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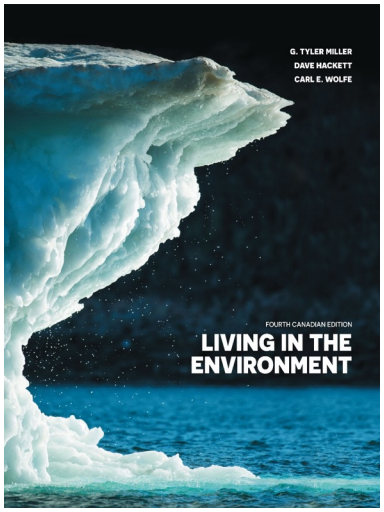


prepared by
Ian Dawe

Chapter 18

Energy Efficiency and Renewable Energy

Key Concepts

Energy efficiency

Renewable energy resources

- Solar (heat, electricity)
- Water (hydroelectricity, tidal)
- Wind
- Biomass
- Geothermal

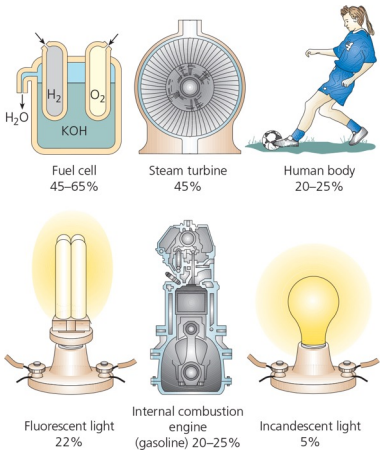
Use of hydrogen as a fuel

Micropower

Economics and politics of renewable energy

What Is Energy Efficiency?

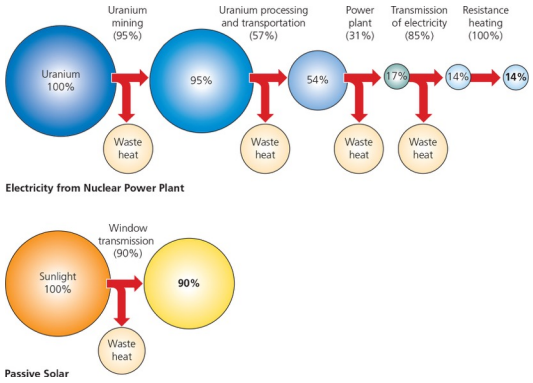
Useful energy produced by a device compared to total energy output (including heat)



What Is Net Energy Efficiency?

To improve net energy efficiency:

1. Minimize the number of conversion steps
2. Maximize the efficiency of each step



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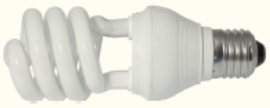
Reducing Energy Waste

FIGURE 18-2 **SOLUTIONS**

Reducing Energy Waste

Advantages of reducing energy waste. Global improvements in energy efficiency could save the world about $1 trillion (U.S.) per year—an average of $114 million per hour!



- 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
- Improves local economy by reducing flow of money out to pay for energy
- Creates local jobs

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Ways to Improve Energy Efficiency

Industry
- Cogeneration
- Replace inefficient electric motors
- Higher efficiency lighting

Transportation
- Increased fuel economy
- Hybrid-electric vehicles
- Fuel-cell vehicles

Building Design
- Insulation
- Energy-efficiency standards for fixtures

How Can We Save Energy in Industry?

