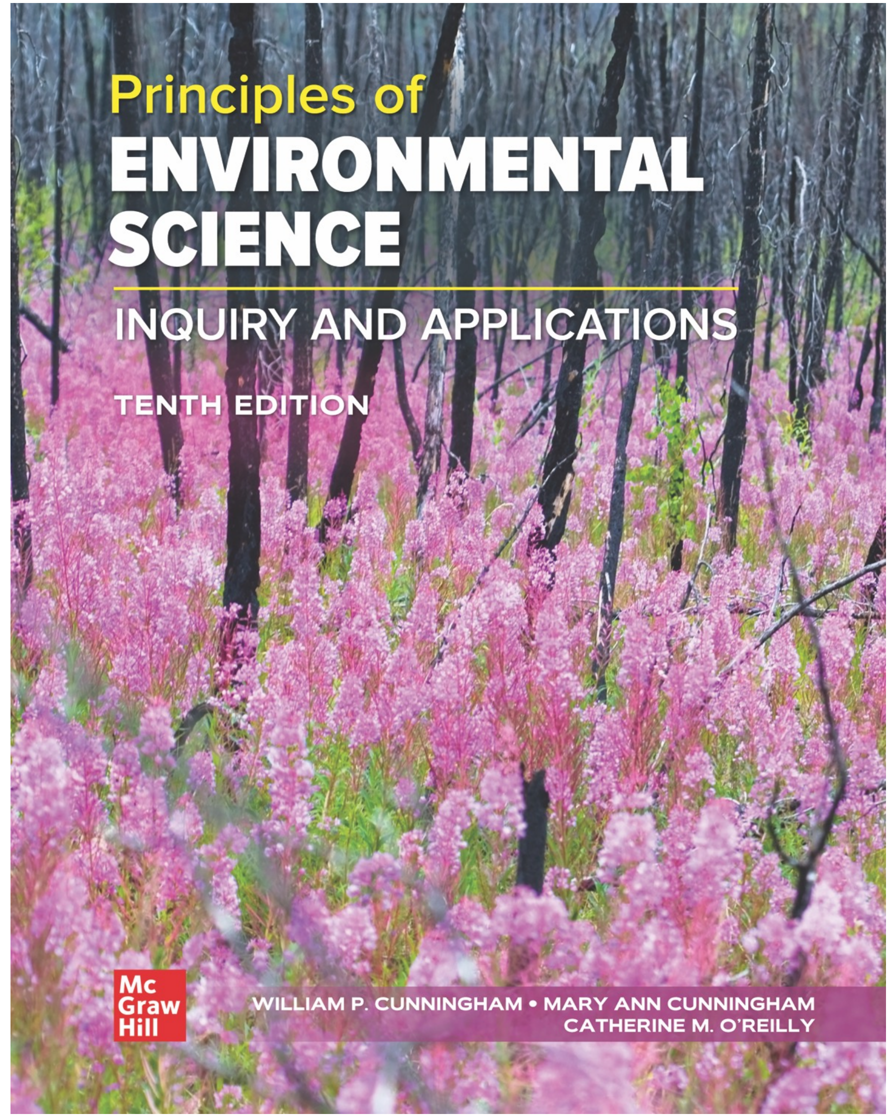
Because learning changes everything.®

Chapter 13 Lecture Outline



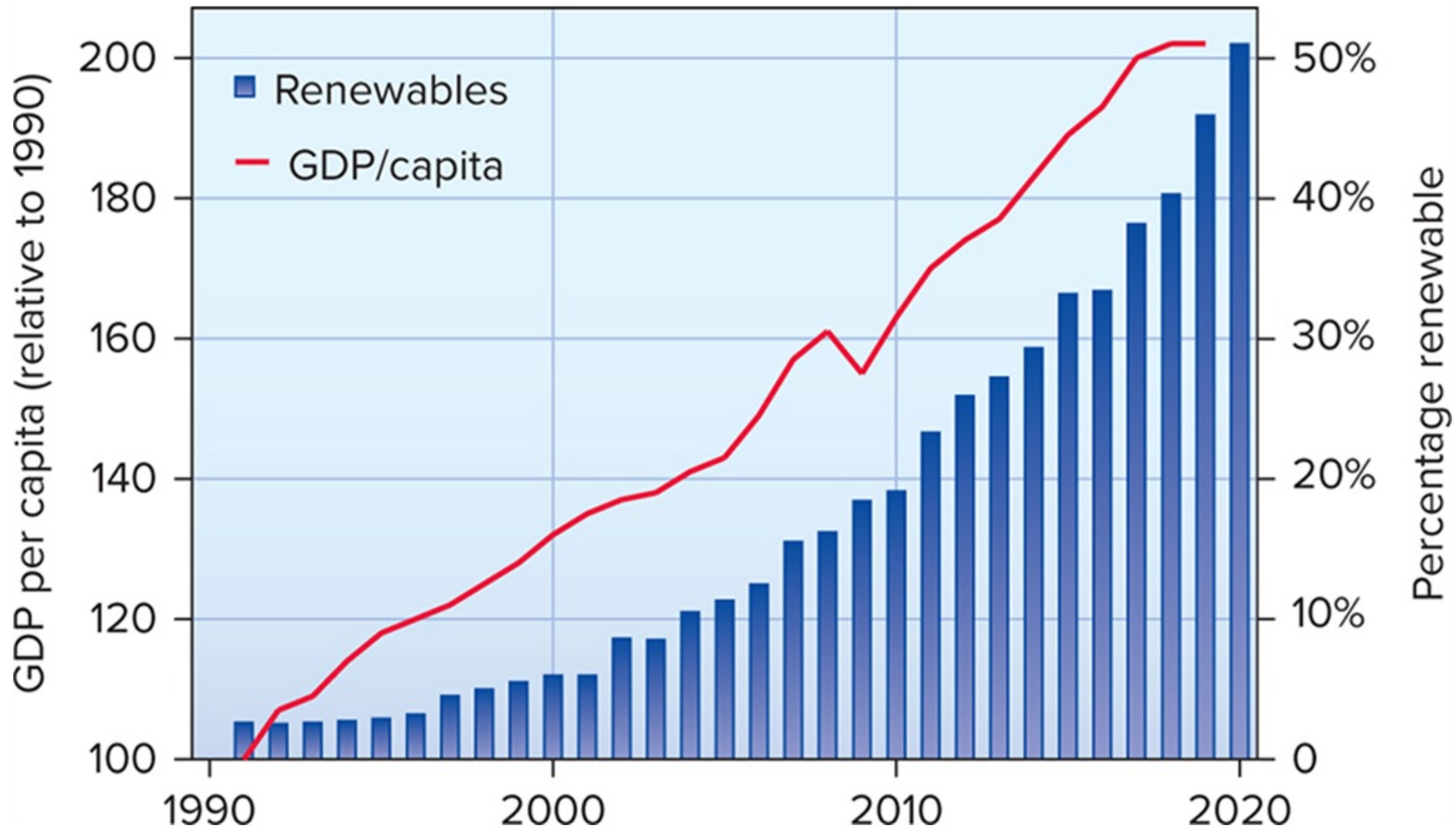
Learning Outcomes

***After studying this chapter, you should be able to answer the following questions*:**

- What are our dominant sources of energy?
- What is peak oil production? Why is it hard to evaluate future oil production?
- How important is coal in domestic energy production?
- What are the environmental effects of coal burning?
- How do nuclear reactors work? What are some of their advantages and disadvantages?
- What are our main renewable forms of energy?
- Could solar, wind, hydropower, and other renewables eliminate the need for fossil fuels?
- What are photovoltaic cells, and how do they work?
- What are biofuels? What are arguments for and against their use?

The stone age didn't end because we ran out of stones.—Sheik Yamani, former Saudi oil minister

CASE STUDY: A Renewable Energy Transition



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Source: Fraunhofer Gesellschaft and World Bank, 2021.

13.1 Energy Resources

Modern life runs on energy.

Electricity and abundant fuel make our lives better by providing heating, cooling, and transportation.

We use energy to grow and prepare food, to work at our jobs, and to entertain ourselves. Fossil fuels—oil, gas, and coal—provide the bulk of this energy.

Hydropower and nuclear power supplement these, and increasingly wind, solar, and other renewable forms of energy are part of our standard energy supply.

Energy Uses

TABLE 13.2 Energy Uses

USES	kilowatt hour/YEAR*
Computer	100
Television	125
100 Watts light bulb	250
15 Watts fluorescent bulb	40
Dehumidifier	400
Dishwasher	600
Electric stove/oven	650
Clothes dryer	900
Refrigerator	1,100

*Averages shown; actual rates vary greatly.
SOURCE: U.S. Department of Energy.

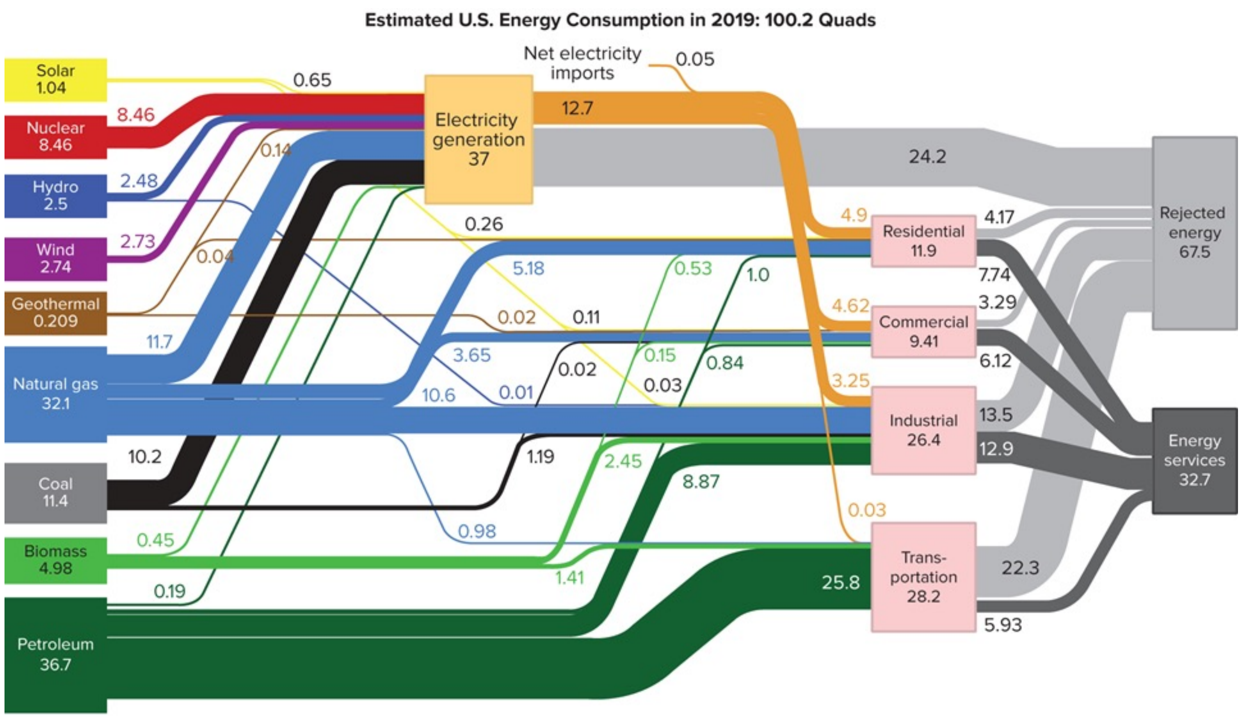
The Future of Energy Is not the Past

Work is the application of force over distance, and we measure work in units called **joules**

Energy is the capacity to do work.

