Efficiency

Getting more for the money
Efficiency

- Efficiency is the effective operation as measured by a comparison of production with cost (as in energy, time, and money)
Energy Efficiency

- The term *energy efficiency* refers to the measure of the useful energy.
- An energy efficient appliance would convert the energy supplied to it with a minimal amount of heat returned as energy.
2nd Law of Thermodynamics

- The 2nd Law of Thermodynamics states that in any spontaneous change, the entropy of the universe must increase; which means that the quality of energy deteriorates gradually over time.
- Entropy is the measure of randomness or disorder in a system and is also a measure of unusable energy within a closed or isolated system.
Implications of the 2\textsuperscript{nd} Law

• During a chemical reaction, energy is converted from one form to another.

• There is also a certain amount of energy that is converted into heat. Heat is a form of energy of lower quality and not as “usable”

  chemical $\rightarrow$ mechanical (+ heat)
The Components

- **Input** is all components (matter and/or energy) entering the system.
- **Throughput** is the flow of all components within the system.
- **Output** is all components leaving the system.
Measure of Efficiency

- The efficiency of a product can be measured by:
  \[
  \text{\% efficiency} = \left( \frac{\text{output}}{\text{input}} \right) \times 100
  \]
  
  - output is mechanical work or energy (watts or joules)
  - input is the quantity of work or energy

- Cannot exceed 100\% because of the Law of Conservation of Energy
Feedback

- A feedback loop is a circular process
- A feedback loop is how the output becomes input and affects the system.
  - Negative feedback: reverses the direction of the flow.
  - Positive feedback: changes the rate of the throughput, but not the direction.
Positive Feedback

- A feedback loop in which output of one type acts as input that moves the system in the same direction. The input and output drive the system further toward one extreme or another.
  - Positive feedback will result in exponential (unlimited) growth.
  - Positive feedback is BAD
Negative Feedback

- A feedback loop in which the output of one type acts as input that moves the system in the opposite direction. The input and output essentially neutralize each other’s effects and stabilizes the system.
  - A thermostat in a room controls and maintains the temperature.
  - Negative feedback is GOOD
High Throughput

- A high throughput economy is one that has a high output.
  - The economy is boosted by a one-way flow of matter/energy
  - Generates a large amount of waste and pollution
  - Energy output is low quality
Low Throughput

- A Low Throughput economy is one that has a balance of input and output.
- Generates little waste
- Maximizes energy efficiency
- Not an economic leader but an environmental leader
Calculating Efficiency

- Choose one of the appliances below and determine the efficiency of a traditional appliance versus a “green” appliance. Calculate based on the % efficiency formula.
  - Clothes Washer & Dryer
  - Dishwasher
  - Oven
  - Microwave Oven
  - Water Heater
  - Refrigerator
  - Lighting
  - Heat Pump (AC and Heat)
  - Computers
Core Case Study: The Coming Energy-Efficiency and Renewable-Energy Revolution

- It is possible to get electricity from solar cells that convert sunlight into electricity.
  - Can be attached like shingles on a roof.
  - Can be applied to window glass as a coating.
  - Can be mounted on racks almost anywhere.
Core Case Study: The Coming Energy-Efficiency and Renewable-Energy Revolution

- The heating bill for this energy-efficient passive solar radiation office in Colorado is $50 a year.
Reducing energy waste and improving energy efficiency

- Flow of commercial energy through the U.S. economy.
- 84% of all commercial energy used in the U.S. is wasted
- 41% wasted due to 2\textsuperscript{nd} law of thermodynamics.
Reducing Energy Waste And Improving Energy Efficiency

- Four widely used devices waste large amounts of energy:
  - *Incandescent light bulb*: 95% is lost as heat.
  - *Internal combustion engine*: 94% of the energy in its fuel is wasted.
  - *Nuclear power plant*: 92% of energy is wasted through nuclear fuel and energy needed for waste management.
  - *Coal-burning power plant*: 66% of the energy released by burning coal is lost.
Solutions

