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Global Ethanol Mandates: Opportunities for U.S. Exports of Ethanol and DDGS

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Abstract

Before 2001, only Brazil and Paraguay required ethanol to be blended with gasoline for fuel use. With biofuel production still in the nascent stage, these countries were unable to meet those mandates. From 2001 to 2010, ethanol-use mandates adopted by the United States and the European Union (EU), along with favorable market conditions, stimulated a rapid increase in ethanol production in the United States, the EU, and Brazil. By 2016, an additional 26 countries had adopted mandates, and others had set ethanol targets or were using ethanol without an official requirement. Many of these countries have difficulty meeting their mandates with domestic production. Some import ethanol (e.g., Canada and Japan); others have barriers against imports (e.g., Argentina and China). If these countries strive to meet their mandates and open their borders to trade, they could present strong export opportunities for U.S. ethanol, assuming the United States can sufficiently expand production. The United States currently is the world's largest producer and exporter of ethanol. It also supplies 85 percent of the world's distillers' dried grains with solubles (DDGS), a coproduct of grain-based ethanol production that is used in animal feed. This report also discusses the potential for changes in DDGS trade.

Keywords: Ethanol, DDGS, trade, U.S., global

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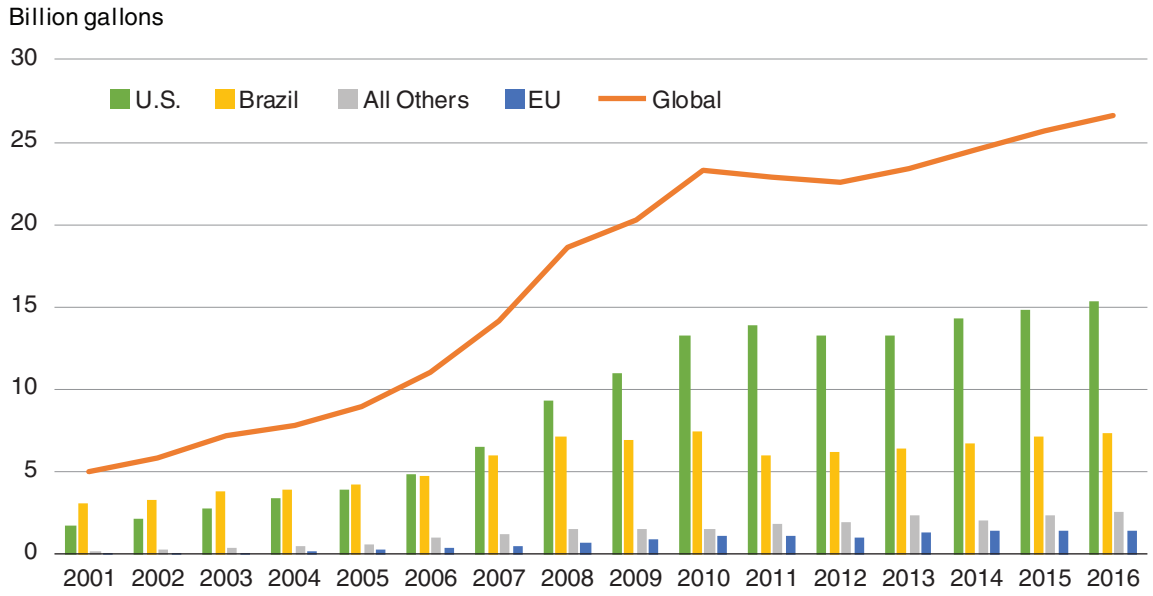
Introduction

Ethanol production has increased rapidly over the last two decades, making ethanol an important component of today's transportation fuels. From 2001 to 2016, global ethanol production grew 400 percent, from 5 billion gallons to almost 27 billion gallons (fig. 1). Historically, the United States, Brazil, and the European Union (EU) were the world's major ethanol markets. In the United States alone, ethanol makes up 10 percent of total gasoline use. Government blending mandates have helped fuel increases in ethanol production and consumption worldwide. For example, China set ambitious targets and boosted production by over two-thirds in the past decade, making it the world's third-largest ethanol-producing and ethanol-consuming nation. Despite the global increase in ethanol production, however, many countries do not meet their mandates. Of the ethanol-producing countries outside of the United States, Brazil, and the EU ("All Others" category in fig. 1), five countries—Argentina, Canada, China, India, and Thailand—account for 80 percent of the production.