Power is the rate of energy flow or the rate of work done: for example, one **watt (W)** is one joule per second.

Fossil Fuels Supply Most of Our Energy



Like most other industrialized nations, the U.S. gets a vast majority of its energy from fossil fuels.

Renewable energy uses is increasing.

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Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019).

We Measure Energy in Unity Such as Joule and Watt

Energy can be measured in many ways

Work is the application of force over distance, and we measure work in units called **joules**

Energy is the capacity to do work.

Power is the rate of energy flow or the rate of work done: for example, one **watt (W)** is one joule per second.

1 Watt = 1 joule per second

How Do We Measure Energy?

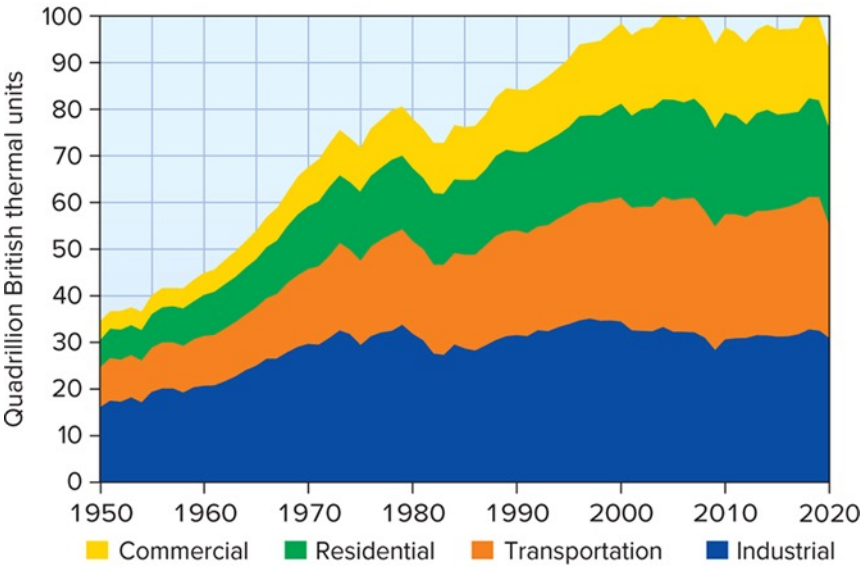
TABLE 13.1 Energy Units

1 joule (J) = work needed to accelerate 1 kilogram 1 meter/second^2 for 1 meter (or 1 ampere/second flowing through 1 ohm resistance)
1 watt (W) = 1 Joule per second
1 terawatt (TW) = 1 trillion watts
1 kilowatt hour (kWh) = 1,000 Watt exerted for 1 hour (or 3.6 million Joule)
1 megawatt (MW) = 1 million (10^6) Watt
1 gigajoule (GJ) = 1 billion (10^9) Joule
1 standard barrel (bbl) of oil = 42 gallon (160 liters)

How Much Energy Do We Use?

The largest share of the energy used in the U.S. is consumed by industry.

Residential use accounts for 22% of energy use.



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Source: U.S. EIA 2020.

13.2 Fossil Fuels

Fossil fuels are organic (carbon-based) compounds derived from decomposed plants, algae, and other organisms buried in rock layers for hundreds of millions of years.

Most of the richest deposits date to about 286 million to 360 million years ago (the Mississippian, Pennsylvanian, and Permian periods: when the Earth’s climate was much warmer and wetter than it is now.

Coal Resources Are Greater Than We Can Use

World coal deposits are enormous, ten times greater than conventional oil and gas resources combined.

Almost all the world's coal is in North America, Europe and Asia and just three countries, the U.S., Russia, and China, account for 2/3 of all proven reserves.

The total resource is estimated to be 10 trillion metric tons--a several thousand years’ supply.

But coal mining is a dirty, dangerous activity.

Mountain Top Removal in Appalachia

David T. Stephenson/Shutterstock

Coal Burning Releases Huge Amounts of Air Pollution

Every year the roughly one billion tons of coal burned in the U.S. releases close to a trillion metric tons of carbon dioxide (CO_2). This is about half of the industrial CO_2 released by the United States each year.

Coal also contains toxic impurities, such as mercury, arsenic, chromium, and lead, which are released into the air during combustion.

It's possible to make either gas or liquid fuels out of coal, but these processes are even dirtier and more expensive than burning the coal directly.

Coal Use Is Declining in the U.S.

Coal is fading quickly from our energy picture.

Only half a dozen new coal-fired power plants are now under construction or in the planning stage. And when the last of those plants is finished about five years from now, no other new projects are proposed for the foreseeable future.

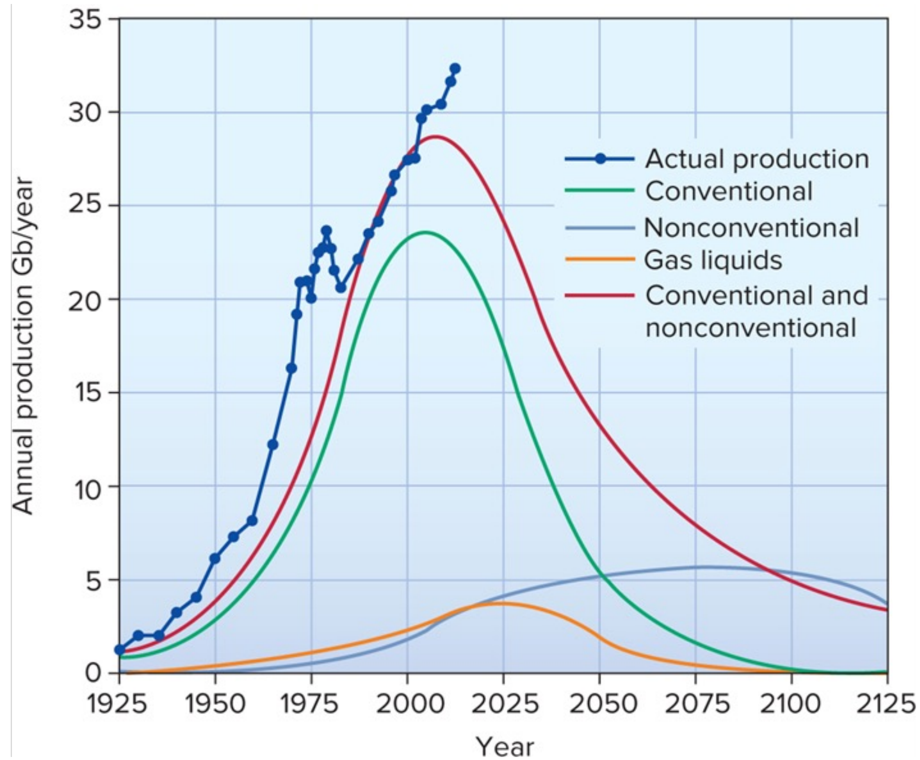
Federal regulations are part of this decline.

2012 EPA Mercury and Air Toxics Standards and proposed limitations on carbon emissions are making coal plants more expensive to operate.

When Will We Run Out Of Oil?

We have already used more than 0.5 trillion barrel—almost half of proven oil reserves.

The remainder is expected to last 41 years at current consumption rates of 30.7 billion barrel per year.



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Source: Jean Laherrère, www.hubbertpeak.org; International Energy Agency, 2011.

