Chapter 16—Energy Efficiency and Renewable Energy

Energy Conservation & Efficiency

- **Energy Conservation:** finding and implementing ways to use less energy
  - Some ways individuals can conserve energy include:
    - lowering household thermostat during cold months (using less energy to heat)
    - turning up household thermostat during summer months (using less energy to run AC)
    - Turning off computer when it is not being used
    - Consolidating errands to drive fewer miles
    - Carpooling or using public transportation
    - Replace energy wasting electric motors- Many old electric motors used to power machines and appliances run at full speed and are slowed down by a throttle (braking system); this is an unnecessary waste of energy. Modern *variable speed electric motors* run at a minimum speed necessary to complete the task and adjust speed as necessary.
  - Some ways governments can encourage/support energy conservation include:
    - Taxing, electricity oil and gas since higher taxes discourage use
    - Offer rebates and tax credits for individuals or companies that purchase energy efficient appliances
    - Tiered rate system: electric companies can use a tiered rate system in which customers pay a low rate for the first increment of electricity they use and pay higher rates as use goes up.
    - Reduce peak demand—Peak demand: the greatest quantity of energy used at any one time
      - To reduce peak demand energy companies can set up a variable pricing system in which customers pay lower rates during periods of low demand.
    - Cogeneration or combined heat and power (CHP)- In a CHP system two useful forms of energy (such as steam and electricity) are produced from the same source such as a coal-fired power plant. Rather than releasing the steam into the environment the steam can be piped into nearby buildings for heating.
- **Energy Efficiency:** The measure of how much work we can get from each unit of energy we use. In other words, a device or building that is energy-efficient uses relatively little energy to provide the power it needs.
  - **Lighting**- Modern changes in lighting are a good example of how steadily increasing energy efficiency results in overall energy conservation.
    - Compact fluorescent (CFL) lightbulbs use 1/4th as much energy to provide the same amount of light as incandescent bulbs.
    - LED (light emitting diodes) use 1/6th as much energy as incandescent.
    - Overtime the widespread transition to more efficient lightbulbs will lead to substantially less energy used to provide lighting.
  - **Appliances**- Modern appliances—such as dishwashers, clothes washers and dryers, refrigerators, etc.—that meet the standards for U.S. Environmental Protection Agency's Energy Star Program use less energy to do the same amount of work as less efficient machines.
    - For example, an Energy Star air conditioner may use 0.2 kilowatt-hours less electricity per hour than a non-Energy Star unit. If 100,000 households in a city switched to Energy Star air conditioners, the city would reduce its energy use by 20 MW, or 4-percent of the output of a typical plant.

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Sustainable Design

- Sustainable design can improve the efficiency of the buildings and communities in which we live and work.
- **Passive solar design**
  - Passive solar heating In the Northern Hemisphere constructing a house with windows along a south-facing wall allows the Sun's rays to penetrate and warm the house, especially in winter when the sun more prominent in the southern sky.
  - In the winter, when the Sun is low in the sky it shines directly into the windows and heats them house. In the summer, when the sun is higher in the sky, the roof overhang blocks incoming sunlight and the house stays cool.
  - Office building, schools, and business can build structures that in which each floor extends out over the one below it. This blocks out higher summer sun on each floor to reduce the need for cooling costs but allows the lower winter sun to help light and heat each floor during the day.
  - High-efficiency double-paned windows insulate while allowing solar radiation to warm the house.
  - Dark materials on the roof or exterior absorb more solar energy than light colored materials and can help to warm a structure, while light-colored materials reflect heat away keeping it cooler.
  - Windows, blinds, and skylights open and close as need to take advantage of natural light.
    - Duh! We can cool buildings naturally opening windows when cooler outside (night-time), then closing them when it is warmer (day-time); trapping the cold air inside. Oh, and fans also work to circulate air.
  - **Thermal mass**: a property of building material that allows it to maintain heat or cold. To reduce demand for heating at night and cooling during the day, builders can construct well-insulated structures consisting of materials with high thermal mass such as such as brick stone or concrete and orient them towards the south.
- **Active solar heating**
  - Captures energy from the sun by pumping a heat absorbing fluid (such as water or antifreeze solution) through solar collectors mounted on a roof or special racks to face the sun. The heated fluid can either be used to heat the home through radiators that heat the air, or to heat water for use in kitchens and bathrooms.
- **Green architecture**: Uses money saving, energy efficient designs, makes use of natural lighting, passive solar heating, solar cells, solar hot water heating, geothermal heat pumps, recycled waste-water, energy efficient appliances and lighting, and recycled building materials and insulation (denim, fly-ash, etc.)
  - **Green/living roofs**: A sustainable design in which buildings roofs have soil and growing plants. They help to cool and shade the building, improve overall air quality, and retain rainwater, which can then be used to recharge the ground water.
- **U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED)**
  - LEED Certification: Leadership in Energy and Environmental Design
  - Third-party certification program for design, operation and construction of high performance green buildings.
  - Awarded points for sustainability for things like energy-efficient lighting, low-flow plumbing fixtures and collection of water, recycled construction materials, energy efficient appliances, green roof
  - Commanding higher rental rates and great occupancy than the non-green buildings.
  - Bronze, Silver, Gold, Platinum

- **Existing buildings can be retrofitted to become more energy-efficient**
  - Conduct an energy survey
  - 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

Why are we still wasting so much energy and how can we shift to renewable energy?

