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Global Demand for Fuel Ethanol Through 2030

Steven Ramsey, Brian Williams, Philip Jarrell, and Todd Hubbs

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Abstract

After seeing strong growth for several years, U.S. ethanol-based demand for corn has plateaued over the last decade at about 5 billion bushels, or roughly 40 percent of U.S. corn production. Recently, demand for transportation fuels was reduced by the Coronavirus (COVID-19) pandemic. Though these markets largely recovered, moving forward, increased adoption of hybrid or electric vehicles and continued fuel efficiency gains will decrease domestic gasoline consumption, which in turn could decrease domestic fuel ethanol demand. These impacts could result in additional unutilized U.S. ethanol-production capacity. Ethanol policies in potential export markets are another factor that could influence the economic health of the U.S. corn-based ethanol industry and are the focus of this report. The report summarizes the U.S. and international fuel ethanol markets and provides two scenarios of future fuel ethanol demand in international markets: A "Historical Blends" scenario that assumes countries continue to blend ethanol at historical rates, and a "Targeted Blends" scenario that assumes countries with higher stated goals or mandates fully meet those goals or mandates. Results indicate that countries fully meeting ethanol blend rates or other policies will be required to see significant growth in fuel ethanol demand.

Keywords: biofuel policy, corn, fuel ethanol, motor gasoline

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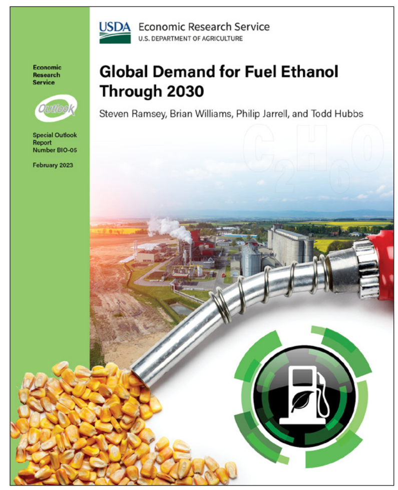


What Is the Issue?

Ethanol manufacturers use about 40 percent of the U.S. corn crop for ethanol and related co-products, with the majority of the ethanol being consumed in the domestic transportation fuel market. After seeing strong growth for several years, ethanol-based demand for corn plateaued over the last decade. Recently, demand for ethanol saw reductions in response to measures taken to combat the Coronavirus (COVID-19) pandemic, such as pandemic-related restrictions, remote work and school, and other social distancing efforts. Though U.S. ethanol consumption has largely recovered from these COVID-19 impacts, increased adoption of hybrid or electric vehicles and continued fuel efficiency gains in gasoline vehicles may decrease domestic gasoline consumption, which in turn could decrease fuel ethanol demand. Moving forward, ethanol policies in export market countries may be an important determinant in whether total demand for U.S. corn-based ethanol increases or decreases. This report has two overarching objectives: first, to summarize the current U.S. and international fuel ethanol markets, and second, to explore potential market opportunities for U.S. ethanol via projections of future fuel ethanol demand in international markets. In the report, USDA, Economic Research Service (ERS) authors make projections under a "Historical Blends" (HB) scenario, where countries continue to blend ethanol at historical rates, and a "Targeted Blends" (TB) scenario, where countries fully meet stated ethanol blending targets or mandates.

What Did the Study Find?

The U.S. Department of Energy's Energy Information Administration (EIA) projections to 2030 indicate that U.S. motor gasoline consumption is expected to see changes ranging from a 4.5-billion-gallon decrease (3.3 percent) to a 7.2-billion-gallon increase (5.3 percent) from 2021 levels. These figures correspond to average consumption changes of between -499 million and 797 million gallons per year. EIA projections also indicate that U.S. consumption of ethanol in motor gasoline and E85 is expected to increase between 196 million gallons (1.4 percent) and 1.4 billion gallons (10.4 percent) above 2021 levels, depending on U.S. economic growth over the decade. The projected increase in ethanol consumption across all scenarios—despite falling gasoline consumption in some scenarios—is due in part to EIA's assumption that the Renewable Fuel Standard will increase total U.S. consumption of renewable fuels.

Total global demand for gasoline is expected to stagnate over the next decade, leaving changes in blend rates—domestically or abroad—as the main determinant for future changes in fuel ethanol demand. The second part of this study focused on blend rates outside of the United States and the impact that non-U.S. countries meeting their targets has on projected demand for fuel ethanol.

- Under the "Historical Blends" (HB) scenario, international fuel ethanol consumption is projected to increase by 0.75 billion gallons (5.7 percent) between 2018 and 2030 and by 0.95 billion gallons (7.4 percent) between 2021 and 2030. The projected 2018 to 2030 increase is primarily driven by an increased demand of 234 million gallons in India, 276 million gallons in Brazil, and 347 million gallons in China. The projected 2021 to 2030 increase is primarily driven by an increased demand of 113 million gallons in Thailand, 193 million gallons in China, and 739 million gallons in Brazil.

- Under the "Targeted Blends" (TB) scenario, international fuel ethanol consumption is projected to increase by 23.7 billion gallons (180 percent) between 2018 and 2030 and by 23.4 billion gallons (173 percent) between 2021 and 2030. The largest increases from 2018 to 2030 are projected to occur in Canada (3.3 billion gallons), China (5.6 billion gallons), and Brazil (6.4 billion gallons). The largest increases from 2021 to 2030 are also projected to occur in Canada (3.4 billion gallons), China (5.5 billion gallons), and Brazil (6.9 billion gallons).

Taken together, the HB and TB scenarios present an evaluation of fuel ethanol consumption outside the United States over the next decade. The HB scenario represents a USDA, Economic Research Service estimate under current trends, and the TB scenario represents a potential upper boundary based on certain policy and market scenarios. The study does not assign the likelihood of any policy being implemented or discontinued. USDA's ERS researchers did not model a scenario where countries reduce their ethanol consumption as there was not an established non-ad hoc approach to determining which countries would reduce consumption and by how much.

How Was the Study Conducted?

USDA's ERS researchers estimated the demand for motor gasoline and fuel ethanol using data and projections from the EIA, USDA's Foreign Agricultural Service (FAS), and the International Energy Agency (IEA). The researchers used projections for U.S. consumption of fuel ethanol and motor gasoline from EIA's Annual Energy Outlook 2022. International demand projections in the report are based on a combination of historical fuel ethanol consumption data from EIA and USDA's FAS and energy-demand projections from IEA's World Energy Outlook 2020. The researchers obtained blending targets or mandates for countries that have historically consumed fuel ethanol.

This study focused primarily on potential demand for fuel ethanol but not current or forecasted future ethanol production. Additionally, though non-fuel ethanol is covered briefly, data limitations prevented a more thorough analysis of these markets.

Global Demand for Fuel Ethanol Through 2030

Introduction

Consumption of ethanol as a transportation fuel (largely sourced from corn) has seen significant growth in the last couple of decades in the United States. As a result, the current importance of fuel ethanol consumption to the U.S. agricultural sector is hard to overstate. Moving forward, continuation of the Renewable Fuel Standard (RFS) program in the United States, combined with expansion of global vehicle numbers and rising demand for high-octane fuels, could maintain global demand for ethanol. Conversely, technological change in fuel efficiency and alternative drivetrains (e.g., electric vehicles) may slow the growth of—or even decrease—U.S. ethanol consumption. This report summarizes the current U.S. and international fuel ethanol markets and explores potential market opportunities for U.S. ethanol via projections of future fuel ethanol demand in international markets.

U.S. Fuel Ethanol Market

Much of the early demand for ethanol in the United States stemmed from its use as a motor gasoline oxygenate. Particularly, ethanol served as an alternative to methyl tertiary-butyl ether (MTBE). MTBE use started in 1979 as an octane booster to replace tetraethyl lead (U.S. Environmental Protection Agency, 2016). MTBE, like ethanol, also adds oxygen to gasoline in addition to boosting octane. Passage of the Clean Air Act Amendments (CAAA) in 1990 mandated the use of oxygenates (such as MTBE), which helped MTBE become a staple component of motor gasoline (Wright, 2014). Specifically, the CAAA mandated that motor gasoline in certain "nonattainment" geographical areas with excessive carbon monoxide levels contain at least 2.7 percent oxygen (by weight) to reduce carbon monoxide emissions. The CAAA also introduced reformulated gasoline requirements to contain at least 2 percent oxygen (by weight) in certain places with ground-level ozone problems. However, MTBE would soon face scrutiny of its own due to concerns over groundwater contamination. As a result, 25 States[1] enacted complete or partial bans on MTBE as a fuel additive by September 2005 (EPA, 2007). These bans, combined with other liability issues, effectively phased out the commercial use of MTBE in fuel. Refinery and blender MTBE utilization peaked in 1999 at 4 billion gallons but by 2007 had fallen to 67 million gallons and has not surpassed 50 million gallons in any year since (EIA, 2022).

Due to the combined effects of the CAAA emissions requirements and MTBE concerns and bans, alternative oxygenates were needed to boost the octane level of U.S. gasoline. Given its high octane rating, ethanol has similar blending properties to those of MTBE, which made it a viable oxygenate source. Additionally, there was growing public support in the early 2000s for increasing U.S. energy independence and security via reducing the need for foreign oil. As such, the 2005 Energy Policy Act simultaneously removed the oxygenate requirement—a further blow to MTBE demand—and established the Renewable Fuel Program (eventually, the Renewable Fuel Standard), which began with a 4-billion-gallon renewable-fuel target in 2006, rising to 7.5 billion gallons in 2012. The statutory volumes were revised soon after by the Energy Independence and Security Act of 2007, which raised the 2012 requirement to 15.2 billion gallons and set a 2022 requirement of 36.0 billion gallons. Of the 2012 and 2022 total volumes, advanced biofuels—which do not include corn-based ethanol—were to comprise 2 billion gallons and 21 billion gallons, respectively. Actual volume requirements are set by the U.S. Environmental Protection Agency (EPA), which has the authority to waive the statutory requirements. The statutory volumes and the final or proposed volumes for 2010–2025 are shown in table 1. Beginning in 2023, the EPA has the authority to set RFS obligations independent of a congressionally established schedule (though as previously noted, the EPA has the authority to waive the statutory requirements).

[1] Arizona, California, Colorado, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Rhode Island, South Dakota, Vermont, Washington, and Wisconsin.

Table 1

Renewable Fuel Standard statutory and EPA final/proposed volume standards, 2010–25 (billions of ethanol-equivalent gallons)

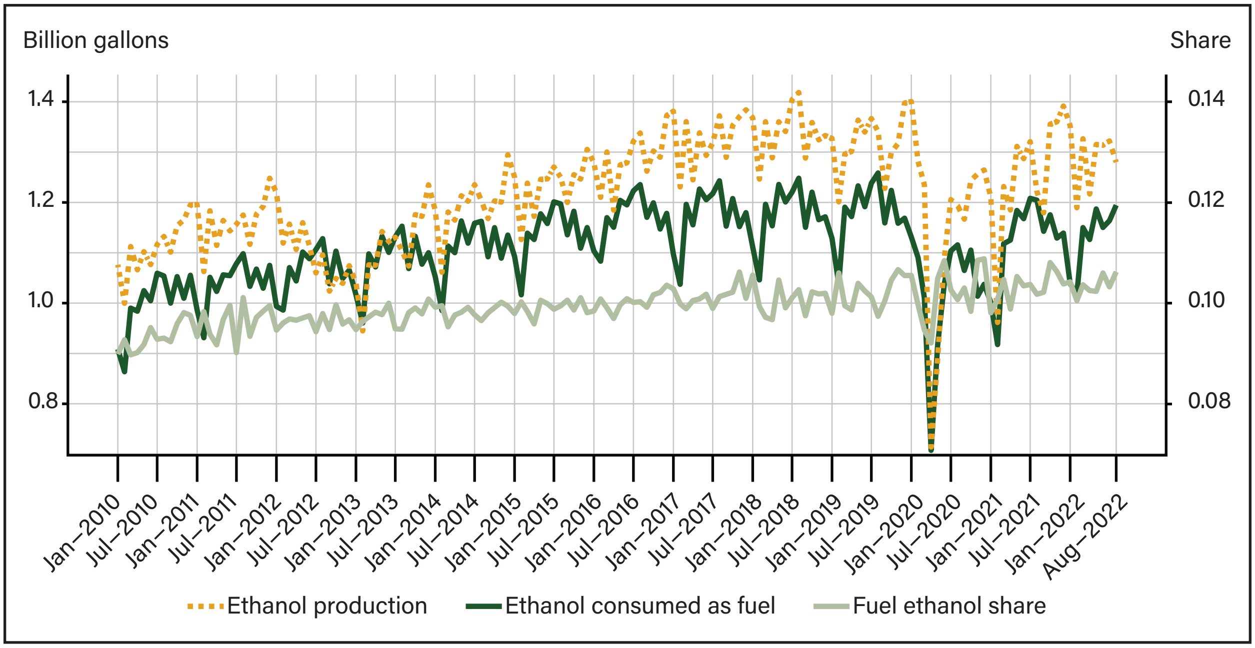
Year	Statutory volumes			EPA final/proposed volumes		
	Advanced biofuel	Total renewable fuel	Unspecified (e.g., ethanol)	Advanced biofuel	Total renewable fuel	Unspecified (e.g., ethanol)
2010	0.95	12.95	12.00	0.95	12.95	12.00
2011	1.35	13.95	12.60	1.35	13.95	12.60
2012	2.00	15.20	13.20	2.00	15.20	13.20
2013	2.75	16.55	13.80	2.75	16.55	13.80
2014	3.75	18.15	14.40	2.67	16.28	13.61
2015	5.50	20.50	15.00	2.88	16.93	14.05
2016	7.25	22.25	15.00	3.61	18.11	14.50
2017	9.00	24.00	15.00	4.28	19.28	15.00
2018	11.00	26.00	15.00	4.29	19.29	15.00
2019	13.00	28.00	15.00	4.92	19.92	15.00
2020	15.00	30.00	15.00	4.63	17.13	12.50
2021	18.00	33.00	15.00	5.05	18.84	13.79
2022	21.00	36.00	15.00	5.63	20.87	15.25
2023	NA	NA	NA	5.82	21.07	15.25
2024	NA	NA	NA	6.62	21.87	15.25
2025	NA	NA	NA	7.43	22.68	15.25

Note: EPA = U.S. Environmental Protection Agency; NA = not available. The 2020–22 EPA volumes were finalized on June 3, 2022. The 2023–25 volumes were proposed by EPA in November 2022. The 2022 and 2023 total renewable fuel obligations include 250 million Renewable Identification Number (RIN; 1 RIN = 1 ethanol-equivalent gallon) supplemental obligations that were added to address a shortfall in the 2014–16 volumes. The supplemental obligations can be satisfied with any category of RIN.

Source: USDA, Economic Research Service using data from Energy Policy Act of 2005, Energy Independence and Security Act of 2007, and the EPA.

For several years, the overall ethanol blend rate in the United States hovered at around 10 percent, as seen in figure 1. At the pump, motor gasoline blends that contain 10 percent ethanol are commonly referred to as E10. Though the RFS plays an important role in these blend rates, other factors can lead to deviations around the 10-percent level, such as the price for ethanol versus the prices for other oxygenates and wholesale gasoline. Between 2010 and 2020, these blending rates resulted in an average consumption of 13.3 billion gallons of fuel ethanol per year, 8.7 percent below an average production rate of 14.5 billion gallons. Domestic ethanol groups and farm organizations have pushed for higher blend levels such as E15 (10.5 to 15 percent ethanol) and E85 (51 to 83 percent ethanol) (U.S. Department of Energy, 2021), but use of these blends remains limited. Stagnant motor gasoline consumption has provided further motivation for the ethanol industry's push for higher blends.

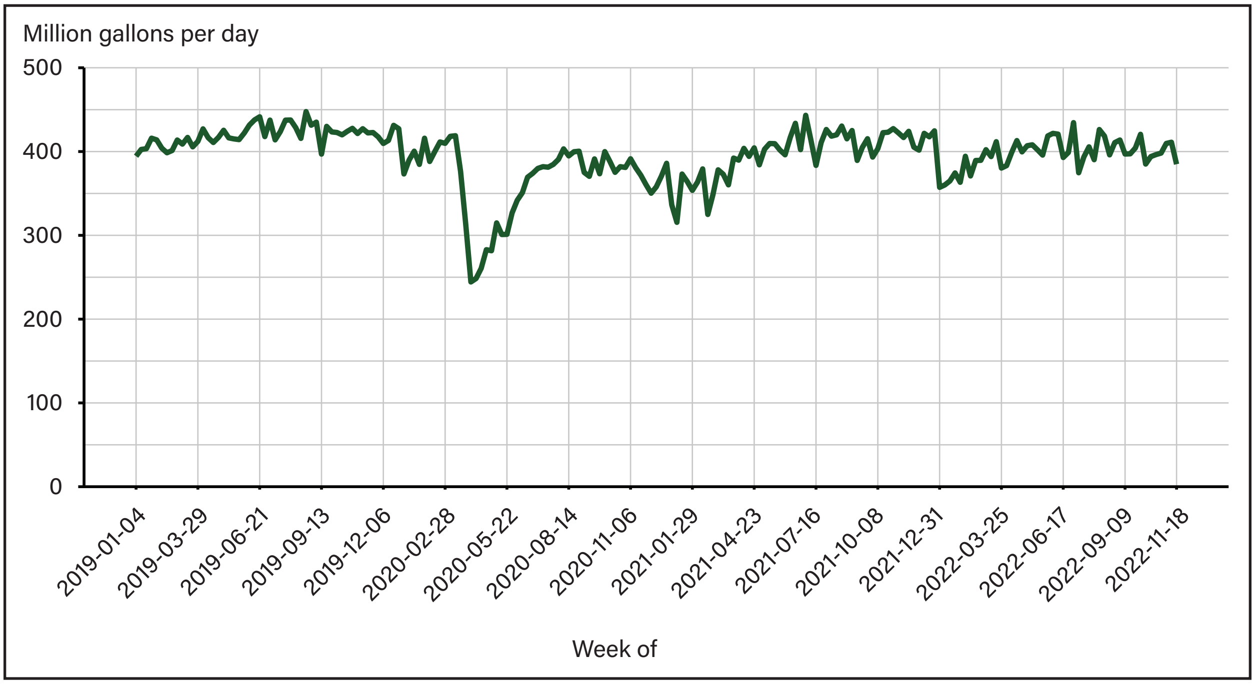
Figure 1
U.S. monthly ethanol production, consumption as fuel, and share of finished motor gasoline, January 2010–August 2022



Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

The COVID-19 pandemic decreased demand for transportation fuels in the United States and elsewhere. As shown in figure 2, U.S. weekly consumption of motor gasoline dropped sharply in March and April 2020. This drop can be attributed to pandemic-related restrictions, remote work and school, and other social distancing efforts. Though the magnitude of this impact lessened over time, from a year-over-year decrease of 43 percent in the first week of April 2020 to an average decline from 2019 levels of 5.1 percent in 2022 (through November 18, 2022), the overall downward pressure persisted for many months and consumption did not return to pre-pandemic levels until mid-2021. The extent to which telecommuting features in future work environments will largely dictate if this is a structural change in motor gasoline demand. Additionally, it is unknown what impact post-pandemic perceptions will have on various commuting methods and whether public transportation will be used less in favor of private transport that could be deemed to be a safer alternative in a COVID-19 environment.

Figure 2
Weekly U.S. finished motor gasoline supplied, week of January 4, 2019–week of November 18, 2022

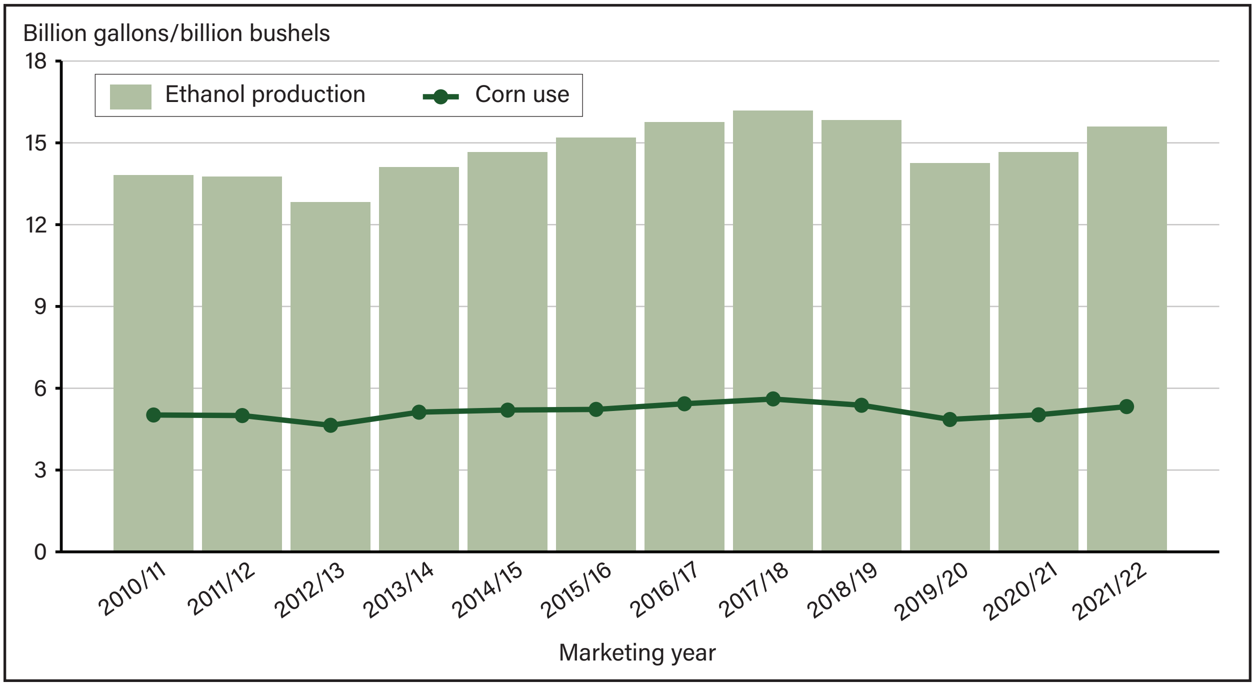


Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

The background presented above provides an overview to the current state of U.S. fuel ethanol consumption, which plays an important role in U.S. agriculture. Indeed, ethanol production has been a key driver of corn demand since the mid-2000s and between the 2010/11 and 2021/22 corn marketing years (MYs)[2] averaged approximately 38 percent of total corn use. As seen in figure 3, ethanol production hit a peak in the 2017/18 MY at 16.2 billion gallons. This increase led to an expansion of corn use for ethanol to over 5.6 billion bushels in the 2017/18 MY, before weaker export markets and the pandemic set in. Due to decreased driving during the pandemic, ethanol production fell to about 14.3 billion gallons in the 2019/20 MY. As a result, corn use for ethanol decreased to about 4.9 billion bushels.

[2] The corn marketing year is defined as September through August, e.g., the 2020/21 corn marketing year was September 2020 through August 2021. Ethanol production across corn marketing years was calculated by summing production across the months in a marketing year. For example, the 2020/21 ethanol value is the sum of monthly production values from September 2020 through August 2021.

Figure 3
U.S. ethanol plant production and corn use by marketing year, 2010/11–2021/22



Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, National Agricultural Statistics Service.

U.S. Fuel Ethanol Market: Looking Forward

Projections in this section come from the Energy Information Administration's (EIA) Annual Energy Outlook 2022 (AEO). The AEO provides projections under nine different scenarios: "High Economic Growth," "Low Economic Growth," "High Oil Price," "Low Oil Price," "High Oil and Gas Supply," "Low Oil and Gas Supply," "High Renewables Cost," "Low Renewables Cost," and a reference scenario. Some of the assumptions underlying these scenarios are presented in table 2. Additional information on the EIA AEO modeling approach and underlying assumptions can be found online.

Table 2

Scenario assumptions in the Annual Energy Outlook 2022 models

Macroeconomic growth rates, 2021–2030			
	Low economic growth scenario	Reference scenario	High economic growth scenario
Productivity	1.5%	2.0%	2.4%
Nonfarm employment	0.6%	1.0%	1.6%
Real gross domestic product	2.1%	2.6%	3.3%
Brent crude oil spot prices (2021 dollars per barrel)			
	High oil price scenario	Reference scenario	Low oil price scenario
2021	71.59	71.59	71.59
2025	132.58	66.97	35.25
2030	145.13	73.93	38.47
Technically recoverable resources			
	High oil and gas supply scenario	Reference scenario	Low oil and gas supply scenario
Oil (billion barrels)	470	326	182
Natural gas (trillion cubic feet)	3,562	2,460	1,359

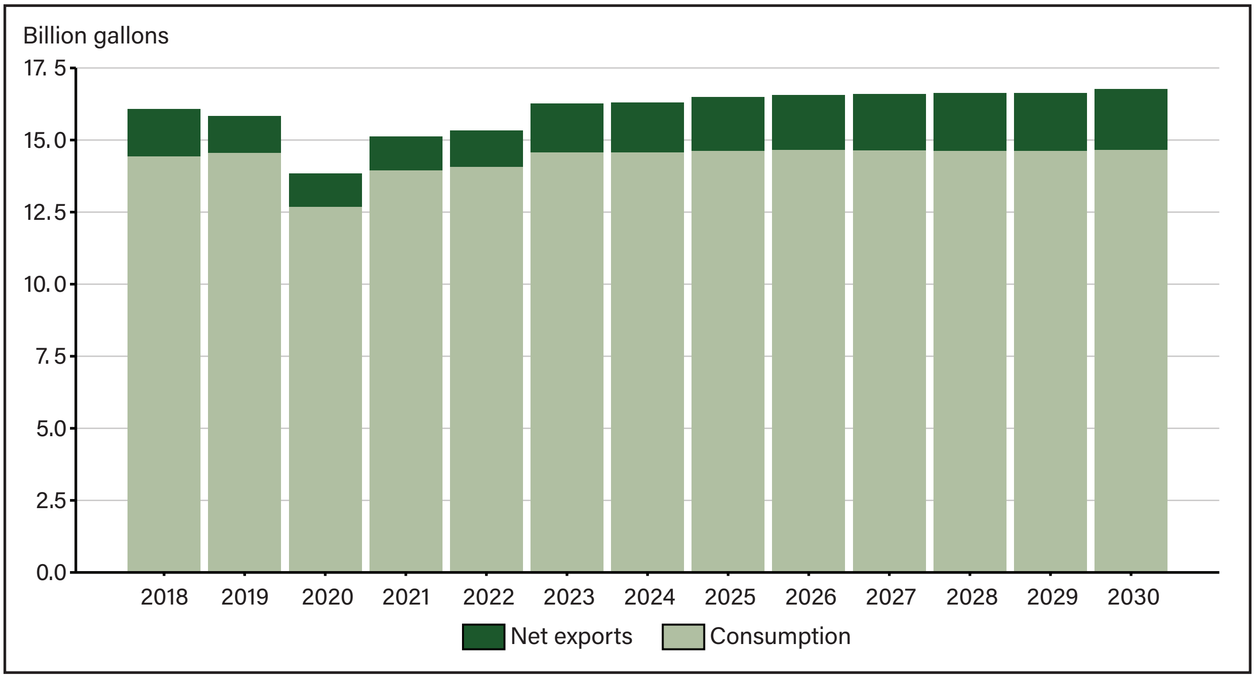
Source: USDA Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Projections through 2030 from the AEO 2022 indicate increasing domestic fuel ethanol consumption over the next decade. In the reference scenario, total domestic consumption of fuel ethanol in motor gasoline and E85 increases 5.1 percent from about 13.9 billion gallons in 2021 to 14.7 billion gallons in 2030,[3] though much of this increase occurs between 2021 and 2023 (figure 4). Compared with 2018 and 2019, the 2030 consumption represents increases of 1.7 and 0.7 percent, respectively. Meanwhile, net exports (exports minus imports) are projected at 2.1 billion gallons in 2030, representing increases of 27 percent, 65 percent, and 78 percent above 2018, 2019, and 2021 levels, respectively. Domestic production for 2030 is projected at 16.3 billion gallons, which would be increases of 1.4 percent, 3.4 percent, and 8.7 percent above 2018, 2019, and 2021 levels, respectively. Based on these results, by 2030, there may continue to be unutilized ethanol-production capacity in the United States. As of January 1, 2021, U.S. ethanol-production capacity was estimated at about 17.5 billion gallons per year (EIA, 2021).

[3] The EIA AEO 2022 reports ethanol consumed in motor gasoline and E85 in quadrillion British thermal units (Btu). The authors converted to gallons using a ratio of 84,714 Btu/gallon of ethanol.

Figure 4

Actual and projected U.S. fuel ethanol consumption and exports, EIA reference case, 2018–30

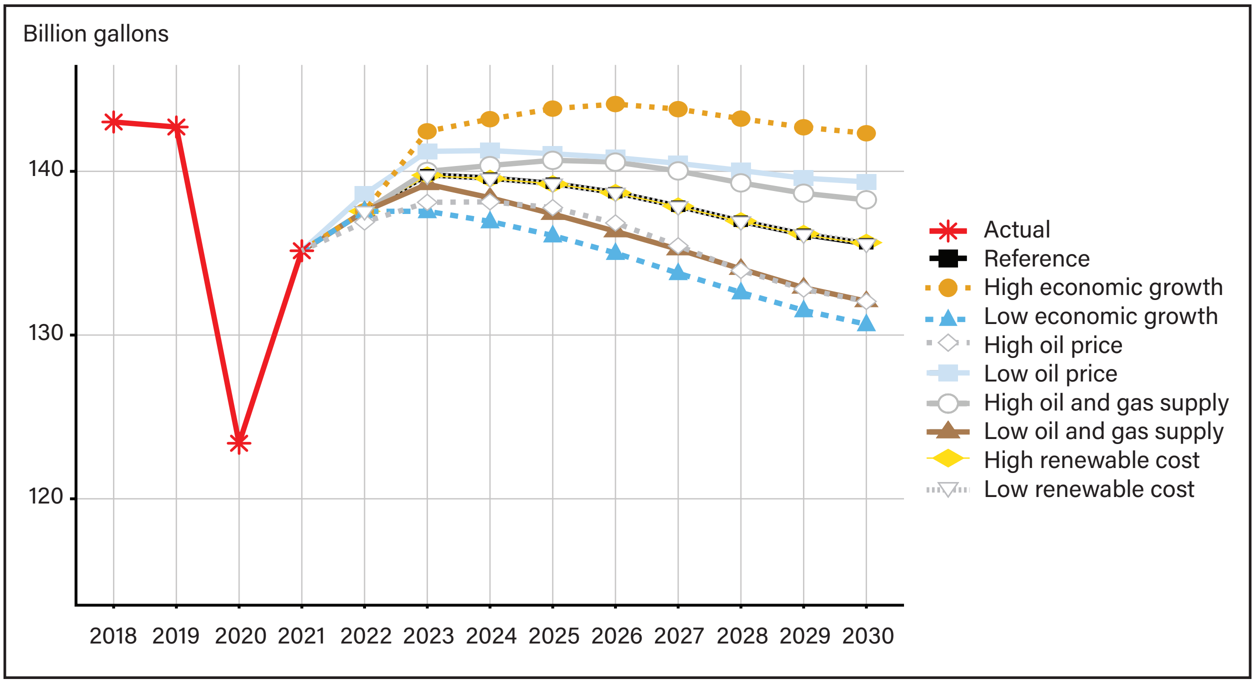


Note: Values for 2018–21 represent actual values; values for 2022–30 are Energy Information Administration (EIA) projections.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, EIA.

As has historically been the case, U.S. motor gasoline consumption is likely to be the key driver of future domestic fuel ethanol demand. The EIA projections include multiple outcomes for U.S. motor gasoline consumption under various scenarios. In the reference case, motor gasoline use in the United States increases about 0.3 percent from 135.1 billion gallons in 2021 to 135.6 billion gallons in 2030 (figure 5). The projection for 2030 motor gasoline consumption represents a decline of 5 percent from consumption in 2018 and 2019. The lowest 2030 consumption seen across all scenarios is about 130.7 billion gallons under "low economic growth," while the largest consumption is about 142.3 billion gallons under "high economic growth."

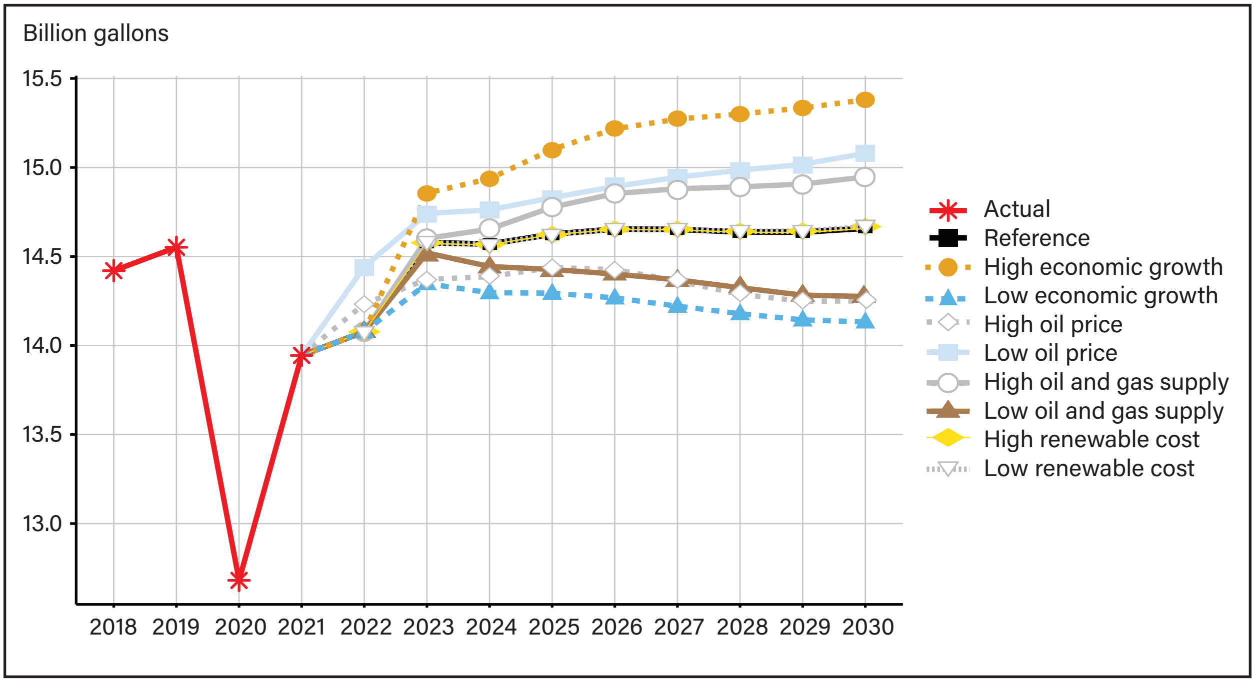
Figure 5
Actual and projected motor gasoline use across EIA scenarios, 2018–30



Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration (EIA).

As with motor gasoline, the various scenarios for economic growth or oil prices show the possibility of different outcomes for fuel ethanol consumption over the next decade, though all scenarios suggest consumption in 2030 will be higher than consumption in 2021 (figure 6). Compared with 2021, the projected increases range from 188 million gallons (decreases of 288 million gallons and 419 million gallons compared with 2018 and 2019, respectively) under "low economic growth" to 1.4 billion gallons (960 million gallons and 828 million gallons compared with 2018 and 2019, respectively) under "high economic growth." Based on the 2021 total U.S. nameplate capacity (the amount of ethanol a plant can produce in 12 months under normal operating conditions), these figures suggest that between 2.2 billion (under "high economic growth" in 2030) and 3.5 billion gallons (under multiple scenarios in 2022) of ethanol capacity would be available for exports.

Figure 6
Actual and projected U.S. fuel ethanol consumption, EIA reference case, 2018–30



Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration (EIA).

EIA estimates total miles traveled by conventional-gasoline light-duty vehicles (LDVs) at 2.43 trillion miles in 2021, down from 2.55 trillion miles in 2018 and 2.58 trillion miles in 2019.[4] By 2030, total miles traveled by conventional-gasoline LDVs is projected to increase to 2.73 trillion miles. However, the LDV average fuel efficiency is projected to increase from 24.2 miles per gallon (mpg) to 27.7 mpg as the new vehicle fuel efficiency moves from 36.3 to 38.5 mpg from 2021 to 2030, suppressing fuel demand.

Another key factor in reduced motor gasoline use involves the rise of hybrid and electric vehicles. The uncertainties surrounding the pace of technological change in batteries, consumer adoption of these vehicles, and various infrastructure issues create a range of possible outcomes for the vehicle fleet over the next decade and beyond. EIA's reference scenario estimated electric and hybrid vehicles composed 2.6 percent of the light-duty vehicle stock in 2021, up from 2.3 percent in 2018 and 2.4 percent in 2019 and 2020.[5] This share is projected to increase to 6.5 percent in 2030 (figure 7). These values do not change much across scenarios, but the highest share by 2030 is seen in the "high oil price scenario" at 8.7 percent, while the lowest came from the "low oil price scenario" at 5.8 percent.

In terms of total electric vehicle (EV) numbers, EIA projects the 2030 fleet to include between 3.8 and 7.4 times the number of EVs in the 2021 fleet. By comparison, the International Energy Agency's (IEA) "Stated Policies Scenario" in its World Energy Outlook 2020 projects the number of EVs in the United States to grow fivefold by 2030.[6] The potential for EV adoption (at levels greater than those in the EIA projections) appears robust. First, as of the time of this writing, Brent oil prices are around $101 per barrel, 41 percent above the 2021 assumption of $71.59 per barrel across the EIA scenarios. Second, major vehicle makers across all classes of cars and trucks are making investments in EV technologies. For example, in 2020, General Motors

[4] EIA does not appear to report actual vehicle miles traveled for this vehicle type. As such, the 2018, 2019, and 2021 values represent the estimates put forth in the 2019, 2020, and 2022 Annual Energy Outlook reports, respectively.

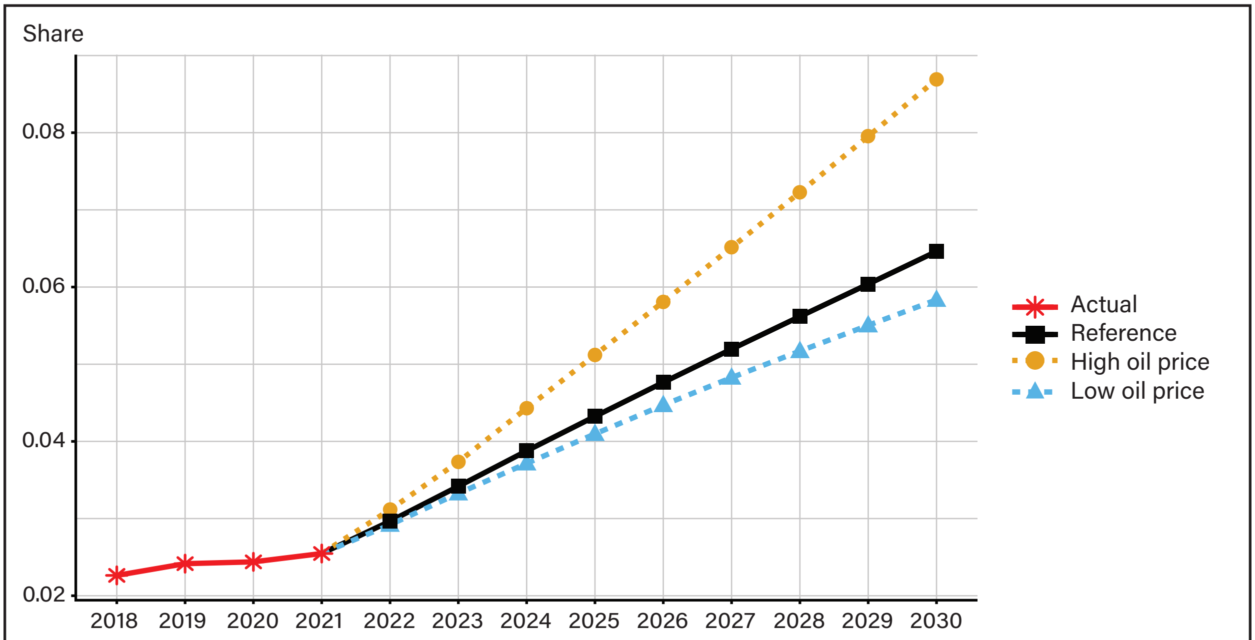
[5] EIA does not appear to publish vehicle stock numbers by technology type outside of the Annual Energy Outlook reports (AEO). As such, these values are based on the reference scenarios from previous AEOs.

[6] The base year was not clear but appears to be either 2019 or 2021.

(GM) announced plans to invest $27 billion in EVs and autonomous vehicles, and in 2021, Ford announced plans to invest $22 billion in EVs, both by 2025 (Baldwin, 2021; Beresford, 2020). In 2021, GM increased planned EV investments to $35 billion (General Motors, 2021), while in 2022 Ford increased planned EV investments to $50 billion by 2026 (Nair et al., 2022). Changes in the Federal fleet could also influence the speed at which these changes occur, such as the U.S. Postal Service's (USPS) transition to "Next Generation Delivery Vehicles," which will include EVs. More broadly, Executive Order 14057 is targeting 100-percent zero-emission vehicle acquisitions by 2030, with 100 percent being achieved for LDV acquisitions by 2027. Other new or existing Government policies may also play a role. For example, the Federal Government's Qualified Plug-In Electric Vehicle Tax Credit provides a base credit of $2,500 and a total credit of up to $7,500 for the purchase of a qualifying EV. More recently, the Federal "Inflation Reduction Act" (passed on August 16, 2022) retained the maximum credit of $7,500 but increased the base tax credit to $3,750. The act also added a credit for qualifying used EVs equal to the lesser of $4,000 and 30 percent of the vehicle's sale price. Though the speed at which EV adoption will occur is unknown, ultimately, the impacts on motor gasoline—and thus fuel ethanol use—as this technology matures and finds market penetration are likely to be significant. Given fast-moving developments in this field, the question may require further exploration and analysis to provide biofuels-concerned policy makers with a more complete view of the current situation and what may influence future developments.

Figure 7

Electric and hybrid share of cars and noncommercial light-duty trucks, 2018–30



Note: The Energy Information Administration (EIA) does not appear to publish actual vehicle stocks. As such, values for 2018–21 are based on reference-scenario projections from EIA 2019–22 Annual Energy Outlook reports.

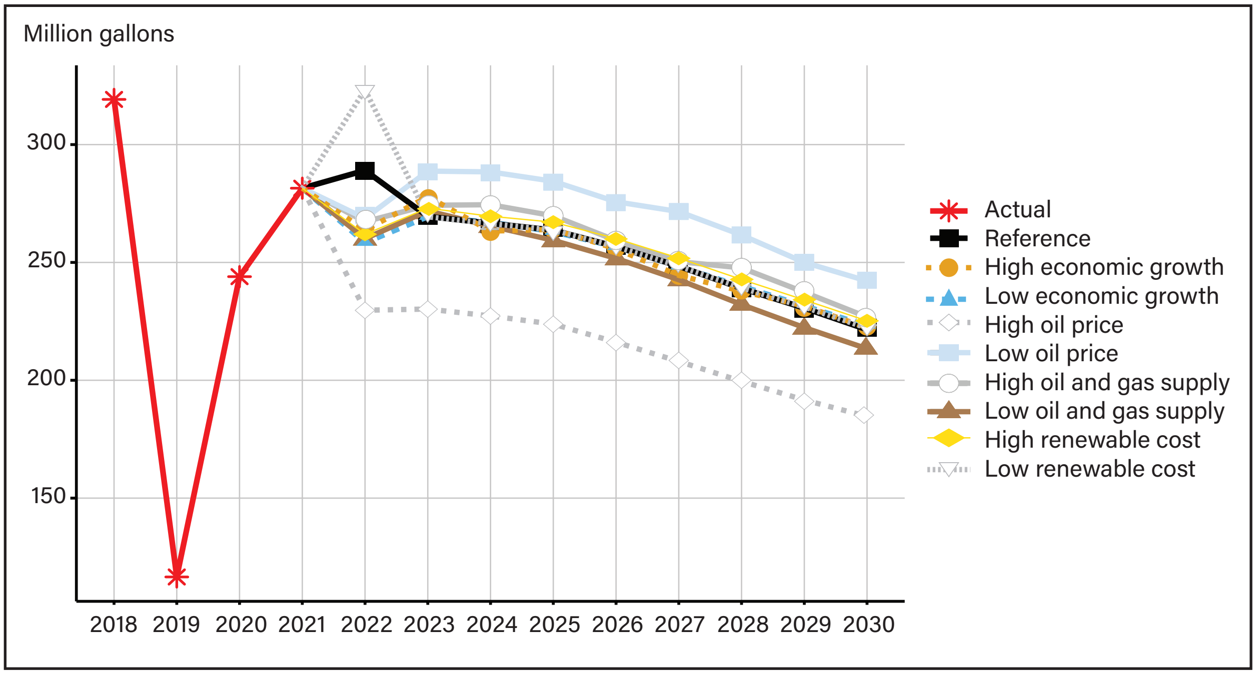
Source: USDA, Economic Research Service using data from U.S. Department of Energy, EIA.

Despite the efforts to promote the usage of higher-blend fuel E85 through policy interventions and incentives for flex fuel vehicles, E85 consumption is projected to follow recent declining trends and comprise a small portion of ethanol used in the fuel supply. Between 2018 and 2021, consumption of E85 ranged between 158 million gallons (2019) and 431 million gallons (2018). Surprisingly, consumption of E85 in 2020 at 330 million gallons exceeded 2019 consumption (158 million gallons) despite COVID-19 impacts.[7] Based

[7] EIA does not appear to publish E85 consumption estimates outside of the Annual Energy Outlook reports (AEO). As such, these values are based on the reference scenarios from previous AEOs.

on EIA's reference scenario, E85 consumption over the decade is expected to fall from 380 million gallons in 2021 to 299 million gallons in 2030. Thus, the share of fuel ethanol consumption via E85 is projected to fall. Assuming an average blend rate of 74[8] percent for E85, these volumes would correspond to a decrease in ethanol used for E85 from 281 million gallons in 2021 to 222 million gallons in 2030 (figure 8). Ethanol consumed via E85 in 2030, across EIA's scenarios, is expected to range between 185 million ("high oil price") and 242 million gallons ("low oil price").

Figure 8
Ethanol used in E85, 2018–30



Note: E85 is a blend of gasoline and ethanol containing 51- to 83-percent ethanol. Energy Information Administration (EIA) does not appear to publish annual E85 consumption. As such, values for 2018–21 are based on reference-scenario projections from the EIA 2019–22 Annual Energy Outlook reports.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, EIA.

A second possibility for higher ethanol blends to compensate for reduced motor gasoline consumption is via blend rates between E10 and E85. At the policy level, the EPA finalized regulatory changes in May 2019 that allowed for the year-round sale of E15 in conventional gasoline areas by allowing E15 to take advantage of the 1-pound per square inch (psi) Reid vapor pressure (RVP) waiver that previously applied only to E10.[9] The D.C. Circuit Court of Appeals vacated this E15 waiver in an opinion issued on July 2, 2021. However, beginning on April 29, 2022, the EPA issued a series of seven[10] "emergency fuel waivers" allowing E15 to be sold

[8] According to the EIA (2022), "E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for these projections."

[9] Reid vapor pressure (RVP) is a common measure for fuel volatility. The EPA regulates gasoline vapor pressure during "summer ozone months" (June 1 to September 15) to reduce evaporative emissions from gasoline (U.S. Department of Energy, Energy Information Administration, 2021). The EPA provides a 1-pound per square inch RVP allowance for E10.

