Chapter 12
Nonrenewable Energy Resources

Module 34
Patterns of Energy Use

After reading this module, you should be able to

- describe the use of nonrenewable energy in the world and in the United States.
- explain why different forms of energy are best suited for certain purposes.
- understand the primary ways that electricity is generated in the United States.

Nonrenewable energy is used worldwide and in the United States

- **Fossil fuel** A fuel derived from biological material that became fossilized millions of years ago.

- **Nonrenewable energy resource** An energy source with a finite supply, primarily the fossil fuels and nuclear fuels.

- **Nuclear fuel** Fuel derived from radioactive materials that give off energy.

Worldwide Patterns of Energy Use

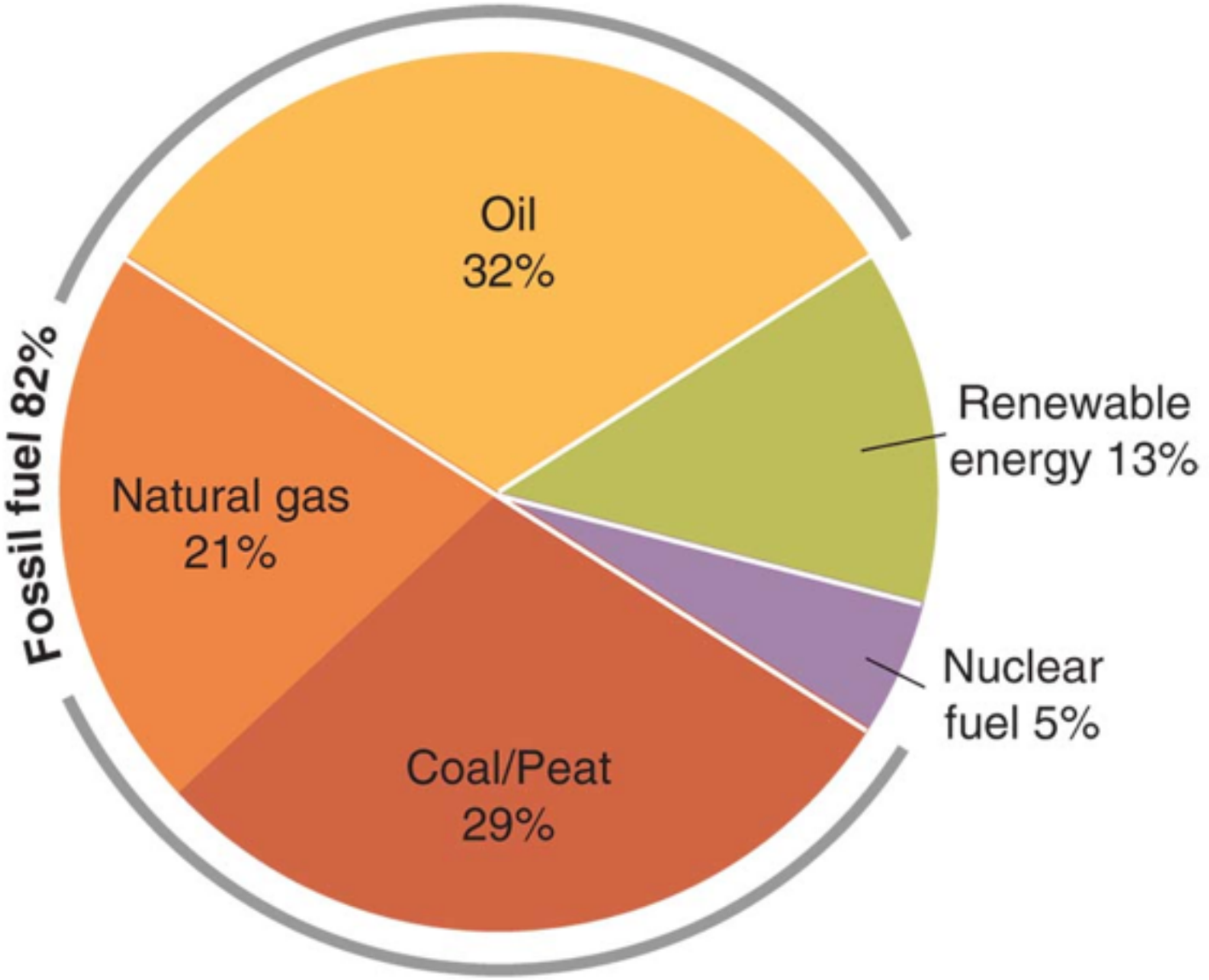


Figure 34.1
Environmental Science for AP®, Second Edition
Data from the International Energy Agency, 2013

Worldwide annual energy consumption, by resource, in 2011.
Oil, coal and peat, and natural gas are the major sources of energy for the world.

Worldwide Patterns of Energy Use

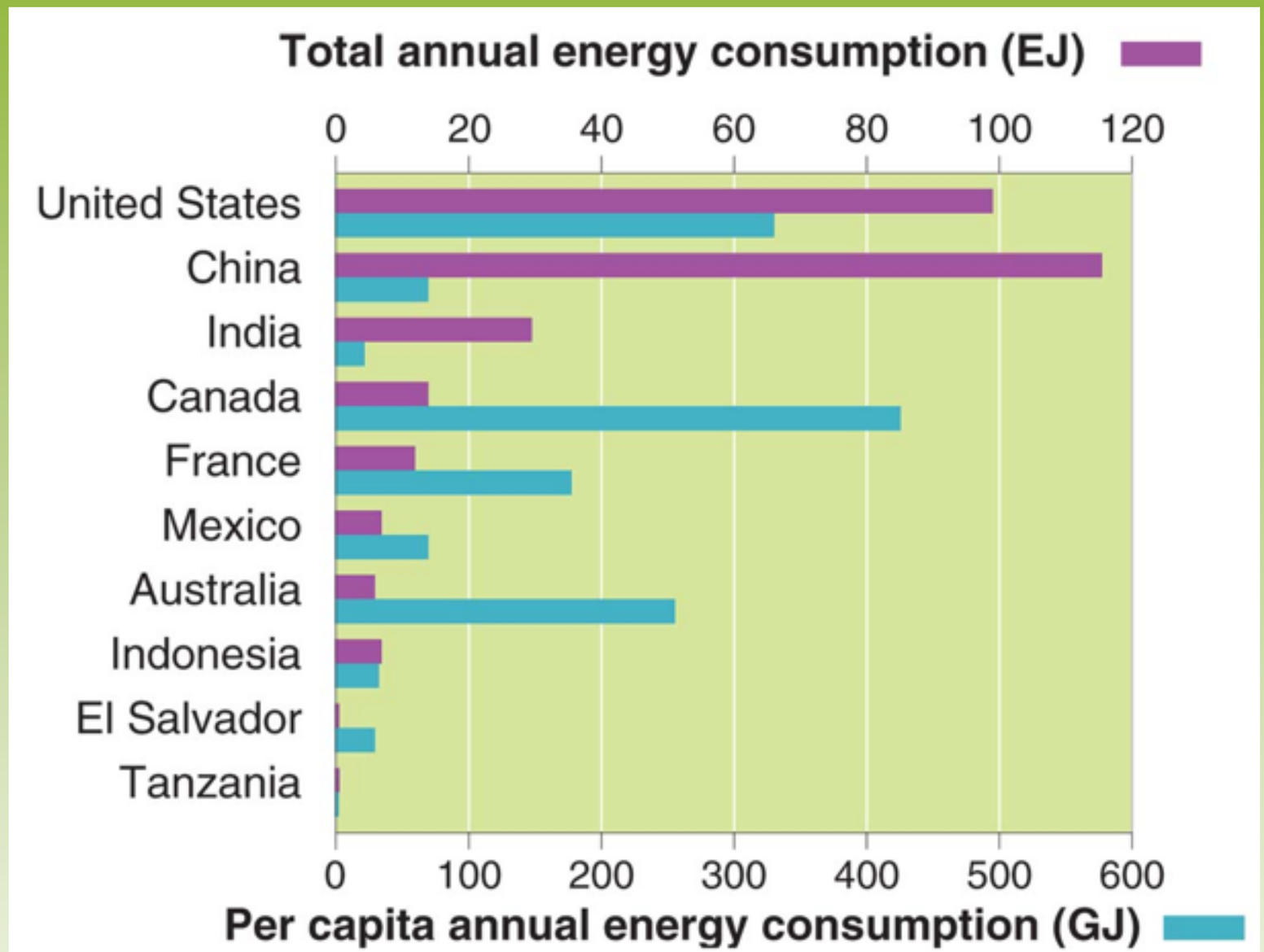


Figure 34.2
Environmental Science for AP®, Second Edition
Data from the U.S. Department of Energy, Energy Information Administration, 2012

