6.4 HYDROELECTRIC POWER AND ENERGY FROM BIOMASS

College Board Topics 6.7 and 6.9

Related Reading: Chapter 20

Learning Objectives and Essential Knowledge

ENDURING UNDERSTANDING

ENG-3

Humans use energy from a variety of sources, resulting in positive and negative consequences.

LEARNING OBJECTIVE

ENG-3.I

Describe the effects of the use of biomass in power generation on the environment.

SUGGESTED SKILL

Environmental Solutions

7.B

Describe potential responses or approaches to environmental problems.

ESSENTIAL KNOWLEDGE

ENG-3.I.1

Burning of biomass produces heat for energy at a relatively low cost, but it also produces carbon dioxide, carbon monoxide, nitrogen oxides, particulates, and volatile organic compounds. The overharvesting of trees for fuel also causes deforestation.

ENG-3.I.2

Ethanol can be used as a substitute for gasoline. Burning ethanol does not introduce additional carbon into the atmosphere via combustion, but the energy return on energy investment for ethanol is low.

ENDURING UNDERSTANDING

ENG-3

Humans use energy from a variety of sources, resulting in positive and negative consequences.

LEARNING OBJECTIVE

ENG-3.L

Describe the use of hydroelectricity in power generation.

SUGGESTED SKILL

Environmental Solutions

7.F

Justify a proposed solution, by explaining potential advantages.

ENG-3.M

Describe the effects of the use of hydroelectricity in power generation on the environment.

ESSENTIAL KNOWLEDGE

ENG-3.L.1

Hydroelectric power can be generated in several ways. Dams built across rivers collect water in reservoirs. The moving water can be used to spin a turbine. Turbines can also be placed in small rivers, where the flowing water spins the turbine.

ENG-3.L.2

Tidal energy uses the energy produced by tidal flows to turn a turbine.

ENG-3.M.1

Hydroelectric power does not generate air pollution or waste, but construction of the power plants can be expensive, and there may be a loss of or change in habitats following the construction of dams.

Hydroelectric Power

- ***Hydropower***
  - Uses the kinetic energy of moving water to turn turbines and power a generator to produce electricity
  - Water moves either with natural current of river, or by falling vertically through channel in a dam
  - There are three approaches to hydropower:
    - Storage approach (water impoundment)
    - Pumped Storage approach
    - Run of River approach
- By far the largest *renewable* source of electricity globally.
  - China, Brazil, and US = 3 biggest hydroelectricity producers.
  - But many of the best rivers, in countries with the economic means to build large dam projects, have already been dammed, limiting the future potential for the growth of hydroelectric power.
  - 98% of appropriate rivers in the U.S. have already been dammed.