Reducing Energy Waste

- Prolongs fossil fuel supplies
- Reduces oil imports
- Very high net energy
- Low cost
- Reduces pollution and environmental degradation
- Buys time to phase in renewable energy
- Less need for military protection of Middle East oil resources
- Creates local jobs
Net Energy Efficiency: Honest Accounting

- Comparison of net energy efficiency for two types of space heating.
Ways to improve energy efficiency

- Industry can save energy and money by producing both heat and electricity from one energy source and by using more energy-efficient electric motors and lighting.
  - Industry accounts for about 42% of U.S. energy consumption.
- We can save energy in transportation by increasing fuel efficiency and making vehicles from lighter and stronger materials.
WAYS TO IMPROVE ENERGY EFFICIENCY

- The government Corporate Average Fuel Economy (CAFE) has not increased after 1985.

Figure 17-5
WAYS TO IMPROVE ENERGY EFFICIENCY

- Inflation adjusted price of gasoline (in 2006 dollars) in the U.S.
- Motor vehicles in the U.S. use 40% of the world’s gasoline.

Figure 17-6
WAYS TO IMPROVE ENERGY EFFICIENCY

- General features of a car powered by a hybrid-electric engine.
- “Gas sipping” cars account for less than 1% of all new car sales in the U.S.
Hybrid Vehicles, Sustainable Wind Power, and Oil imports

- Hybrid gasoline-electric engines with an extra plug-in battery could be powered mostly by electricity produced by wind and get twice the mileage of current hybrid cars.
- Currently plug-in batteries would be generated by coal and nuclear power plants.
Fuel-Cell Vehicles

- Fuel-efficient vehicles powered by a fuel cell that runs on hydrogen gas are being developed.
- Combines hydrogen gas ($\text{H}_2$) and oxygen gas ($\text{O}_2$) fuel to produce electricity and water vapor ($2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$).
- Emits no air pollution or $\text{CO}_2$ if the hydrogen is produced from renewable-energy sources.
Body attachments
Mechanical locks that secure the body to the chassis

Air system management
Fuel-cell stack
Converts hydrogen fuel into electricity
Front crush zone
Absorbs crash energy

Universal docking connection
Connects the chassis with the drive-by-wire system in the body
Rear crush zone
Absorbs crash energy
Drive-by-wire system controls

Cabin heating unit
Side-mounted radiators
Release heat generated by the fuel cell, vehicle electronics, and wheel motors

Hydrogen fuel tanks

Electric wheel motors
Provide four-wheel drive; have built-in brakes

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Fig. 17-8, p. 390
WAYS TO IMPROVE ENERGY EFFICIENCY

- We can save energy in building by getting heat from the sun, superinsulating them, and using plant covered green roofs.
- We can save energy in existing buildings by insulating them, plugging leaks, and using energy-efficient heating and cooling systems, appliances, and lighting.
Strawbale is a superinsulator that is made from bales of low-cost straw covered with plaster or adobe. Depending on the thickness of the bales, its strength exceeds standard construction.
Living Roofs

- Roofs covered with plants have been used for decades in Europe and Iceland.
- These roofs are built from a blend of light-weight compost, mulch and sponge-like materials that hold water.
About one-third of the heated air in typical U.S. homes and buildings escapes through closed windows and holes and cracks.
Why Are We Still Wasting So Much Energy?

- Low-priced fossil fuels and few government tax breaks or other financial incentives for saving energy promote energy waste.
How Would You Vote?

Should the United States (or the country where you live) greatly increase its emphasis on improving energy efficiency?