*per capita – per person

Global variation in total annual energy consumption and per capita energy consumption. The 10 countries shown are among the largest and the smallest energy users in the world.

Worldwide Patterns of Energy Use

- **Commercial energy source** An energy source that is bought and sold.

- **Subsistence energy source** An energy source gathered by individuals for their own immediate needs.

Different energy forms are best suited for specific purposes

- The best form of energy to use depends on the particular purpose for which it is needed.
- For Example: transportation sector uses liquid fuels (gas and diesel) they are relatively compact and they have a high energy to mass ratio

Different energy forms are best suited for specific purposes

- It is possible to determine energy efficiency by calculating the energy return on energy investment (EROEI)

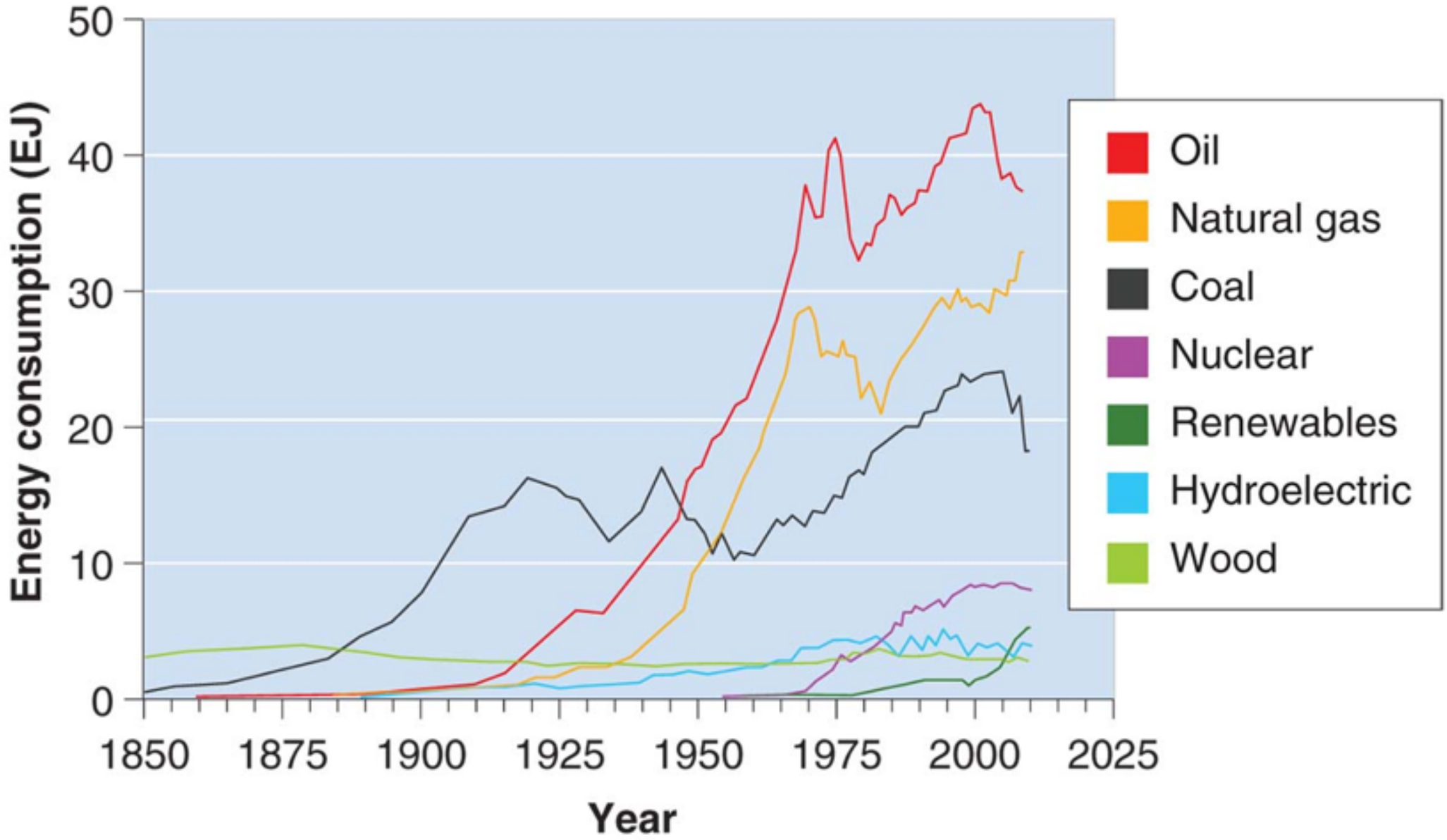
EROI = Energy obtained from fuel ÷ Energy invested to obtain fuel

- The larger the value of EROI, the more efficient the fuel.

The efficiency of producing electricity from coal is approximately 35%

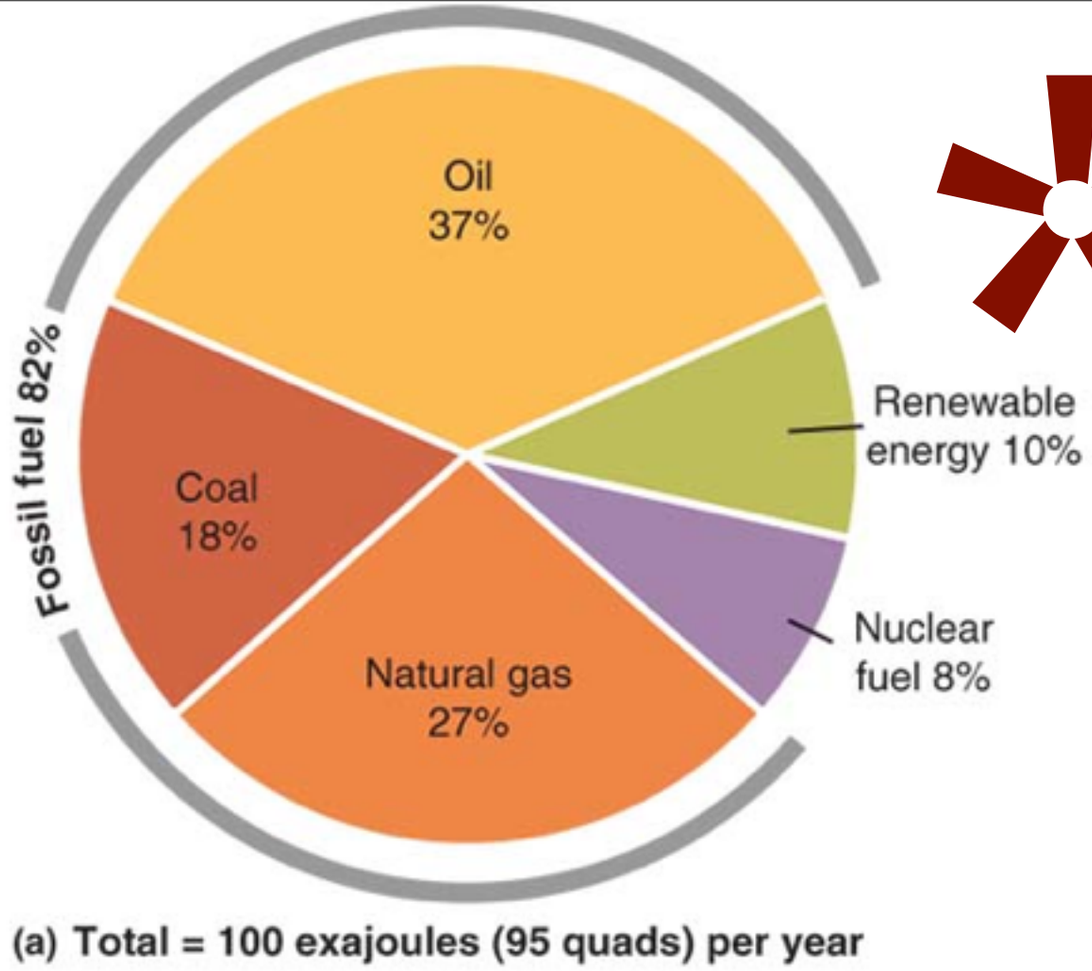
Electric water heating is roughly 35% efficient where as gas water heating approaches 80% efficient