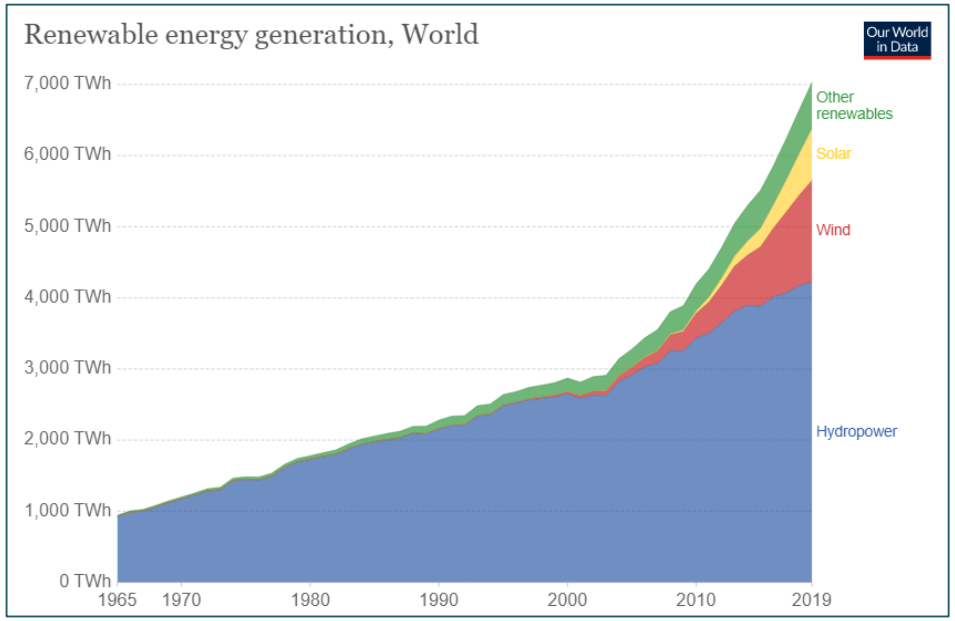
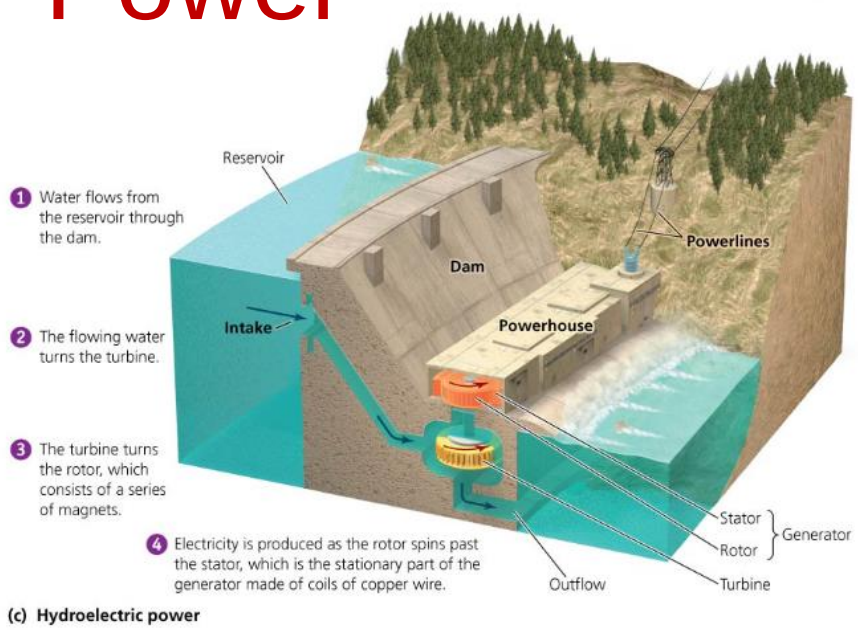


TABLE 20.4 Top Producers of Hydropower

NATION	HYDROPOWER PRODUCED (Percentage of world total)	PERCENTAGE OF NATION'S ELECTRICITY GENERATION FROM HYDROPOWER
China	20.5	17.2
Brazil	11.5	78.2
Canada	10.0	57.8
United States	8.1	6.5
Russia	4.8	16.2
Norway	3.4	94.7
India	3.3	11.9
Japan	2.6	8.1
Venezuela	2.2	64.9
France	1.9	11.7
Rest of world	31.7	15.4

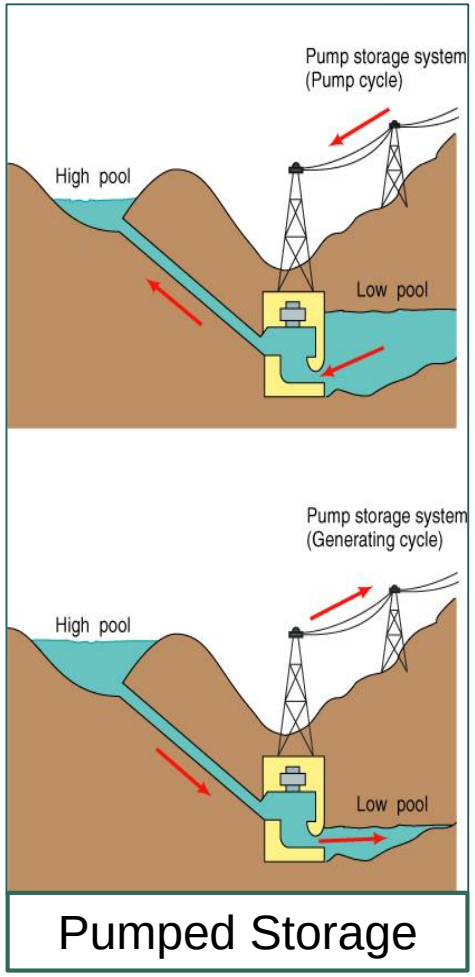
Data from the International Energy Agency.

