

# Biofuels

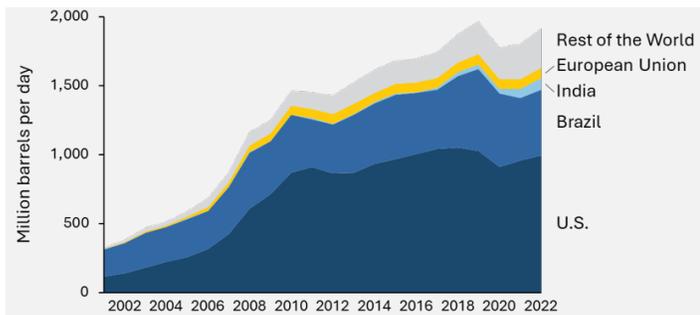
Biofuels, primarily ethanol and biodiesel, are liquid fuels produced from biological sources, including plants, animal fat, and algae.<sup>1</sup> Biofuels can reduce energy and greenhouse gas emission intensities associated with transportation, but may have significant societal and environmental effects. Depending on demand, crop conditions, and technology, they may require significant increases in cropland area and irrigation water use, and can affect food prices.

## Patterns of Use

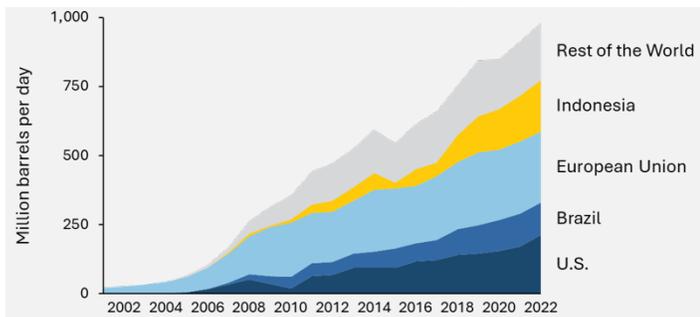
### Production

- Ethanol, an alcohol blended with gasoline for vehicle fuel, is the most produced (82%) and used (75%) biofuel in the U.S.<sup>2</sup>
- The U.S. and Brazil produced 80% of global ethanol in 2022.<sup>3</sup> 94% of U.S. ethanol is derived from corn,<sup>4</sup> while Brazil uses sugarcane.<sup>4</sup>
- In the 2024/25 season, 5.5B bushels of corn, 36% of the U.S. corn supply, were used as ethanol feedstock.<sup>5</sup>
- Cellulosic ethanol is made from feedstocks like corn stalks, plant residue, waste wood chips, and switchgrass. Production is more difficult because cellulose does not break down into sugars easily.<sup>6</sup> The U.S. had no commercial cellulosic ethanol production as of 2022.<sup>7</sup>
- Biodiesel accounted for 9% of U.S. biofuel production in 2022.<sup>2</sup> It can be made from animal fats, grease, vegetable oils, and algae. Common U.S. feedstocks include soybean oil, corn oil, and recycled cooking oils.<sup>8</sup>

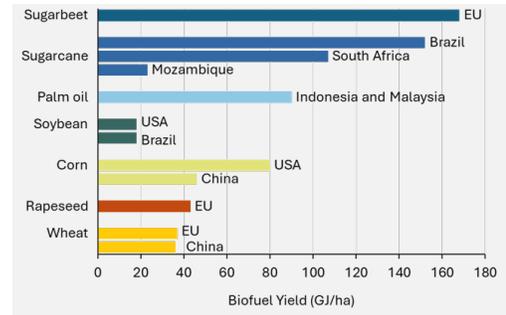
World Ethanol Production (M bbl/d)<sup>3</sup>



World Biodiesel Production (M bbl/d)<sup>3</sup>



Biofuel Yield by Region and Feedstock (GJ/ha)<sup>10</sup>



- Algae could potentially produce 10-100 times more fuel per acre than other crops, making biodiesel from algae an active research area.<sup>9</sup>
- In 2024, the U.S. had 187 ethanol refineries, with total production capacity of 18,010M gal/yr, and 56 biodiesel production plants.<sup>11, 12</sup> Many biodiesel producers depend on federal tax credits and remain sensitive to feedstock (soybean oil) and energy (petroleum) prices. The Inflation Reduction Act (IRA) reinstated and extended several biofuel tax incentives through 2027, which were recently extended again through 2029.<sup>13, 14, 47</sup>