- Traditional fossil fuel-based energy remains artificially cheap because of:
  - Government subsidies (in favor of fossil fuel-based energy)
  - Tax breaks (in favor of fossil fuel-based energy)
  - Fossil fuel-based energy prices don't include true cost
- Few large and long-lasting incentives to transition to energy efficiency and renewable energy such as:
  - Tax breaks
  - Rebates
  - Low-interest loans
- Renewable energy would become cheaper if we eliminate
  - Inequitable subsidies that are in favor of fossil fuel-based energy and replace them with subsidies for energy efficiency and renewable energy
  - The artificially low pricing of nonrenewable energy, fossil fuel-based energy makes them affordable while renewable energy is out-of-reach financially for the average consumer or small-business. Making pricing of renewable energy artificially low would have an immediate impact.

Smart Grid

- An increased reliance on renewable energy will means that energy will be produced in many locations and will need to be delivered to other locations.
- Our current, traditional energy distribution system—the grid—was not originally designed for this purpose.
- There are regions of the country that cannot supply enough generating capacity, while in other locations the electrical infrastructure cannot accommodate all the electricity that is generated.
- Smart grid: An efficient, self-regulating electricity distribution network that accepts any source of electricity and distributes it automatically to end users.
  - A smart grid is a departure from the traditional centralized system with one-main power plant per region.
  - Instead, ultra-high-voltage, super-efficient transmission lines would be responsive to local and regional changes in supply and demand.
  - Involves a two-way flow of energy and information between producers and users of electricity. Digitally controlled using "smart meters" to inform encourage consumers to use appliances during off-peak, less expensive periods; "smart" appliances could be equipped with times and programed to run at such times.
  - A smart grid system would consist of many small-scale electricity generation "parks" that rely on a mix of fossil fuel and renewable energy sources. Domestic energy supplies such as residential solar panels would be essential part of such a smart grid.
  - A decentralized system such as this would be flexible and reliable.

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CAFE Standards & Energy Efficient Vehicles

- Transportation accounts for 28% of energy consumption and two-thirds of the oil consumption in the United States.
- Fuel economy: The amount of gasoline or diesel fuel that a vehicle uses per mile; miles per gallon (MPG). → Examples:
    - 2018 Ford F-150 pickup truck MPG: Up to 20 city/26 highway
    - 2018 Subaru Impreza MPG: Up to 28 city/38 highway
    - 2018 Toyota Prius MPG: Up to 58 city/53 highway
- **CAFE Standards-** First enacted by Congress in 1975, the purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and light trucks.
- The CAFE standards are fleet-wide averages that must be achieved by each automaker for its car and truck fleet, each year, since 1978.
- When these standards are raised, automakers respond by creating a more fuel-efficient fleet, which improves our nation's energy security and saves consumers money at the pump, while also reducing greenhouse gas (GHG) emissions.
- **Passenger Car and Light Truck Standards for 2017 and beyond**
- In 2012, the U.S. Department of Transportation established final passenger car and light truck CAFE standards for model years 2017-2021, which the agency projects will require in model year 2021, on average, a combined fleet-wide fuel economy of 40.3-41.0 mpg.
- As part of the same rulemaking action, EPA issued GHG standards, which are harmonized with USDOT's fuel economy standards that are projected to require 163 grams/mile of carbon dioxide (CO_2) in model year 2025.

- **How to encourage energy efficient vehicles**
    - The hidden cost of gasoline: **Subsidies** (payments intended to help businesses survive and thrive) and **tax breaks** for oil companies reduce the real cost of gasoline. The true cost of gasoline or full cost pricing would include externalities such as the cost of pollution control and cleanup, medical bills and higher health care premiums resulting from pollution related health problems.
    - One way to include the true cost of gasoline would be to include gasoline taxes, while reducing payroll taxes; e.g. carbon tax. This would discourage over consumption.
    - A way for governments to encourage efficient vehicles and fuel conservation is to incentivize purchasing fuel-efficient vehicle such as hybrid electric cars. This could be achieved by offering tax credits to people who purchase hybrid electric or electric cars.
    - Revenue to offset tax credits could be generated through a "gas-guzzler" tax or a tax or *fee* on in-efficient vehicles that goes into a fund for tax credit of *rebates* for to people who purchase hybrid electric or electric cars; e.g. this has been referred to a as a "*fee-bate"*.
    - Hidden prices in gasoline: $12/gallon
    - Car manufacturers and oil companies lobby to prevent laws to raise fuel taxes

Energy-Efficient Vehicles

- To meet a person's transportation needs, any car should be able to drive at least 300 miles between refueling, be refueled quickly and easily, and keep up with other traffic on the road.
- A gasoline-powered *internal combustion engine* (ICE) meets these requirements, but produces relatively large amounts of pollution and gets generally poor gas mileage; 1-gallon of gasoline weighs 6 pounds and when burned emits the carbon combines with oxygen from the air to produce nearly 20 pounds of carbon dioxide.

