Environmental Science, 15e

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13

Energy Resources

Core Case Study: The Astounding Potential for Wind Power in the U.S.

- Wind farms are being developed in the U.S. to convert wind power to electrical energy that can move through power grids to consumers
  - The wind turbines can be located on land or sea and can produce more electricity at lower costs – creating new jobs
- How are wind farms supporting the principle of solar sustainability?

13.1 What Is Net Energy and Why Is It Important?

- Net energy yield is the amount of energy obtained from a resource minus the amount of energy needed to produce it
- Net energy yield values vary greatly depending on the source of energy

Net Energy Is the Only Energy That Really Counts

- Energy input: energy needed to produce energy
- Net energy yield = total energy produced – energy required to produce it
  - Scientists look at net energy yield as the best measure for determining long-term usefulness of an energy resource
  - If a net energy yield is zero or a negative number – the resource cannot compete in the marketplace

Net Energy Yields for Various Energy Resources

Electricity	Net Energy Yield
Energy efficiency	High
Hydropower	High
Wind	High
Coal	High
Natural gas	Medium
Geothermal energy	Medium
Solar cells	Low to medium
Nuclear fuel cycle	Low
Hydrogen	Negative (Energy loss)

High-Temperature Industrial Heat	Net Energy Yield
Energy efficiency (cogeneration)	High
Coal	High
Natural gas	Medium
Oil	Medium
Heavy shale oil	Low
Heavy oil from tar sands	Low
Direct solar (concentrated)	Low
Hydrogen	Negative (Energy loss)

Space Heating	Net Energy Yield
Energy efficiency	High
Passive solar	Medium
Natural gas	Medium
Geothermal energy	Medium
Oil	Medium
Active solar	Low to medium
Heavy shale oil	Low
Heavy oil from tar sands	Low
Electricity	Low
Hydrogen	Negative (Energy loss)

Transportation	Net Energy Yield
Energy efficiency	High
Gasoline	High
Natural gas	Medium
Ethanol (from sugarcane)	Medium
Diesel	Medium
Gasoline from heavy shale oil	Low
Gasoline from heavy tar sand oil	Low
Ethanol (from corn)	Low
Biodiesel (from soy)	Low
Hydrogen	Negative (Energy loss)

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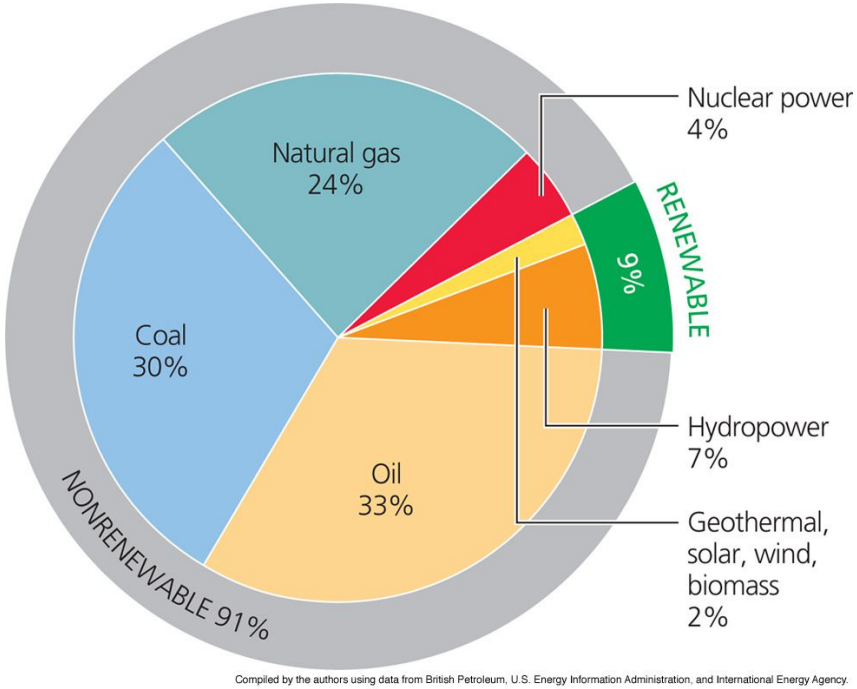
13.2 What Are the Advantages and Disadvantages of Using Fossil Fuel?