Production of ethanol from corn, sorghum, wheat, and other grains results in a coproduct called "distillers' grains with solubles," or DGS (see box, "Grain-Based Ethanol Production"). DGS are used in animal feed, substituting for corn and soybean meal. Approximately one-third of the grains used to produce ethanol is returned to the market in the form of DGS. Not surprisingly, as the world's largest producer and exporter of grain-based ethanol, the United States is also the global leader in the production and exportation of DGS, with an 85-percent share of the market. The United States exports a dried form of DGS, referred to as distillers' dried grains with solubles, or DDGS, which constitutes the majority of U.S.-produced DGS.[1] Most countries that produce DDGS consume it domestically.

Figure 1
Ethanol production (billion gallons)



Source: U.S. Department of Energy, Energy Information Administration (EIA, 2016a), 2000-12 data; Renewable Fuels Association (RFA, 2017), 2013-16 data.

[1]The rest of the report will mention only DDGS because they provide the export opportunities.

Box 1

Grain-Based Ethanol Production

Ethanol production plants can either be dry- or wet-mill based. The wet-milling process is designed to extract the most uses from the grain, but it is more capital intensive than dry milling, with higher operating costs. The dry-milling process focuses primarily on the production of ethanol. Nearly 95 percent of U.S. ethanol plants use the corn dry-milling process, accounting for 89 percent of the total volume of U.S.-produced ethanol (AFDC, 2016). Whether dry- or wet-mill based, most ethanol plants that use grains produce "distillers' grains with solubles" (DGS) in the milling process. Initially, DGS are wet (known as WDGS). WDGS have a limited shelf life (Lemenager et al., 2006, put it at 3-7 days), and they are usually consumed in close proximity to the ethanol plant. However, DGS can be dried, creating "distillers' *dried* grains with solubles" (DDGS), which have an almost indefinite shelf life and can be transported long distances (Pottgüter, 2015).

Prior to 2001, only Brazil and Paraguay had ethanol mandates. Since then, the number of countries with ethanol mandates has grown considerably as governments adopt the policies to promote energy independence and for other economic and environmental reasons. By 2016, the United States, Brazil, the 28 countries in the European Union, and 26 other countries had ethanol mandates.[2] Most recently, some African countries have instituted ethanol blending mandates, ranging from 2 percent in South Africa to 15 percent in Zimbabwe. Additional countries have ethanol blending targets, and others use ethanol without an official requirement.

The growing importance of other countries in the global ethanol market highlights the need to better understand their market and policy conditions, including their capabilities of meeting mandates with domestic production and their need for imports. The increase in mandates presents strong and diverse export market opportunities for U.S. ethanol.

[2]Angola, Argentina, Australia, Canada, China, Colombia, Costa Rica, Ecuador, Ethiopia, India, Indonesia, Jamaica, Malawi, Mexico, Mozambique, Norway, Paraguay, Peru, the Philippines, South Africa, Sudan, Thailand, Turkey, Ukraine, Vietnam, Zimbabwe. (Japan's mandate started in 2017.)

The Status of the U.S. Ethanol Industry

The United States has produced at least 1 billion gallons of corn-based ethanol annually since 1993 (RFA, 2016b). Production was less than 5 billion gallons until the mid-2000s, when it began rapidly increasing (table 1). Key to the increase was creation of the Renewable Fuel Standard (RFS) program, enacted under the Energy Policy Act of 2005, which mandates a certain volume of biofuel use in gasoline, but also limits the amount that can be derived from corn-based ethanol. By 2006, the United States was the world's largest ethanol producer. Indeed, the production of ethanol so far exceeded the 2005 volume mandates for U.S. consumption (RFS1), Congress revised the mandates in 2007 (RFS2). (For information on the mandates, see Beckman (2015) and Schnepf and Yacobucci (2013).) U.S. production has slowed in recent years, however, as it neared the E10 "blend wall"—the 10-percent limit on ethanol in the ethanol/gasoline mixture commonly used in the United States.

Similarly, there is a blend wall for DDGS. Because of the fermentation process that removes the starch component of the corn during ethanol production, DDGS have a higher protein, fat, and fiber content than corn. These features lead to limits on the percentage of DDGS that can be used in livestock feed (see Box, "'Blend Wall' Limits Consumption of Ethanol and Its DDGS Coproduct").