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- **Gasoline hybrid-electric cars (HEV)**
  - The Toyota Prius, the world's most popular hybrid car, uses a combination of an internal combustion engine and a battery electric drive system to increase fuel economy and reduce emissions.
  - When pulling away from a stop, the electric motor powers the car, drawing on the battery for power. Up to 15 mph, the vehicle uses only the electrical motor for power. This is one of the reasons why hybrids are more efficient during city driving than on the highway.
  - During normal cruising only the gasoline engine is used because this is when it is most efficient. During cruising, the gasoline engine can also power the generator, which produces electricity and stores it in the batteries for later use.
  - During heavy acceleration both the gasoline engine and the electric motor work together to increase power to the wheels. The joint effort of the engine and motor working together is only possible because of the power-split transmission, which combines the torque that each one puts out. At this time, the gasoline engine also powers the generator. The electric motor uses electricity from the battery and the generator as needed.
  - The Prius reaches 51 mpg in the city and 48 mpg on the highway (combined gas/electric motor). Emits 65% less CO_2 per kilometer than a comparable conventional ICE car emits.
  - With a full fuel tank (11.9 gallons) the Toyota Prius can travel 571 miles.

- **Plugin gasoline hybrid-electric cars**
  - A hybrid with a second more powerful battery that can be plugged into an electrical outlet and recharged.
  - By running primarily on electricity plugin hybrids
  - 95 miles per gallon combined city/highway + combined gas/electric motor
  - With a full fuel tank (11.3 gallons) and a fully-charged battery, the Prius plug-in hybrid can cover up to 640 miles.
- **Electric Cars i.e. battery electric vehicles (BEV)**
  - An electric car is an automobile that is propelled only by an electric motor and using electrical energy stored in batteries.
  - Electric cars produce no emissions as they operate, but they still rely on electricity, which is often produced by coal-fired power plants to recharge the battery.
  - Electric cars are significantly more expensive than ICE’s and HEV’s due to the additional cost of their lithium-ion battery pack.
  - Also, they lack of recharging stations and driver’s fear of running out of energy before reaching their destination discourages many prospective buyers.
  - A 2018 Nissan LEAF costs $29,990 and can travel 151 miles on a fully charged 40 kWh lithium-ion battery.
  - According to a blog, a Nissan LEAF’s lithium-ion battery’s lifespan is about 100,000 miles and cost as much as $8,000 to replace.
  - **Battery Challenges & Environmental Impacts**
    - To bring electric cars to mass market battery capacity must by increased and cost of lithium-ion batteries must be decreased.
    - Mining lithium has significant environmental impacts.
    - Additionally, depleted batteries pose a waste disposal problem because they contain hazardous toxic materials.

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Solar Power

- **Passive solar**: As discussed previously, passive solar applications include positioning windows on south facing walls to admit solar radiation in winter, covering buildings with dark material in order to absorb the maximum amount of heat.
    - **Solar cookers/ovens**: A cooking device that uses reflective surfaces to concentrate sunlight for cooking food or sterilizing water. Useful in un-developed countries where fuel wood depletion and deforestation are problematic; also, where clean drinking water is scarce.
- **Active solar**
    - **Solar water heating systems**: When a solar water heating system is used in a house, non-freezing liquid is circulated by an electric pump through a closed loop of pipes. The circulating liquid moves from a water storage tank to a solar collector on the roof, where it is heated, and then sent back to the tank, where a heat exchanger transfers the heat to water.
- **Solar power to produce electricity**
    - **Concentrated solar power (CSP); a.k.a. concentrated solar thermal**
        - Uses lenses or curved parabolic mirrors to focus sunlight shining on a large area into a small beam. The heat of the concentrated beam is directed to a central receiver "power tower" and used to evaporate water or other liquid to produce steam that turns a turbine to generate electricity.
        - Require large amounts of water which is scarce in arid desert area where CSP is possible.
        - Excess heat generated during the day can be stored in *molten salt* and used to evaporate water, to create steam and turn turbines to generate electricity *at night*.

    CSP solar power plant
        - The Ivanpah Solar Electric Generating System is a concentrated solar thermal plant in the Mojave Desert. It is located at the base of Clark Mountain in California, across the state line from Primm, Nevada. The plant has a gross capacity of 392 megawatts (MW) and was connected to the electrical grid in September 2013; the facility formally opened on February 13, 2014; at the time it was the world's largest solar thermal power station.

Trade-Offs **Concentrated solar power (CSP)**	
Advantages No direct CO_2 emissions or other air pollutants! Where sunlight is abundant electricity too, will be abundant!	**Disadvantages** Habitat disruption/fragmentation; large amount of land required. – Desert tortoise (endangered species) Birds are killed by concentrated light beam. Needs backup or energy storage system for cloudy days/nighttime. High costs and low net energy

- **Photovoltaic systems (PV); a.k.a. solar cells or solar panels**
    - Solar panels are made of materials called semi-conductors such as silicon, monocrystalline silicon, and gallium sulfide. These materials can transfer the Sun's energy to electricity and conduct electricity at relatively low temperature.
    - Electromagnetic radiation from the sun consists, in large part, of energized particles called *photons*. Photons strike the semi-conductor material in the solar panel and excite electrons in the material causing the flow of electrons through the material; i.e. a direct electric current.
    - The electric current is then amplified and converted to an alternating current and allowed to flow into the electric grid system or into residential or commercial electrical systems.
    - Solar panels can be mounted on rooftops to provide electricity for residential or commercial use, arranged in large arrays to collect electricity on an industrial scale to create a solar cell power plant.

PV solar power plant

- Mesquite Solar 1 is a 150MW solar power plant located at Maricopa county of Arizona, US. The plant commenced operations in January 2013. It is expandable, up to 700MW capacity, making it the largest photovoltaic solar power plant in North America when complete.
- The plant is owned by Sempra US Gas & Power and developed by Zachry Holdings. The investment on the first phase of the plant was $600m.
- The plant currently generates 350GWh of electricity, which is sufficient to supply for 56,000 households and offset approximately 200,000t of greenhouse gas emissions per year.