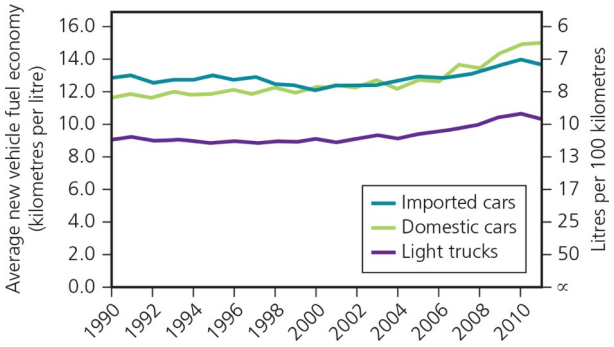
Cogeneration (combined heat and power [CHP])
- Produce two useful forms of energy
  - *For example,* steam + electricity
- Energy efficiency: 80–90%
  - *vs*. 30–40% for coal/nuclear electricity-only
- 66% less CO_2 per unit of energy than coal

Replace inefficient electric motors
- Inefficient non-adjustable power output
- May consume 10x more power than it cost to purchase

Higher efficiency lighting
- Fluorescent or LED

How Can We Save Energy in Transportation?

- **Fuel Efficiency**
  - Promote stronger minimum standards, offer tax breaks



Source: Data from the Research and Innovative Technology Administration, 2012

All-Electric Car

Problem is the distance one can drive on a single charge

Tesla Model S runs for about 400 kilometres.

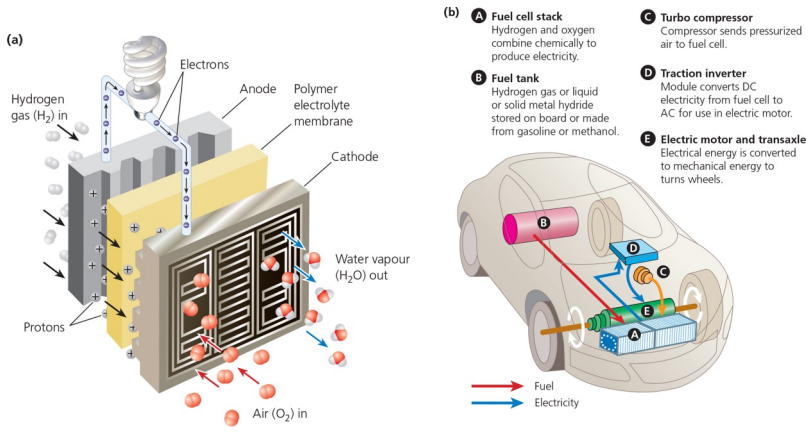
But it's very expensive.

© JOHANNES EISELE/Getty Images

Hybrid-Electric Internal Combustion

- Increases fuel efficiency by only using the gasoline engine for acceleration or hill climbing
- Relies on rechargeable electric motor for all other functions
- The Chevy Volt even recharges itself, using the gasoline engine.

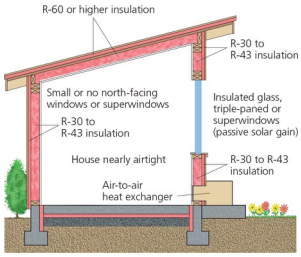
Fuel Cells



Source: Concept information from DaimlerChrysler, Ford, Ballard, Toyota, and Honda.

How Can We Save Energy in Buildings?

1. Building Design: Superinsulated Housing



Courtesy of www.StrawBale.com

How Can We Save Energy in Buildings?
Continued

2. Modifications to existing buildings

Insulate and plug leaks.

Use energy-efficient windows.

Stop other heating/cooling losses.

Use efficient house and water heating.

Use efficient lighting.

Unplug devices when not in use.

How Can We Save Energy in Buildings?
Continued 2

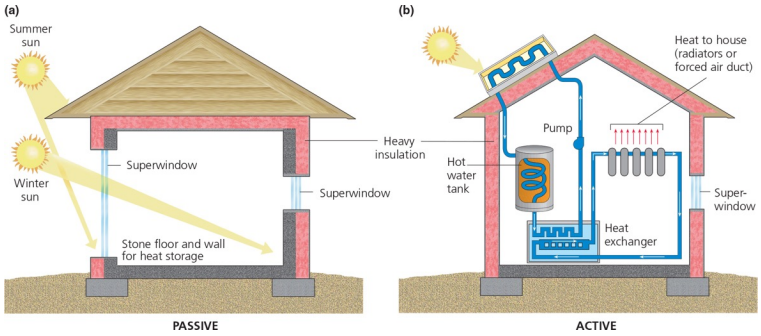
Healthy House in Toronto

Source: Canada Mortgage and Housing Corporation (CMHC). CMHC's Family-Occupied Healthy House in Toronto, 2010. All rights reserved. Reproduced with the consent of CMHC. All other uses and reproductions of this material are expressly prohibited.

