

**Energy Efficiency and
Renewable Energy**

Chapter 16

**Core Case Study: Iceland's Vision of a
Renewable-Energy Economy (1)**

- Supplies 75% of its primary energy and almost all of its electrical energy using
 - Geothermal energy
 - Hydroelectric power

- No fossil fuel deposits: imports oil

- Bragi Arnason: "Dr. Hydrogen"
 - Energy vision

**Core Case Study: Iceland's Vision of a
Renewable-Energy Economy (2)**

- 2003: World's first commercial hydrogen filling station

- 2003–2007: three prototype fuel-cell buses

- 2008: 10 Toyota Prius test vehicles
 - Hydrogen-fueled

- Whale-watching boat: partially powered by a hydrogen fuel cell

The Krafla Geothermal Power Station in Northern Iceland



16-1 Why Is Energy Efficiency an Important Energy Resource?

- **Concept 16-1** *We could save as much as 43% of all the energy we use by improving energy efficiency.*

We Waste Huge Amounts of Energy (1)

- **Energy conservation**
- **Energy efficiency**
- Advantages of reducing energy waste:
 - Quick and clean
 - Usually the cheapest to provide more energy
 - Reduce pollution and degradation
 - Slow global warming
 - Increase economic and national security

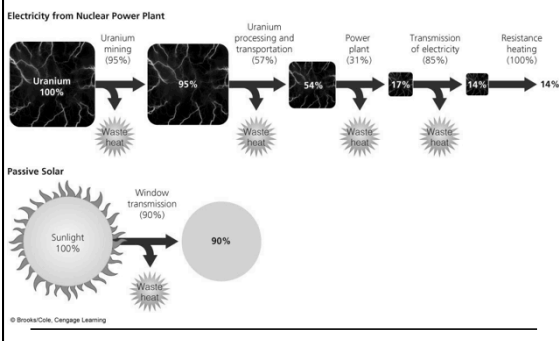
We Waste Huge Amounts of Energy (2)

- Four widely used devices that waste energy
 - Incandescent light bulb
 - Motor vehicle with an internal combustion engine
 - Nuclear power plant
 - Coal-fired power plant

- Possible alternatives for the “outdated four”

- **Net** energy efficiency is the energy that counts

Comparison of the Net Energy Efficiency for Two Types of Space Heating



SOLUTIONS

Reducing Energy Waste

- Prolongs fossil fuel supplies
- Reduces oil imports and improves energy security
- Very high net energy yield
- Low cost
- Reduces pollution and environmental degradation
- Buys time to phase in renewable energy
- Creates local jobs



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Fig. 16-3, p. 401

16-2 How Can We Cut Energy Waste?

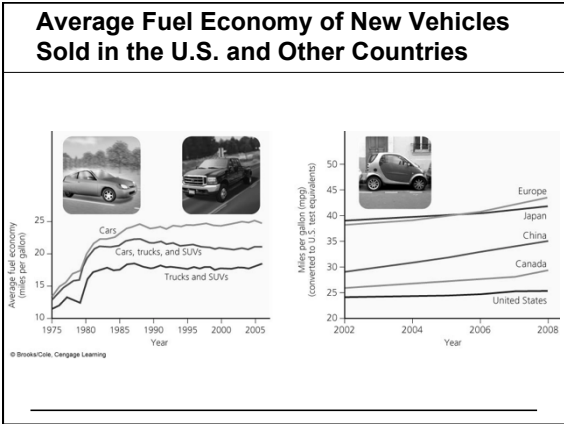
- **Concept 16-2** *We have a variety of technologies for sharply increasing the energy efficiency of industrial operations, motor vehicles, and buildings.*

We Can Save Energy and Money in Industry

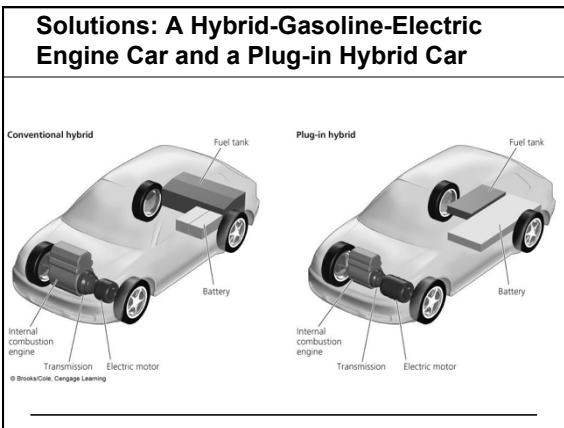
- **Cogeneration or combined heat and power (CHP)**
- Replace energy-wasting electric motors
- Recycling materials
- Switch from low-efficiency incandescent lighting to higher-efficiency fluorescent and LED lighting
- Electrical grid system: outdated and wasteful
- Utility companies promote use of energy
- Dow Chemical Company: improvements in efficiency