[10] First waiver: issued April 29, 2022; effective May 1, 2022; expired May 20, 2022. Second waiver: issued May 19, 2022; effective May 21, 2022; expired June 10, 2022. Third waiver: issued June 9, 2022; effective June 11, 2022; expired June 30, 2022. Fourth waiver: issued June 29, 2022; effective July 1, 2022; expired July 20, 2022. Fifth waiver: issued July 19, 2022; effective July 21, 2022; expired August 9, 2022. Sixth waiver: issued August 8, 2022; effective August 10, 2022; expired August 29, 2022. Seventh waiver: issued August 26, 2022; effective August 30, 2022; expires September 15, 2022, when the summer volatility control period ends.

during the summer of 2022. Just prior to issuance of the first waiver, a group of eight Governors[11] wrote to the EPA requesting a permanent waiver that would allow for the unrestricted year-round sale of E15. Around this same time, the State of Iowa passed House File 2128, which requires a retail dealer owning or operating a retail motor fuel site to advertise and sell E15. Additionally, the State of Nebraska experimented with E30 in State vehicles. In September 2018, the EPA approved a pilot project in which Nebraska would operate a portion of its State-owned vehicle fleet on E30 to assess the impacts on vehicle fuel economy, performance, and emissions. Results from the assessment suggest that the use of a 30-percent ethanol blend in non-flex fuel vehicles does not cause long-term damage to the vehicle (Saha et al., 2021). In November 2022, the Consumer and Fuel Retailer Choice Act of 2022 was introduced in the U.S. Senate. This legislation would allow the year-round, nationwide sale of ethanol blends higher than 10 percent by extending the RVP waiver to fuels with ethanol blends of more than 10 percent.

The production of sustainable aviation fuel (SAF) via alcohol-to-jet fuel technology could provide another future source of ethanol demand. For example, Microsoft recently invested $50 million in a facility that plans to produce jet fuel from ethanol beginning in 2023 (Sanicola, 2022). However, SAFs have not been economically competitive (Romero-Izquierdo et al., 2021). The recently passed Federal Inflation Reduction Act created an SAF tax credit of between $1.25 and $1.75 per gallon for qualifying fuels.

Though there is uncertainty surrounding EIA's projections for ethanol's trajectory in the domestic fuel market through the next decade (i.e., which scenario will most resemble reality), even the highest projected consumption in 2030 is below current production capacity in the United States. Additional uncertainty arises because these projections align with the current regulatory environment and do not project the impacts of, for example, a national policy similar to California's Low Carbon Fuel Standard or a supply-side shock in the oil market. Many of the factors affecting fuel ethanol in the United States—such as domestic policy, technological change, and economic growth—apply globally but can also be unique to a given jurisdiction.

International Fuel Ethanol Markets

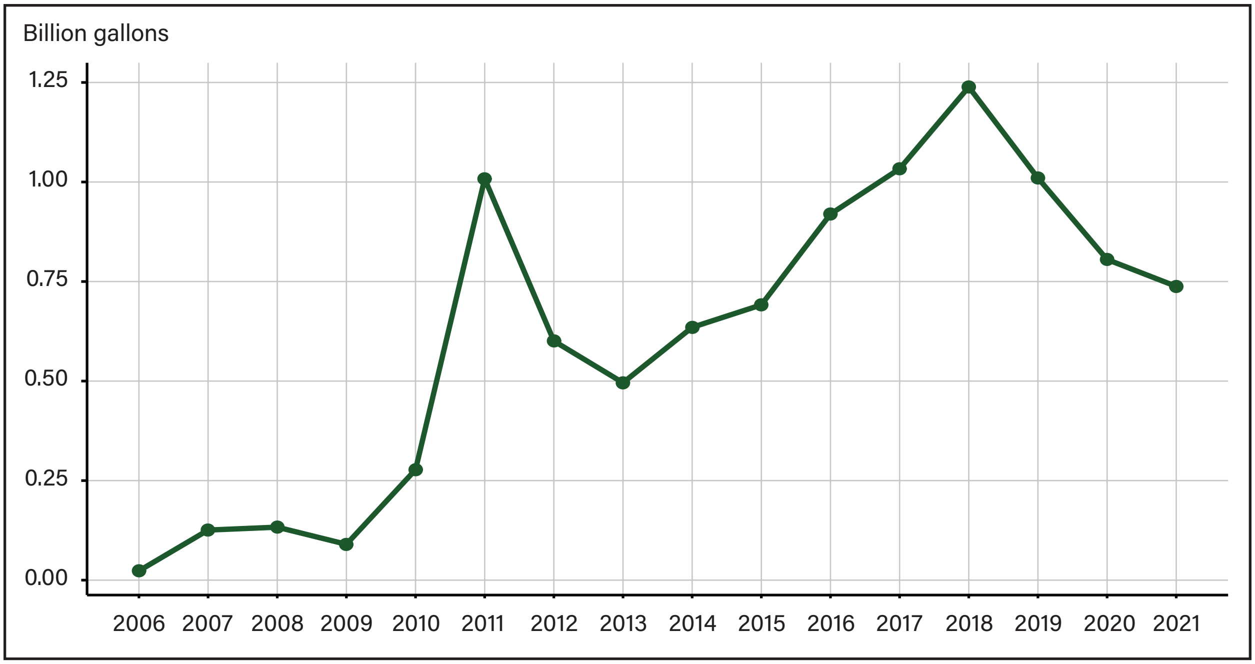
U.S. Fuel Ethanol Exports

As global consumption of fuel ethanol has grown, so too have U.S. exports of fuel ethanol, increasing from 23 million gallons in 2006 to a peak of 1 billion gallons in 2019 (figure 9) (USDA, FAS, 2022). The 1 billion gallons exported in 2019 represent about 5.7 percent of the total 2021 U.S. production capacity of approximately 17.5 billion gallons per year (EIA, 2021). Moreover, as domestic consumption has plateaued in recent years, the export market has become an increasingly important source of demand: The share of total fuel ethanol production going to exports over the last decade has risen from 0.5 percent in 2006 to a peak of 7.7 percent in 2018. This share fell in each of the following 3 years, and in 2021, it was at 4.9 percent. Fuel ethanol exports fell to 805 million gallons in 2020 due in part to the impact of COVID-19 on global transportation patterns. Exports fell again in 2021 to 738 million gallons.

Between 2012 and 2021, Canada and Brazil imported the largest volumes of U.S. fuel ethanol exports, averaging 298 million gallons and 214 million gallons, respectively, over those years. Combined, these two countries imported an average of 62 percent of total U.S. fuel ethanol exports during this period. China was the only other country that had years with more than 100 million gallons of fuel ethanol imported from the United States over this period.

[11] Kim Reynolds (Iowa), Pete Ricketts (Nebraska), JB Pritzker (Illinois), Laura Kelly (Kansas), Tim Walz (Minnesota), Doug Burgum (North Dakota), Kristi Noem (South Dakota), and Tony Evers (Wisconsin).

Figure 9
U.S. annual exports of fuel ethanol, 2006–21



Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service.

Table 3
U.S. fuel ethanol exports by destination, 2012–21 (millions of gallons)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Brazil	81	46	111	116	269	430	489	331	186	76
Canada	279	291	306	289	282	293	312	298	294	333
China	0	4	3	75	198	55	54	0	32	100
Colombia	0	4	2	2	5	17	49	83	71	36
EU+UK	139	22	40	30	10	51	89	97	111	100
Oman	24	0	0	33	13	22	30	37	0	0
Peru	30	30	15	29	43	43	47	48	44	44
Philippines	4	52	68	72	57	61	79	66	44	32
UAE	27	38	68	29	22	40	70	29	2	0
Total	601	496	635	691	919	1,033	1,239	1,010	805	738

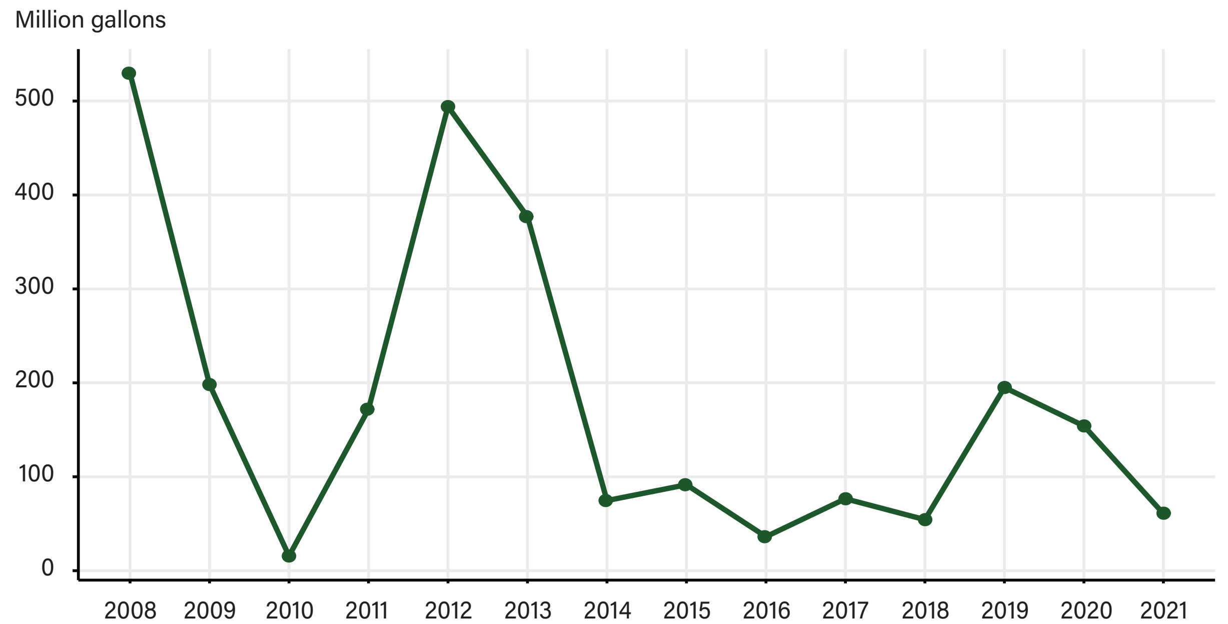
Note: EU+UK = European Union and the United Kingdom; UAE = United Arab Emirates.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service.

U.S. Fuel Ethanol Imports

In contrast to U.S. exports of fuel ethanol, U.S. imports of fuel ethanol between 2008 and 2021 have seen a series of highs and lows (figure 10). Across these years, the largest volume of imports came in 2008 at 530 million gallons. Over the next 4 years, imports reached a low for the period of 16 million gallons in 2010 before returning to 494 million gallons in 2012. By 2014, imports had fallen to 75 million gallons and have not exceeded 195 million gallons in any year since. As such, imports remain small relative to domestic production and use. For example, in 2008, imports were equivalent to 6 percent of total U.S. production of ethanol in that year. Since then, imports have not exceeded 4 percent of production in a given year.

Figure 10
U.S. annual fuel ethanol imports, 2008–21



Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

The majority of U.S. fuel ethanol imports have come from Brazil since at least 2012 (table 4). Between 2012 and 2021, the share of U.S. ethanol imports coming from Brazil has averaged 93 percent, while no other country has accounted for more than 14 percent. Since 2019, all reported imports of fuel ethanol have come from Brazil. In 2020, all imports from Brazil entered through California due to the State's Low Carbon Fuel Standard (LCFS), which assigns less carbon dioxide emissions to Brazilian sugarcane ethanol (Shi and Hill, 2021). The LCFS impact may be present in other years as well, given that the share of U.S. fuel ethanol imports entering through the west coast has been 100 percent since 2018 (table 4).

Table 4
U.S. fuel ethanol imports by origin, 2012–21 (millions of gallons)

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Brazil	404	322	56	88	36	77	53	195	154	61
Canada	4	5	5	3	1	NA	NA	NA	NA	NA
Costa Rica	9	21	NA	NA	NA	NA	NA	NA	NA	NA
El Salvador	25	15	NA	NA	NA	NA	NA	NA	NA	NA
Guatemala	5	NA	10	NA	NA	NA	1	NA	NA	NA
Jamaica	40	14	NA	NA	NA	NA	NA	NA	NA	NA
Netherlands	4	NA	2	NA	NA	NA	NA	NA	NA	NA
Nicaragua	3	NA	1	NA	NA	NA	NA	NA	NA	NA
Singapore	NA	NA	1	NA	NA	NA	NA	NA	NA	NA
Total	494	377	75	92	36	77	54	195	154	61
Imports entering through West Coast PADD	100	126	13	44	32	72	54	195	154	61

Note: NA = not available; PADD = Petroleum Administration for Defense Districts. These are regions the U.S. Department of Energy, Energy Information Administration (EIA) uses for aggregating data. The West Coast PADD consists of Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, EIA.

Global Overview

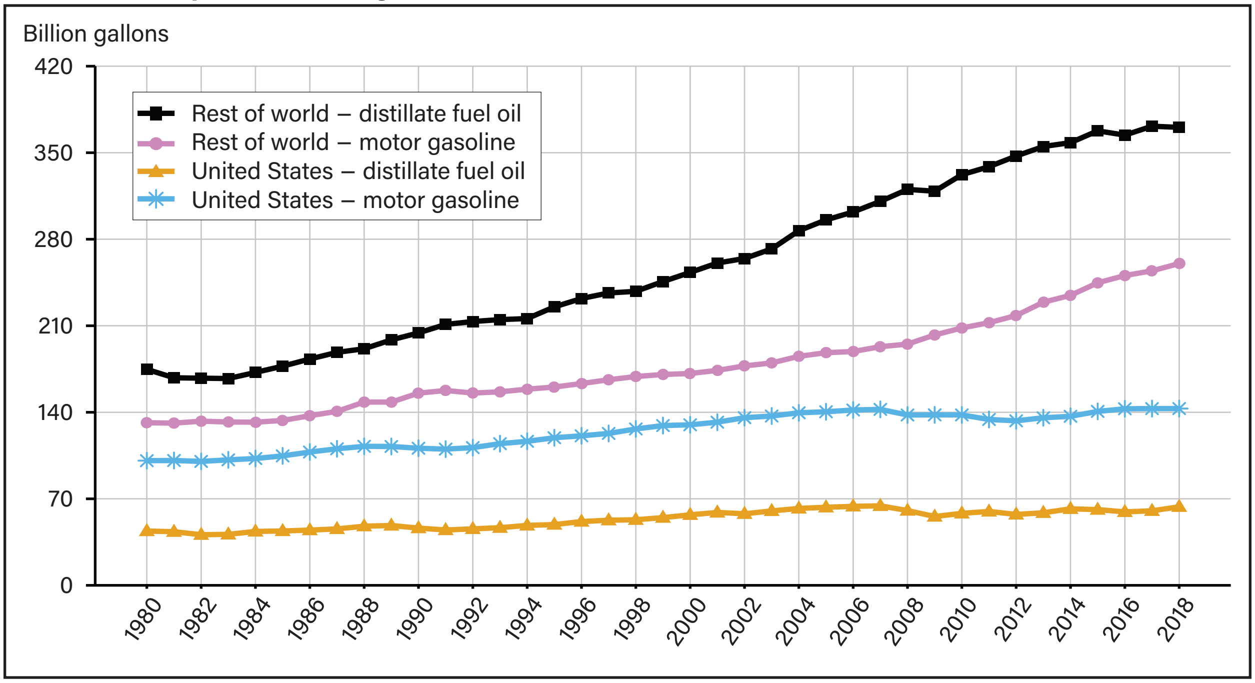
As with U.S. fuel ethanol consumption, global fuel ethanol consumption is influenced by several factors, including government policy and ethanol's economic value as a transportation fuel (e.g., as an octane enhancer and oxygenate). In most fuel ethanol-consuming countries, ethanol policy typically serves two purposes: to reduce greenhouse gas and exhaust emissions under clean air policies and support the domestic agricultural industry. In recent years, ethanol's use has also expanded as an economical blending feedstock to produce higher grades of finished gasoline. Whether consumption is driven by economics or policies, in almost all markets, ethanol is directly blended with and thus linked to motor gasoline consumption. Understanding motor gasoline markets, the rate that fuel ethanol is blended in these markets, and the potential changes to both are key to understanding the potential for future fuel ethanol consumption.

World Motor Gasoline Consumption Pre-COVID-19

Prior to COVID-19, global motor gasoline consumption increased steadily over the last few decades, growing 74 percent from 1980 to 2018 (EIA, 2022; USDA, FAS, 2021). This growth was largely driven by international consumption, which nearly doubled over the time period compared with an increase of about 42 percent in the United States. Thus, though the United States remained the largest consumer of motor gasoline, the U.S. share of total motor gasoline consumption fell from 43 percent in 1980 to 35 percent in 2018. U.S. Government estimates put global motor gasoline consumption at about 403 billion gallons in 2018, of which 260 billion gallons were non-U.S. consumption (figure 11) (EIA, 2022; USDA, FAS, 2021). Note that EIA and USDA's FAS "motor gasoline" volumes include ethanol volumes. To provide a more holistic view of transportation fuel consumption, figure 11 also provides U.S. and non-U.S. consumption of distillate fuel oil, which can be viewed as a proxy for consumption of diesel fuel.[12] Distillate fuel oil consumption has grown both in the United States and in the rest of the world, though like motor gasoline consumption, growth has been more pronounced in the rest of the world (more than doubling between 1980 and 2018 compared with an increase of about 45 percent in the United States). U.S. consumption of distillate fuel oil as a share of motor gasoline consumption has averaged about 43 percent over the 1980–2018 period and has been relatively stable. Internationally, this share grew steadily until 2008 but has since been declining, resulting in a period average of about 144 percent.

Figure 11

Global consumption of motor gasoline and distillate fuel oil, 1980–2018



Note: Motor gasoline includes the fuel ethanol component. Distillate fuel oil includes diesel fuels and fuel oils.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

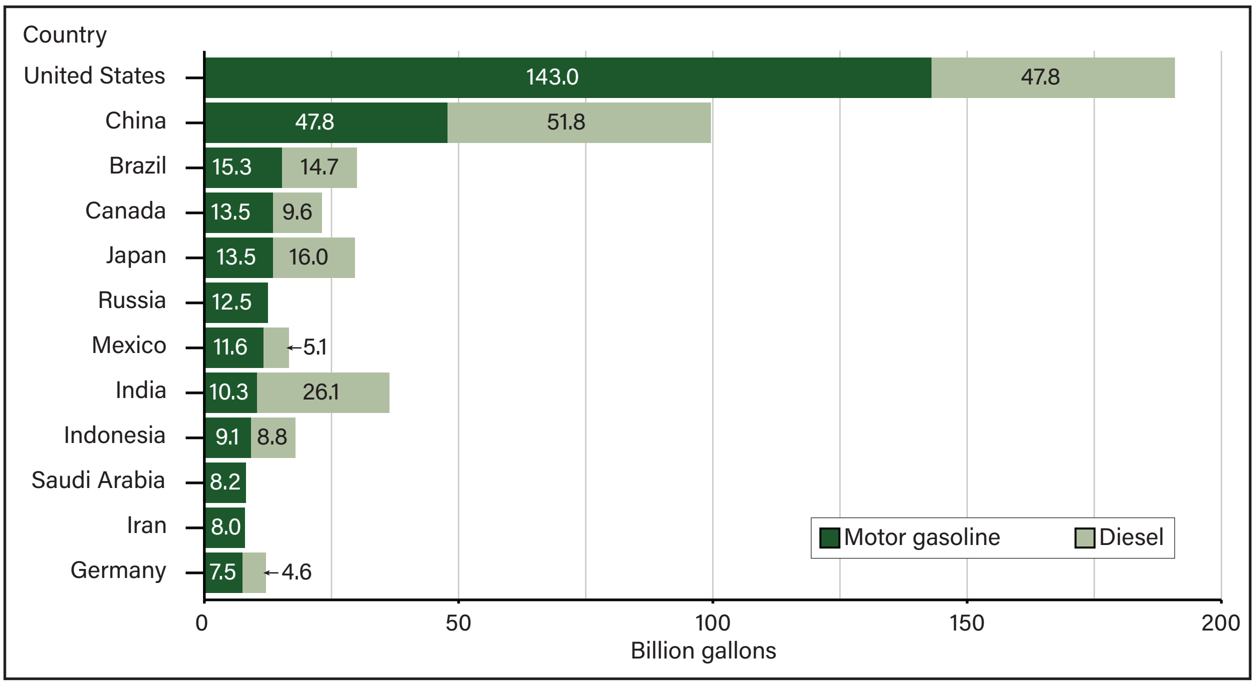
Since 2004, China has been the second largest consumer of motor gasoline behind the United States, a position held by Japan from 1992 to 2003 and by the former U.S.S.R from 1980 to 1991 (EIA, 2022; USDA, FAS, 2021). In 2018, China consumed about 47.8 billion gallons of motor gasoline (figure 12), more than three times the 15.3 billion gallons consumed by Brazil, the third largest consumer (EIA, 2022; USDA, FAS, 2021), and a tripling of China's own consumption since 2003. Taken as a bloc, the members of the European Union (EU) consumed about 25.3 billion gallons of motor gasoline in 2018, or about half of China's consumption. Consumption in the EU bloc has been mostly declining—with a slight rebound between 2016 and 2018—and by 2018, motor gasoline consumption stood at 64 percent of 1998 consumption (EIA, 2022).

[12] Data for international diesel consumption does not appear to be available from EIA for the 1980–2018 time period. EIA defines distillate fuel oil as "A general classification for one of the petroleum fractions produced in conventional distillation operations. It includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation." Additionally, EIA notes that "Beginning in 2009, [fuel oil distillate] includes biodiesel and renewable diesel fuel blended into distillate fuel oil. For 2011–2020, also includes biodiesel adjustments (supply of biodiesel not reported as input on surveys) reclassified as distillate fuel oil adjustments. Beginning in 2021, also includes renewable heating oil blended into distillate fuel oil."

In 2018, the five largest non-U.S. consumers—China, Brazil, Canada, Japan, and Russia—consumed 103 billion gallons of gasoline, or about 25 percent of global consumption (EIA, 2022; USDA, FAS, 2021). The next six largest consumers—India, Indonesia, Saudi Arabia, Iran, Germany, and Brazil—accounted for an additional 14 percent of global consumption. Including the United States, these large motor gasoline markets—each consuming over 5 billion gallons of motor gasoline (includes ethanol volumes) in 2018 – accounted for 300 billion gallons or 74 percent of world motor gasoline use. In several of these countries (for which data was available), except for the United States, consumption of diesel is either close to or exceeds the consumption of motor gasoline. The diesel consumption numbers suggest that substitutions toward or away from motor gasoline—and away from or toward diesel—could lead to changes in fuel ethanol demand in these countries. For example, while India is the eighth largest consumer of motor gasoline, it is the third largest (of those countries in figure 12 with available data for both fuels) combined consumer of motor gasoline and diesel behind the United States and China.

Figure 12

Motor gasoline and diesel consumption in large motor gasoline market countries, 2018

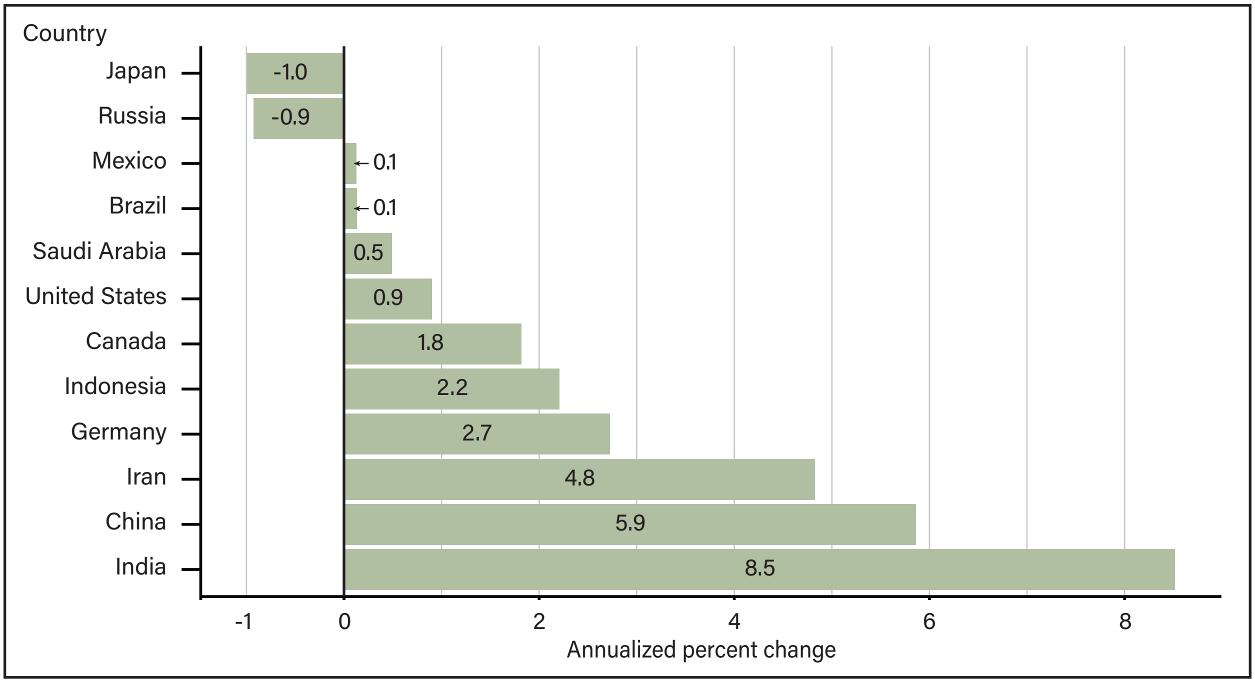


Note: Motor gasoline includes the fuel ethanol component. Diesel consumption for U.S. is distillate fuel oil in the transportation sector and contains biodiesel/renewable diesel components. Germany diesel consumption is consumption by private households. Diesel consumption was not available for Russia, Saudi Arabia, or Iran.

Sources: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration; USDA , Foreign Agricultural Service; the Federal Statistical Office of Germany; and Petroleos Mexicanos.

Future changes in economic development, mobility, and habits could lead to a re-ordering of this list in figure 11 in the future. From 2014–2018, the annualized growth in motor gasoline consumption in India, 8.5 percent, exceeded that of the remaining 11 countries. Consumption in China grew at the second fastest pace of 5.9 percent (figure 13). Canada, the United States, Saudi Arabia, Brazil, and Mexico saw annualized growth rates of 2 percent or less while Russia and Japan saw negative annualized consumption growth rates.

Figure 13
Annualized motor gasoline consumption growth rates in large motor gasoline market countries, 2014–18

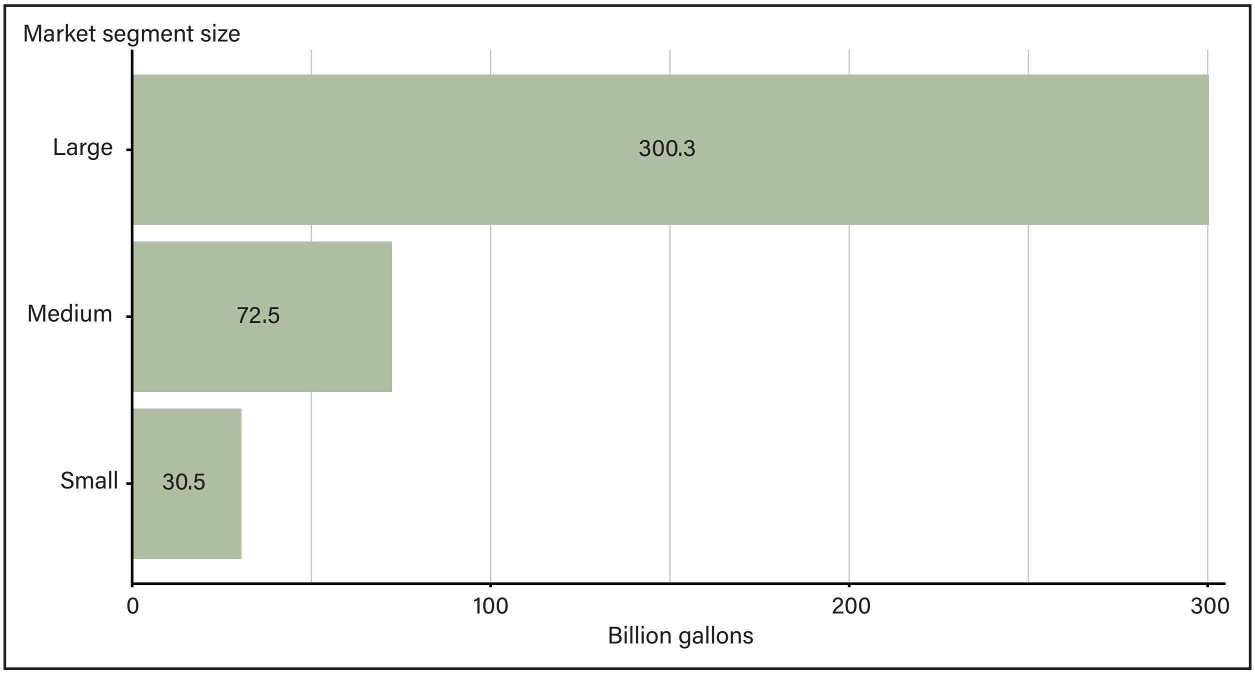


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

After the large markets, there are 30 medium-size markets that consumed from 1 billion to 5 billion gallons of motor gasoline in 2018 (includes fuel ethanol). In 2018, these countries accounted for approximately 72.5 billion gallons or 18 percent of global motor gasoline consumption. The remaining smaller markets (less than 1 billion gallons consumed) consumed a combined 30.5 billion gallons of motor gasoline in 2018, or 8 percent of global motor gasoline consumption. As can be seen in figure 14, most motor gasoline consumption occurred in large markets.

Figure 14
Motor gasoline consumption by motor gasoline market size, 2018



Note: Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline includes the fuel ethanol component.

Sources: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

The current sizes of countries' motor gasoline markets are likely the best indicators for where the largest fuel ethanol demand could be through 2030, though other factors such as growth (or decline) rates in motor gasoline consumption will also be important. However, the changes required in motor gasoline consumption to yield equivalent potential across countries of different market sizes are unlikely in many instances due to motor gasoline-market size discrepancies (see table 5). As such, many of the sections to follow maintain these market classifications for use in organizing data and results.

Table 5
Motor gasoline consumption statistics by market size, billions of gallons

Motor gasoline market size	Minimum	Maximum	Average
Large (United States included)	7.5 (Germany)	143.0 (United States)	25.0
Large (United States excluded)	7.5 (Germany)	47.8 (China)	14.3
Medium	1.1 (Israel)	5.0 (Australia)	2.4
Small	0.0 (multiple)	0.9 (Puerto Rico)	0.2

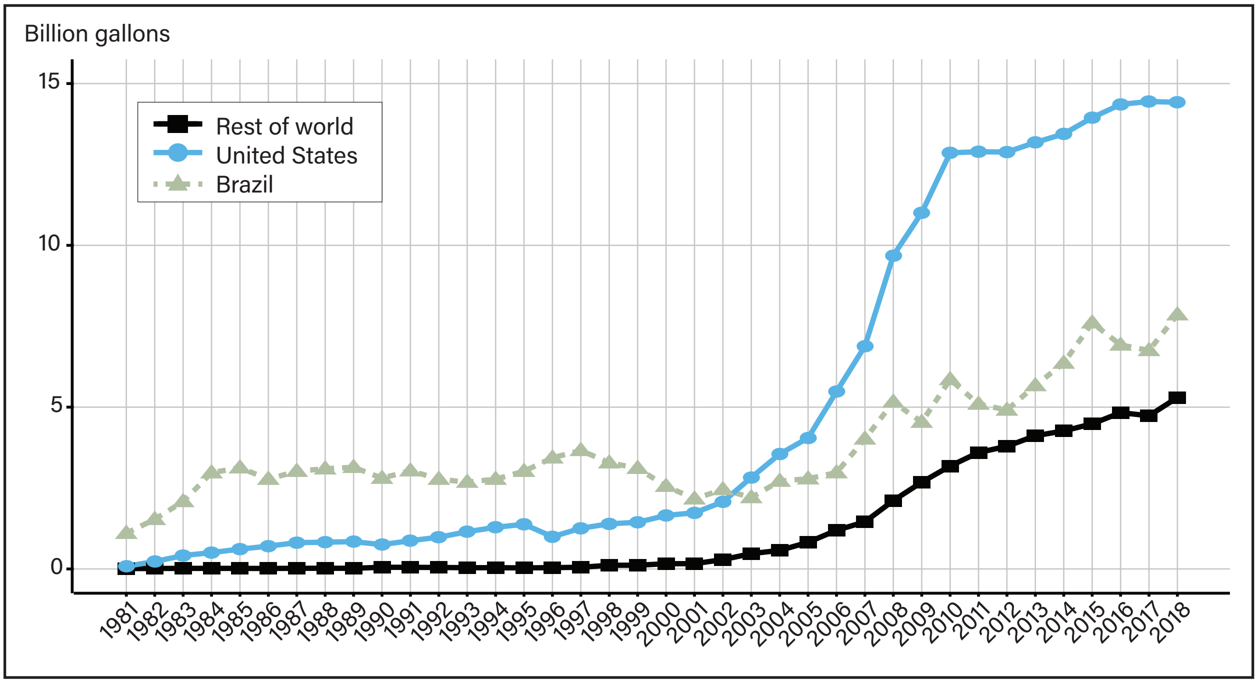
Notes: Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline includes the fuel ethanol component.

Sources. USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

World Fuel Ethanol Consumption

In 2000, only two countries mandated the use of ethanol in transportation and only seven countries consumed fuel ethanol. However, currently, at least 51 countries have either mandated the use of fuel ethanol or have some version of a biofuel mandate or target (see table A-3), and 51 countries consumed fuel ethanol,[13] according to EIA and USDA's Foreign Agricultural Service (USDA, FAS) data. As a result, global fuel ethanol consumption has grown faster than its motor gasoline counterpart: Between 1981 and 2018, consumption is estimated to have grown from about 1.2 billion gallons to 27.6 billion gallons, a 2,203-percent increase (EIA, 2022; USDA, FAS, 2021). Though much of this growth was due to a rapid expansion in the United States, this U.S. expansion was not the only factor: Consumption of fuel ethanol outside the United States increased 1,080 percent, from 1.1 billion gallons in 1981 to 13.2 billion gallons in 2018 (figure 15) (EIA, 2022; USDA, FAS, 2021). Excluding both the United States and Brazil, growth in fuel ethanol consumption has been even larger (in percentage terms), having gone from 10.7 million gallons in 1981 to 5.3 billion gallons in 2018. It should be noted, however, that some of this change could be due to a lack of fuel ethanol consumption data in the early part of the period.

Figure 15
Global consumption of fuel ethanol, 1981–2018

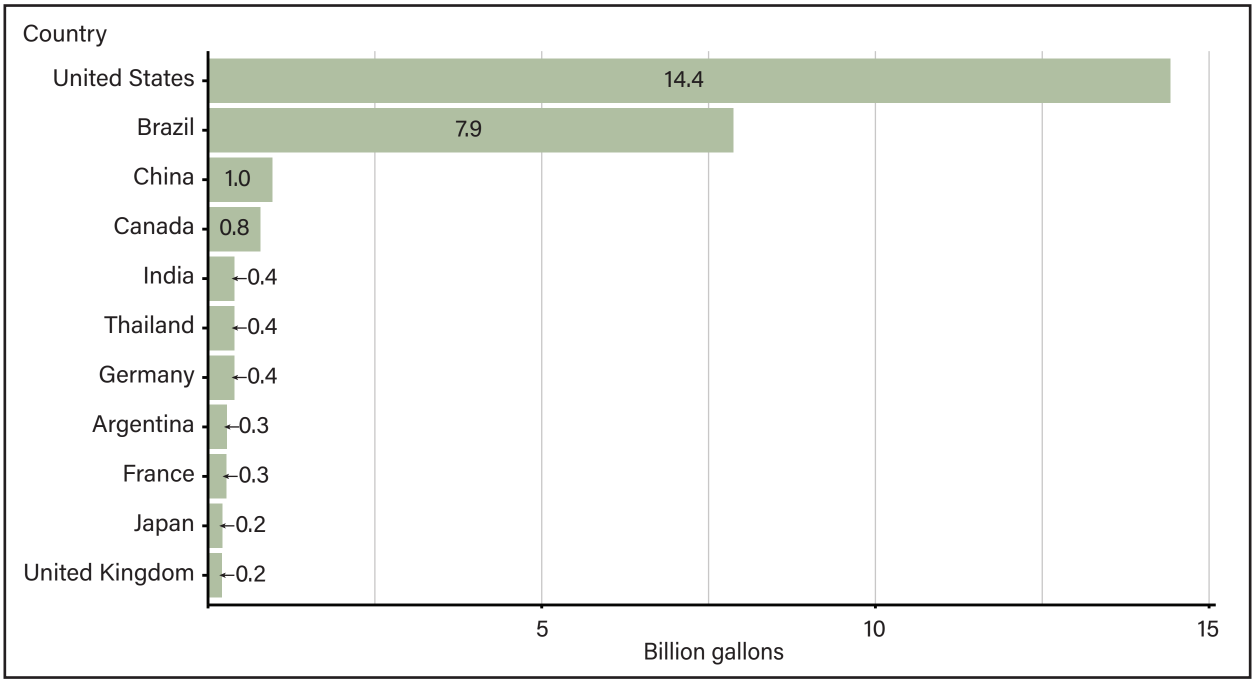


Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

[13] A country is not necessarily in both groups.

For fuel ethanol, Brazil was the world's largest consumer from 1981 to 2002 and was the second largest consumer, behind the United States, from 2003 to 2018 (EIA, 2022; USDA, FAS, 2021). Excluding the United States and Brazil, China was the largest consumer of fuel ethanol from 2002 to 2018. In 2018, ethanol for fuel use in Brazil has been estimated at 7.9 billion gallons, more than eight times the two next largest consumers, China (0.96 billion gallons) and Canada (0.79 billion gallons) (figure 16) (EIA, 2022; USDA, FAS, 2021). Combined, Brazil, China, and Canada accounted for 35 percent of global fuel ethanol consumption and 73 percent of all non-U.S. consumption in 2018 (EIA, 2022; USDA, FAS, 2021). Adding in the next 7 largest fuel ethanol consumers—India, Thailand, Germany, Argentina, France, Japan, and the United Kingdom—these 10 countries consumed about 11.7 billion gallons in 2018, or about 43 percent of global consumption (EIA, 2022; USDA, FAS, 2021). As the largest consumer, the United States accounted for about 52 percent of global fuel ethanol consumption in 2018, while those countries outside of the top 11 fuel ethanol consumers accounted for only 5 percent (EIA, 2021). Thus, while fuel ethanol consumption has grown in many markets, the bulk of consumption remains in several larger markets.

Figure 16
Fuel ethanol consumption in large motor gasoline market countries, 2018



Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Ethanol Blend Rates

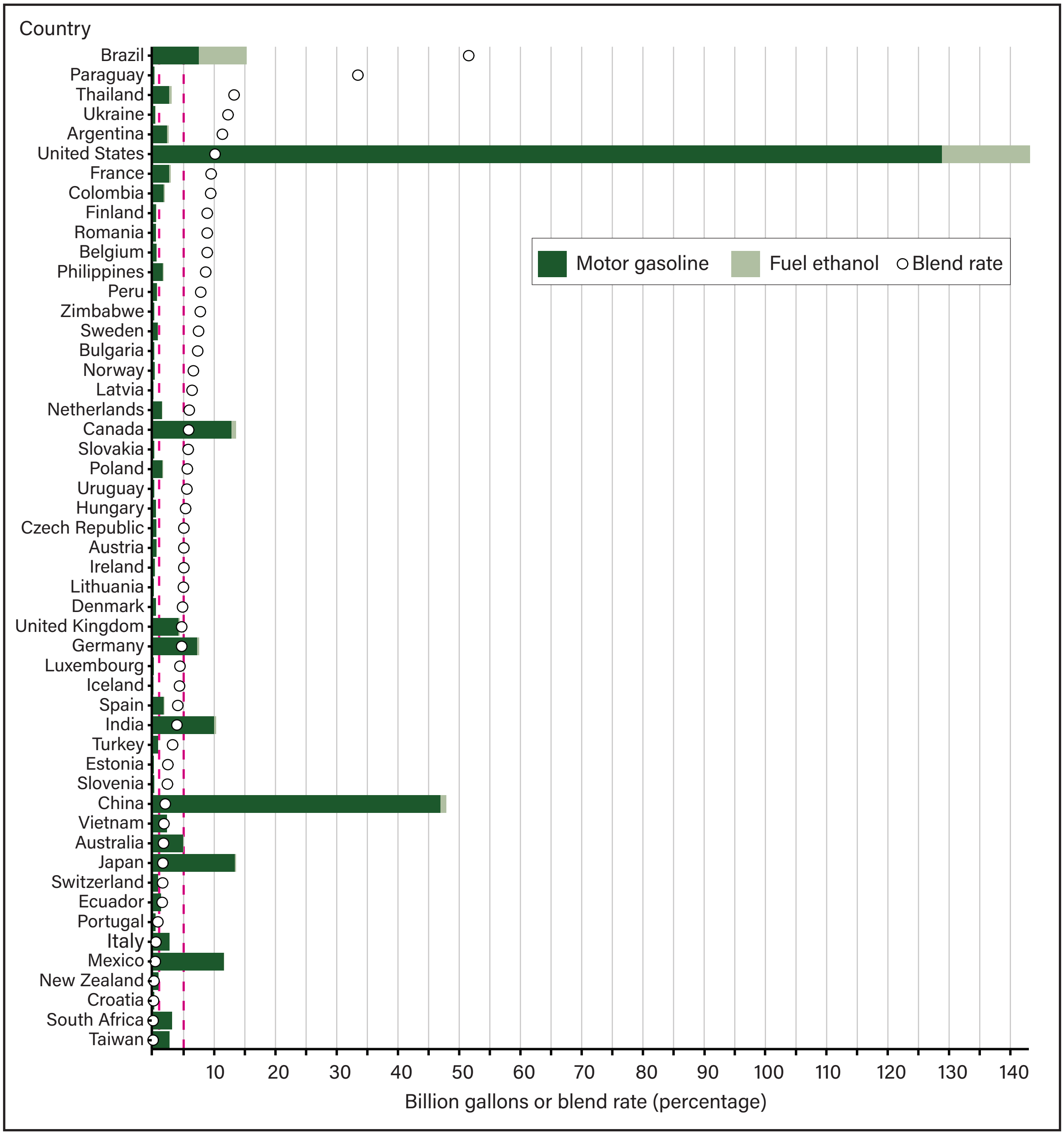
While the effective fuel ethanol blend rate (the ratio of the fuel ethanol volume to the combined fuel ethanol and motor gasoline volume[14]) in the United States has remained around 10 percent for much of the last decade, as of 2018, the global effective blend rate (excluding the United States) is only about 5 percent. Moreover, this global rate is skewed by the high use of fuel ethanol in Brazil, where the ethanol is used either at high-blend levels or directly as a fuel. Excluding the United States and Brazil, the global effective blending rate is about 2 percent. Blending rates vary widely by country, with only a handful of countries blending ethanol at the E10 level or higher, and the remaining countries either blending at a low rate or not at all. As seen in figure 17, this is true regardless of the size of the motor gasoline market: In 2018, only two non-U.S.

[14] For the ratio calculation, to avoid double counting, the motor gasoline volume would not include the ethanol component.

large gasoline market countries blended ethanol at or above 5 percent—Brazil and Canada; only 7 of 30 medium market countries (or 23 percent) blended at 5 percent or higher; and only 17 of 170 (10 percent) small market countries blended at or above that rate. Understanding blend rates, along with motor gasoline market size and consumption trends, is helpful in estimating the potential for countries to expand fuel ethanol use.

Figure 17

International motor gasoline and fuel ethanol consumption and blend rates, 2018



Note: Motor gasoline calculated by subtracting the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Fuel Ethanol Trade

Though data on global fuel ethanol trade are limited, the data that are available can provide some insights. USDA's FAS, for example, provides estimated and forecasted data for a small set of countries (table 6). Of those countries, Canada has typically been the largest importer of fuel ethanol (average of 297 million gallons per year between 2012 and 2021), whereas Brazil has typically been the largest exporter (average of 263 million gallons per year between 2012 and 2021). Total imports for these countries have mostly increased since 2012, driven by relatively stable growth in India and Japan. For 2021, imports into these countries were forecasted at 1.2 billion gallons, an increase of 667 million gallons (or 119 percent) from 2012. Conversely, exports from these countries fell 79 percent from 2012 to 2021, though much of this is due to a decrease from 336 million gallons in 2020 to 161 million gallons in 2021. Each of the countries listed in table 6—for which both imports and exports of fuel ethanol are available—have typically been net importers of fuel ethanol.

Globally, the Organisation of Economic Co-operation and Development (OECD) and the Food and Agriculture Organization (FAO) of the United Nations provides estimates of historical and projected future ethanol trade totals in the OECD-FAO Agricultural Outlook reports. For 2021, OECD-FAO estimated total exports of ethanol at 3.2 billion gallons and total imports at 3.1 billion gallons (figure 18). These values represented increases of 1.2 billion gallons (57 percent) for exports and 0.7 billion gallons (30 percent) for imports above 2011 levels. Based on USDA's FAS data for U.S. fuel ethanol exports, the U.S. share of the global ethanol exports estimated by OECD-FAO from 2012 through 2021 ranged between 50 percent in 2018 and 23 percent for an average of 36 percent. Based on EIA data for U.S. fuel ethanol imports, the U.S. share of global ethanol imports estimated by OECD-FAO from 2012 through 2021 ranged between 29 percent and 2 percent for an average of 8 percent. However, this share did not exceed 8 percent from 2014 to 2021, and over this period, averaged only 4 percent. OECD-FAO projected both imports and exports of ethanol below 2021 levels (exports of 3.2 billion gallons, imports of 3.1 billion gallons) for 2022 through 2031 at average annual volumes of 3.1 billion gallons for exports and 2.8 billion gallons for imports.

Table 6
Country-level imports and exports of fuel ethanol, 2012–21 (millions of gallons)

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021[1]
Imports										
Australia	10	1	3	4	7	1	11	8	1	3
Brazil	146	35	106	132	214	473	468	384	260	127
Canada	213	285	301	287	294	321	326	322	308	317
China	1	0	7	126	230	2	201	0	17	211
Colombia	2	6	5	2	6	20	53	70	67	42
India	1	29	51	54	114	191	160	186	191	198
Japan	92	104	137	161	196	215	211	209	223	218
Peru	30	30	17	30	30	30	46	50	40	48
Philippines	66	78	90	82	69	73	75	68	64	63
Total[2]	561	568	716	878	1,160	1,326	1,550	1,297	1,171	1,228

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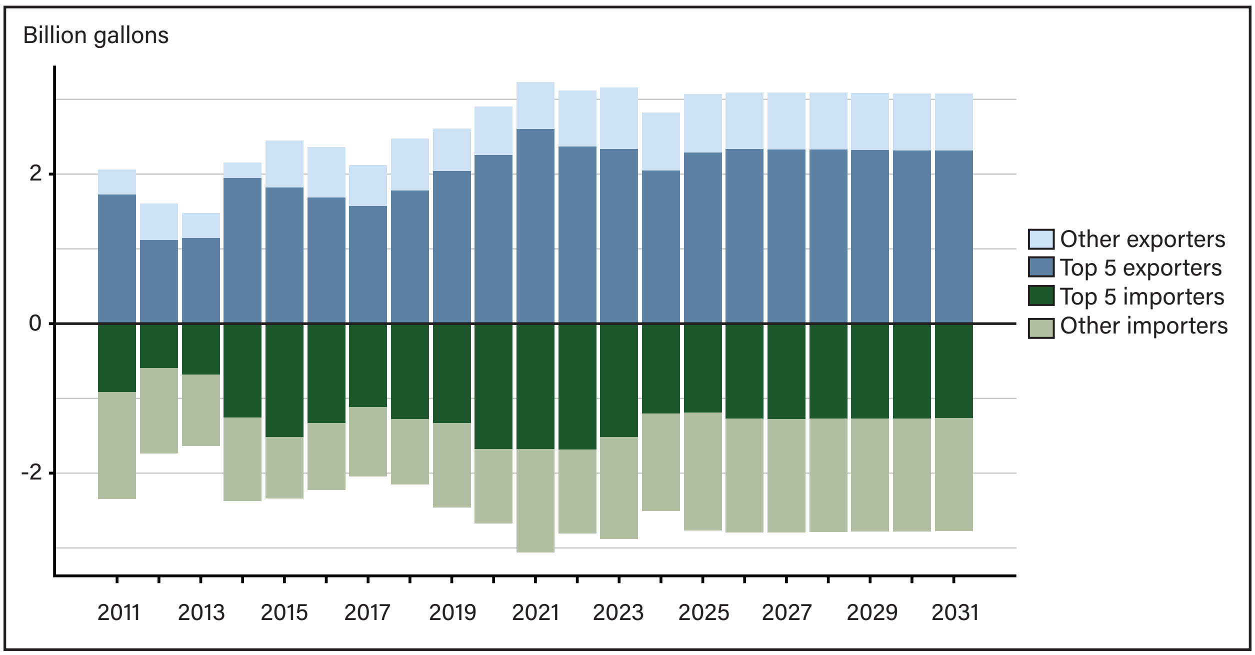
Exports										
Australia	7	9	1	3	11	1	2	2	4	4
Brazil	660	516	206	238	106	117	222	288	225	53
Canada	0	0	0	0	0	0	3	7	28	30
China	2	1	1	0	0	1	9	2	6	0
India	47	62	48	44	36	37	34	13	35	37
Indonesia	1	1	5	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0	0	0	0
Peru	32	39	27	25	30	24	29	45	38	37
Total[2]	749	627	287	310	183	180	298	357	336	161

[1]Forecasted values.