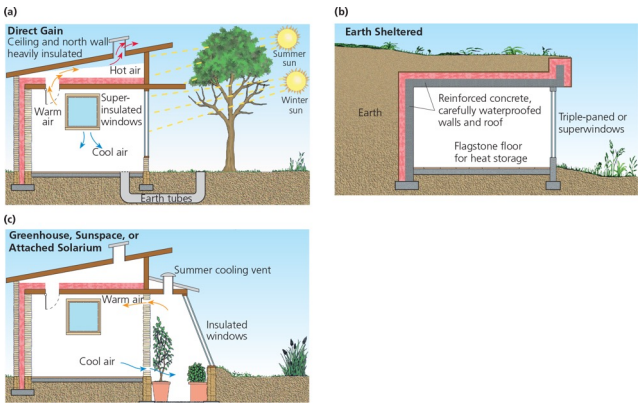
Main Types of Renewable Energy

- Solar
- Flowing water
- Wind
- Biomass
- Geothermal
- Hydrogen fuel

Passive and Active Solar Heating



Solar Heating House Design



Passive or Active Solar Heating

FIGURE 18-16 **TRADE-OFFS**

Passive or Active Solar Heating

Advantages and disadvantages of heating a house with passive or active solar energy. Pick the single advantage and the single disadvantage that you think are the most important.

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

- Needs access to sun 60% of the time
- Blockage of sun access by other structures
- Needs heat storage system
- High cost (active)
- Active system needs maintenance and repair.
- Active collectors unattractive

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Solar Energy for High-Temperature Heat and Electricity

FIGURE 18-17 **TRADE-OFFS**

Solar Energy for High-Temperature Heat and Electricity

Advantages and disadvantages of using solar energy to generate high-temperature heat and electricity. Pick the single advantage and the single disadvantage that you think are the most important.

Advantages

- Moderate net energy
- Moderate environmental impact
- No CO_2 emissions
- Fast construction (1–2 years)
- Costs reduced with natural gas turbine backup

Disadvantages

- Low efficiency
- High costs
- Need backup or storage system
- Need access to sun most of the time
- High land use
- May disturb desert areas

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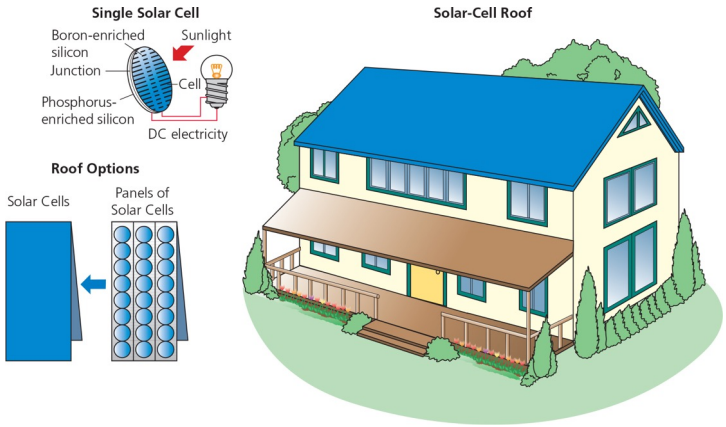
Solar Photovoltaic Electricity

Photovoltaic (PV) cells use a semiconductor to absorb light and directly generate DC electrical current.

R&D advances in thinner, cheaper, and flexible materials for PV.