We Can Save Energy and Money in Transportation

- Corporate average fuel standards (CAFE) standards
 - Fuel economy standards lower in the U.S. than many other countries
- Fuel-efficient cars are on the market
- No environmental or health costs in gasoline prices
- Should there be tax breaks for buying fuel-efficient cars, or **feebate**?



- ### More Energy-Efficient Vehicles Are on the Way
- Superefficient and ultralight cars
 - Gasoline-electric hybrid car
 - Plug-in hybrid electric vehicle
 - Energy-efficient diesel car
 - Electric vehicle with a fuel cell



We Can Design Buildings That Save Energy and Money

- Green architecture
- Living or green roofs
- Straw bale houses (covered w/plaster or adobe)
- U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED)

A Green or Living Roof in Chicago, IL (U.S.)



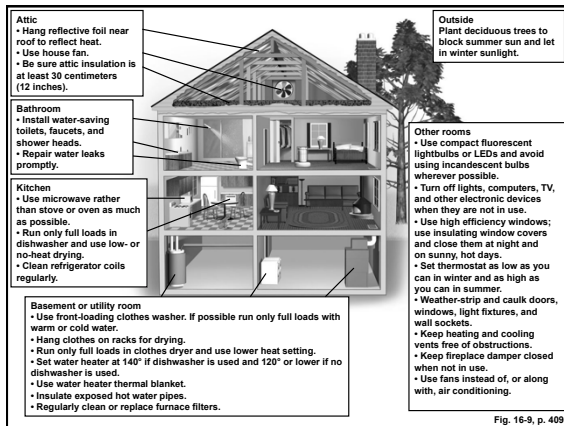
We Can Save Energy and Money in Existing Buildings

- Insulate and plug leaks
- Use energy-efficient windows
- Stop other heating and cooling losses
- Heat houses more efficiently
- Heat water more efficiently
- Use energy-efficient appliances
- Use energy-efficient lighting

A Thermogram Showing Heat Loss Around Houses and Stores



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Why Are We Still Wasting So Much Energy?

- Energy remains artificially cheap
- Few large and long-lasting government incentives
- What about the **rebound effect**?

We Can Use Renewable Energy in Place of Nonrenewable Energy Sources

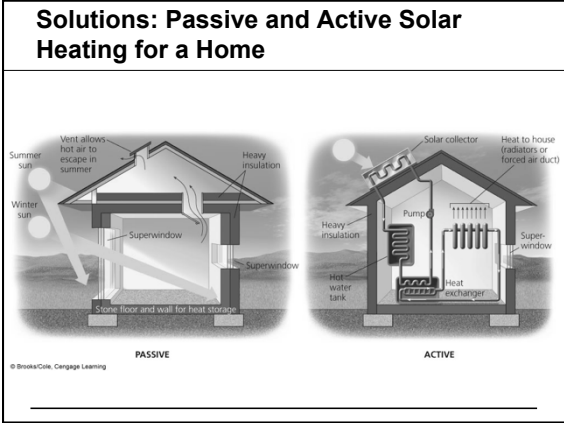
- Renewable energy
 - Solar energy: direct or indirect
 - Geothermal energy
- Benefits of shifting toward a variety of locally available renewable energy resources

16-3 What Are the Advantages and Disadvantages of Solar Energy?

- *Concept 16-3* Passive and active solar heating systems can heat water and buildings effectively, and the costs of using direct sunlight to produce high-temperature heat and electricity are coming down.



We Can Heat Buildings and Water with Solar Energy

- Passive solar heating system
- Active solar heating system
- Some countries using solar energy to heat water, some require it.