Worldwide Patterns of Energy Use



Energy consumption in the United States from 1850 through 2012. Wood and then coal once dominated our energy supply. Today a mix of three fossil fuels accounts for most of our energy use. The recent increase in natural gas and decrease in oil and coal is quite evident.

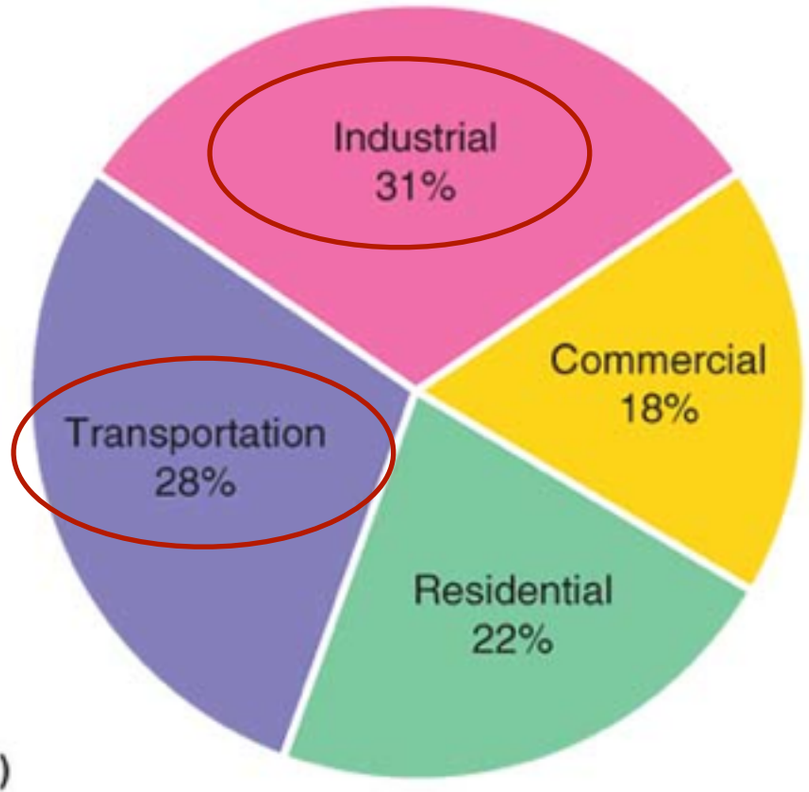
Worldwide Patterns of Energy Use



(a) Total = 100 exajoules (95 quads) per year

United States annual energy consumption by resource and end use in 2012.

These graphs show energy consumption and end use in the United States. (a) United States annual energy consumption by fuel type in 2012. (b) United States end use energy sectors in 2012. Commercial includes businesses and schools.

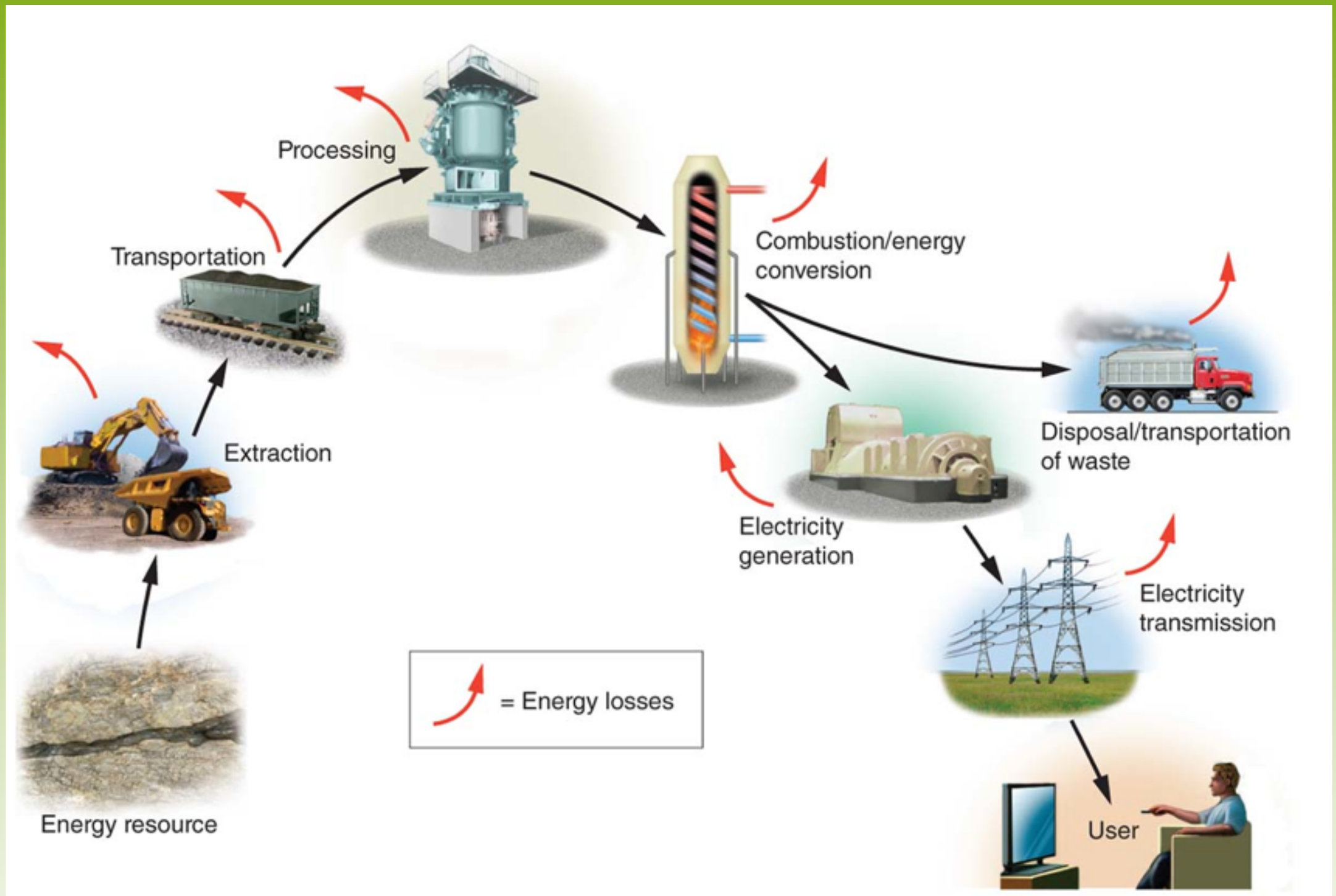


(b)

U.S. produces ~85% of its energy and imports the remaining 15%

U.S. produces most of its electricity through coal

Quantifying Energy Efficiency



Inefficiencies in energy extraction and use. Coal provides an example of inefficiencies in energy extraction and use. Energy is lost at each stage of the process, from extraction, processing, and transport of the fuel to the disposal of waste products.