Solar Photovoltaic Electricity
Continued



Solar Photovoltaic Electricity
Continued 2

FIGURE 18-19 **TRADE-OFFS**

Solar Cells

Advantages and disadvantages of using solar cells to produce electricity. Pick the single advantage and the single disadvantage that you think are the most important.

Advantages

- Fairly high net energy
- Works on cloudy days
- Quick installation
- Easily expanded or moved
- No CO_2 emissions
- Low environmental impact
- Lasts 20–40 years
- Low land use (if on roof or built into walls or windows)
- Reduces dependence on fossil fuels

Disadvantages

- Needs access to sun
- Low efficiency
- Needs electricity storage system or backup
- High land use (solar-cell power plants) could disrupt desert areas.
- High costs (but should be competitive in 5–15 years)
- DC current must be converted to AC.

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Producing Electricity From the Water Cycle

Water flow from high to low elevations in rivers and streams can be used to turn a turbine and generate electricity.

Electricity supplied by hydroelectric power (2012)

- 19% globally
- 97% in Norway
- 52% in New Zealand
- 60% in Canada
- 17% in China
- 7% in the United States

Producing Electricity From the Water Cycle: Large- or Small-Scale?

Streamflow can be controlled and more power generated by the use of a **dam** or **reservoir.**

Large-scale hydropower

- High dam across a large river to create a reservoir
- Issues with flooding, ecological impact on fish

Small-scale (run-of-river) hydropower

- Low or no dam used in a small stream
- Lower impact, but less reliable flow/output

Producing Electricity From the Water Cycle: Large Scale Hydropower–Trade-Offs

FIGURE 18-21 TRADE-OFFS

Large-Scale Hydropower

Advantages and disadvantages of using large dams and reservoirs to produce electricity.
Pick the single advantage and the single disadvantage that you think are the most important.

Advantages

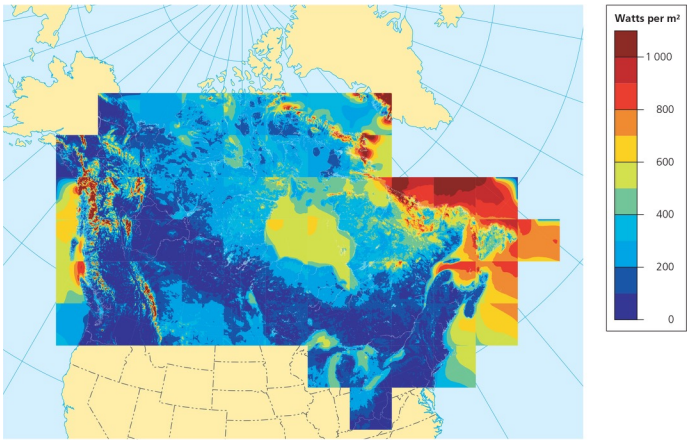
- Moderate to high net energy
- High efficiency (90%)
- Large untapped potential
- Low-cost electricity
- Long life span
- No CO_2 emissions during operation in temperate areas
- May provide flood control below dam
- Provides water for year-round irrigation of cropland
- Reservoir is useful for fishing and recreation.

Disadvantages

- High construction costs
- High environmental impact from flooding land to form a reservoir
- High CO_2 emissions from biomass decay in shallow tropical reservoirs
- Floods natural areas behind dam
- Converts land habitat to lake habitat
- Danger of collapse
- Uproots people
- Decreases fish harvest below dam
- Decreases flow of natural fertilizer (silt) to land below dam

(Left): © Petr Malyshev/Shutterstock; (Right): © Andrew Zarivny/Shutterstock

Producing Electricity from Wind: Available Wind Energy in Canada



Source: Canadian Wind Atlas, http://www.windatlas.ca/en/EU_50m_national.pdf, Environment Canada, 2003. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2012. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment, 2003.