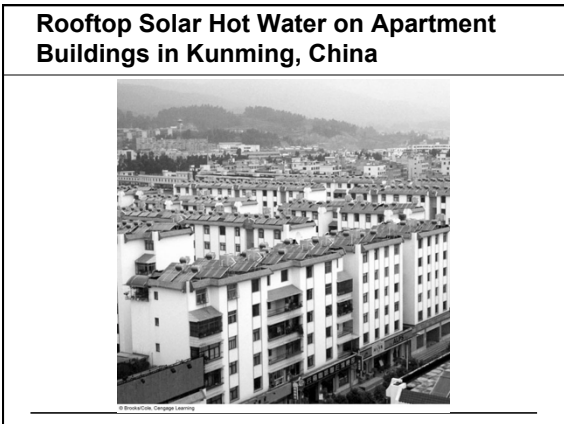


TRADE-OFFS

Passive or Active Solar Heating

<p>Advantages</p> <ul style="list-style-type: none"> Energy is free Net energy is moderate (active) to high (passive) Quick installation No CO₂ emissions Very low air and water pollution Very low land disturbance (built into roof or windows) Moderate cost (passive) 	 	<p>Disadvantages</p> <ul style="list-style-type: none"> Need access to sun 60% of time Sun can be blocked by trees and other structures Environmental costs not included in market price Need heat storage system High cost (active) Active system needs maintenance and repair Active collectors unattractive
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**Case Study: The Rocky Mountain Institute
—Solar Powered Office and Home**

- Location: Snowmass, CO (U.S.)
- No conventional heating system (solar heat, super insulation)
- Heating bills: <\$50/year

**Sustainable Energy: Rocky Mountain
Institute in Colorado, U.S.**



We Can Cool Buildings Naturally

- Technologies available
 - Superinsulation and high-efficiency windows
 - Overhangs or awnings on windows
 - Light-colored roof
 - Reflective insulating foil in an attic
 - Geothermal pumps
 - Plastic **earth tubes** underground

We Can Use Sunlight to Produce High-Temperature Heat and Electricity

- **Solar thermal systems**
 - Central receiver system
 - Other collecting systems

- Unfeasible for widespread use
 - High cost
 - Low net energy yields
 - Limited suitable sites
 - Sunny, desert sites

Trade-Offs: Solar Energy for High-Temperature Heat and Electricity

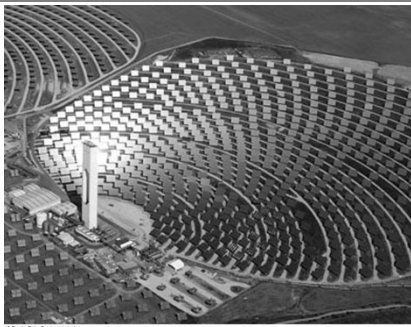
Advantages

- Moderate net energy
- Moderate environmental impact
- No CO₂ emissions
- Fast construction (1-2 years)
- Costs reduced with natural gas turbine backup

Disadvantages

- Low efficiency
- High costs
- Environmental costs not included in market price
- Needs backup or storage system
- Need access to sun most of the time
- Vulnerable to sabotage
- May disturb desert areas

Commercial Solar Power Tower Plant Near Seville in Southern Spain



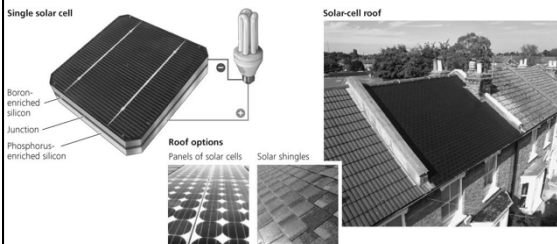
Solutions: Woman in India Uses a Solar Cooker



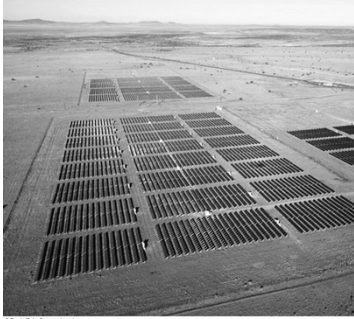
We Can Use Solar Cells to Produce Electricity

- **Photovoltaic (PV) cells (solar cells)**
 - Convert solar energy to electric energy
- Design of solar cells
- Benefits of using solar cells
- Solar-cell PV power plants
 - Agua Caliente: Yuma, AZ