- Humans use fossil fuels because they are easily available and inexpensive to extract and process
- Using these nonrenewable fuels degrades the environment, causes air and water pollution, and releases greenhouse gases into the atmosphere

Fossil Fuels Supply Most of Our Commercial Energy

- Fossil fuels produce most of our energy, but they are nonrenewable energy – violating the principle of sustainability
  - Total energy used = 87% fossil fuels, 4% nuclear power, and 9% from renewable sources – biomass, hydropower, geothermal, wind and solar energy
- Crude oil/petroleum: formed by pressure applied to decayed organic remains

Energy Used By Source



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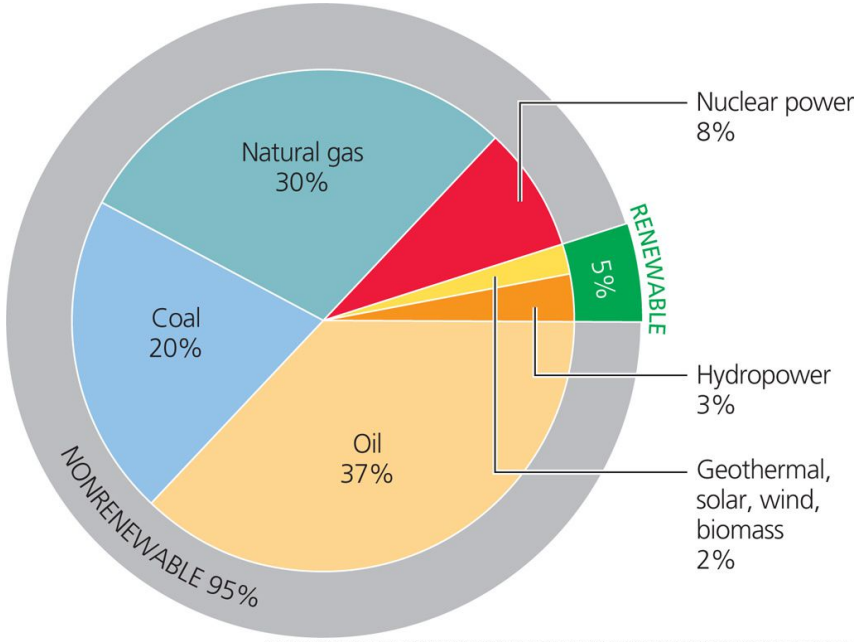

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Extracting and Refining Oil

- Finding/extracting oil: 3-D seismic maps and computers to find deposits, drill to check deposits, then drill production wells
  - Peak production: highest return on well – as time passes, production of well declines
- Crude oil must be refined to be usable – reduces net energy yield
  - We will not run out of crude oil in the near future – but the supply is not unlimited

Other Oil Possibilities

- Use of oil as an energy resource adds greenhouse gases to the atmosphere and contributes to climate change
- Shale oil: oil found within layers of rock
  - Net energy yield is low – currently not economically viable/harmful to environment
- Tar sands/oil sands: oil mixed with clay, sand, water and bitumen – low net energy yield and harmful to environment

Heavy Oils From Oil Shale and Tar Sand

Trade-Offs

Heavy Oils from Oil Shale and Tar Sand

Advantages	Disadvantages
Large potential supplies	Low net energy yield
Easily transported within and between countries	Releases CO_2 and other air pollutants when produced and burned
Efficient distribution system in place	Severe land disruption and high water use

Natural Gas as an Alternative

- Natural gas: mixture of gases (50-90% methane) – provides 28% of energy
  - With a medium net energy yield – used in cooking, heating and industrial purposes; cleaner than oil and coal
- Liquefied petroleum gas (propane and butane): tapped from deposits and stored in pressurized tanks
  - By 2050, U.S. demand will double but supply will be met within U.S. deposits

Trade-Offs: Conventional Natural Gas

Trade-Offs

Conventional Natural Gas

Advantages

- Ample supplies
- Versatile fuel
- Medium net energy yield
- Emits less CO_2 and other air pollutants than other fossil fuels when burned