- **Challenges**
  - High cost, but price is coming down with increased mass production (mainly in China).
  - As government *subsidies and tax breaks* increase for solar panel manufacturers and consumers this energy technology will become more accessible and widespread.
  - Cost is also coming down as engineers and scientists seek and develop cheaper and more efficient photovoltaic materials and systems.
  - Semi-conductor materials, such as silicon and gallium must be mined from the earth and therefore have an environmental impact.
  - Manufacturing PV cells requires a great deal of water and energy and involves a variety of toxic metals and industrial chemicals that can be released into the environment during the manufacturing process, although newer types of solar panels may reduce reliance on toxic materials.
  - The end-of-life reclamation and recycling of PV cells is another potential source of contamination, particularly if cells are not recycled properly. However, engineers and scientists are working to extend the life of solar panels to as much as 50-years, which will significantly reduce this problem.
- **Nanosolar**: Eventually, production is likely to grow for thin-film nanotechnology solar cells and become cheap enough to compete with other forms of energy generation and perhaps make conventional solar panels obsolete.
  - Imagine your *electric car* covered with a nanosolar coating! Your car could, possibly, charge anytime, if it were sunny...you could drive forever! Maybe not forever be think of the possibilities. Imagine if buildings and roads were coated with nanosolar material! Wow!

Trade-Offs **Photovoltaic (PV) solar power**	
Advantages	**Disadvantages**
Moderate net energy yield No direct emissions of CO_2 and other air pollutants! Easy to install, move, and expand as needed. Competitive cost as new technology is developed and mass produced	Need access to sun Need electricity storage backup system Traditionally high cost, but that is changing Solar cell power plants could disrupt desert ecosystems

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Wind Power

- Wind is an indirect form of solar energy. Wind is the result of the unequal heating of the Earth's surface by the Sun. Warmer, less dense air rises, and cooler denser air sinks creating circulation patterns that result in the surface flow of air that we call wind.
- **Generating electricity from the wind**: A wind turbine converts the kinetic energy of moving air into electricity. Wind turns the blades of the wind turbine and the blades transfer energy to a gearbox that in turn transfers energy to a generator that generates electricity.
- A modern wind turbine may sit on a tower as tall as 330 feet and have blades 130-250 feet long.
- Under average wind conditions, a wind turbine on land might produce electricity 25 percent of the time. While spinning, it might produce 2-3 MW and, in a year, it might produce 4.4 million kWh of electricity, enough to supply more than 400 homes.
- Offshore wind turbines are even more desirable for electricity generation because the wind blows up to 35 percent of the time and can be built much larger. Offshore wind parks, which are clusters of wind turbines, are operating in Denmark, the Netherlands, Sweden, and elsewhere. A project—consisting of 130 wind turbines with the potential to produce up to 420 MW of electricity, 75% of the areas use—has been proposed off Cape Cod in Nantucket sound.
- The United States has astounding potential for wind power and has been called the "Saudi Arabia of wind power"; due to the wind potential in the states of North Dakota, South Dakota, Kansas, and Texas.
- Despite its large generating capacity, the U.S. generated only about 6 percent of its electricity from wind in 2016.
- Wind energy is nondepletable and once installed, wind turbines produce no pollution/greenhouse gases.
- Unlike solar power plants which disrupt large amounts of land, wind farms can share the land for other uses, such as cattle grazing and ranchers are paid royalties, as much as $10,000 per year per turbine, by utility companies.
- Developing the wind power industry in the U.S. could create up to 500,000 jobs.
- **Drawbacks**
  - Windy areas may be often remote and sparsely populated. Thus, the need to develop grid system to transfer electricity to urban centers where greater electricity demand exists.
  - It's not windy all the time; back-up energy sources and energy storage capacity must to be developed.
  - Wind turbines kill birds, however statistically they kill fewer birds annually, than housecats and automobiles. Plus, scientists have extensively researched migratory bird pathways and are being careful not to plan new wind power development in these areas. Additionally turbines are being designed to be less lethal to birds.
  - **"Not in my backyard"**- Many people regard wind turbines and electricity transmission lines as unsightly or ugly. Plus, wind turbines are noisy.
  - Construction of roads to access wind turbines disturb and fragment habitat.
  - **Good news**: Offshore wind parks solve many of these problems and generate more electricity than land-based wind farms.

Trade-Offs **Wind power**	
Advantages Moderate to high net energy yield Widely available Low electricity cost Little or no direct emissions of CO_2 and other air pollutants Easy to build and expand	**Disadvantages** Needs backup or storage system when winds die down Visual pollution for some people Low-level noise bothers some people Can kill birds if not properly designed and located