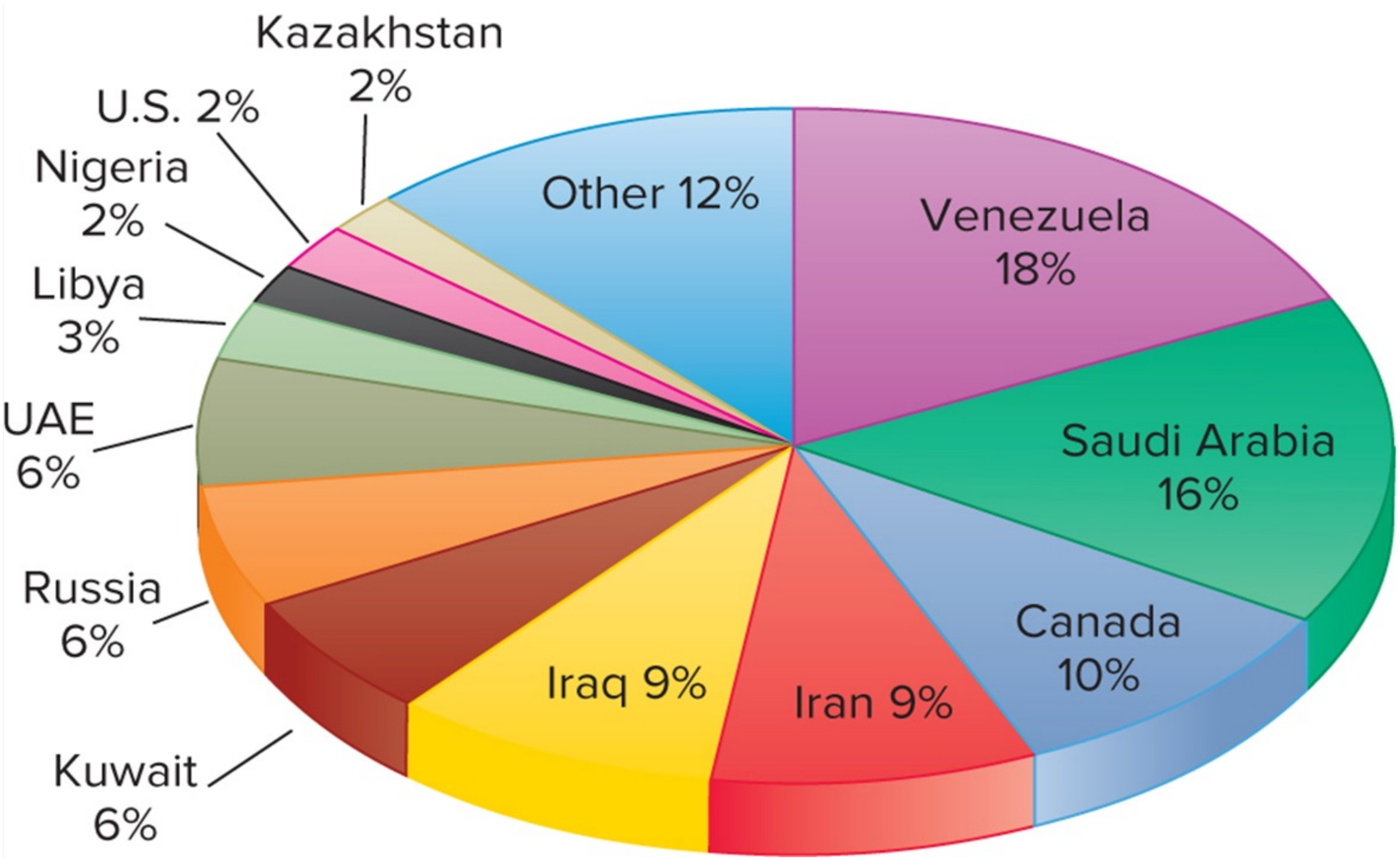
Domestic Oil Supplies Are Limited

The U.S. has used more than half of its technically recoverable petroleum resources.

At 2010 rates of consumption, that’s enough for about 4.2 years, if we were to stop all imports. Opening the Arctic National Wildlife Refuge to drilling would only add enough for another 4 to 10 months, according to the U.S.G.S.

Other U.S. regions with potential for new oil discoveries include the continental shelf on the coast of California, the Arctic Ocean, and the Grand Banks.

Global Oil Reserves by Region



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Source: CIA Factbook, 2016.

Deepwater Drilling Poses Dangers

Deep ocean oil wells in remote places pose dangers as the 2010 explosion and sinking of the Deepwater Horizon in the Gulf of Mexico showed.

U.S. Coast Guard/Getty Images News/Getty Images

Extreme Oil and Tar Sands Extend Our Supplies

Tar sands are composed of sand and shale particles coated with bitumen, a viscous mixture of long-chain hydrocarbons. Shallow tar sands are excavated and mixed with hot water and steam to extract the bitumen.

The U.S. also has large supplies of unconventional oil. **Oil shales** are fine-grained sedimentary rock rich in solid organic material called kerogen. Like tar sands, the kerogen can be heated, liquefied, and pumped out like liquid crude oil.

Alberta Tar Sands

dan_prat/Getty Images

Natural Gas Is Growing in Importance

Because natural gas produces only half as much CO_2 as an equivalent amount of coal, substitution could help reduce global warming.

More than half of all the world’s proven natural gas reserves are in the Middle East and the former Soviet Union.

The total ultimately recoverable natural gas resources in the world are estimated to be 10,000 10,000 trillion $feet^3$. Current gas reserves represent roughly a 60-year supply at present usage rates.

Natural Gas Wells in Wyoming’s Upper Green River Basin

Peter Aengst/Wilderness Society/Lighthawk

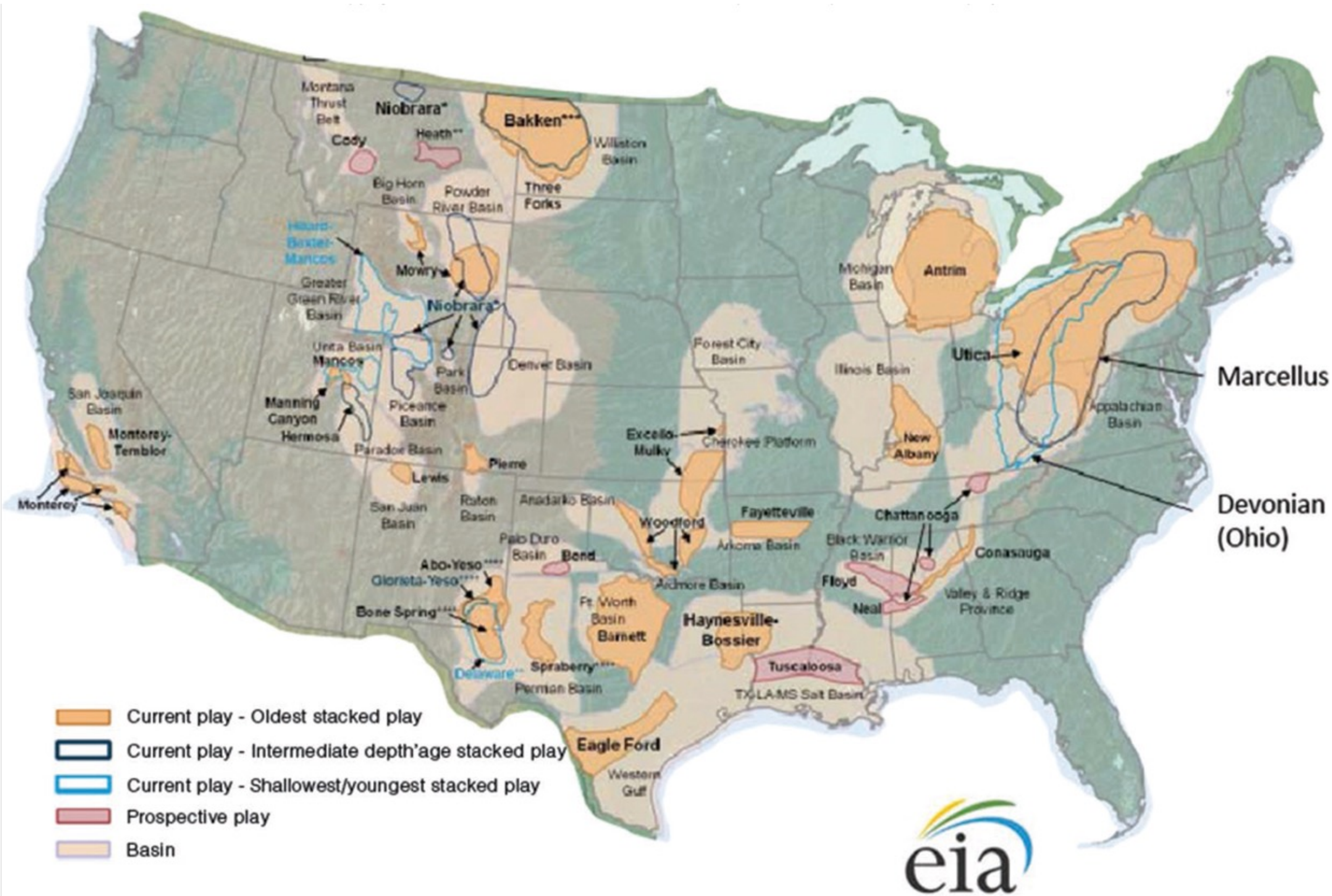
Hydraulic Fracturing Opens Up Tight Gas Resources 1

When shale deposits are in “tight” formations, gas doesn’t flow easily. To boost well output, mining companies rely on hydraulic fracturing (or “fracking”).

A mixture of water, sand, and various chemicals is pumped into the ground and rock formations at extremely high pressure. The pressurized fluid cracks sediments and releases the gas.

Fracturing rock formations often disrupts aquifers, however, and contaminates water wells.

Hydraulic Fracturing Opens Up Tight Gas Resources 2



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Source: Based on data from the Energy Information Association.

13.3 Nuclear Power and Hydropower

In 1953 President Dwight Eisenhower presented his "Atoms for Peace" speech to the United Nations.

He announced that the United States would build nuclear-powered electrical generators to provide clean, abundant energy.

Today there are about 440 reactors in use worldwide, 104 of these in the United States.

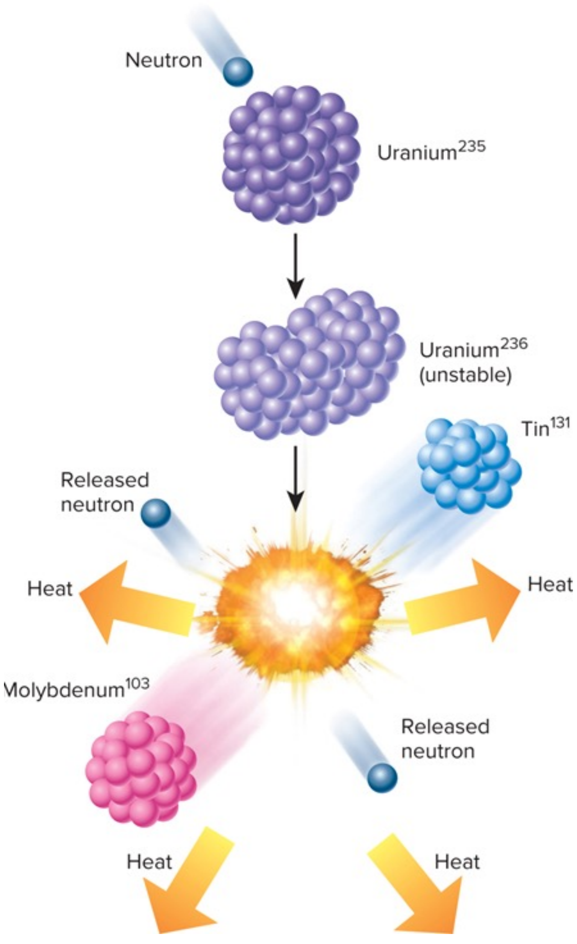
Half of the U.S. plants (52) are more than 30 years old and are thus approaching the end of their expected operational life.

New York’s Indian Point Nuclear Power Plant

©William P. Cunningham

How Do Nuclear Reactors Work?