Storage Approaches to Hydroelectric Power



(c) Hydroelectric power

- ***Storage (Impoundment) approach*** to hydropower
  - Dams are constructed across a river to create a reservoir which stores water behind it.
  - As water passes through the dam it turns turbines
  - The amount of power generated depends on the distance the water falls and the volume of water released.
  - Storage allows a predictable supply of water and electricity

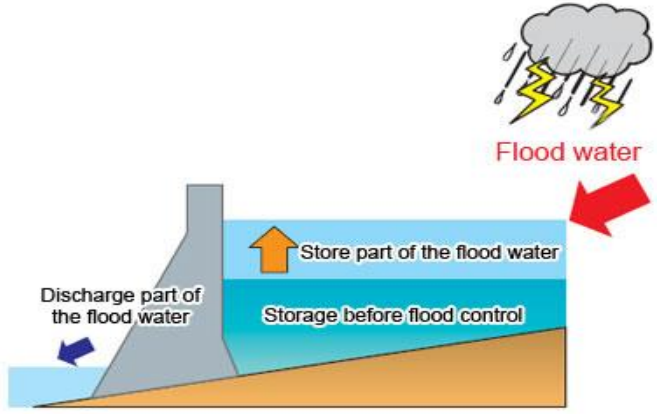


Pumped Storage

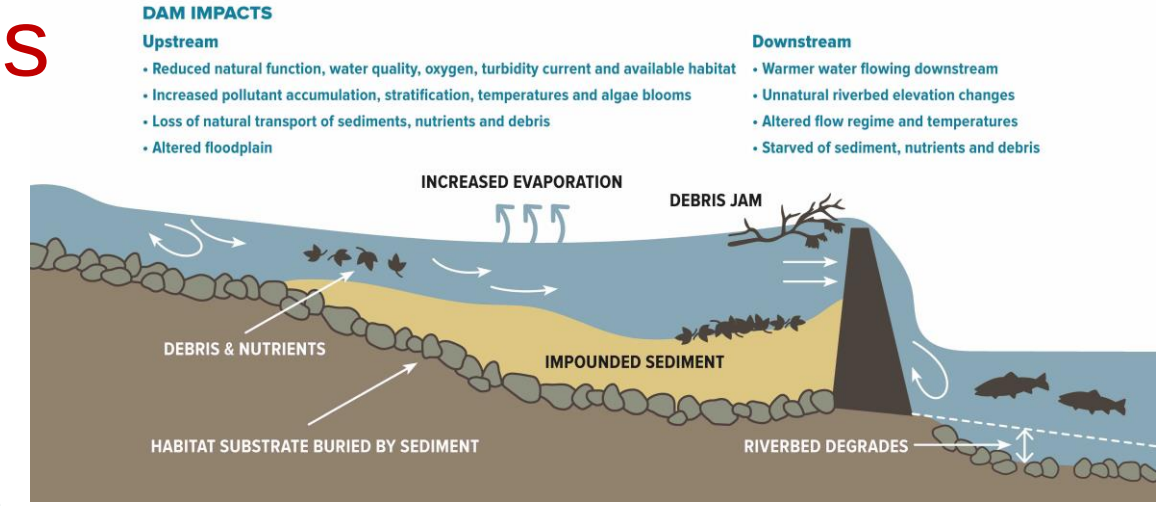
- ***Pumped Storage***
  - Water is pumped against gravity from a low reservoir to a high reservoir.
  - Pumping the water against gravity requires energy, most often from solar.
  - The net transport of water into the high reservoir occurs during the day, when solar output is high and energy demand is low.
  - Water is allowed to flow with gravity, from the upper reservoir to lower reservoir, generating electricity during times of peak electricity demand (usually evening hours).