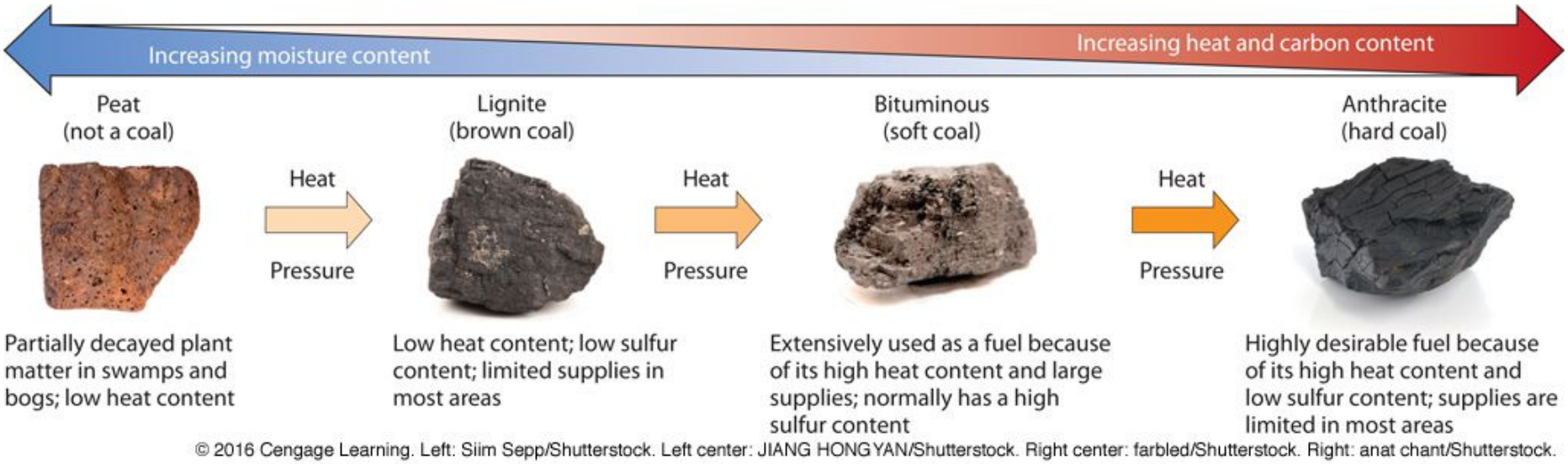
Disadvantages

- Low net energy yield for LNG
- Production and delivery may emit more CO_2 and CH_4 per unit of energy produced than coal
- Fracking uses and pollutes large volumes of water
- Potential groundwater pollution from fracking

Coal

- Coal: solid fossil fuel formed from decaying organic matter exposed to heat and pressure over millions of years
- Coal is the dirtiest fossil fuel, polluting air and water
  - As coal burns, particles are released into the air – contributing to human health problems
- Coal burning power/industrial plants – largest emitters of greenhouse gases

Types of Coal



Cost of Coal

- Some coal-burning plants use scrubbers to remove pollutants before leaving smoke stacks – this produces toxic coal ash
  - Some ash is buried, some gets into the water systems, and some is sold for construction –a mix of toxic chemicals
- Coal is cheap due to low market pricing
  - Regulations for usage are needed, but utilities using coal fight regulations and taxes

Trade-offs: Advantages and Disadvantages of Coal

Trade-Offs

Coal

Advantages	Disadvantages
Ample supplies in many countries	Severe land disturbance and water pollution
Medium to high net energy yield	Fine particle and toxic mercury emissions threaten human health
Low cost when environmental costs are not included	Emits large amounts of CO_2 and other air pollutants when produced and burned

13.3 What Are the Advantages and Disadvantages of Using Nuclear Power?

- Nuclear power has little environmental impact and a very low accident risk, but usage is limited due to its low net energy yield
- Fear of accidents and the long life of radioactive wastes are also limiting issues

How Does a Nuclear Fission Reactor Work?

- Task of the reactor is to boil water to produce steam that spins a turbine and generates electricity
- Nuclear fission chemical reactions provide the heat inside a reactor – process is complex and costly
  - Fuel is uranium ore contained in fuel rods and water as a coolant circulates through the reactor – reactor is surrounded by a steel containment shell

Radioactive Nuclear Wastes

- After 3-4 years, the radioactive uranium fuel rods become spent (useless) and must be replaced
  - The issue is what to do with these spent rods?
    - Storage is in water-filled ponds and then in dry casks – may be sufficient for 100 years, but not the thousands of years needed for the rods to be safe
  - Many methods have been suggested to contain plants after closure – but at high cost

Future of Nuclear Power

- Construction and use of nuclear power plants generates CO_2 emissions and contributes to climate change
- The prediction that nuclear energy would dramatically replace traditional sources has not occurred
  - Nuclear power (low net energy yield) is only possible because of government subsidies
    - Use of new technology (thorium instead of uranium) may change nuclear power development

Nuclear Fusion?