- a. No. The free market already encourages investments in energy efficiency.
- b. Yes. Without government participation, there is little incentive to improve energy efficiency until a crisis occurs.
USING RENEWABLE SOLAR ENERGY TO PROVIDE HEAT AND ELECTRICITY

- A variety of renewable-energy resources are available but their use has been hindered by a lack of government support compared to nonrenewable fossil fuels and nuclear power.
  - Direct solar
  - Moving water
  - Wind
  - Geothermal
USING RENEWABLE SOLAR ENERGY TO PROVIDE HEAT AND ELECTRICITY

- The European Union aims to get 22% of its electricity from renewable energy by 2010.
- Costa Rica gets 92% of its energy from renewable resources.
- China aims to get 10% of its total energy from renewable resources by 2020.
- In 2004, California got about 12% of its electricity from wind and plans to increase this to 50% by 2030.
USING RENEWABLE SOLAR ENERGY TO PROVIDE HEAT AND ELECTRICITY

• Denmark now gets 20% of its electricity from wind and plans to increase this to 50% by 2030.
• Brazil gets 20% of its gasoline from sugarcane residue.
• In 2004, the world’s renewable-energy industries provided 1.7 million jobs.
We can heat buildings by orienting them toward the sun or by pumping a liquid such as water through rooftop collectors.
Passive Solar Heating

- Passive solar heating system absorbs and stores heat from the sun directly within a structure without the need for pumps to distribute the heat.
### Trade-Offs

#### Passive or Active Solar Heating

**Advantages**
- Energy is free
- Net energy is moderate (active) to high (passive)
- Quick installation
- No CO$_2$ emissions
- Very low air and water pollution
- Very low land disturbance (built into roof or window)
- Moderate cost (passive)

**Disadvantages**
- Need access to sun 60% of time
- Sun blocked by other structures
- Need heat storage system
- High cost (active)
- Active system needs maintenance and repair
- Active collectors unattractive

---

Fig. 17-14, p. 396
Cooling Houses Naturally

- We can cool houses by:
  - Superinsulating them.
  - Taking advantages of breezes.
  - Shading them.
  - Having light colored or green roofs.
  - Using geothermal cooling.
Using Solar Energy to Generate High-Temperature Heat and Electricity

- Large arrays of solar collectors in sunny deserts can produce high-temperature heat to spin turbines for electricity, but costs are high.
Producing Electricity with Solar Cells

- Solar cells convert sunlight to electricity.
- Their costs are high, but expected to fall.
Photovoltaic (PV) cells can provide electricity for a house or building using solar-cell roof shingles.
Producing Electricity with Solar Cells

- Solar cells can be used in rural villages with ample sunlight who are not connected to an electrical grid.
## Trade-Offs: Solar Cells

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairly high net energy</td>
<td>Need access to sun</td>
</tr>
<tr>
<td>Work on cloudy days</td>
<td>Low efficiency</td>
</tr>
<tr>
<td>Quick installation</td>
<td>Need electricity storage system or backup</td>
</tr>
<tr>
<td>Easily expanded or moved</td>
<td>High land use (solar-cell power plants) could disrupt desert areas</td>
</tr>
<tr>
<td>No CO₂ emissions</td>
<td>High costs (but should be competitive in 5–15 years)</td>
</tr>
<tr>
<td>Low environmental impact</td>
<td>DC current must be converted to AC</td>
</tr>
<tr>
<td>Last 20–40 years</td>
<td></td>
</tr>
<tr>
<td>Low land use (if on roof or built into walls or windows)</td>
<td></td>
</tr>
<tr>
<td>Reduces dependence on fossil fuels</td>
<td></td>
</tr>
</tbody>
</table>

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### Producing Electricity with Solar Cells