Efficiency and Transportation

- Nearly 30 percent of energy use in the United States is for transportation, This is an area in which efficiency is particularly important.

- Transportation is achieved primarily through the use of vehicles fueled by petroleum products, such as gasoline and diesel.

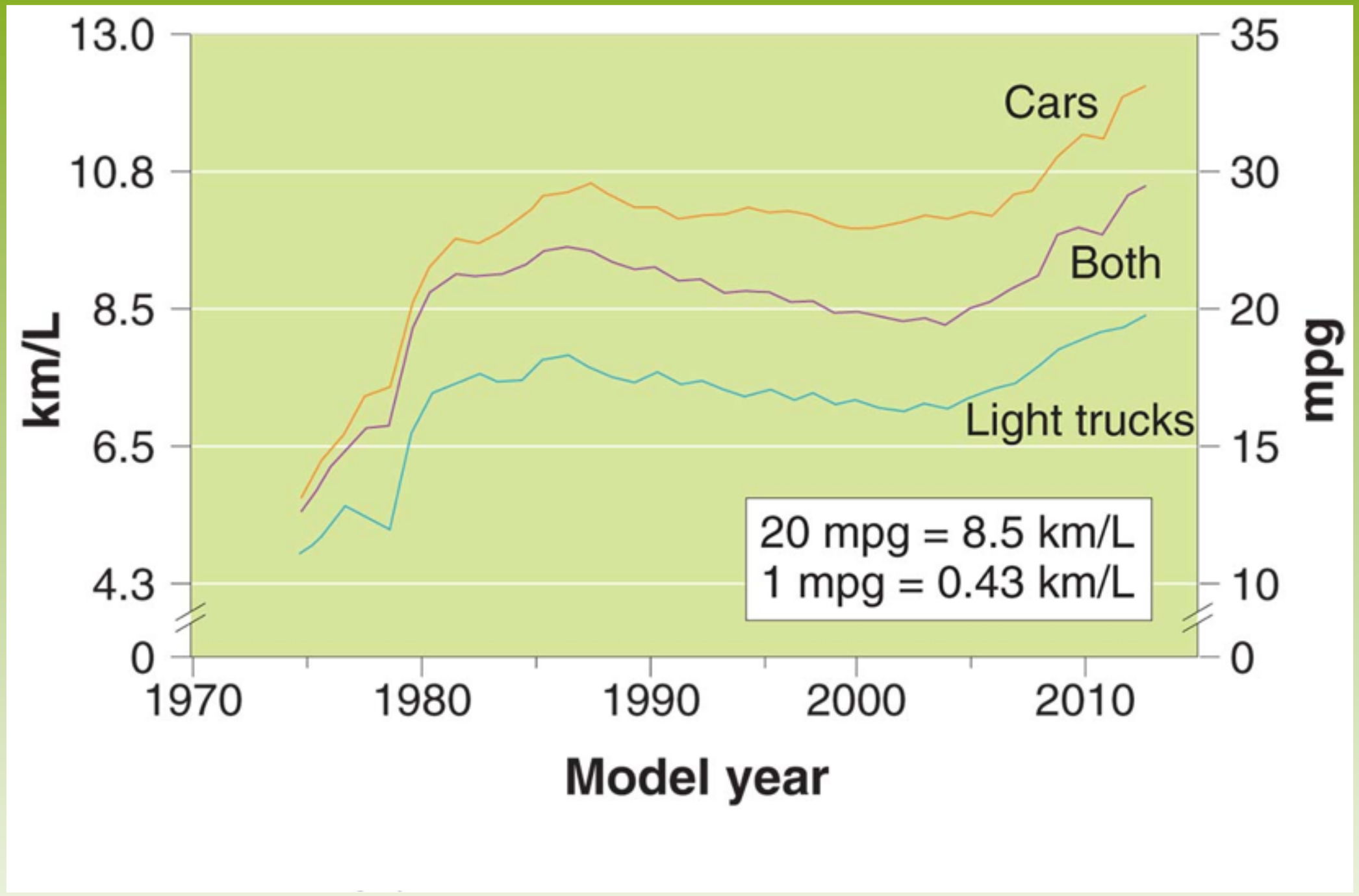
Efficiency and Transportation

TABLE 34.1 Energy expended for different modes of transportation in the United States

Mode	MJ per passenger-kilometer
Air	2.1
Passenger car (driver alone)	3.6
Motorcycle	1.1
Train (Amtrak)	1.1
Bus	1.7

Vehicles are the Primary source that moves people and goods, fueled on petroleum products

Efficiency and Transportation



Overall fuel efficiency of U.S. automobiles from 1975 through 2013. As more buyers moved from cars to light trucks (a category that includes pickup trucks, minivans, and SUVs) for their personal vehicles, the fuel economy of the total U.S. fleet declined. Only recently has it begun to increase.

Electricity accounts for 40 percent of our energy use (BUT only 13% of this energy reaches the end users)

- Electricity can be generated from many different sources

- **Energy carrier** Something that can move and deliver energy in a convenient, usable form to end users.

The Process of Electricity Generation

- All thermal power plants convert the potential energy of a fuel into electricity.