Radioactive uranium atoms are unstable—when struck by a high-energy neutron, they undergo **nuclear fission (splitting)**, releasing energy and more neutrons causing a self-sustaining **chain reaction.**



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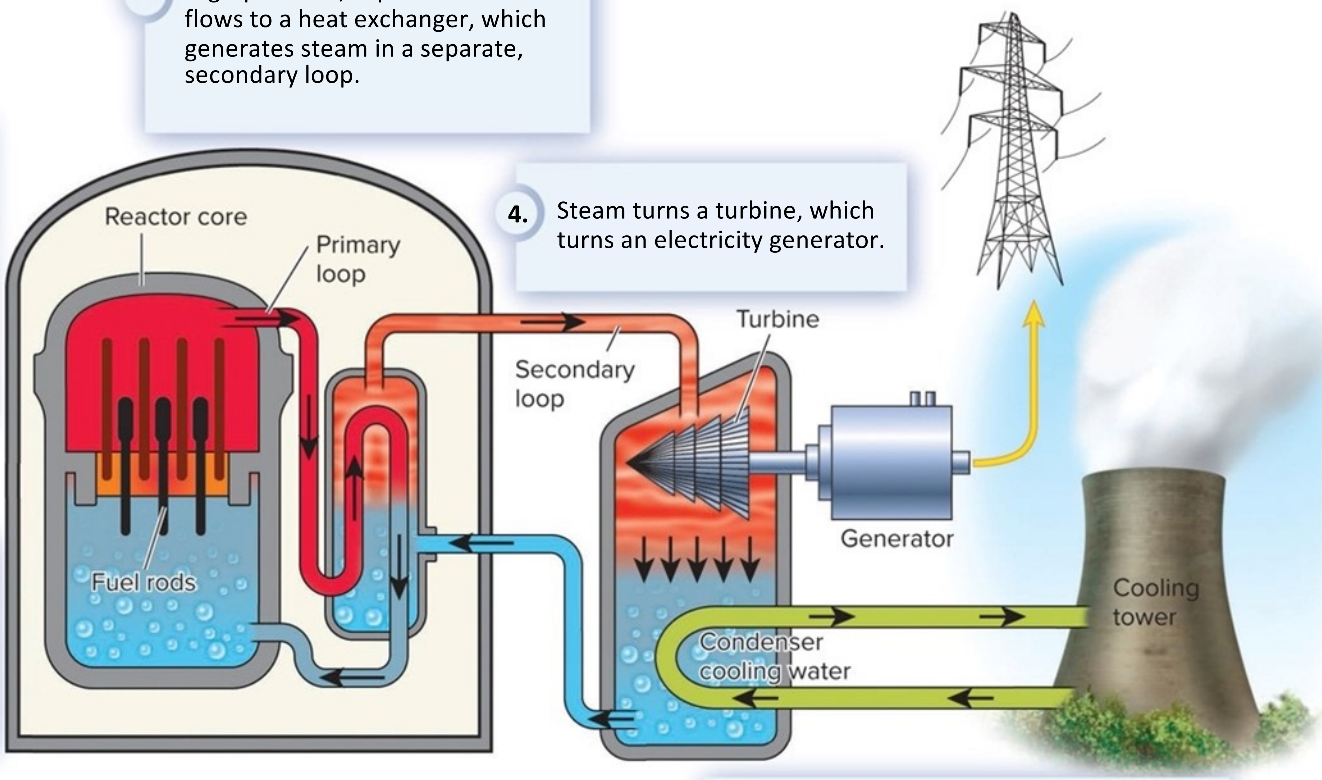
Pressurized Water Nuclear Reactor

1. Fuel rods containing Uranium 235 are placed in water in reactor core, interspersed with neutron-absorbing control rods, containing boron or cadmium.

2. When control rods are raised, a chain reaction of nuclear fission occurs in fuel rods, creating heat.

3. High-pressure, superheated water flows to a heat exchanger, which generates steam in a separate, secondary loop.

4. Steam turns a turbine, which turns an electricity generator.



5. Cooling water condenses steam to water, which returns to the heat exchanger.

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We Lack Safe Storage for Radioactive Waste [1]

One of the most difficult problems associated with nuclear power is the disposal of wastes produced during mining, fuel production, and reactor operation.

How these wastes are managed may ultimately be the overriding obstacle to nuclear power.

Craig F. Walker/The Boston Globe/Getty Images

We Lack Safe Storage for Radioactive Waste 2

In 1987 the U.S. Department of Energy announced plans to build the first high-level waste repository on a barren desert ridge under Yucca Mountain, Nevada.

Waste was to be buried deep in the ground, where it was hoped it would remain unexposed to groundwater and earthquakes for the thousands of years required for the radioactive materials to decay.

However, President Obama cut off funding for the project in 2009 after 20 years of research and $100 billion in exploratory drilling and development.

Moving Water Is One of Our Oldest Power Sources

Water power was our first industrial power source. Most early American settlements were built where falling water could drive gristmills and sawmills.

The invention of water turbines in the nineteenth century greatly increased the efficiency of electricity-producing hydropower dams.

By 1925 falling water generated 40 percent of the world's electric power. Since then, hydroelectric production capacity has grown 15-fold, but fossil fuel use has risen much faster, so water power is now only one-quarter of total electrical generation.

Large Dams Have Large Impacts

menabrea/iStockphoto/Getty Images

13.4 Energy Efficiency and Conservation

It's often said that the cheapest form of energy is conservation.

Energy reductions are not as visible or exciting as a power plant or a dam, but they can "produce" just as much available energy just by avoiding inefficient uses.

Conservation can save money as well as reducing our energy footprint.

Costs Can Depend on How You Calculate Them

Much of the energy we consume is wasted.

Our ways of using energy are so inefficient that most potential energy in fuel is lost as waste heat.

Conservation involves technology innovation as well as changes in behavior, but we have met these challenges in the past.

High-efficiency automobiles are now available. Low-emission, hybrid gas-electric vehicles get up to 72 miles per gallon (30.3 kilometers/liter) on the highway. And walking, biking, or taking public transport can lower your personal energy footprint far more.

An Energy Audit Can Show You Where Your House is Losing Energy

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Passive Housing Is Becoming Standard in Some Areas 1

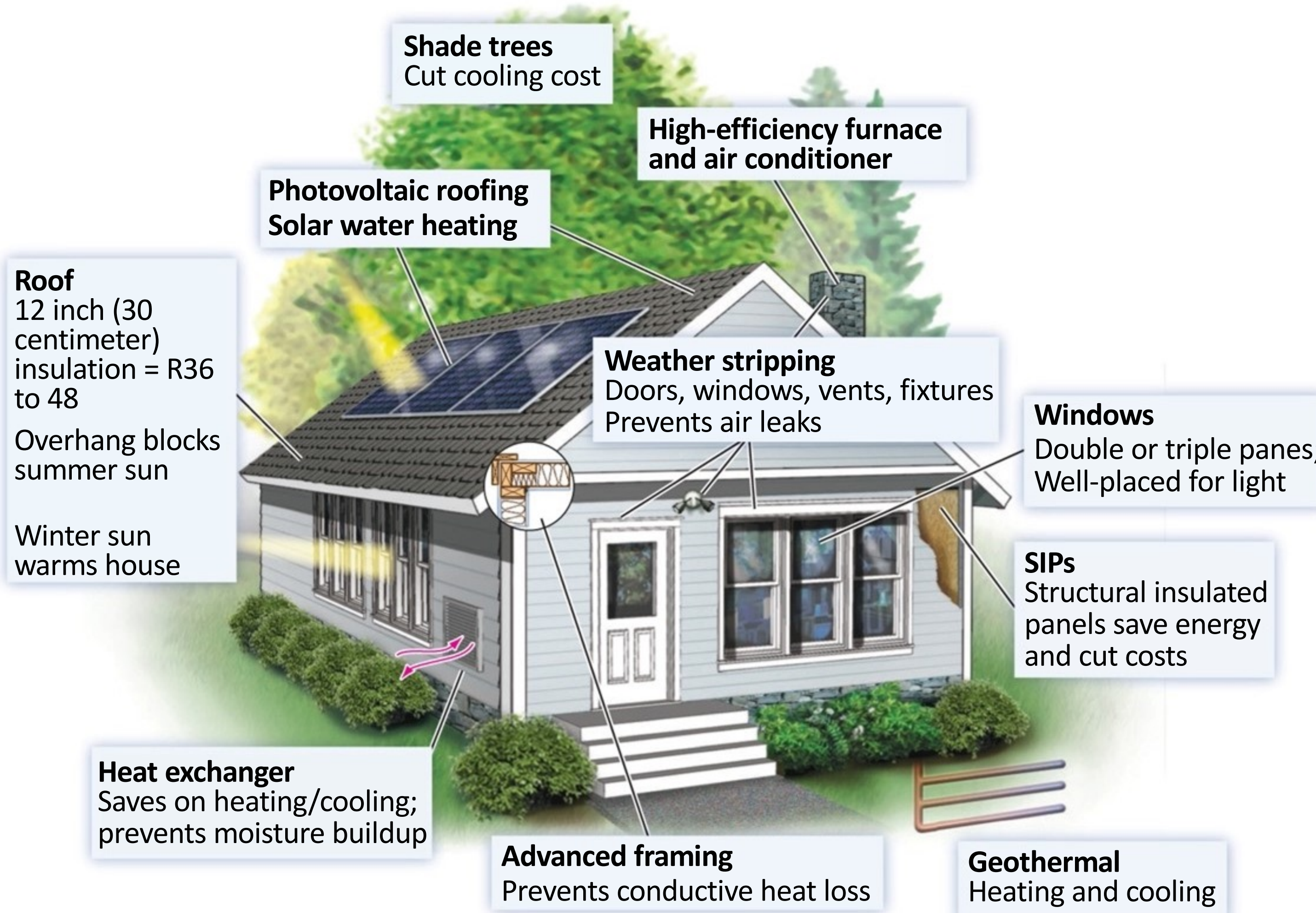
Germany has long been a leader in energy innovation and efficiency.

Many regions in Germany have begun to require that new buildings conform to **passive house** standards.

These standards are strict energy use limits, along with guidelines for building practices that reduce energy consumption to just 10 percent of what normal buildings use

In the U.S., incentives, such as faster permitting or tax breaks to building projects that meet passive standards, are increasingly common.

