



Generations of Biofuels

Objective

Introduce students to the 3 generations of biofuels and the vocabulary and ideas behind biofuels.

Skill Level: Middle school and high school	Class time: 50 min
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Materials

- Paper
- Markers
- Generations of Biofuels worksheet
- Biofuels flash cards

Next Generation Science Standards

Disciplinary Core Idea:
ESS3: Earth and human activity

Performance Expectations:
MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geoscience processes.

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

<u>Practices</u>	<u>Crosscutting Concepts</u>
<input checked="" type="checkbox"/> Asking questions / defining problems <input type="checkbox"/> Developing / using models <input type="checkbox"/> Planning / carrying out investigations <input type="checkbox"/> Analyzing / interpreting data <input type="checkbox"/> Math / computational thinking <input type="checkbox"/> Constructing explanations / design solutions <input type="checkbox"/> Engaging in argument from evidence	<input type="checkbox"/> Patterns <input type="checkbox"/> Cause and effect: Mechanism / explanation <input type="checkbox"/> Scale, proportion, and quantity <input type="checkbox"/> Systems and system models <input checked="" type="checkbox"/> Energy / matter: Flows, cycles, conservation <input type="checkbox"/> Structure and function


 Obtaining / evaluate / communicate

 Stability and change

Background Information

Introduction:

Biofuels are energy sources made from recently grown biomass (plant or animal matter). Biofuels have been around for a long time, but petroleum and coal have been used primarily as energy sources due to their high abundance, high energy value, and cheap prices. Fossil fuels such as coal and petroleum also come from biomass but the difference is that they took millions of years to produce. Biofuels are making a resurgence due to increasing oil prices, dwindling fossil fuel reserves, the desire to have a renewable, reliable source of energy and as a way to mitigate the effects of climate change. Biofuels are a renewable resource because they are continually replenished. Fossil fuels on the other hand are not renewable since they require millions of years to form.

There are three types of biofuels: 1st, 2nd and 3rd generation biofuels. They are characterized by their sources of biomass, their limitations as a renewable source of energy, and their technological progress. The main drawback of 1st generation biofuels is that they come from biomass that is also a food source. This presents a problem when there is not enough food to feed everyone. 2nd generation biofuels come from non-food biomass, but still compete with food production for land use. Finally, 3rd generation biofuels present the best possibility for alternative fuel because they don't compete with food. However, there are still some challenges in making them economically feasible.

Background:

First generation biofuels, also known as conventional biofuels, are made from sugar, starch or vegetable oil. First generation biofuels are produced through well-understood technologies and processes, like fermentation, distillation and transesterification. These processes have been used for hundreds of years in many uses, such as making alcohol. Sugars and starches are fermented to produce primarily ethanol, and in smaller quantities, butanol and propanol. Ethanol has one-third of the energy density of gasoline, but is currently used in many countries, including the United States, as an additive to gasoline. A benefit of ethanol is that it burns cleaner than gasoline and therefore produces less greenhouse gases. Another 1st generation biofuel, called biodiesel, is produced when plant oil or animal fat goes through a process called transesterification. This process involves exposing oils with an alcohol such as methanol in the presence of a catalyst. The distillation process involves separating the main product from any of the byproducts of the reactions. Biodiesel can be used in place of petroleum diesel in many diesel engines or in a mixture of the two. The Figure 1 shows the process of how 1st generation biofuels are made.