Table 1
U.S. corn used for ethanol, ethanol and DDGS production and export, and implied mandated corn-based ethanol volumes, 2001-16

Year	Corn Used	Ethanol			Mandate Amount		DDGS	
	for Ethanol	Production	Export	Imports	RFS1	RFS2	Production	Export
	(million bushels)	(billion gallons)					(million metric tons)	
2001	707	1.77		0.01				
2002	996	2.14		0.01				
2003	1,168	2.80		0.01				
2004	1,323	3.40		0.15				
2005	1,603	3.90	0.06	0.14			10.1	1.2
2006	2,119	4.88	0.04	0.73	4		13.6	1.8
2007	3,049	6.52	0.15	0.44	4.7		20.8	3.9
2008	3,709	9.31	0.16	0.53	5.4	9	27.2	5.0
2009	4,591	10.94	0.11	0.2	6.1	10.5	33.7	8.3
2010	5,019	13.30	0.40	0.02	6.8	12	36.9	8.3
2011	5,000	13.93	1.20	0.17	7.4	12.6	36.7	7.6
2012	4,641	13.22	0.74	0.49	7.5	13.2	33.9	8.2
2013	5,124	13.31	0.62	0.38	7.6	13.8	37.0	12.0
2014	5,200	14.34	0.85	0.07	7.7	13.61	37.5	11.6
2015	5,206	14.81	0.84	0.09	7.8	14.05	37.2	11.7
2016	5,300	15.33	1.05	0.03	7.9	14.50	37.8	10.3

Note: DDGS = distillers' dried grains with solubles. Corn used for ethanol and DDGS data are based on marketing year; ethanol production is based on calendar year. RFS1 represents the original Renewable Fuel Standard (RFS)(2005) maximum amount of ethanol; RFS2 represents the revised amounts for total renewable fuel in the Energy Independence and Security Act of 2007. RFS2 implied 15 billion gallons of corn-based ethanol by 2015; however, the amounts were revised down beginning in 2014.

Source: USDA, Economic Research Service (ERS) calculations from U.S. Department of Energy, Energy Information Administration (EIA, 2016b); USDA, ERS (2016c); Informa (2016); Renewable Fuels Association (RFA, 2017); and Schnepf and Yacobucci (2013).

Box 2

‘Blend’ Wall Limits Consumption of Ethanol and Its DDGS Coproduct

Globally, most gasoline-powered vehicles run on some mixture of ethanol and gasoline, where ethanol is used as an additive to raise the octane rating of fuel and, thus, increase the air-fuel mixture before it will burn. E10, a mixture of 10-percent ethanol, is the most common ethanol blend used in the United States. Blends of 15-percent ethanol have been approved for use in model year 2001 and newer passenger cars, light trucks, and medium-duty vehicles, which is approximately 80 percent of the U.S. automotive fleet. However, delivery infrastructure (e.g., pumps at gas stations) for blends above E10 is limited, especially in regions outside the Midwest, where most gasoline is consumed. The physical amount of ethanol that can be blended is commonly known as the “blend wall.”

Historically, DDGS have served as a lower cost protein supplement (relative to soybean meal) in cattle diets. The availability of DDGS grew concurrent with the increase in ethanol production (Beckman et al., 2011). However, there are physical limitations to how much DDGS can be fed to livestock because of nutritional constraints, which differ based on the type of animal (Hoffman and Baker, 2011).

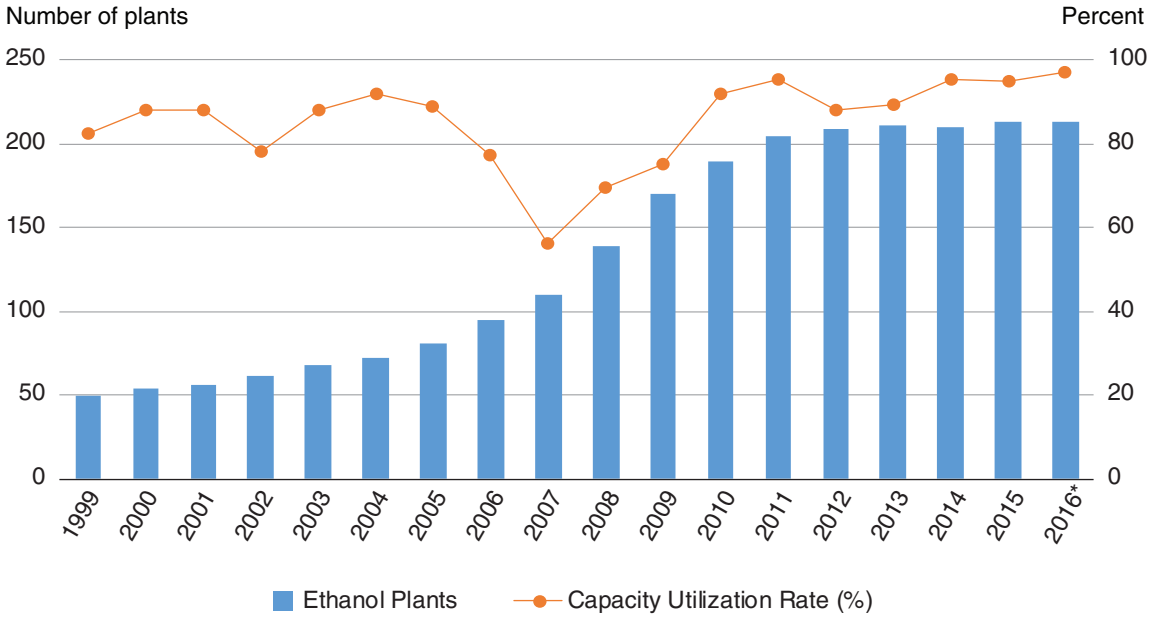
The United States was a net importer of ethanol until 2010, when it exported 396 million more gallons than it imported. With favorable market conditions, the United States exported 1.2 billion gallons in 2011, overtaking world-export leader Brazil, which struggled with drought and high ethanol feedstock prices. Brazil regained the top spot in 2012, but the United States became the largest exporter (by volume) again in 2013 and has remained so since then. As a share of total U.S. production, exports hit their highest point in 2011, when 8.6 percent of total U.S. ethanol production was exported. Traditionally, Canada and Brazil accounted for the largest share of U.S. ethanol exports. However, South Korea, India, and China may increase their share of U.S. exports in the future (ITA, 2016).