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Biomass & Biofuels

- All fossil fuels and most renewable energy sources ultimately come from the sun. Fossil fuels, biomass, and biofuels are all the product of photosynthesis. Fossil fuels were formed from the rapid burial of plants and phytoplankton millions of years ago. Whereas, biomass and biofuels were formed from plants very recently.
- **Biomass** energy resources are mostly used directly as a fuel for heating and cooking; wood. charcoal, and manure.
- **Biofuels** are liquid fuels that are made from plants—ethanol and biodiesel—that are used as gasoline substitutes to power automobiles.
- Like fossil fuels, biomass contains a great deal of carbon, and burning it releases carbon into the atmosphere.
- The carbon growing in plants today was in the atmosphere in the form of carbon dioxide until recently when it was incorporated into the bodies of plants through photosynthesis.
- <u>Modern carbon</u>: Carbon in plants that was recently in the atmosphere.
- <u>Fossil carbon</u>: Carbon in fossil fuels.
- Unlike modern carbon, fossil carbon has been buried for millions of years. Fossil carbon is carbon that was out of circulation until humans discovered it. The burning of fossil fuels results in a rapid increase in atmospheric CO_2 concentrations because we are unlocking or releasing stored carbon that was last in the atmosphere millions of years ago.
- *In theory,* the burning of biomass (modern carbon) should not result in a net increase in atmospheric CO_2 concentrations because we are returning carbon to the atmosphere, where it had been until recently. *And,* if we allow vegetation to grow back in areas where biomass was recently harvested, that new vegetation will take up the amount of CO_2 more or less equal to the amount we released earlier by burning the biomass.
- Over time, the net concentration in atmospheric CO_2 should be zero. An activity that does not change atmospheric CO_2 concentrations is referred to as carbon neutral.
- **Biomass: wood, charcoal, and manure**
  - Biomass is plant materials and animal waste and is burned mostly for heating and cooking, but also for industrial processes and generating electricity.
  - Throughout the world, 2 billion to 3 billion people rely on wood for heating and cooking.
  - **Wood;** *<u>Fuelwood crisis and increasing atmospheric</u>* CO_2. Removing more timber (wood/trees) than is replaced by growth, or net removal, is an unsustainable practice that leads to deforestation. This net removal of forest together with the burning of wood results in a net increase in atmospheric CO_2. The CO_2 released from burned wood is not balanced by photosynthetic carbon fixation that would occur in new tree growth.
  - To address the problem of deforestation and fuelwood depletion in developing countries, biomass plantations, where fast-growing trees are cultivated for fuel wood, have been developed. Draw backs to biomass plantations are: reduced biodiversity, introduction of invasive species, and intensive cultivation often results in depletion of soil nutrients.
  - **Charcoal**: A black carbon-based cooking fuel that is made mostly from burning wood from trees in a low oxygen environment such as a kiln.
  - Many people in the developing world make, sell, and use charcoal. Charcoal is a superior fuel because it is lighter than wood and contains approximately twice as much energy per unit of weight. A charcoal fire produces less smoke and does not need to be tended as much as a wood fire. For those that can afford charcoal, it is the fuel of choice in the developing world.
  - **Unfortunately**, harvesters who clear land for charcoal production often leave it almost completely devoid of trees. Plus, often burned indoors in poorly ventilated rooms.

- **Animal manure:** In regions where wood is scarce, such as parts of Africa and India, people often use dried animal manure as a fuel for indoor heating and cooking.
- Burning manure releases particulate matter and other pollutants into the air that cause a variety of respiratory illnesses, from emphysema to cancer (as well as, carbon monoxide, CO, and nitrogen oxides, NO_x).
- The problem is exacerbated when the manure is burned indoors in poorly ventilated rooms, a common situation in developing countries. The World Health Organization estimates that indoor air pollution is responsible for nearly 2 million deaths annually.

Trade-Offs **Biomass**	
Advantages	**Disadvantages**
Widely available in some areas Moderate costs No net CO_2 increase if harvested, burned, and replanted sustainably Plantations can help restore degraded land	Moderate to high environmental impact Increases CO_2 emissions if harvested and burned unsustainably Clear cutting can cause soil erosion, water pollution, and loss of wildlife habitat Often burned in inefficient and polluting open fires and stoves

- **Biofuels: Ethanol and Biodiesel**
- The liquid biofuels—ethanol and biodiesel—can be substitutes for gasoline and diesel, respectively.
- ***Ethanol*** is an alcohol made by converting starches and sugars (fermentation) from plant material into alcohol and carbon dioxide. More than 90 percent of ethanol produced in the United States comes from corn and corn byproducts, although ethanol can be produced from sugarcane, wood chips, crop waste, or switchgrass.
- ***Biodiesel***, is a diesel substitute produced by extracting and chemically altering oil from plants, is a substitute for regular petroleum diesel. It is usually produced by extracting oil from algae and plants such as soybean and palm oil.
- The biggest producers of *biofuel* are: The United States, Brazil, The European Union, and China.
  - **Biodiesel**- Biodiesel is produced from vegetable oil from various sources, including: soybeans, rapeseed, sunflower seeds, and oil palms to name a few. It can also be made from vegetable oil leftover from restaurants.
  - *Reduced CO_2 emissions*: About 22.4 pounds of CO_2 are produced from burning a gallon of *diesel* fuel. B20 is a commonly sold biodiesel fuel. B20 contains 20% biodiesel and 80% petroleum diesel fuel. Burning a gallon of B20 results in the emission of about 17.9 pounds of CO_2 that is emitted from the fossil fuel.
  - The European Union (E.U.) produces 95% of the world's biodiesel. Half of the cars and trucks in the E.U. run on diesel fuel. Much of the E.U.'s biodiesel is produced from rapeseed and sunflower seeds.
  - However, a rapidly growing amount is being produced from palm oil that is imported from Brazil, Malaysia, and Indonesia. Increased burning and clearing of tropical forests for palm oil plantations poses a serious threat to biodiversity through habitat disruption and fragmentation.
  - Clearing tropical rainforests to grow oil palms reduces CO_2 uptake
  - The net energy yield for biodiesel from palm oil is five times that from rapeseeds used in Europe and eight times higher than the yield from soybeans in the United States.