Solutions: Solar Cells Can Provide Electricity Using Solar-Cell Roof Shingles



Solar-Cell Power Plant in Arizona, U.S., Is the Largest Solar-Cell Power Plant



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Total Costs of Electricity from Different Sources in 2004

Table 16-1

Total Costs of Electricity from Different Sources in 2004
(in U.S. cents per kilowatt-hour)

Electricity Source	Generating Costs	Environmental Costs	Total Costs
Wind	4.7–6.3	0.1–0.3	4.8–6.6
Geothermal	4.8	1.0 (approximately)	5.8
Hydropower	4.9–8.5	0.3–1.1	5.2–9.6
Natural gas	5.2–6.5	1.1–4.5	6.3–11.0
Biomass	5.5–6.4	1.0–3.4	6.5–9.8
Nuclear*	5.9–12.0	0.2–0.7	6.1–12.7
Coal	4.5–5.4	3.0–17.0	7.5–22.4
Solar cells	12.4–26.0	0.7	13.1–26.7




*Plant only. Costs are much higher if entire nuclear fuel cycle is included.
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The Solar Power Industry Is Expanding Rapidly

- Solar cells: 0.2% of the world’s electricity
- 2040: could solar cells produce 16%?
- Nanosolar: California (U.S.)
- Germany: huge investment in solar cell technology
- General Electric: entered the solar cell market

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Solar Cells

<p>Advantages</p> <ul style="list-style-type: none"> Fairly high net energy yield Work on cloudy days Quick installation Easily expanded or moved No CO₂ emissions Low environmental impact Last 20–40 years Low land use (if on roof or built into walls or windows) Reduces dependence on fossil fuels 	  	<p>Disadvantages</p> <ul style="list-style-type: none"> Need access to sun Low efficiency Need electricity storage system or backup Environmental costs not included in market price High costs (but should be competitive in 5–15 years) High land use (solar-cell power plants) could disrupt desert areas DC current must be converted to AC
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16-4 Advantages and Disadvantages of Producing Electricity from the Water Cycle




- *Concept 16-4* Water flowing over dams, tidal flows, and ocean waves can be used to generate electricity, but environmental concerns and limited availability of suitable sites may limit the use of these energy resources.

We Can Produce Electricity from Falling and Flowing Water

- Hydropower (review Ch. 13 on water resources)
 - World’s leading renewable energy source used to produce electricity
 - Hydroelectric power: Iceland
- Advantages (Fig. 16-21)
- Disadvantages
- **Micro-hydropower generators (portable)**

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Large-Scale Hydropower

<p>Advantages</p> <ul style="list-style-type: none"> Moderate to high net energy High efficiency (80%) Large untapped potential Low-cost electricity Long life span No CO₂ emissions during operation in temperate areas Can provide flood control below dam Provides irrigation water Reservoir useful for fishing and recreation 	  	<p>Disadvantages</p> <ul style="list-style-type: none"> High construction costs High environmental impact from flooding land to form a reservoir Environmental costs not included in market price High CO₂ emissions from rapid biomass decay in shallow tropical reservoirs Danger of collapse Uproots people Decreases fish harvest below dam Decreases flow of natural fertilizer (silt) to land below dam
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Tides, Waves and Currents Can Be Used to Produce Electricity

- Produce electricity from flowing water
 - Ocean tides and waves (& geostrophic currents)
- So far, power systems are limited
 - Norway
 - New York City
- Disadvantages
 - Few suitable sites
 - High costs
 - Equipment damaged by storms and corrosion
 - Environmental concerns

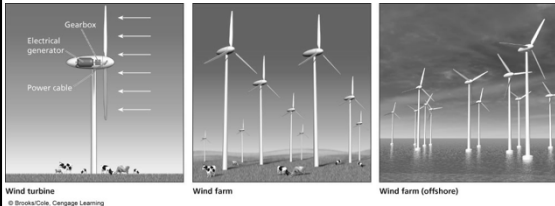
16-5 Advantages and Disadvantages of Producing Electricity from Wind

- **Concept 16-5** *When environmental costs of energy resources are included in market prices, wind energy is the least expensive and least polluting way to produce electricity.*

Using Wind to Produce Electricity Is an Important Step toward Sustainability (1)

- Wind: indirect form of solar energy (see Ch. 7)
 - Captured by turbines
 - Converted into electrical energy
- Second fastest-growing source of energy
- What is the global potential for wind energy?
- Wind farms: on land and offshore

Solutions: Wind Turbine and Wind Farms on Land and Offshore



Using Wind to Produce Electricity Is an Important Step toward Sustainability (2)


- Four U.S. states: “Saudi Arabia of wind power”
 - North Dakota
 - South Dakota
 - Kansas
 - Texas
- How much electricity is possible with wind farms in those states?