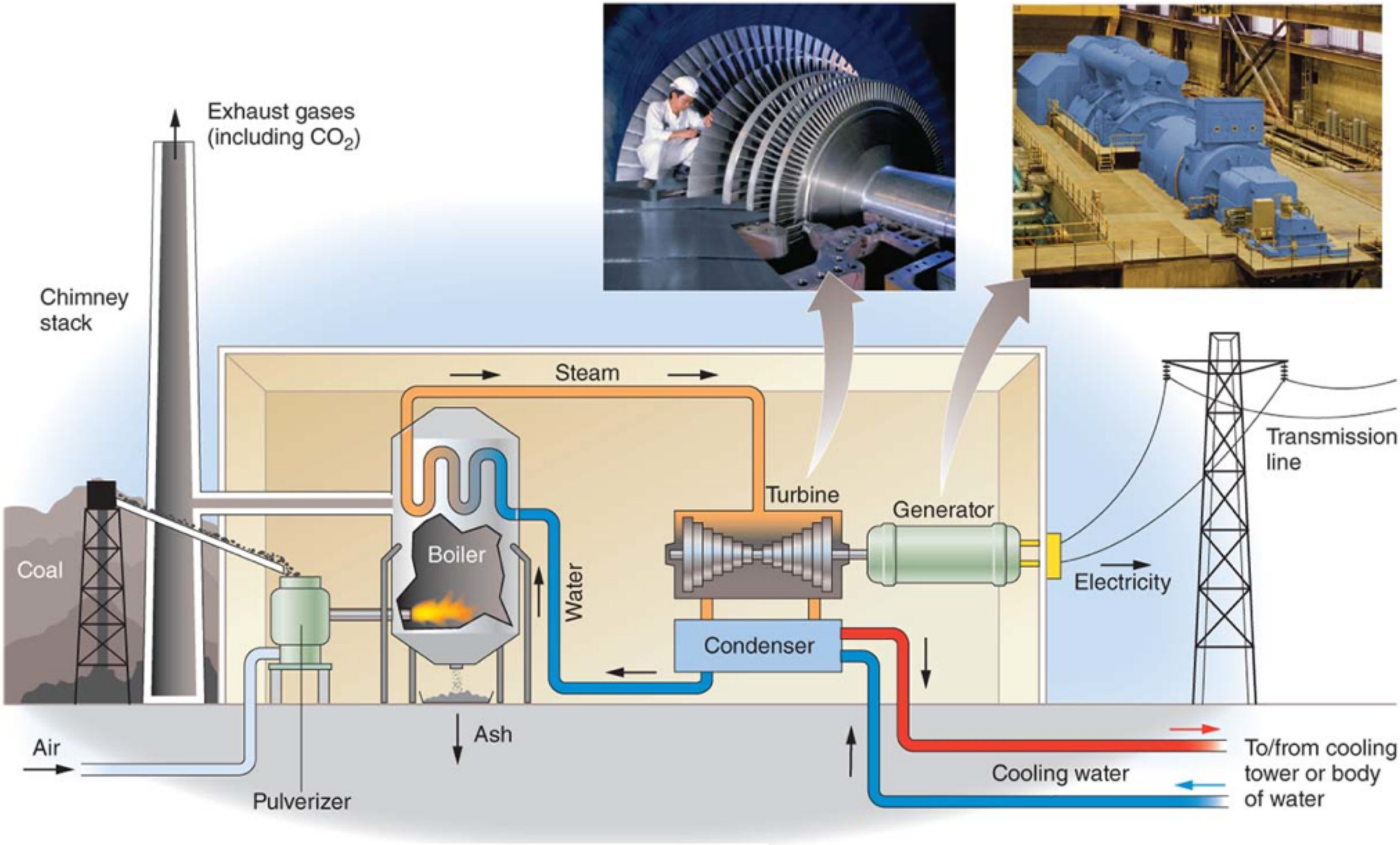
- **Turbine** A device with blades that can be turned by water, wind, steam, or exhaust gas from combustion that turns a generator in an electricity-producing plant.

- **Electrical grid** A network of interconnected transmission lines that joins power plants together and links them with end users of electricity.

The Process of Electricity Generation

Steps for using coal to produce electricity:

- The burning fuel from coal transfers energy to water, which becomes steam.
- The kinetic energy contained within the steam is transferred to the blades of a turbine, a large device that resembles a fan.
- As the energy in the steam turns the turbine, the shaft in the center of the turbine turns the generator.
- This mechanical motion generates electricity.



A coal-fired electricity generation plant. Energy from coal combustion converts water into steam, which turns a turbine. The turbine turns a generator, which produces electricity.

Efficiency of Electricity Generation

- **Combined cycle** A power plant that uses both exhaust gases and steam turbines to generate electricity.

- **Capacity** In reference to an electricity-generating plant, the maximum electrical output.

- **Capacity factor** The fraction of time a power plant operates in a year.

Efficiency of Electricity Generation

- **Cogeneration** The use of a fuel to generate electricity and produce heat. Also known as combined heat and power.

- For example, if steam is used for industrial purposes or to heat buildings it is diverted to turn a turbine first.

- This improves the efficiency to as high as 90 percent.

Module 35
Fossil Fuel Resources

After reading this module, you should be able to

- discuss the uses of coal and its consequences.
- discuss the uses of petroleum and its consequences.
- discuss the uses of natural gas and its consequences.
- discuss the uses of oil sands and liquefied coal and their consequences.
- describe future prospects for fossil fuel use.

Coal is the most abundant and dirtiest of the fossil fuels

- **Coal** A solid fuel formed primarily from the remains of trees, ferns, and other plant materials preserved 280 million to 360 million years ago.

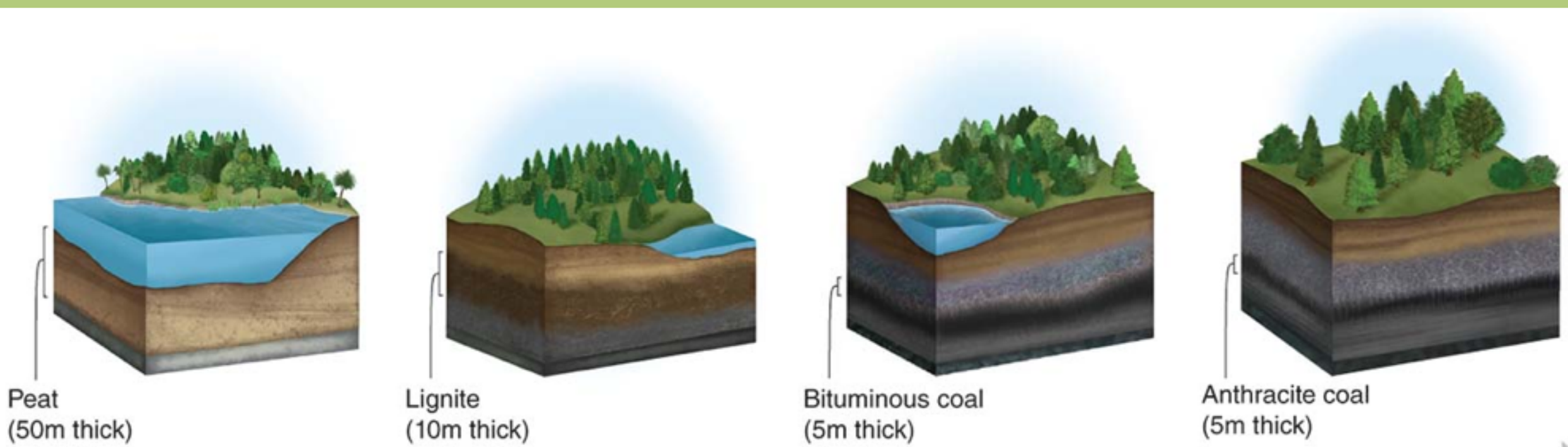
There are four types of coal:

- lignite, sub-bituminous, bituminous, anthracite.

- The largest coal reserves are in the United States, Russia, China, and India.
- Easy to extract, handle and process
- Fuel most commonly used to generate electricity

Coal

The coal formation process. Peat is the raw material from which coal is formed. Over millions of years and under increasing pressure due to burial under more and more layers of rock and sediment, various types of coal are formed.



Advantages of Coal

- Energy-dense
- Plentiful
- Easy to exploit by surface mining
- Needs little refining
- Inexpensive
- Easy to handle and transport

Disadvantages of Coal

- Contains impurities
- Releases impurities into air when burned
- Trace metals like mercury, lead, and arsenic are found in coal
- Combustion leads to increased levels air pollutants
- Ash is left behind, leads to possible runoff
- Carbon is released into the atmosphere