Benefits of Hydroelectric Power

- Perpetually renewable resource that will continue to operate as long as rain fills the reservoirs.
- Hydroelectric power is very reliable and efficient (EROI).
- No air pollution during operation.
  - Three Gorges Dam in China (Worlds Largest) produces as much electricity as a dozen large coal fired power plants.
- Creation of reservoirs results in more reliable, less seasonal, source of water for agricultural and residential uses.
- Dams can regulate the flow of water down stream and be used to reduce flooding downstream of the dam after precipitation events.
- Creates reservoirs which have recreational and economic benefits for people.



Hydroelectric Power Concerns



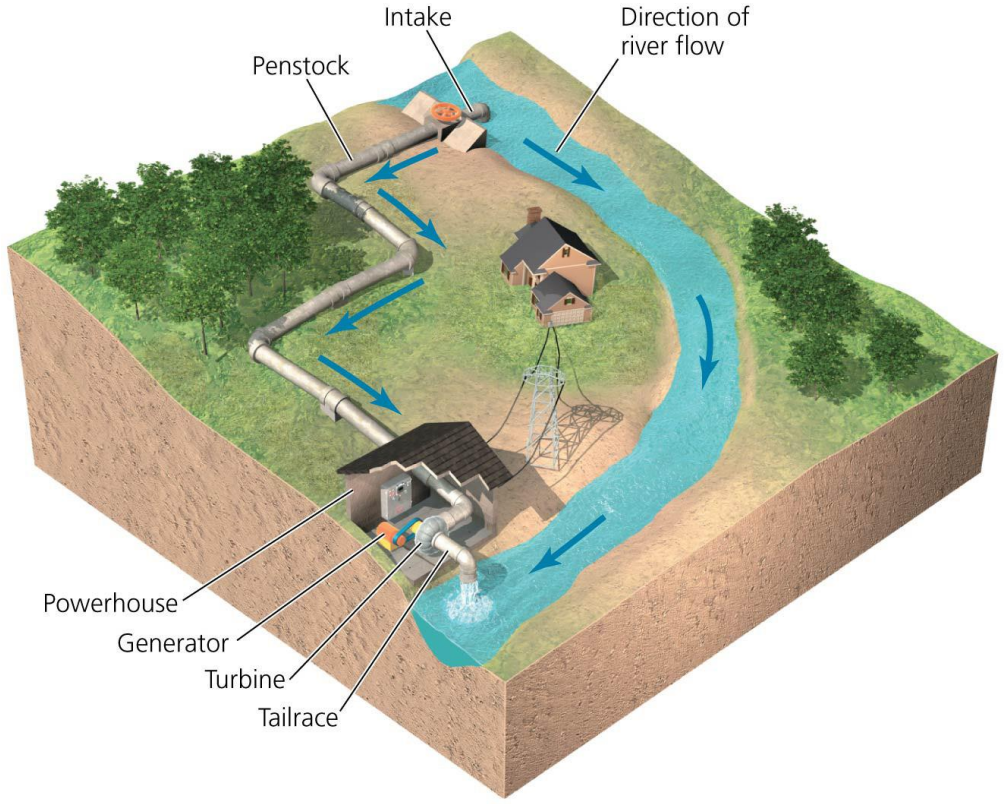
- Alteration of habitat
  - Upstream areas are flooded.
    - Terrestrial ecosystems are lost below the waters of the reservoir.
    - River ecosystems become lakes (different temperatures, light levels, nutrient supplies, DO levels, pollutant concentrations).
  - Downstream locations are starved of nutrients and sediment and experience more variable conditions (flow rates, water temp.).
  - Dams without ***fish ladders*** upstream migration of fish, such as salmon, that spawn in the headwaters of streams

- Increased evaporation due to larger surface area.
- ***Sedimentation*** behind dams can reduce useful lifespan of hydroelectric dams or require regular dredging

- Dams displace people and cultural sites (1,000,000+ people relocated for the building of Three Gorges dam).
- Large up front costs for construction of dam and power plant.

