7.26 World energy consumption by source, in billions of kilowatt-hours: 2006. (credit: KVDP)

The World's Growing Energy Needs

World energy consumption continues to rise, especially in the developing countries. (See Figure 7.27.) Global demand for energy has tripled in the past 50 years and might triple again in the next 30 years. While much of this growth will come from the rapidly booming economies of China and India, many of the developed countries, especially those in Europe, are hoping to meet their energy needs by expanding the use of renewable sources. Although presently only a small percentage, renewable energy is growing very fast, especially wind energy. For example, Germany plans to meet 65% of its power and 30% of its overall energy needs with renewable resources by the year 2030. (See Figure 7.28.) Energy is a key constraint in the rapid economic growth of China and India. In 2003, China surpassed Japan as the world's second largest consumer of oil. However, over 1/3 of this is imported. Unlike most Western countries, coal dominates the commercial energy resources of China, accounting for 2/3 of its energy consumption. In 2009 China surpassed the United States as the largest generator of CO_2 . In India, the main energy resources are biomass (wood and dung) and coal. Half of India's oil is imported. About 70% of India's electricity is generated by highly polluting coal. Yet there are sizeable strides being made in renewable energy. India has a rapidly growing wind energy base, and it has the largest solar cooking program in the world. China has invested substantially in building solar collection farms as well as hydroelectric plants.

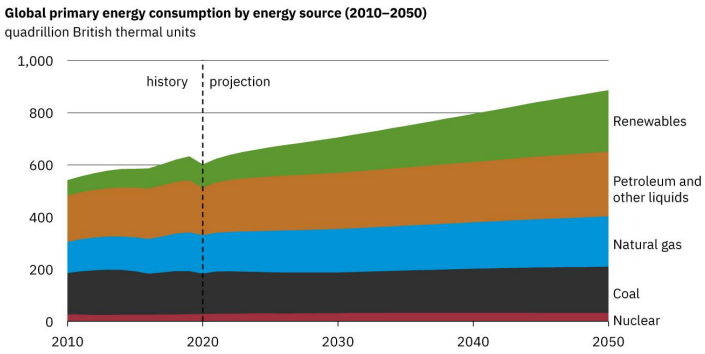

Figure 7.27 Past and projected world energy use (source: Based on data from U.S. Energy Information Administration, 2021)

Figure 7.28 Solar cell arrays at a power plant in California (credit: Bureau of Land Management, Flickr)

Table 7.6 displays the 2020 commercial energy mix by country for some of the prime energy users in the world. While non-renewable sources dominate, some countries get a sizeable percentage of their electricity from renewable resources. For example, about two-thirds of New Zealand's electricity demand is met by hydroelectric. Only 10% of the U.S. electricity is generated by renewable resources, primarily hydroelectric. It is difficult to determine total sources and consumers of energy in many countries, and estimates vary somewhat by data source and type of measurement.

Country	Consumption, in EJ (10^{18} J)	Oil	Natural Gas	Coal	Nuclear	Hydro	Other Renewables
Australia	5.6	1.8%	1.5%	1.7%	0%	0.1%	0.5%
Brazil	12	4.6%	1.2%	0.6%	0.1%	3.5%	2%
China	145.5	28.5%	11.9%	82.3%	3.3%	11.7%	7.8%
Egypt	3.7	1.3%	2.1%	0.03%	0%	0.1%	0.1%
Germany	12.1	4.2%	3.1%	1.9%	0.6%	0.2%	2.2%
India	31.99	9%	2.2%	17.5%	0.4%	1.5%	1.4%
Indonesia	8.1	2.8%	1.5%	3.3%	0%	0.2%	0.4%
Japan	17	6.5%	3.8%	4.6%	0.4%	0.7%	1.1%
United Kingdom	6.9	2.4%	2.6%	0.2%	0.5%	0.1%	1.2%
Russia	28.3	6.4%	14.8%	3.2%	1.9%	1.9%	0.5%
U.S.	87.8	32.5%	30%	9.2%	7.4%	2.6%	6.2%
World	**557.1**	**174.2%**	**137.6%**	**151.4%**	**24%**	**38.2%**	**31.7%**

Table 7.6 Energy Consumption—Selected Countries (2020)

Energy and Economic Well-being

Economic well-being is dependent upon energy use, and in most countries higher standards of living, as measured by GDP (gross domestic product) per capita, are matched by higher levels of energy consumption per capita. This is borne out in Figure 7.29. Increased efficiency of energy use will change this dependency. A global problem is balancing energy resource development against the harmful effects upon the environment in its extraction and use.