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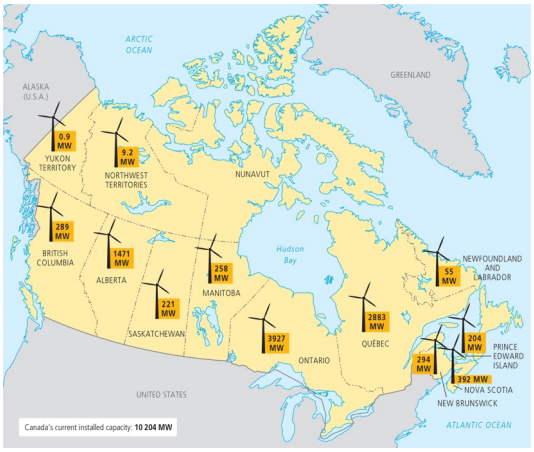
Producing Electricity from Wind: Installed Windmill Capacity Across Canada



Source: Courtesy of Canadian Wind Energy Association (CanWEA).

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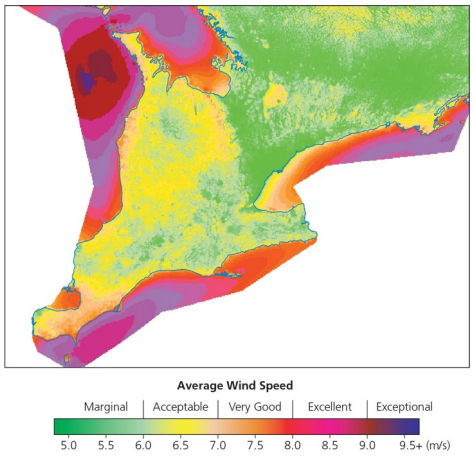
Producing Electricity from Wind: Wind Energy in Ontario



Source: Ontario Ministry of Natural Resources Wind Resource Atlas, http://www.ontariowindatlas.ca/en.

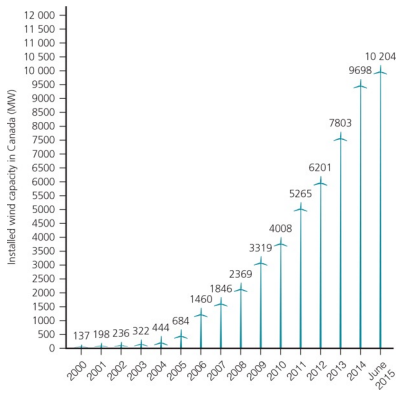
Producing Electricity from Wind: Growth of Wind Energy

Second fastest-growing source of energy

- More than 100x since 1990

Existing installed capacity (2014)

- China 31%
- United States 18%
- **Canada 2.6% (7th ranked)**



Source: Courtesy of Canadian Wind Energy Association (CanWEA).

Producing Electricity from Wind: Growth of Wind Energy continued

Newly installed capacity (during 2014)

- China 45%
- United States 9%
- **Canada 3.6% (6th ranked)**

Untapped available resource (2009)

- Canada: 40x current electricity needs

Wind Power: Trade-Offs

FIGURE 18-27 TRADE-OFFS

Wind Power

Advantages and disadvantages of using wind to produce electricity. Wind power experts project that by 2025 wind power could supply more than 10% of the world's electricity and 20% of the electricity used in Canada. Pick the single advantage and the single disadvantage that you think are the most important.

Advantages

- Moderate to high net energy yield
- High efficiency
- Moderate capital cost
- Low electricity cost (and falling)
- Very low environmental impact
- No CO_2 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

(Left): © Rene Hartmann/Shutterstock; (Right): © pedrosala/Shutterstock

How Is Biomass Used to Provide Energy?