Passive Housing Is Becoming Standard in Some Areas 2



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What Does Passive Housing Involve? The Main Principles Are These:

No thermal bridges (wood or metal components conduct heat through walls, roof, or foundation)

Roof and wall insulation 24 to 32 centimeters (10 to 14 inches) thick

Well-sealed windows and doors to prevent heat loss or gain

Heat exchangers, to warm or cool fresh air as it is exchanged with stale air leaving the building

Triple-pane windows that reduce radiative heat loss or gain

Windows well positioned to let in daylight

Cogeneration Makes Electricity from Waste Heat

One of the fastest growing sources of new energy is **cogeneration,** the simultaneous production of both electricity and steam or hot water in the same plant.

By producing two kinds of useful energy in the same facility, the net energy yield from the primary fuel is increased from 30 to 35 percent to 80 to 90 percent.

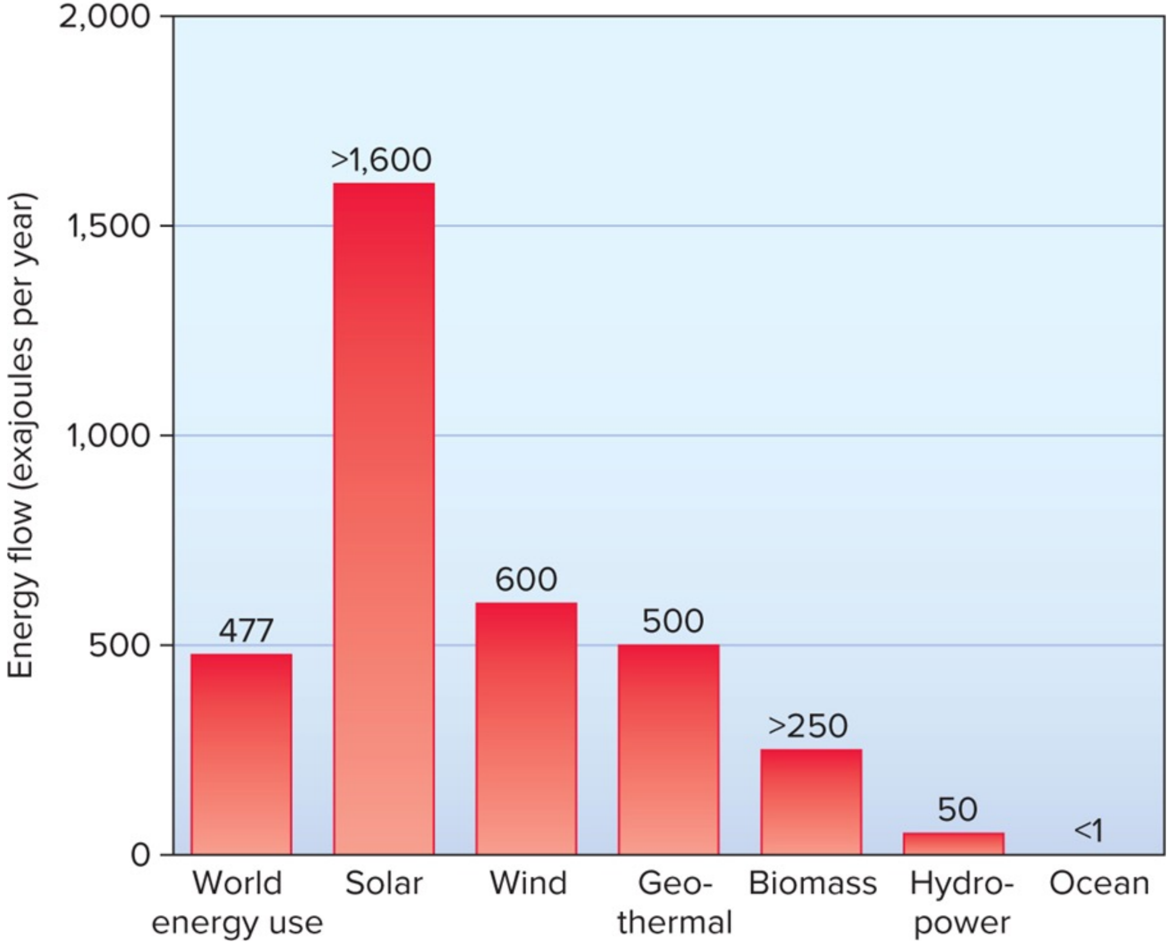
The EPA estimates that cogeneration could produce almost 20 percent of U.S. electrical use, or the equivalent of 400 coal-fired plants.

13.5 Renewable Energy

In his 2011 State of the Union speech, President Barack Obama said:

"To truly transform our economy, protect our security, and save our planet from the ravages of climate change, we need to ultimately make clean, renewable energy the profitable kind of energy. . . . So tonight, I challenge you to join me in setting a new goal: By 2035, 80 percent of America's electricity will come from clean energy sources."

Ethanol and Biodiesel Can Contribute to Fuel Supplies



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Source: UNDP and International Energy Agency.

Wind Could Meet All Our Energy Needs 1

Wind power is the world's fastest-growing energy source.

With 370 Gigawatts of globally installed capacity in 2014, wind power is Energy Association predicts that 1.5 million Megawatt of capacity could be possible by 2020.

Wind power could replace all the commercial energy we now use, if we chose to develop it.

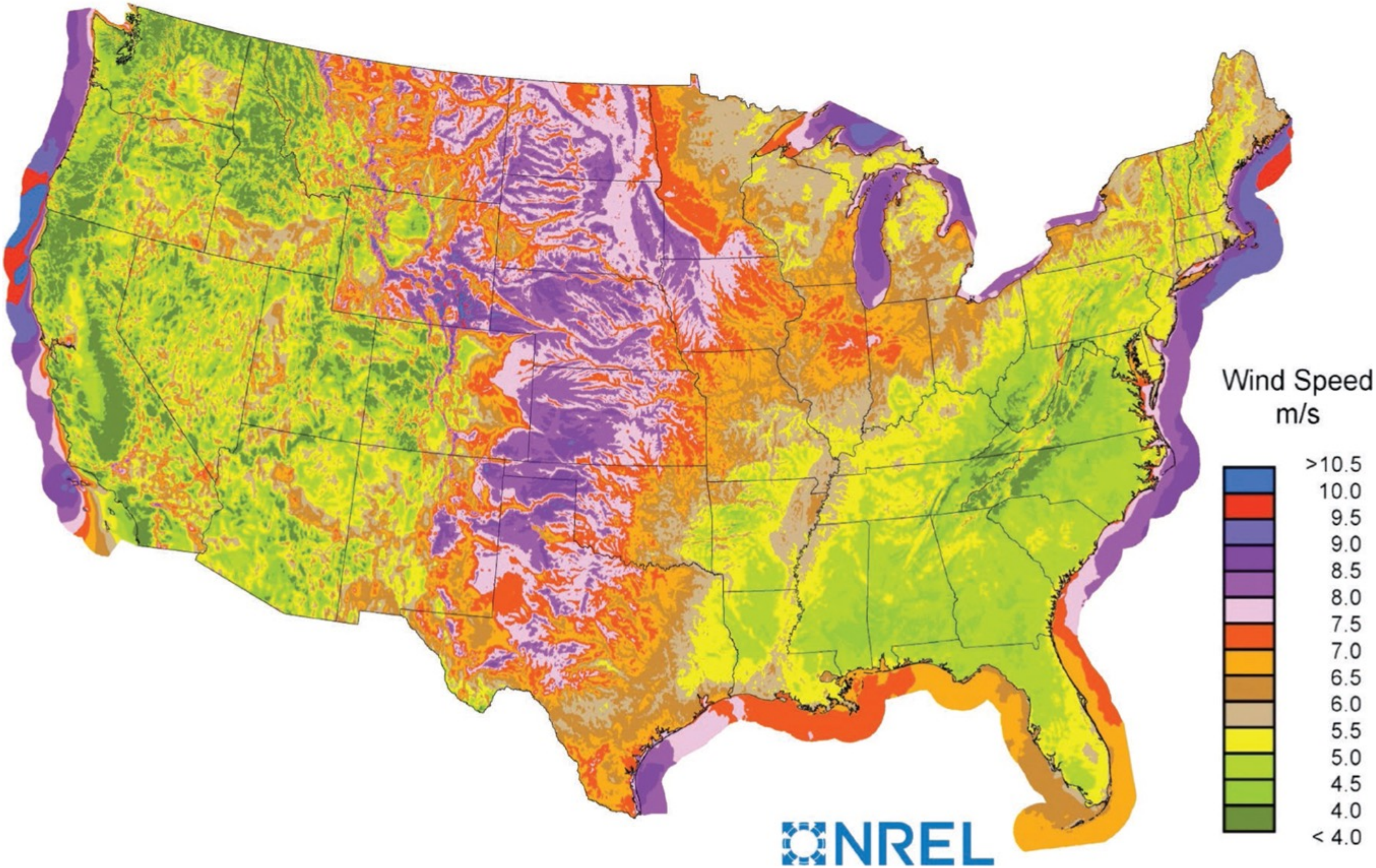
Wind Could Meet All Our Energy Needs 2

China is the world's largest producer of wind turbines and has the second largest installed wind capacity, after Europe.

Clean technology provides more than 1 million jobs in China, manufacturing equipment for domestic use and for export. China now has over 63 Gigawatts of wind power, or about one-quarter of the world total.