[2]Individual amounts may not sum to totals due to rounding.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service.

Figure 18
Estimated and projected global ethanol trade, 2011–31



Source: USDA, Economic Research Service using data from Organization for Economic Co-operation and Development (OECD)-Food and Agriculture Organization (FAO) Agricultural Outlook 2022–2031.

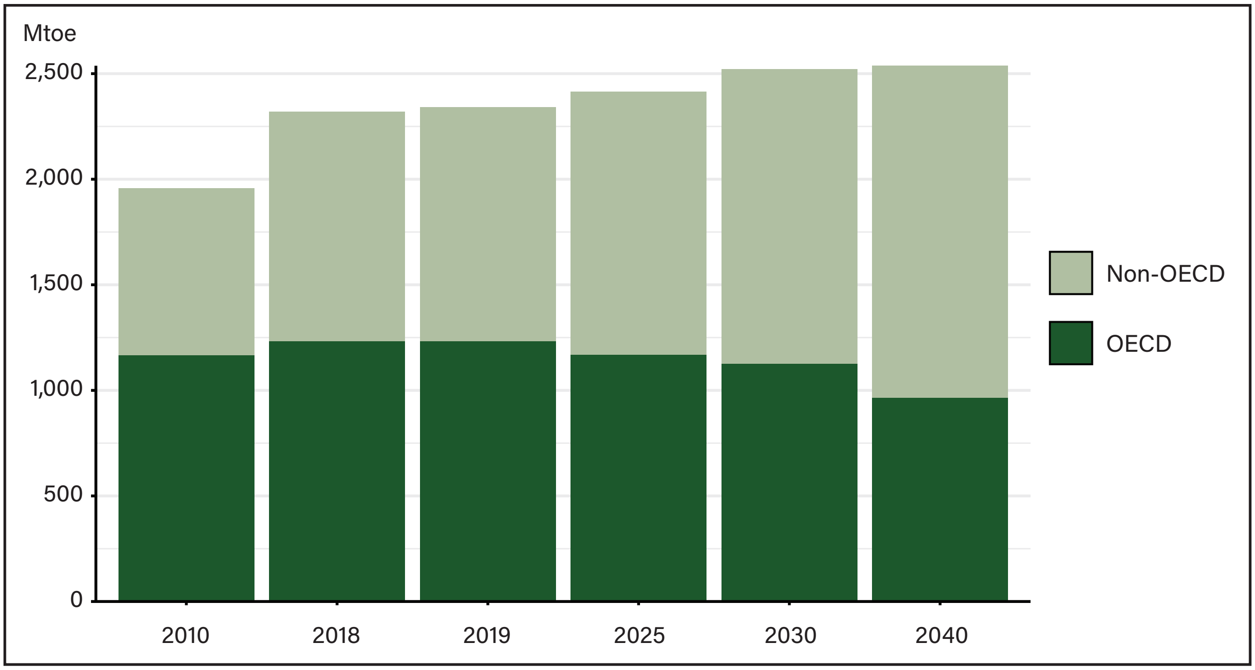
Going Forward

While global motor gasoline consumption grew considerably over the last several decades, COVID-19 reduced consumption of transportation fuels in 2020. In Brazil, for example, the 2020 consumption of Gasoline C—a mixture of 27 percent ethanol and 73 percent gasoline—was estimated by USDA's Foreign Agricultural Service (FAS) at 9.5 billion gallons, a decrease of 6 percent from 2019 (Barros, 2021). Total fuel ethanol consumption in Brazil, meanwhile, was estimated to have fallen 12 percent in 2020 (Barros, 2021). Though motor gasoline consumption in China increased 3.6 percent in 2020 (McGrath, 2021), this number was well below pre-COVID-19 growth rates. Despite the growth in motor gasoline consumption, fuel ethanol consumption in China decreased 11 percent between 2019 and 2020 (McGrath, 2021). Of the countries followed in the USDA's FAS biofuel reports, only two saw increased fuel ethanol usage: Japan and Peru. Japan's fuel ethanol consumption increased 15.9 million gallons (7.6 percent) (Sasatani, 2021), while in Peru fuel ethanol consumption increased 0.3 million gallons (0.5 percent) (Nolte, 2021). For Japan, the increase in consumption was the result of failing to meet target volumes in 2019 as required by the Sophisticated Act and that need to be made up in the following year (Sasatani, 2021). In general, the impacts of local polices and motor gasoline-consumption trends may be important factors in identifying potential future markets for U.S. ethanol exports.

Post-COVID-19

IEA projections indicate that post-COVID-19, global consumption of transportation fuel is no longer increasing for much of the developed world. In the 38 member countries of the OECD, oil and bioenergy consumed in transport are projected to decline beyond 2018 (figure 19). However, global consumption is projected to increase through at least 2040, driven by increases in non-OECD markets. As a result, transportation-based ethanol consumption will be mixed and dependent on individual country situations and ethanol blending rates.

Figure 19
Global consumption of oil and bioenergy in the transport sector, million tonnes of oil equivalent (Mtoe), 2010–40



Note: OECD = Organisation for Economic Cooperation and Development.

Source: USDA, Economic Research Service using data from International Energy Agency, World Energy Outlook 2020.

The Next Decade: Biofuels Policies and Consumption Scenarios

As previously noted, country-level fuel ethanol consumption is primarily a function of the size of the motor gasoline market and the rate at which ethanol is blended in that market. As also noted, the blend rate varies widely among countries ranging from zero to more than 50 percent. To determine the potential for fuel ethanol consumption over the next decade, USDA's Economic Research Service (ERS) combined IEA consumption projections for oil and bioenergy demand growth in the transport sector with EIA and USDA's FAS historical consumption data and assumed blending rates by scenario to calculate potential transportation-based consumption of ethanol. Consumption is estimated under the "Historical Blends" (HB) and "Targeted Blends" (TB) scenarios that differ with respect to the assumed blend rates (or effective blend rates) across countries.

The first scenario, HB, assumes that current ethanol blending practices continue in accordance with historical observations, regardless of the official policies or unofficial targets in place. Thus, in some markets for this scenario, current blending practices are in sync with policies or targets, while in other markets, ethanol blending practices do not align with policies or targets. Furthermore, this scenario does not attempt to account for newer policies, such as RenovaBio in Brazil or the Clean Fuel Standard in Canada, other than the extent to which they may have already impacted historical blending rates. While use of ethanol as an economical motor gasoline blend stock has grown, government policy mandates remain the main driver of fuel ethanol use in most markets, and enforceable mandates have not been widely embraced outside of countries that have domestic feedstock industries. Moreover, some countries have become wary of trading a reliance on oil imports for a reliance on ethanol imports (Carter, 2021).

The second scenario, TB, assumes that countries maintain or follow through on official ethanol blending policies or unofficial targets into the next decade. The TB scenario does not assume that blend rates will increase in all markets. Rather, the scenario assumes targets are met exactly, and these targets may be higher or lower than the historical average rates used in the HB scenario. In general, however, the TB scenario results in an increased blending rate for those countries for which policies or targets were obtained. As such, the TB scenario likely represents an upper boundary on ethanol demand. Detailed policies or targets were generally only assessed for countries that historically consumed ethanol.[15] For the countries with known goals or mandates, this scenario assumes the target/mandate will be achieved in 2030 at the earliest. Additionally, because specific ethanol-related targets or mandates were not always available, some of the assumed blend rates are the result of our translation of less-specific guidelines into actionable numbers. For example, a specific ethanol blending target could not be found for Ukraine. However, Ukraine set a target of 11.5 percent for biofuels' share in the total primary energy supply. As such, an 11.5-percent target rate for ethanol blending was used for Ukraine in the TB scenario. The country-specific policies and targets that were publicly available are presented in table A-3. For the remaining non-consuming countries, zero consumption is assumed to continue through 2030. Countries that historically consumed fuel ethanol, but where detailed policies were not readily accessible, are assumed to maintain historical blending rates throughout the decade. Additional details on the countries where policies were assessed can be found in the appendix.

Each scenario is based on country- or region-specific projections for growth in oil and bioenergy demand in the "Stated Policies Scenario" from IEA's World Energy Outlook 2020. These growth rates are applied to the motor gasoline and fuel ethanol consumption data from EIA and USDA's FAS. Estimation begins with estimating total gasoline equivalents (TGE) that are the same across both scenarios. For example, if the IEA reports a projected growth rate of δ=0.03 between 2018 and 2019, and EIA indicates motor gasoline consumption (not including the fuel ethanol component) in 2018 of G_{2018}=100 million gallons and fuel ethanol consumption of E_{2018}=5 million gallons, TGE for 2019 would be calculated as (in millions of gallons):

$$TGE_{2019}=1.03\left(100+\frac{2}{3}*5\right)=106.6$$

[15] There were two exceptions. One was Greece, in which information was readily available in the same location as other European Union member countries. The other was Indonesia, in which information was readily available from USDA's FAS, along with 11 other countries.

The two-thirds scaling of the ethanol component is performed to account for the lower energy content of ethanol relative to gasoline. Then, given a 2019 ethanol blend rate of r_{2019}, the new fuel ethanol consumption would be calculated as:

$$E_{2019} = \frac{TGE}{\frac{1 - r_{2019}}{r_{2019}} + \frac{2}{3}}$$

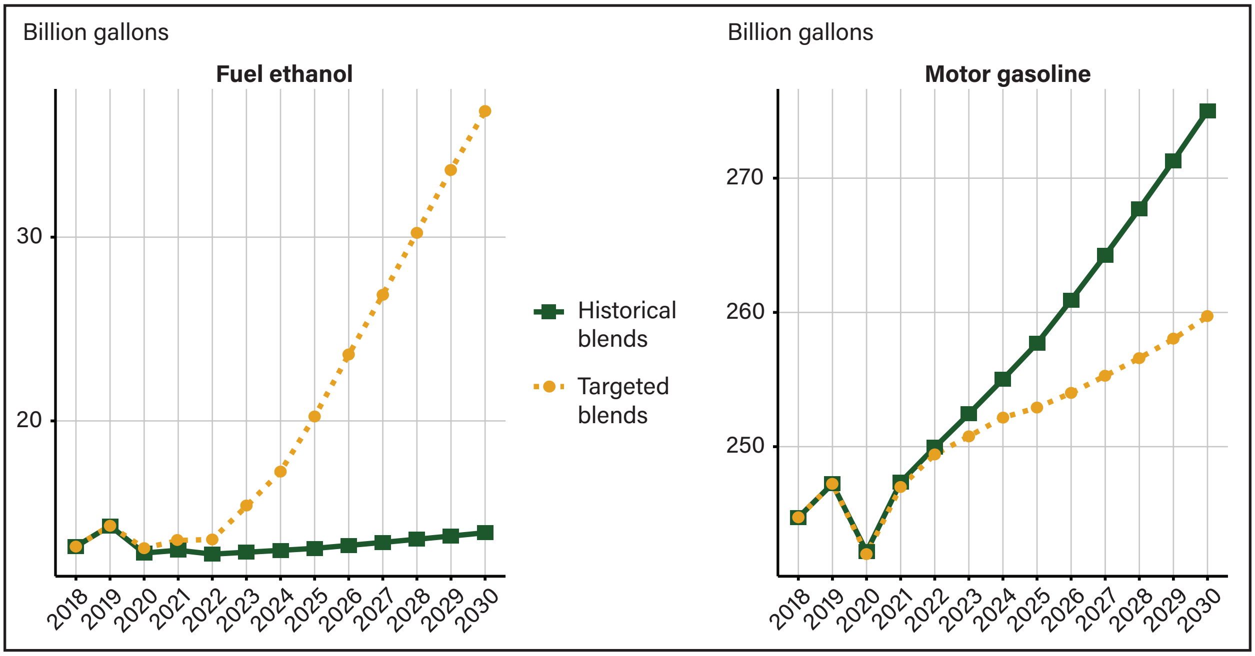
Given that projected changes in TGE demand are the same in both scenarios, the point of divergence between the scenarios is the assumed blending rates assigned to individual countries (i.e., the value of r_{2019} in the HB scenario versus the value of r_{2019} in the TB scenario). For a small subset of countries,[16] ethanol consumption volumes for the TB scenario were estimated using approaches different from the one outlined above. Combined, the HB and TB scenarios present a range for fuel ethanol consumption outside the United States over the next decade. The HB scenario represents an estimate of what seems likely under current trends while the TB scenario represents what could happen under generally higher blending rates.

Note that this study focuses only on potential increases or decreases in demand; that is, the authors do not examine current or forecast future ethanol production. As such, the changes in demand should not be viewed as a net increase or decrease in demand after accounting for production levels. Thus, they should not be viewed as a measure of U.S. export potential. Additionally, this study does not include projections for consumption of ethanol for non-fuel uses, which is an important and growing component of ethanol demand for some countries.

The broad projections are depicted in figure 20 for the period 2018 to 2030. There is little difference in the scenarios early on, but over time, the projections are as expected. By design, fuel ethanol consumption in 2018 (the cutoff year for EIA fuel consumption data) is projected at the same level across both scenarios: 13.2 billion gallons. By 2030, the largest fuel ethanol consumption is projected for the TB scenario at 36.9 billion gallons, while the lowest is projected for the HB scenario at 13.9 billion gallons.

[16] These countries were Brazil, Canada, the Czech Republic, Ireland, Japan, and Slovakia.

Figure 20
Non-U.S. motor gasoline and fuel ethanol consumption projections by scenario, 2018–30



Note: Motor gasoline does not include the fuel ethanol component.

Source: USDA, Economic Research Service estimates based on the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

In the sections to follow, results are analyzed from a few perspectives. First, as mentioned previously, some results are aggregated by the size of countries' motor gasoline markets (including the fuel ethanol component and based on 2018 values): large markets, consisting of countries consuming more than 5 billion gallons; medium markets, consisting of countries consuming between 1 billion and 5 billion gallons; and small markets, consisting of countries consuming less than 1 billion gallons. Secondly, several comparisons are made across two time periods: 2018 through 2030 and 2021 through 2030. These time periods are used for a couple reasons, one being that they provide comparisons to pre- and post-COVID-19. The other reason is these intervals also coincide with the last years of data for EIA and USDA's FAS country-level data (2018 for EIA, 2021 for USDA, FAS). Finally, some results are provided and discussed in the context of whether fuel markets are growing or contracting (or remaining static in the case of fuel ethanol non-consumers). All of the results in the sections below exclude the United States.

Historical Blends (HB) Scenario

Under the HB scenario, fuel ethanol consumption outside of the United States is expected to grow from 13 billion gallons in 2021 to 13.9 billion gallons in 2030, reflecting an increase of 7.4 percent over the 9 years and an increase of 5.7 percent above 2018 levels. Using EIA's 2018 global fuel ethanol production (excluding the United States) as a proxy for international ethanol production capacity, non-U.S. demand exceeds non-U.S. production by 481 million gallons (projected in 2022) to 1.6 billion gallons (projected for 2030). Based on the EIA's Annual Energy Outlook (EIA, 2022) U.S. ethanol consumption projections and assuming U.S. ethanol production capacity remains at the 2021 level, there would be excess ethanol production capacity in the United States of at least 2.2 billion gallons between 2022 and 2030.

Analyzing the results by 2018 international motor gasoline market segments—large, medium, and small—we see the key changes in fuel ethanol consumption shown in table 7. Small changes in blending rates by market segment can be seen due to the use of USDA's FAS estimates and projections for annual consumption values for 12 countries through 2021.[17] See the appendix for country-specific details on policies and projections.

Across all markets, motor gasoline consumption is projected to increase by 30.3 billion gallons (12.4 percent) between 2018 and 2030 and by 27.6 billion gallons (11.2 percent) between 2021 and 2030. In both cases, the majority of this projected increase comes from large market countries, which see motor gasoline consumption increase by 18.8 billion gallons between 2018 and 2030 and by 16.8 billion gallons between 2021 and 2030. Fuel ethanol consumption is also projected to increase across both periods. Between 2018 and 2030, fuel ethanol consumption increases by 0.75 billion gallons (5.7 percent), while between 2021 and 2030, it increases by 0.95 billion gallons (7.4 percent). As with motor gasoline consumption, the projected fuel ethanol consumption increases are due primarily to increases in large market countries, which see fuel ethanol consumption increase by 0.76 billion gallons (7.2 percent) between 2018 and 2030 and by 0.75 billion gallons between 2021 and 2030 (7.1 percent). The only projected decrease in consumption of either fuel is small market countries' consumption of fuel ethanol between 2018 and 2030, which falls by 0.02 billion gallons (2.7 percent). The 2030 blend rate of 4.8 percent is down from the 2018 and 2021 blend rates of 5.1 percent and 5.0 percent.

Table 7

Motor gasoline and fuel ethanol consumption outside the United States by 2018 market size under Historical Blends scenario, 2018, 2021, and 2030 (billions of gallons)

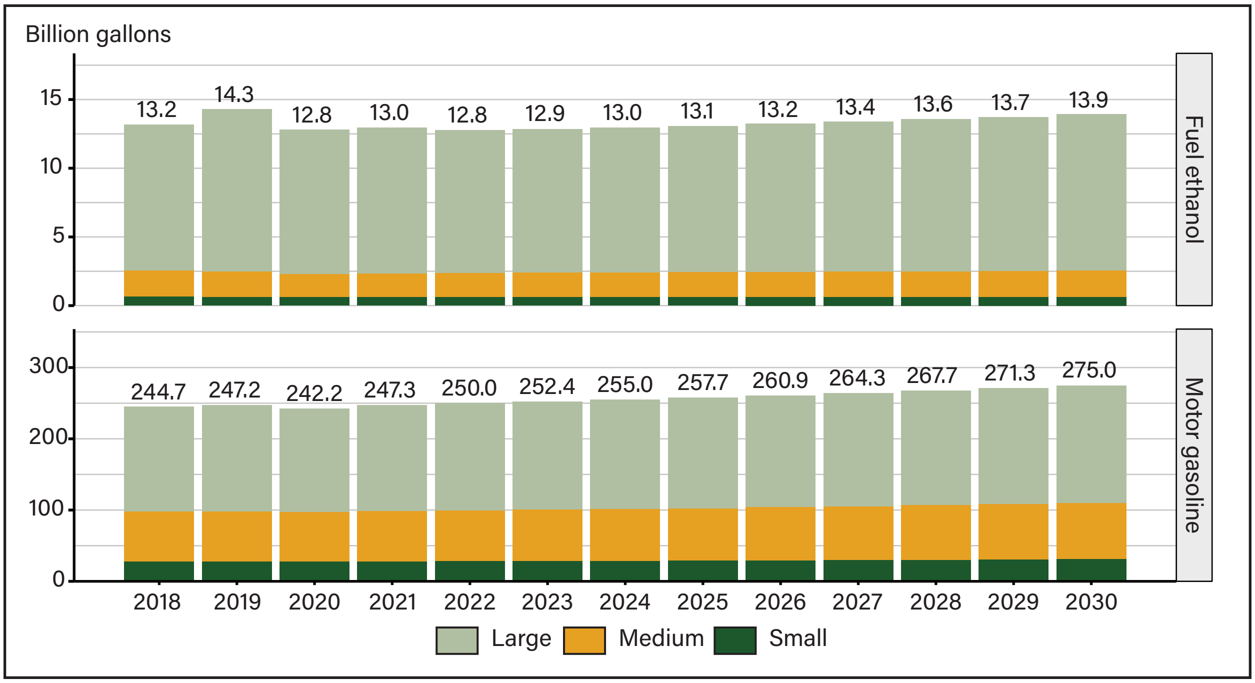
Year	Market	Motor gasoline	Fuel ethanol	Blend rate
2018	Large	146.7	10.6	6.8%
	Medium	70.6	1.9	2.6%
	Small	27.5	0.6	2.3%
	Total	244.7	13.2	5.1%
2021	Large	148.6	10.6	6.7%
	Medium	70.9	1.7	2.3%
	Small	27.9	0.6	2.2%
	Total	247.3	13.0	5.0%
2030	Large	165.4	11.4	6.4%
	Medium	78.6	1.9	2.3%
	Small	30.9	0.6	2.0%
	Total	275.0	13.9	4.8%
Change, 2018–30	Large	12.8%	7.2%	
	Medium	11.4%	0.1%	
	Small	12.6%	-2.7%	
	Total	12.4%	5.7%	
Change, 2021–30	Large	11.3%	7.1%	
	Medium	11.0%	11.0%	
	Small	11.0%	2.0%	
	Total	11.2%	7.4%	

Note: Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline consumption values do not include the fuel ethanol component whereas the market definitions did include the fuel ethanol component.

Source: USDA, Economic Research Service estimates based on the International Energy Agency's World Energy Outlook 2020 projections and on data from the U.S. Department of Energy's Energy Information Administration and USDA, Foreign Agricultural Service.

[17] For most countries, the use of the 5-year-average blend rate begins in 2019. For the 12 countries for which USDA's FAS data is used, the use of the 5-year-average blend rate begins in 2022. Thus, while assumed blend rates are constant for most countries over the 2019–2021 period, it is not for those 12 countries. As a result, there are small changes in the average blend rates between 2021 and 2030.

Figure 21
Non-U.S. fuel ethanol and motor gasoline consumption, Historical Blends scenario, 2018–30



Note: Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline does not include the fuel ethanol component.

Source: USDA, Economic Research Service estimates based on the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

At the country level, multiple outcomes are observed (e.g., both motor gasoline and fuel ethanol consumption increase/decrease or one increases while the other decreases). As shown in table 8, between 2018 and 2030, motor gasoline consumption is projected to increase in 162 countries and decrease in 35 countries. Fuel ethanol consumption, meanwhile, is projected to increase in 23 countries, decrease in 36 countries, and remain unchanged in 138 countries. Projected changes in fuel ethanol consumption generally follow total fuel demand: 21 of the 23 countries where fuel ethanol consumption is projected to increase are also projected to increase motor gasoline consumption. Similarly, 29 of the 36 countries where fuel ethanol consumption is projected to decrease are also projected to decrease motor gasoline consumption. Combined across these 29 countries that are projected to decrease both motor gasoline consumption and fuel ethanol consumption, motor gasoline consumption is projected to fall by 10.1 billion gallons, and fuel ethanol consumption is projected to fall by 0.38 billion gallons. Conversely, 21 countries are projected to increase their consumption of both fuels, which combined account for 24 billion gallons of increased motor gasoline consumption and 1.2 billion gallons of increased fuel ethanol consumption. Ignoring the instances wherein fuel ethanol consumption is projected to remain unchanged (i.e., ethanol consumption remains at zero), there were only nine instances in which fuel ethanol and motor gasoline consumption move in opposite directions. Of these, seven countries are projected to increase motor gasoline consumption but decrease fuel ethanol consumption. The other two countries are projected to increase fuel ethanol consumption but decrease motor gasoline consumption.

Similar patterns are seen between 2021 and 2030: Motor gasoline consumption is projected to increase in 157 countries and decrease in 40 while fuel ethanol consumption is projected to increase in 24 countries, decrease in 35 countries, and remain unchanged in 138 countries. Additionally, the majority of countries that are projected to increase fuel ethanol consumption—22 of 24 countries—are also projected to increase motor gasoline consumption. Across these 22 countries, motor gasoline consumption is projected to increase by 16 billion gallons and fuel ethanol consumption by 1.3 billion gallons. Compared with the 2018 to 2030 interval, projected motor gasoline consumption and fuel ethanol consumption more frequently move in the same direction between 2021 and 2030. Between 2021 and 2030, a projected increase in motor gasoline consumption and a projected decrease in fuel ethanol consumption is seen in only one country, India. Similarly, only two countries—Australia and Canada—see a projected increase in fuel ethanol consumption but a projected decrease in motor gasoline consumption.

In both sets of comparisons—from 2018 to 2030 and from 2021 to 2030—large market countries generally contribute the largest share of the combined projected increases or decreases in fuel consumptions. For example, between 2018 and 2030, 23 countries are projected to increase fuel ethanol consumption by a combined 1.2 billion gallons. Of this total, 0.86 billion gallons (or 73 percent) of this increase comes from three large market countries: Brazil, China, and India. The one exception is the combined 0.43-billion-gallon projected decrease in fuel ethanol consumption across 36 countries between 2018 and 2030. In this case, a projected 0.20-billion-gallon decrease (or 47 percent of the combined decrease) came from nine medium market countries.

Table 8

Summary of changes in motor gasoline and fuel ethanol demand in the Historical Blends scenario, 2018–30 and 2021–30

Changes between 2018 and 2030						
Country-level change in motor gasoline demand	Decrease	Increase	Decrease	Increase	Decrease	Increase
Country-level change in fuel ethanol demand	Decrease	Decrease	Increase	Increase	No change	No change
Total number of countries	**29**	**7**	**2**	**21**	**4**	**134**
Large market countries	3	1	0	3	0	4
Medium market countries	7	2	0	7	3	11
Small market countries	19	4	2	11	1	119
Total motor gasoline change (billion gallons)	**-10.06**	**1.21**	**-0.06**	**24.01**	**-0.74**	**15.91**
Large market countries	-6.08	0.01	0.00	19.90	0.00	4.95
Medium market countries	-2.93	1.10	0.00	3.46	-0.61	7.02
Small market countries	-1.06	0.10	-0.06	0.66	-0.13	3.95
Total fuel ethanol change (billion gallons)	**-0.38**	**-0.05**	**0.00**	**1.18**	**0.00**	**0.00**
Large market countries	-0.09	-0.00	0.00	0.86	0.00	0.00
Medium market countries	-0.18	-0.02	0.00	0.21	0.00	0.00
Small market countries	-0.10	-0.03	0.00	0.11	0.00	0.00

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Changes between 2021 and 2030						
Country-level change in motor gasoline demand	Decrease	Increase	Decrease	Increase	Decrease	Increase
Country-level change in fuel ethanol demand	Decrease	Decrease	Increase	Increase	No change	No change
Total number of countries	**34**	**1**	**2**	**22**	**4**	**134**
Large market countries	3	1	1	2	0	4
Medium market countries	6	0	1	9	3	11
Small market countries	25	0	0	11	1	119
Total motor gasoline change (billion gallons)	**-5.91**	**4.38**	**-0.41**	**16.04**	**-0.59**	**14.14**
Large market countries	-3.24	4.38	-0.01	10.96	0.00	4.73
Medium market countries	-1.71	0.00	-0.40	4.38	-0.48	5.99
Small market countries	-0.96	0.00	0.00	0.71	-0.11	3.42
Total fuel ethanol change (billion gallons)	**-0.23**	**-0.08**	**0.02**	**1.25**	**0.00**	**0.00**
Large market countries	-0.11	-0.08	0.01	0.93	0.00	0.00
Medium market countries	-0.08	0.00	0.01	0.26	0.00	0.00
Small market countries	-0.04	0.00	0.00	0.06	0.00	0.00

Note: Market definitions based on 2018 motor gasoline consumption; Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline consumption values do not include the fuel ethanol component whereas the market definitions did include the fuel ethanol component.

Source: USDA, Economic Research Service estimates based on the International Energy Agency's World Energy Outlook 2020 projections and on data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Across the 2018 to 2030 and 2021 to 2030 intervals, the 10 largest projected increases in motor gasoline consumption are almost identical and led by China, India, and Indonesia (table 9, panel a). The only difference between the two intervals is that between 2018 and 2030, the eighth and ninth largest projected increases are in Egypt and Vietnam, whereas between 2021 and 2030, these positions are held by Brazil and Egypt, respectively. Four medium market countries—Egypt, Malaysia, Nigeria, and Thailand—appear among the 10 largest projected increases in motor gasoline consumption across both intervals. Large market countries also see the largest projected decreases in motor gasoline consumption across both time periods: Japan sees the largest decreases over both periods while Germany sees the third largest decrease between 2018 and 2030 and the second largest between 2021 and 2030 (table 9, panel b). Except for Canada between 2018 and 2030, the remaining largest projected decreases in motor gasoline consumption across both intervals come from medium market countries, including Australia, South Korea, and several European countries. Despite medium market countries seeing some of the largest projected increases and large market countries comprising some of the largest projected decreases, the projected 10 largest motor gasoline consumers in 2030 are exclusively large market countries, headed by China at 62.9 billion gallons and India at 13.2 billion gallons (table 9, panel c).

China also sees the largest projected increase in fuel ethanol consumption between 2018 and 2030, followed by Brazil (table 9, panel d). This order reverses over the 2021 to 2030 period. Only 2 other large market countries are found among the 10 largest projected fuel ethanol increases across either interval: India sees the third largest between 2018 and 2030, and Canada sees the eighth largest between 2021 and 2030. Three small market countries—Bolivia, Costa Rica, and Jamaica—comprise the sixth, ninth, and tenth largest projected increases, respectively, in fuel ethanol consumption between 2018 and 2030, while two small market countries—Paraguay and Peru—comprise the seventh and ninth largest projected increases, respectively, between 2021 and 2030. France, a medium market country, sees the largest projected decrease in fuel ethanol consumption between 2018 and 2030, while India sees the largest projected decrease between 2021 and 2030. Japan sees the second largest projected decrease in fuel ethanol consumption between 2018 and 2030 and sees the third largest projected decrease between 2021 and 2030. The only other large market countries found across either interval are Canada (third largest projected fuel ethanol decrease between 2018 and 2030) and Germany (second largest projected fuel ethanol decrease between 2021 and 2030).

Across both intervals, the only overlap between the largest projected increases in motor gasoline consumption and the largest projected increases in fuel ethanol consumption are Brazil, China, India, and Thailand. This indicates that in many countries where motor gasoline consumption is expected to increase, fuel ethanol blending has been historically low or nonexistent. This is also indicated in table 8 by the number of countries that are projected to increase motor gasoline consumption but decrease or not change fuel ethanol consumption: 141 countries between 2018 and 2030, and 135 countries between 2021 and 2030. Conversely, there is more overlap between the largest projected decreases in motor gasoline consumption and the largest projected decreases in fuel ethanol consumption. This result, and the result that several countries—29 countries between 2018 and 2030, and 34 countries between 2021 and 2030—see a decrease in consumption of both fuels (table 8), suggests that several countries that have historically blended ethanol are expected to see motor gasoline consumption—and thus fuel ethanol consumption—decrease. Despite the changes under this scenario, the projected group of the 10-largest non-U.S. consumers of fuel ethanol remains largely the same in 2030 as it was in 2018, with the exception of Japan and the United Kingdom—the ninth and tenth largest in 2018—being replaced by Colombia and the Philippines, respectively, in 2030.

Table 9

Largest increases and decreases in motor gasoline and fuel ethanol consumption from 2018 to 2030 and from 2021 to 2030; motor gasoline and fuel ethanol consumption in 2030 (billions of gallons)

(a) Largest increases in motor gasoline consumption						(b) Largest decreases in motor gasoline consumption						(c) Largest motor gasoline consumption, 2030	
2018 to 2030			2021 to 2030			2018 to 2030			2021 to 2030				
Country	Increase	2030 total	Country	Increase	2030 total	Country	Decrease	2030 total	Country	Decrease	2030 total	Country	Consumption
China[1]	16.07	62.90	China[1]	10.16	62.90	Japan[1]	-3.60	9.68	Japan[1]	-2.27	9.68	China[1]	62.90
India[1]	3.30	13.20	India[1]	4.38	13.20	Canada[1]	-1.26	11.47	Germany[1]	-0.96	5.95	India[1]	13.20
Indonesia[1]	2.07	11.20	Indonesia[1]	2.26	11.20	Germany[1]	-1.22	5.95	Australia[2]	-0.40	4.03	Russia[1]	13.13
Malaysia[2]	1.58	6.05	Malaysia[2]	1.22	6.05	Australia[2]	-0.87	4.03	Italy[2]	-0.36	2.24	Mexico[1]	11.55
Nigeria[2]	1.42	5.33	Nigeria[2]	1.20	5.33	Italy[2]	-0.44	2.24	France[2]	-0.36	2.21	Canada[1]	11.47
SA[1]	1.14	9.34	SA[1]	1.08	9.34	UK[2]	-0.44	3.68	UK[2]	-0.36	3.68	Indonesia[1]	11.20
Iran[1]	1.10	9.08	Iran[1]	1.05	9.08	France[2]	-0.42	2.21	SK[2]	-0.29	2.98	Japan[1]	9.68
Egypt[2]	0.94	3.53	Brazil[1]	0.80	7.94	SK[2]	-0.36	2.98	Spain[2]	-0.23	1.44	SA[1]	9.34
Vietnam[2]	0.81	3.05	Egypt[2]	0.79	3.53	Spain[2]	-0.29	1.44	Poland[2]	-0.21	1.27	Iran[1]	9.08
Thailand[2]	0.75	3.36	Thailand[2]	0.67	3.36	Poland[2]	-0.25	1.27	Netherlands[2]	-0.19	1.19	Brazil[1]	7.94
(d) Largest increases in fuel ethanol consumption						(e) Largest decreases in fuel ethanol consumption						(f) Largest fuel ethanol consumption, 2030	
2018 to 2030			2021 to 2030			2018 to 2030			2021 to 2030				
Country	Increase	2030 total	Country	Increase	2030 total	Country	Decrease	2030 total	Country	Decrease	2030 total	Country	Consumption
China[1]	0.35	1.31	Brazil[1]	0.74	8.15	France[2]	-0.07	0.20	India[1]	-0.08	0.63	Brazil[1]	8.15
Brazil[1]	0.28	8.15	China[1]	0.19	1.31	Japan[1]	-0.05	0.17	Germany[1]	-0.06	0.35	China[1]	1.31
India[1]	0.23	0.63	Thailand[2]	0.11	0.51	Canada[1]	-0.04	0.75	Japan[1]	-0.05	0.17	Canada[1]	0.75
Thailand[2]	0.11	0.51	Argentina[2]	0.05	0.31	UK[2]	-0.03	0.17	France[2]	-0.03	0.20	India[1]	0.63
Philippines[2]	0.04	0.19	Colombia[2]	0.05	0.20	Netherlands[2]	-0.03	0.06	UK[2]	-0.02	0.17	Thailand[2]	0.51
Bolivia[3]	0.03	0.03	Philippines[2]	0.03	0.19	Australia[2]	-0.03	0.06	Poland[2]	-0.01	0.08	Germany[1]	0.35
Argentina[2]	0.03	0.31	Paraguay[3]	0.02	0.10	Belgium[3]	-0.02	0.03	Spain[2]	-0.01	0.07	Argentina[2]	0.31
Colombia[2]	0.02	0.20	Canada[1]	0.01	0.75	Vietnam[2]	-0.02	0.02	Netherlands[2]	-0.01	0.06	France[2]	0.20
Costa Rica[3]	0.02	0.02	Peru[3]	0.01	0.07	Ukraine[3]	-0.02	0.03	Sweden[3]	-0.01	0.05	Colombia[2]	0.20
Jamaica[3]	0.02	0.02	Australia[2]	0.01	0.06	Poland[2]	-0.02	0.08	Finland[3]	-0.00	0.03	Philippines[2]	0.19

Note: 1 = Large motor gasoline market country; 2 = medium motor gasoline market country, 3 = small motor gasoline market country. Market definitions based on 2018 motor gasoline consumption; Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline consumption values do not include the fuel ethanol component whereas the market definitions did include the fuel ethanol component. SA = Saudi Arabia, SK = South Korea, UK = United Kingdom.

Source: USDA, Economic Research Service estimates using the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Targeted Blends (TB) Scenario

Under the Targeted Blends scenario, non-U.S. motor gasoline consumption increases 15 billion gallons (6.1 percent) between 2018 and 2030 and 12.7 billion gallons (5.1 percent) between 2021 and 2030. Non-U.S. fuel ethanol consumption, meanwhile, is projected to grow from 13.5 billion gallons in 2021 to 36.9 billion gallons in 2030, a total increase of 173 percent and a 180-percent increase above 2018 levels. Compared with the HB scenario, total fuel ethanol consumption is projected at 22.9 billion gallons (or 165 percent) higher in 2030 while the 2030 blend rate of 12.4 percent is more than double that under the HB scenario. The primary driver of the projected increased fuel ethanol consumption in this scenario is the combination of increased ethanol blending rates in large market countries, such as China (5.3 billion more gallons of fuel ethanol than the HB scenario) and the RenovaBio program in Brazil—which is not incorporated into the HB scenario—resulting in Brazil consuming 6.1 billion more gallons of fuel ethanol than in the HB scenario.

Using EIA's 2018 global fuel ethanol production (excluding the United States) as a proxy for international production capacity, non-U.S. fuel ethanol demand is projected to exceed non-U.S. fuel ethanol production by between 1.2 billion gallons in 2021 and 24.6 billion gallons in 2030. Thus, under this scenario, there could be opportunities for U.S. fuel ethanol exports, given excess U.S. ethanol production capacity. From 2022 to 2030, projected excess U.S. ethanol production capacity—based on the EIA's Annual Energy Outlook fuel ethanol consumption projections—ranges between 2.2 billion gallons and 3.7 billion gallons.[18] Analyzing the results by motor gasoline market segment—large, medium, and small—the authors see the key changes in fuel ethanol consumption in table 10. See the appendix for country-specific details on policies and projections.

[18] Assuming that U.S. ethanol production capacity remains at the 2021 level, the excess capacity of 2.2 billion gallons would occur under the "high economic growth" scenario in 2030 while the excess capacity of 3.5 billion gallons applies to multiple scenarios in 2022.

Table 10

Motor gasoline and fuel ethanol consumption outside the United States by 2018 market size under Targeted Blends scenario, 2018, 2021, and 2030 (billions of gallons)

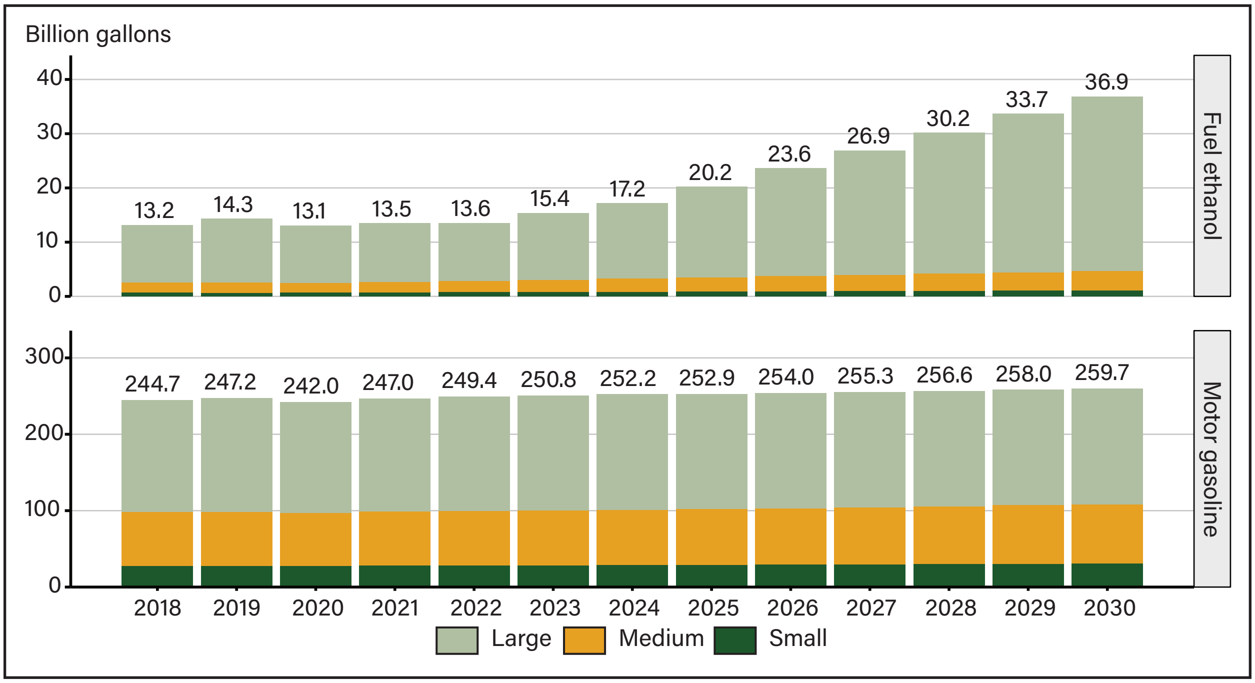
Year	Market	Motor gasoline	Fuel ethanol	Blend rate
2018	Large	146.7	10.6	6.8%
	Medium	70.6	1.9	2.6%
	Small	27.5	0.6	2.3%
	Total	244.7	13.2	5.1%
2021	Large	148.5	10.9	6.8%
	Medium	70.7	1.9	2.6%
	Small	27.8	0.7	2.5%
	Total	247.0	13.5	5.2%
2030	Large	151.6	32.2	17.5%
	Medium	77.5	3.6	4.4%
	Small	30.6	1.1	3.4%
	Total	259.7	36.9	12.4%
Change, 2018–30	Large	3.3%	203.0%	
	Medium	9.8%	89.2%	
	Small	11.5%	65.3%	
	Total	6.1%	179.9%	
Change, 2021–30	Large	2.1%	196.1%	
	Medium	9.6%	88.4%	
	Small	10.2%	49.7%	
	Total	5.1%	173.2%	

Note: Market definitions based on 2018 motor gasoline consumption; Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline consumption values do not include the fuel ethanol component, whereas the market definitions do include the fuel ethanol component.

Source: USDA, Economic Research Service estimates using the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Figure 22

Non-U.S. fuel ethanol and motor gasoline consumption, Targeted Blends scenario, 2018–30



Notes: Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline does not include the fuel ethanol component.

Sources: USDA, Economic Research Service estimates based on the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

As seen in table 11, compared with the HB scenario, the TB scenario results in approximately twice as many countries projected to increase fuel ethanol consumption across both the 2018 to 2030 and 2021 to 2030 intervals. This is mostly due to more countries being projected to increase fuel ethanol consumption and decrease motor gasoline consumption. Noting that, compared with the HB scenario, the TB scenario has 21 fewer countries (across both intervals) projected to decrease consumption of both fuels; there is likely a number of countries where TGE demand is expected to decrease, but the countries are substituting fuel ethanol for motor gasoline to meet blending targets. However, the projected increase in fuel ethanol consumption coming from countries that are projected to increase consumption of both fuels amounts to 12 billion gallons between 2018 and 2030 and to 11.6 billion gallons between 2021 and 2030. By comparison, these values were 1.2 billion and 1.3 billion, respectively, under the HB scenario. This would seem to suggest that much of the total projected increase in ethanol consumption comes from countries where total fuel demand is expected to grow but historically have blended at levels below their targets.

Table 11

Summary of changes in motor gasoline and fuel ethanol demand in the Targeted Blends scenario

Changes between 2018 and 2030						
Country-level change in motor gasoline demand	Decrease	Increase	Decrease	Increase	Decrease	Increase
Country-level change in fuel ethanol demand	Decrease	Decrease	Increase	Increase	No change	No change
Total number of countries	**8**	**3**	**27**	**22**	**3**	**134**
Large market countries	0	0	5	3	0	3
Medium market countries	2	0	5	9	3	11
Small market countries	6	3	17	10	0	120
Total motor gasoline change (billion gallons)	**-1.71**	**0.06**	**-15.77**	**19.15**	**-0.61**	**13.84**
Large market countries	0.00	0.00	-12.78	14.79	0.00	2.88
Medium market countries	-1.32	0.00	-1.99	3.82	-0.61	7.02
Small market countries	-0.39	0.07	-1.00	0.54	0.00	3.95
Total fuel ethanol change (billion gallons)	**-0.08**	**-0.01**	**11.78**	**12.02**	**0.00**	**0.00**
Large market countries	0.00	0.00	11.03	10.56	0.00	0.00
Medium market countries	-0.04	0.00	0.44	1.29	0.00	0.00
Small market countries	-0.04	-0.02	0.31	0.18	0.00	0.00
Changes between 2021 and 2030						
Country-level change in motor gasoline demand	Decrease	Increase	Decrease	Increase	Decrease	Increase
Country-level change in fuel ethanol demand	Decrease	Decrease	Increase	Increase	No change	No change
Total number of countries	**13**	**0**	**25**	**23**	**3**	**133**
Large market countries	1	0	4	3	0	3
Medium market countries	0	0	7	9	3	11
Small market countries	12	0	14	11	0	119
Total motor gasoline change (billion gallons)	**-2.81**	**0.00**	**-10.30**	**14.41**	**-0.48**	**11.89**
Large market countries	-2.31	0.00	-7.22	10.15	0.00	2.47
Medium market countries	0.00	0.00	-2.41	3.69	-0.48	5.99
Small market countries	-0.50	0.00	-0.67	0.57	0.00	3.42
Total fuel ethanol change (billion gallons)	**-0.03**	**0.00**	**11.76**	**11.64**	**0.00**	**0.00**
Large market countries	0.00	0.00	11.25	10.08	0.00	0.00
Medium market countries	0.00	0.00	0.39	1.29	0.00	0.00
Small market countries	-0.03	0.00	0.12	0.26	0.00	0.00

Note: Market definitions based on 2018 motor gasoline consumption; Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline consumption values do not include the fuel ethanol component whereas the market definitions did include the fuel ethanol component.

Source: USDA, Economic Research Service estimates using the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Under this scenario, much of the projected increase in fuel ethanol consumption is concentrated in large motor gasoline markets with ambitious targets. China, for example, has a blending target of 10 percent. India and Indonesia, meanwhile, are targeting a 20-percent blend rate by 2025 (Rahmanulloh, 2021; Chandra, 2021). Under this scenario, these countries see a combined projected increase in fuel ethanol consumption of 10.6 billion gallons above 2018 levels and 10.1 billion gallons above 2021 levels (table 12). This accounts for between 43 percent (2021 to 2030) and 45 percent (2018 to 2030) of the total projected increase in fuel ethanol consumption in this scenario. In each of these countries, the increasing blend rates, along with increasing total fuel demand, leads to increased fuel ethanol consumption. However, these countries have historically been below these targets: The 5-year average blend rates for China, India, and Indonesia are 2.0 percent, 4.6 percent, and 0.0 percent, respectively.

If countries such as China, India, and Indonesia take steps to meet their targets, and markets such as Mexico (projected under the TB scenario to increase fuel ethanol consumption by about 1 billion gallons by 2030) allow ethanol to compete for the oxygenate market, global fuel ethanol consumption could see significant increases over the next decade. Moreover, there is an opportunity with other motor gasoline consumers—South Korea (3.4 billion gallons in 2018), Nigeria (3.9 billion gallons in 2018), Malaysia (4.5 billion gallons in 2018), and so on—that were assumed in this study to maintain zero fuel ethanol consumption to have an impact by easing restrictions or instituting ethanol blending programs. However, countries could also decide to lower blending mandates or targets and thus negatively impact demand.