- Subsidies are promoting rapid growth of biodiesel production in United States, which depends largely on soybean and rapeseed production. This requires huge land area and cultivation typically has low yields. Also, industrialized agriculture results in topsoil loss and fertilizer runoff.

Trade-Offs **Biodiesel**	
Advantages	**Disadvantages**
Reduced CO and CO_2 emissions	Increased NO_x emissions and smog
High net energy yield for palm crops	Low net energy yield for soybean crops
Reduced hydrocarbon emissions	Competes with food for cropland
Better mileage (up to 40%)	Clearing natural areas for plantations reduces biodiversity and increases atmospheric CO_2 levels

- **Ethanol**- Ethanol can be made from plants such as sugarcane, corn, and switchgrass, and from agricultural, forestry and municipal waste. It is an is an alcohol made by converting starches and sugars (fermentation) from plants.
- Brazil is the world's second largest producer of ethanol after the United States.
- Brazil makes its ethanol from bagasse a byproduct of sugarcane production. Ethanol from bagasse (sugarcane) yields 8 times the amount of energy used to produce it, compared with a net energy yield of 5 for gasoline.
- To free itself of the need to import foreign oil, Brazil plans to expand cultivation of sugarcane into the Cerrado, a wooded-grassland and biodiversity hotspot.
- Environmental consequences: producing ethanol requires large amounts of water and water runoff from sugarcane plantations contains large amounts of fertilizers, herbicides, and pesticides. Additionally, replacing habitat with monoculture sugarcane plantations leads to loss of biodiversity through habitat disruption and fragmentation.
- In the United States, most ethanol is made from corn. Ethanol from corn has a low net energy yield because of corn is a product of fossil-fuel dependent industrialized agriculture. A net energy yield of 1.1-1.5 units of energy per unit of fossil fuel input.
- About 19.6 pounds of CO_2 are produced from burning a gallon of gasoline and about 12.7 pounds of CO_2 are produced when a gallon of pure ethanol is combusted.
- Cars running on E85 fuel (85% ethanol and 15% gasoline get 30% lower gas mileage compared to 100% gasoline, which means they need to burn more fuel.
- Traditionally, the United States has supplied about 75% of the world's corn. Increased demand for corn-based ethanol accounted for a 10-15% rise in food prices between 2007 and 2011.
- **Cellulosic ethanol**: An alternative to ethanol from corn and sugarcane is produced from cellulose the material that makes up the cell walls of plants. With this process, cellulose in leaves, stalks, husks, and wood chips can be broken down by enzymes into sugars that can be used to produce ethanol.
- ***Switchgrass*** is a tall, perennial (doesn't need to be replanted every year) plant that grows faster than corn, is disease resistant and drought tolerant (requires much less water) and can be grown without the use of nitrogen fertilizers on land that is unfit for other crops.
- Using switchgrass to produce ethanol yields about 5.4 times as much energy as it takes to grow it.
- **However**, it is difficult and costly to breakdown cellulose and extract the sugar needed to produce ethanol.

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Trade-Offs **Ethanol**	
Advantages Some reduction in CO_2 emissions (sugarcane bagasse) High net energy yield (bagasse and switchgrass) Potentially renewable	**Disadvantages** Low net energy yield (corn) and higher cost Higher CO_2 emissions (corn) Corn ethanol competes with food crops and may raise food prices

- **Biofuel from algae**
  - Algae can be converted into various types of fuels. As they grow algae remove CO_2 from the atmosphere and convert it to lipids (oil). The lipid, or oily part of the algae biomass can be extracted and converted into biodiesel through a process similar to that used for any other vegetable oil.
  - The carbohydrate content of algae can be fermented into bioethanol fuel.
  - Biofuels from algae require much less land, water, and other resources than biofuel cropland plantations and do not compete for cropland or affect food prices.
  - Algae can be cultivated using wastewater or even in sewage treatment plants.
  - Additionally, coal-fired power plants could transfer CO_2 from coal combustion to algae ponds.
  - Producing fuels from algae and bacteria can be done almost anywhere
  - **Challenges**: currently very high costs, research and development is needed to determine if open ponds or bioreactors are more feasible, current methods of extracting oil are time consuming and expensive; must develop methods to scale-up to large production