Wind Energy Is Booming but Still Faces Challenges

- Advantages of wind energy (Fig. 16-23)
- Drawbacks
 - Windy areas may be sparsely populated
 - Winds die down; need back-up energy
 - Storage of wind energy
 - Kills migratory birds
 - “Not in my backyard”

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Wind Power

<p>Advantages</p> <ul style="list-style-type: none"> Moderate to high net energy yield High efficiency Moderate capital cost Low electricity cost (and falling) Very low environmental impact No CO₂ emissions Quick construction Easily expanded Can be located at sea Land below turbines can be used to grow crops or graze livestock 		<p>Disadvantages</p> <ul style="list-style-type: none"> Steady winds needed Backup systems needed when winds are low Plastic components produced from oil Environmental costs not included in market price High land use for wind farm Visual pollution Noise when located near populated areas Can kill birds and interfere with flights of migratory birds
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16-6 Advantages and Disadvantages of Biomass as an Energy Source

- **Concept 16-6A** *Solid biomass is a renewable resource, but burning it faster than it is replenished produces a net gain in atmospheric greenhouse gases, and creating biomass plantations can degrade soil biodiversity.*
- **Concept 16-6B** *Liquid biofuels derived from biomass can be used in place of gasoline and diesel fuels, but creating biofuel plantations could degrade soil and biodiversity and increase food prices and greenhouse gas emissions.*

We Can Get Energy by Burning Solid Biomass

- **Biofuels (indirectly from solar energy)**
- Production of solid mass fuel (ex: wood)
 - Plant fast-growing trees
 - Biomass plantations
 - Collect crop residues and animal manure
- Advantages (Fig. 16-24)
- Disadvantages

TRADE-OFFS
Solid Biomass

<p>Advantages</p> <ul style="list-style-type: none"> Large potential supply in some areas Moderate costs No net CO₂ increase if harvested, burned, and replanted sustainably Plantation can be located on semiarid land not needed for crops Plantation can help restore degraded lands Can make use of agricultural, timber, and urban wastes 	<p>Disadvantages</p> <ul style="list-style-type: none"> Nonrenewable if harvested unsustainably Moderate to high environmental impact Environmental costs not included in market price Increases CO₂ emissions if harvested and burned unsustainably Low photosynthetic efficiency Soil erosion, water pollution, and loss of wildlife habitat Plantations could compete with cropland Often burned in inefficient and polluting open fires and stoves
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We Can Convert Plants and Plant Wastes to Liquid Biofuels (1)

- Liquid biofuels (substitute for petroleum-based)
 - Biodiesel
 - Ethanol
- Biggest producers of biofuel
 - Brazil (45% of autos run on ethanol)
 - The United States
 - The European Union
 - China

We Can Convert Plants and Plant Wastes to Liquid Biofuels (2)

- Major advantages over gasoline and diesel fuel produced from oil
 - Biofuel crops can be grown almost anywhere
 - No net increase in CO₂ emissions if managed properly (growth compensates for combustion)
- Studies warn of problems:
 - Decrease biodiversity
 - Increase soil degrading, erosion, and nutrient leaching
 - Push farmers off their land
 - Raise food prices

Case Study: Is Biodiesel the Answer?

- Biodiesel production from vegetable oil from various sources
- 95% produced by The European Union
- Jatropha shrub: promising new source
- Advantages (see Fig. 16-25)
- Disadvantages

TRADE-OFFS

Biodiesel

<p>Advantages</p> <ul style="list-style-type: none"> Reduced CO emissions Reduced CO₂ emissions (78%) High net energy yield for oil palm crops Moderate net energy yield for rapeseed crops Reduced hydrocarbon emissions Better gas mileage (40%) Potentially renewable 	<p>Disadvantages</p> <ul style="list-style-type: none"> Increased NO_x emissions and more smog Higher cost than regular diesel Environmental costs not included in market price Low net energy yield for soybean crops May compete with growing food on cropland and raise food prices Loss and degradation of biodiversity from crop plantations Can make engines hard to start in cold weather
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Fig. 16-25, p. 424

Case Study: Is Ethanol the Answer? (1)

- Ethanol converted to **gasohol**

- Brazil: "Saudi Arabia of sugarcane"
 - Saved \$50 billion in oil import costs since the 1970s

- United States: ethanol from corn
 - Reduce the need for oil imports?
 - Slow global warming?
 - Reduce air pollution?