#### Table 17-1 Total Costs of Electricity from Different Sources in 2004 (In U.S. cents per kilowatt hour)*

<table>
<thead>
<tr>
<th>Electricity Source</th>
<th>Generating Costs</th>
<th>Environmental Costs</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>3–7</td>
<td>0.1–0.3</td>
<td>3.1–7.3</td>
</tr>
<tr>
<td>Hydropower</td>
<td>3–8</td>
<td>0–1.1</td>
<td>3–9.1</td>
</tr>
<tr>
<td>Natural gas</td>
<td>4–7.0</td>
<td>1.1–4.5</td>
<td>5.5–11.5</td>
</tr>
<tr>
<td>Coal</td>
<td>3–4</td>
<td>2.3–17.0</td>
<td>5.3–21.0</td>
</tr>
<tr>
<td>Geothermal</td>
<td>5–8</td>
<td>1?</td>
<td>6–9</td>
</tr>
<tr>
<td>Biomass</td>
<td>7–9</td>
<td>1–3.4</td>
<td>8–12.4</td>
</tr>
<tr>
<td>Nuclear</td>
<td>10–14</td>
<td>0.2–0.7</td>
<td>10.2–14.7</td>
</tr>
<tr>
<td>Solar cells</td>
<td>24–28</td>
<td>0.7</td>
<td>24.7–28.7</td>
</tr>
</tbody>
</table>

*Data from U.S. Department of Energy and a variety of sources compiled by the Worldwatch Institute.
How Would You Vote?

Should the world greatly increase its dependence on solar cells for producing electricity?

- a. No. Solar cells are too expensive and cannot substantially meet our electricity needs.
- b. Yes. Solar cells are environmentally friendly and could supplement our energy needs.
PRODUCING ELECTRICITY FROM THE WATER CYCLE

- Water flowing in rivers and streams can be trapped in reservoirs behind dams and released as needed to spin turbines and produce electricity.
- There is little room for expansion in the U.S. – Dams and reservoirs have been created on 98% of suitable rivers.
<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate to high net energy</td>
<td>High construction costs</td>
</tr>
<tr>
<td>High efficiency (80%)</td>
<td>High environmental impact from flooding land to form a reservoir</td>
</tr>
<tr>
<td>Large untapped potential</td>
<td>High CO₂ emissions from biomass decay in shallow tropical reservoirs</td>
</tr>
<tr>
<td>Low-cost electricity</td>
<td>Floods natural areas behind dam</td>
</tr>
<tr>
<td>Long life span</td>
<td>Converts land habitat to lake habitat</td>
</tr>
<tr>
<td>No CO₂ emissions during operation in temperate areas</td>
<td>Danger of collapse</td>
</tr>
<tr>
<td>May provide flood control below dam</td>
<td>Uproots people</td>
</tr>
<tr>
<td>Provides water for year-round irrigation of cropland</td>
<td>Decreases fish harvest below dam</td>
</tr>
<tr>
<td>Reservoir is useful for fishing and recreation</td>
<td>Decreases flow of natural fertilizer (silt) to land below dam</td>
</tr>
</tbody>
</table>
How Would You Vote?

Should the world greatly increase its dependence on large-scale dams for producing electricity?

- a. No. Large hydroelectric dams harm the environment and should be replaced by renewable energy.
- b. Yes. We need large dams to meet power demands, protect areas from flooding, and provide water.
PRODUCING ELECTRICITY FROM THE WATER CYCLE

- Ocean tides and waves and temperature differences between surface and bottom waters in tropical waters are not expected to provide much of the world’s electrical needs.
- Only two large tidal energy dams are currently operating: one in La Rance, France and Nova Scotia’s bay of Fundy where the tidal amplitude can be as high as 16 meters (63 feet).
PRODUCING ELECTRICITY FROM WIND

- Wind power is the world’s most promising energy resource because it is abundant, inexhaustible, widely distributed, cheap, clean, and emits no greenhouse gases.
- Much of the world’s potential for wind power remains untapped.
- Capturing only 20% of the wind energy at the world’s best energy sites could meet all the world’s energy demands.
Wind turbines can be used individually to produce electricity. They are also used interconnected in arrays on wind farms.
The United States once led the wind power industry, but Europe now leads this rapidly growing business.

- The U.S. government lacked subsidies, tax breaks and other financial incentives.

- European companies manufacture 80% of the wind turbines sold in the global market
  - The success has been aided by strong government subsidies.
How Would You Vote?

Should the United States (or the country where you live) greatly increase its dependence on wind power?

• a. No. Wind turbines need research and mass-production before they will be competitive in the energy market.