### Consumption and Demand

- In 2023, over 98% of U.S. gasoline contained ethanol,<sup>4</sup> and 10% of U.S. vehicle fuel use (by volume) was ethanol<sup>15</sup>.
- E85 (flex fuel) sells for less than regular gasoline but contains less energy per gal, reducing fuel economy by 15-27%.<sup>16</sup>
- The share of biofuels in total liquid transport fuel demand is projected to expand from 5.6% in 2023 to 6.4% in 2030, to reach 56.8B gal/yr.<sup>48</sup> 85% of this growth is concentrated in the U.S., Europe, Brazil, Indonesia, and India.<sup>48</sup>
- In 2024, ethanol prices dropped 25% while biodiesel and renewable diesel prices fell over 35% from 2022 level, primarily a result of lower feedstock costs, with price declines for sugar (-10%), corn (-35%), and vegetable oils (-30%).<sup>48</sup>

## Life Cycle Impact

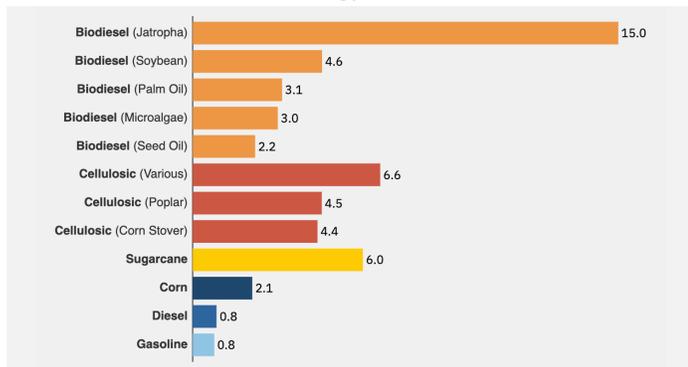
### Energy

- The Fossil Energy Ratio (FER) is the ratio of energy output to nonrenewable energy inputs.<sup>17</sup> Gasoline has a FER of 0.8 (1.2 Btu of fossil fuel needed per 1 Btu at the pump).<sup>24</sup> Ethanol's FER is about 1.5, though highly efficient corn regions like Iowa and Minnesota achieve FERs near 4.<sup>22</sup>
- From 1990-2006, soybean biodiesel's FER improved from 3.2 to 5.5,<sup>23</sup> while ethanol transitioned from an energy sink to net energy gain, largely through reduced fertilizer inputs for corn production.<sup>22</sup> In comparison, petrodiesel has a FER of 0.83.<sup>24</sup>

### Greenhouse Gases (GHGs)

- Globally, biofuels replaced 2M barrels of oil equivalent per day in 2022, 4% of the global transportation sector oil demand.<sup>14</sup>

## Fuel Return on Fossil Energy Investment<sup>17, 18, 19, 20</sup>



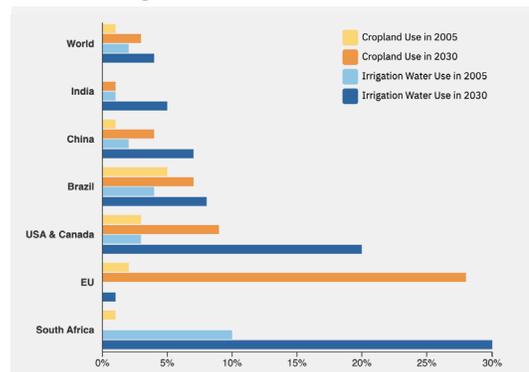
- GHG emissions from corn ethanol average 39% lower than gasoline, and NG-fueled refineries achieve a 43% reduction.<sup>25</sup> Cellulosic ethanol averages 97% lower emissions than gasoline when including land use change (LUC) and 93% lower excluding LUC.<sup>26</sup>
- B20 (20% biodiesel, 80% petroleum diesel), a common U.S. blend,<sup>27</sup> reduces CO<sub>2</sub> emissions by 15% compared to petroleum diesel, while B100 (pure biodiesel) reduces emissions by 74%.<sup>28</sup>
- Biodiesel CO<sub>2</sub> emissions are assumed to be reabsorbed by new feedstock growth,<sup>29</sup> thus, tailpipe CO<sub>2</sub> emissions from biofuels are excluded from emissions calculations.<sup>30</sup>
- Increased U.S. biofuel production may increase global GHG emissions due to higher crop prices motivating farmers elsewhere to convert non-cropland to cropland, releasing stored carbon and preventing future carbon storage.<sup>31</sup>