The recent fall in oil prices showed that not only government policies, but market forces can influence U.S. ethanol production and trade. The rapid decline in oil prices from $106 per barrel in June 2014 to less than $30 per barrel by January 2016 (a 70-percent decline) led to lower gasoline prices, which had an impact on domestic demand for ethanol.[3] Higher gasoline demand raises the need for ethanol for blending. However, lower gas prices severely limit the consumption of ethanol in blends greater than 10 percent, as the price of ethanol becomes relatively more costly as the price of gasoline drops (Marshall et al., 2015). Lower gasoline prices can also affect U.S. ethanol trade because the amount of ethanol available for export depends largely on how much ethanol is produced beyond that required to meet the RFS mandates. To date, U.S. ethanol production has been fairly resilient, due largely to low feedstock costs and favorable biofuel policy. It is likely that lower gasoline prices could, over time, discourage ethanol plant-capacity expansion and dampen the availability of ethanol for export in the medium or long term (Beckman, 2015).

[3]2016 U.S. gasoline consumption was the highest on record, beating the previous 2007 record.

In addition to biofuel policies and market conditions, future exports also depend on U.S. ethanol plant capacity. Plant construction has slowed since 2011; however, the utilization rate has remained high, averaging 92 percent from 2011-15 (fig. 2). In 2014-16, U.S. ethanol plants were operating at an average of 95 percent of the average installed plant capacity of 15 billion gallons. In 2016, production totaled 15.33 billion gallons, while consumption was 14.54 billion gallons (RFA, 2017). After accounting for stocks, imports, and actual use, approximately 1 billion gallons were available for export, an amount larger than previous annual export levels with the exception of 2011.

Figure 2
U.S. ethanol plants and utilization rate, 1999-2016*



Note: * = estimates.
Source: USDA, Economic Research Service calculations from U.S. Department of Energy, Alternative Fuels Data Center (AFCD, 2016); U.S. Department of Energy, Energy Information Administration (EIA, 2016b); and Nebraska Energy Office (NEO, 2016).

The Status of the U.S. DDGS Industry

With about one-third of the grain used to produce ethanol returned to the market as DDGS, the large increase in U.S. ethanol production led to an upsurge in DDGS production. DDGS production grew from 10 million metric tons in 2005 to 38 million in 2016 (table 1). (A bushel (56 pounds) of corn used in dry-mill ethanol production generates about 17.4 pounds of DDGS.) In 2015, 54 percent of domestically consumed DDGS was fed to beef cattle, 34 percent to dairy cattle, 7 percent to swine, and 5 percent to poultry (Wisner, 2016).

Growth in ethanol production, limits on the volume of DDGS that can be used in feed, and favorable export markets led to increases in U.S. DDGS exports. In 2005, 12 percent of DDGS produced in the United States was exported; by 2015, the share had grown to 31 percent. In 2005, the EU consumed 39 percent of U.S. DDGS exports (table 2). In 2006-10, Mexico generally acquired the largest share, followed by Canada. China became the largest importer in 2011 and has remained so, accounting for 46 percent of U.S. DDGS exports in 2015.