• b. Yes. Wind power is becoming competitive and produces more clean energy than most other energy sources.
Trade-Offs
Wind Power

Advantages

- Moderate to high net energy
- 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

Disadvantages

- Steady winds needed
- Backup systems needed when winds are low
- High land use for wind farm
- Visual pollution
- Noise when located near populated areas
- May interfere in flights of migratory birds and kill birds of prey
PRODUCING ENERGY FROM BIOMASS

- Plant materials and animal wastes can be burned to provide heat or electricity or converted into gaseous or liquid biofuels.

**Solid Biomass Fuels**
- Wood logs and pellets
- Charcoal
- Agricultural waste (stalks and other plant debris)
- Timbering wastes (branches, treetops, and wood chips)
- Animal wastes (dung)
- Aquatic plants (kelp and water hyacinths)
- Urban wastes (paper, cardboard, and other combustible materials)

![Diagram showing biomass energy production processes](Figure 17-23)
The scarcity of fuelwood causes people to make fuel briquettes from cow dung in India. This deprives soil of plant nutrients.
**Trade-Offs**

**Solid Biomass**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large potential supply in some areas</td>
<td>Nonrenewable if harvested unsustainably</td>
</tr>
<tr>
<td>Moderate costs</td>
<td>Moderate to high environmental impact</td>
</tr>
<tr>
<td>No net CO₂ increase if harvested and burned sustainably</td>
<td>CO₂ emissions if harvested and burned unsustainably</td>
</tr>
<tr>
<td>Plantation can be located on semiarid land not needed for crops</td>
<td>Low photosynthetic efficiency</td>
</tr>
<tr>
<td>Plantation can help restore degraded lands</td>
<td>Soil erosion, water pollution, and loss of wildlife habitat</td>
</tr>
<tr>
<td>Can make use of agricultural, timber, and urban wastes</td>
<td>Plantations could compete with cropland</td>
</tr>
<tr>
<td></td>
<td>Often burned in inefficient and polluting open fires and stoves</td>
</tr>
</tbody>
</table>

Fig. 17-25, p. 405

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How Would You Vote?

Should we greatly increase our dependence on burning solid biomass to provide heat and produce electricity?

- a. No. Increased utilization of solid biomass may result in net greenhouse gas emissions, deforestation, and competition for valuable farmland.

- b. Yes. Biomass incineration would decrease the landfilling of wastes.
Converting Plants and Plant Wastes to Liquid Biofuels: An Overview

- Motor vehicles can run on ethanol, biodiesel, and methanol produced from plants and plant wastes.
- The major advantages of biofuels are:
  - Crops used for production can be grown almost anywhere.
  - There is no net increase in CO$_2$ emissions.
  - Widely available and easy to store and transport.
Case Study: Producing Ethanol

- Crops such as sugarcane, corn, and switchgrass and agricultural, forestry and municipal wastes can be converted to ethanol.

- Switchgrass can remove CO$_2$ from the troposphere and store it in the soil.
Case Study: Producing Ethanol

• 10-23% pure ethanol makes gasohol which can be run in conventional motors.
• 85% ethanol (E85) must be burned in flex-fuel cars.
• Processing all corn grown in the U.S. into ethanol would cover only about 55 days of current driving.
• Biodiesel is made by combining alcohol with vegetable oil made from a variety of different plants.
Ethanol Fuel

**Advantages**
- High octane
- Some reduction in CO$_2$ emissions
- High net energy (bagasse and switchgrass)
- Reduced CO emissions
- Can be sold as gasohol
- Potentially renewable

**Disadvantages**
- Large fuel tank needed
- Lower driving range
- Low net energy (corn)
- Much higher cost
- Corn supply limited
- May compete with growing food on cropland
- Higher NO emissions
- Corrosive
- Hard to start in cold weather
Case Study: Producing Ethanol

- Biodiesel has the potential to supply about 10% of the country’s diesel fuel needs.
Trade-Offs