Hydroelectric Power

- ***Run-of-river approach***
  - A small diversion dam or a pipe can be used to divert water from the river to a turbine to power a generator and produce electricity.
  - River water is not impounded into a large reservoir.
  - Water is returned to the stream, downstream of where it was diverted.
  - Generates electricity without completely disrupting the river's flow.
    - Limits the disruption to habitat.
    - Does not alter rates of evaporation
    - Does not displace people or wildlife or block fish migration.



- The amount of power available for electricity production is much less than with impoundments.
- Run of river systems are susceptible to seasonally reduced production when water levels drop during dry periods.

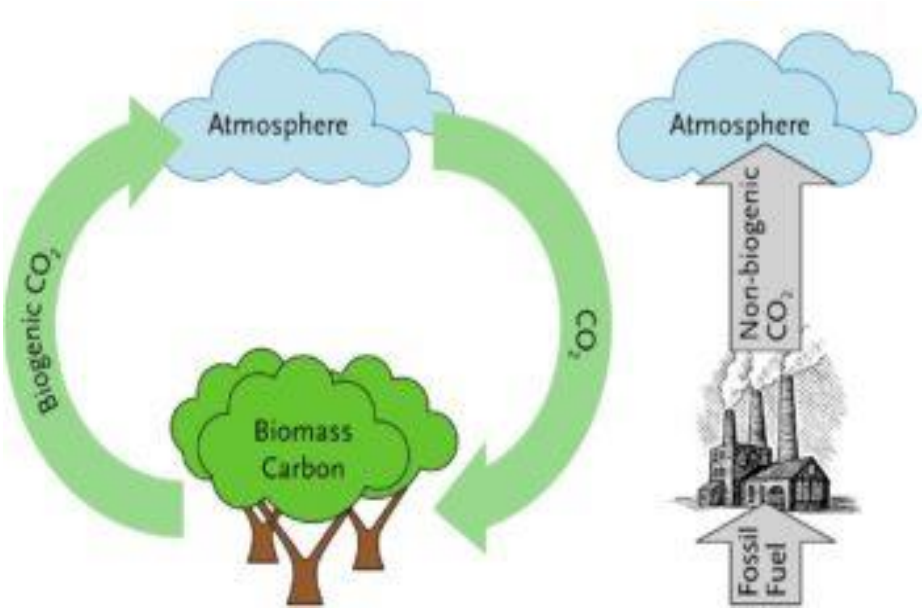
Energy from biomass

- ***Biomass***
  - organic material that makes up organisms and contains energy that originated with photosynthesis
  - Wood, charcoal, crop residues, dried animal manure
  - Burned to release heat for heating, cooking, and light
- In developing nations, fuel wood, charcoal, and animal dung account for one-third of energy use, and up to 90% in the poorest nations.
  - Easy to harvest, available, cheap/free (subsistence fuel).
- Biomass can also be burned in power plants to generate electricity (far less common than fossil fuels)
  - Waste products from industries can be used as fuels (woody debris from logging and lumber mills, crop residues, animal waste, organic waste from landfills).
  - Bioenergy crops are grown specifically to be used to generate electricity. Ex:fast growing grasses (bamboo) or tress (poplar)

A 70 MW power plant fueled by sugar cane residue. Stalks would have been burned in the field generating even more air pollution and no electricity

Benefits of biomass

- Biomass burning is considered ***carbon neutral.***
  - Biomass burning releases CO_2, but doesn't increase atmospheric CO_2 levels like fossil fuel burning does
  - Burning biomass releases ***modern carbon*** (CO_2 that was recently sequestered, or taken out of the atmosphere) whereas fossil fuel burning releases ***fossil carbon*** that had been stored for millions of years.