Paul Springett 10/Alamy Stock Photo

Wind Could Meet All Our Energy Needs 3



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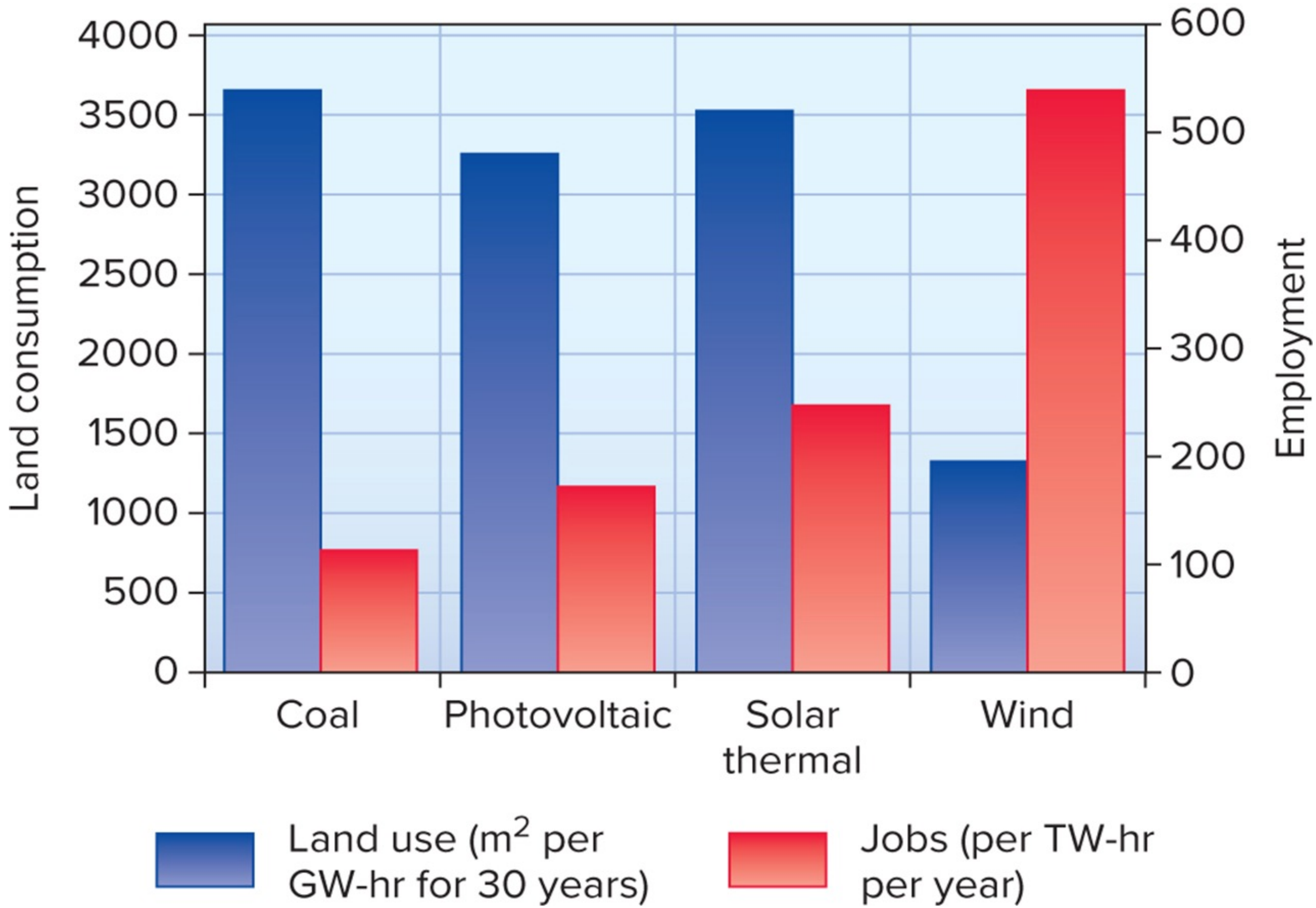
Source: National Renewable Energy Laboratory (NREL).

Wind Energy, Land Consumption, and Jobs



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Wind Power Provides Local Control of Energy

Cooperatives are springing up to help landowners and communities finance, build, and operate their own wind generators.

One gigawatt of wind power (equivalent to one large nuclear or fossil fuel plant) can create more than 3,000 permanent jobs, while paying about $4 million in rent to landowners and $3.6 million in tax payments to local governments.

About 20 Native American tribes, for example, have formed a coalition to study wind power. Together their reservations (which are in the windiest, least productive parts of the Great Plains) could generate at least 350 Gigawatts of electrical power, equivalent to about half of the current total U.S. installed electrical capacity.

Solar Thermal Systems Collect Usable Heat

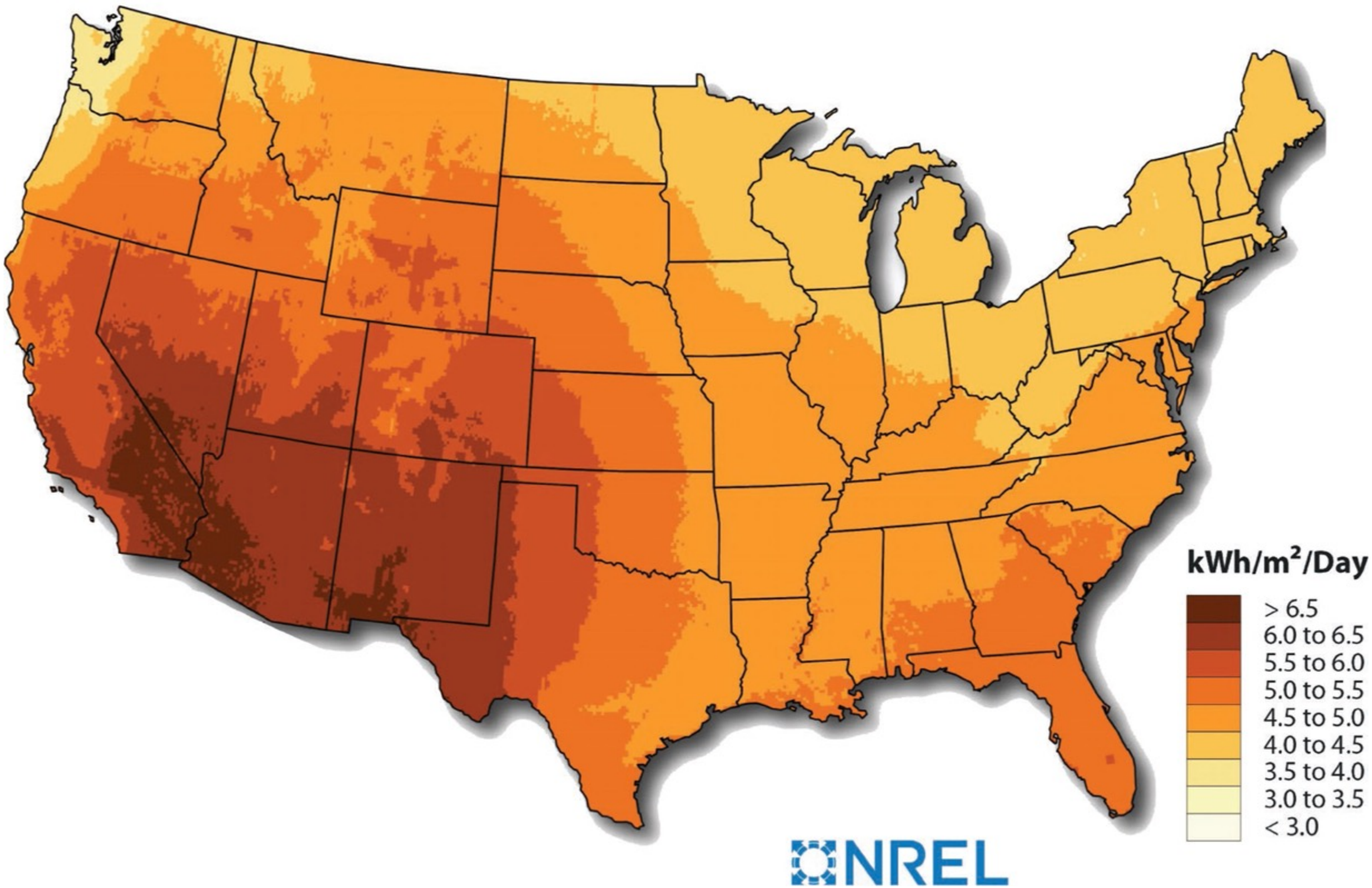
Solar power has always been our ultimate energy source.

Solar energy drives winds and the hydrologic cycle, and it has produced all biomass, including fossil fuels and our food.

The average amount of solar energy that reaches the earth’s surface is about 10,000 times all the commercial energy used each year.

This amount varies geographically, but solar energy is sufficient for economical production even at high latitudes, as in northern Europe.

U.S. Solar Resources



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Source: National Renewable Energy Laboratory (NREL).

CSP Makes Electricity from Heat

Solar thermal systems can produce extremely hot water, hot enough to make steam and run a turbine in **concentrating solar power** (CSP) systems.

CSP often uses long, trough-shaped, parabolic mirrors to reflect and concentrate sunlight on a central tube containing a heat-absorbing fluid.

Reaching extremely high temperatures, the fluid passes through a heat exchanger, where it heats water and generates steam.

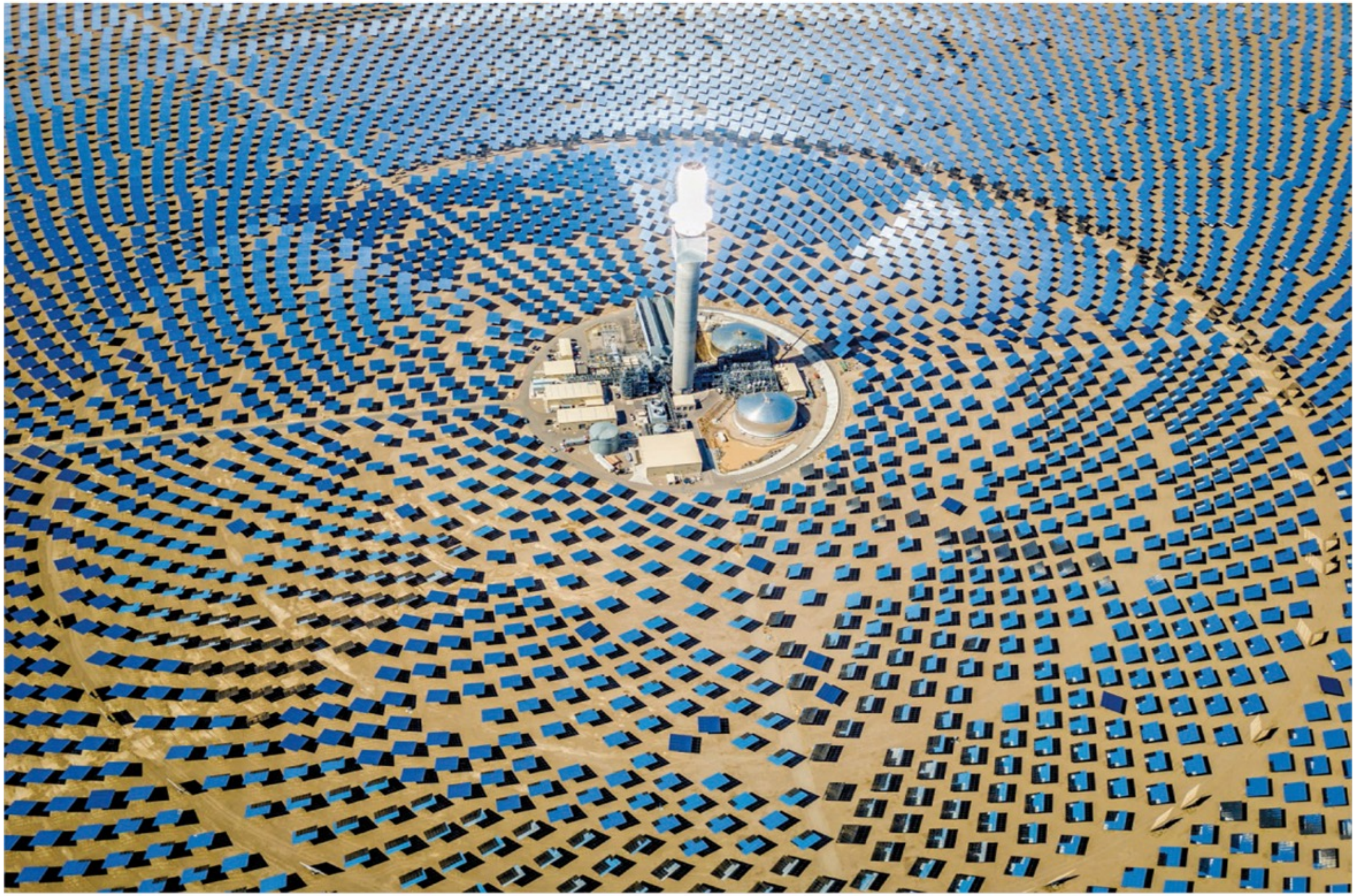
The steam turns a turbine to produce electricity. Heat from the transfer fluid also can be stored in a medium such as molten salt for later use.