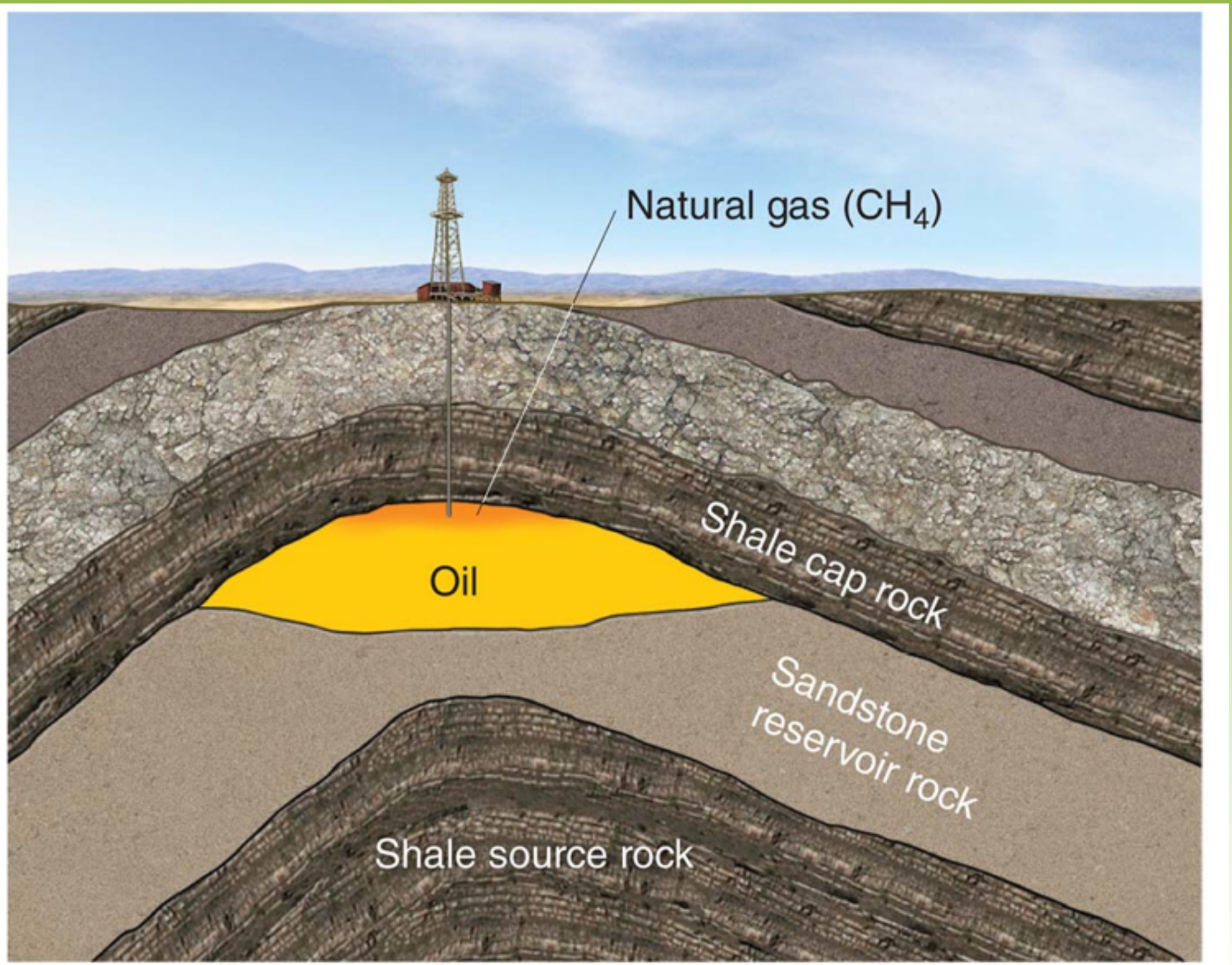
Petroleum is cleaner than coal

- **Petroleum** A fossil fuel that occurs in underground deposits, composed of a liquid mixture of hydrocarbons, water, and sulfur.

- **Crude oil** Liquid petroleum removed from the ground.

-

Petroleum accumulation underground. Petroleum migrates to the highest point in a formation of porous rock and accumulates there. Such accumulations of petroleum can be removed by drilling a well.



Advantages of Petroleum

- Convenient to transport and use
- Relatively energy-dense
- Cleaner-burning than coal
- Oil is used in many other applications

Petroleum

- Primary fuel used in transportation
- Top producing countries: Saudi Arabia, Russia, U.S., Iran, China, Canada, Mexico
- Oil is used in many other applications such as plastics, lubricants, pharmaceuticals, cleaning solvents

Disadvantages of Petroleum

- Releases carbon dioxide into atmosphere
- Possibility of leaks when extracted and transported
- Runoff enters marine waterways
- Releases sulfur, mercury, lead, and arsenic into the atmosphere when burned

Disadvantages of Petroleum

Arctic National Wildlife Refuge (ANWR):

- Debates continue over the trade-off between extracting oil domestically and the consequences for habitat and species living near oil wells or pipelines.

- Proponents of exploration suggest that ANWR might yield 25 million gallons to 378 billion gallons of oil and substantial quantities of natural gas.

- Humans and wildlife have been harmed by oil extraction

Natural Gas is the Cleanest of the Fossil Fuels

- Natural gas exists as a component of petroleum in the ground as well as in gaseous deposits separate from petroleum.

- Natural gas contains 80 to 95 percent methane and 5 to 20 percent ethane, propane, and butane.

- The two largest uses of natural gas in the United States are electricity generation and industrial processes.

- Natural gas is also used to manufacture nitrogen fertilizers and in residences for heating homes and cooking.

Advantages of Natural Gas

- Contains fewer impurities, emits almost no sulfur dioxide or particulates
- Emits only 60 percent as much carbon dioxide as coal

Natural Gas

- What is the process of hydraulic fracking?
- What are the environmental consequences of hydraulic fracking?
- What are the benefits of hydraulic fracking?

Disadvantages of Natural Gas

- Methane that escapes into the atmosphere is a potent (25X better than Carbon Dioxide in trapping heat) greenhouse gas

- Exploration for natural gas can contaminate groundwater, due fracking chemicals

- Requires a lot of water

Oil sands and liquefied coal are also fossil fuels

- **Oil sands** Slow-flowing, viscous deposits of bitumen mixed with sand, water, and clay.

- **Bitumen** A degraded petroleum that forms when petroleum migrates to the surface of Earth and is modified by bacteria.

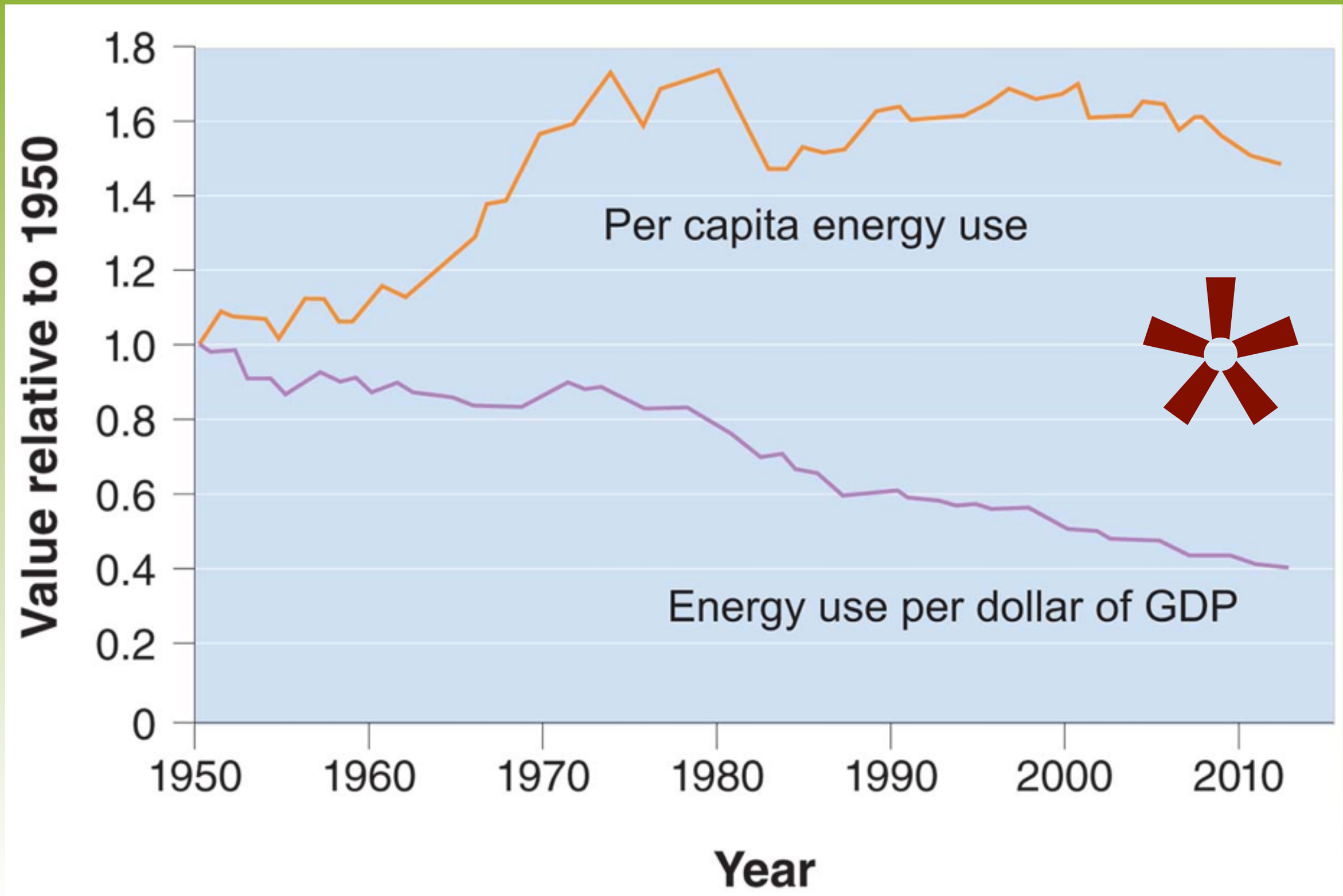
- **CTL (coal to liquid)** The process of converting solid coal into liquid fuel.