- It is better for human health than fossil fuels since it produces less sulfur dioxide and mercury.
- Using biomass resources can support rural economies and reduce countries' dependence on imported fuels.
  - If biomass is sourced from the waste of other industries, it reduces overall waste and limits dependence on virgin resources, reducing impacts on natural environments.
- But growing crops for fuel deprives the soil of nutrients
  - Continued use will deplete the soil
  - Relying solely on bioenergy is not a sustainable option

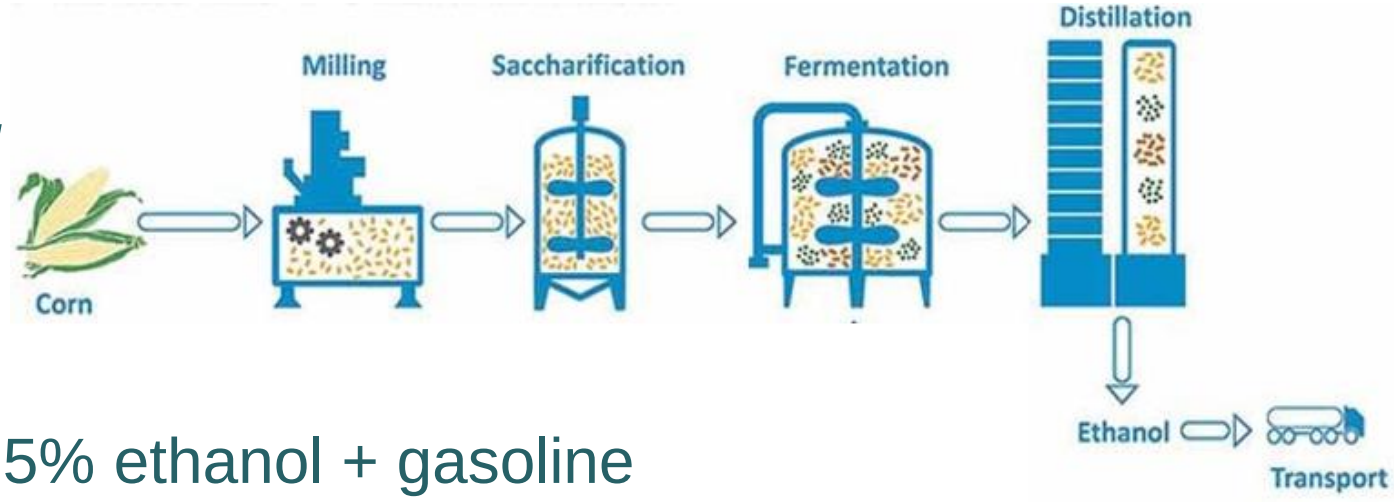
Human health & environmental consequences of biomass burning

- Using biomass can lead to deforestation.
  - Overharvesting of wood from forests can lead to deforestation.
  - In some regions people travel miles to collect firewood daily, since previously forested areas have already been cleared.
- Consequences of deforestation:
  - Soil erosion and possible desertification.
  - Loss of habitat and reduced biodiversity.
  - Reduced CO_2 uptake globally.

- Production of air pollutants.
  - Smog forming pollutants (CO, NOx, VOC, PM).
  - Acid rain forming pollutants (NOx)
  - All respiratory irritants
- Biomass burning indoors worsens the effects
  - Pollutants become concentrated.
  - Worsened asthma, bronchitis, COPD, emphysema, eye irritation.
  - 3 billion people globally cook on open, biomass fires, mostly in developing world.

Biofuels: Ethanol

- Corn & sugar cane are ***fermented*** into ethanol, which is mixed w/ gasoline.
  - Glucose (high starch corn / sugar cane) + yeast → CO_2 + ethanol