## Other Impacts

- Feedstock demand for road transportation is projected to increase 13% to over 700 Mt by 2030, accounting for nearly 90% of global biofuel feedstock demand growth. Vegetable oils and residue oils support most biodiesel and renewable diesel expansion, while new ethanol production in Brazil and India relies on corn and sugarcane.<sup>48</sup>
- Increasing corn ethanol acreage without changing cultivation techniques will result in increasing fertilizer runoff from Midwestern farms. Excess nutrients that travel down the Mississippi/Atchafalaya River fuel a large hypoxic region in the Gulf of Mexico each summer.<sup>32</sup> This “dead zone” is an area of low to no oxygen that can kill fish and other marine life, and is forecast to be 5,827 mi<sup>2</sup> in 2024, similar to the size of Connecticut.<sup>33</sup>
- Globally, arable land used for biofuels is predicted to rise from 2.5% to 6% in 2050. The impacts of growing biofuel crops vary widely due to regional differences in climate and farmland availability.<sup>34</sup>
- Water intensity is generally higher for biofuels than fossil fuels but is extremely variable. Irrigated soybean biodiesel ranges from 6.32 to 6,320 gal/GJ, while conventional oil ranges from 0.63 to 632 gal/GJ.<sup>36</sup>

- The average surface and groundwater consumption of ethanol and biodiesel consumed in Europe is 972 gal/GJ and 502 gal/GJ respectively—this is 40 and 60 times higher than fossil alternatives.<sup>37</sup>
- Feedstock irrigation accounts for over 80% of water used in corn-ethanol production in most U.S. states. In Nebraska, which produced 12% of U.S. corn ethanol in 2013, 99% of water used for corn ethanol production was for irrigation.<sup>38</sup>
- Biofuel feedstock growth contributed 20-50% to corn price increases during 2006-2008.<sup>40</sup>
- Land use change resulting from an increase in biofuel demand is expected to increase global corn and wheat prices 1-2% and vegetable oil prices by around 10%.<sup>40</sup>

## Cropland and Irrigation for Biofuels, 2005 & 2030<sup>35</sup>



## Solutions and Sustainable Actions

- The latest renewable fuel standard set by the U.S. EPA requires production of 34B gal of biofuels in 2025, a 15% increase from 2022.<sup>41</sup>
- U.S. ethanol producers, blenders, and resellers have been supported by tax incentives, some of which were extended in 2022 by the IRA and then further extended through 2029. Producers can qualify for up to \$1/gal of nonaviation fuel and \$1.75/gal of aviation fuel.<sup>13,47,49</sup>
- Fuel content standards are one policy option to encourage biofuel use. Regular gasoline sold in Brazil is required to contain 27% ethanol.<sup>42</sup>
- There is concern that replacing gasoline with corn ethanol is unlikely to contribute significantly to climate change mitigation.<sup>43,44</sup> Advances in technology and policies are needed to realize the potential environmental benefits of biofuels.<sup>43,45</sup>
- Strategies to reduce the carbon intensity of corn ethanol production include adoption of precision agriculture systems, retention of soil carbon, use of alternative energy, and increased demand for ethanol production co-products.<sup>46</sup>
- Public transportation, carpooling, biking, and telecommuting are excellent ways to reduce transportation energy use and related impacts. See [Personal Transportation Factsheet](#).