New and diversified energy sources do, however, greatly increase economic opportunity and stability. First, the extensive employment opportunities in renewable energy make it one of the most sustainable and secure fields to enter. Second, renewable energy provides countries and localities with increased levels of resiliency in the face of natural disasters, conflict, or other disruptions. The 21st century has already seen major economic impacts from energy disruptions: Hurricane Katrina, Superstorm Sandy, various wildfires, Hurricane Maria, and the 2021 Texas Winter Storm demonstrate the vulnerability of United States power systems. Diversifying energy sources through renewables and other fossil-fuel alternatives brings power grids and transportation systems back online much more quickly, saving lives and enabling a more swift return to economic operations. And as critical emerging information infrastructure, such as data

centers, requires more of the world's energy, supplying those growing systems during normal operations and crises will be increasingly important.

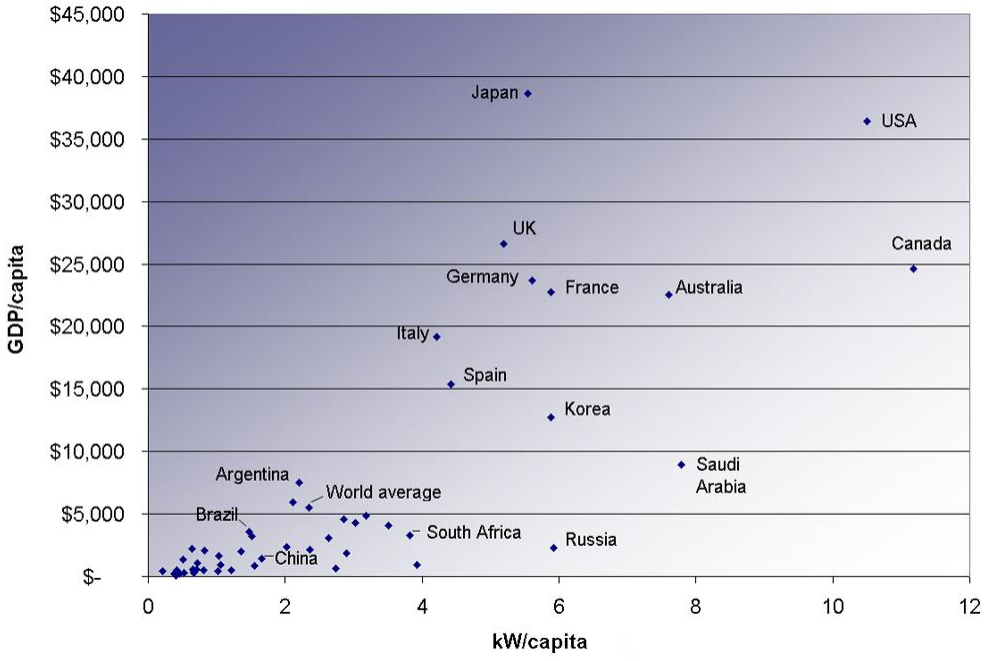

Figure 7.29 Power consumption per capita versus GDP per capita for various countries. Note the increase in energy usage with increasing GDP. (2007, credit: Frank van Mierlo, Wikimedia Commons)

Conserving Energy

As we finish this chapter on energy and work, it is relevant to draw some distinctions between two sometimes misunderstood terms in the area of energy use. As has been mentioned elsewhere, the "law of the conservation of energy" is a very useful principle in analyzing physical processes. It is a statement that cannot be proven from basic principles, but is a very good bookkeeping device, and no exceptions have ever been found. It states that the total amount of energy in an isolated system will always remain constant. Related to this principle, but remarkably different from it, is the important philosophy of energy conservation. This concept has to do with seeking to decrease the amount of energy used by an individual or group through (1) reduced activities (e.g., turning down thermostats, driving fewer kilometers) and/or (2) increasing conversion efficiencies in the performance of a particular task—such as developing and using more efficient room heaters, cars that have greater miles-per-gallon ratings, energy-efficient compact fluorescent lights, etc.

Since energy in an isolated system is not destroyed or created or generated, one might wonder why we need to be concerned about our energy resources, since energy is a conserved quantity. The problem is that the final result of most energy transformations is waste heat transfer to the environment and conversion to energy forms no longer useful for doing work. To state it in another way, the potential for energy to produce useful work has been "degraded" in the energy transformation. (This will be discussed in more detail in Thermodynamics.)