BIODIESEL AND ETHANOL

Biofuels, which are liquid fuels made from biomass, can be used as a replacement or a supplement for petroleum-based fuel products used to power cars, trucks, planes, and ships. The two most common biofuels in use today are biodiesel and ethanol. Other biofuels are discussed in “Renewable hydrocarbons” and “Other alternative fuels.”

Ethanol is a clear liquid that can be produced from corn grain (the predominant feedstock used in the U.S.), sugar cane (the predominant feedstock used in Brazil), or cellulosic feedstocks (such as wood chips and crop residues) and used to power spark-ignition engines. Ethanol is available at the gas pump in the form of E10 (a blend of 10% ethanol with 90% gasoline). Another form, E85 (also called “flex fuel,” a blend of up to 85% ethanol with gasoline), is available at special pumping stations.[1]

Biodiesel is made of vegetable oils, animal fats, or recycled restaurant grease, and it is used to power compression-ignition engines. The most common blends of biodiesel are B5 (up to 5% biodiesel mixed with petroleum-based diesel), B20 (6-20% biodiesel mixed with petroleum-based diesel), and B100 (pure biodiesel). B5 and B20 can be used in any diesel engine without modifications. B100 and other high-level blends are less common, and they require special handling and equipment modifications.[2] Biodiesel is distinct from green or renewable diesel, which we discuss in “Other alternative fuels.”

Starch-based biofuels (corn, grain sorghum) are called “conventional” biofuels. All other types of biofuels, including those made from cellulosic feedstocks (wood, straw, waste), sugar feedstocks, vegetable or waste grease, algae, and any biofuels that may exist in the future, are called “advanced biofuels.”[3] Algae-based biofuels are still in the research and development phase and have not yet been commercially deployed.[4] They can be made from microalgae or macroalgae (seaweed).

Microalgae is 20-80% oil by dry weight, has rapid growth rates, and can be grown on non-arable lands, such as in ponds or enclosed photobioreactor systems. It can then be harvested by using gravity or a centrifuge. Oil is then extracted using a solvent, and further processed into biodiesel. From the 1980s to the 1990s, the Department of Energy invested heavily in developing biofuels from algae, but wound up concluding that it was too expensive. However, in recent years, algal biofuel production has again become a topic of interest. Commercial viability will depend on reducing costs through cultivation of faster-growing or more oil-dense varieties of algae. Algae cultivation can have side benefits: for instance, when cultivated in

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[1] DOE Alternative Fuels Data Center. “Ethanol fuel basics.” https://afdc.energy.gov/fuels/ethanol_fuel_basics.html
[2] DOE Alternative Fuels Data Center. “Biodiesel blends.” https://afdc.energy.gov/fuels/biodiesel_blends.html
[3] DOE Alternative Fuels Data Center. “Renewable Fuel Standard.” https://afdc.energy.gov/laws/RFS
[4] EPA. “Economics of biofuels.” https://www.epa.gov/environmental-economics/economics-biofuels

wastewater treatment lagoons, algae can reduce the amount of chemicals needed to clean and purify water.[5]

There is also growing interest in developing biofuels from kelp, including an ambitious Department of Energy research program focused on kelp, called the "Macroalgae Research Inspiring Novel Energy Resources," or MARINER for short.[6] Kelp grows much faster than terrestrial species and absorbs over 178 tons/acre of CO_2, helping to keep its lifecycle GHG emissions low. While terrestrial feedstocks can only be grown on two-dimensional land, kelp can be grown in the three-dimensional water column, helping it achieve production rates of over 69 tons/acre compared to under 14 tons/acre for corn.[7]