Ambitious programs in Brazil (the RenovaBio program) and Canada (the Clean Fuel Standard) also yield large contributions to the projected increase in fuel ethanol consumption. For Brazil, fuel ethanol consumption is projected to increase by between 6.4 billion gallons (2018 to 2030) and 6.9 billion gallons (2021 to 2030). For Canada, projected increases range from 3.3 billion gallons (2018 to 2030) to 3.4 billion gallons (2021 to 2030). Combined, Brazil and Canada account for 41 percent (2018 to 2030) to 44 percent (2021 to 2030) of the total projected increase in fuel ethanol consumption. In contrast to China, India, and Indonesia, motor gasoline consumption decreases in Brazil and Canada. Thus, effective blending rates increase in Brazil and Canada even though the RenovaBio and Clean Fuel Standard do not specifically target any particular blend rate.

By 2030, the projected four largest consumers of fuel ethanol remain as they were in 2018: Brazil, China, Canada, and India. Thailand and Germany—the fifth and sixth largest consumers of fuel ethanol in 2018—are surpassed under this scenario by Indonesia and Mexico. Neither Indonesia nor Mexico was among the projected 10 largest consumers of fuel ethanol in 2018. Likewise, the Philippines is projected as the ninth largest consumer, while Japan is no longer included among this group. The United Kingdom remains projected as the tenth largest non-U.S. consumer of fuel ethanol. Overall, the projected 10 largest consumers of fuel ethanol in 2030 account for about 95 percent of the total projected increase in fuel ethanol consumption.

Table 12

Largest increases and decreases in motor gasoline and fuel ethanol consumption from 2018 to 2030 and from 2021 to 2030; motor gasoline and fuel ethanol consumption in 2030 under Targeted Blends scenario (billions of gallons)

(a) Largest increases in motor gasoline consumption						(b) Largest decreases in motor gasoline consumption						(c) Largest motor gasoline consumption, 2030	
2018 to 2030			2021 to 2030			2018 to 2030			2021 to 2030				
Country	Increase	2030 total	Country	Increase	2030 total	Country	Decrease	2030 total	Country	Decrease	2030 total	Country	Consumption
China[1]	12.54	59.38	China[1]	6.64	59.38	Japan[1]	-3.63	9.65	Brazil[1]	-3.29	3.86	China[1]	59.38
India[1]	1.77	11.67	India[1]	2.86	11.67	Brazil[1]	-3.55	3.86	Japan[1]	-2.31	9.65	Russia[1]	13.13
Malaysia[2]	1.58	6.05	Malaysia[2]	1.22	6.05	Canada[1]	-3.49	9.24	Canada[1]	-2.24	9.24	India[1]	11.67
Nigeria[2]	1.42	5.33	Nigeria[2]	1.20	5.33	Germany[1]	-1.33	5.83	Germany[1]	-1.05	5.83	Mexico[1]	10.78
SA[1]	1.14	9.34	SA[1]	1.08	9.34	Australia[2]	-0.87	4.03	Mexico[1]	-0.64	10.78	Japan[1]	9.65
Iran[1]	1.10	9.08	Iran[1]	1.05	9.08	Mexico1	-0.76	10.78	UK[2]	-0.47	3.54	Indonesia[1]	9.60
Egypt[2]	0.94	3.53	Egypt[2]	0.79	3.53	UK[2]	-0.59	3.54	Italy[2]	-0.41	2.17	SA[1]	9.34
Russia[1]	0.64	13.13	Indonesia[1]	0.66	9.60	Italy[2]	-0.51	2.17	Australia[2]	-0.40	4.03	Canada[1]	9.24
Venezuela[2]	0.64	3.55	Venezuela[2]	0.62	3.55	France[2]	-0.46	2.18	France[2]	-0.39	2.18	Iran[1]	9.08
Pakistan[2]	0.62	3.47	Pakistan[2]	0.61	3.47	SK[2]	-0.36	2.98	SK[2]	-0.29	2.98	Malaysia[2]	6.05
(d) Largest increases in fuel ethanol consumption						(e) Largest decreases in fuel ethanol consumption						(f) Largest fuel ethanol consumption, 2030	
2018 to 2030			2021 to 2030			2018 to 2030			2021 to 2030				
Country	Increase	2030 total	Country	Increase	2030 total	Country	Decrease	2030 total	Country	Decrease	2030 total	Country	Consumption
Brazil[1]	6.40	14.27	Brazil[1]	6.86	14.27	Australia[2]	-0.03	0.06	Sweden[3]	-0.01	0.05	Brazil[1]	14.27
China[1]	5.63	6.60	China[1]	5.48	6.60	Finland[3]	-0.02	0.03	Finland[3]	-0.01	0.03	China[1]	6.60
Canada[1]	3.30	4.09	Canada[1]	3.36	4.09	Sweden[3]	-0.01	0.05	Ireland[3]	-0.00	0.01	Canada[1]	4.09
India[1]	2.52	2.92	Indonesia[1]	2.40	2.40	France[2]	-0.01	0.26	CR[3]	-0.00	0.03	India[1]	2.92
Indonesia[1]	2.40	2.40	India[1]	2.20	2.92	Paraguay[3]	-0.01	0.08	Latvia[3]	-0.00	0.00	Indonesia[1]	2.40
Mexico[1]	1.16	1.20	Mexico[1]	0.95	1.20	Romania[3]	-0.01	0.03	Turkey[3]	-0.00	0.02	Mexico[1]	1.20
Thailand[2]	0.40	0.79	Thailand[2]	0.40	0.79	Switzerland[3]	-0.01	0.01	Estonia[3]	-0.00	0.00	Thailand[2]	0.79
Philippines[2]	0.30	0.45	Philippines[2]	0.30	0.45	Latvia[3]	-0.00	0.00	Romania[3]	-0.00	0.03	Germany[1]	0.52
Vietnam[2]	0.28	0.32	Vietnam[2]	0.26	0.32	Turkey[3]	-0.00	0.02	Portugal[3]	-0.00	0.00	Philippines[2]	0.45
UK[2]	0.19	0.39	UK[2]	0.16	0.39	Estonia[3]	-0.00	0.00	Switzerland[3]	-0.00	0.01	UK[2]	0.39

Note: 1 = Large motor gasoline market country; 2 = medium motor gasoline market country; 3 = small motor gasoline market country. Market definitions based on 2018 motor gasoline consumption; Large = >5 billion gallons; Medium = 1 billion–5 billion gallons; Small = <1 billion gallons. Motor gasoline consumption values do not include the fuel ethanol component, whereas the market definitions do include the fuel ethanol component. CR = Czech Republic, SA = Saudi Arabia, SK = South Korea, UK = United Kingdom.

Source: USDA, Economic Research Service estimates using the International Energy Agency's World Energy Outlook 2020 projections and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service.

Non-Fuel Ethanol

As noted, this study does not incorporate non-fuel ethanol consumption into the potential demand projections provided in the previous sections. Unlike fuel ethanol consumption, there is not widespread data by country for non-fuel ethanol consumption, making the incorporation of projections for this component infeasible for the current study. However, it should be kept in mind that non-fuel demand could provide markets for U.S. ethanol producers not captured in this study.

Non-fuel ethanol applications have served as an intermediate in the production of other chemicals; for use as a solvent; and in the production of drugs, cosmetics, and other products (Strohm, 2014). Ethanol use in hand sanitizers, for example, served as an outlet for ethanol production in the early stages of the COVID-19 pandemic. Ethanol is also used as a food additive. For example, ethanol can promote the distribution of food coloring, enhance flavors, and produce extracts (ChemicalSafetyFacts.org, 2022). Though not necessarily new, ethanol's use in plastics could increase, along with consumers'—and subsequently companies'—desire for more eco-friendly products. For example, The Coca-Cola Company recently announced efforts to produce a 100-percent plant-based bottle. The process relies partly on bio-monoethylene glycol (bMEG), which is typically produced by converting bio-ethanol to bio-ethylene glycol (The Coca-Cola Company, 2021). The company intends to bypass this production method by producing bMEG directly from sugars (such as hardwood feedstock) to avoid competing with fuel. However, if demand for fuel ethanol falls, the ethanol-to-bMEG approach could become more feasible to The Coca-Cola Company or other companies looking to implement similar practices. Additionally, the U.S. Department of Energy's Pacific Northwest National Laboratory recently developed a catalyst that converts ethanol into butadiene, which is a molecular "building block for just about every major synthetic plastic or rubber" (Drennan, 2018).

Non-fuel uses of ethanol (including beverage applications) have been estimated to be between 13 and 20 percent of global consumption of ethanol (S&P Global, 2022; Expert Market Research, 2021). Based on an estimate of 2019 global fuel ethanol consumption of 28.7 billion gallons from EIA and USDA's FAS, these shares would correspond to between 4.3 billion and 7.2 billon gallons of non-fuel ethanol consumption. Based on reports from USDA's FAS, much of this consumption likely comes from just a handful of consumers (table 13). Of those countries for which data is available, China has consistently been the largest consumer of non-fuel ethanol. In 2021, USDA's FAS estimated China would consume 1.9 billion gallons of non-fuel ethanol, almost four times the amount of Brazil, the second-largest consumer (of those countries for which data is available). For these countries, total consumption increased by 1.2 billion gallons between 2012 and 2021, though this increase was primarily due to China, where non-fuel ethanol consumption increased by 1.3 billion gallons over the period. The market share (across the countries in table 13) for non-fuel ethanol averaged 21 percent over this period and ranged between 19 percent in 2019 and 23 percent in 2017. Market shares across individual years and countries saw a wider variance, ranging between zero and 100 percent. Total consumption across these countries is estimated at 3 billion gallons in 2021.

Table 13

Foreign Agricultural Service estimates of non-fuel ethanol consumption, 2012–21 (millions of gallons)

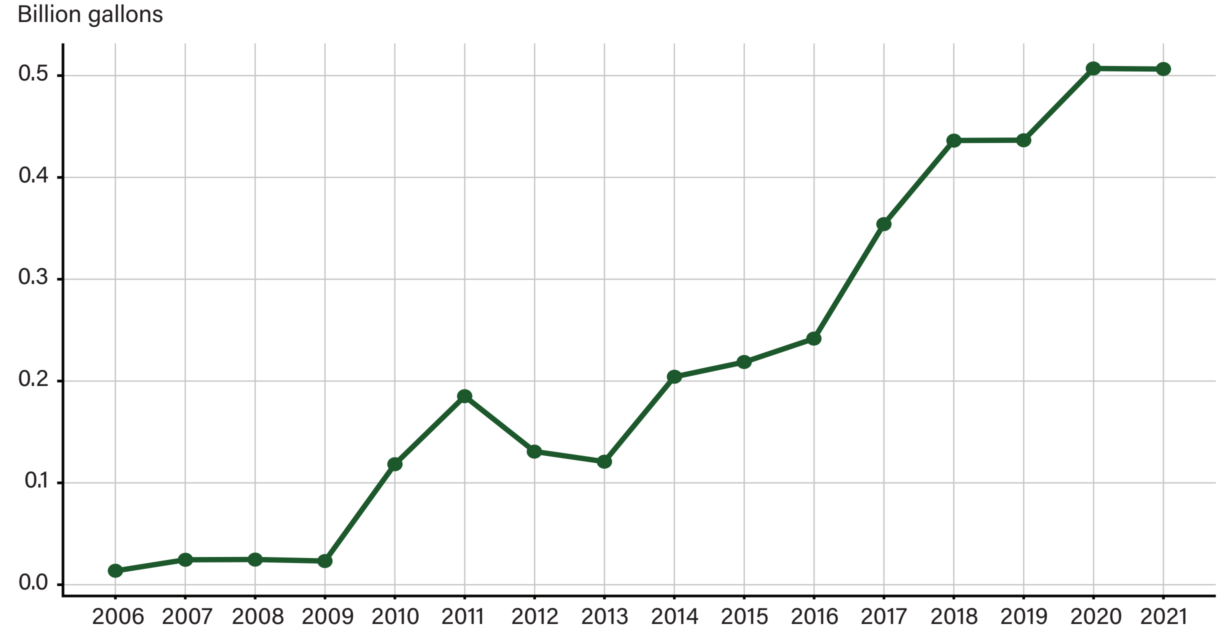
Country		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021*
Brazil	Non-fuel	585	608	621	568	388	538	528	561	625	528
	Fuel	4,700	5,668	6,363	7,607	6,922	6,753	7,856	8,678	7,643	7,394
	Non-fuel share	11.1%	9.7%	8.9%	6.9%	5.3%	7.4%	6.3%	6.1%	7.6%	6.7%
Canada	Non-fuel	17	11	6	44	33	29	77	**	**	**
	Fuel	660	738	765	742	753	778	785	805	720	731
	Non-fuel share	2.5%	1.4%	0.8%	5.6%	4.2%	3.6%	8.9%	**	**	**
China	Non-fuel	635	746	1,041	1,358	1,459	1,599	1,872	1,715	1,767	1,937
	Fuel	754	775	786	896	899	805	961	1,144	1,015	1,115
	Non-fuel share	45.7%	49.1%	57.0%	60.2%	61.9%	66.5%	66.1%	60.0%	63.5%	63.5%
Colombia	Non-fuel	21	31	21	27	22	22	17	3	1	4
	Fuel	100	107	113	123	121	123	177	188	166	145
	Non-fuel share	17.5%	22.4%	15.7%	18.0%	15.7%	15.5%	8.7%	1.4%	0.8%	2.7%
India	Non-fuel	436	409	436	439	312	411	402	388	415	375
	Fuel	81	101	92	181	293	178	396	499	457	713
	Non-fuel share	84.4%	80.2%	82.5%	70.8%	51.5%	69.7%	50.3%	43.8%	47.6%	34.5%
Indonesia	Non-fuel	36	36	36	36	36	36	36	37	46	46
	Fuel	0	0	0	0	0	0	0	0	0	0
	Non-fuel share	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	Non-fuel	78	87	98	87	109	102	102	96	146	122
	Fuel	95	110	133	164	196	216	217	209	225	217
	Non-fuel share	45.2%	44.2%	42.4%	34.7%	35.8%	32.1%	32.0%	31.5%	39.4%	35.9%
Malaysia	Non-fuel	3	3	3	3	3	3	3	3	5	5
	Fuel	0	0	0	0	0	0	0	0	0	0
	Non-fuel share	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Peru	Non-fuel	0	0	0	0	0	0	5	12	13	15
	Fuel	33	42	44	46	48	49	51	54	54	54
	Non-fuel share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.9%	18.7%	19.6%	21.2%
Thailand	Non-fuel	6	5	7	7	8	8	10	8	10	10
	Fuel	134	251	278	311	338	380	396	426	392	393
	Non-fuel share	4.5%	2.1%	2.3%	2.1%	2.3%	2.0%	2.4%	1.9%	2.6%	2.4%
Total	**Non-fuel**	**1,816**	**1,936**	**2,268**	**2,568**	**2,370**	**2,748**	**3,052**	**2,824**	**3,028**	**3,042**
	Fuel	**6,555**	**7,793**	**8,574**	**10,070**	**9,570**	**9,281**	**10,839**	**12,002**	**10,672**	**10,763**
	Non-fuel share	**21.7%**	**19.9%**	**20.9%**	**20.3%**	**19.9%**	**22.8%**	**22.0%**	**19.0%**	**22.1%**	**22.0%**

Note: *USDA, Foreign Agricultural Service (FAS) forecast values. **USDA, FAS reported values of not available for Canada for these years.

Source: USDA, Economic Research Service share calculations using USDA, FAS data.

The volume of U.S. non-fuel ethanol exports has also been growing over the last several years, going from 14 million gallons in 2006 to 506 million gallons in 2021 (figure 23) (USDA, FAS, 2022). The share of total U.S. ethanol exports going to non-fuel ethanol averaged about 25 percent over this period but has been higher recently at 39 percent in 2020 and 41 percent in 2021. India has frequently been the destination for the largest share of these exports, averaging about 102 million gallons per year from 2012 to 2021 (table 14).

Figure 23
U.S. annual exports of non-fuel ethanol, 2006–21



Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service.

Table 14
U.S. non-fuel ethanol exports by destination, 2012–21 (millions of gallons)

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Canada	31	32	34	32	31	33	35	33	33	37
EU+UK	35	5	10	8	2	13	22	24	28	25
India	0	21	40	38	91	184	151	165	176	156
Mexico	34	29	29	34	30	29	29	29	64	47
Nigeria	15	3	17	7	22	25	22	22	37	44
Saudi Arabia	0	0	0	0	5	6	22	15	12	20
South Korea	10	5	36	64	42	49	86	121	104	152
Rest of world	6	24	38	36	18	16	70	27	54	25
Total	131	121	204	219	242	354	436	437	507	506

Note: EU+UK = European Union and the United Kingdom.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service.

Despite increasing global consumption and U.S. exports of non-fuel ethanol, this market still represents a small share for U.S. ethanol producers. Across the 2012–2021 period, the largest volume of non-fuel ethanol exports came in 2020 at 507 million gallons, which would represent 3 percent of current U.S. ethanol production capacity. Though volumes are not available for U.S. production of non-fuel ethanol (or alternatively the volumes going to non-fuel uses), USDA, Economic Research Service corn-use data suggest that a small volume of corn is being used for these purposes. In the 2020/21 corn marketing year, for example, only 157 million bushels went to "alcohol for beverages and manufacturing use," compared with 5.4 billion bushels that went to "alcohol for fuel use." Regardless, adding non-U.S., non-fuel ethanol consumption to the HB and TB projections may provide a more realistic view of the potential total addressable market for U.S. ethanol producers in the future. Assuming the 3-billion-gallon non-fuel ethanol consumption estimate for 2021 from USDA's FAS represents global consumption and that it remains constant, by 2030, the combined fuel and non-fuel demand under the HB scenario would be 16.9 billion gallons (or 22 percent more than the fuel ethanol demand). Under the TB scenario, combined demand in 2030 would be 39.9 billion gallons, an increase of a little more than 8 percent above the fuel ethanol demand. It should be noted that these are rough calculations and should not be viewed as projections for non-fuel ethanol consumption. More data and information are needed for such projections and should be the focus of future research.

Conclusion

In the United States, fuel ethanol consumption is expected to remain below 2021 production capacity across all EIA scenarios and years. This could result in unutilized ethanol-production capacity and potentially reduce ethanol-based demand for corn. Thus, this study estimates future demand for fuel ethanol outside of the United States to gain insights regarding the potential for this market to provide an outlet for excess U.S. ethanol capacity.

Global consumption of fuel ethanol outside the United States will depend upon the blend rates seen in the international community. If historical practices continue, fuel ethanol consumption outside of the United States is expected to grow about 7.4 percent between 2021 and 2030, or about 5.7 percent above 2018 levels. If, however, multiple countries follow through on stated ethanol policies or targets and increase blending rates, fuel ethanol use could nearly triple over the period. While these numbers are projections and subject to change (with modifications to the underlying models and assumptions), a key takeaway from the study is that international policy support to meet blending targets could result in significant growth in international demand for fuel ethanol.

There are important limitations of this analysis that should be noted. First, the authors do not include trade flows, trade barriers, and trade projections. Trade agreements such as the EU-Southern Common Market (commonly, MERCOSUR) agreement will likely have an impact on the export opportunities for U.S. ethanol. Second, the authors do not look at or comment on the legality of countries' policies (e.g., the inclusion of domestic buying provisions in their ethanol mandates). Moreover, there could be inaccuracies in our interpretation or projections regarding countries' ethanol targets. Third, the authors do not include consumption of ethanol for non-fuel uses, which is an important component of ethanol demand in some countries. Fourth, the authors do not look at current or projected production capacity within countries. Ethanol blending mandates are often an attempt to support domestic agriculture. As such, if countries increase their blending rates, they may also increase their ethanol production capacity. Finally, these projections do not account for ethanol prices. That is, if production capacity were to remain stagnant, increasing demand for fuel ethanol would lead to increasing ethanol prices, thus depressing quantities demanded for fuel ethanol. Increasing prices could also lead to expansions in U.S. and non-U.S. ethanol production. Each of these limitations could be addressed in future research.

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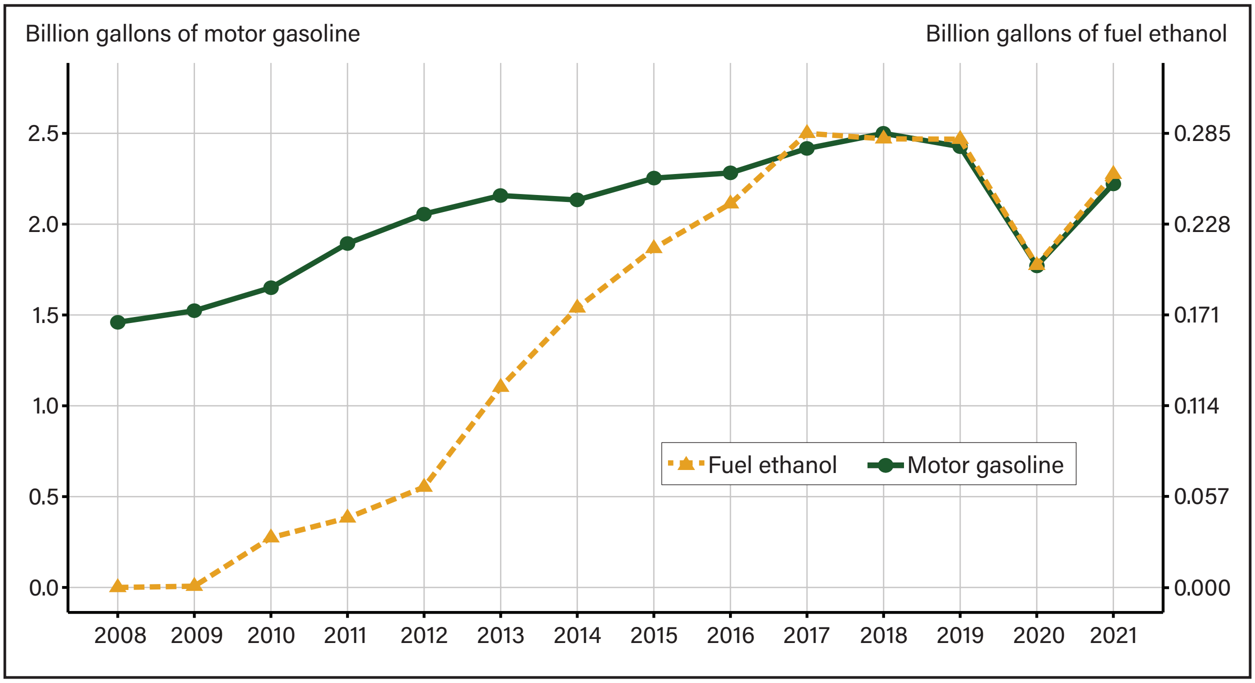
Appendix

Country Observations, Policy Insights, and Selected Statistics

This section provides background information on fuel ethanol policies for selected countries. Additionally, for these countries, historical consumption of fuel ethanol, motor gasoline, and effective blending rates are provided. Assumed 2030 effective blend rates for the "Targeted Blends" scenario are also presented when applicable.

Argentina

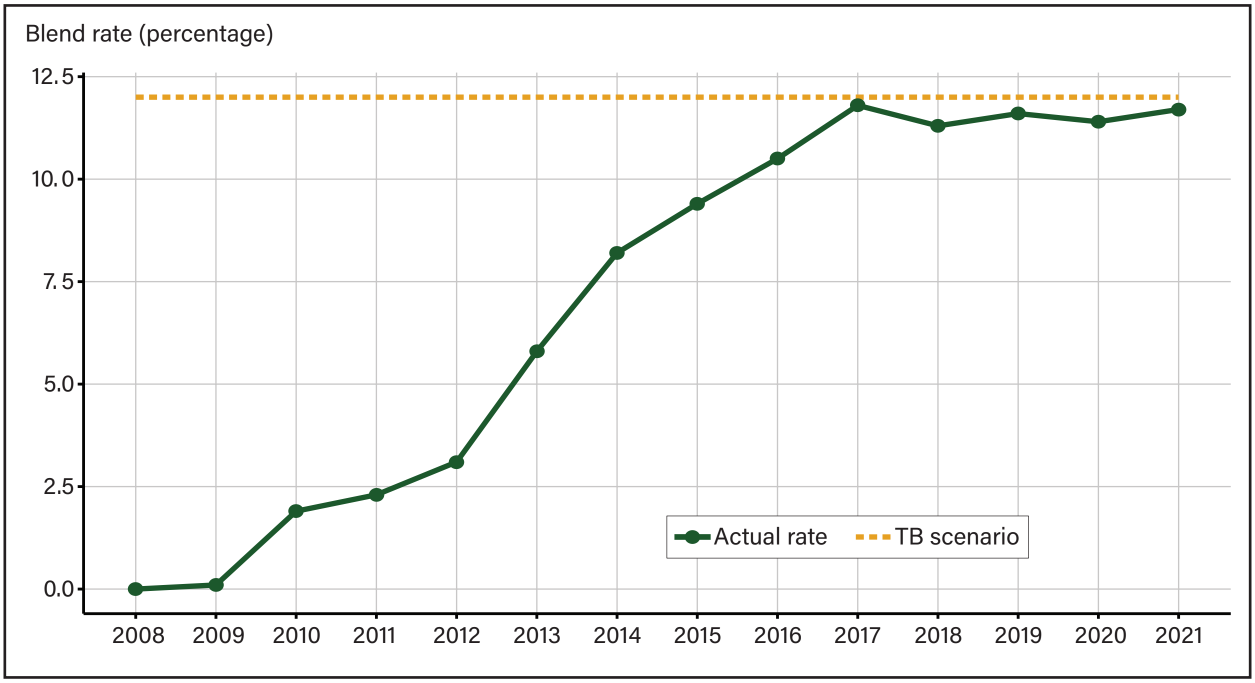
Figure A-1
Argentina: fuel ethanol and motor gasoline consumption, 2008–21



Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-2
Argentina: actual blend rates, 2008–21, and Targeted Blends (TB) scenario target rate



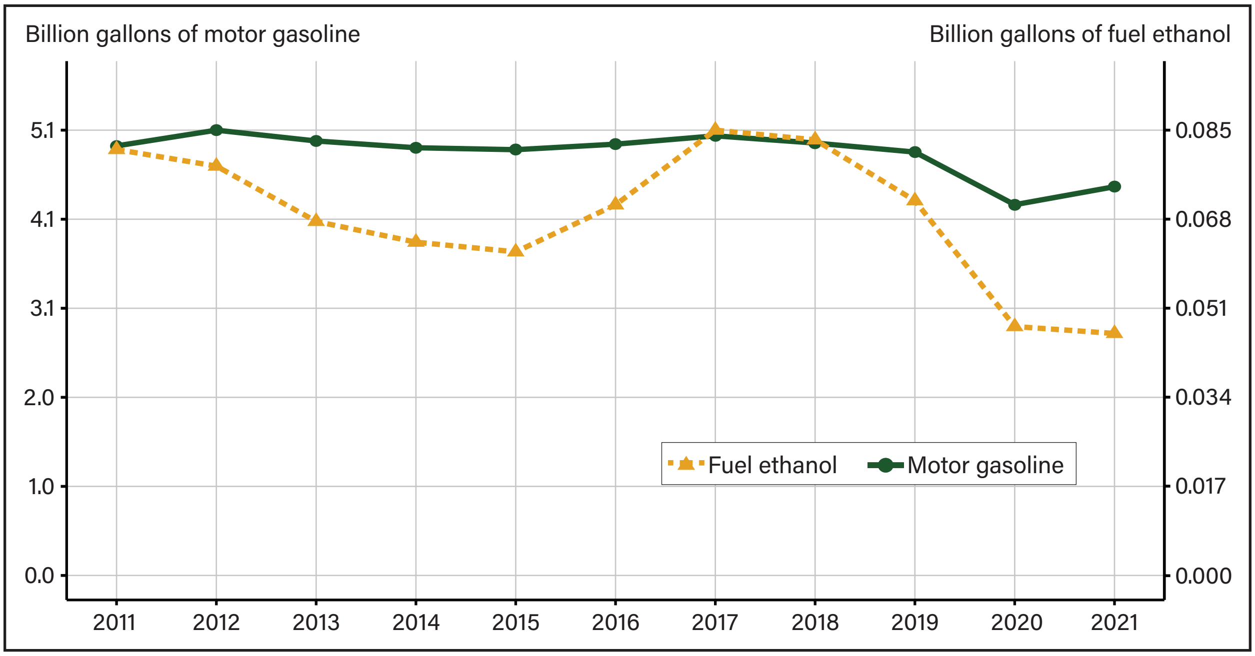
Note: The TB scenario rate is the rate Argentina is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

For much of its history, Argentina's consumption of fuel ethanol was largely nonexistent, with no estimated consumption prior to 2009. From 2009 to 2017, however, consumption grew quickly from 0.8 million gallons to 285 million gallons. Motor gasoline consumption (includes fuel ethanol) also grew over this time, but more slowly than fuel ethanol consumption, and reached a peak of 2.5 billion gallons in 2018. Argentina mandated a 12-percent blend in April 2016 (Joseph, 2020) and has seen effective blending rates at around this level since that time. In July 2021, Argentina passed Biofuels Law 27640, which maintains the 12-percent mandate, though the law also allows the mandate to be reduced to 9 percent if economically necessary (Joseph, 2021). Additionally, the new law requires an even split between sugar-based and corn-based ethanol (Joseph, 2021).

Currently, ethanol production capacity is only 433 million gallons per year (Joseph, 2021), so to meet higher blend rates, or to maintain a 12 percent rate under increased motor gasoline consumption, Argentina would likely need to build additional capacity or rely on imports. However, only domestically produced ethanol may be used currently to fulfill mandate requirements unless exceptions are made by the Argentine Energy Secretariat (Joseph, 2020). Thus, in the absence of changes to trade policy, U.S. ethanol producers would likely see no trade increases to Argentina from increased demand for fuel ethanol in Argentina.

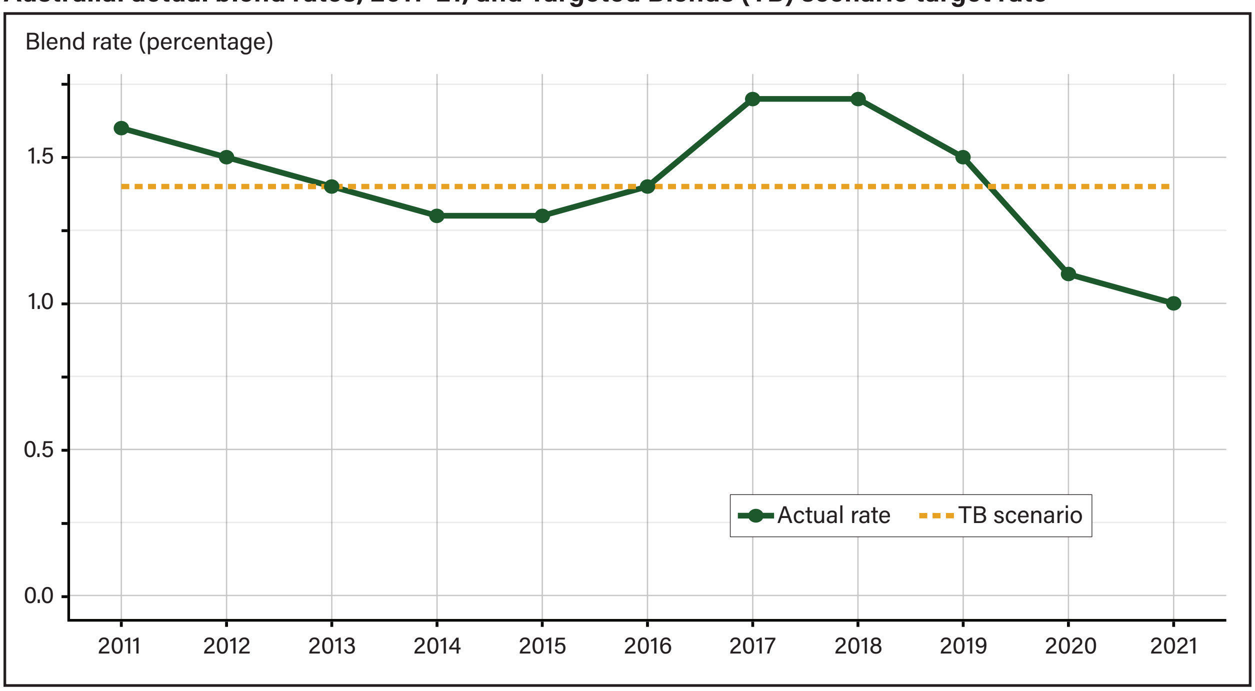
Figure A-3
Australia: fuel ethanol and motor gasoline consumption, 2011–21



Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-4
Australia: actual blend rates, 2011–21, and Targeted Blends (TB) scenario target rate



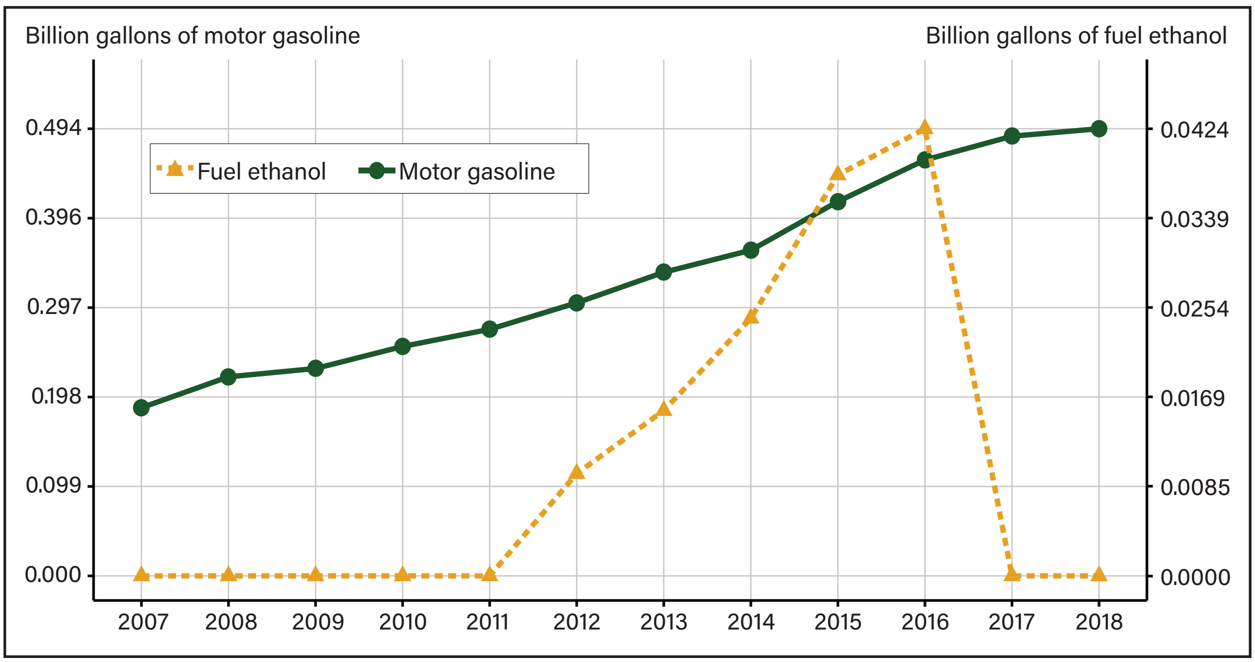
Note: The TB scenario rate is the rate Australia is assumed to achieve in 2030. There was no target found for Australia, so the target blend rate equals the Historical Blends scenario rate.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol blend rates in Australia have consistently been around 1–2 percent. Peak ethanol consumption of 85 million gallons occurred in 2017 and has declined every year since that time to a projected level of 46 million gallons in 2021. Motor gasoline consumption (includes fuel ethanol) was relatively flat during this period, ranging from a low of 4.3 billion gallons in 2020 to a high of 5.2 billion gallons in 2009. Currently, there is no national ethanol blending requirement, though this potentially could change following the completion of the nation's first Bioenergy Roadmap (BR). Even if the BR results in blending mandates, however, ethanol consumption growth may face some headwinds in the form of an increasing share of diesel vehicles in the national fleet and some increase in electric vehicle sales (Biki, 2020). Given the current production capacity of about 116 million gallons (Biki, 2021), there is room to expand consumption before imports or additional capacity would be required.

Bolivia

Figure A-5
Bolivia: fuel ethanol and motor gasoline consumption, 2007–18

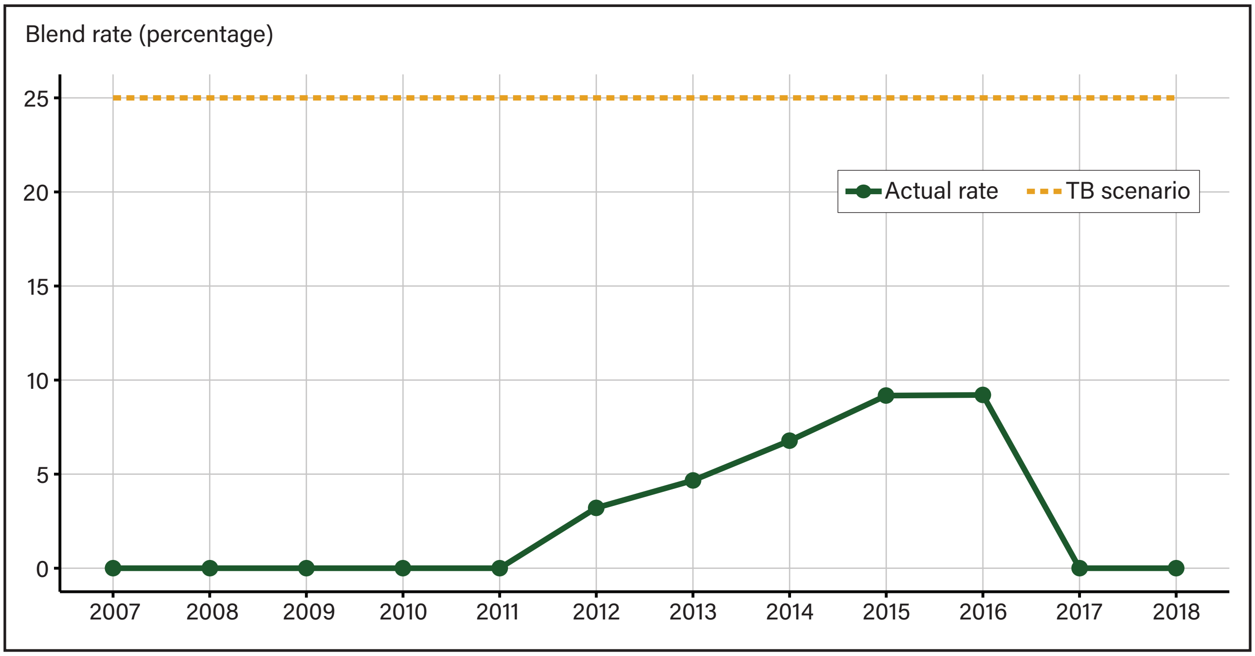


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-6

Bolivia: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



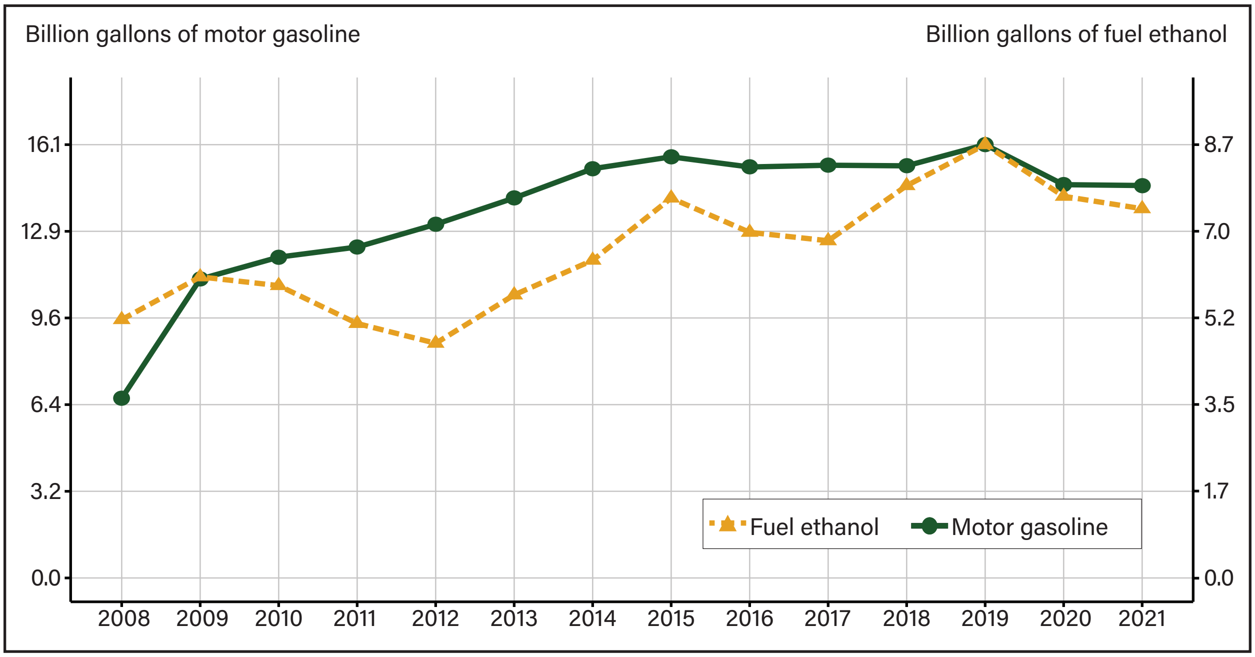
Note: The TB scenario rate is the rate Bolivia is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Based on data from the U.S. Department of Energy's Energy Information Administration (EIA), Bolivia first began consuming fuel ethanol in 2012, when it consumed 10 million gallons. Consumption rose steadily for the next several years from 2013 to 2016 to peak at 42 million gallons, after which the EIA indicates consumption returned to zero. Motor gasoline consumption steadily increased from 2007 to 2018 when it hit a high of 494 million gallons. If the data are correct, this consumption is well below the mandated level of 10 percent for 2018 (Nolte G.E., 2018). This mandate was to increase to 25 percent in 2025 (Nolte G.E., 2018).

Figure A-7

Brazil: fuel ethanol and motor gasoline consumption, 2008–21

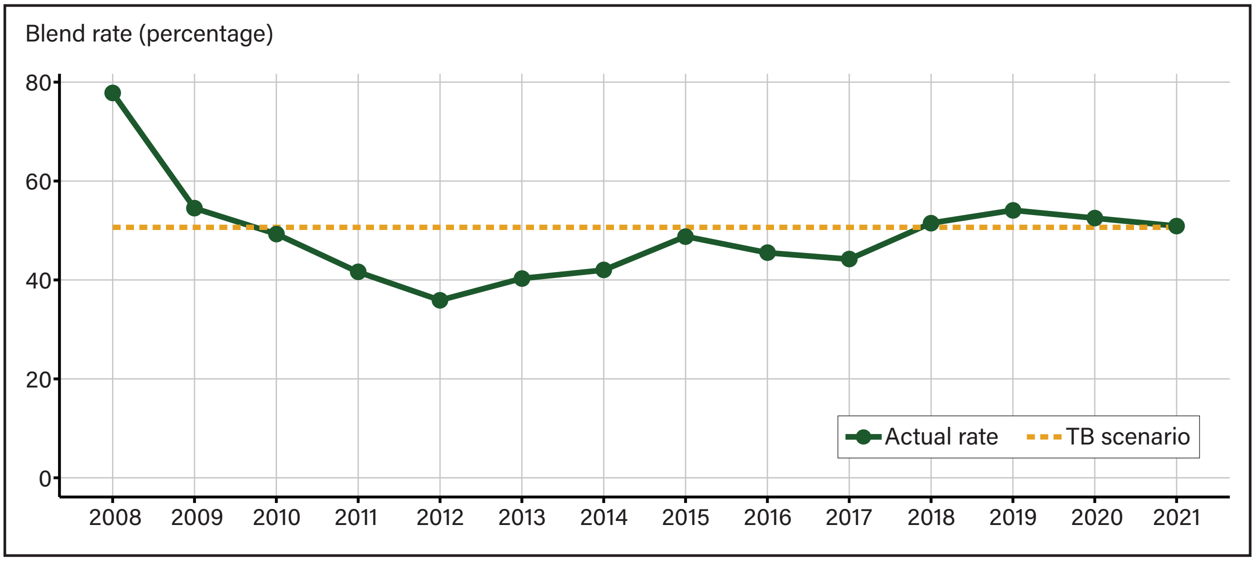


Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-8

Brazil: actual blend rates, 2008–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Brazil is assumed to achieve in 2030. Fuel ethanol in Brazil is consumed as hydrous ethanol or as anhydrous ethanol, which are diferentiated by their water contents. In Brazil, hydrous ethanol can have a maximum water content of 4.9 percent by volume, while anhydrous ethanol can contain up to 0.4 percent water by volume (Martins et al., 2016). In Brazil, hydrous ethanol is consumed in transpotartion directly as E100—in other words, as pure ethanol—by compatible vehicles. Anhydrous ethanol is consumed in Brazil in a fuel known in Portuguese as "gasolina comum" (Barros, 2021), which translates to English as "regular gasoline." Gasolina comum—typically referred to as "Gasoline C" in English-based reporting—is a mixture of anhydrous ethanol and gasoline. The overall effective blend rate in Brazil is determined using the consumption of both hydrous ethanol (as E100) and anhydrous ethanol (via Gasoline C). While Brazil has a mandated blend rate for Gasoline C—currently set at 27 percent—it does not have an overall blend rate target or mandate. As such, the target blend rate is equal to the Historical Blends scenario rate. In the TB scenario, Brazil is able to exceed this target rate due to the RenovaBio program.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Brazil has been the world's second largest consumer of ethanol (behind the United States) since 2002, and consumption has continued to trend upward: Between 2008 and 2019, Brazilian ethanol consumption increased 68 percent from 5.2 billion gallons to 8.7 billion gallons. This increase is due primarily to the total demand for transportation energy, though there has been variation in effective blending rates, which have ranged between 36 (2012) and 78 percent (2008). For blended gasoline, Gasoline C, the mandated blend rate of 27 percent was achieved from 2016 through 2020 (Barros, Biofuels Annual - Brazil, 2020). The additional fuel ethanol consumption comes in the form of hydrous E100, the only other option available to drivers (Barros, 2020).

There are some mechanisms by which consumption could increase. First, legislation allows for the Gasoline C blend rate to be set at up to 27.5 percent (Barros, 2020). Second, through its RenovaBio program (2016), Brazil:

- Is targeting a 10.2-percent reduction in carbon intensity for transportation fuels;
- Has created a certification scheme for biofuels' efficiencies in reducing greenhouse gas emissions; and
- Created decarbonization credits—CBios—that correspond to one metric ton of carbon saved through the utilization of biofuels instead of fossil fuels (Barros, 2020). Current target is for 620 million CBios to be sold between 2019-2029 (Barros, 2021).

Table A-1

Annual RenovaBio CBios requirements, 2021–30 (millions of CBios)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CBios	24.86	35.98	42.35	50.81	58.91	66.49	72.93	79.29	85.51	90.67

Note: CBios = decarbonization credits.

Source: USDA, Economic Research Service using data from Ribeiro and da Cunha (2022).