Case Study: Is Ethanol the Answer? (2)

- **Cellulosic ethanol:** alternative to corn ethanol

- Sources
 - Switchgrass (see Fig. 16-26)
 - Crop residues
 - Municipal wastes

- Advantages (see Fig. 16-27)
- Disadvantages




Natural Capital: Rapidly Growing Switchgrass in Kansas, U.S.



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TRADE-OFFS

Ethanol Fuel

<p>Advantages</p> <p>High octane</p> <p>Some reduction in CO₂ emissions (sugarcane bagasse)</p> <p>High net energy yield (bagasse and switchgrass)</p> <p>Reduced CO emissions</p> <p>Can be sold as E85 or pure ethanol</p> <p>Potentially renewable</p>	  	<p>Disadvantages</p> <p>Lower driving range</p> <p>Low net energy yield (corn)</p> <p>Higher CO₂ emissions (corn)</p> <p>Much higher cost</p> <p>Environmental costs not included in market price</p> <p>May compete with growing food and raise food prices</p> <p>Higher NO_x emissions and more smog</p> <p>Corrosive</p> <p>Can make engines hard to start in cold weather</p>
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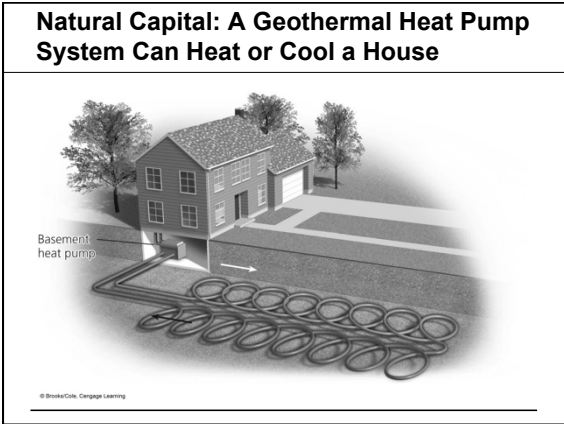
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16-7 What Are the Advantages and Disadvantages of Geothermal Energy?

- **Concept 16-7** *Geothermal energy has great potential for supplying many areas with heat and electricity and generally has a low environmental impact, but locations where it can be exploited economically are limited.*

Getting Energy from the Earth's Internal Heat (1)

- **Geothermal energy:** heat stored in
 - Soil
 - Underground rocks
 - Fluids in the earth's mantle
- Geothermal heat pump system (Fig. 16-28)
 - Energy efficient and reliable
 - Environmentally clean
 - Cost effective to heat or cool a space




Getting Energy from the Earth's Internal Heat (2)

- **Hydrothermal reservoirs**
 - Iceland, USA, Philippines...
- **Geothermal energy: two problems**
 - High cost of tapping large-scale hydrothermal reservoirs
 - Dry- or wet-steam geothermal reservoirs could be depleted

See Trade-offs – Fig. 16-29

TRADE-OFFS

Geothermal Energy

Advantages <ul style="list-style-type: none">Very high efficiencyModerate net energy at accessible sitesLower CO₂ emissions than fossil fuelsLow cost at favorable sitesLow land use and disturbanceModerate environmental impact	 Disadvantages <ul style="list-style-type: none">Scarcity of suitable sitesCan be depleted if used too rapidlyEnvironmental costs not included in market priceCO₂ emissionsModerate to high local air pollutionNoise and odor (H₂S)High cost except at the most concentrated and accessible sources
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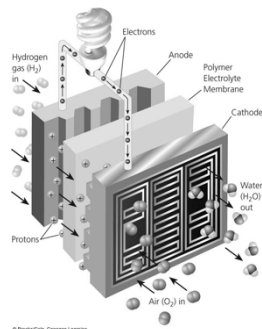
16-8 The Advantages and Disadvantages of Hydrogen as an Energy Source