Table 2
U.S. DDGS exports by selected destinations (1,000 metric tons)

Country/ Region	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
China	0	1	5	98	2,177	1,588	2,228	2,793	6,183	5,366	3,372
Mexico	281	608	1,001	1,387	1,613	1,823	1,539	1,273	1,496	1,592	1,901
Vietnam	13	48	101	184	383	456	456	375	508	552	1,006
South Korea	11	88	176	279	351	385	377	376	519	621	845
EU	481	204	168	117	265	723	138	286	382	472	651
Thailand	26	51	130	270	283	269	179	251	285	407	587
Canada	114	190	683	714	1,078	882	647	524	330	548	548
Japan	29	79	151	211	229	285	338	399	459	295	296
Philippines	49	67	96	128	88	142	146	108	96	107	143
Rest of the world	226	445	1,409	1,581	1,812	1,733	1,537	1,796	1,747	1,668	2,377

Note: DDGS = distillers' dried grain with solubles. EU = European Union. Data are in marketing years, September-August.
Source: USDA, Economic Research Service (ERS, 2016b).

Individual Country Case Studies

Before 2001, Brazil and the United States were the only major ethanol-producing countries. From 2007-10, ethanol production grew rapidly in Brazil, the United States, and the EU, which together accounted for the largest share of world production (see Beckman, 2015). By 2016, although production was still concentrated largely in those three regions, several other countries had annual production totaling more than 100 million gallons. The increase in production was brought about by the rise in gasoline prices during the end of the 2000s and aggressive mandates (table 3). Today, countries with significant production growth potential include China, India, Latin American energy exporters (Argentina and Colombia), Asian energy exporters (Indonesia, Vietnam, and Malaysia), Thailand, and the Philippines.

In 2015, Beckman (2015) reviewed the production, consumption, and trade activities for Brazil, the United States, and the EU. This report focuses on eight other countries with more than 100 million gallons annual ethanol production or consumption: Argentina, Canada, China, Columbia, India, Japan, the Philippines, and Thailand. It also discusses potential U.S. export destinations that do not have mandates.[4]

Argentina

Ethanol

Argentina enacted a law requiring the use of biofuels beginning in 2010, mandating a blend of ethanol at 5 percent (E5). The law seeks to diversify the supply of energy, foster environmental conservation, and promote the development of rural areas (FAS, 2017a). Companies that produce biofuels are eligible for tax incentives if the biofuels are consumed domestically. The country reached its E5 goal in 2013. In January 2014, the ethanol mandate was increased to 8 percent. In December of that year, it was revised to 10 percent. Beginning in April 2016, it was increased again, to 12 percent (BI, 2016).

Ethanol production has grown in Argentina from 6 million gallons in 2009 (with no production before that) to 240 million gallons in 2016 (fig. 3). Argentina currently uses both molasses and corn to produce ethanol. With a 20-percent export tax on corn, ethanol producers had been able to purchase corn locally at domestic prices well below international prices. However, the export tax was removed in 2015 (WSJ, 2015). Despite the resulting increase in corn prices, the ethanol industry is still profitable (FAS, 2017a). Production capacity is estimated to be around 330 million gallons in 2016. While Argentina imports molasses to produce ethanol, it is a net exporter of sugar, the world's third-largest exporter of corn, and a large exporter of sorghum. Thus, feedstocks are available for ethanol plant expansion.

[4]Information and data for this report are drawn primarily from the USDA, Foreign Agricultural Service (FAS) Global Agricultural Information Network (GAIN) report for each of the countries. For more information and data, refer to GAIN reports shown in the references.