Chapter 16—Energy Efficiency and Renewable Energy

Hydropower

- Hydroelectricity accounts for 7 percent of electricity generation in the United States. More than one-half of that electricity is generated in three states: Washington, California, and Oregon. Worldwide, nearly 20 percent of all electricity comes from hydroelectricity, with China the leading producer, followed by Brazil, Canada, and the United States.
- A hydroelectric power plant captures the kinetic energy of moving water and uses it to spin a turbine that turns a generator to produce electricity.
- **Types of hydroelectricity: run-of-the-river systems, tidal systems, & water impoundment systems**
    - *Run of the river systems*: Hydroelectricity generation in which water is retained behind a low dam and the river water is partially diverted and channeled into a conduit with turbine generators and then allowed to flow back into the river.
        - Advantages: Relatively little flooding upstream, seasonal changes in river flow are generally not disrupted.
        - Disadvantages: Since they are generally small and rely on natural water flows electricity generation can fluctuate and the system cannot generate an electricity in hot, dry periods when water flow is low.
    - *Tidal systems*: hydroelectric power that comes from the movement of water driven by the gravitational pull of the moon.
        - Tidal systems use gates and turbines to capture kinetic energy of flowing water through estuaries, rivers, and bays and convert this energy to electricity.
        - Tidal systems do not have the potential to become a major energy source because in many places the difference between high and low tide is not great enough to provide the volume of moving water required to generate sufficient amounts of electricity.
        - La Rance, on the northern coast of France and Nova Scotia's Bay of Fundy both have operational tidal systems.
        - Disadvantages: few suitable sites, high costs, equipment damaged by storms and corrosion
    - ***Water impoundment Systems a.k.a. hydroelectric dams***:
        - Water impoundment: The storage of water in a reservoir behind a dam.
        - The amount of electricity that can be generated depends on the flow rate, the vertical distance the water falls, or both. The amount of electricity generated depends on vertical distance the water falls; the greater the distance, the more potential energy the water has and the more electricity it can generate. The flow rate is the amount of water that flows past a certain point per unit of time. The greater the flow rate the more electricity can be generated. The larger the reservoir and the taller the dam the more potential energy exists for electricity generation.
        - By managing the flow of water from the reservoir and into the conduits that flow through to turbines hydroelectric dam operators can control the flow rate of water that turns the turbine and in turn the generator; and thereby the amount of electricity that is produced.
        - Water impoundment or hydroelectric dams are the most common type hydroelectricity generation because it usually allows for the generation of electricity on demand.
        - **Grand Coulee Dam, Washington State, Estados Unidos-** The largest hydroelectric water impoundment dam in the United States; generates 6,800 MW at peak capacity.
        - **The Three Gorges Dam on the Yangtze River, China-** The largest dam in the world and at capacity can generate 18,000 MW and can generate almost 85 billion kWh per year, approximately 11 percent of China's total electricity demand.

- **Hydroelectricity and sustainability**
  - Major hydroelectric dam projects have brought electricity to large numbers of rural residents in many countries, including the United States, Canada, India, China, Brazil, and Egypt.
  - Hydroelectric dams are expensive to build, but once built they require a minimum amount of fossil fuel for operation.
  - In general, the benefits of water impoundment hydroelectric systems are great: They generate large quantities of electricity without producing air pollution, waste products, or CO_2 emissions. Electricity from hydroelectric dams is generally inexpensive and ranges from 5 to 11 cents per kilowatt-hour.
  - In addition, the reservoir behind the dam can provide recreational and economic opportunities as well as downstream flood control for flood-prone areas. Lake Powell, the reservoir impounded by the hydroelectric Glen Canyon Dam, draws more than 2.5 million visitors a year and generates more than $400 million annually for local and regional economies in Arizona and Utah.
  - ***However,*** hydroelectric dams do have negative consequences. By building a dam and creating a reservoir a free-flowing river is significantly altered. The reservoir may flood hundreds or thousands of hectares of prime agricultural land, or areas with great aesthetic or archaeological value, and may force people to relocate.
    - The Three Gorges Dam displaced more than 1.3 million people and submerged ancient cultural and archaeological sites as well as large areas of farmland.
  - Impounding the flow of a river in this way may also make it unsuitable for organisms or recreational activities that depend on a free-flowing river.
    - Large reservoirs of standing water hold more heat and contain less dissolved oxygen than do free-flowing rivers, thereby affecting which species can survive in the waters. Certain human parasites also become more abundant in impounded water in tropical regions.
  - Dams also alter the flow of water downstream. Some rivers have sandbars created during period of low flow that follow periods of flooding. Species of plants, such as cottonwood trees, cannot reproduce in the absence of these sandbars.
  - The life cycles of certain aquatic species such as salmon, certain trout species, and freshwater clams and mussels, also depend on seasonal variation in water flow.
    - Fish ladders can be installed to allow migrating fish to travel back upstream; however, some fish fail to use them and they are more vulnerable to predators, such aa bears, while in the fish ladders.
  - Other environmental consequences of hydroelectric dams include the release of greenhouse gases to the atmosphere, both during construction and after filling the reservoir.
    - Production of cement—a major component of dams—is responsible for 5 percent of global anthropogenic CO_2 emissions to the atmosphere.
    - Was the dam is completed, the impoundment usually covers forests or grasslands. The dead plants and organic materials in the flooded soils decompose anaerobically and release methane, a potent greenhouse gas.
    - A fast-moving river carries sediments that settle out when the river feeds into the reservoir. The accumulation of these sediments on the bottom of the reservoir is known as siltation.
    - Overtime, the reservoir fills up with sediment and it must be removed by dredging and the generating capacity and lifespan of the dam is reduced. Additionally, this sediments are also crucial as nutrients and the physical base of downstream ecosystems such as floodplain wetlands and estuaries.

- **Aswan High Dam (Egypt),** was built in the 1960's to provide flood control and irrigation water for the lower Nile basin and electricity for Cairo and other parts of Egypt (one-third of Egypt's electricity production). The silt that made the Nile region fertile settled in the reservoir, causing the gradual decrease in the fertility of agricultural lands in the Nile delta. Also, the parasitic disease schistosomiasis thrives in the stagnant water of the reservoir. The reduction of waterborne nutrients flowing into the Mediterranean is suspected to be the cause of a decline in anchovy populations in the eastern Mediterranean. The end of flooding has sharply reduced the number of fish in the Nile, many of which were migratory.