- **Concept 16-8** *Hydrogen fuel holds great promise for powering cars and generating electricity, but to be environmentally beneficial, it would have to be produced without the use of fossil fuels.*

Hydrogen Is a Promising Fuel but There Are Challenges (1)

- Hydrogen as a fuel
 - Eliminate most of the air pollution problems
 - Reduce threats of global warming
- Some challenges
 - Chemically locked in water and organic compounds
 - Fuel cells are the best way to use hydrogen
 - CO₂ levels dependent on method of hydrogen production

A Fuel Cell Separates the Hydrogen Atoms' Electrons from Their Protons



Hydrogen Is a Promising Fuel but There Are Challenges (2)

- Production and storage of H₂
- Hydrogen-powered vehicles: prototypes available
- Can we produce hydrogen on demand?
 - Practical with renewable power (wind, hydro, solar, geothermal)

Hydrogen	
<p>Advantages</p> <ul style="list-style-type: none"> Can be produced from plentiful water Low environmental impact Renewable if produced from renewable energy resources No CO₂ emissions if produced from water Good substitute for oil Competitive price if environmental and social costs are included in cost comparisons Easier to store than electricity Safer than gasoline and natural gas Nontoxic High efficiency (45–65%) in fuel cells 	<p>Disadvantages</p> <ul style="list-style-type: none"> Not found as H₂ in nature Energy is needed to produce fuel Negative net energy CO₂ emissions if produced from carbon-containing compounds Environmental costs not included in market price Nonrenewable if generated by fossil fuels or nuclear power High costs (that may eventually come down) Will take 25 to 50 years to phase in Short driving range for current fuel-cell cars No fuel distribution system in place Excessive H₂ leaks may deplete ozone in the atmosphere

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16-9 How Can We Make a Transition to a More Sustainable Energy Future?

- **Concept 16-9** *We can make a transition to a more sustainable future if we greatly improve energy efficiency, use a mix of renewable energy resources, and include environmental costs in the market prices of all energy resources.*

Choosing Energy Paths (1)


- How will energy policies be created?
- **Supply-side, hard-path** approach
- **Demand-side, soft-path** approach

Choosing Energy Paths (2)

- General conclusions about possible energy paths
 - Gradual shift to smaller, decentralized micropower systems
 - Transition to a diverse mix of locally available renewable energy resources Improved energy efficiency
 - How?
 - Fossil fuels will still be used in large amounts
 - Why?

SOLUTIONS

Making the Transition to a More Sustainable Energy Future

<p>Improve Energy Efficiency</p> <p>Increase fuel-efficiency standards for vehicles, buildings, and appliances</p> <p>Mandate government purchases of efficient vehicles and other devices</p> <p>Provide large tax credits or feebates for buying efficient cars, houses, and appliances</p> <p>Offer large tax credits for investments in energy efficiency</p> <p>Reward utilities for reducing demand for electricity</p> <p>Greatly increase energy efficiency research and development</p>		<p>More Renewable Energy</p> <p>Greatly increase use of renewable energy</p> <p>Provide large subsidies and tax credits for use of renewable energy</p> <p>Include environmental costs in prices for all energy resources</p> <p>Encourage government purchase of renewable energy devices</p> <p>Greatly increase renewable energy research and development</p> <p>Reduce Pollution and Health Risk</p> <p>Cut coal use 50% by 2020</p> <p>Phase out coal subsidies</p> <p>Levy taxes on coal and oil use</p> <p>Phase out nuclear power subsidies, tax breaks, and loan guarantees</p>
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Fig. 16-33, p. 432

What Can you Do? Shifting to Sustainable Energy Use

WHAT CAN YOU DO?

Shifting to Sustainable Energy Use

- Get an energy audit done for your house or office
- Drive a car that gets at least 15 kilometers per liter (35 miles per gallon)
- Use a carpool to get to work or to school
- Walk, bike, and use mass transit
- Superinsulate your house and plug all air leaks
- Turn off lights, TV sets, computers, and other electronic equipment when they are not in use
- Wash laundry in warm or cold water
- Use passive solar heating
- For cooling, open windows and use ceiling fans or whole-house attic or window fans
- Turn thermostats down in winter and up in summer
- Buy the most energy-efficient home, lights, and appliances available
- Turn down the thermostat on water heaters to 43–49 °C (110–120 °F) and insulate hot water heaters and pipes

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ABC Video: MTBE pollution