- Nuclear fusion: when two lighter atoms are forced together at high temperatures to form a heavier atom, energy is released
- Scientists hope that using controlled nuclear fusion will create almost limitless supplies of energy
  - Can reduce meltdown risk; release of radioactivity
  - No solution at an affordable cost is in sight

13.4 Why Is Energy Efficiency an Important Energy Resource?

- Improved energy efficiency could save1/3 of global energy used and 43% of the energy used in the United States

We Use Energy Inefficiently

- Energy efficiency: measure of work from each unit of energy, meaning that we need more work for less energy
  - Poor insulation in badly designed buildings – wastes the energy to heat and cool them
  - Three out of 4 Americans commute to work (only 5% use mass transit)
  - Internet data centers (and cloud-based storage) use 10% of electrical energy from grid – other 90% is wasted as heat

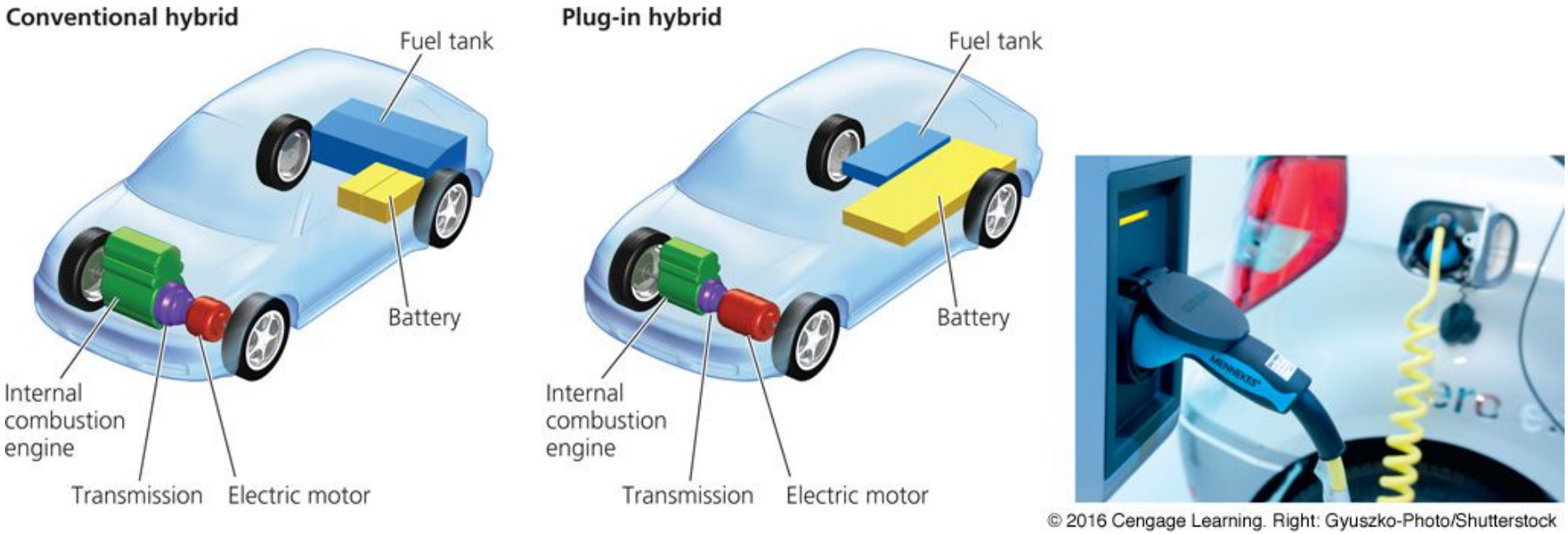
Improving Energy Efficiency

- Cogeneration: use a combined heat and power system to recycle steam as heat
- Make electric car motors more efficient
- Recycle materials, especially steel and other metals
- Improve designs of data centers
- Convert electrical grids into smart grids
- Connect solar and wind power to grids

Other Ways To Improve Energy Efficiency

- Include hidden costs in market pricing – through higher gas taxes
  - When hidden costs of gas use are added in, a gallon of gas would be $15 – full-cost pricing
- Give consumers tax breaks/subsidies to buy fuel efficient, smaller vehicles
- Build/improve mass transit systems
- Increase funding for research of hybrid car development and recharging stations

Conventional Gasoline-Electric Hybrid Vehicle



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Energy Efficiency and Green Construction

- Use principles of sustainability
  - Build facing sun to use solar power
  - Green architecture – solar heating, efficient windows, appliances and lighting
  - Green roofs – soil and vegetation roofs that help insulate a building
  - Superinsulation (uses 90% less energy) – air tight structures are heated/cooled mainly with sunlight, appliances and body heat