Biodiesel

Advantages

- Reduced CO emissions
- Reduced CO\textsubscript{2} emissions (78%)
- Reduced hydrocarbon emissions
- Better gas mileage (40%)
- High yield for oil palm crops
- Moderate yield for rapeseed crops
- Potentially renewable

Disadvantages

- Slightly increased emissions of nitrogen oxides
- Higher cost than regular diesel
- Low yield for soybean crops
- May compete with growing food on cropland
- Loss and degradation of biodiversity from crop plantations
- Hard to start in cold weather

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Case Study: Biodiesel and Methanol

- Growing crops for biodiesel could potentially promote deforestation.
- Methanol is made mostly from natural gas but can also be produced at a higher cost from CO$_2$ from the atmosphere which could help slow global warming.
- Can also be converted to other hydrocarbons to produce chemicals that are now made from petroleum and natural gas.
### Methanol Fuel

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>High octane</td>
<td>Large fuel tank needed</td>
</tr>
<tr>
<td>Some reduction in CO₂ emissions</td>
<td>Half the driving range</td>
</tr>
<tr>
<td>Lower total air pollution (30–40%)</td>
<td>Corrodes metal, rubber, plastic</td>
</tr>
<tr>
<td>Can be made from natural gas, agricultural wastes, sewage sludge, garbage, and CO₂</td>
<td>High CO₂ emissions if made from coal</td>
</tr>
<tr>
<td>Can be used to produce H₂ for fuel cells</td>
<td>Expensive to produce</td>
</tr>
<tr>
<td></td>
<td>Hard to start in cold weather</td>
</tr>
</tbody>
</table>
GEOTHERMAL ENERGY

- Geothermal energy consists of heat stored in soil, underground rocks, and fluids in the earth’s mantle.
- We can use geothermal energy stored in the earth’s mantle to heat and cool buildings and to produce electricity.
  - A geothermal heat pump (GHP) can heat and cool a house by exploiting the difference between the earth’s surface and underground temperatures.
Geothermal Heat Pump

- The house is heated in the winter by transferring heat from the ground into the house.
- The process is reversed in the summer to cool the house.
GEOTHERMAL ENERGY

- Deeper more concentrated hydrothermal reservoirs can be used to heat homes and buildings and spin turbines:
  - *Dry steam*: water vapor with no water droplets.
  - *Wet steam*: a mixture of steam and water droplets.
  - *Hot water*: is trapped in fractured or porous rock.
**Geothermal Energy**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high efficiency</td>
<td>Scarcity of suitable sites</td>
</tr>
<tr>
<td>Moderate net energy at accessible sites</td>
<td>Depleted if used too rapidly</td>
</tr>
<tr>
<td>Lower CO₂ emissions than fossil fuels</td>
<td>CO₂ emissions</td>
</tr>
<tr>
<td>Low cost at favorable sites</td>
<td>Moderate to high local air pollution</td>
</tr>
<tr>
<td>Low land use</td>
<td>Noise and odor (H₂S)</td>
</tr>
<tr>
<td>Low land disturbance</td>
<td>Cost too high except at the most concentrated and accessible sources</td>
</tr>
<tr>
<td>Moderate environmental impact</td>
<td></td>
</tr>
</tbody>
</table>
How Would You Vote?

Should the United States (or the country where you live) greatly increase its dependence on geothermal energy to provide heat and to produce electricity?

- a. No. Most sites in the U.S. would not benefit from geothermal power.
- b. Yes. Geothermal energy has environmental advantages. Potentially suitable sites for geothermal power plants exist in Hawaii, Alaska, California, and several other states.
HYDROGEN

• Some energy experts view hydrogen gas as the best fuel to replace oil during the last half of the century, but there are several hurdles to overcome:
  • Hydrogen is chemically locked up in water and organic compounds.
  • It takes energy and money to produce it (net energy is low).
  • Fuel cells are expensive.
  • Hydrogen may be produced by using fossil fuels.
Converting to a Hydrogen Economy