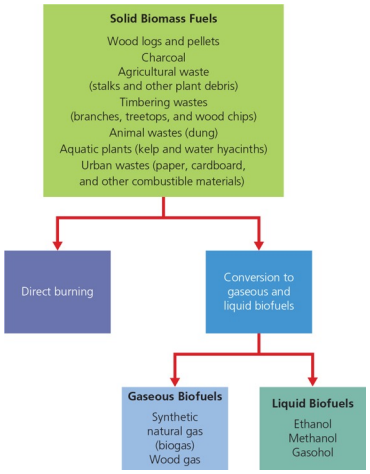
Made of plant materials and animal wastes

Solid biomass

- Burned directly as fuel

Gaseous biofuels

Liquid biofuels



Solid Biomass

FIGURE 18-29 TRADE-OFFS

Solid Biomass

General advantages and disadvantages of burning solid biomass as a fuel. Pick the single advantage and single disadvantage that you think are the most important.

Advantages

- Large potential supply in some areas
- Moderate costs
- No net CO_2 increase if harvested and burned sustainably
- Plantations can be located on semiarid land not needed for crops.
- Plantations can help restore degraded lands.
- Can make use of agricultural, timber, and urban wastes

Disadvantages

- Nonrenewable if harvested unsustainably
- Moderate to high environmental impact
- CO_2 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

(Left): © chocorange/Shutterstock; (Right): © janceluch/Shutterstock

Biodiesel

- Diesel fuel made from biomass
- Has low carbon emissions and no sulphur
- But it has lower caloric value than conventional diesel
- Can also “gel” at low temperatures, harming engines

Biogas

- Bacteria convert biomass into gaseous biofuels
- Inefficient, unreliable, and generates CO_2

Using Liquid Ethanol for Fuel

FIGURE 18-30 TRADE-OFFS

Ethanol Fuel

General advantages and disadvantages of using ethanol as a vehicle fuel compared to gasoline.
Pick the single advantage and single disadvantage that you think are the most important.

Advantages

- High octane
- Some reduction in CO_2 emissions
- Reduced CO emissions
- Can be sold as gasohol
- Potentially renewable

Disadvantages

- Large fuel tank needed
- Lower driving range
- Net energy loss
- Much higher cost
- Corn supply limited
- May compete with growing food on cropland
- Higher NO emissions
- Corrosive
- Hard to start in cold weather

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What Is Geothermal Energy?

Geothermal heat pumps
Geothermal exchange
Dry and wet steam
Hot water
Molten rock (magma)
Hot dry-rock zones and warm-rock reservoirs

Current Usage
22 countries (mostly developing nations)
Only 1% of global electricity

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Geothermal Energy: Trade-offs

FIGURE 18-32 TRADE-OFFS

Geothermal Energy

Advantages and disadvantages of using geothermal energy for space heating and to produce electricity or high-temperature heat for industrial processes. Pick the single advantage and the single disadvantage that you think are the most important.

Advantages

- Very high efficiency
- Moderate net energy at accessible sites
- Lower CO_2 emissions than fossil fuels
- Low cost at favourable sites
- Low land use
- Low land disturbance
- Moderate environmental impact

Disadvantages

- Scarcity of suitable sites
- Depleted if used too rapidly
- CO_2 emissions
- Moderate to high local air pollution
- Noise and odour (H_2S)
- Cost too high except at the most concentrated and accessible sources

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Hydrogen: Can Hydrogen Replace Oil?

Hydrogen isn't a primary energy resource;

it is a **fuel** we produce to store and use energy.

FIGURE 18-33 TRADE-OFFS

Hydrogen

Advantages and disadvantages of using hydrogen as a fuel for vehicles and for providing heat and electricity. Pick the single advantage and the single disadvantage that you think are the most important.

(Left): © Brooks Kraft/Corbis; (Right): Courtesy of Lawrence Livermore National Laboratory

Advantages

- Can be produced from plentiful water
- Low environmental impact
- Renewable if produced from renewable energy resources
- No CO_2 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

Disadvantages

- Not found in ecosphere
- Energy is needed to produce fuel
- Negative net energy (energy loss)
- 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 25–50 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.