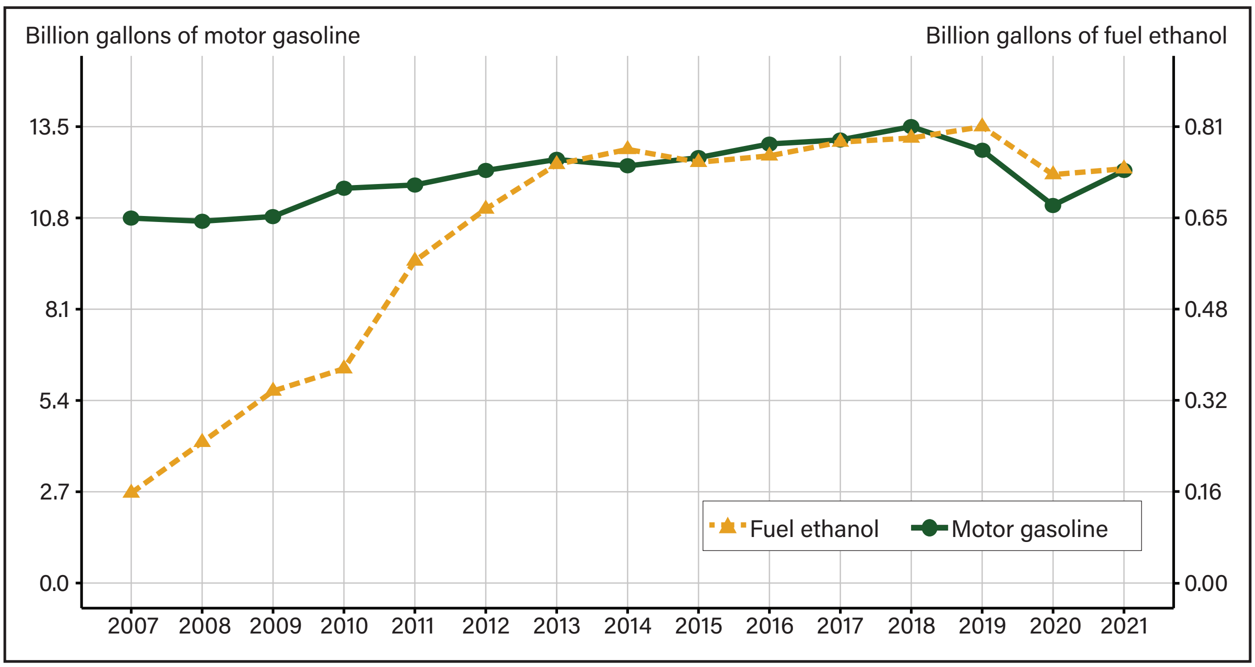
The RenovaBio program and recent fuel tax changes that favor ethanol are expected to favorably impact Brazilian ethanol consumption, with Brazil being the only major market expected to see a robust expansion of ethanol over the next decade. Key questions remain about availability of sugarcane ethanol to meet expanding demand, the ability of non-Brazilian ethanol to participate in the program, as well as the potential for continued growth in corn ethanol production in Brazil, which could be substantial.

Virtually all Brazilian ethanol imports for the last several years came from the United States, though Paraguay increased its market share in 2019–20 (Barros, 2020), and U.S. share of total Brazilian ethanol consumption fell as Brazil imposed import restrictions. The lower share of U.S. ethanol in Brazil's consumption mix could solidify in coming years because of recent policy actions: In December 2020, Brazil let its tariff rate quota on U.S. ethanol expire and replaced the quota with a flat 20-percent tariff on all ethanol imports, except those coming from Southern Common Market (commonly, MERCOSUR) countries[19] (Barros, 2021). However, in March 2022, Brazil suspended its tariffs on ethanol imports to combat inflation (Tomson, 2022).

Canada

Figure A-9

Canada: fuel ethanol and motor gasoline consumption, 2007–21



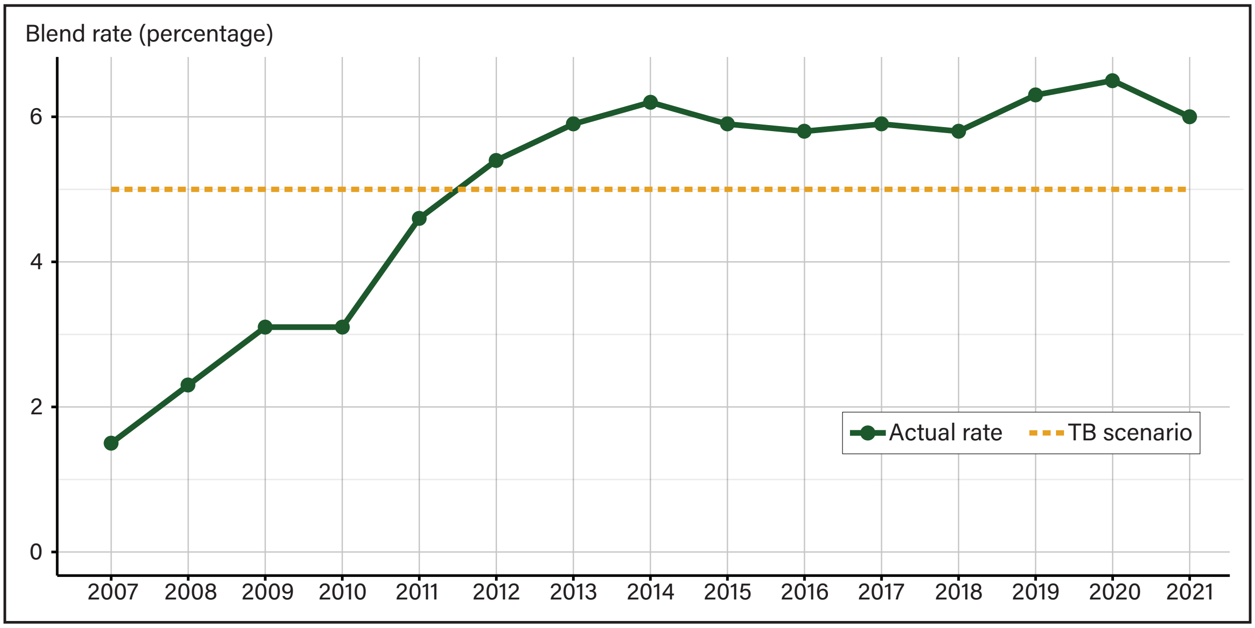
Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

[19] MECROSUR "States Parties" include Argentina, Brazil, Paraguay, Uruguay, and Venezuela. MERCOSUR "Associated Parties" include Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Surinam.

Figure A-10

Canada: actual blend rates, 2007–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Canada is assumed to achieve in 2030. In the TB scenario, Canada is able to exceed this target rate due to the Clean Fuel Standard program.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Canada trended steadily upward between 1998 and 2006, growing from 55 million gallons to 71 million gallons (EIA, 2021). Consumption jumped sharply in 2007 to 159 million gallons (Dessureault, 2015) and has trended upward since, reaching 805 million gallons in 2019 (Danielson, 2021). Similarly, Canada's effective blending rate increased to 6.3 percent in 2019 from 1.5 percent in 2007.

As of 2021, Canada's ethanol production capacity was only about 497 million gallons (Danielson, 2021). Thus, imports have played an important role in Canada's consumption of fuel ethanol. National policy in Canada requires that fuel producers and importers have an average ethanol content of at least 5 percent (Danielson, 2020). Some provinces have set higher rates: Ontario at 10 percent for 2020 through 2024, 11 percent for 2025 through 2027, 13 percent for 2028 and 2029, and 15 percent for 2030; Quebec has produced draft regulation that would set blend rates at 10 percent in 2023, 12 percent in 2025, 14 percent in 2028, and 15 percent in 2030; and Saskatchewan has a mandate of 7.5 percent (Danielson, 2021). Additional demand for ethanol may result from the Clean Fuel Standard Act under development, which will seek to lower the lifecycle carbon intensity of fuels and energy (Danielson, 2021). The carbon intensity limits for gasoline—given a reference carbon intensity score of 92—are shown in table A-2 (Government of Canada, 2019).

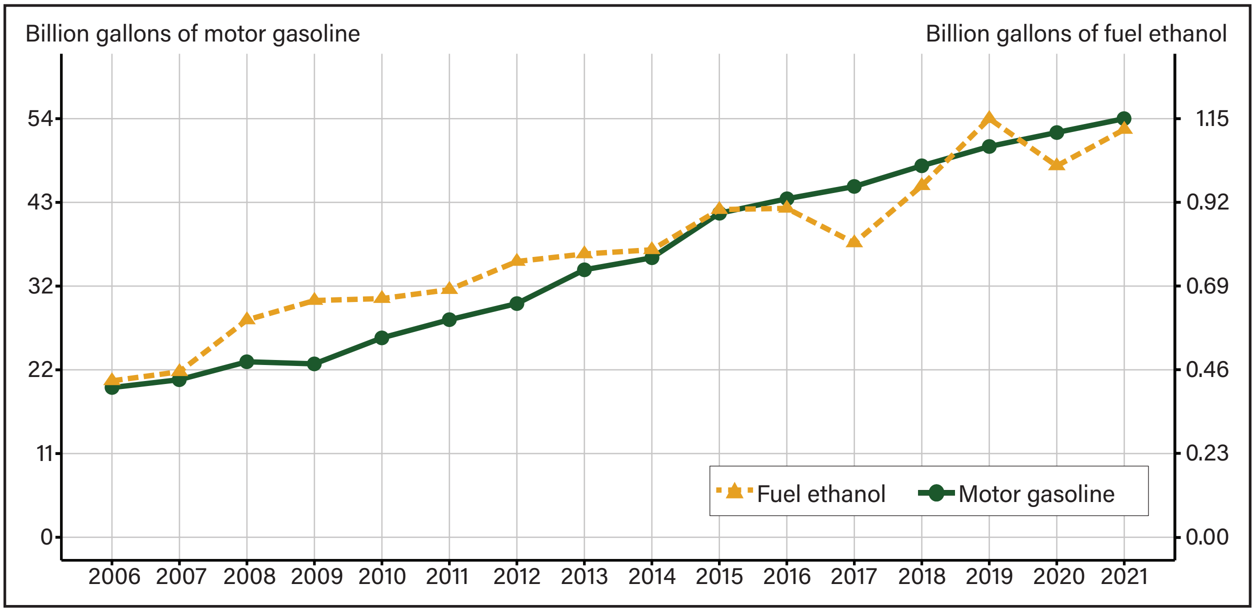
Table A-2

Gasoline carbon intensity requirements under proposed Canadian Clean Fuel Standard regulations, 2022–30

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Gasoline carbon intensity requirement	88.4	87.6	86.8	86	85.2	84.4	83.6	82.8	82.0

Source: USDA, Economic Research Service using data from the Government of Canada.

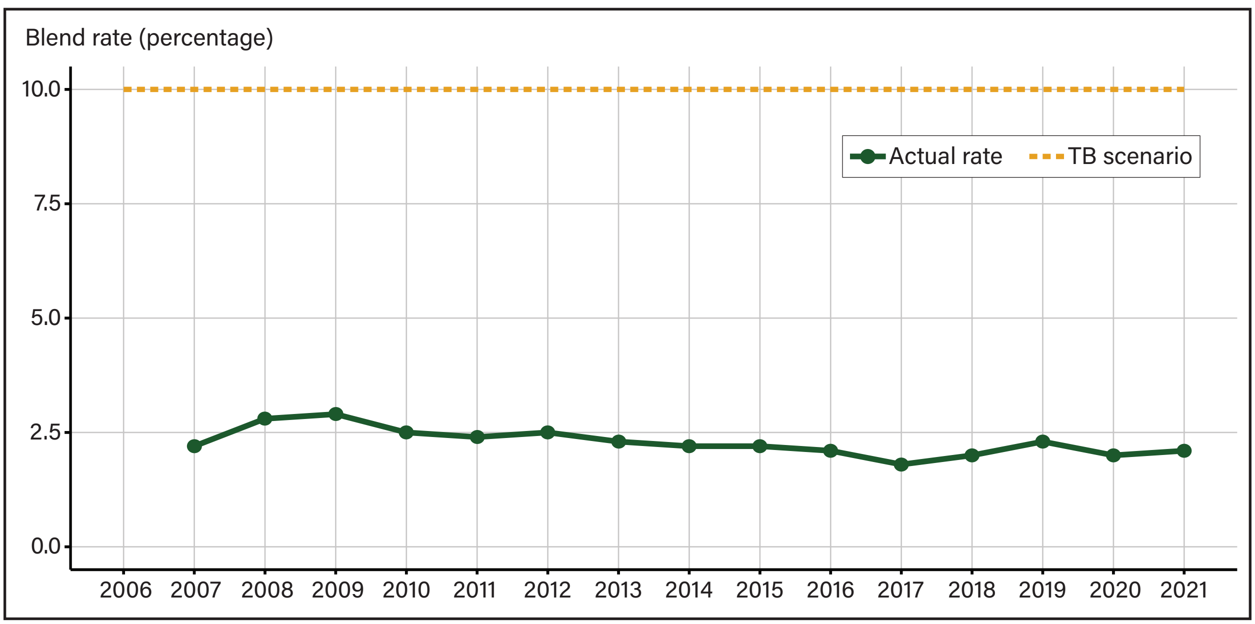
Figure A-11
China: fuel ethanol and motor gasoline consumption, 2006–21



Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-12
China: actual blend rates, 2006–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate China is assumed to achieve in 2030.

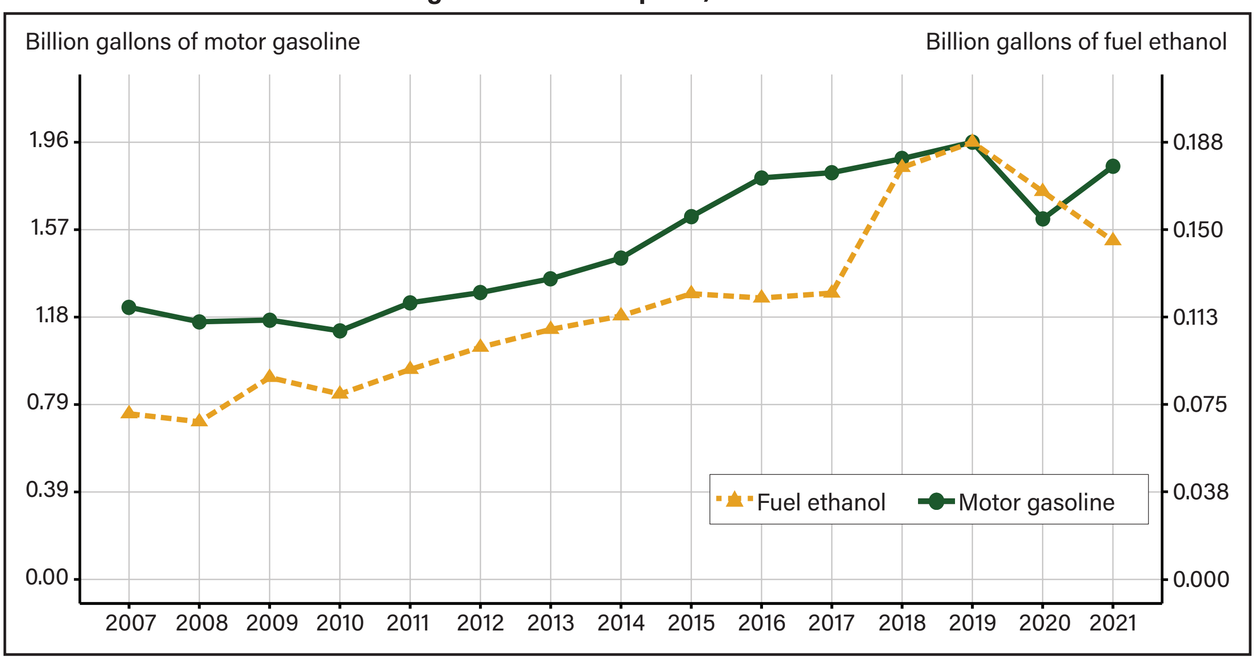
Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

The first year for which Energy Information Administration data show fuel ethanol consumption in China was 2002, at 77 million gallons. Consumption increased about 176 percent the following year to 212 million gallons and increased almost every year since—though at smaller rates—through 2019. The lone decrease from 2006 to 2019 (based on USDA, FAS data) was going from 899 million gallons in 2016 to 805 million gallons in 2017. By 2019, consumption reached 1.1 billion gallons. China's effective blend rate has remained around 2–3 percent since at least 2006. These rates fall below the 2020 Government's blend rate goal of 10 percent, as called for by the Implementation Plan Regarding the Expansion of Ethanol Production and Promotion for Transportation Fuel (McGrath, 2020). There remains an open question regarding whether China is committed to implementing its on and off again fuel ethanol program. However, if the E10 Government goal is abandoned nationally, the goal could still proceed provincially, as China has reportedly given authority to Provincial governments to make E10 decisions (McGrath, 2021).

Assuming a static blend rate, growth in fuel ethanol demand could slow in the coming years if growth in motor gasoline demand begins to decelerate. One reason this reduction could happen would be increased market share for new energy vehicles (NEVs), which China defines as plug-in electrics and gas/diesel-electric hybrids (McGrath, 2020). NEVs constituted 1.5 percent of the passenger vehicle market in 2019, but policies are in place that may increase this number (McGrath, 2020). Several NEV subsidies are in place through 2022, and a 1-million-unit production quota for pure electric vehicles was set for 2020 (McGrath, 2020). Ultimately, China is targeting a 20-percent NEV share by 2025, and the NEV share for 2030 is projected at 30 percent (McGrath, 2020). China's policy intentions remain an unknown in the potential market for fuel ethanol. Regardless of demand, U.S. ethanol producers are currently at a disadvantage to other international producers due to less favorable Chinese import tariff rates on U.S. ethanol.

Colombia

Figure A-13
Colombia: fuel ethanol and motor gasoline consumption, 2007–21

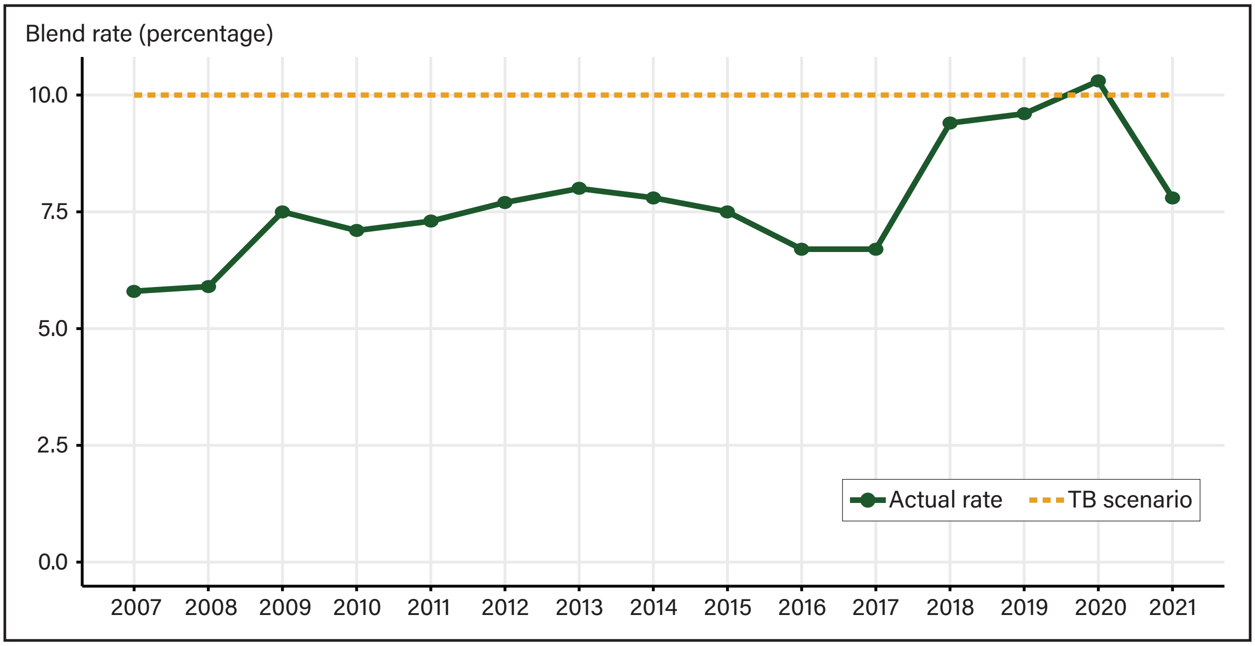


Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-14

Colombia: actual blend rates, 2007–21, and Targeted Blends (TB) scenario target rate

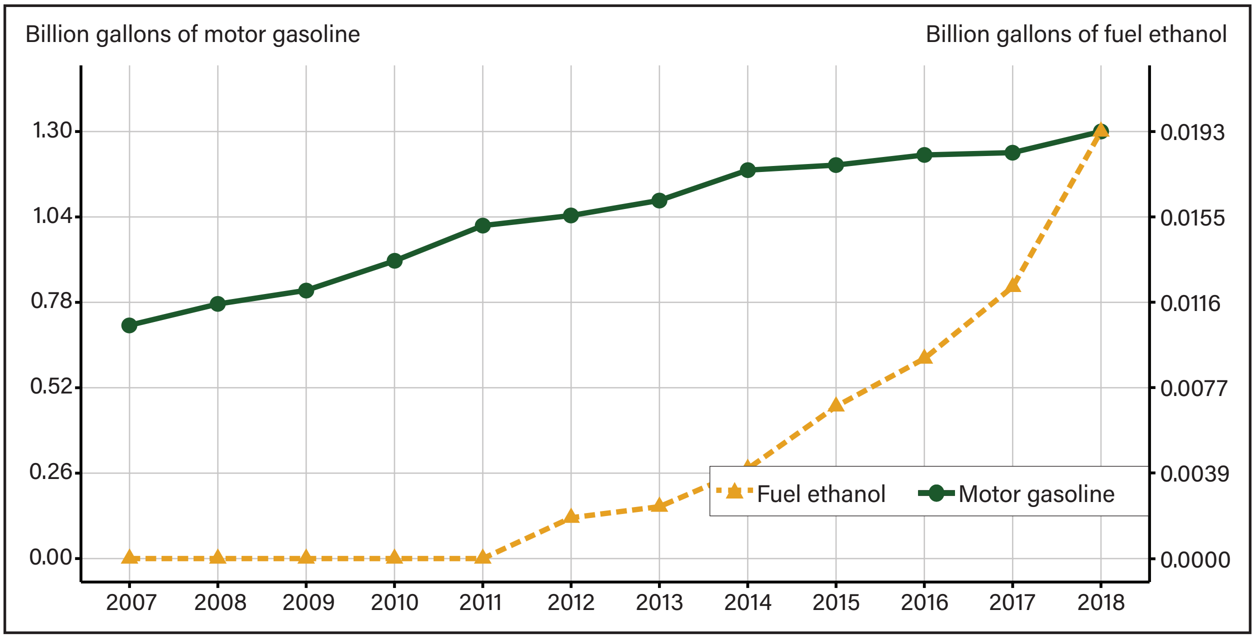


Note: The TB scenario rate is the rate Colombia is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Since increasing from 8 million gallons in 2005 to 71 million gallons in 2006 (an 820-percent increase), Colombia's fuel ethanol consumption has continued to grow (but at a more modest average rate) to 188 million gallons in 2019 (EIA, 2021; Klein, 2021). Fuel ethanol consumption fell in 2020 and is projected to fall again in 2021, despite a rebound in motor gasoline consumption (Klein, 2021). Colombia's blending rate has been increasing alongside consumption, going from 5.8 percent in 2007 (Gilbert and Pinzon, 2015) to 10.3 percent in 2020 (Klein, 2021). Despite this growth, consumption has occasionally fallen short of the E10 mandate, which was introduced in March of 2018 but has been suspended at times due to production shortages (USDA, FAS, Bogota Staff, 2020). The E10 mandate was temporarily lowered to E4 for a portion of 2021 (Klein, 2021).

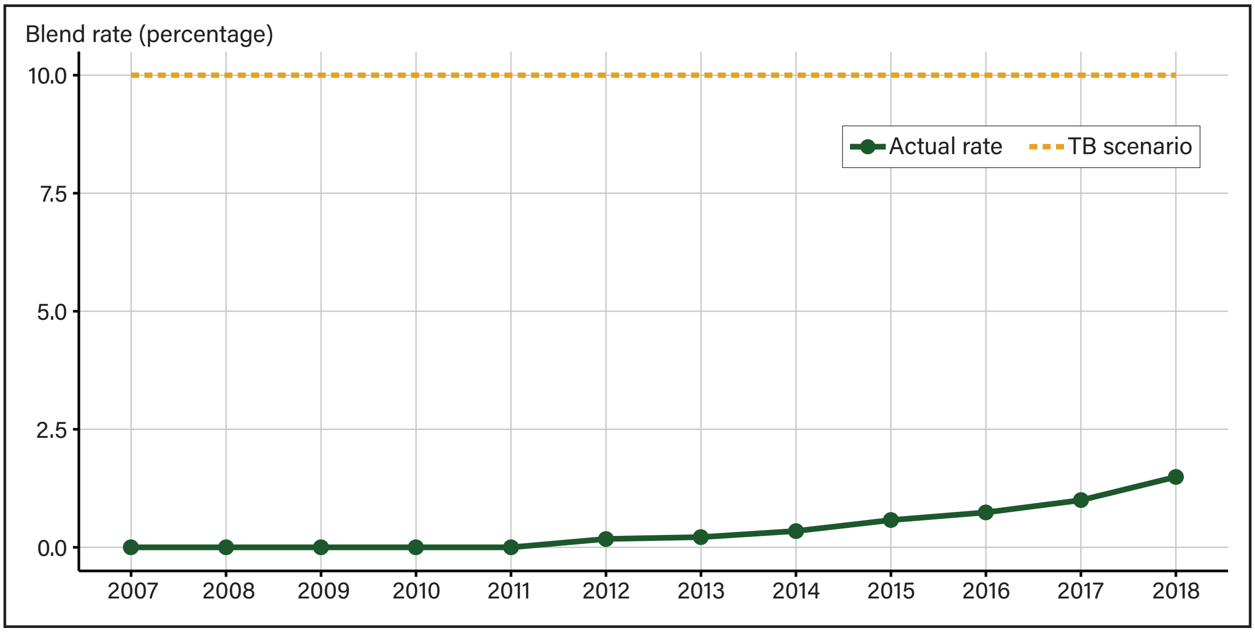
Figure A-15
Ecuador: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-16
Ecuador: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Ecuador is assumed to achieve in 2030.

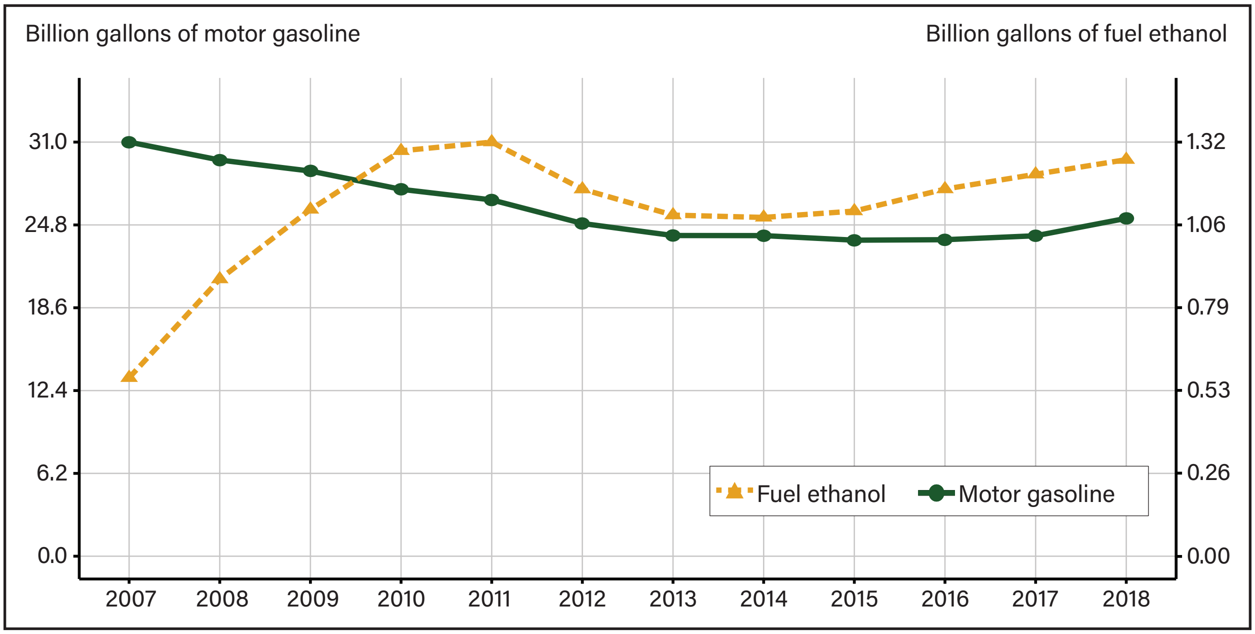
Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

As of 2018, the consumption of fuel ethanol in Ecuador was 19 million gallons, up from 2 million gallons in 2012 (EIA, 2021). EIA (2021) data indicate no consumption prior to this point. Meanwhile, motor gasoline consumption has increased from 1 billion gallons in 2012 to 1.3 billion gallons in 2018 (EIA, 2021). The effective blend rate has been increasing, but only recently, in 2018, did it exceed 1 percent with a rate of 1.5 percent. The average blend rate over the 2012–2018 period was only about 0.6 percent. The country has had voluntary targets for ethanol since at least 2010 when an E5 pilot program was initiated in two cities (FAS Quito Staff, 2018). This initiative ultimately moved nationwide, and the target rate was increased to 10 percent in 2015 (FAS Quito Staff, 2015).

European Union

Figure A-17

European Union: fuel ethanol and motor gasoline consumption, 2007–18

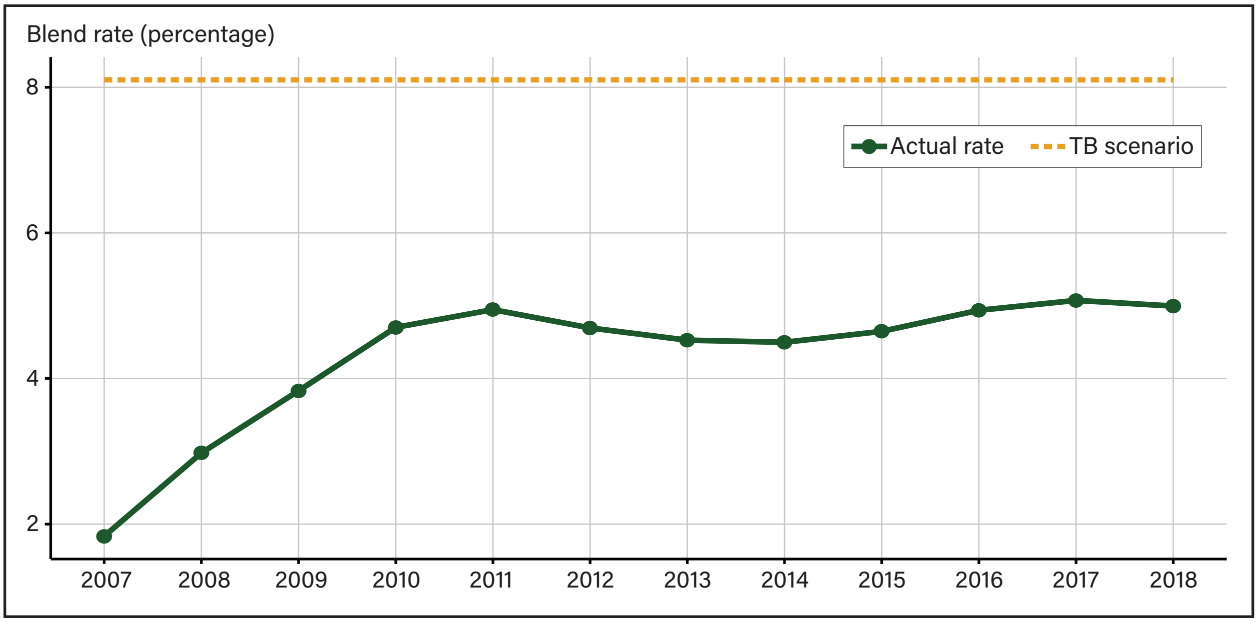


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-18

European Union: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



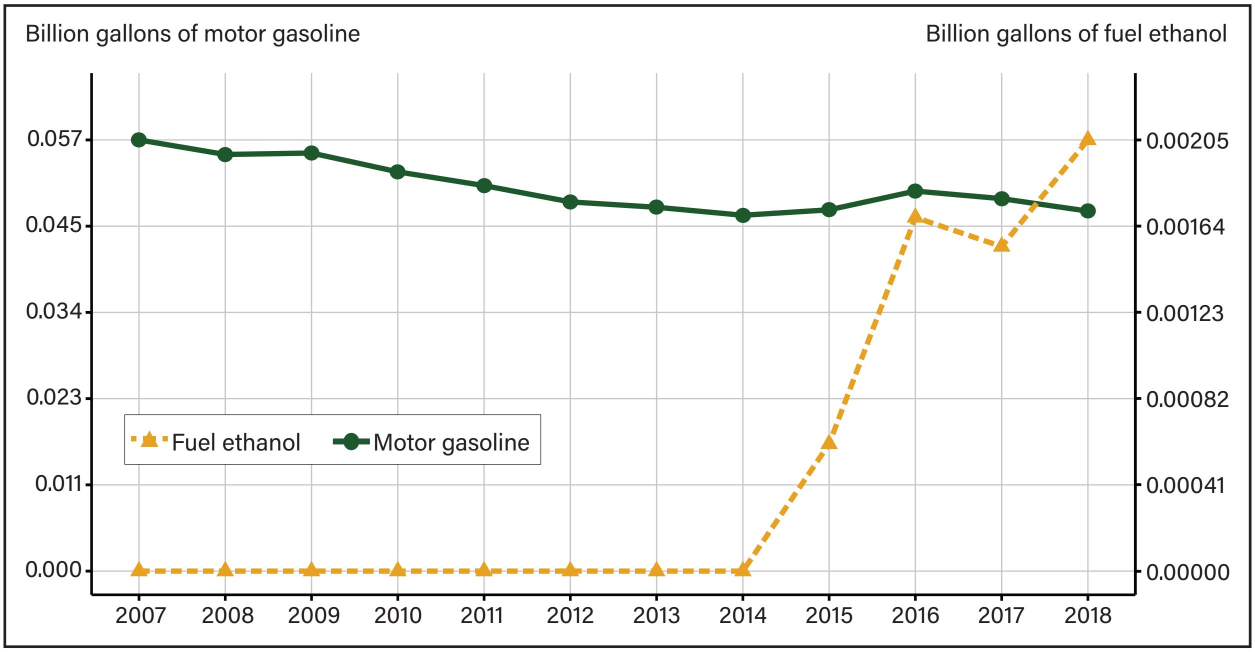
Note: The TB scenario rate is the rate the European Union is assumed to achieve in 2030. The TB scenario rate is the composite effective blending rate in 2030 for the countries composing the European Union under the Targeted Blends scenario.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Data on fuel ethanol consumption in the European Union (EU) began at about 2 million gallons in 1992, attributed solely to France (EIA, 2021). France remained as the sole consumer (according to EIA data) until 2001 when Sweden added 6 million gallons of consumption to France's EU-leading 28 million gallons (EIA, 2021). In 2018, total EU consumption had grown to 1.3 billion gallons (EIA, 2021), an increase of roughly 839 percent from France's 1992 consumption. In 2018, the five largest EU fuel ethanol consumers were Germany (352 million gallons), France (275 million gallons), Poland (90 million gallons), Netherlands (89 million gallons), and Spain (73 million gallons). The only member states with zero consumption in 2018 were Cyprus, Greece, and Malta—which was in line with historic consumption for these countries. The overall blending rate in the EU over the 1992–2018 period increased from 0.4 percent to 4.8 percent, though the rate has been relatively flat since about 2010.

Combined, the EU represents the third largest global fuel ethanol market behind the United States and Brazil. However, future growth in ethanol consumption may be limited under the revised Renewable Energy Directive (RED II), which went into force in 2018. Under the revised directive, the share of biofuels produced from food and feed crops of a country's transportation energy consumption is not allowed to be more than 1 percent higher than the same share in 2020, with a maximum of 7 percent of final energy consumption in the road and rail transport sectors for each member country. An exception applies when the 2020 share is less than 1 percent. In this case, the maximum allowable share is 2 percent. In addition to these caps, the RED II also requires biofuels greenhouse gas savings of at least 50 percent and up to 65 percent for fuels produced in facilities that began operation on or after January 1, 2021.

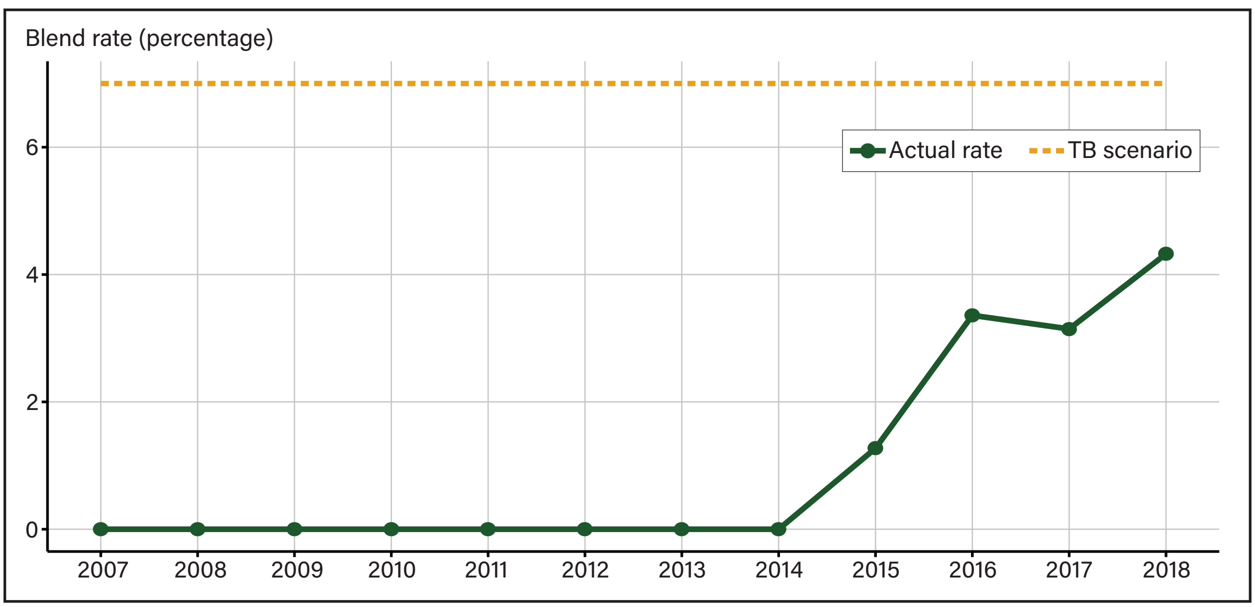
Figure A-19
Iceland: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-20
Iceland: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



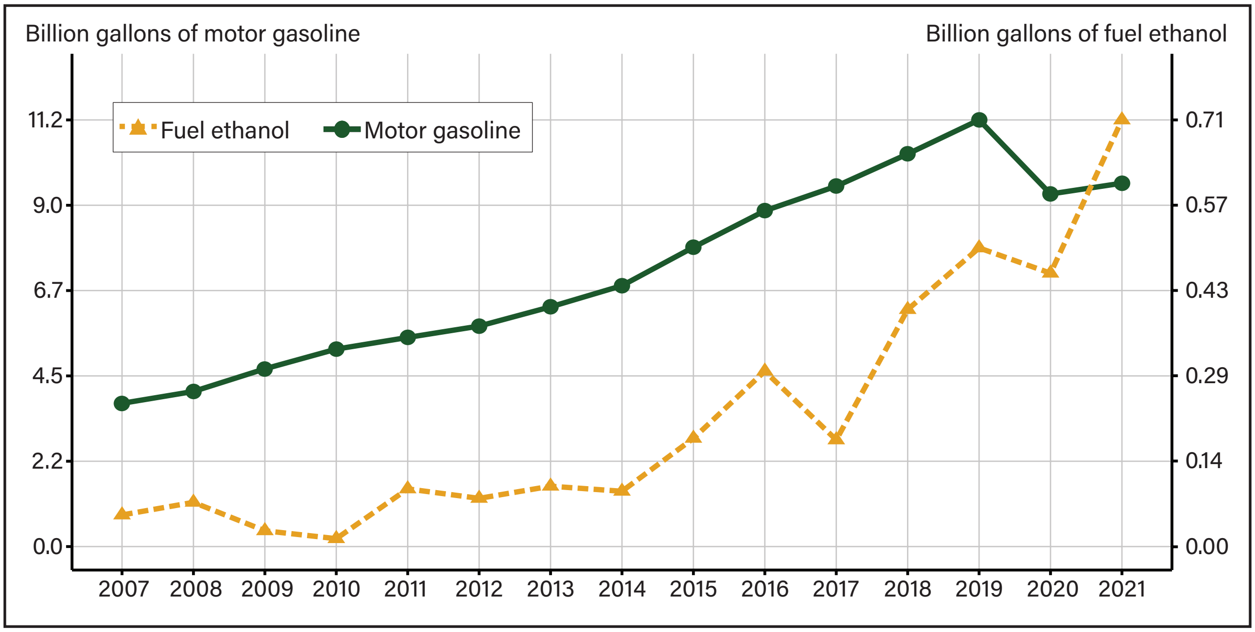
Note: The TB scenario rate is the rate Iceland is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Iceland is a relatively small market for motor gasoline and fuel ethanol and has only recently consumed fuel ethanol (based on EIA data). Between 2015 and 2018, fuel ethanol consumption in gallons was 0.6 million (2015), 1.7 million (2016), 1.5 million (2017), and 2 million (2018). Motor gasoline consumption averaged 48.5 million gallons over this time. Based on these levels, the effective blend rate in Iceland ranged from 1.3 percent (2015) to 4.3 percent (2018), with an average of 3 percent. In May 2017, Iceland approved a parliamentary resolution that set a goal of increasing the share of renewables in land-based transport from 6 percent to 10 percent by 2020 and to 40 percent by 2030. However, biofuels must emit at least 50 percent less greenhouse gases than fossil fuels, and the maximum permitted fuel of the "first generation" was set to 7 percent, though "first generation" was not defined. Additionally, the resolution stated that most cars would be powered by renewable methanol.

India

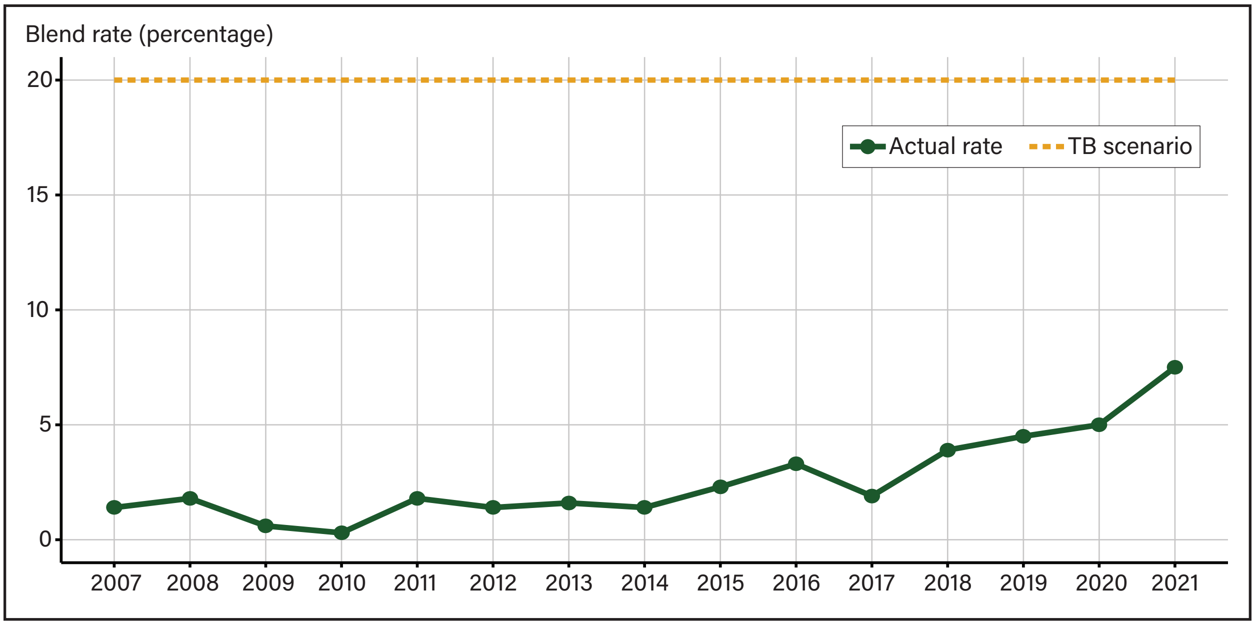
Figure A-21
India: fuel ethanol and motor gasoline consumption, 2007–21



Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-22
India: actual blend rates , 2007–21, and Targeted Blends (TB) scenario target rate

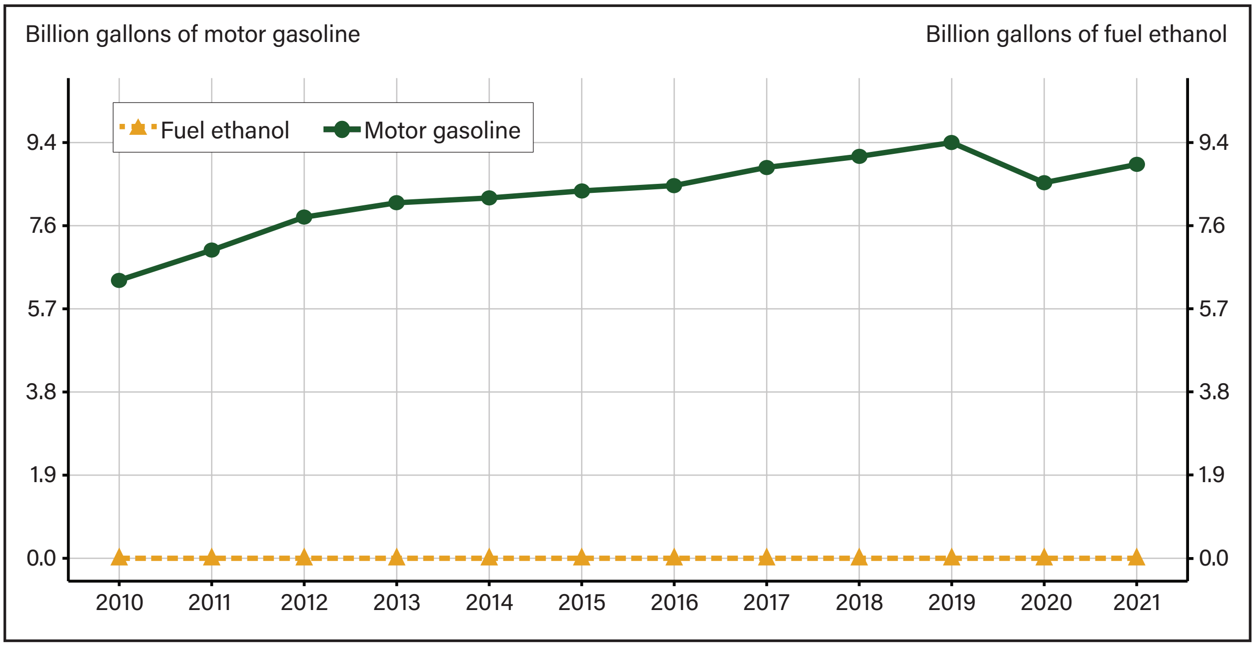


Note: The TB scenario rate is the rate India is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

India has been consuming fuel ethanol since at least 2000 when the country consumed about 45 million gallons (EIA, 2021). By 2019, consumption had grown to 499 million gallons (Chandra, 2021), a roughly 11-fold increase, outpacing the growth in motor gasoline consumption (which includes fuel ethanol) from 2.4 to 11.2 billion gallons (EIA, 2021; Chandra, 2021). India is expected to see its highest blending rate in 2021 at 7.5 percent. Prior to 2020, the blending rate had not achieved 5 percent. Despite relatively low historic blending rates, the Indian Government has set ambitious goals of a 10-percent rate in 2022 and 20 percent by 2025 (Chandra, 2021). Achieving higher blend rates may be challenging due to: (1) limitations in blending infrastructure and interstate commerce barriers around procurement, (2) limited domestic capacity, (3) minimal success in programs aimed at boosting domestic production (Chandra, 2020), and (4) a ban on the imports of ethanol for fuel blending (Chandra, 2021). Future growth may also be impacted by the "Faster Adoption of Manufacturing of (Hybrid) and Electric Vehicles" (FAME) program that increased duties on electric vehicles to encourage domestic production (Chandra, 2020). Ownership of these vehicle types was about 3 percent in 2018 and is expected to grow to 33 percent by 2022 and 45 percent by 2030 (Chandra, 2020). To address some of these issues, the Indian Government has attempted to aid domestic production (e.g., by expanding the viable feedstocks to surplus rice and corn) and by promoting the use of higher blend fuels (e.g., the introduction of E85/E100 vehicles to regions with surplus ethanol and permitting the sale of E100) (Chandra, 2021). While India is a large producer of sugar, there would have to be a significant capital expenditure to re-orient the sugar industry toward producing more ethanol, which has been a previous impediment. Currently, most sugar ethanol is produced from molasses after sugar has already been produced.

