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FIRST AND SECOND GENERATION BIOFUELS

WHAT'S THE DIFFERENCE

Biofuels are renewable fuels made from recently living organic materials (called "biomass", such as agricultural crops, forest residue, by-products, or waste. They can be used as alternatives to non-renewable fossil fuels, such as oil or natural gas, which were formed geologically from organic material over millions of years. Common types of biofuel are ethanol and biodiesel.

FIRST-GENERATION BIOFUELS

(also referred to as "conventional" biofuels)

First-generation biofuels are produced from types of biomass that are often used for food, such as corn, soy, and sugarcane. These biofuels are made through fermentation or chemical processes that convert the oils, sugars, and starches in the biomass into liquid fuels. First-generation biofuel markets and technologies are well-established, the most common in the U.S. being corn ethanol, which is blended into most gasoline sold domestically.

SECOND-GENERATION BIOFUELS

(also referred to as "next-generation" biofuels)

Second-generation biofuels are produced from non-food biomass, such as perennial grass and fast-growing trees. The processes to make them are more complex and undeveloped than those for first-generation biofuels and often involve converting fibrous non-edible material called "cellulose" into fuel. Currently, there is no commercial-scale second-generation biofuel production in the U.S., but there has been extensive research on their potential economic and environmental advantages over first-generation biofuels.

THE RISE OF FIRST-GENERATION

Production of first-generation biofuels greatly expanded after the adoption the U.S. Renewable Fuel Standard in 2005 (see Figure 1), which sets federal mandates for levels of renewable fuel that must be blended into U.S. transportation fuels. The Renewable Fuel Standard was designed to boost energy independence by increasing domestic fuel production (this was prior to the oil and gas boom that followed the widespread adoption of hydraulic fracking in fossil fuel drilling technology). It was also seen as a way to encourage a more environmentally-friendly, renewable alternative to fossil fuel consumption, though the environmental benefits of biofuels depend on supply chain and production practices and are still hotly debated.

Regardless of the environmental impact, the increase in demand for first-generation biofuels has provided new economic opportunities by expanding markets for conventional commodity crops. In 2011, fuel passed up feed as the largest end use for the U.S. corn crop (see Figure 2); biodiesel production is projected to account for over one third of U.S.

1ST GEN BIOMASS SOURCES

Grains and starch crops (e.g., corn, sugar cane, sugar beets)

Vegetable oils (e.g., soy, canola, palm)

2ND GEN BIOMASS SOURCES

Perennial grasses (e.g., switchgrass, miscanthus)

Fast-growing trees (e.g., hybrid poplar, willow)

By-products & waste (e.g., corn stover, wheat straw, forest residue, municipal waste, used cooking oil)

soy oil use in coming years. Additionally, growers have also been able to sell the by-products of these first-generation crops, thus providing additional value. For example, the by-product of converting corn into ethanol, called distiller's grains, is repurposed in the U.S. as an important source of livestock feed.

FOOD VS. FUEL

In addition to environmental concerns, there is considerable concern that the rapid expansion of first-generation biofuel production could impact global food production. First-generation biofuel crops are seen as competing directly with food, and any displacement of food crops due to biofuel crop production could decrease food supply and increase food prices. These concerns have given rise to an interest in a "second-generation" of biofuel crops, which are non-food crops and are more suited to being grown on land not used for food production.

It can be difficult to draw a hard line between food and fuel uses for agricultural crops. For example, switchgrass, which is considered a second-generation crop, can also be fed to cattle to produce beef.

BENEFITS OF AND BARRIERS TO SECOND-GENERATION BIOFUELS

In addition to not directly displacing food crops, second-generation biofuel potentially offers other benefits over first-generation biofuels. Many types of second-generation biomass are perennial crops, meaning they don't have to be replanted every year, as opposed to first-generation crops which are generally annual grains. For example, a switchgrass stand may be productive for up to ten years once it's established. Perennial crops also require fewer inputs (fertilizer, pesticides, water) to produce, conserve and build soil, and they maintain habitat for grassland species.

However, markets and technology for second generation bioenergy crops are not well established. Converting second-generation feedstock into energy requires different processing technology. Further, second-generation biomass can be bulkier than feedstock made of starch or oil. More research and development is needed to efficiently produce, transport, and convert these crops into energy. Moreover, even second-generation biofuel crops will create trade-offs with current land use (habitat, wildlife, and other ecosystem services) as well as compete for agricultural inputs such as farm labor and assets, fuel, irrigation water, and fertilizer. Current technology, agriculture and energy markets, and land uses have not led to widespread development of second-generation bioenergy production in the U.S.

BEYOND SECOND-GENERATION

The biofuel progression does not end at the second generation. In recent years, interest has increased in a third and fourth generation of biofuels. Third-generation biofuels are derived from algae or engineered biofuel crops, which are specifically designed to be more efficient converters of biomass to fuel.

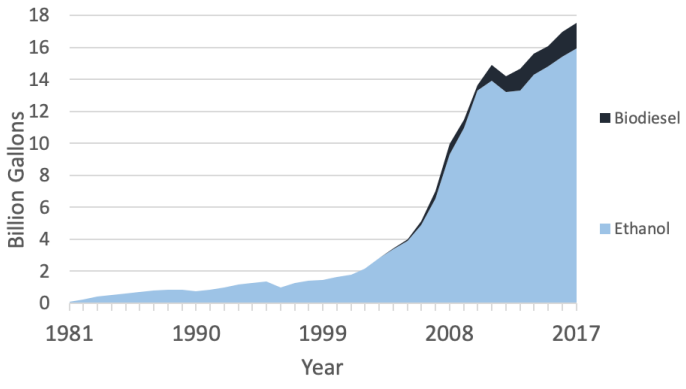

Figure 1. U.S. Transportation Biofuel Production, 1981-2017. Source: U.S. Energy Information Administration Monthly Energy Review, 2018

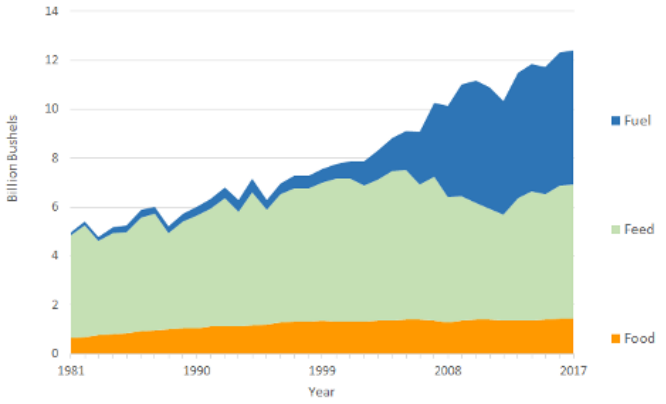

Figure 2. U.S. Corn Production by Domestic Use, 1981-2017. Source: USDA Economic Research Service, Feed Grains Yearbook, 2018

Fourth-generation biofuels are biofuels that capture and sequester carbon dioxide, first through the production of the biomass itself (that is, the biofuel crops absorb carbon dioxide as they grow) and then through technology that captures the CO2 released during fuel production and stores it in geologic formations underground (referred to as Bioenergy with Carbon Capture and Storage or BECCS).

As with second-generation, third- and fourth-generation biofuels still require additional research and development before the technologies and markets could be commercially viable. However, there is continued interest in these as the possible future of biofuels.

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