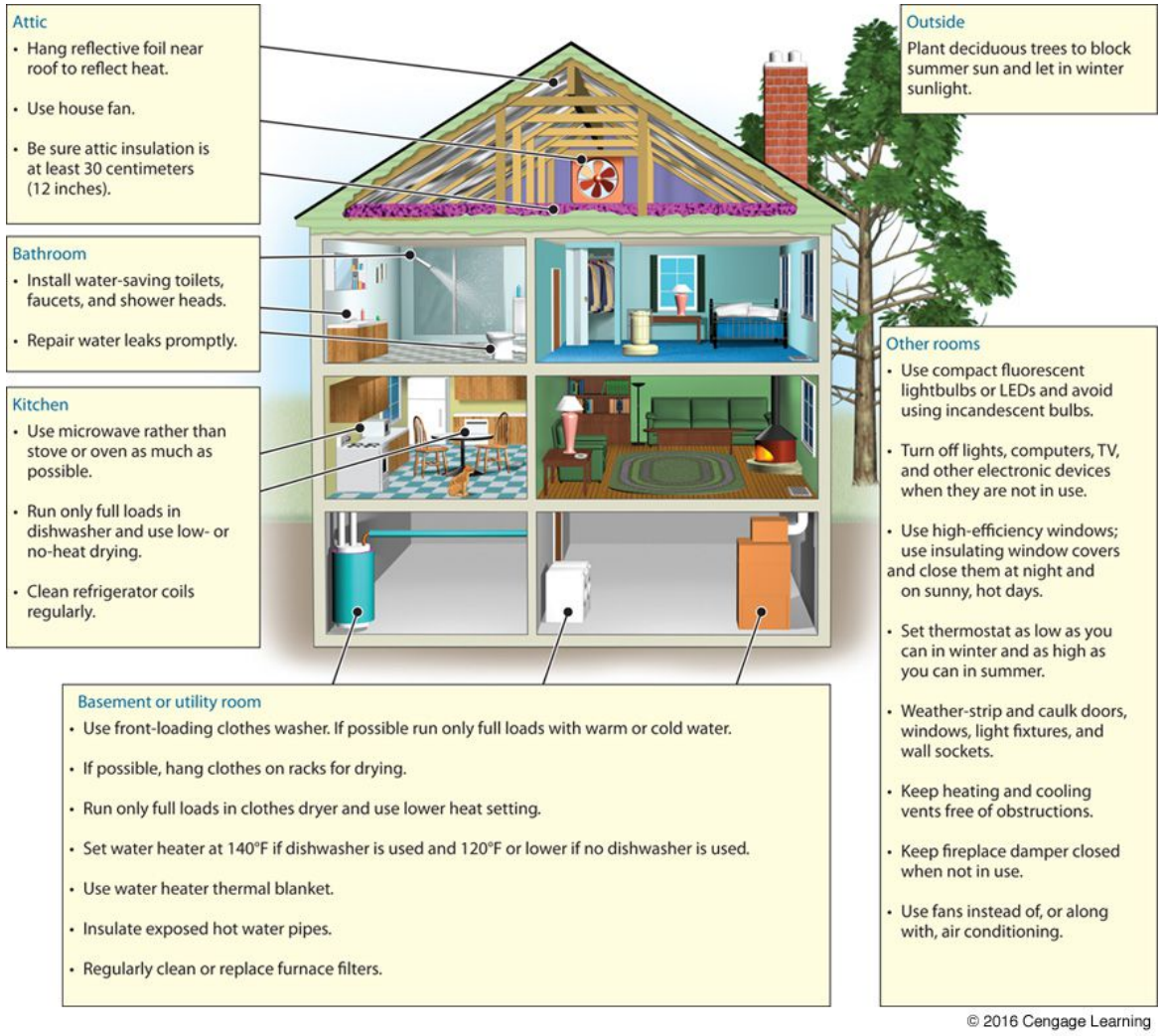
Improving Energy Efficiency in Existing Buildings

- To improve efficiency and save money:
  - Insulate buildings/plug leaks
  - Use superinsulation, geothermal heat pumps, and solar heating to heat buildings
  - Heat water more efficiently by using tankless hot water systems/energy saving appliances
  - Plug electrical devices into smart power strips and don't leave electronics in standby mode
  - Use energy-efficient computers and lighting

Why Are We Still Wasting Energy and Money?