- Iceland plans to run its economy mostly on hydrogen (produced via hydropower, geothermal, and wind energy), but doing this in industrialized nations is more difficult.
  - Must convert economy to energy farming (e.g. solar, wind) from *energy hunter-gatherers* seeking new fossil fuels.
  - No infrastructure for hydrogen-fueling stations (12,000 needed at $1 million apiece).
  - High cost of fuel cells.
Trade-Offs
Hydrogen

Advantages

Can be produced from plentiful water
Low environmental impact
Renewable if from renewable resources
No CO$_2$ emissions if produced from water
Good substitute for oil
Competitive price if environmental & 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

Disadvantages

Not found in nature
Energy is needed to produce fuel
Negative net energy
CO$_2$ emissions if produced from carbon-containing compounds
Nonrenewable if generated by fossil fuels or nuclear power
High costs (but 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 H$_2$ leaks may deplete ozone in the atmosphere
A SUSTAINABLE ENERGY STRATEGY

- Shifts in the use of commercial energy resources in the U.S. since 1800, with projected changes to 2100.

Figure 17-34
A SUSTAINABLE ENERGY STRATEGY

- A more sustainable energy policy would improve energy efficiency, rely more on renewable energy, and reduce the harmful effects of using fossil fuels and nuclear energy.
- There will be a gradual shift from large, centralized macropower systems to smaller, decentralized micropower systems.
What Can You Do?

Energy Use and Waste

- Get an energy audit at your house or office.
- Drive a car that gets at least 15 kilometers per liter (35 miles per gallon) and join a carpool.
- Use mass transit, walking, and bicycling.
- 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, up in summer.
- Buy the most energy-efficient homes, lights, cars, and appliances available.
- Turn down the thermostat on water heaters to 43–49° C (110–120° F) and insulate hot water heaters and pipes.
### Improve Energy Efficiency

- Increase fuel-efficiency standards for vehicles, buildings, and appliances
- Mandate government purchases of efficient vehicles and other devices
- Provide large tax credits for buying efficient cars, houses, and appliances
- Offer large tax credits for investments in energy efficiency
- Reward utilities for reducing demand for electricity
- Encourage independent power producers
- Greatly increase energy efficiency research and development

### More Renewable Energy

- Increase renewable energy to 20% by 2020 and 50% by 2050
- Provide large subsidies and tax credits for renewable energy
- Use full-cost accounting and life-cycle cost for comparing all energy alternatives
- Encourage government purchase of renewable energy devices
- Greatly increase renewable energy R&D

### Reduce Pollution and Health Risk

- Cut coal use 50% by 2020
- Phase out coal subsidies
- Levy taxes on coal and oil use
- Phase out nuclear power or put it on hold until 2020
- Phase out nuclear power subsidies
Governments can use a combination of subsidies, tax breaks, rebates, taxes and public education to promote or discourage use of various energy alternatives:

- Can keep prices artificially low to encourage selected energy resources.
- Can keep prices artificially high to discourage other energy resources.
- Emphasize consumer education.
Energy Star

• ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping us all save money and protect the environment through energy efficient products and practices.

• Results are already adding up. Americans, with the help of ENERGY STAR, saved enough energy in 2007 alone to avoid greenhouse gas emissions equivalent to those from 27 million cars — all while saving $16 billion on their utility bills.
On October 3, 2008, President Bush signed into law the “Emergency Economic Stabilization Act of 2008.” This bill extended tax credits for energy efficient home improvements (windows, doors, roofs, insulation, HVAC, and non-solar water heaters). Tax credits for these residential products, which had expired at the end of 2007, will now be available for improvements made during 2009. However, improvements made during 2008 are not eligible for a tax credit.

The bill also extended tax credits for solar energy systems and fuel cells to 2016. New tax credits were established for small wind energy systems and plug-in hybrid electric vehicles. Tax credits for builders of new energy efficient homes and tax deductions for owners and designers of energy efficient commercial buildings were also extended.