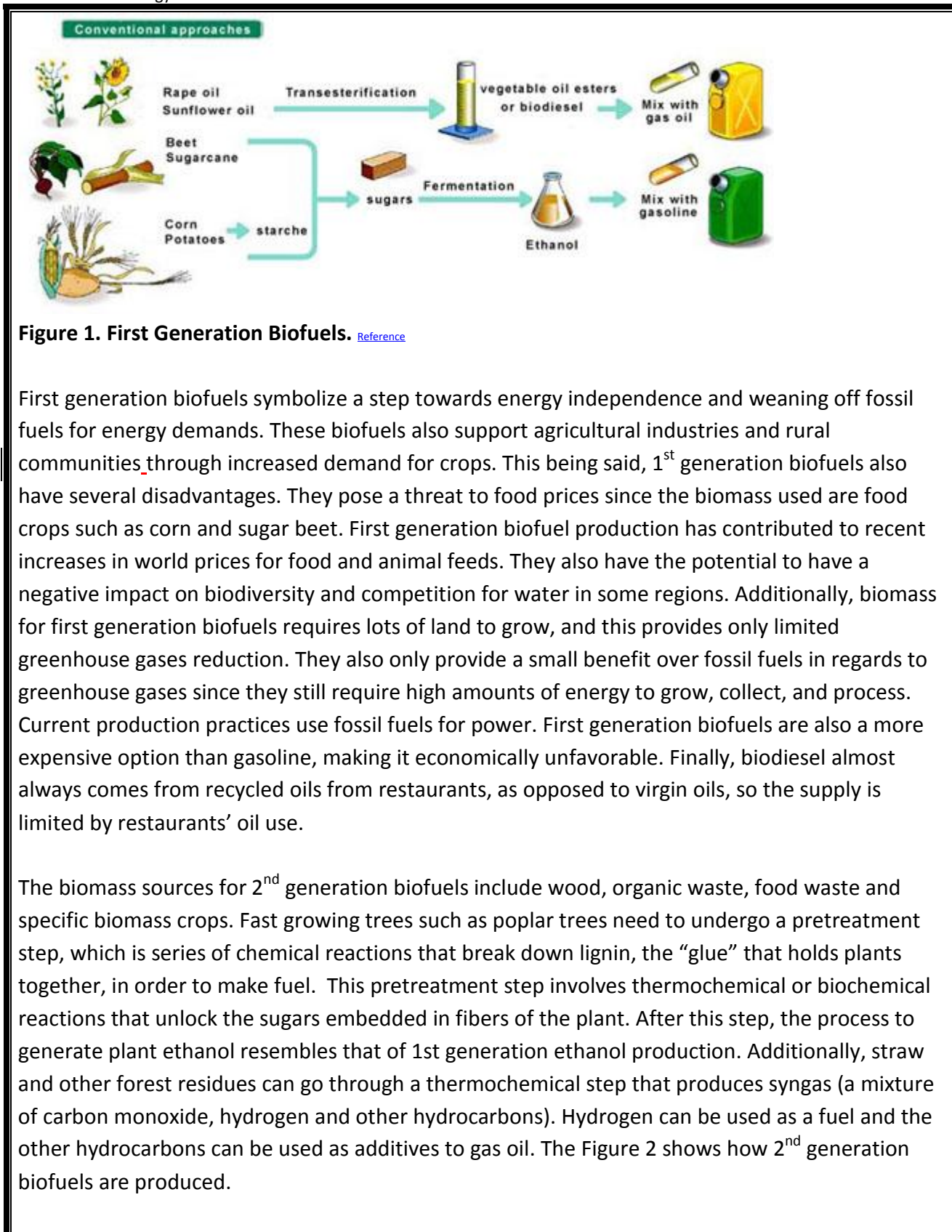


Figure 1. First Generation Biofuels. [Reference](#)

First generation biofuels symbolize a step towards energy independence and weaning off fossil fuels for energy demands. These biofuels also support agricultural industries and rural communities through increased demand for crops. This being said, 1st generation biofuels also have several disadvantages. They pose a threat to food prices since the biomass used are food crops such as corn and sugar beet. First generation biofuel production has contributed to recent increases in world prices for food and animal feeds. They also have the potential to have a negative impact on biodiversity and competition for water in some regions. Additionally, biomass for first generation biofuels requires lots of land to grow, and this provides only limited greenhouse gases reduction. They also only provide a small benefit over fossil fuels in regards to greenhouse gases since they still require high amounts of energy to grow, collect, and process. Current production practices use fossil fuels for power. First generation biofuels are also a more expensive option than gasoline, making it economically unfavorable. Finally, biodiesel almost always comes from recycled oils from restaurants, as opposed to virgin oils, so the supply is limited by restaurants' oil use.

The biomass sources for 2nd generation biofuels include wood, organic waste, food waste and specific biomass crops. Fast growing trees such as poplar trees need to undergo a pretreatment step, which is series of chemical reactions that break down lignin, the "glue" that holds plants together, in order to make fuel. This pretreatment step involves thermochemical or biochemical reactions that unlock the sugars embedded in fibers of the plant. After this step, the process to generate plant ethanol resembles that of 1st generation ethanol production. Additionally, straw and other forest residues can go through a thermochemical step that produces syngas (a mixture of carbon monoxide, hydrogen and other hydrocarbons). Hydrogen can be used as a fuel and the other hydrocarbons can be used as additives to gas oil. The Figure 2 shows how 2nd generation biofuels are produced.