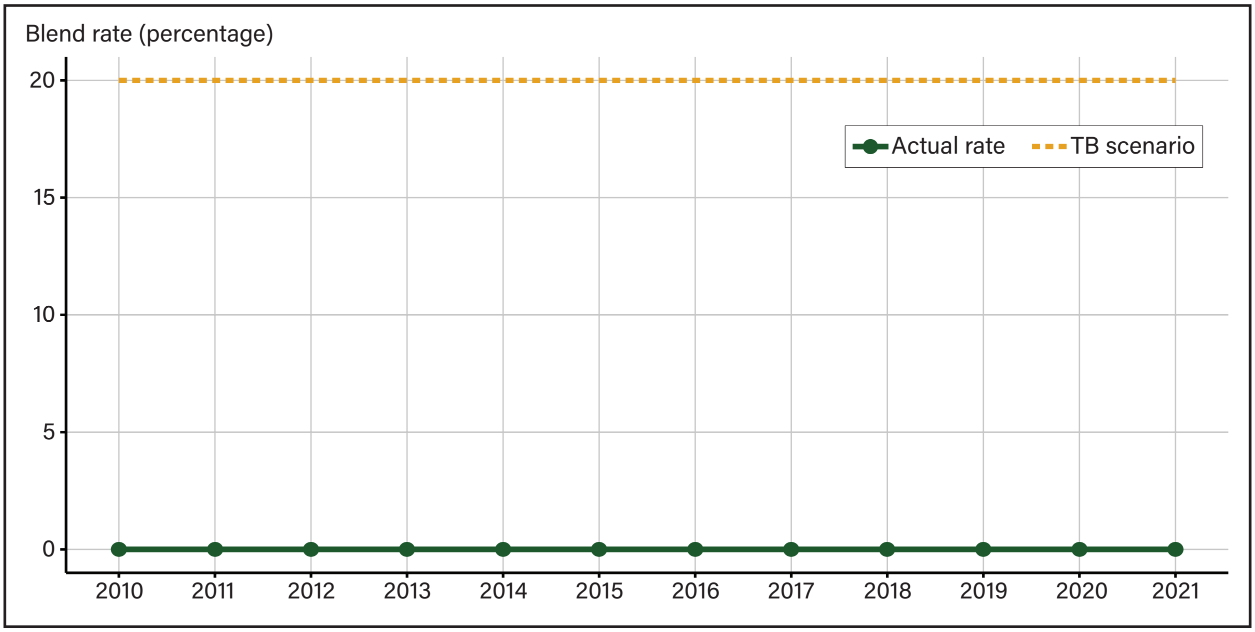
Figure A-23
Indonesia: fuel ethanol and motor gasoline consumption, 2010–21



Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-24
Indonesia: actual blend rates, 2010–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Indonesia is assumed to achieve in 2030.

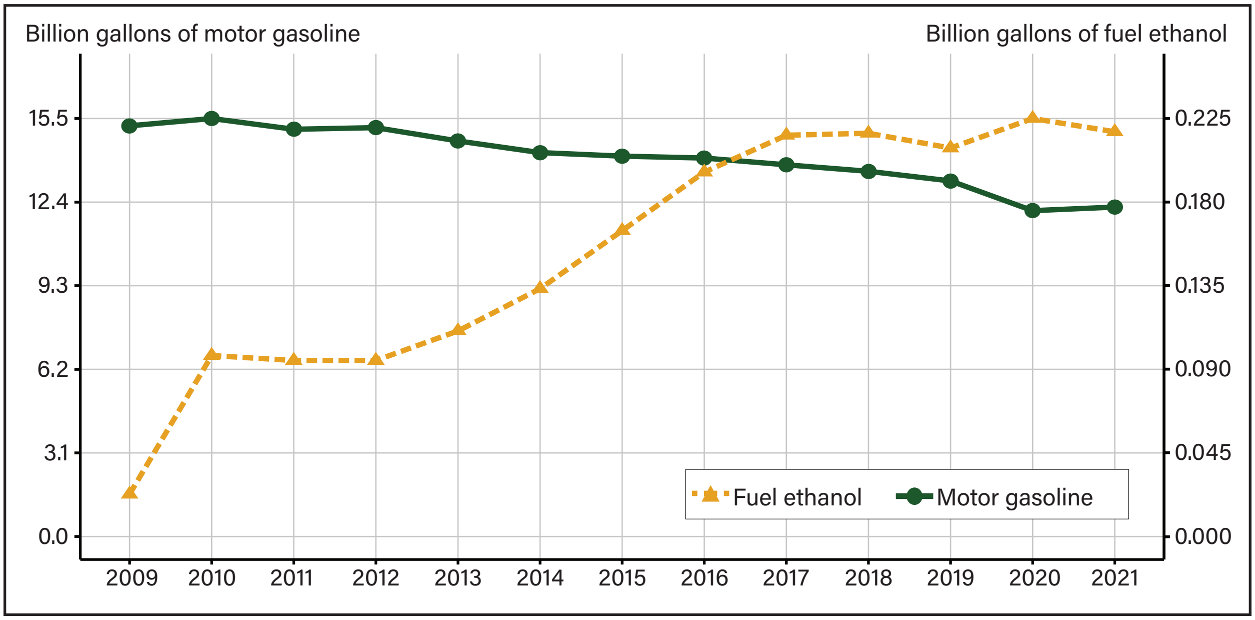
Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Indonesia has not historically been a consumer of fuel ethanol. However, Indonesia has set an ethanol blend rate target of 20 percent by 2025 through its Public Sector Obligations, though there has been little progress in achieving this goal (Rahmanulloh, 2020). More recently, the National Energy Plan (2014) called for economy-wide renewable fuel use of 23 percent by 2025 and 31 percent by 2050 (Rahmanulloh, 2021). Given a production capacity of only 26 million gallons (Rahmanulloh, 2021), the country would need to either substantially increase capacity or rely on imports to meet its blending targets. In March 2020, Pertamina (a state-owned energy company) removed a prohibition on ethanol in motor gasoline import tenders (bids for fulfilling the order) (Rahmanulloh, 2021).

Japan

Figure A-25

Japan: fuel ethanol and motor gasoline consumption, 2009–21

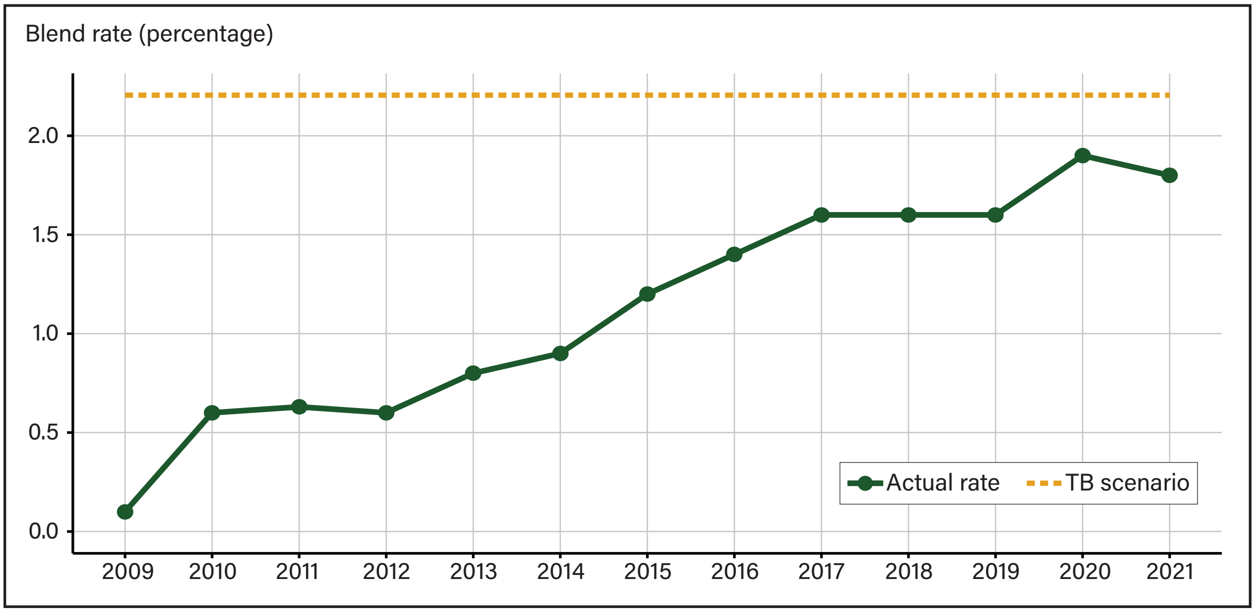


Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-26

Japan: actual blend rates, 2009–21, and Targeted Blends (TB) scenario target rate

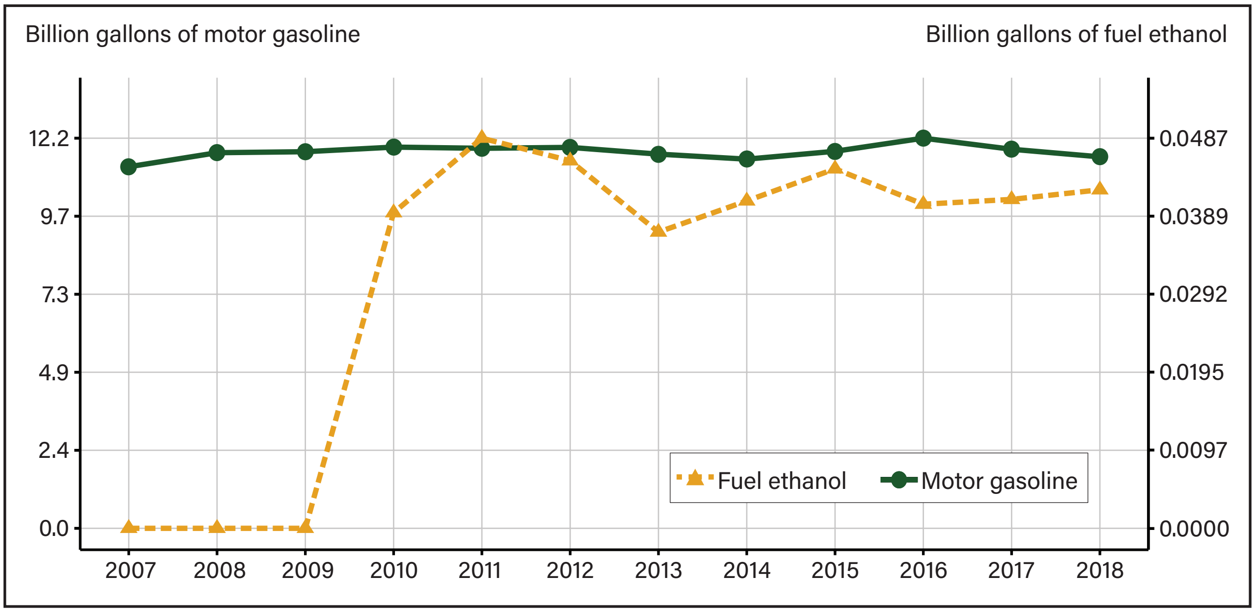


Note: The TB scenario rate is the rate Japan is assumed to achieve in 2030. Japan does not have a blend rate target. The displayed TB scenario rate is the effective rate in 2030 that arises due to the mandated ethanol usage of 500 million gallons of crude oil equivalent.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Japan grew from about 23 million gallons in 2009 to 225 million gallons in 2020, while motor gasoline consumption (includes fuel ethanol) over the same period decreased steadily from 15.2 billion to 12.0 billion gallons. As a result, the country's blend rate also increased quickly but remains relatively low and is projected at 1.8 percent in 2021 (Sasatani, 2021). Biofuel mandates stem from the Sophisticated Methods of Energy Supply (fiscal year 2022 revision expected) structure and currently stand at 500 million liters of crude oil equivalent. These mandates are entirely fulfilled via bio-ethyl tertiary-butyl ether (bio-ETBE)—composed of 47 percent ethanol—that is blended with motor gasoline (Sasatani, 2020). Fuel ethanol is also supported by exemptions from a gasoline tax and an oil and coal tax, making its retail price comparable with that of motor gasoline, and no tariffs on imports of bio-ETBE, ethanol for bio-ETBE production, or industrial ethanol (Sasatani, 2020). Moving forward, ethanol expansion could be aided by the U.S.-Japan Trade Agreement that will (gradually over 10 years) eliminate a 10-percent tariff on ethanol imports for other uses—e.g., direct blending (Sasatani, 2020). Additionally, Japan has set a renewable target of 20 percent of energy supply for 2030, compared with about 2 percent in 2021 (Sasatani, 2021). However, the plan does not call for increased usage of biofuels in meeting targets. Ethanol expansion could be constrained by: (1) an intent to meet GHG-emissions-reduction goals for the transport sector primarily through advances in fuel efficiency and fuel cell/electric vehicles and (2) declining motor gasoline demand that is expected to continue (Sasatani, 2020).

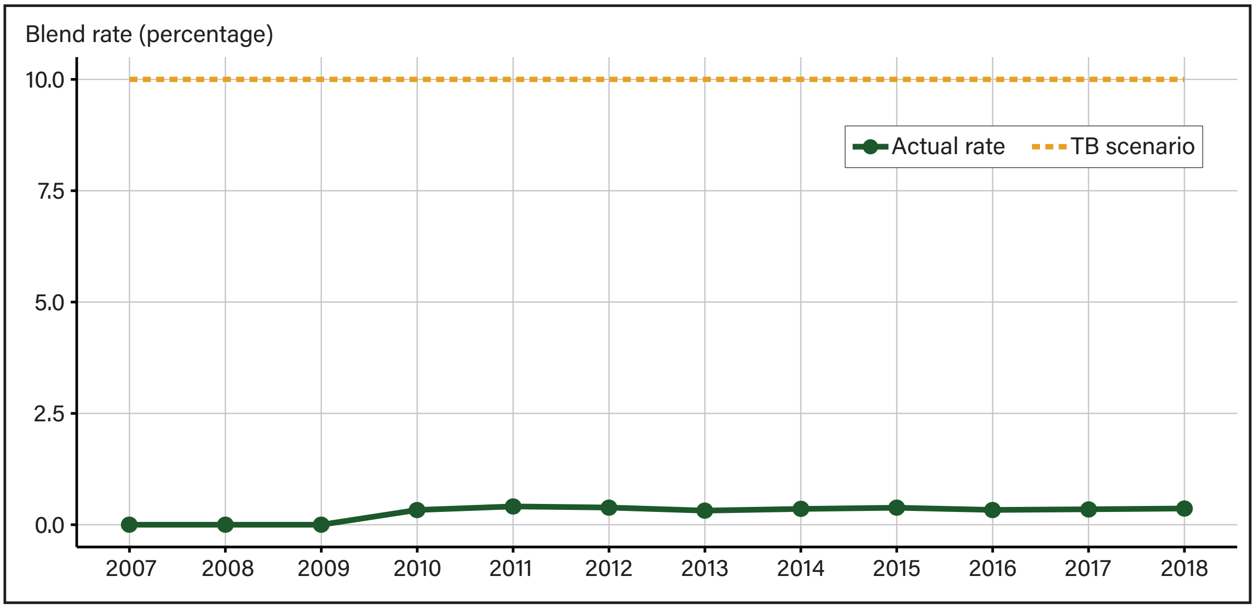
Figure A-27
Mexico: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-28
Mexico: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



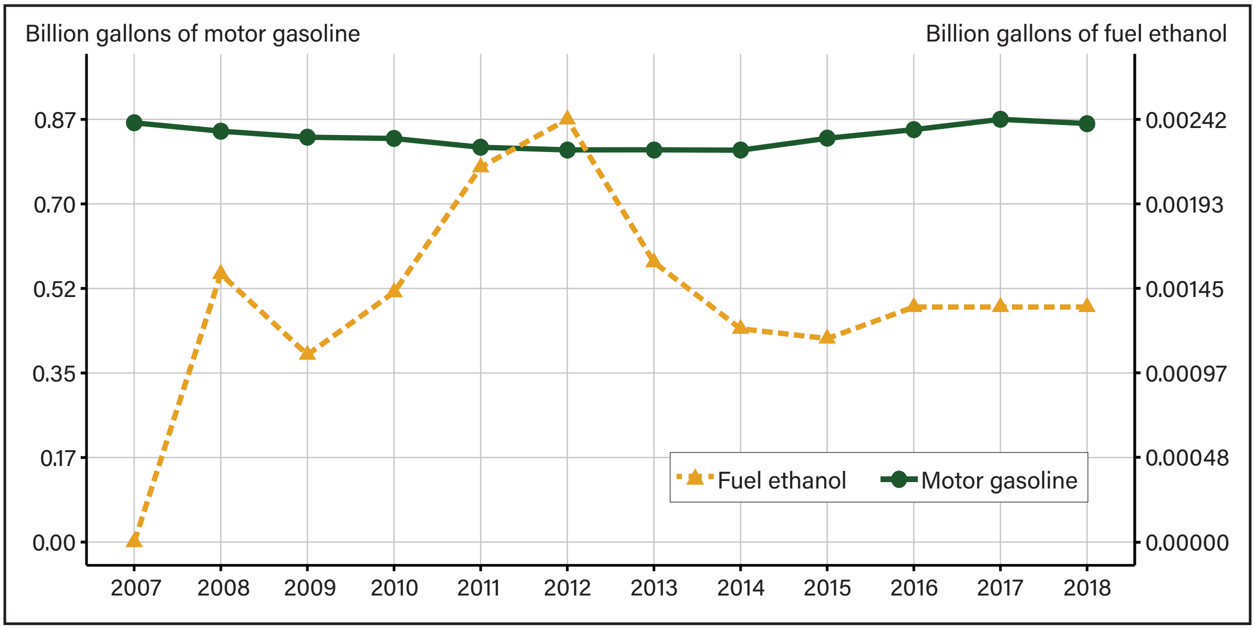
Note: The TB scenario rate is the rate Mexico is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Mexico has a relatively short history, with estimates starting at 39 million gallons in 2010 (EIA, 2021). Consumption has remained relatively flat since then and stood at 42 million gallons in 2018 (EIA, 2021). Consumption of motor gasoline (includes fuel ethanol) over this time has averaged about 11.8 billion gallons per year, resulting in low blend rates that have not exceeded the 0.4 percent seen in 2011. There is no blending requirement in Mexico, and ethanol is not permitted within the major urban areas of Mexico City, Guadalajara, and Monterrey, which account for around 26 percent of the country's motor gasoline consumption (U.S. Grains Council, 2021). Outside of these cities, the maximum blending rate was 5.8 percent through July of 2017, at which time it was increased to 10 percent (Biofuels International, 2020). However, the Mexico Supreme Court overturned this change in early 2020 on procedural grounds, arguing that the Energy Regulatory Commission exceeded its authority (Reuters, 2020). Mexico's fuel ethanol-production capacity is unclear, though the U.S. Grains Council has estimated this capacity at about 26 million gallons per year (U.S. Grains Council, 2021).

New Zealand

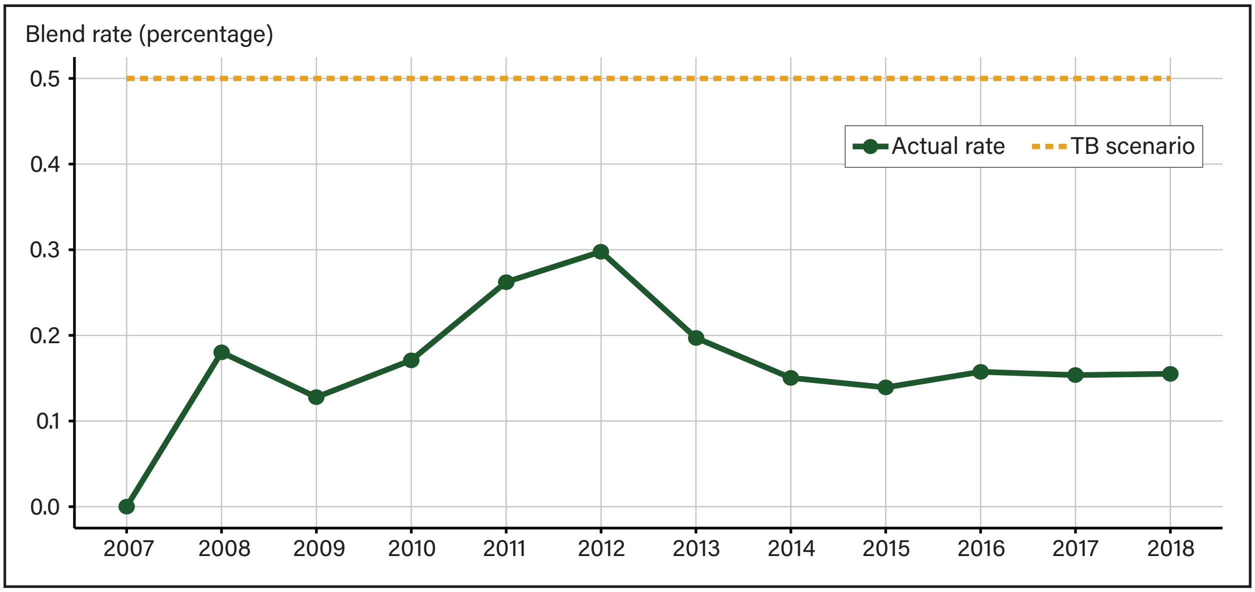
Figure A-29
New Zealand: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-30
New Zealand: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



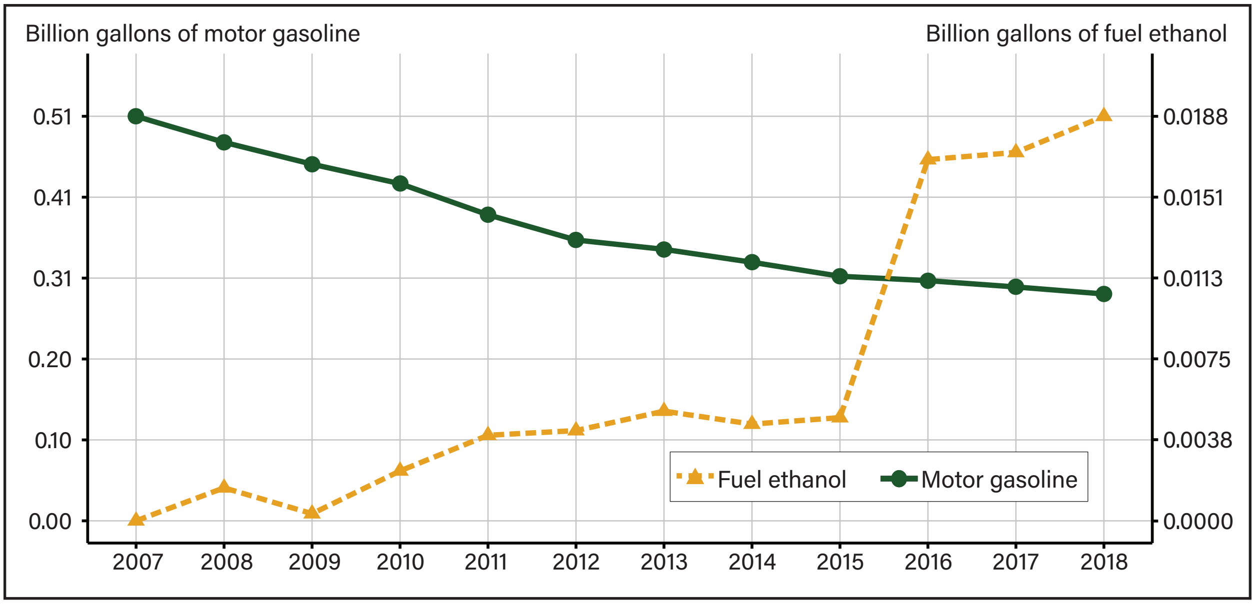
Note: The TB scenario rate is the rate New Zealand is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Consumption of fuel ethanol in New Zealand has been mostly flat since first being recorded at 1.5 million gallons in 2008 (EIA, 2021). Since then, consumption has seen a high of 2.4 million gallons in 2012 and a low of 1.1 million gallons in 2009 (EIA, 2021). Average consumption over the 2008–2018 period was 1.5 million gallons (EIA, 2021). Motor gasoline consumption (includes fuel ethanol) over this time was also relatively flat (around an average of 837 million gallons), ranging from 811 million gallons (2014) to 875 million gallons (2017) (EIA, 2021). As a result, effective blend rates have also seen little variation around an average of 0.2 percent.

Moving forward, the Government of New Zealand (GNZ) has agreed in principle to implement a biofuels mandate (New Zealand Ministry of Transport, 2021). The GNZ is reviewing its 2008 Biofuels Sales Obligation for reinstatement, which set the biofuel proportion of 0.5 percent of liable suppliers' petrol sales. Through the review, the GNZ is seeking to: (1) confirm the sales obligation will be a net benefit to New Zealand and (2) update the target proportions based on biofuels developments and policies in other countries.

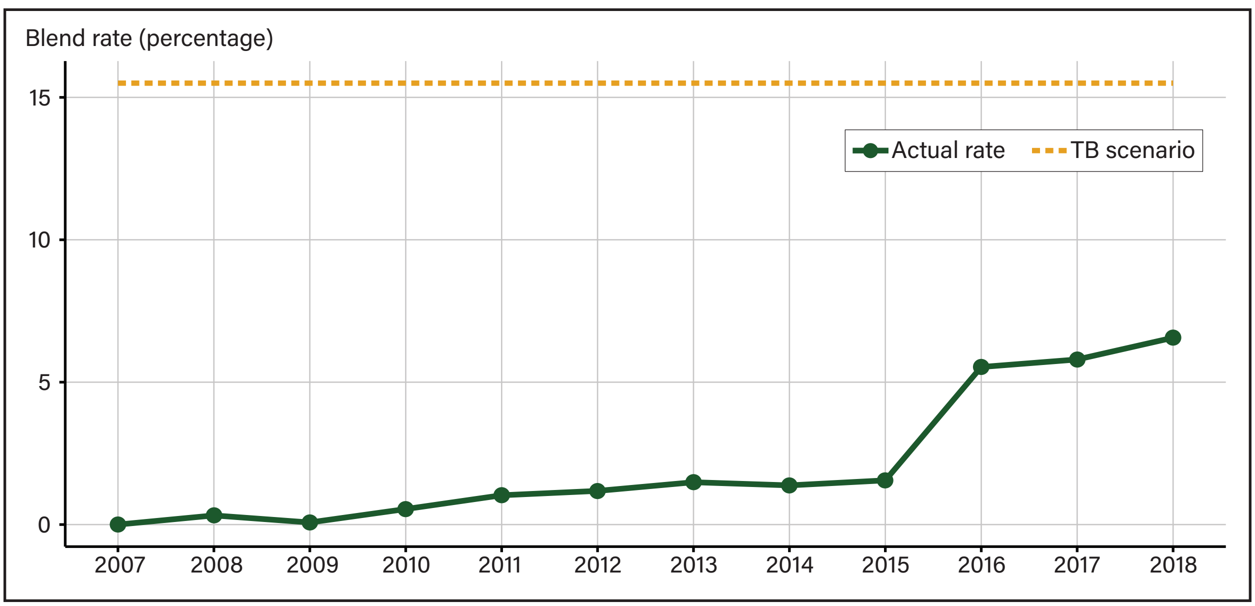
Figure A-31
Norway: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-32
Norway: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



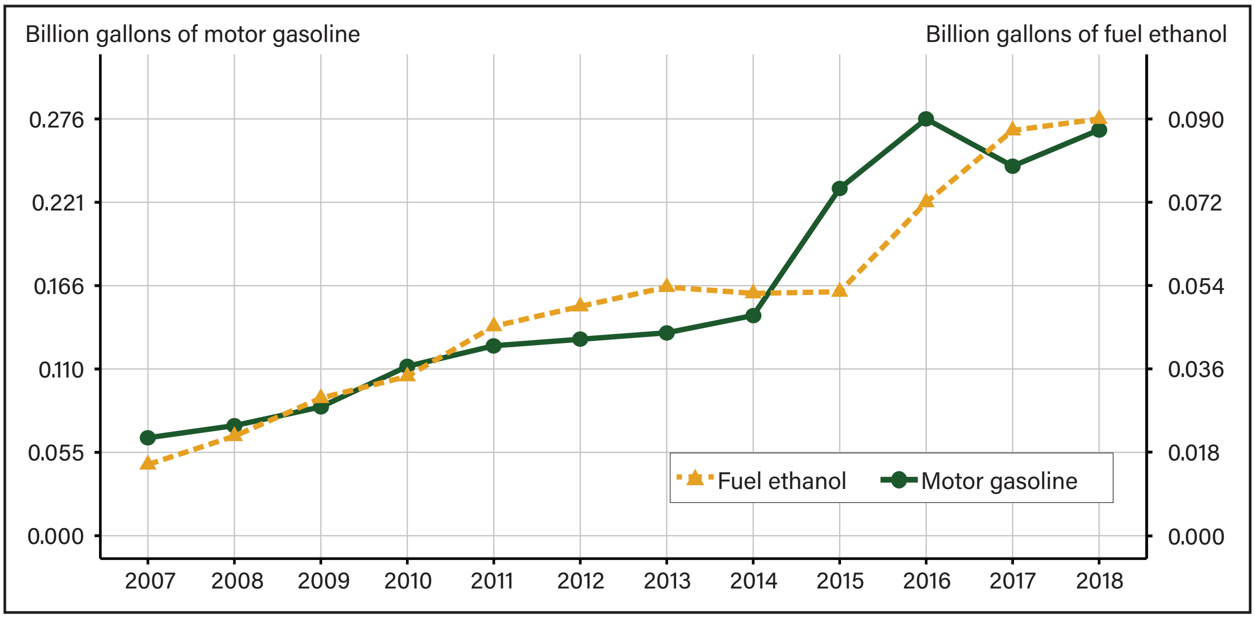
Note: The TB scenario rate is the rate Norway is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

In 2009, Norway introduced a blending obligation that required a biofuel share of at least 2.5 percent in the total sales of fuel for road transport (Norwegian Ministry of Climate and Environment, 2019). Despite the quota, the ethanol blending rate in 2009 was less than 0.1 percent and the lowest of any year between 2008 and 2018 (EIA, 2021). This was also true for gross consumption, which stood at 0.3 million gallons (EIA, 2021). Since then, consumption of fuel ethanol and its effective blending rate increased steadily to 4.8 million gallons and 1.6 percent in 2015 (EIA, 2021). A larger increase was seen in 2016 when consumption reached 16.8 million gallons and yielded a blend rate of 5.5 percent. Both figures increased in the subsequent years, and by 2018, consumption had reached 18.8 million gallons, and the blend rate stood at 6.6 percent. The original quota, meanwhile, increased to 24.5 percent on January 1, 2021, and the proportion coming from advanced biofuels was raised to 9 percent (Norwegian Ministry of Climate and Environment, 2021). Despite these requirements, Norway seems to view electric vehicles as its future and has set a goal of 100-percent EV share for new vehicle sales by 2025, a figure that stood at 54.3 percent in 2020 (Klesty, 2021).

Paraguay

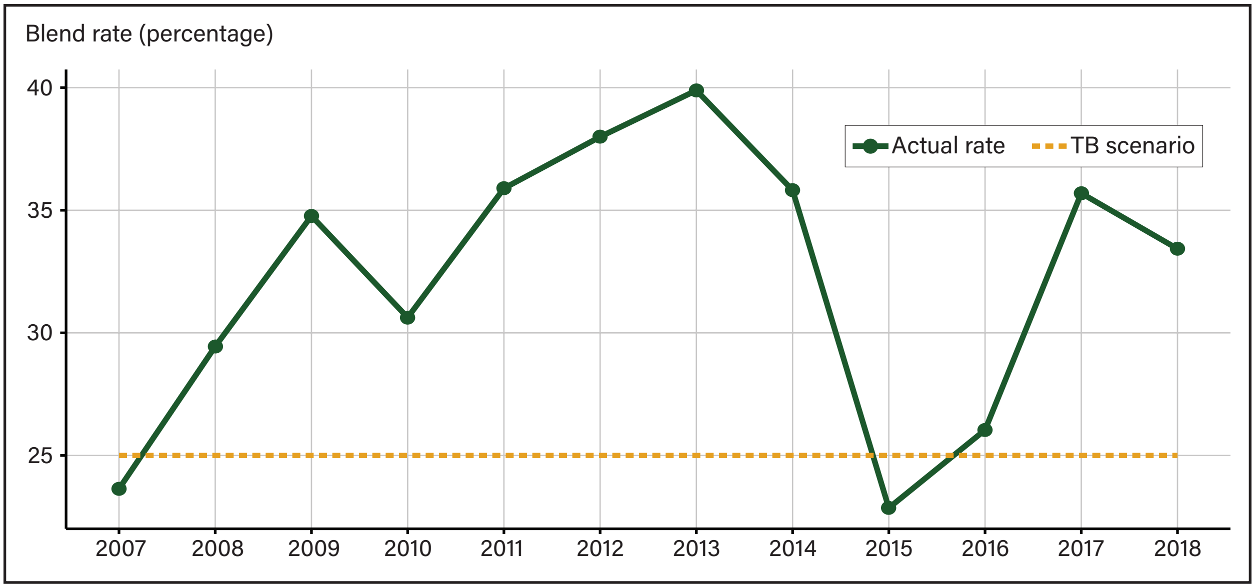
Figure A-33
Paraguay: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-34
Paraguay: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate

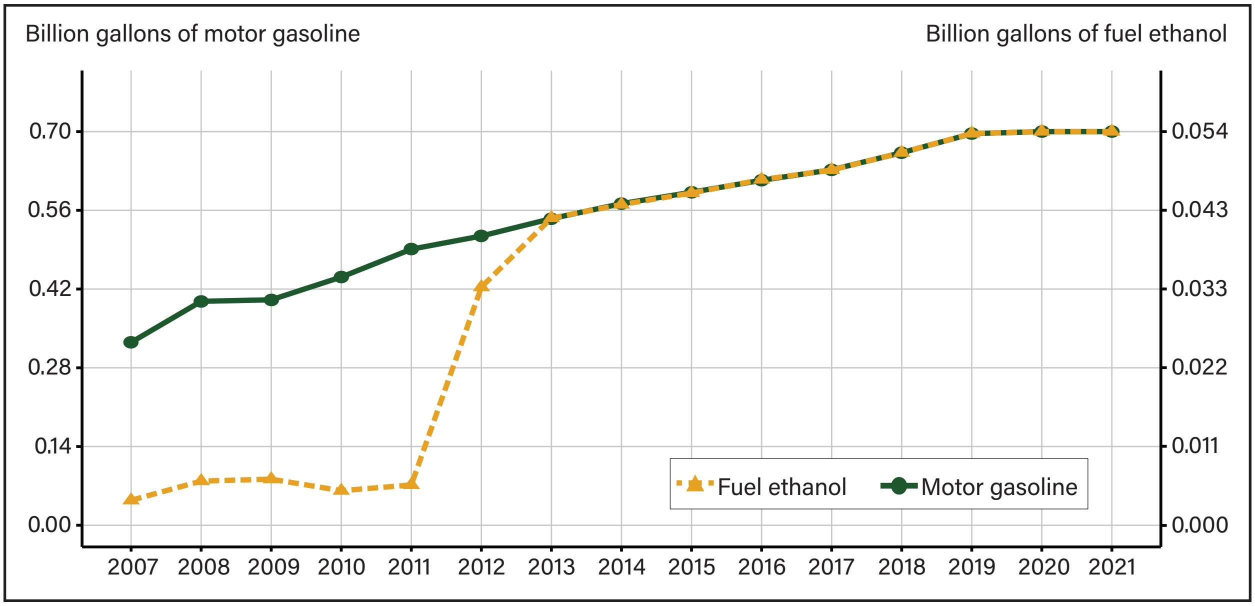


Note: The TB scenario rate is the rate Paraguay is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Paraguay has set ethanol blending rates of 20 percent or more since the mid-2000s, and by 2018, the rate stood at 33 percent (EIA, 2022). As a result, fuel ethanol consumption has increased from about 1.5 million gallons in 1981 to about 90 million gallons in 2018 (EIA, 2022). Law 5444, "Promotion of Consumption of Ethanol," sought to promote E85 by requiring local motor gasoline distributors to guarantee the fuel's availability nationally and implement a switch to E85 in the Government fleet (Joseph K., 2015), though it is unclear to what extent these efforts have succeeded. After Brazil, Paraguay has remained one of the highest users of ethanol on a percentage basis. The official blending mandate was at 25 percent as of 2019 (Trindade et al., 2019).

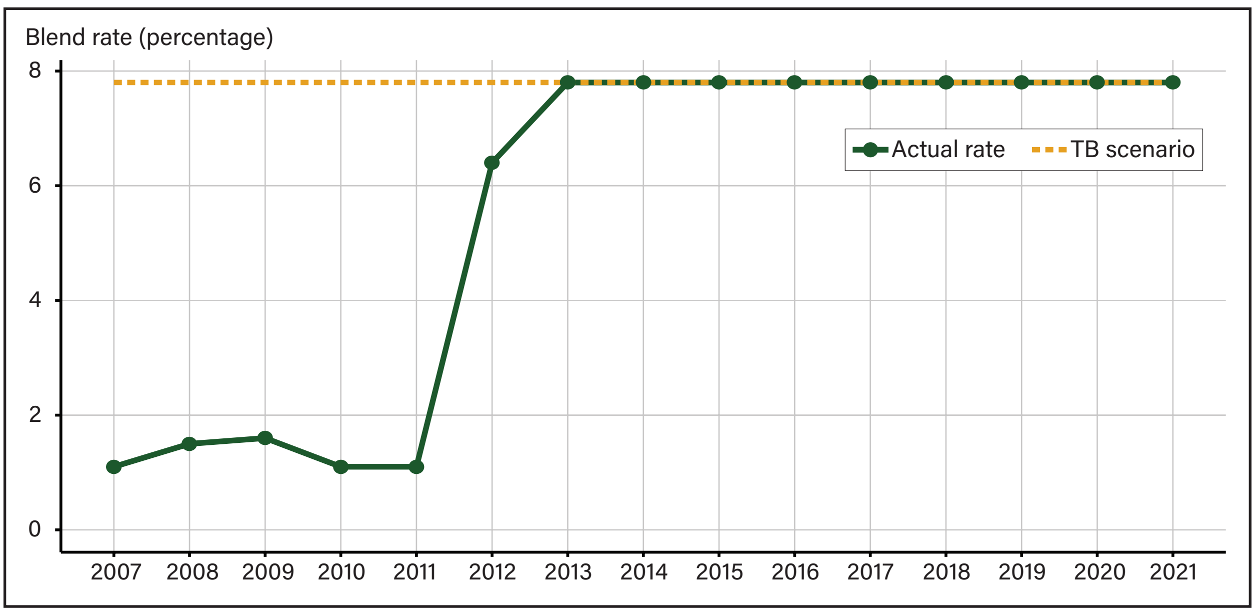
Figure A-35
Peru: fuel ethanol and motor gasoline consumption, 2007–21



Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-36
Peru: actual blend rates, 2007–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Peru is assumed to achieve in 2030.

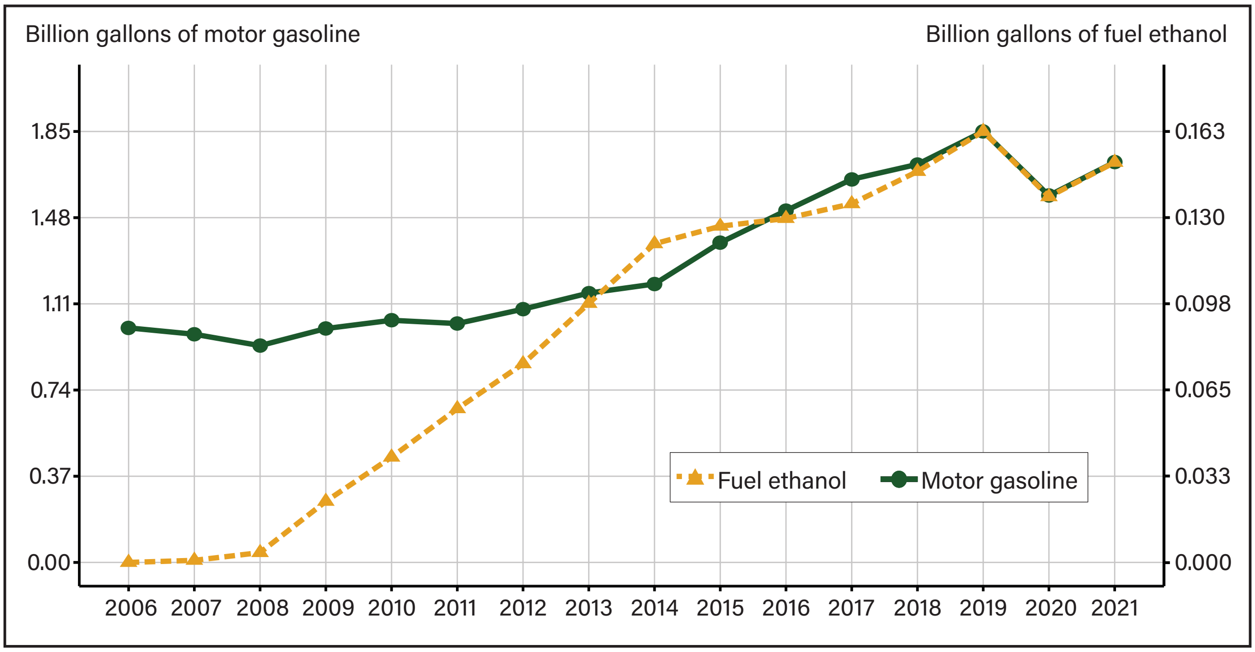
Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Peru has grown from 3 million gallons in 2007 to a projected 54 million gallons in 2021. Though the 2021 ethanol volume is small on the global scale, it is projected as an effective blend rate of 7.8 percent, which is their mandatory blend rate (Nolte, 2021). According to Nolte (2021), Peru has maintained the 7.8 percent blend rate since 2013. Total consumption has increased along with total motor gasoline consumption, which is projected at 696 million gallons in 2021 (includes fuel ethanol). Growth in motor gasoline consumption is likely to be the most important driver for growth in ethanol demand in Peru, but the country has incorporated biofuels in governmental strategies to achieve 30-percent emissions reductions by 2030 (Nolte, 2021).

Philippines

Figure A-37

Philippines: fuel ethanol and motor gasoline consumption, 2006–21

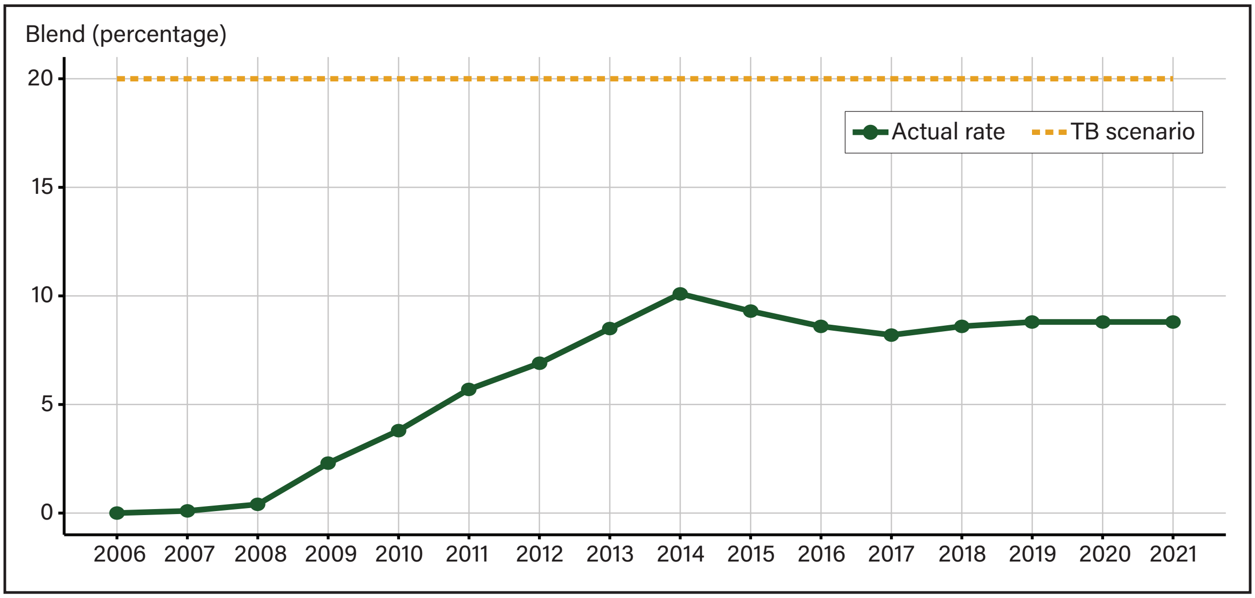


Note: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-38

Philippines: actual blend rates, 2006–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Philippines is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

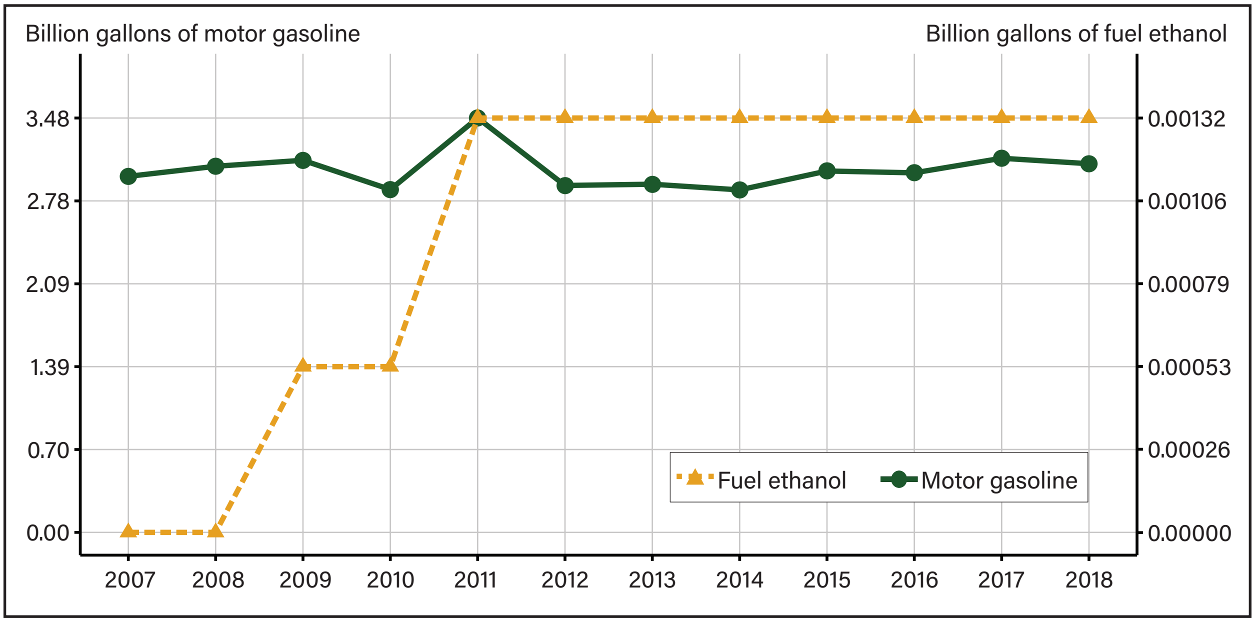
Fuel ethanol consumption in the Philippines increased from about 0.8 million gallons in 2007 to 163 million gallons in 2019, before falling during the COVID-19 pandemic. Motor gasoline consumption (includes fuel ethanol) in 2019 was 1.9 billion gallons, yielding a blend rate of about 9 percent, which was slightly below the 10 percent mandate (Mojica-Sevilla, 2021). The country is targeting a blend rate of 20 percent in 2020 and beyond, though this is expected to be a voluntary target rather than an official mandate (Mojica-Sevilla, 2021). An additional boost to demand could come from an 85-percent blend that the Government would like to make available for voluntary promotion by 2025 (Bedford, 2020).