Table 3

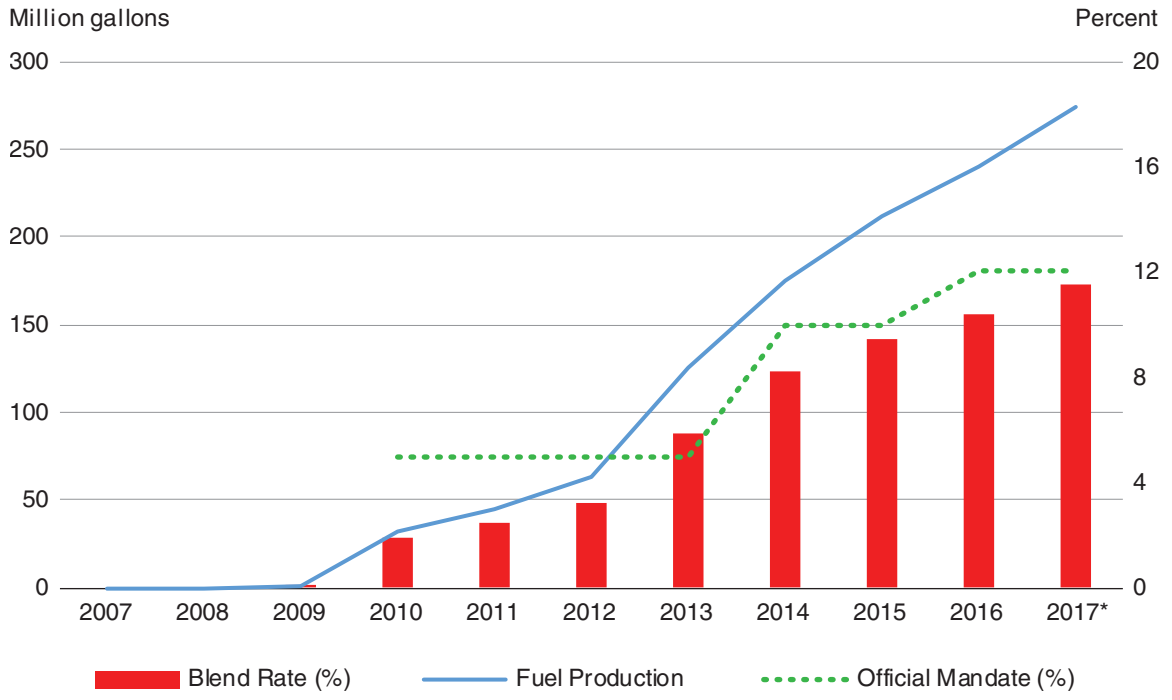
Ethanol mandates and targets, selected countries (expressed as percent of blended retail fuel that is ethanol, except where noted)

	Notes	pre-2003	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Brazil	Anydrous blend rate	24-25%	20-25%	20%	22%	20%	23-25%	25%	25%	20-25%	18%	18%	18-25%	25-27.5%	27.5%	27.50%
EU	RED target of 10% renewables transport-energy use in 2020; only 7% can be from food-crop-based biofuels															
U.S.	Billion gallons					4	4.7	9	10.5	12	12.6	13.2	13.8	13.6	14.1	14.5
Americas																
Argentina										5%	5%	5%	5%	5-10%	10%	12%
Canada	Some provinces started earlier									5%	5%	5%	5%	5%	5%	5%
Colombia	8-10% varied by province							8-10%	8-10%	8-10%	8-10%	8-10%	8-10%	8%	8%	8%
Costa Rica								7%	7%	7%	7%	7%	7%	7%	7%	7%
Ecuador															10%	10%
Jamaica											10%	10%	10%	10%	10%	10%
Mexico	Applies to rural areas only															5.8%
Panama	Program suspended in 2014												2%	5%		
Paraguay		20%	20%	20%	20%	20%	20%	20%	24-25%	24-25%	24-25%	24-25%	24-25%	25%	25%	25%
Peru										7.8%	7.8%	7.8%	7.8%	7.8%	7.8%	7.8%
Asia-Pacific																
Australia										7% in New South Wales			2% in Queensland			
China	10% in 6 provinces (Heilongjiang, Jilin, Liaoning, Henan, Anhui, and Guangxi); by 2016, 11 provinces and 40 cities have a mandate															
India			5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Indonesia								3%	3%	3%	3%	3%	3%	3%	3%	3%
Philippines									5%	7%	10%	10%	10%	10%	10%	10%
Thailand	Production target converted into %															9%
Vietnam															5%	5%
Europe																
Norway										3.5%	3.5%	3.5%	3.5%	3.5%	3.5-5.5%	5.5%
Turkey													2%	3%	3%	3%
Ukraine														5%	5%	5%
Africa																
Angola													10%	10%	10%	10%
Ethiopia										5%	5-10%	10%	10%	10%	10%	10%
Malawi															10%	10%
Mozambique															10%	10%
South Africa															2%	2%
Sudan												5%	5%	5%	5%	5%
Zimbabwe													5-15%	5-15%	5-15%	5-15%

Note: RED = Renewable Energy Directive.

Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service Global Agricultural Information Network (GAIN) reports and Lane (2016). Information on mandates in Africa is from the International Renewable Energy Agency (IRENA, 2016).