- Fossil fuels are cheap, but violate full-cost pricing principle of sustainability
  - Few, if any, economic incentives for encouraging energy efficiency
  - Lack of public education about energy use
- Japan earthquake/tsunami closed nuclear plants – now Japan has replaced ½ its power use by conserving electricity!

You Can Save Energy and Money Where You Live



13.5 Advantages and Disadvantages of Using Renewable Energy

- Using renewable energy resources can meet our energy needs while reducing the effects on the environment – less pollution, greenhouse gas emissions, and biodiversity loss

Use of Renewable Energy

- Rely on renewable solar and geothermal energy – why are we not using more?
  - Government financial subsidies for research much less than those for fossil fuels
  - Subsidies must be renewed more often – resulting in political pressure possibilities
  - Free-market competition with fossil fuels does not include full-cost pricing
  - Transitioning from one type of fuel to another takes about 60 years

Heating and Cooling Buildings

- Heat buildings and water with solar energy
  - Passive (building absorbs heat directly)
  - Active solar heating (energy stored in rooftop solar collectors)
- Cool buildings
  - Plant trees for shade
  - Use light colored roofs to reflect heat and geothermal heat pumps to pump cool air from underground

Using Sunlight To Produce Heat and Electricity

- Solar cells convert sunlight to electrical energy (no pollutants/greenhouse gases)
  - May provide electricity to isolated areas of less-developed countries
  - Low to medium net energy yield, but efficiency technology is improving
  - May be the number one source of energy for the world by 2100

Electricity From Falling and Flowing Water

- Hydropower: use of (kinetic energy) falling or flowing water to generate electricity
  - Building dams, but sediment accumulates behind them and new systems need to be built – decomposing sediments can release greenhouse gases
  - Only 13% of hydropower potential developed
  - Microhydropower generators: portable floating turbines that can use a stream or river for power without altering the environment

Electricity and Wind Power

- Wind power has the potential to produce 40x the current global use of electricity
  - Onshore wind farms
  - Offshore wind farms
  - With subsidy support and smart grids, once in place Atlantic/Gulf Coast wind farms could generate more than enough electricity to replace all of U.S.'s coal fired power plants
  - Even with full-cost pricing, wind power is the least costly way to produce electricity

Conversion of Plants to Liquid Biofuels

- Biomass can be burned as a solid fuel
- Ethanol (from plants and plant wastes) and biodiesel (from vegetable oil) have advantages over gasoline
  - Biofuel crops grow anywhere and reduce dependence on imported oil
  - If used sustainably – no increase in CO_2 gas
  - Easy to store/transport, especially in cars

Geothermal Energy

- Heat stored in soil, underground rocks and fluids in the earth's mantle – can be used to heat/cool buildings and produce electricity – and captured by:
  - Geothermal heat pump systems
  - Hydrothermal reservoirs of geothermal energy
  - Hot, dry rocks deep underground

13.6 How Can We Make the Transition To a More Sustainable Energy Future?

- Dramatically improve energy efficiency
- Use a mix of renewable energy resources
- Adjust market prices to include environmental and health costs

Choosing Energy Paths

- Projections suggest:
  - During this century, there will probably be a gradual shift away from non-renewable fossil fuel use to a mix of renewable energy resources (solar, wind, hydro, geothermal)
    - Transition best made by improving energy efficiency and regulating the use of natural gas
  - As fossil fuels are abundant and artificially cheap, they will be used – the key is to reduce harmful environmental and health impacts

Additional Case Study: Green Energy – The Bloom Box

- The Bloom Box
  - A “power in a box” concept, introduced in 2010, can provide commercial, industrial enterprises, and homes with 24/7 electricity
  - Used natural gas-powered fuel cells made from baked sand and coated on each side with special ink
  - Used in tandem with an added oxidant – electrons move into the fuel cell’s circuitry to produce electricity

Additional Case Study: Green Energy – The Bloom Box

- The Bloom Box does not produce carbon emissions
  - Currently used by E-Bay, Google, Wal-mart, Staples and FEDEX
- In what important aspect do the bloom box and solar power differ?
- Do you think the Bloom Box is a potential electricity source for home use?
- Would you buy one for your home?

The Bloom Box and the Three Big Ideas

- What is the net energy yield?
- Along with direct/indirect solar, geothermal and biofuel usage, the Bloom Box could reduce pollution/greenhouse gases/ biodiversity losses
- Transitioning to a sustainable future requires increased energy efficiency as well as the research/development of new alternatives like the Bloom Box