This allows the system to continue to generate electricity on cloudy days or at night.

Solar Water Heaters

dbimages/Alamy Stock Photo

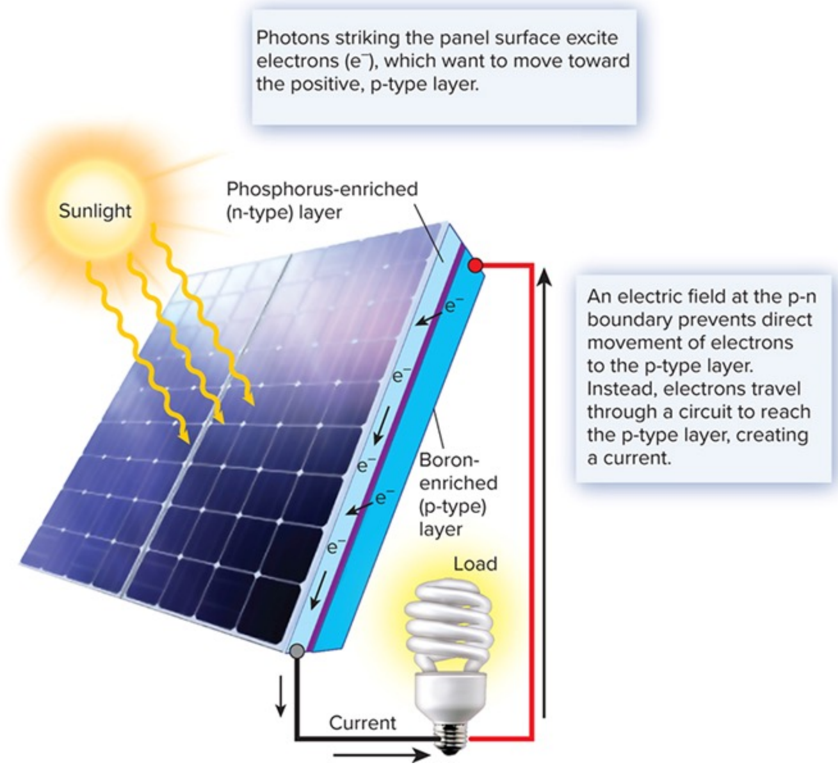
Solar Energy “Power Tower”



Mlenny/Getty Images

Photovoltaic Cells Generate Electricity Directly

Photovoltaic (PV) cells capture solar energy and convert it directly to electrical current by separating electrons from their parent atoms and accelerating them across a one-way electrostatic barrier formed by the junction between two different types of semiconductor material.



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Solar Energy and Photovoltaic Cells

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(a) Source: Jenson/Shutterstock; (b) Source: Monty Rakusen/Getty Images; (c) Source: NREL/U.S. Department of Energy, Craig Miller Productions

Biomass Includes Fuelwood, Ethanol, and Other Forms

Plants capture immense amounts of solar energy by storing it in the chemical bonds of plant cells.

Firewood is probably our first fuel source.

For more than a billion people in developing countries, burning **biomass** (plant materials) remains the principal energy source for heating and cooking.

An estimated 1,500 meters^3 of fuelwood is gathered each year globally. This amounts to half of all wood harvested.

Wood gathering and charcoal burning are important causes of deforestation in many rural areas. Providing efficient wood stoves can improve people's lives while also saving forests.

Ethanol Has Been the Main Focus

Biofuels, ethanol and biodiesel, are by far the biggest recent news in biomass energy.

Globally, production of these two fuels is booming, from Brazil to Southeast Asia to the U.S. and Europe.

One-fifth of the corn (maize) crop currently is used to make ethanol.

Oils from crops such as soybeans, sunflower seed, rape seed, and palm oil fruits are relatively easy to make into biodiesel and many need only minimal cleaning for use in standard diesel engines.

Liquid Biofuels

Source: U.S. Department of Energy

Cellulosic Ethanol Could Be an Alternative

Producing 36 billion gallons of ethanol from corn, would use the entire U.S. corn crop and a good portion of our water resources.

So there has been great interest in developing ethanol from crop waste and other non-food biomass.

A number of techniques have been proposed for extracting sugars from cellulosic materials.

Most involve mechanical chopping or shredding followed by treatment with bacteria or fungi to break down cellulose into soluble sugars.

Methane from Biomass Is Efficient and Clean

Just about any organic waste, but especially sewage and manure, can be used to produce methane.

Methane gas, the main component of natural gas, is produced when anaerobic bacteria (bacteria living in an oxygen-free space) digest organic matter.

Methane is a relatively efficient and clean burning molecule which oxidizes easily, producing CO_2 and H_2O (water vapor).

Concerns about greenhouse gases may lead to further development.

Could Algae Be a Hope for the Future?

Some algal species growing in a photobioreactor might produce 30 times as much high-quality oil as *Miscanthus*.

Researchers have found strains of algae that grow rapidly under hot and saline conditions, producing lipids (oils) that could be converted to biodiesel.

One of the most intriguing benefits of algal growth facilities is that they could be placed next to conventional power plants, where CO_2 from burning either fossil fuels or biomass could be captured and used for algal growth.

Geothermal Heat Could Provide Electricity and Heat

The Earth’s internal temperature can provide a useful source of energy in some places.

This **geothermal energy** is expressed in the form of hot springs, geysers, and fumaroles.

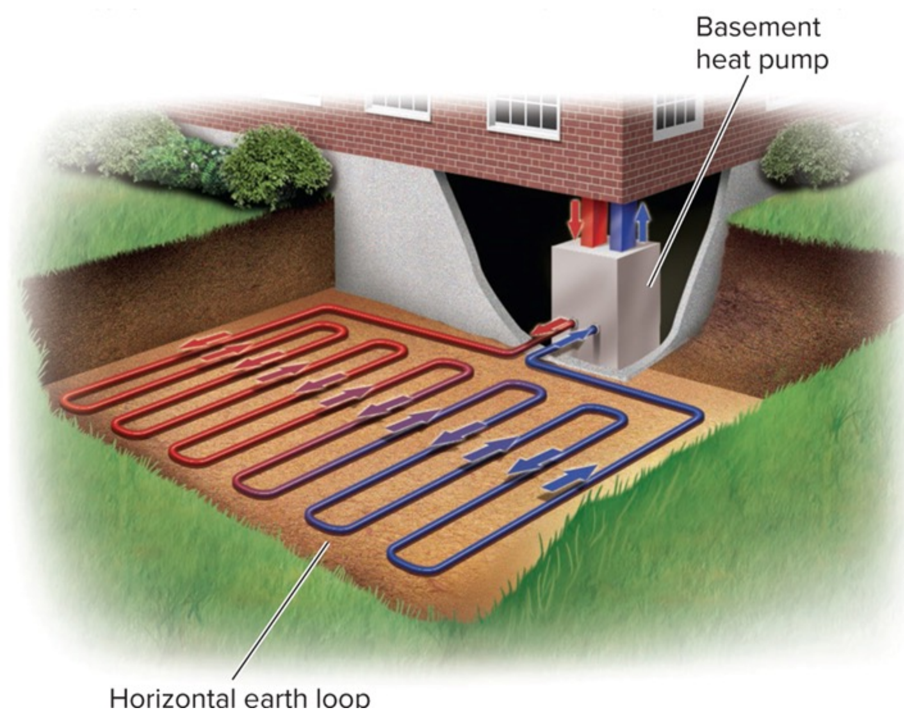
Iceland, which sits on a midocean ridge, has abundant geothermal energy.

Iceland has ambitious plans to be the first carbon-neutral country, largely because the Earth’s heat provides steam for heat and electric energy.

Geothermal Heat Pumps Can Heat and Cool Efficiently

While few places have geothermal steam, the Earth’s warmth can help reduce energy costs nearly everywhere.

Pumping fluids through deeply buried pipes can exchange temperatures with the soil to efficiently heat or cool a home.



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13.6 What Does an Energy Transition Look Like?

Rather than store and transport energy, another alternative is to generate it locally, on demand. **Fuel cells** are devices that use ongoing electrochemical reactions to produce an electrical current.

They are similar to batteries except that they are recharged by adding a fuel or a source of hydrogen atoms, while a battery is recharged by adding electrical current.

Depending on the environmental costs of input fuels, fuel cells can be a clean energy source for office buildings, hospitals, or even homes.

Utilities Can Promote Renewables

Utility restructuring currently being planned in the United States could include policies to encourage conservation and alternative energy sources.

Among the proposed policies are:

- “distributional surcharges” in which a small per kilowatt-hour charge is levied on all utility customers to help finance renewable energy research and development,
- “renewables portfolio” standards to require power suppliers to obtain a minimum percentage of their energy from sustainable sources
- green pricing that allows utilities to profit from conservation programs and charge premium prices for energy from renewable sources.