(Left): © Brooks Kraft/Corbis; (Right): Courtesy of Lawrence Livermore National Laboratory

(Left): © Brooks Kraft/Corbis; (Right): Courtesy of Lawrence Livermore National Laboratory

Hydrogen Fuel Production

Hydrogen gas does not generally occur in nature.

- It is chemically locked up in water or hydrocarbons.

Current technology for generating H_2

- **Electrolysis from water**
  - Uses large amounts of electricity (usually from fossil fuels)
- **Cracking hydrocarbons**
  - Generates more CO_2 than simply burning the fossil fuels

Future alternative methods for H_2 production

- H_2-producing algae
- Direct from water using sunlight and chemical catalysts

Hydrogen Storage

We don't yet know how best to store H_2, unlike current fuels.

Compressed gas

- Low energy density + safety concerns

Liquid hydrogen

- Low temperature required uses money and energy

Hydrogen Storage continued

Metal hydrides

– Chemically bound to metal compounds

Adsorption on carbon

– Activated charcoal or graphite

Trapping in nanostructured molecules

– Clathrate hydrates or glass microspheres

All of these illustrate a problem: Hydrogen costs energy to make AND to store.

What Is Micropower?

Decentralization

Dispersed, small-scale generation

Smart metering for transmission and distribution

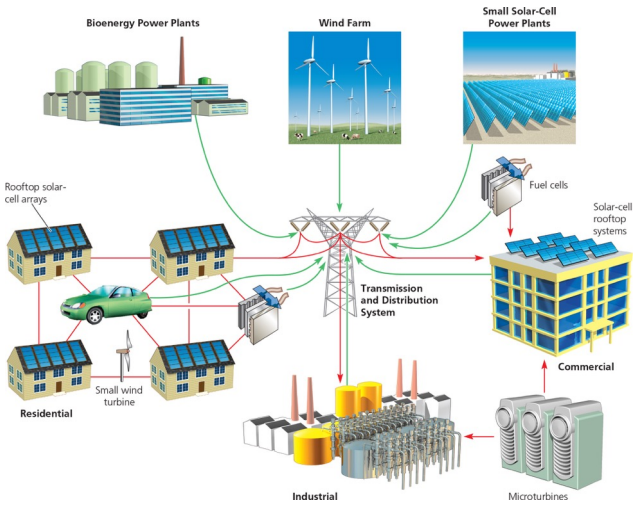
Advantages of Micropower

- Small modular units
- Fast factory production
- Fast installation (hours to days)
- Can add or remove modules as needed
- High energy efficiency (60%-80%)
- Low or no CO_2 emissions
- Low air pollution emissions

More Advantages of Micropower

- Reliable
- Easy to repair
- Much less vulnerable to power outages
- Increase national security by dispersal of targets
- Useful anywhere
- Especially useful in rural areas in developing countries with no power
- Can use locally available renewable energy resources
- Easily financed (costs included in mortgage and commercial load)

Decentralized Micropower



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How Can We Develop a More Sustainable Energy Future?

Improve Energy Efficiency

Increase fuel-efficiency standards for vehicles, buildings, and appliances.

Mandate government purchases of efficient vehicles and other devices.

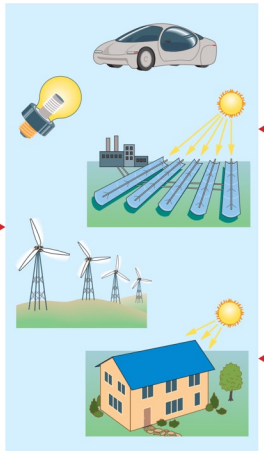
Provide large tax credits for buying efficient cars, houses, and appliances.

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 research and development.

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.

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Conclusion

Many potential sources of renewable energy.

All require investment, both financially and conceptually.

We need to rethink our relationship with energy, its generation, and its distribution.