Kelp can be processed into ethanol or bio-crude (oil derived from organic materials, which can be processed in existing refineries into fuels for trucks and planes). Cultivation is constrained by the depth of the photic zone (the level in the ocean water column to which sunlight penetrates), but researchers recently pioneered a "kelp elevator" that lowers and raises kelp throughout the day so that it can soak up sunlight while at the surface and nutrients while at depth.[8] A recent project in Alaska developed a process to combine kelp and fish waste from processing plants to make bio-crude. The end product cost about half of what it costs to fly petroleum-based fuel into Alaska from out of state, and it can be used in place of diesel in local generators and fishing boats.[9]

Biofuels offer several benefits. First, unlike fossil fuels, biofuels are renewable resources that can be replenished in perpetuity. Second, they have lower lifecycle GHG emissions than fossil fuels because plant-based feedstocks sequester CO_2 while growing. Cellulosic and algae-based biofuels have the biggest GHG emissions reduction potential relative to fossil fuels because they can be produced on marginal land or in water. Biofuels produced using waste have the added advantage that they require no additional agricultural production, and if these wastes have no other productive uses, then their GHG emissions relative to decomposition are minimal.[10]

However, biofuels also have some potential negative side-effects. Terrestrial feedstocks can compete for land and water with food crops, possibly causing food prices to increase and leading to an increase in the agricultural footprint along with fertilizer and water use. Cultivation of feedstocks can also lead to deforestation and other changes in land use, leading

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[5] Wen, Zhiyou (April 3, 2019). "Algae for biofuel production." *Farm Energy* https://farm-energy.extension.org/algae-for-biofuel-production/

[6] ARPA-E. "Macroalgae Research Inspiring Novel Energy Resources." https://arpa-e.energy.gov/technologies/programs/mariner

[7] Bellona Europe. "Factsheet: Pros and cons – seaweed for biofuels." https://bellona.org/assets/sites/3/2017/03/FACTSHEET-seaweed-for-energy.pdf

[8] Kim, Diane et al. (April 1, 2021). "Move over, corn and soybeans: The next biofuel source could be giant sea kelp." *The Conversation.* https://theconversation.com/move-over-corn-and-soybeans-the-next-biofuel-source-could-be-giant-sea-kelp-156728

[9] Adkisson, Kelsey (August 2, 2021). "Waste to energy: Biofuel from kelp harvest and fish." https://www.pnnl.gov/news-media/waste-energy-biofuel-kelp-harvesting-and-fish

[10] EPA. "Economics of biofuels." https://www.epa.gov/environmental-economics/economics-biofuels

these biofuels to result in a net increase in GHG emissions over fossil fuel energy by releasing terrestrial carbon and by removing vegetation-based carbon sequestration capacity. Feedstock cultivation can also increase water pollution caused by runoff of nutrients, pesticides, and sediments, while releasing GHG emissions through fertilizer use, which is associated with emissions of nitrous oxide.[11]

The leading argument for using kelp as a biofuel feedstock is that it does not compete with food and other crops for land and freshwater.[12] However, little is known about how kelp production for biofuels might displace food production in the ocean, such as wild fisheries. According to one statistic, the U.S. could replace 10% of its petroleum-based transportation fuels with biofuels by cultivating an ocean area equivalent to the size of Utah.[13] Clearly, reaching higher percentage numbers could require substantial amounts of space that are currently being used by commercial fishermen and the species they depend on. There is also discussion about co-locating kelp cultivation with other potentially invasive energy activities, such as offshore wind.[14] While kelp has been demonstrated to have beneficial effects for fisheries in some cases (e.g., by buffering water pH against ocean acidification, creating three-dimensional habitat and predator refuge[15]), large-scale kelp cultivation could also have unpredictable ripple effects on the fishery food web, as well as on oceanic carbon cycling.[16] In sum, there is still much that needs to be understood before we can fully understand the fishery impacts of large-scale kelp cultivation on marine ecosystems.