Figure 3
Argentina ethanol production, official mandate, and blend rate, 2007-17



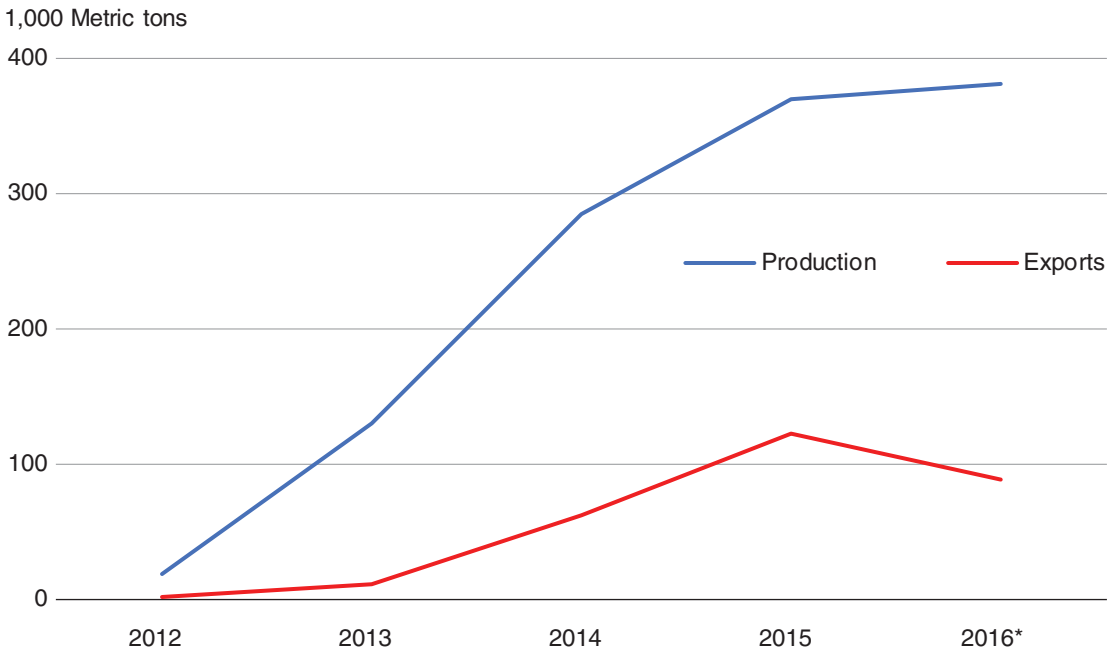
Note: * = estimates.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017a).

Argentina has not exported ethanol, largely because local producers focus on fulfilling the domestic mandate. Although the four Mercosur countries (including Brazil) could export ethanol to Argentina duty-free, they have not. Non-Mercosur countries face a 20-percent tariff. With policy designed to strengthen domestic production, Argentina could become an exporter, and with favorable market access to other South American countries, it might displace U.S. exports to Brazil or other South American countries.

DDGS

Because half of Argentina's ethanol is produced from corn, it also produces DDGS. Not all ethanol plants are capable of drying DDGS sufficiently for shipping long distances, which has a negative impact on export capabilities. DDGS production began in 2012 when grains began to be used in ethanol production (fig. 4). DDGS production increased by almost 2,000 percent between 2012 and 2015, closely following the increase in ethanol production. Argentina has exported between 8 percent (2013) and 32 percent (2015) of its DDGS to its South American neighbors and Southeast Asia. Uruguay has been the largest importer (more than 50 percent) and the only country to import DDGS from Argentina every year.

Figure 4
Argentina DDGS production and exports, 2012-16



Note: * = estimates; DDGS = distillers' dried grains with solubles. DDGS exports fall under the trade classification of Brewing or Distilling Dregs and Water, which could also include coproducts from other production types such as whiskey.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017a) and United Nations Comtrade (UN Comtrade, 2016).