In meeting the mandate, priority is given to domestic ethanol, but imports have averaged about 43 percent of consumption over the last few years, with the United States being the primary supplier (Mojica-Sevilla, 2021). In 2016, ethanol tariffs within the Association of Southeast Asian Nations fell to zero and have remained at that level (Mojica-Sevilla, 2021). Similarly, Most Favored Nation tariffs for World Trade Organization member countries remain at zero percent (Mojica-Sevilla, 2021). However, a 1-percent duty is imposed and paid by oil companies if ethanol is used for fuel-blending purposes (Mojica-Sevilla, 2021). Imported, pre-blended gasoline is charged an extra 10-percent duty as of May 2, 2020, though this duty was to be a short-term COVID-19 response (Bedford, 2020).

Electric vehicles are limited at around 2,000 units, and the charging infrastructure is lacking, but tariffs on electric-vehicle components were reduced. Electric vehicles are also exempt from certain excise taxes (Bedford, 2020). In general, the Government is attempting to accelerate development of the electric vehicle industry (Bedford, 2020).

Figure A-39

South Africa: fuel ethanol and motor gasoline consumption, 2007–18

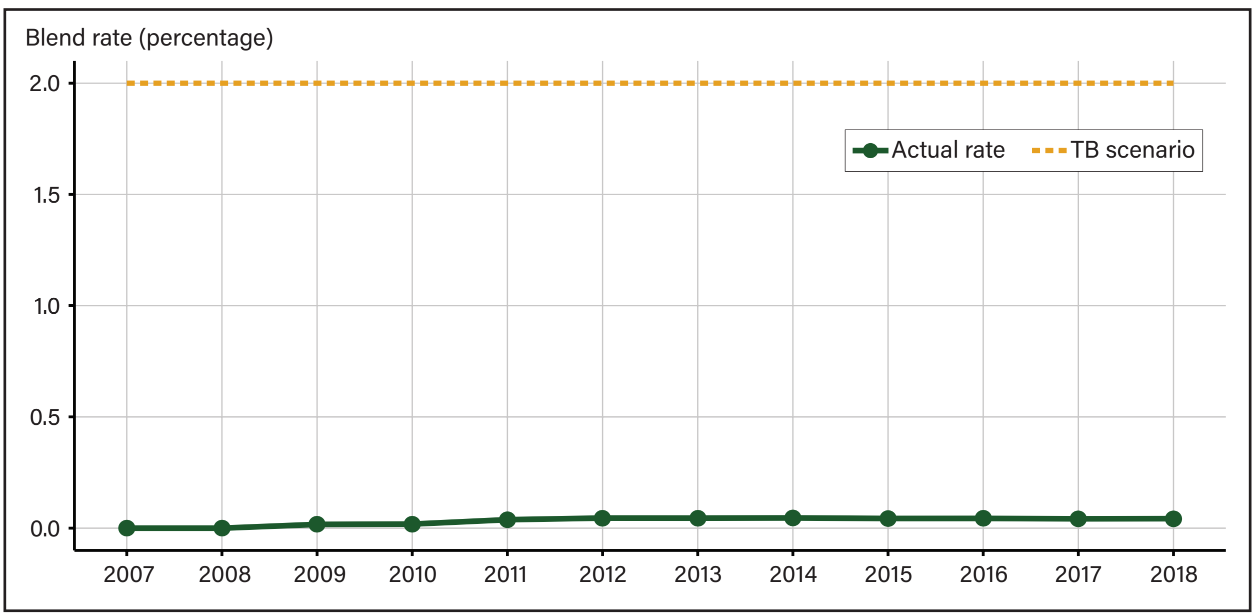


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-40

South Africa: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



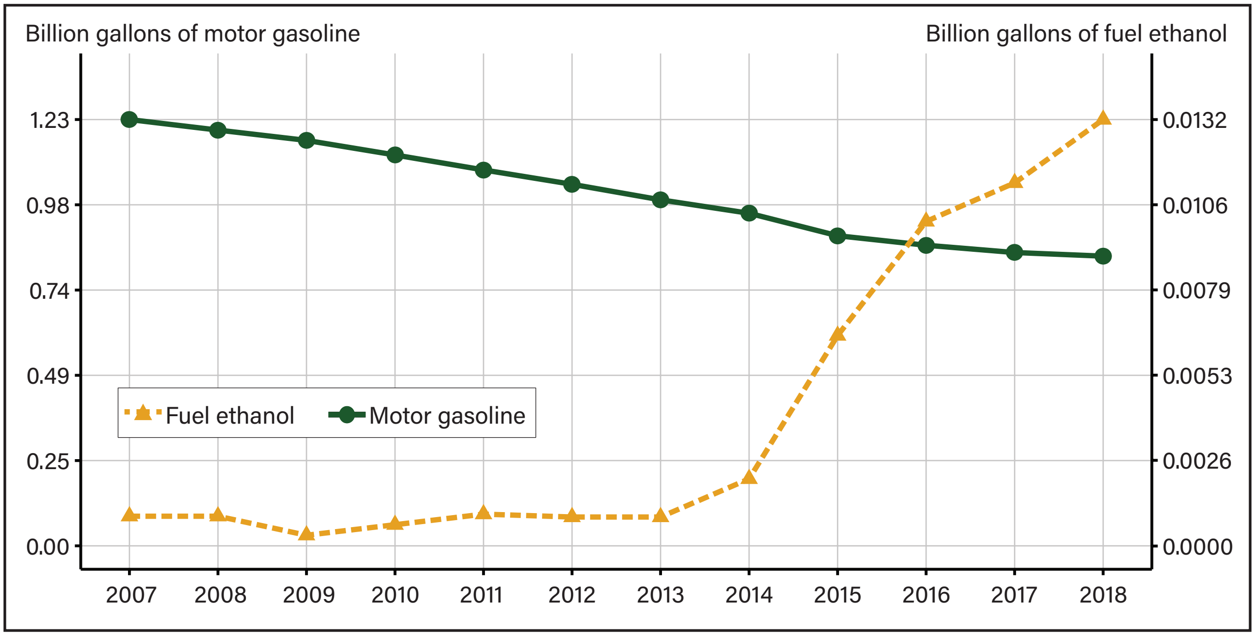
Note: The TB scenario rate is the rate South Africa is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

In December 2007, South Africa approved the Biofuels Industrial Strategy, which provided for a pilot program from 2008 to 2013 when the country was to achieve a 2-percent penetration by biofuels into the motor gasoline and diesel pools. 2009 was the first year for which EIA (2022) showed ethanol consumption, at an amount of 0.5 million gallons. Consumption stayed at this level in 2010 before increasing to 1.3 million gallons in 2011, where it has remained (EIA, 2022). Motor gasoline consumption has also been stable, ranging from 2.9 billion gallons in 2010 to 3.1 billion gallons in 2017 (EIA, 2022). These levels resulted in low effective blending rates, averaging 0.03 percent over the 2009 to 2018 period. A mandatory bioethanol blending of 2 percent—from locally produced sources—was implemented in 2015. The South African Biofuels Regulatory Framework, approved in December 2019, indicates the current target is for 4.5-percent penetration by biofuels, with 2 percent coming from first-generation biofuels.

Switzerland

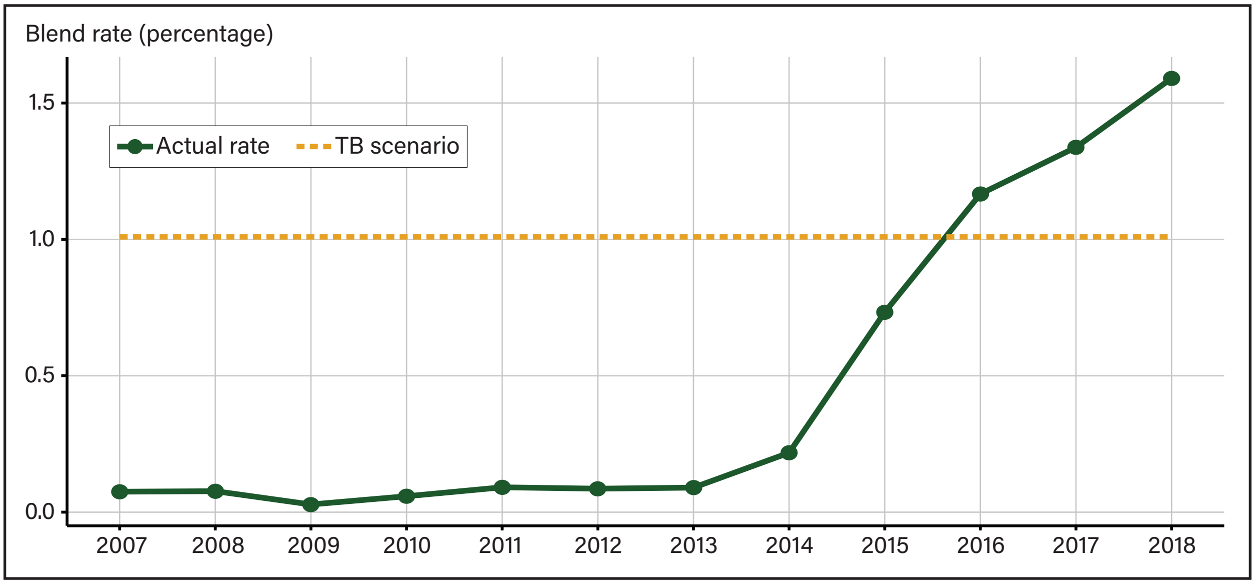
Figure A-41
Switzerland: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-42
Switzerland: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate

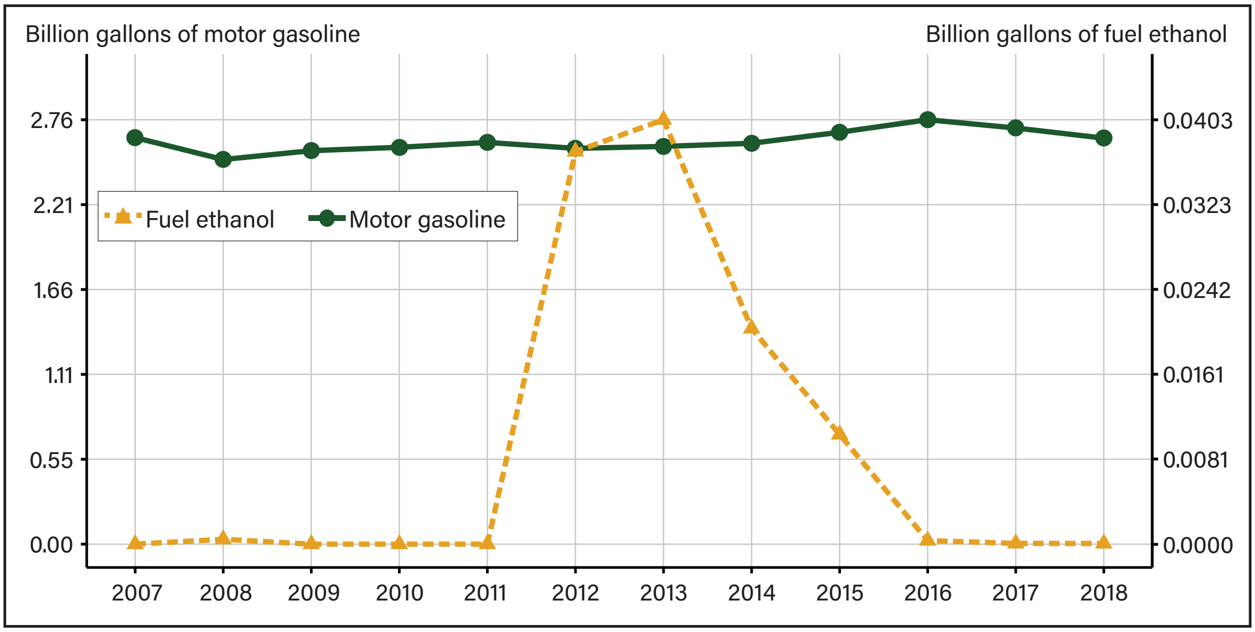


Note: The TB scenario rate is the rate Switzerland is assumed to achieve in 2030. There was no target found for Switzerland, so the target blend rate equals the Historical Blends scenario rate.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Switzerland consumed small quantities of fuel ethanol since the consumption of 0.3 million gallons was registered in 2005 and 2006 (EIA, 2022). Consumption hit a momentary peak of 1 million gallons in 2011 before falling to 0.9 million gallons in the following 2 years (EIA, 2022). Larger increases followed in the years since that time, and by 2018, consumption had reached 13.2 million gallons (EIA, 2022). Meanwhile, motor gasoline consumption decreased every year over this time, falling from 1.3 billion gallons in 2005 to 833 million gallons in 2018. As a result, effective ethanol blending rates generally increased, going from 0.02 percent in 2005 to 1.6 percent in 2018. Though no biofuel blending requirement could be found, Switzerland has historically incentivized biofuel usage through exemption from a mineral oils tax (Swiss Confederation, Federal Department of Finance, 2021).

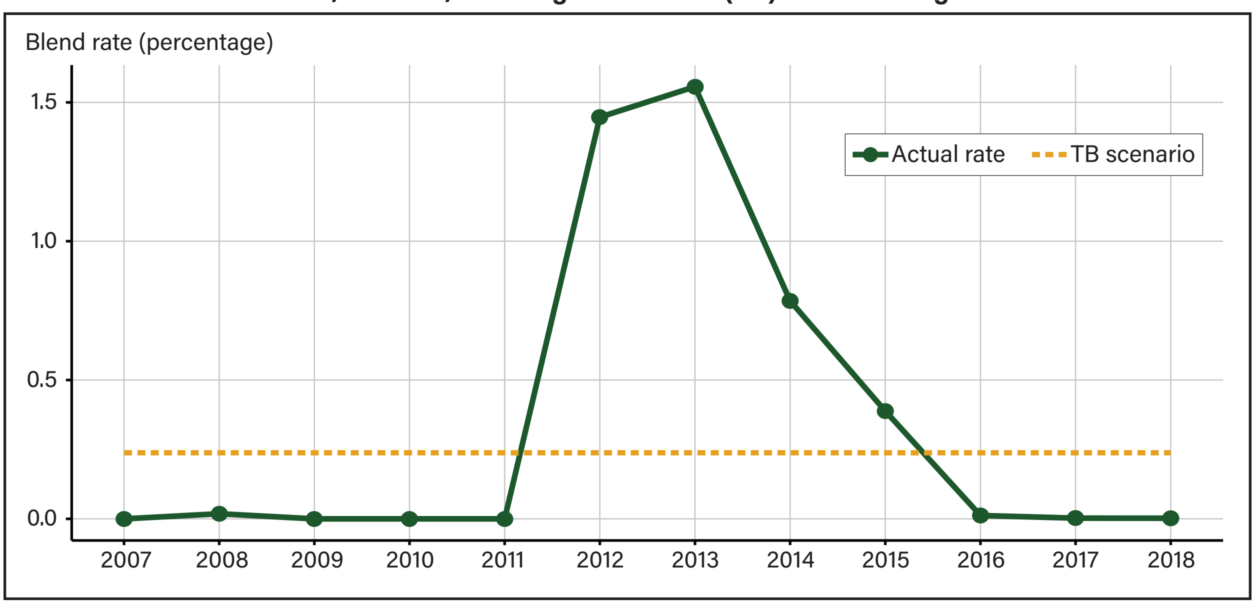
Figure A-43
Taiwan: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-44
Taiwan: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



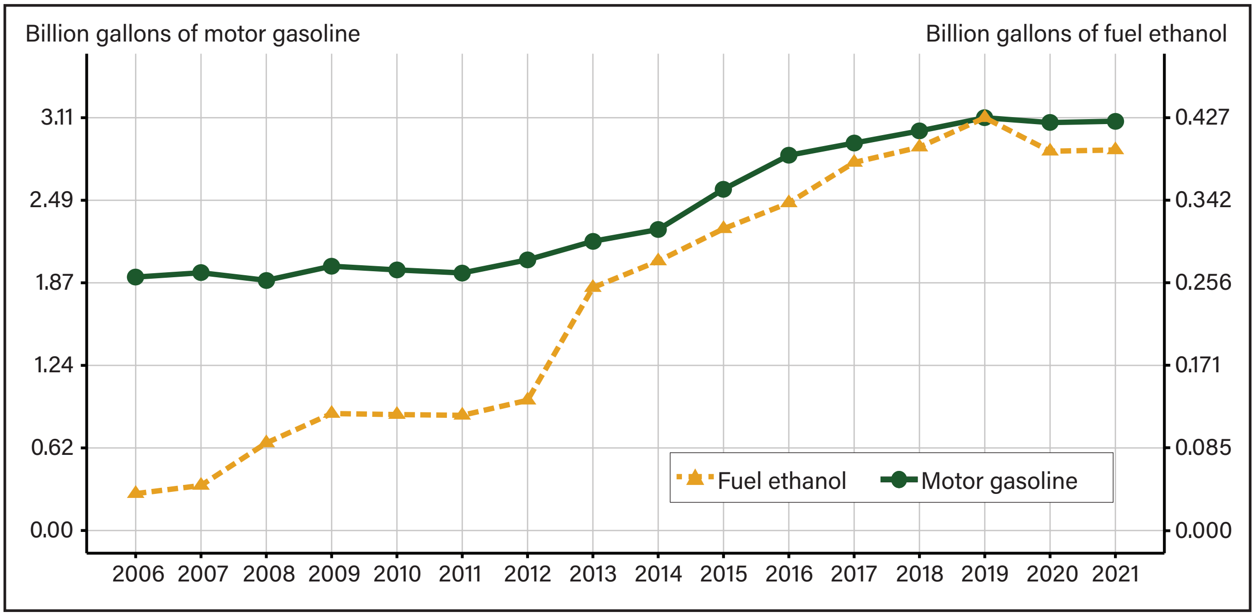
Note: The TB scenario rate is the rate Taiwan is assumed to achieve in 2030. There was no target found for Taiwan, so the target blend rate equals the Historical Blends scenario rate.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Taiwan has been small and decreasing, falling from 37.3 million gallons in 2012 to 60,000 gallons in 2018 (EIA, 2022). Motor gasoline consumption has been stable around an average of 2.7 billion gallons over this time (EIA, 2021). As a result, effective blend rates fell as well, decreasing from 1.5 percent in 2012 to practically zero in 2018 (0.002 percent). There are no apparent ethanol mandates in Taiwan, though there has been an E3 pilot program since 2017 at 14 state-owned gasoline stations (Lin, 2021).

Thailand

Figure A-45
Thailand: fuel ethanol and motor gasoline consumption, 2006–21

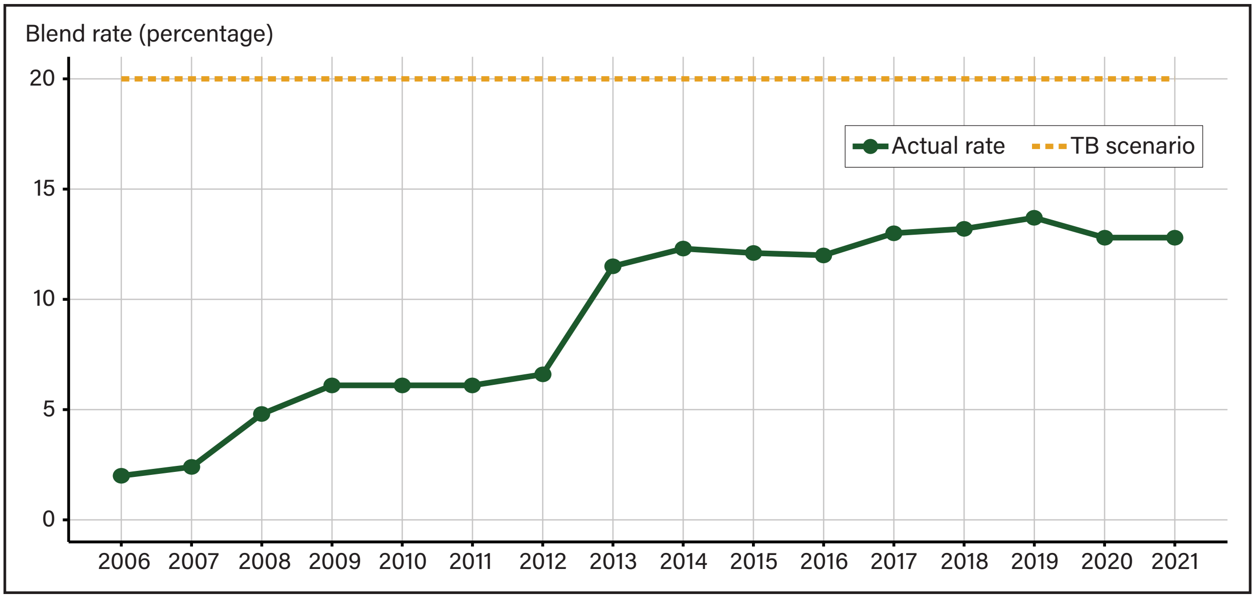


Notes: Motor gasoline includes the fuel ethanol component. The 2021 value is a USDA, Foreign Agricultural Service (FAS) projected value.

Source: USDA, Economic Research Service using data from USDA, FAS.

Figure A-46

Thailand: actual blend rates, 2006–21, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Thailand is assumed to achieve in 2030.

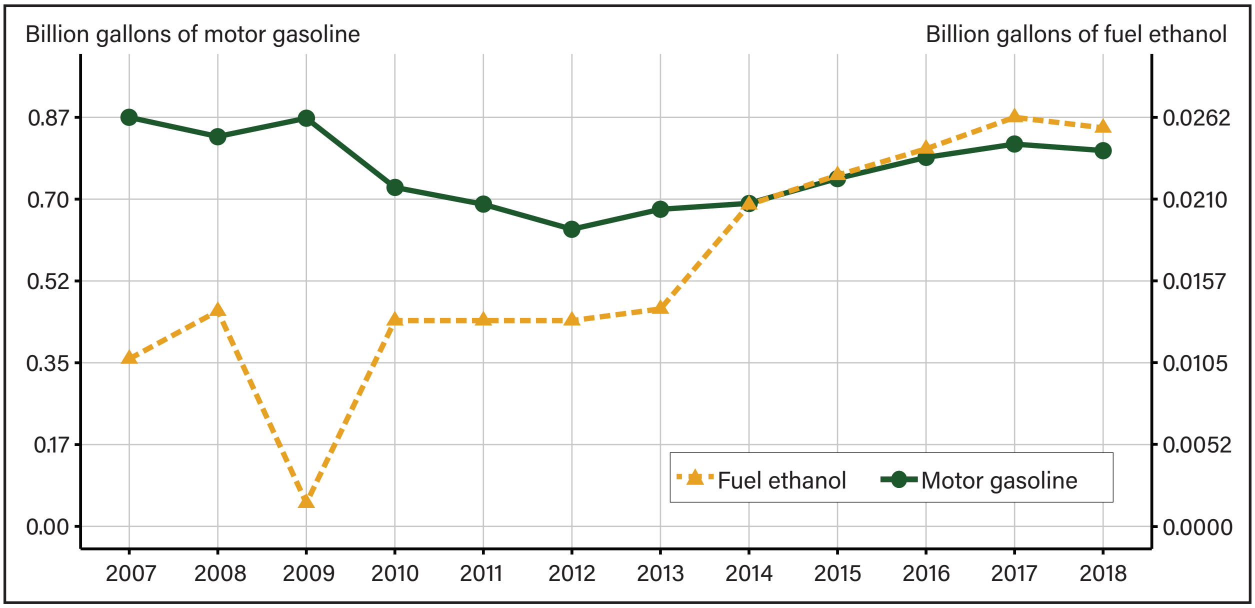
Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service for actual rate and Targeted Blends scenario for TB scenario rate.

Thailand has consumed fuel ethanol since at least the mid-2000s (Mullis, 2021). Consumption grew steadily in the years to follow and ultimately hit an all-time high level of 427 million gallons in 2019 (Mullis, 2021). Motor gasoline consumption (includes fuel ethanol) grew from 1.9 billion gallons in 2006 (Preechajarn and Prasertsri, 2014) to a projected 3.1 billion gallons in 2021 (Mullis, 2021). Like ethanol consumption, the blend rate has also been trending up over time, going from 2 percent in 2006 (Preechajarn and Prasertsri, 2014) to 12.8 percent in 2021 (Mullis, 2021). The blend rate has been above 10 percent since it jumped from 6.6 percent in 2012 to 11.5 percent in 2013 (Mullis, 2021).

Thailand has relatively high blending rates without an official blending mandate, though the country plans to phase out E10 and E85 by 2027, thus making E20 the primary gasohol (Mullis, 2021). However, the elimination of E10 has already been delayed several times (Mullis, 2021). The Government is also targeting electric vehicle usage of 1.05 million units by 2025 and 15.58 million units by 2035.

Figure A-47

Turkey: fuel ethanol and motor gasoline consumption, 2007–18

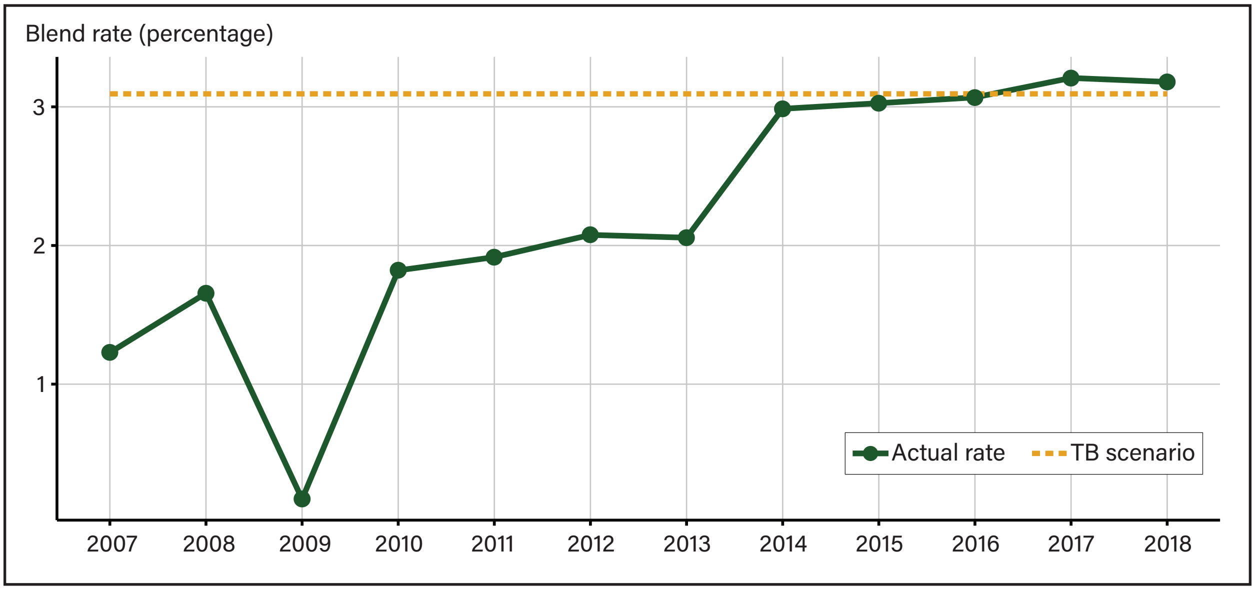


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-48

Turkey: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



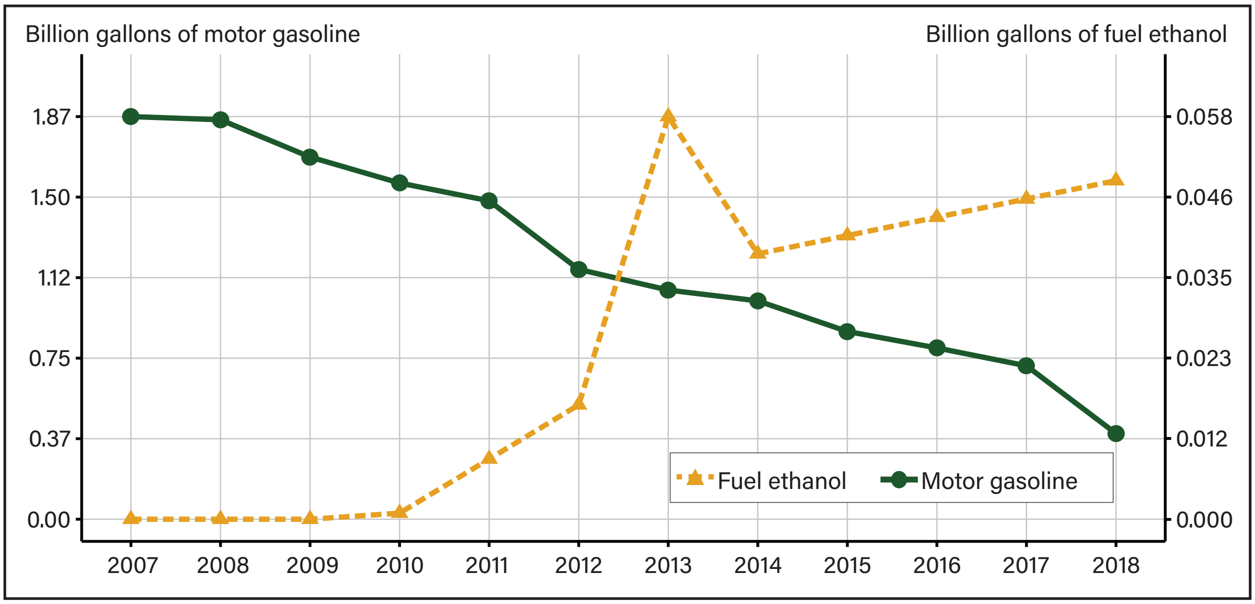
Note: The TB scenario rate is the rate Turkey is assumed to achieve in 2030. There was no target found for Turkey, so the target blend rate equals the Historical Blends scenario rate.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Turkey increased from 8 million gallons in 2005 to 26 million gallons in 2018 (EIA, 2022). Motor gasoline consumption (includes fuel ethanol) over this time decreased but at a lower rate, from 949 million gallons to 803 million gallons (EIA, 2022). Effective blending rates have thus been increasing, going from 0.8 percent to 3.2 percent, though the rate has been relatively flat since 2014. Though there are no apparent blending requirements, Turkey is developing benchmarking on alternative fuels and vehicles that use these fuels to assess costs and environmental impacts (Ministry of Energy and Natural Resources, 2018). Potentially, these analyses could result in a push for increased usage of fuels such as ethanol.

Ukraine

Figure A-49
Ukraine: fuel ethanol and motor gasoline consumption, 2007–18

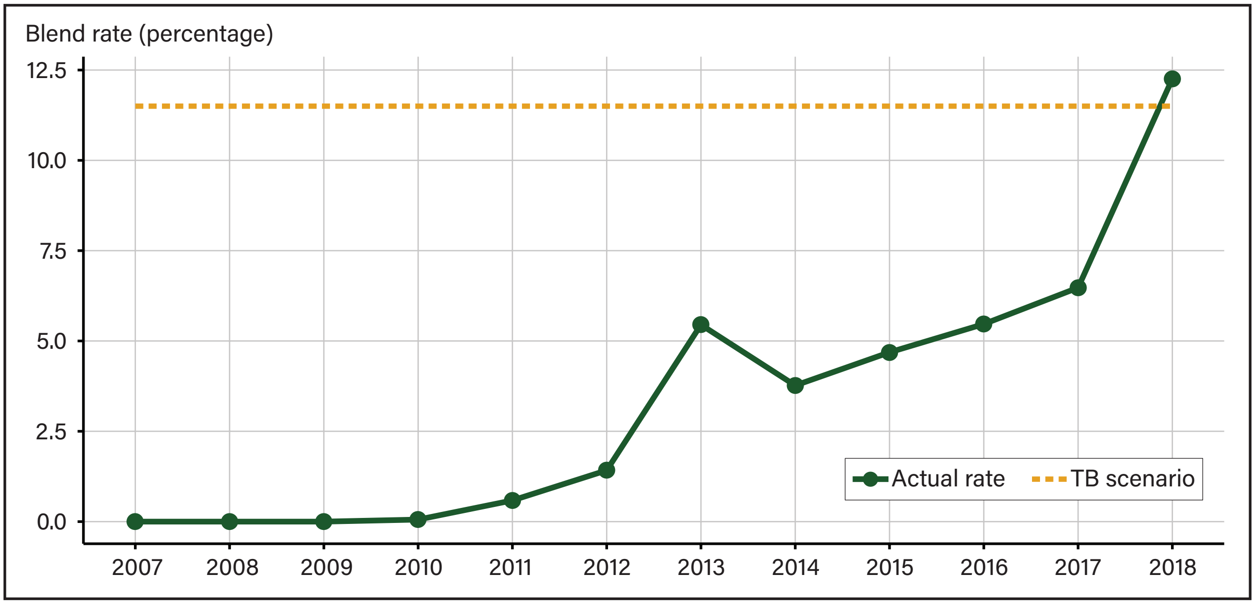


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-50

Ukraine: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate

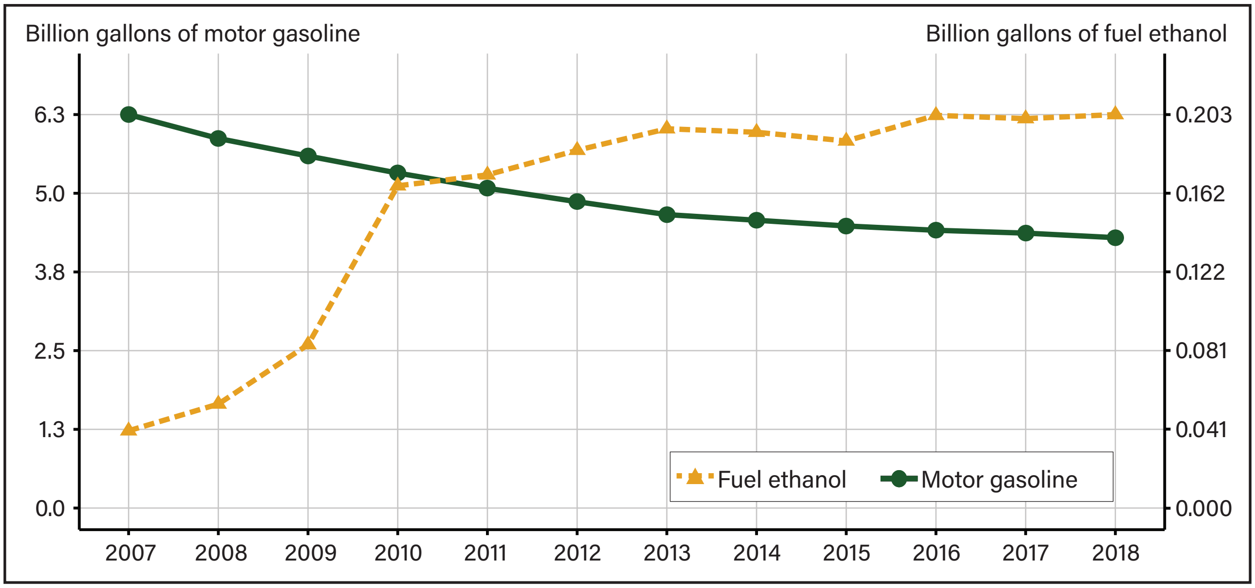


Note: The TB scenario rate is the rate Ukraine is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

EIA estimated zero Ukrainian ethanol consumption until a 0.9-million-gallon estimate for 2010. Consumption has increased almost every year since (2014 as the lone exception), reaching approximately 49 million gallons in 2018. Over the same period, motor gasoline consumption (includes fuel ethanol) decreased from 1.6 billion gallons to 399 million gallons. This decline was likely due to economic recessions in the country, as well as a heavy dependence on imports for oil that have been subject to disruptions. Increasing numbers of diesel vehicles (Kosatka Media, 2019) may have also played a role. Whatever the causes, Ukraine's effective blending rate increased from about 0.06 percent in 2010 to about 12.3 percent in 2018, with an average rate over the period of 4.5 percent. Though there is no apparent ethanol blending mandate, the "Energy Strategy of Ukraine until 2035"—adopted in 2016—set a target of 11.5 percent for biofuels' share in the total primary energy supply.

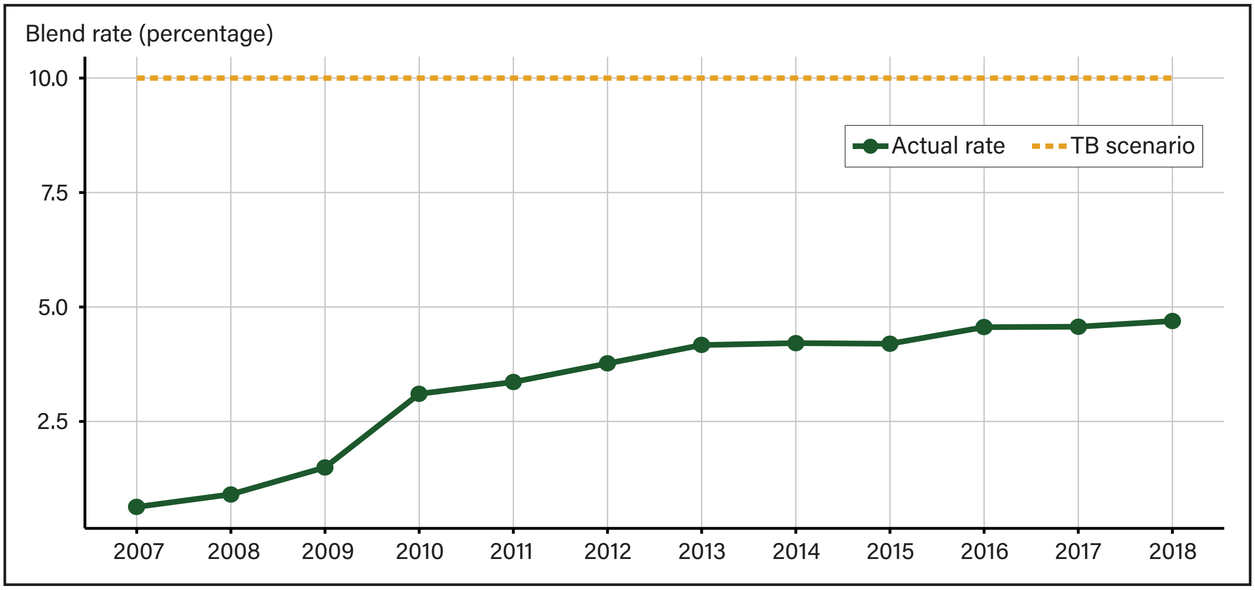
Figure A-51
United Kingdom: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-52
United Kingdom: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



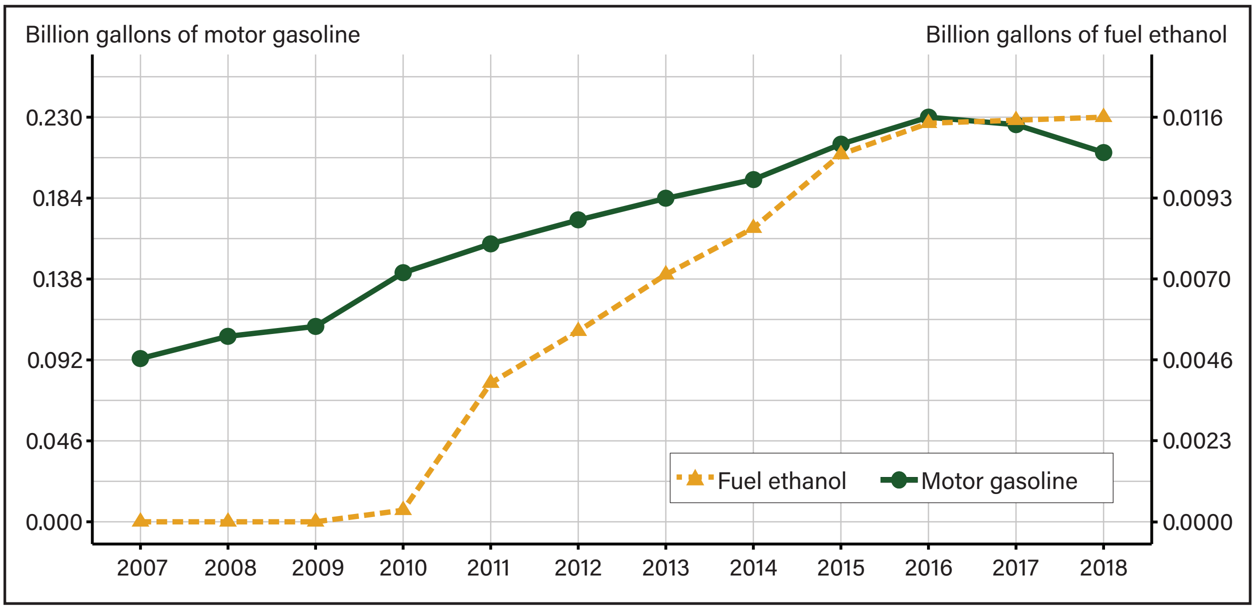
Note: The TB scenario rate is the rate United Kingdom is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Ethanol consumption in the United Kingdom (UK) grew from about 23 million gallons in 2005 to 203 million gallons in 2018 (EIA, 2022). Meanwhile, motor gasoline consumption (includes fuel ethanol) decreased steadily from 6.7 billion gallons to 4.3 billion gallons (EIA, 2022). As a result, the blending rate increased from 0.3 percent to 4.7 percent. Blend rates stabilized around this level, with a rate of 4.6 percent seen in both 2016 and 2017. However, in summer 2021, E10 became the "standard" grade offered at retail locations, while E5 was to continue to be available in "super" grade gasoline (United Kingdom Department for Transport, 2021). This grade will likely increase consumption of fuel ethanol in the UK. Ethanol production capacity in the UK was estimated at around 240 million gallons per year as recently as 2016 (Voegele, 2017).

Uruguay

Figure A-53
Uruguay: fuel ethanol and motor gasoline consumption, 2007–18

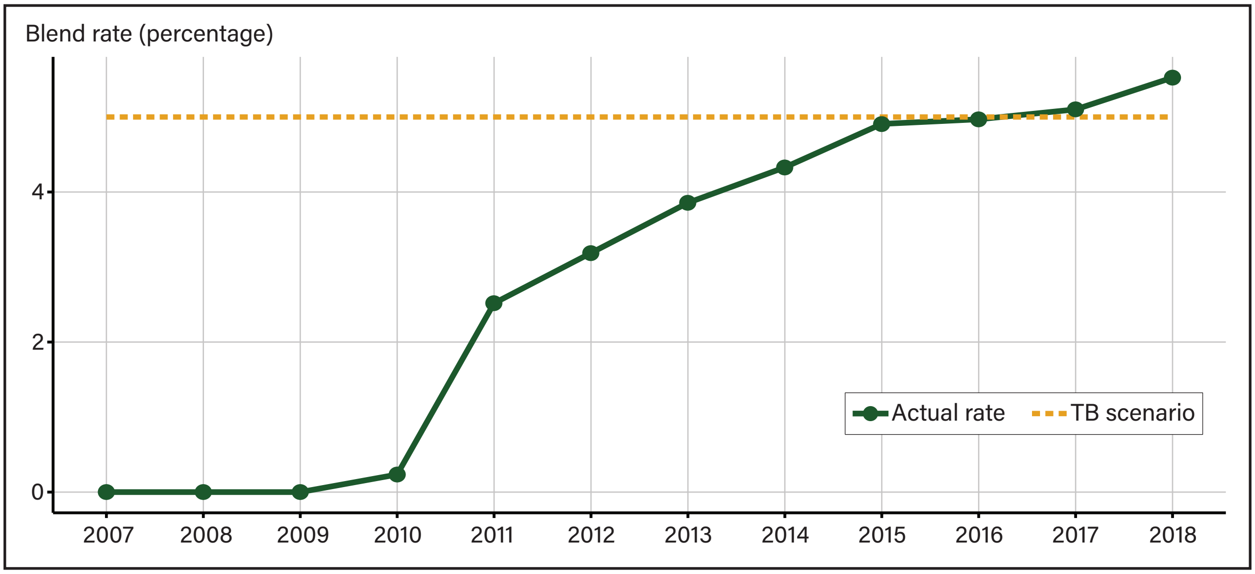


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-54

Uruguay: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



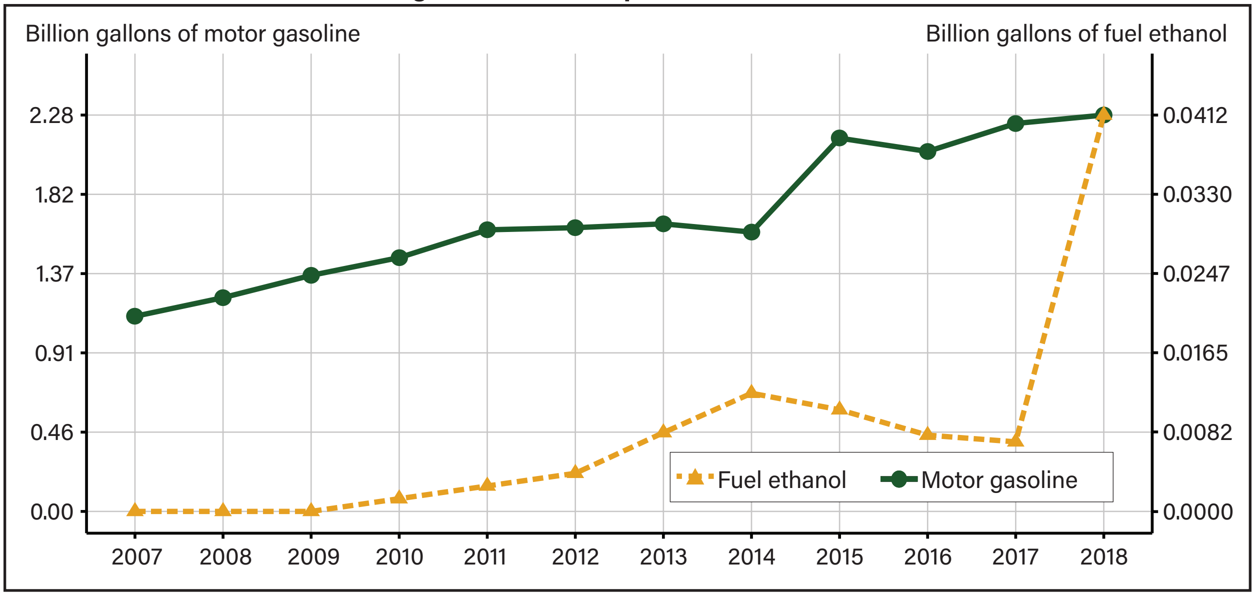
Note: The TB scenario rate is the rate Uruguay is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

As of 2015, Uruguay was still operating under its long-term energy strategy, the National Energy Policy 2005–2030, which was approved in 2008 (IRENA, 2015). Broadly, this plan set a 50-percent target for the share of renewable energy in total primary energy by 2015 (IRENA, 2015). With respect to ethanol, the country instituted a 5-percent blend mandate beyond 2015 (IRENA, 2015). The mandate was to be filled using locally produced ethanol, though exceptions could be made for "national interest" (IRENA, 2015). Assuming these are still the current mandates, the country only recently met its requirement in 2016, when Uruguay reached 11 million gallons and the effective blend rate hit 5 percent. Prior to this, Uruguay did not achieve a 5-percent blend rate in any year between 2010 and 2015, though the country was just slightly under this threshold in 2015 (4.9 percent). However, the blend rate increased every year during this period as the rate grew from an initial level of 0.2 percent in 2010. It remains to be seen if the growth in the blend rate stalls now that the mandated level has been achieved. If so, further expansion of ethanol consumption may be dependent upon increasing motor gasoline consumption (includes fuel ethanol), which saw 126-percent growth over the 2007–2018 period but decreased 8.7 percent between 2016 and 2018.