Biofuel incentives have been in place nationally in the U.S. since the enactment of the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007. These pieces of legislation prescribe the issuance of grants, cash awards, income tax credits, subsidies and loans to promote biofuel research and development. They also establish a Renewable Fuel Standard mandating a minimum threshold of biofuel production nationally. The most recent standard sets a goal of producing 36 billion gallons of biofuels by 2022, with 21 billion of these gallons derived from advanced biofuels derived from feedstocks other than corn. The Energy Independence and Security Act also requires biofuels to reduce their life-cycle GHG emissions

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[11] EPA. "Economics of biofuels." https://www.epa.gov/environmental-economics/economics-biofuels

[12] Pool, Rebecca (October 15, 2020). "Is seaweed the future of fuel?" *Engineering and Technology.* https://eandt.theiet.org/content/articles/2020/10/is-seaweed-the-future-of-fuel/

[13] Sneed, Annie (March 16, 2020). "Could our energy come from giant seaweed farms in the ocean?" *Scientific American*. https://www.scientificamerican.com/article/could-our-energy-come-from-giant-seaweed-farms-in-the-ocean/

[14] Bellona Europe. "Fact sheet: Pros and cons – Seaweed for biofuel." https://bellona.org/assets/sites/3/2017/03/FACTSHEET-seaweed-for-energy.pdf

[15] Jones, Robert et al. (April 12, 2021). "Assessing the habitat benefits of kelp aquaculture in New Zealand and Maine." *The Fish Site*. https://thefishsite.com/articles/assessing-the-habitat-benefits-of-kelp-aquaculture-in-new-zealand-and-maine

[16] Sneed, Annie (March 16, 2020). "Could our energy come from giant seaweed farms in the ocean?" *Scientific American*. https://www.scientificamerican.com/article/could-our-energy-come-from-giant-seaweed-farms-in-the-ocean/

by 20% for corn-based biofuels, 50% for biodiesel and advanced biofuels, and 60% for cellulosic biofuels.[17]

- Fishery friendliness: Biofuel feedstock cultivation has a number of potential environmental impacts that may impact marine and aquatic resources. Potential impacts of terrestrial feedstock production include deforestation and runoff of nutrients, pesticides, and sediments. Potential impacts of marine production include spatial displacement of fishing activities and impacts to carbon cycling and food webs. Fishery-friendly impacts may also occur: for example, kelp can help buffer ocean water pH against acidification and provide habitat and refuge for marine organisms.
- Co-benefits: When produced from waste products, such as recycled restaurant grease, wood chips, or algae grown in wastewater, biofuels can help repurpose a waste stream into a useful product.
- Environmental externalities: Production of biofuel feedstocks has a significant potential for environmental externalities that should be considered and guarded against. Potential impacts of terrestrial production include displacement of human food crops (with consequent increases in food prices), deforestation, and runoff of nutrients, pesticides, and sediments. Potential impacts of marine production include mammal entanglements and impacts to carbon cycling and food webs. Potential positive impacts may occur as well: for instance, kelp can help buffer ocean water pH against acidification and provide habitat and refuge for marine organisms.
- Policy catalysts: Production of biofuels can be promoted through grants, cash awards, tax credits, subsidies, and loans to promote biofuel research and development. Use and production of biofuels can be promoted through fuel economy or low-carbon fuels standards and carbon pricing.
- More information:
    - DOE. "Alternative Fuels Data Center: Biodiesel."
    - DOE. "Alternative Fuels Data Center: Ethanol."
    - EPA. "Economics of Biofuels."
    - Sneed, Annie (March 16, 2020). "Could our energy come from giant seaweed farms in the ocean?" *Scientific American*.
    - Held, Lisa (July 20, 2021). "Kelp at the crossroads: Should seaweed farming be better regulated?" *Civil Eats*.
    - Pool, Rebecca (October 15, 2020). "Is seaweed the future of fuel?" *Engineering and Technology.*

Continue reading at https://fisheryfriendlyclimateaction.org/solutions

[17] EPA. "Economics of biofuels." https://www.epa.gov/environmental-economics/economics-biofuels