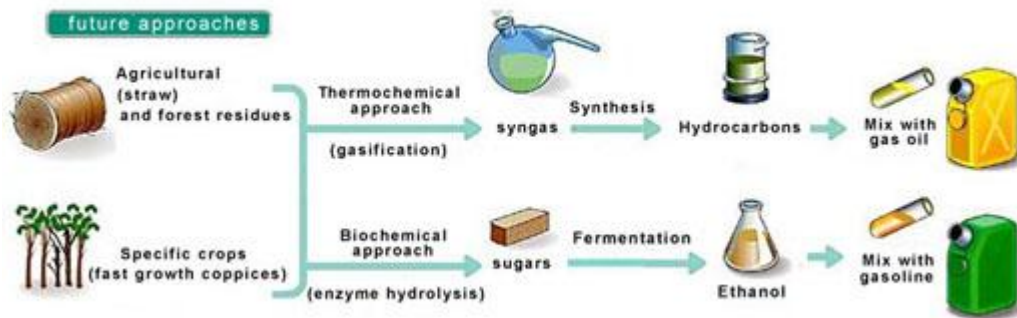


Figure 2. Second Generation Biofuels. [Reference](#)

Second generation biofuels address many issues associated with 1st generation biofuels. They don't compete between fuels and food crops since they come from distinct biomass. Second generation biofuels also generate higher energy yields per acre than 1st generation fuels. They allow for use of poorer quality land where food crops may not be able to grow. The technology is fairly immature, so it still has potential of cost reductions and increased production efficiency as scientific advances occur. However, some biomasses for second-generation biofuels still compete with land use since some of the biomass grows in the same climate as food crops. This leaves farmers and policy makers with the hard decision of which crop to grow. Cellulosic sources that grow alongside food crops could be used for biomass, such as corn stover (leaves, stalk, and stem of corn). However, this would take away too many nutrients from the soil and would need to be replenished through fertilizer. In addition, the process to produce 2nd generation fuels is more elaborate than 1st generation biofuels because it requires pretreating the biomass to release the trapped sugars. This requires more energy and materials.

Third generation biofuels use specially engineered crops such as algae as the energy source. These algae are grown and harvested to extract oil within them. The oil can then be converted into biodiesel through a similar process as 1st generation biofuels, or it can be refined into other fuels as replacements to petroleum-based fuels. The Figure 3 shows the general steps of how 3rd generation biofuels are produced.