Fossil fuels are a finite resource

- **Energy intensity** The energy use per unit of gross domestic product.

- Our energy use per capita has been dropping, but with rising population numbers, total energy use continues to rise.

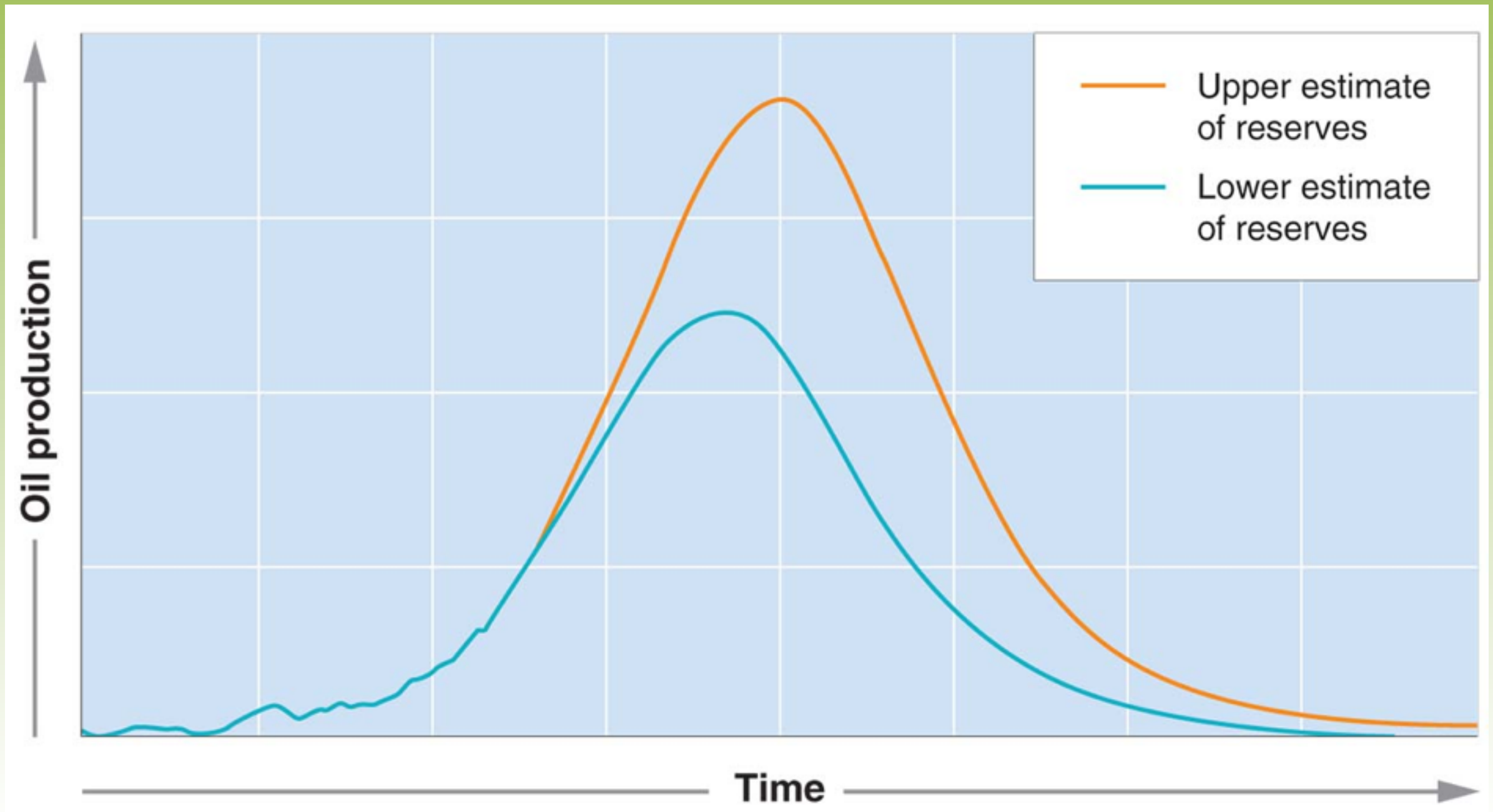
U.S. energy use per capita and energy intensity. Our energy use per capita was level and has been dropping in recent years. Our energy intensity, or energy use per dollar of GDP, has been decreasing steadily since 1980. However, because of the increasing U.S. population, total energy use of the nation has been roughly constant between 2000 and 2012.



The Hubbert Curve

A generalized version of the Hubbert curve. Whether an upper estimate or a lower estimate of total petroleum reserves is used, the date by which petroleum reserves will be depleted does not change substantially.

Should we be concerned about the future supplies of fossil fuels?



The Future of Fossil Use

- If current global use continues without significant additional discovery, we may run out of conventional oil in less than 50 years.

- Coal supplies will last for at least 200 years, and probably much longer.

- New technology and concern about the release of greenhouse gases is encouraging people to explore alternative energy sources.

Group Work / Homework

	Oil	Coal	Natural Gas	Nuclear
Advantages				
Disadvantages				

Module 36
Nuclear Energy Resources

After reading this module, you should be able to

- describe how nuclear energy is used to generate electricity.