- **Pumped-storage hydroelectricity**
  - Pumped-storage hydroelectricity (PSH), or pumped hydroelectric energy storage (PHES), is a type energy storage. By pumping water from a lower elevation reservoir to a higher elevation reservoir energy is being stored in the for of gravitational potential energy. When electricity is in demand, the stored water is released through turbines to produce electric power. Pumped-storage hydroelectricity has potential to store surplus energy from intermittent sources, such as solar and wind power. When the wind is blowing and the sun is shining water can be pumped uphill and when the wind dies down or at night the stored water can then be released through turbines to produce electric power.

Geothermal

- ***Geothermal heat pump systems*** can heat or cool a house by taking advantage of the temperature difference between the air at the Earth's surface and the soil underground; at a depth of 10-20 feet where the temperature is 50-60 °F year-round.
  - In winter a closed-loop of buried pipes pumps fluid, which as it circulates, extracts heat from the ground and carries it to a heat exchanger that transfers the heat to the homes heating and cooling distribution/ventilation system. In the summer the system works in reverse, bringing cooler air from underground, which removes the heat from the home.
  - Since geothermal heat pumps heat and cool the home to levels just above or below comfortable room temperature (50-60 °F) a heating and cooling system is usually still need in the home, however energy and financial savings are substantial.
  - According to the EPA, a well-designed geothermal heat pump system is the most energy efficient, reliable, environmentally clean, and cost-effective way to heat or cool a home.
- **Geothermal energy**: We can tap into Earth's geothermal energy by drilling wells to extract dry steam (steam with a low water content), wet steam (steam with a high-water content), or hot water, which is then used to heat homes and buildings, provide hot water, or spin turbines to produce electricity.
- The most widely developed type of geothermal power plant (known as hydrothermal plants) are located near geologic "hot spots" where hot molten rock is close to the earth's crust and produces hot water and steam.
- Iceland currently produces about 25 percent of its electricity using geothermal energy. In the United States, geothermal energy accounts for about 2 percent of the renewable energy used. Geothermal power plants are currently operational in California, Nevada, New Mexico, Oregon, Hawaii, & Utah.

- Environmental impact of hydrothermal plants: The distinction between open- and closed-loop systems is important with respect to air emissions water use and quality. In open-loop systems in which water and air are not reinjected, some pollution and waste does occur.
- Open-loop systems emit hydrogen sulfide, carbon dioxide, ammonia, methane, and boron. Hydrogen sulfide, which has a distinctive "rotten egg" smell, is the most common emission.
- Once in the atmosphere, hydrogen sulfide changes into sulfur dioxide (SO_2) and can react with water to form sulfuric acid, and acid rain.
- Also, open-loop systems can produce a watery sludge or brine composed of the captured materials, including sulfur, vanadium, silica compounds, chlorides, arsenic, mercury, nickel, and other heavy metals. This mineralized geothermal brine and toxic sludge contains **corrosive** salts and heavy metals that require disposal at hazardous waste sites or chemical processing to remove select materials for use as a valuable raw material in several industrial processes.

Hydrogen

- Free hydrogen gas is relatively rare in the atmosphere, hydrogen tends to bond with other molecules forming water (H_2O) and methane (CH_4). Producing hydrogen requires separating it from these compounds which requires electricity.
- Electrolysis: The application of an electric current to water molecules to split them apart into hydrogen and oxygen.
- Note: pure hydrogen gas is extremely explosive.
- In this way, hydrogen gas is not an energy resource like coal or oil. It is a fuel produced using other forms of energy, and therefore has a *negative net energy yield*.
- However, if hydrogen gas were produced using renewable, non-carbon emitting technologies it could be a viable energy fuel.
- Hydrogen fuel is not burned to yield energy, rather it is run through a *fuel cell* which generates electricity.
- A fuel cell is an electro-chemical device that converts a fuel, such as hydrogen, into an electric current.
- In a hydrogen fuel cell, hydrogen is passed through a membrane that separates the hydrogen atoms electrons from their protons. The electrons flow through wires to produce an electric current. On the other side of the membrane the reduced hydrogen atom bonds with atmospheric oxygen to form water. So, in this way, a hydrogen fuel cell is pollution free. It just depends on how the hydrogen gas was formed, making hydrogen gas with electricity from coal-fired power plants would be just plain stupid.
- ***Here's the thing!*** Renewable energy sources such as wind and solar cannot produce electricity constantly, but the electricity they produce can be used to generate hydrogen, which can be stored until it is needed. Thus, if we could generate electricity for electrolysis using a clean, nondepletable energy source such as wind or solar energy, hydrogen could be a sustainable energy carrier.

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Sustainable Energy Future

Solutions

Making the Transition to a More Sustainable Energy Future

Improve Energy Efficiency

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

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

Reward utilities for reducing demand for electricity

Greatly increase energy efficiency research and development

More Renewable Energy

Greatly increase use of renewable energy

Provide large subsidies and tax credits for use of renewable energy

Greatly increase renewable energy research and development

Reduce Pollution and Health Risk

Phase out coal subsidies and tax breaks

Levy taxes on coal and oil use

Phase out nuclear power subsidies, tax breaks, and loan guarantees

What Can You Do?

Shifting to More Sustainable Energy Use

- Get an energy audit done for your house or office
- Drive a vehicle 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 heating and cooling systems, 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