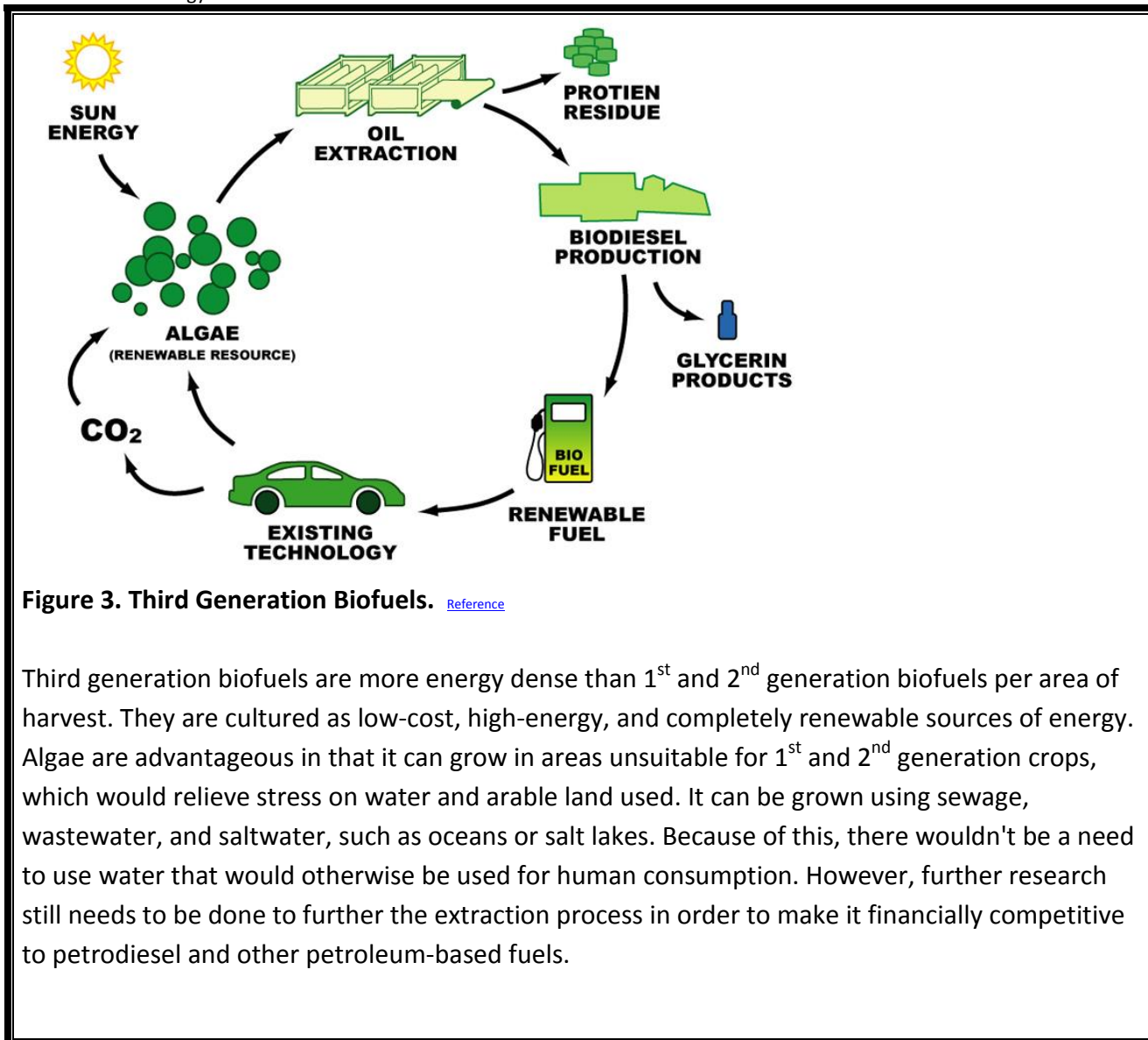


Figure 3. Third Generation Biofuels. [Reference](#)

Third generation biofuels are more energy dense than 1st and 2nd generation biofuels per area of harvest. They are cultured as low-cost, high-energy, and completely renewable sources of energy. Algae are advantageous in that it can grow in areas unsuitable for 1st and 2nd generation crops, which would relieve stress on water and arable land used. It can be grown using sewage, wastewater, and saltwater, such as oceans or salt lakes. Because of this, there wouldn't be a need to use water that would otherwise be used for human consumption. However, further research still needs to be done to further the extraction process in order to make it financially competitive to petrodiesel and other petroleum-based fuels.

Engage

The challenge is finding an energy source that is sufficient to provide for our energy needs. At the same time, this energy source must be dependable, renewable, and non-contributing to climate change. First generation biofuels represent a step toward cleaner, renewable energy, but they lag behind gasoline because of energy density and economic factors. They also present an ethical dilemma with regards to use of food crops, as there are millions of people starving around the world. This is especially pertinent in countries with large populations where corn is grown like China, Brazil and Mexico (the 2nd, 3rd and 4th largest producers of corn, 1st, 5th and 11th largest country populations, respectively). Second generation biofuels provide some benefits, but the biomass requires pretreating steps and competes with food crops over arable land in some parts of the world. Third generation biofuels show the most hope, but plenty of research still needs to



be done to reduce production costs and make this type of fuel production commercially viable.

Explore

Experiment Questions:

Fossil fuels are a nonrenewable, finite source of energy. As more countries with large populations such as China, Brazil and India become industrialized, the already limited sources of fossil fuels are going to continue to decrease. In order to keep up with the energy needs that we are accustomed to, we will need new energy sources.

Procedure:

1. Lead students in a discussion about the different generations of biofuels, their biomasses, and their products.
2. Students do the vocabulary activity.
3. Have students brainstorm some possible pros and cons for each generation of biofuels.
4. Students do the pros and cons activity.

Explain

- How do you think fossil fuel sources are currently divided across nations/socioeconomic systems? Are fossil fuels evenly spread out across the world?
- How would biofuel technology benefit those nations that do not have fossil fuels reservoirs? Could biofuels still be beneficial for nonagricultural countries?
- What might be the disadvantages of having biofuels that come from food sources such as corn, sugar beets, etc.? Do you think crops or fuel deserve a higher consideration?
- If you were in charge of what was planted, how would you divide land for food crops and land for biomass for fuel?



Elaborate

Students research a biofuel company. They should report back where the company is located, what fuel(s) they produce, what generation of biofuels it corresponds to and what do they use as a biomass source. As a further challenge, can they find any 2nd or 3rd generation biofuel companies? Examples of biofuel companies include:

- [Lignol](#)
- [Pacific Biodiesel](#)
- [ZeaChem](#)

Resources

Additional Resources:

- [Biofuel Activities](#) (Click links)
- [More activities and background material](#)

Resources Used:

- [From First to Second Generation Biofuels](#)
- [Biofuels Directory](#)
- [Generations of Biofuels](#)
- [National Geographic: Biofuels](#)
- [Biofuel Production Technologies](#)
- [Practical Biofuel Activities](#)
- [Biofuels Production and Use Lesson](#)
- [Challenges of Producing a Commodity from Biomass](#)