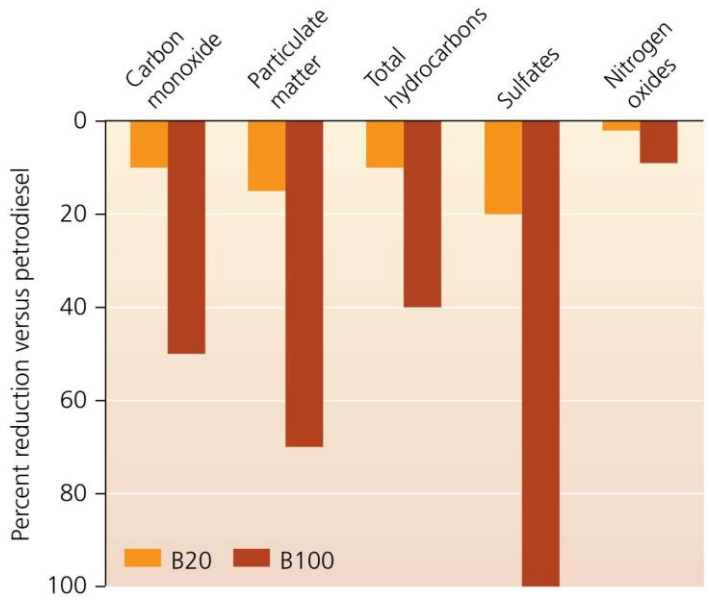


- ***E85 or flex fuel*** is a mix of up to 85% ethanol + gasoline
  - Used in flex-fuel vehicles.
  - Decreases oil consumption for fuel production, but is less efficient than pure gasoline (lower mpg)
  - EROI of about 1.3 to, due to energy costs of crop production and fermenting

- Sustainable and renewable only to the extent that the crops are produced sustainably.
  - Soil erosion, loss of biodiversity (species and genetic level), GHG release (ag. soils, tractors, fertilizers) H_2O use, fertilizers, pesticides
  - Sugar cane is a perennial, and is more sustainable than corn
  - Corn for fuel competes with the need to grow food for a growing population. Arable land is limited.

Biofuels: Biodiesel

- ***Biodiesel*** is a liquid fuel produced specifically from plant oils (soy, canola, palm, algae, and used cooking oils)
  - Plant oils are mixed with small amounts of ethanol in the presence of a chemical catalyst to produce biodiesel
  - Diesel engines can operate on pure biodiesel, but it is most commonly mixed with petrodiesel (***B20***).



- Benefits of biodiesel:
  - Reduced emissions of CO2, NOx, SOx, CO, PM, and VOC's compared to petrodiesel.
  - Nontoxic and biodegradable
  - Can be sustainable when produced from waste oil and algae shows promise.
  - Algae is fast growing, tolerates a range of water types (wastewater, saltwater) can be grown in areas not suitable for traditional agriculture, can be used to capture CO_2 emissions.
- Consequences of Biodiesel:
  - Slightly lower fuel economy and more expensive compared to petrodiesel.
  - All of the impacts associated with agriculture when produced from purposefully grown crops.
  - Competes with growing food for people.

Video Resources

- Hydroelectric Power
  - https://www.youtube.com/watch?v=Mly-ylHrDv4&feature=emb_logo
- Bioenergy (video covers all renewables)
  - https://www.youtube.com/watch?v=B8WuEyL-YNY&feature=emb_logo

Practice

Which of the following best describes an advantage of burning biomass rather than burning fossil fuels in developing countries?

A Biomass production requires less open space than fossil fuel extraction does, so land is available for other purposes.

B Burning biomass is associated with fewer human respiratory concerns than fossil fuels are because it does not give off sulfur oxides and nitrogen oxides.

C Biomass production is cheaper than fossil fuel extraction, making it more readily available for use.

D Burning biomass is more efficient than burning fossil fuels, providing more available energy from less of the resource.

Practice

Throughout the world, especially the less-developed countries, burning wood or other biomass for heating or cooking in homes is common. One negative environmental impact of this practice is the production of particulates indoors, which can be a health hazard to humans.

Which of the following describes the best strategy for mitigating this potential problem?

A. Installing effective ventilation systems in dwellings

B. Updating dwellings with well-sealed windows

C. Planting native plants around the dwelling

D. Equipping dwellings with rainwater collection systems

Practice

Which of the following is a drawback to using biofuels, such as ethanol, as a fuel source?

A Ethanol-blended gasoline has higher carbon emissions than petroleum alone.

B The global demand for biofuels is continually decreasing.

C There is high energy investment in producing and processing the crops needed for ethanol production.

D Ethanol-blended gasoline increases the likelihood of freezing gas lines in winter months.