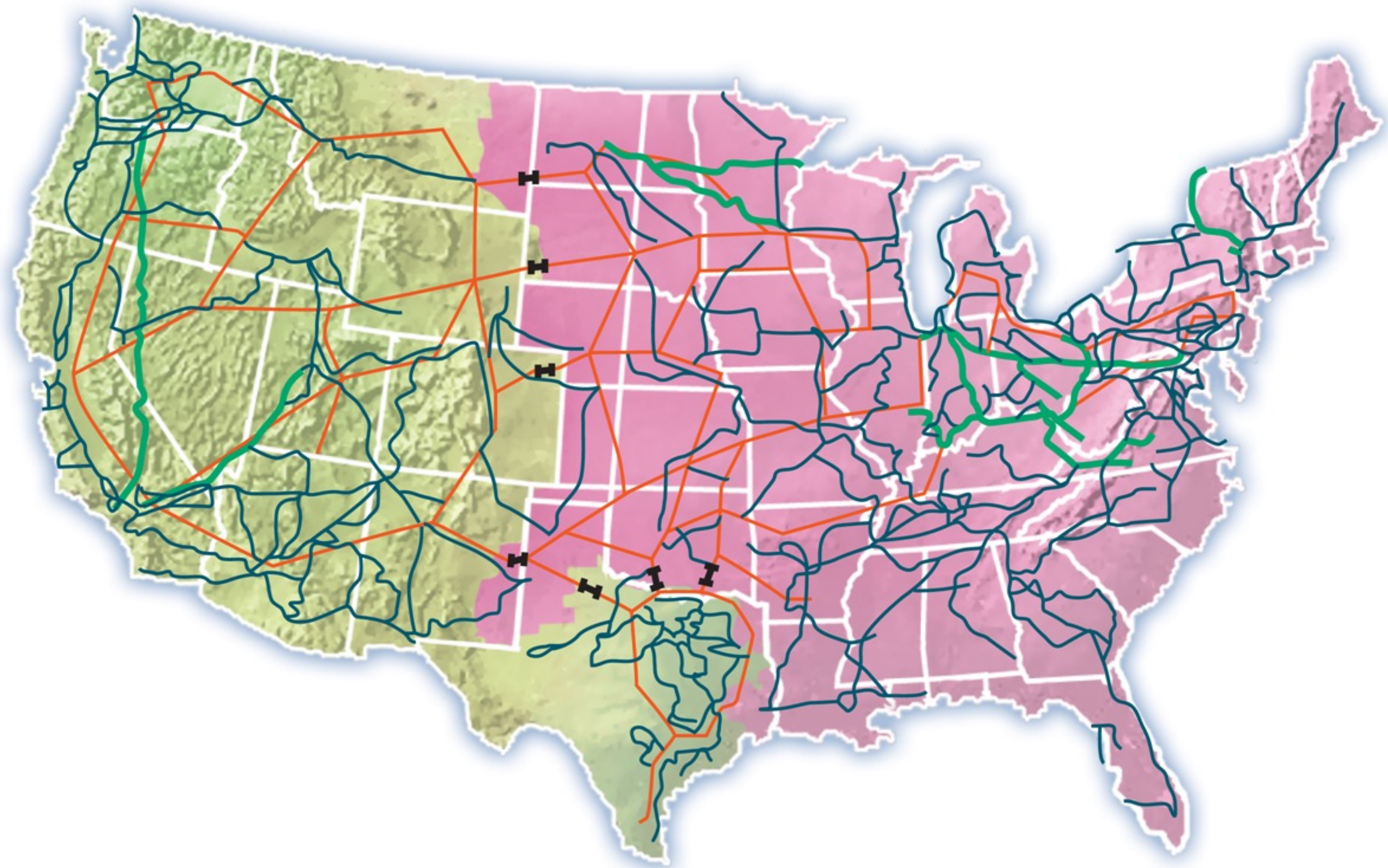
What’s Our Energy Future?

Could we get all our electricity from renewable, environmentally-friendly sources?

Mark Jacobson from Stanford University and Mark Delucchi from the University of California, Davis believe we can.

They calculate that currently available wind, water, and solar technologies could supply 100% of the world’s energy by 2030 and completely eliminate all our use of fossil fuels.

High-Voltage Power Lines in the U.S.



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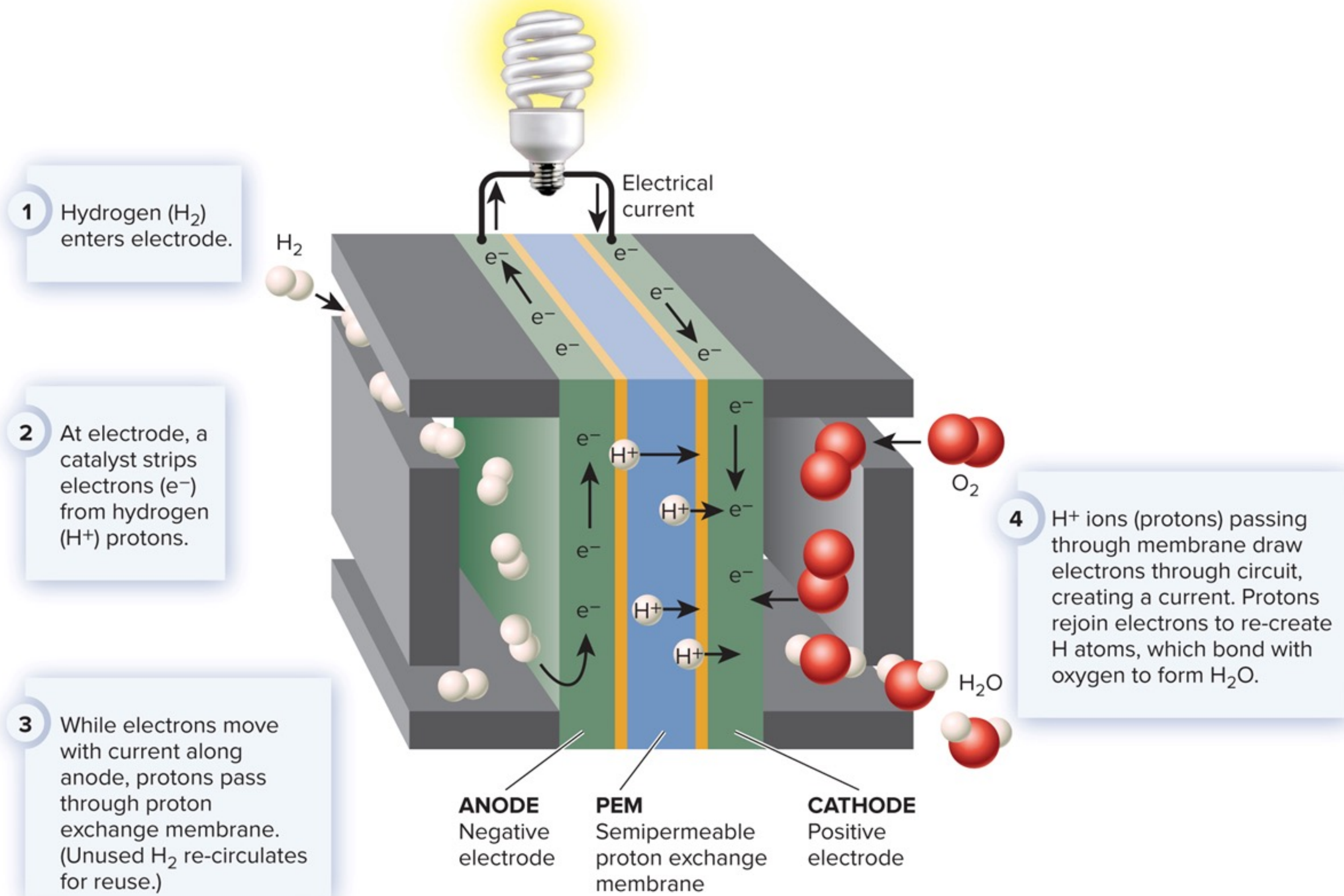
Fuel Cell Operation



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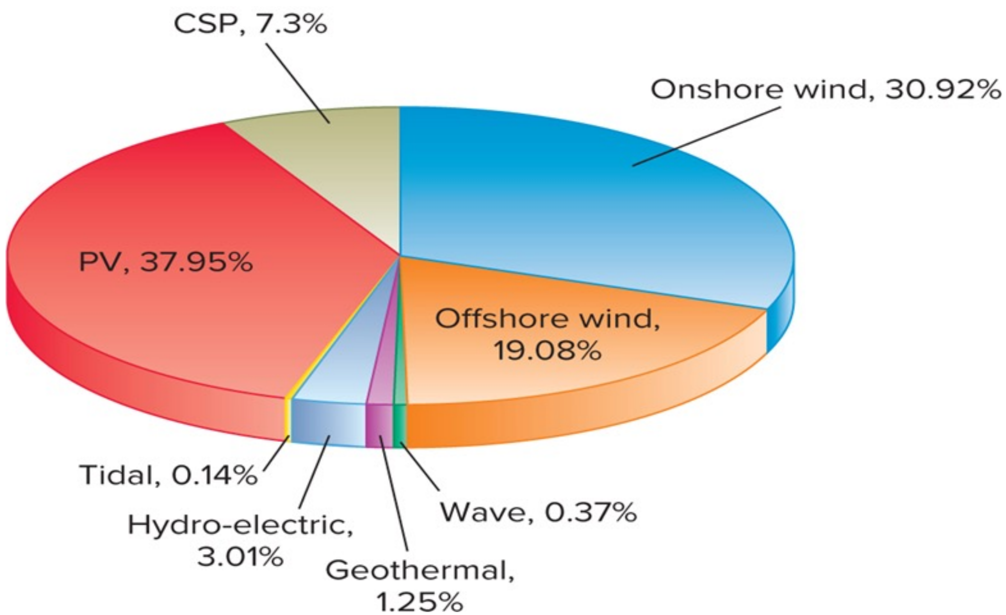
A Renewable Energy Scenario for 2050.



Is there enough clean energy to meet our needs? Yes, there is.

The World Energy Council projects that renewables could provide about 60 percent of world cumulative energy consumption in 2030.

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 Source: Jacobson, M. et al. 2015, 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States. *Energy Environ. Sci.,* 2015, 8, 2093–2117.

Take-Away Points

Energy choices will determine if the world meets climate protection goals.

Fossil fuels still dominate energy production.

A transition to a climate-safe energy system requires a combination of technologies.

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