Figure A-55

Vietnam: fuel ethanol and motor gasoline consumption, 2007–18

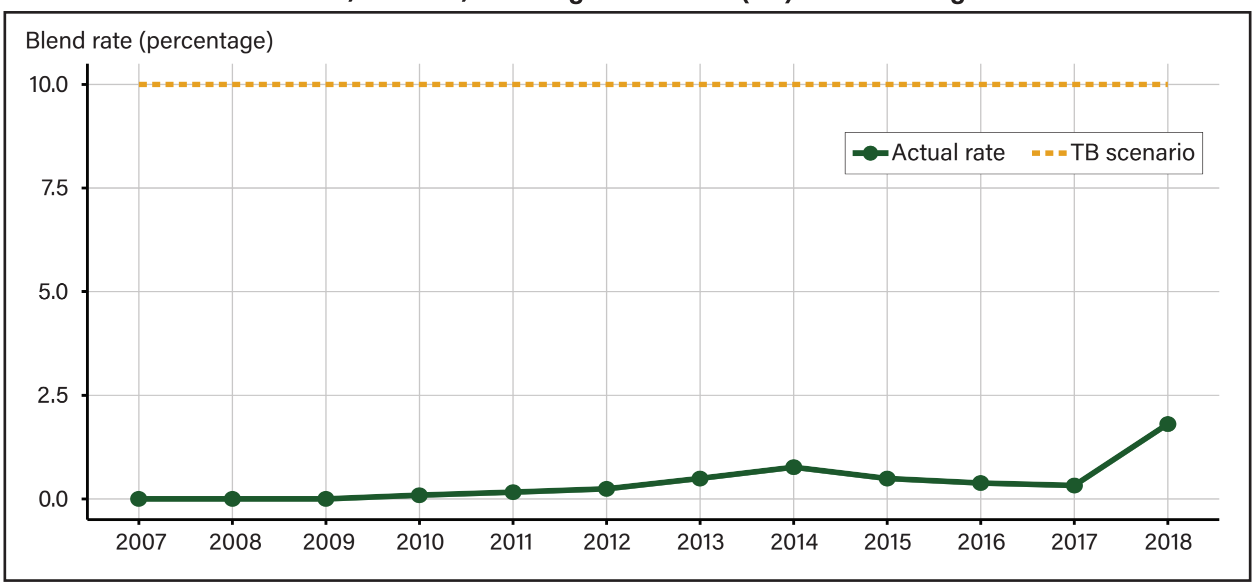


Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-56

Vietnam: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Vietnam is assumed to achieve in 2030.

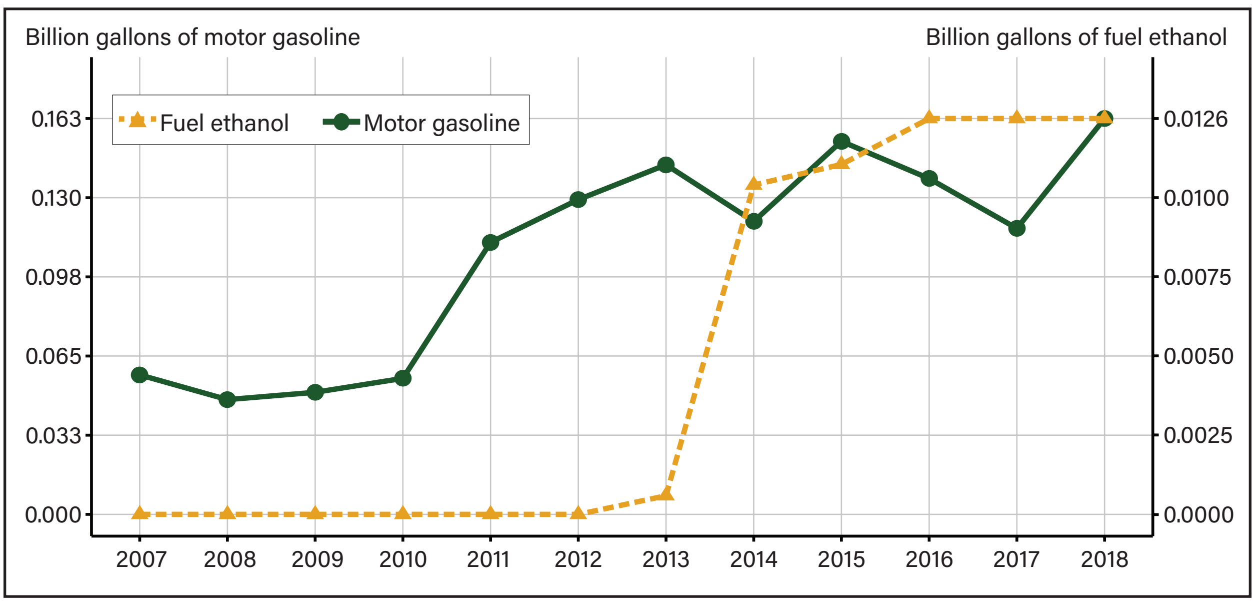
Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Fuel ethanol consumption in Vietnam has been minimal but growing, increasing from 1 million gallons in 2010 to 41 million gallons in 2018 (EIA, 2022). Motor gasoline consumption (includes fuel ethanol) over this time increased from 1.5 billion gallons to 2.3 billion gallons (EIA, 2022), resulting in an effective blending rate that increased from 0.1 percent to 1.8 percent. Prior to 2018, the effective blend rate did not exceed 0.8 percent. Ethanol production capacity in Vietnam was estimated at 111 million gallons per year (Truong et al., 2016).

Vietnam has had targets for ethanol since at least 2012, when Decision 53 set a goal of nationwide commercialization of E5 by December 2015 and E10 by December 2017 (Francic, 2020). However, the E5 mandate was not officially launched until 2018 (Francic, 2020). Additionally, the mandate only ensures that E5 92 octane fuel is available to consumers alongside—and at a slight discount to—95 octane gasoline (Francic, 2020). A move to E10 is still planned (Francic, 2020), though the timeline is uncertain. Another factor that could shape ethanol consumption in Vietnam is the prevalence of motorbikes, for which new sales generally exceed those of automobiles by a rate of more than 10-to-1. The high usage of motorbikes could limit expansion of ethanol consumption because of an increasing interest in electric motorbikes due to high pollution in the country.

Zimbabwe

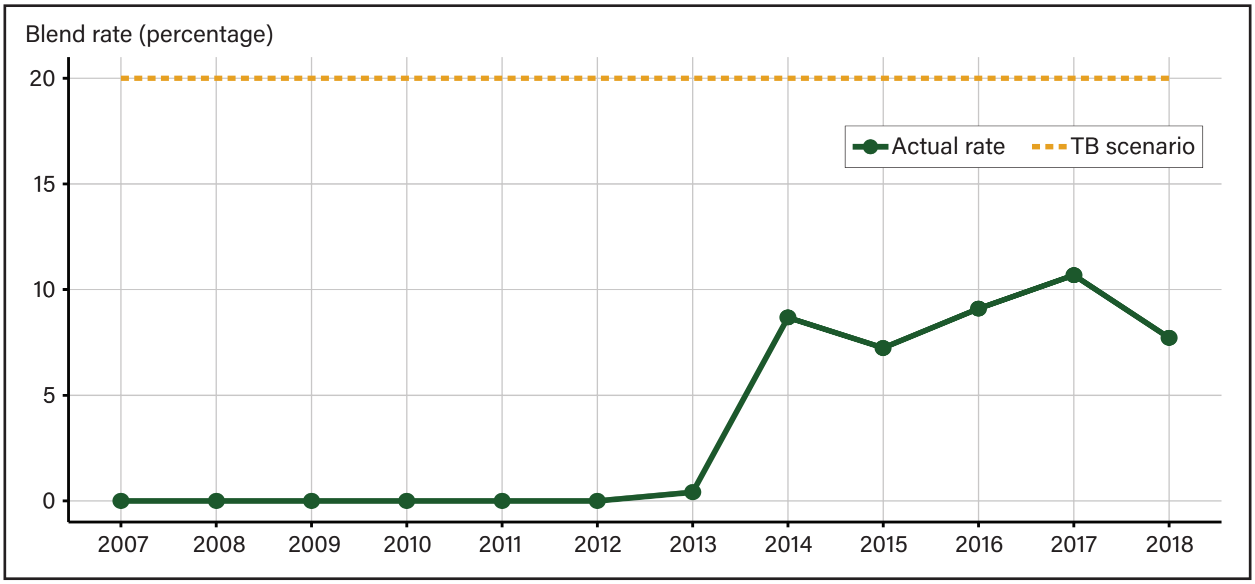
Figure A-57
Zimbabwe: fuel ethanol and motor gasoline consumption, 2007–18



Note: Motor gasoline includes the fuel ethanol component.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration.

Figure A-58
Zimbabwe: actual blend rates, 2007–18, and Targeted Blends (TB) scenario target rate



Note: The TB scenario rate is the rate Zimbabwe is assumed to achieve in 2030.

Source: USDA, Economic Research Service using data from U.S. Department of Energy, Energy Information Administration for actual rate and Targeted Blends scenario for TB scenario rate.

Mandatory ethanol blending in Zimbabwe dates back to at least the 2013 passage of the Petroleum (Mandatory Blending of Anhydrous Ethanol with Unleaded Petrol) Regulations. Under these regulations, all motor gasoline sold was required to be blended with a minimum of 5 percent ethanol. The regulation also required the ethanol be locally produced. The Government has shown a willingness to revise the mandate based on economic conditions, such as in 2017 when the rate was increased to 10 percent, following a reduction from 15 percent to 5 percent (Biofuels International, 2017). More recently, the mandate was revised down to 10 percent from 20 percent due to rain-related harvest difficulties (Sapp, 2020). The change to a 20-percent mandate had come from a 2020 amendment to the regulation. Given the Government's willingness to revise mandates downward to reflect tightened domestic supplies, a higher rate may not provide opportunities for foreign ethanol producers.

EIA (2022) data on Zimbabwean ethanol consumption also dates to 2013 and shows 0.6 million gallons were consumed that year. Consumption increased to 10 million gallons in 2014 and 11 million gallons in 2015 before increasing to 13 million gallons in 2016, where it remained through 2018. Motor gasoline consumption (including fuel ethanol) over these 6 years varied between 118 million gallons in 2017 and 163 million gallons in 2018. Effective blending rates were at least 7.2 percent in each of these years except 2015, which saw a rate of 0.4 percent.

Non-Consuming Countries

Based on EIA and USDA's FAS data, most countries and regions did not consume any fuel ethanol during the decade spanning 2009 to 2018. These non-consuming countries and regions consumed 83 billion gallons of motor gasoline in 2018, making this, in aggregate, a large potential market. However, in the absence of organic consumer demand, penetrating this market could require Government-imposed blending mandates. Such mandates may not be likely in many areas such as the member countries of the Organization of the Petroleum Exporting Countries (OPEC) and OPEC Plus.

Omitting OPEC, OPEC Plus (includes Russia), and any European Union countries, the total motor gasoline consumption in 2018 in non-fuel ethanol-consuming countries falls to 28.8 billion gallons. Of these countries, the five largest motor gasoline consumers were Indonesia (9.1 billion gallons), Egypt (2.6 billion gallons), Chile (1.2 billion gallons), Israel (1.1 billion gallons), and Puerto Rico (941 million gallons).

In Indonesia, bioethanol mandates were proposed in 2008, but no progress has been made: 2 percent for public service obligation (PSO) transportation, 5 percent for non-PSO transportation, and 5 percent industry by 2016; 5 percent for PSO, 10 percent for non-PSO, and 10 percent for industry by 2020; and 20 percent for all three categories by 2025 (Rahmanulloh, 2020). More recently, the National Energy Plan (2014) called for economywide renewable fuel use of 23 percent by 2025 and 31 percent by 2050 (Rahmanulloh, 2021). In Chile, an E5 target was in place as of 2017, but there was no official mandate (Nguyen et al., 2017). Ethanol mandates or targets in Egypt, Israel, or Puerto Rico could not be found.

Table A-3

Country-specific biofuel/ethanol policies or targets

Country	Policy/target
Argentina	A 12-percent blend rate was mandated in April 2016 that was to expire in May 2021. In July 2021, Argentina passed Biofuels Law 27640, which maintains the 12-percent mandate, though the law also allows the mandate to be reduced to 9 percent if economically necessary (Joseph, 2021).
Australia	Australia does not have a national mandate for ethanol blending, and the federal government may not have the authority to implement a mandate (Biki, 2021).
Austria*	Austria is targeting a bioethanol share of 7–10 percent by volume by 2030 (Federal Ministry Republic of Austria, 2019).
Belgium*	There is a biofuel incorporation rate of 9.55 percent for 2020, increasing to 13.9 percent in 2029 and 2030. The incorporation rate for first-generation biofuels is set at 7 percent for the full period (Government of Belgium, 2019).
Bolivia	Had a mandated level of 10 percent for 2018 that was to increase to 25 percent in 2025 (Nolte, 2018).
Brazil	For blended gasoline, the current blend mandate is 27 percent; legislation allows this mandate to increase to 27.5 percent. The new RenovaBio program creates a credit trading program where one credit, a CBio, represents greenhouse gas savings of 1 metric ton. Fuel distributors are required to purchase CBios (Barros, 2020). By 2030, the targeted number of CBios is 90.67 million.
Bulgaria*	With respect to total energy in the transport sector (measured in millions of tonnes of oil equivalent), Bulgaria was targeting a biofuel share of 7 percent in 2021, which would ultimately decrease to 4.7 percent in 2030 (Republic of Bulgaria, Ministry of Energy and Ministry of the Environment and Water, 2020).
Canada	Fuel producers and importers must have an average ethanol content of at least 5 percent. Higher rates have been set in some provinces (Danielson, 2020). The draft Clean Fuel Standard will seek to lower the lifecycle carbon intensity (CI) of fuels and energy (Danielson, 2021). Gasoline (which was assigned a CI score of 92) has a target CI of 82 in 2030—which could be met, for example, by blending with lower CI-score ethanol.
China	Legislation enacted in 2017 called for a nationwide blending rate of 10 percent by 2020 (McGrath, 2020).
Colombia	An E10 mandate was introduced in March 2018 (USDA, Foreign Agricultural Service, Bogota Staff, 2020).
Costa Rica	As of early 2020, the Government was planning to introduce an 8-percent blending rate, following nine failed attempts at the same legislation (Sapp, 2020). It is unclear if this blending rate was implemented.
Croatia*	Croatia is projecting a share of about 1 percent for first-generation biofuels in the transport sector in 2021, increasing to about 2 percent in 2030 (estimated from figure 2-4 in Croatia's Integrated National Energy and Climate Plan).

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Cyprus*	Cyprus does not intend to blend ethanol with gasoline (Republic of Cyprus, 2020).
Czech Republic*	The Czech Republic is projecting ethanol consumption of 1,998 terajoules in 2021 and 2,629.8 terajoules by 2030 (Government of the Czech Republic, 2019).
Denmark*	Denmark projects that first-generation biofuel usage will remain constant at 5 percent of total transport energy through 2030 (Danish Ministry of Climate, Energy and Utilities, 2019).
Ecuador	Ecuador has had voluntary targets for ethanol since at least 2010 when an E5 pilot program was initiated in two cities (FAS Quito Staff, 2018). This initiative ultimately moved nationwide. In 2015, the target rate was increased to 10 percent (FAS Quito Staff, 2015).
Estonia*	Estonia is projecting no contribution from first-generation biofuels to total energy consumption in the transport sector by 2025 (Government of Estonia, 2019).
Ethiopia	Ethiopia has a 10-percent blending mandate (Gabisa et al., 2019).
Finland*	Finland projects the share of non-double counted biofuels will be 7 percent from 2020 to 2030 (Finland Ministry of Economic Afairs and Employment, 2019).
France*	With respect to first-generation biofuels, France intends to “maintain and not exceed a level of 7 percent by 2023 and 2028” (Government of France, 2020).
Germany*	Germany plans to limit the share of first-generation biofuels allowed under the Renewable Energy Directive to 5.3 percent in 2030 (Government of Germany, 2020).
Greece*	Greece projects a non-advanced biofuel share of energy in the transport sector of 2.2 percent in 2020, increasing to 2.7 percent in 2030 (Hellenic Republic, Ministry of the Environment and Energy, 2019).
Hungary*	Hungary has set the target of a minimum 14-percent share of renewable energy in transport by 2030 and will increase the share of first-generation biofuels produced from food crops and fodder plants to roughly 7 percent (Government of Hungary, Ministry of Innovation and Technology, 2020).
Iceland	In May 2017, Iceland approved a parliamentary resolution that set a goal of increasing the share of renewables in land-based transport from 6 to 10 percent by 2020 and to 40 percent by 2030. Biofuels must emit at least 50 percent less greenhouse gases than fossil fuels, and the maximum permitted fuel of the “first generation” was set to 7 percent (Government of Iceland, 146th Legislative Assembly, 2017).
India	India has goals of a 10-percent rate in 2022 and a 20-percent rate by 2025 (Chandra, 2021).
Indonesia	Indonesia is targeting an ethanol blend rate of 20 percent by 2025 and then maintaining this rate through 2050 (Rahmanulloh, 2021).
Ireland*	Ireland projects consumption of food or feed ethanol to range between 28.7 thousand tonnes of oil equivalent (ktoe) in 2030 and 34.3 ktoe in 2024 and 2025 (Government of Ireland, Department of Communications, Climate Action and Environment, 2019).
Italy*	Italy projects a decrease in first-generation biofuels to reach a contribution in the transport sector of approximately 0.7 million tonnes of oil equivalent, equal to 3 percent of total energy consumption in the transport sector, by 2030 (Government of Italy: Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, and the Ministry of Infrastructure and Transport , 2019).
Jamaica	According to the National Energy Policy 2009–2030 (NEP), Jamaica decided to phase out the use of methyl tertiary-butyl ether and replace it with ethanol, creating E10. It is unclear if this ever got beyond a pilot program. The NEP indicates Jamaica is targeting a 20-percent renewable share in its energy mix by 2030, though the report is primarily focused on electricity generation. Based on the Integrated Resource Plan (2020), this appears to still be the target.
Japan	The Sophisticated Methods of Energy Supply (fiscal year 2022 revision expected) mandates an ethanol usage of 500 million gallons of crude oil equivalent (Sasatani, 2020).
Latvia*	Latvia’s projections for the share of energy in the transport sector going to first-generation biofuels appears to be about 3 percent in 2020 and decreasing to about 1 percent in 2030 (estimated from figure 51 in Latvia’s National Energy and Climate Plan).
Lithuania*	Based on Lithuania’s National Energy and Climate Action Plan of the Republic of Lithuania for 2021–2030, Lithuania appears to be targeting a 7-percent share of energy content in the gasoline pool coming from biofuels.

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Luxembourg*	Luxembourg assumes "that the biofuel mix up to and including 2030 will consist of a maximum of 5 percent of first-generation fuels, measured by total road transport fuel demand" (Government of Luxembourg, 2018).
Malta*	Malta's stance on ethanol is unclear. For example, on page 67 of Malta's 2030 National Energy and Climate Plan (NECP), "Malta already has in place a substitution obligation on importers of petrol and diesel to blend an increasing share of biofuels in their mix with the aim of meeting the target of a 10-percent share of renewable energy sources in transport in 2020." However, page 68 of the NECP also states, "Bioethanol is currently not available for consumption in Malta…. Therefore, unless petrol with a sufficiently low Reid vapor pressure (RVP) is readily available in relatively small volumes and competitive prices, the warm climate in Malta would drive the vapour pressure of bioethanol-petrol blends above the limit determined by EN 228." As such, the authors take a conservative approach and assume Malta's ethanol consumption reduces in a linear fashion from a 1.6-percent blend rate in 2019 (the 2014–2018 average) to a zero-percent blend rate in 2030.
Mexico	There is no blending requirement in Mexico, and ethanol is not permitted within the major urban areas of Mexico City, Guadalajara, and Monterrey—which account for around 26 percent of the country's gasoline consumption (U.S. Grains Council, 2021). Outside of these cities, the maximum blending rate was 5.8 percent through July 2017, at which time it was increased to 10 percent (Biofuels International, 2020). However, the Mexico Supreme Court overturned this change in early 2020 on procedural grounds, arguing that the Energy Regulatory Commission exceeded its authority (Reuters, 2020).
Netherlands*	The Netherlands was planning to require all petrol stations with at least two pumps to supply E10 beginning in October 2019 (Government of The Netherlands, Ministry of Economic Affairs and Climate Policy, 2019).
New Zealand	New Zealand's Government has agreed in principle to implement a biofuels mandate (New Zealand Ministry of Transport, 2021). New Zealand is reviewing its 2008 Biofuels Sales Obligation for reinstatement, which set the biofuel proportion of 0.5 percent of liable suppliers' petrol sales.
Norway	Norway uses biofuel quotas to ensure that certain proportions of all fuel sales are biofuels. In January 2021, Norway set the biofuel quota at 24.5, of which 9 percent was to be advanced biofuels (Norwegian Ministry of Climate and Environment, 2021).
Panama	Law 42 (2011) mandated a 10-percent blend was to take effect by 2016, but this mandate was suspended in 2014 (IRENA, 2018). There is no indication that the mandate has been reinstated. El Plan Energetico Nacional 2015–2050 (2015) called for a 5-percent ethanol-blending rate by 2020 (Gionet, 2017).
Paraguay	Law 5444 (July 2015) sought to promote E85 by requiring local gasoline distributors to guarantee E85's availability nationally and implementing a switch to E85 in the Government fleet (Joseph, 2015), though it is unclear to what extent these efforts have succeeded. The official blending mandate appears to have been 25 percent, as of 2019 (Trindade et al., 2019).
Peru	The official blend mandate is 7.8 percent (Nolte, 2021). Peru is considering biofuels in strategies to achieve 30-percent emissions reductions by 2030 (Nolte, 2021).
Philippines	The Philippines is targeting a blend rate of 20 percent in 2020 and beyond, though this rate is expected to be a voluntary target rather than an official mandate (Mojica-Sevilla, 2021).
Poland*	Poland projected the share of energy in the transport sector coming from "first-generation biofuels/first-generation (hydrotreated vegetable oil)/(catalytically hydroconverted vegetable oil)" to be 6 percent in 2025 and 5.3 percent in 2030 (Government of Poland, 2019).
Slovakia*	Slovakia projected the total contribution from bioethanol/bio-ethyl tertiary-butyl ether in transport to grow from 50 (units not given but assumed to be in thousand tonnes of oil equivalent (ktoe)) in 2020 to 55 ktoe in 2030 (Slovak Ministry of Economy, 2019).
South Africa	A mandatory bioethanol blending of 2 percent—from locally produced sources—was implemented in 2015 via the Biofuels Industrial Strategy. The South African Biofuels Regulatory Framework (approved in December 2019) indicates the current target is for 4.5-percent penetration by biofuels, with 2 percent coming from first-generation biofuels.

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Spain*	Spain was projecting the share of energy in the transport sector coming from biofuels produced with food and feed crops to remain just under 7 percent from 2020 to 2030 (Government of Spain, 2020).
Thailand	Thailand has no official blending mandate, though the country plans to phase out E10 and E85 by 2027, thus making E20 the primary gasohol (Mullis, 2021).
Ukraine	Ukraine has no apparent ethanol blending mandate. The "Energy Strategy of Ukraine until 2035"—adopted in 2016—set a target of 11.5 percent for biofuels' share in the total primary energy supply.
United Kingdom	E10 became the "standard" grade offered at retail locations beginning in the summer of 2021. E5 continues to be available in "super" grade gasoline (United Kingdom Department for Transport, 2021).
United States	Required ethanol blending is determined by the renewable volume requirements set by the Environmental Protection Agency. There is no statutory requirement for "conventional" biofuels. Rather, this amount is determined by subtracting the advanced biofuels requirements from the total renewable fuel requirement. This residual "conventional" biofuel requirement is primarily met through the use of corn-based ethanol. The requirement for conventional biofuels in 2022 is 15.25 billion gallons, which includes a 250-million-gallon supplemental obligation (Renewable Fuel Standard (RFS) Program: RFS Annual Rules, 87 Fed. Reg. 39600, 2022).
Uruguay	Uruguay instituted a 5-percent blend mandate beyond 2015 (IRENA, 2015). The mandate was to be filled using locally produced ethanol, though exceptions could be made for "national interest" (IRENA, 2015).
Vietnam	Decision 53 set a goal of nationwide commercialization of E5 by December 2015 and E10 by December 2017 (Francic, 2020). However, the E5 mandate was not officially launched until 2018 (Francic, 2020). A move to E10 is still planned (Francic, 2020), though the timeline is uncertain.
Zimbabwe	Mandatory ethanol blending in Zimbabwe dates to at least the 2013 passage of the Petroleum (Mandatory Blending of Anhydrous Ethanol with Unleaded Petrol) Regulations. Under these regulations, all gasoline sold was required to be blended with a minimum of 5 percent ethanol. The Government has revised the mandate (based on economic conditions), such as in 2017 when the rate was increased to 10 percent, following a reduction from 15 percent to 5 percent (Biofuels International, 2017). More recently, the mandate was revised down to 10 percent from 20 percent due to rain-related harvest difficulties (Sapp, 2020). The change to a 20-percent mandate had come from a 2020 amendment to the regulation.

*Under the European Union's Renewable Energy Directive II, the share of biofuels derived from food/feed crops is capped at the lower of 1 percent higher than 2020 share or 7 percent of final consumption of energy in the road and rail transport sectors. However, if the 2020 share was less than 1 percent, the cap would be 2 percent. Percentages may include double-counting methods.

Source: USDA, Economic Research Service.

The table below presents the assumed blending rates for select countries under the Historical Blends (HB) and Targeted Blends (TB) scenarios. For those countries for which USDA's Foreign Agricultural Service data were used (denoted with *), the assumed rates begin in 2022. For those countries for which the U.S. Department of Energy's Energy Information Administration's data were used, the assumed blending rates begin in 2019. For Brazil, Canada, Czech Republic, Ireland, Japan, and Slovakia, the TB blend rates are the result of the approaches found in the "Targeted Blends Scenarios for Select Countries" subsection of this appendix.

Table A-4

Historical and assumed blending rates for select countries, 2018–30

Country	Scenario	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Argentina*	HB	11.3%	11.6%	11.4%	11.7%	11.6%	11.6%	11.6%	11.6%	11.6%	11.6%	11.6%	11.6%	11.6%
	TB	11.3%	11.6%	11.4%	11.7%	11.6%	11.6%	11.7%	11.7%	11.8%	11.8%	11.9%	11.9%	12.0%
Australia*	HB	1.7%	1.5%	1.1%	1.0%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
	TB	1.7%	1.5%	1.1%	1.0%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
Austria	HB	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
	TB	5.0%	5.0%	5.5%	5.9%	6.4%	6.8%	7.3%	7.7%	8.2%	8.6%	9.1%	9.5%	10.0%
Belgium	HB	8.8%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%
	TB	8.8%	5.9%	6.3%	6.8%	7.2%	7.7%	8.1%	8.5%	9.0%	9.4%	9.9%	10.3%	10.7%
Bolivia	HB	0.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
	TB	0.0%	5.0%	6.8%	8.7%	10.5%	12.3%	14.1%	15.9%	17.7%	19.6%	21.4%	23.2%	25.0%
Brazil*	HB	51.5%	54.1%	52.5%	50.9%	50.6%	50.6%	50.6%	50.6%	50.6%	50.6%	50.6%	50.6%	50.6%
	TB	51.5%	54.1%	52.5%	50.9%	50.6%	50.6%	50.6%	56.2%	62.5%	67.4%	72.1%	76.2%	78.7%
Bulgaria	HB	7.3%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%
	TB	7.3%	6.8%	6.8%	6.9%	6.9%	7.0%	7.0%	7.0%	7.1%	7.1%	7.2%	7.2%	7.2%
Canada*	HB	5.8%	6.3%	6.5%	6.0%	6.1%	6.1%	6.1%	6.1%	6.1%	6.1%	6.1%	6.1%	6.1%
	TB	5.8%	6.3%	6.5%	6.0%	6.1%	9.2%	12.2%	15.3%	18.4%	21.5%	24.5%	27.6%	30.7%
China*	HB	2.0%	2.3%	2.0%	2.1%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
	TB	2.0%	2.3%	2.0%	2.1%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%
Colombia*	HB	9.4%	9.6%	10.3%	7.8%	8.8%	8.8%	8.8%	8.8%	8.8%	8.8%	8.8%	8.8%	8.8%
	TB	9.4%	9.6%	10.3%	7.8%	8.8%	8.9%	9.1%	9.2%	9.4%	9.5%	9.7%	9.8%	10.0%
Costa Rica	HB	0.0%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
	TB	0.0%	4.6%	4.8%	5.0%	5.2%	5.5%	5.7%	5.9%	6.1%	6.3%	6.6%	6.8%	7.0%
Croatia	HB	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TB	0.1%	0.0%	0.3%	0.6%	0.9%	1.2%	1.5%	1.8%	2.0%	2.3%	2.6%	2.9%	3.2%
Cyprus	HB	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	TB	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Czech Republic	HB	5.0%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%
	TB	5.0%	5.7%	6.3%	6.4%	6.4%	6.4%	6.5%	6.5%	6.6%	6.6%	6.7%	6.8%	6.8%
Denmark	HB	4.8%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
	TB	4.8%	4.6%	4.9%	5.2%	5.4%	5.7%	6.0%	6.3%	6.6%	6.9%	7.2%	7.5%	7.8%

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Country	Scenario	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Ecuador	HB	1.5%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
	TB	1.5%	0.8%	1.7%	2.5%	3.3%	4.2%	5.0%	5.8%	6.7%	7.5%	8.3%	9.2%	10.0%
Estonia	HB	2.4%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
	TB	2.4%	1.7%	1.5%	1.4%	1.2%	1.1%	0.9%	0.8%	0.6%	0.5%	0.3%	0.2%	0.0%
Ethiopia	HB	0.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
	TB	0.0%	2.0%	2.7%	3.5%	4.2%	4.9%	5.6%	6.4%	7.1%	7.8%	8.5%	9.3%	10.0%
Finland	HB	8.9%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%	7.2%
	TB	8.9%	7.2%	7.1%	7.1%	7.1%	7.1%	7.1%	7.1%	7.1%	7.0%	7.0%	7.0%	7.0%
France	HB	9.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%
	TB	9.4%	8.4%	8.6%	8.8%	9.0%	9.2%	9.5%	9.7%	9.9%	10.1%	10.3%	10.5%	10.7%
Germany	HB	4.7%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
	TB	4.7%	5.5%	5.8%	6.0%	6.3%	6.5%	6.8%	7.0%	7.2%	7.5%	7.7%	8.0%	8.2%
Greece	HB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TB	0.0%	0.0%	0.4%	0.8%	1.2%	1.5%	1.9%	2.3%	2.7%	3.1%	3.5%	3.9%	4.3%
Hungary	HB	5.3%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%
	TB	5.3%	5.2%	5.7%	6.2%	6.7%	7.2%	7.7%	8.2%	8.7%	9.2%	9.7%	10.2%	10.7%
Iceland	HB	4.3%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
	TB	4.3%	2.4%	2.8%	3.3%	3.7%	4.1%	4.5%	4.9%	5.3%	5.8%	6.2%	6.6%	7.0%
India*	HB	3.9%	4.5%	5.0%	7.5%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
	TB	3.9%	4.5%	5.0%	7.5%	4.6%	6.5%	8.4%	10.3%	12.3%	14.2%	16.1%	18.1%	20.0%
Indonesia*	HB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TB	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	5.0%	7.5%	10.0%	12.5%	15.0%	17.5%	20.0%
Ireland	HB	5.0%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
	TB	5.0%	5.3%	5.8%	6.3%	6.4%	6.5%	6.6%	6.7%	6.8%	6.7%	6.6%	6.5%	6.2%
Italy	HB	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	TB	0.5%	0.4%	0.8%	1.2%	1.6%	2.0%	2.4%	2.8%	3.1%	3.5%	3.9%	4.3%	4.7%
Jamaica	HB	0.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
	TB	0.0%	8.0%	9.1%	10.2%	11.3%	12.4%	13.5%	14.6%	15.7%	16.7%	17.8%	18.9%	20.0%
Japan*	HB	1.6%	1.6%	1.9%	1.8%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
	TB	1.6%	1.6%	1.9%	1.8%	1.8%	1.9%	1.9%	2.0%	2.0%	2.1%	2.1%	2.2%	2.2%
Latvia	HB	6.4%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%
	TB	6.4%	5.3%	5.0%	4.6%	4.3%	3.9%	3.6%	3.2%	2.9%	2.5%	2.1%	1.8%	1.4%

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Country	Scenario	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lithuania	HB	4.9%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
	TB	4.9%	5.0%	5.5%	6.0%	6.5%	7.1%	7.6%	8.1%	8.6%	9.2%	9.7%	10.2%	10.7%
Luxembourg	HB	4.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%
	TB	4.4%	3.4%	3.8%	4.2%	4.6%	5.0%	5.4%	5.8%	6.2%	6.6%	7.0%	7.4%	7.8%
Malta	HB	0.0%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%
	TB	0.0%	1.6%	1.5%	1.3%	1.2%	1.0%	0.9%	0.7%	0.6%	0.4%	0.3%	0.1%	0.0%
Mexico	HB	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	TB	0.4%	0.4%	1.2%	2.1%	3.0%	3.9%	4.7%	5.6%	6.5%	7.4%	8.2%	9.1%	10.0%
Mozambique	HB	0.0%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
	TB	0.0%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Netherlands	HB	5.9%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
	TB	5.9%	4.8%	5.3%	5.8%	6.2%	6.7%	7.2%	7.7%	8.1%	8.6%	9.1%	9.5%	10.0%
New Zealand	HB	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	TB	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%
Norway	HB	6.6%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%
	TB	6.6%	4.2%	5.2%	6.2%	7.3%	8.3%	9.3%	10.3%	11.4%	12.4%	13.4%	14.5%	15.5%
Panama	HB	0.0%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
	TB	0.0%	1.7%	2.0%	2.3%	2.6%	2.9%	3.2%	3.5%	3.8%	4.1%	4.4%	4.7%	5.0%
Paraguay	HB	33.4%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%	30.8%
	TB	33.4%	30.8%	30.2%	29.7%	29.2%	28.7%	28.1%	27.6%	27.1%	26.6%	26.0%	25.5%	25.0%
Peru*	HB	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%
	TB	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%
Philippines	HB	8.6%	8.8%	8.8%	8.8%	8.6%	8.6%	8.6%	8.6%	8.6%	8.6%	8.6%	8.6%	8.6%
	TB	8.6%	8.8%	8.8%	8.8%	8.6%	10.1%	11.5%	12.9%	14.3%	15.7%	17.2%	18.6%	20.0%
Poland	HB	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
	TB	5.6%	5.6%	5.8%	6.1%	6.4%	6.6%	6.9%	7.2%	7.4%	7.7%	8.0%	8.2%	8.5%
Portugal	HB	0.8%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
	TB	0.8%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Romania	HB	8.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%
	TB	8.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%
Slovakia	HB	5.7%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
	TB	5.7%	5.6%	5.6%	12.7%	12.9%	13.1%	13.2%	13.4%	14.9%	15.2%	15.5%	15.8%	16.1%

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Country	Scenario	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Slovenia	HB	2.3%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
	TB	2.3%	1.8%	2.4%	2.9%	3.5%	4.0%	4.5%	5.1%	5.6%	6.2%	6.7%	7.3%	7.8%
South Africa	HB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TB	0.0%	0.0%	0.2%	0.4%	0.6%	0.8%	0.9%	1.1%	1.3%	1.5%	1.6%	1.8%	2.0%
Spain	HB	4.0%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
	TB	4.0%	4.6%	5.1%	5.6%	6.2%	6.7%	7.2%	7.8%	8.3%	8.9%	9.4%	9.9%	10.5%
Sweden	HB	7.4%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%
	TB	7.4%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%	6.9%
Switzerland	HB	1.6%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
	TB	1.6%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Taiwan	HB	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	TB	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Thailand*	HB	13.2%	13.7%	12.8%	12.8%	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%
	TB	13.2%	13.7%	12.8%	12.8%	13.1%	14.0%	14.8%	15.7%	16.5%	17.4%	18.3%	19.1%	20.0%
Turkey	HB	3.2%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%
	TB	3.2%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%
Ukraine	HB	12.3%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%
	TB	12.3%	6.5%	7.0%	7.4%	7.9%	8.3%	8.8%	9.2%	9.7%	10.1%	10.6%	11.0%	11.5%
United Kingdom	HB	4.7%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
	TB	4.7%	4.4%	5.0%	5.5%	6.0%	6.5%	7.0%	7.5%	8.0%	8.5%	9.0%	9.5%	10.0%
United States	HB	10.1%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
	TB	10.1%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Uruguay	HB	5.5%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
	TB	5.5%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Vietnam	HB	1.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
	TB	1.8%	0.8%	1.6%	2.4%	3.3%	4.1%	5.0%	5.8%	6.6%	7.5%	8.3%	9.2%	10.0%
Zimbabwe	HB	7.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%	8.7%
	TB	7.7%	8.7%	9.7%	10.7%	11.8%	12.8%	13.8%	14.9%	15.9%	16.9%	17.9%	19.0%	20.0%

Notes: HB = Historical Blends scenario; TB = Targeted Blends scenario.

Source: USDA, Economic Research Service using assumed rates for the TB scenario and data from U.S. Department of Energy, Energy Information Administration and USDA, Foreign Agricultural Service for the HB scenario.

Targeted Blends Scenarios for Select Countries

Brazil

The RenovaBio program was used to set a minimum consumption level under the Targeted Blends scenario. The starting point is CBios requirements per year (table A-1). From this, the authors calculated the share of CBios going to ethanol based on Ribeiro and da Cunha's (2022) projections for CBios issued for ethanol and biodiesel.

Table A-5

Estimated ethanol and total CBios from Ribeiro and da Cunha, 2021–29 (million of CBios)

	2022	2023	2024	2025	2026	2027	2028	2029
Ethanol CBios	39.16	40.27	46.34	52.63	59.27	65.48	70.95	76.71
Total CBios	58.90	62.10	69.00	76.10	83.50	90.60	96.4	103.00
Ethanol share	66.5%	64.8%	67.2%	69.2%	71.0%	72.3%	73.6%	74.5%

Source: USDA, Economic Research Service using data from Riberio and da Cunha (2022).

We then applied these shares and an assumed ratio of 800 liters of ethanol per CBio (based on de Castro (2020)) to the total CBios requirements (see table A-1) to yield the minimum ethanol consumption levels under the TB scenario:

Table A-6

Assumed minimum ethanol consumption levels under the Targeted Blends scenario, 2021–29

	2022	2023	2024	2025	2026	2027	2028	2029
Ethanol share[1]	66.5%	64.8%	67.2%	69.2%	71.0%	72.3%	73.6%	74.5%
CBios requirements (millions)[2]	35.98	42.35	50.81	58.91	66.49	72.93	79.29	85.51
Assumed ethanol CBios (millions)	23.93	27.44	34.14	40.77	47.21	52.73	58.36	63.70
Liters of ethanol per CBio[3]	800	800	800	800	800	800	800	800
Assumed ethanol minimum (billion liters)	19.14	21.95	27.32	32.61	37.77	42.18	46.69	50.96
Assumed ethanolmini-mum (billion gallons)	5.06	5.80	7.21	8.61	9.97	11.14	12.33	13.46

Notes: [1]Reflects data from Ribeiro and da Cunha (2022), [2]reflects data from Barros (2021), and [3]reflects data from Castro (2022).

Source: USDA, Economic Research Service calculations using data from Ribeiro and da Cunha (2022), Barros (2021), and Castro (2022).

Because Ribeiro and da Cunha (2022) did not estimate CBios for 2030, the authors assumed the 2030 share of CBios going to ethanol is the same as that used for 2029. The minimum ethanol consumption level for 2030 is then calculated in the same manner as those above and was set at 14.27 billion gallons.

Canada

Canada's Clean Fuel Standard (CFS) has set carbon intensity (CI) limits for gasoline through 2030 (table A-2). Under the CFS, there are three broad options by which CI limits can be met. For each compliance period, a primary supplier will have an emissions reduction requirement for each liquid fossil fuel type and must satisfy these requirements with credits that represent emissions reductions. Credits can be created by primary suppliers and other parties through three compliance categories, including the following:

- **The supply of low-CI fuels.** A key pathway to reducing the lifecycle CI of fossil fuels is to blend low-CI fuels with fossil fuels or use low-CI fuels in their neat form (not combined with other fuels). Low-CI fuels are fuels (excluding the fossil fuels subject to CI reduction requirements) that have a CI of 90 percent or less than the credit reference CI value for the fuel. Credits accrue for low-CI fuels whether domestically produced in or imported to Canada. Eligible fuels in the liquid class may include (but are not limited to): ethanol, renewable diesel, biodiesel, hydrotreated vegetable oil, low-CI jet fuel, synthetic fuels, and renewable methanol.

The authors assume that Canada achieves its CI reduction goal—a corresponding CI score of 82 grams of carbon dioxide equivalents per megajoule (g CO_2e/MJ)—for gasoline in 2030. To turn this into a blend rate, the authors use the following equation:

$$\frac{g\ CO_2e}{MJ} = \frac{\alpha * CI_E * MJ_E + (1-\alpha) * CI_G * MJ_G}{\alpha * MJ_E + (1-\alpha) * MJ_G} = CI_T$$

where CI_E is the CI of ethanol, CI_G is the CI of gasoline, MJ_E is megajoules per liter of ethanol, MJ_G is megajoules per liter of gasoline, α is the blend rate, and CI_T is the target emissions for gasoline in 2030. Solving this for α yields

$$\alpha = \frac{MJ_G CI_T - CI_G MJ_G}{CI_E MJ_E - CI_G MJ_G - MJ_E CI_T + MJ_G CI_T}$$

The authors use the following values below to determine the 2030 blend rate. All values except for MJ_G come from Canada's "Clean Fuel Standard: proposed regulatory approach" as the CFS document did not provide an energy density for gasoline. As such, that value was obtained from Boechler et al. (2021):

- CI_E = ethanol baseline carbon intensity of 49 g CO_2e/MJ
- CI_G = gasoline baseline carbon intensity of 92 g CO_2e/MJ
- MJ_E = 23.42 MJ/liter
- MJ_G = 34.2 MJ/liter
- CI_T = 82

Thus, the authors get a blend rate of $\alpha \approx 0.3067$, or about 30.7 percent.

Note that this a very simplistic approach and likely represents an upper boundary for reasons including:

- Assumes no credit creation from "actions throughout the lifecycle of a fossil fuel that reduce its carbon intensity" (Government of Canada, 2019).
- Assumes no credit creation from "specific end-use fuel switching in transportation" (Government of Canada, 2019).
- Ignores that the CFS "will allow primary suppliers to apply any type of credit to satisfy any fossil fuel type's reduction requirement" (Government of Canada, 2019).

Czech Republic

The Czech Republic projects the following ethanol consumption in the transport section (table 20 from the National Energy and Climate Plan of the Czech Republic):

Table A-7
Expected Czech Republic consumption of bioenergy in the transport sector, 2016–30 (terajoules (TJ))

	2016	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Ethanol	1,998.0	2,836.5	2,842.9	2,823.8	2,802.3	2,780.0	2,756.9	2,728.7	2,700.5	2,674.5	2,653.4	2,629.8

Notes: The authors use a linear interpolation using the 2016 and 2020 values to assign a value of 2,626.9 TJ for 2019.

Source: USDA, Economic Research Service using data from National Energy and Climate Plan of the Czech Republic.

Assuming 76,330 British thermal units (Btu) in a gallon of ethanol and 1,055 joules per Btu yields 80,531,315 joules in a gallon of ethanol. Since 1 TJ = 1,000,000,000,000 joules; 1 gallon of ethanol = 0.000080531315 TJ. Thus, the above numbers correspond to the following ethanol volumes (billions of gallons):

Table A-8
Expected Czech Republic consumption of ethanol, 2019-30 (millions of gallons)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Ethanol	32.62	35.22	35.30	35.07	34.80	34.52	34.24	33.89	33.53	33.21	32.95	32.66

Sources: USDA, Economic Research Service calculations using data from National Energy and Climate Plan of the Czech Republic.

Ireland

From table 6 of Ireland's National Energy and Climate Plan:

Table A-9
Ireland renewable transport consumption by source, 2018–30 (kilotonnes of oil equivalent)

	2018	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Food or feed ethanol	27.3	33.9	34.1	34.2	34.3	34.3	34.2	33.4	32.2	30.7	28.7

Note: Because values were not provided for 2019 and 2020, kilotonnes of oil equivalent (ktoe) values for these years were estimated using a linear interpolation based on the 2018 and 2021 values. The resulting values were 29.5 ktoe for 2019 and 31.7 ktoe for 2020.

Source: USDA, Economic Research Service using data from Ireland's National Energy and Climate Plan.

Using 39,652,608,749 Btu/ktoe and 76,330 Btu/gallon of ethanol yields the following ethanol volumes (millions of gallons):

Table A-10
Assumed ethanol consumption for Ireland in the Targeted Blends scenario, 2019–30 (millions of gallons)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Ethanol	15.32	16.47	17.61	17.71	17.77	17.82	17.82	17.77	17.35	16.73	15.95	14.91

Source: USDA, Economic Research Service calculations using Ireland's National Energy and Climate Plan.

Japan

Japan is assumed to maintain its 500-liter crude-oil-equivalent (LOE) requirement through 2030. Based on Rakhovskaya (2021), 1 liter of ethanol = 0.607 LOE, so this corresponds to an ethanol consumption of 823 million liters (or 218 million gallons) per year.

From table 14 in Slovakia's Integrated National Energy and Climate Plan for 2021 to 2030 (NECP):

Table A-11
Slovakia's estimated ethanol contribution to the transport sector, 2021–30 (kilotonnes of oil equivalent)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Bioethanol/bio-ETBE	50	50	50	50	50	55	55	55	55	55

Note: bio-ETBE = bio-ethyl tertiary-butyl ether.

Source: USDA, Economic Research Service using data from Slovakia's Integrated National Energy and Climate Plan for 2021 to 2030.

Units were not provided for table A-11 in Slovakia's NECP; it is assumed they are ktoe. Using 39,652,608,749 Btu/ktoe and 76,330 Btu/gallon of ethanol yields the following ethanol volumes (millions of gallons):

Table A-12
Assumed ethanol consumption for Slovakia in the Targeted Blends scenario, 2021–30 (millions of gallons)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Bioethanol/bio-ETBE	25.97	25.97	25.97	25.97	25.97	28.57	28.57	28.57	28.57	28.57

Note: bio-ETBE = bio-ethyl tertiary-butyl ether.

Source: USDA, Economic Research Service calculations using data from Slovakia's Integrated National Energy and Climate Plan 2021 to 2030.

Ethanol consumption for 2019 and 2020 were set equal to the Historical Blends values. As seen in table A-4, these volumes, result in an effective blending rate of 16.1 percent in 2030. The European Union's Renewable Energy Directive II caps the share of biofuels derived from food/feed crops is capped at the lower of 1 percent higher than 2020 share or 7 percent of final energy consumption in the road and transport sectors. Note, however, that 7 percent of total energy does not lead to specific requirements for percent by volume. Regardless, it is likely that much of the projected ethanol consumption for Slovakia under the Targeted Blends scenario would need to come from non-food/feed crop-based ethanol.