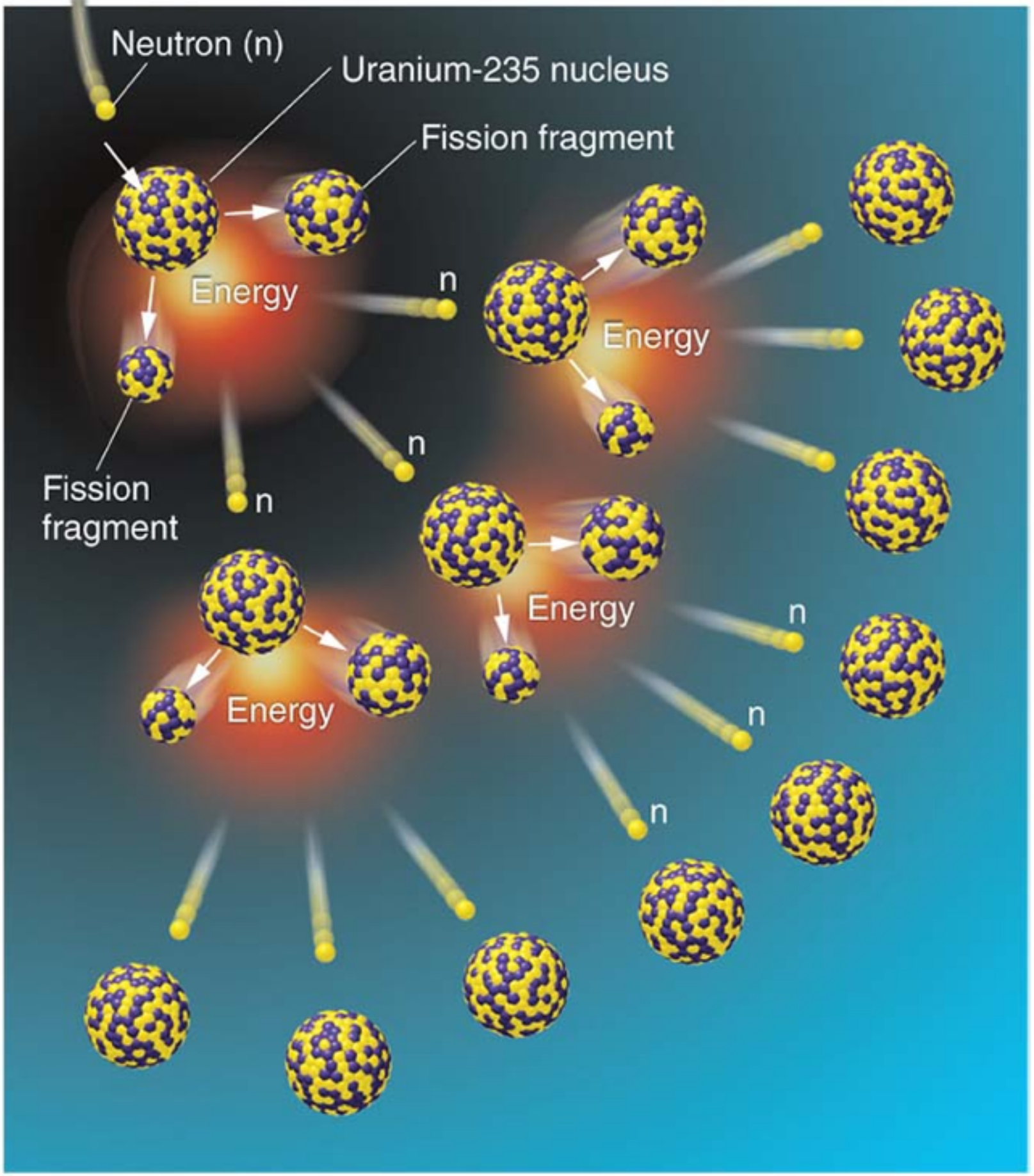
- discuss the advantages and disadvantages of using nuclear fuels to generate electricity.

Nuclear reactors use fission to generate electricity

- Electricity generation from nuclear fuel uses uranium-235 as a fuel source.

- **Fission** A nuclear reaction in which a neutron strikes a relatively large atomic nucleus, which then splits into two or more parts, releasing additional neutrons and energy in the form of heat.

- A nuclear power plant uses heat from nuclear fission to boil water. This water produces the steam to turn the turbine, which turns a generator.



Nuclear fission. Energy is released when a neutron strikes a large atomic nucleus, which then splits into two or more parts.

1 Gram of Uranium 235 has 2-3 MILLION times MORE energy than 1 gram of Coal

Nuclear reactors use fission to generate electricity

- **Fuel rod** A cylindrical tube that encloses nuclear fuel within a nuclear reactor.

- **Control rod** A cylindrical device inserted between the fuel rods in a nuclear reactor to absorb excess neutrons and slow or stop the fission reaction.

Nuclear energy has advantages & disadvantages

Advantages:

- No air pollution
- Reduces need to import oil

Nuclear energy has advantages & disadvantages

Disadvantages:

- Possibility of accidents
- Difficult to dispose of waste
- Concern about nuclear material being misused Disadvantages:
- Cost to build is high and cost to decommission is even more costly

Radioactive waste

- **Radioactive waste** Nuclear fuel that can no longer produce enough heat to be useful in a power plant but continues to emit radioactivity.

- **Becquerel (Bq)** Unit that measures the rate at which a sample of radioactive material decays; 1 Bq = decay of 1 atom or nucleus per second.

- **Curie** A unit of measure for radiation; 1 curie = 37 billion decays per second.

Radioactive Waste

- High-level radioactive waste comes from used in fuel rods.
- Low-level radioactive waste is found on the protective clothing, tools, rags, and other items used in routine plant maintenance.
- Uranium mine tailings are the residue left after uranium ore is mined and enriched.
- In each case, disposal must be handled with great care.

Radioactive Waste

- 100 sites in the U.S. are storing spent fuel rods, eventually all this waste will have to be moved to a permanent site
- The permanent site will store this waste indefinitely!
- This site must be away from geologically active sites, away from ground water, far from human habitation, and safe guarded from terrorist attacks
- Yucca Mountain in Nevada is the leading candidate, but “NIMBY” has prevented its implementation

Fusion Power

- **Nuclear fusion** A reaction when lighter nuclei are forced together to produce heavier nuclei.
- Nuclear fusion powers the Sun and other stars.
- Fusion is a promising, unlimited source of energy in the future, but so far scientists have had difficulty containing the heat that is produced.
- On earth it requires a temp 10X greater than the core of the sun.
- Currently energy input exceeds energy output.

TABLE 36.1 Comparison of nonrenewable energy fuels

Energy Type	Advantages	Disadvantages	Pollutant and greenhouse gas emissions	Electricity (cents/kWh)	Energy return on energy investment*
Oil/gasoline	• Ideal for mobile combustion (high energy/mass ratio) • Quick ignition/turn-off capability • Cleaner burning than coal	• Significant refining required • Oil spill potential effect on habitats near drilling sites • Significant dust and emissions from fossil fuels used to power earth-moving equipment • Human rights/ environmental justice issues in developing countries that export oil • Will probably be much less available in the next 40 years or so	• Second highest emitter of CO_2 among fossil fuels • Hydrocarbons • Hydrogen sulfide	• Relatively little electricity is generated from oil	4.0 (gasoline) 5.7 (diesel)
Coal	• Energy-dense and abundant—U.S. resources will last at least 200 years • No refining necessary • Easy, safe to transport • Economic backbone of some small towns	• Mining practices frequently risk human lives and dramatically alter natural landscapes • Coal power plants are slow to reach full operating capacity • A large contributing factor to acid rain in the United States	• Highest emitter of CO_2 among energy sources • Sulfur • Trace amounts of toxic metals such as mercury	5 cents/kWh	14

Natural Gas	• Cogeneration power plants can have efficiencies up to 60% • Efficient for cooking, home heating, etc. • Fewer impurities than coal or oil	• Risk of leaks/ explosions • Twenty-five times more effective as a greenhouse gas than CO_2 • Not available everywhere because it is transported by pipelines	• Methane • Hydrocarbons • Hydrogen sulfide	6–8 cents/kWh	8
Nuclear Energy	• Emits no CO_2 once plant is operational • Offers independence from imported oil • High energy density, ample supply	• Very unpopular; generates protests • Plants are very expensive to build because of legal challenges • Meltdown could be catastrophic • Possible target for terrorist attacks	• Radioactive waste is dangerous for hundreds of thousands of years • No long-term plan currently in place to manage radioactive waste • No air pollution during production	12–15 cents/kWh	8