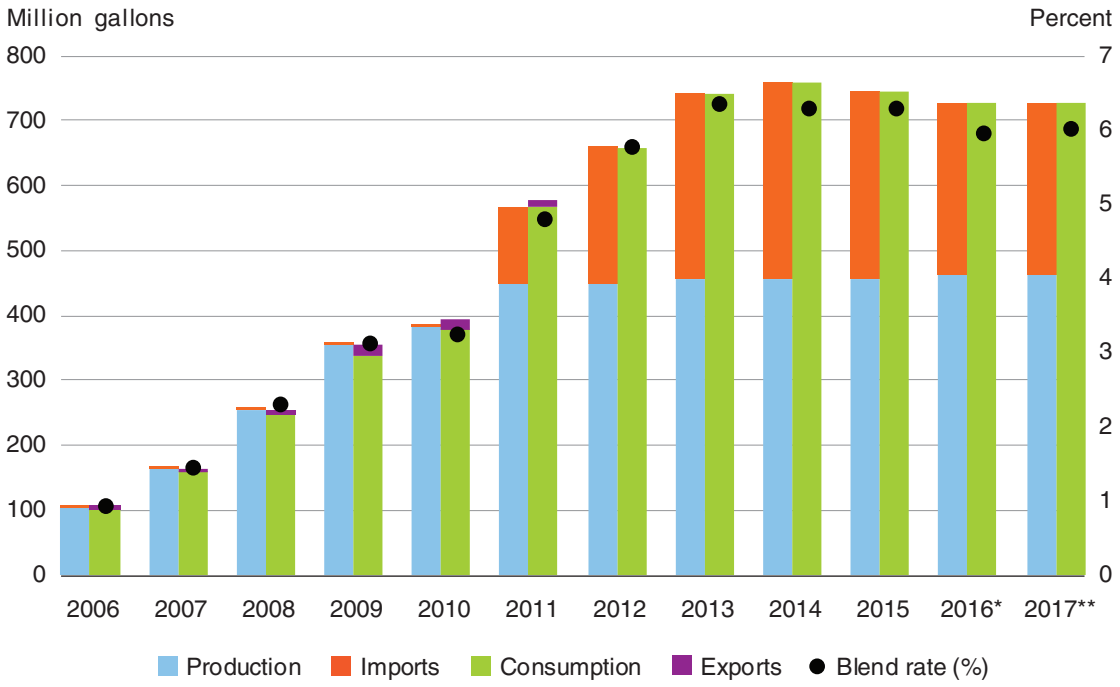
Canada

Ethanol

Canada mandates a 5-percent ethanol blend in gasoline. However, 2 of its 10 provinces have higher blend mandates: Saskatchewan at 7.5 percent and Manitoba at 8.5 percent (Webb, 2013), pushing the effective national ethanol blend rate to around 6.2 percent. Coad and Bristow (2011) note that mandates are used to reduce greenhouse gas emissions. To a lesser extent, renewable fuel policies are also seen as a means to encourage rural economic development and to help diversify revenue streams for agricultural producers.

Ethanol consumption in Canada rapidly increased from 2010 to 2013 (fig. 5), reaching its peak in 2014 at around 759 million gallons. It has since leveled off to around 750 million gallons. Since 2011, with consumption exceeding production, Canada has relied on imports from the United States to meet domestic demand. Ethanol production peaked near 10-percent capacity (450 million gallons) in 2011, and no new capacity has been added. Federal production incentives are small, decreasing from $0.1/liter ($0.026/gallon) in 2008/09 to $0.04/liter ($0.011/gallon) in 2015/16, and are scheduled to terminate in 2017. Production capacity is limited by infrastructure constraints and competition from U.S. imports. The main feedstocks are corn (estimated at 77 percent) and wheat (23 percent) (FAS, 2016a).

Figure 5
Canada ethanol production, consumption, trade, and blend rate, 2006-17



Note: * = estimates; ** = forecasts.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2016a).

Imports cover between 30 and 40 percent of domestic consumption, with nearly all imports coming from the United States. In 2014, Canadian ethanol imports reached a record of 300 million gallons; in 2016, imports are estimated at 264 million gallons. U.S. ethanol is exported to Canada tariff-free under the North American Free Trade Agreement (NAFTA). Other countries face a $0.05/liter ($0.013/gallon) ethanol import tariff. The absence of tariffs and the relatively low costs to transport U.S. ethanol to Canada suggest that it is likely to continue to import ethanol from the United States (ITA, 2016). From 2012 to 2016, there were little or no Canadian ethanol exports.

DDGS

All of Canada's ethanol is produced from grains; thus, it produces a sizeable amount of DDGS. Canadian feed regulations dictate that DDGS meet a minimum energy-content level, requiring more corn oil to be left in the DDGS than is required for U.S. DDGS. As a result, Canadian DDGS imports declined beginning in 2011 (table 4). Previously, U.S. corn-based DDGS had a competitive advantage with Canadian wheat-based DDGS because of the higher fat content of the U.S. product (Jessen, 2011). Due to its close proximity and low transportation costs, the United States is Canada's largest DDGS trading partner. The United States is the only source of Canadian DDGS imports, and it was the destination for 85 percent of Canadian DDGS exports in 2007-15 (table 4). Other destinations for Canadian DDGS include the EU (6 percent average share); Japan (3 percent average share); and, to a lesser extent, the Philippines (2009-10) and Turkey (2007-08).

Table 4
Canada DDGS production and trade by destination (% share), 2007-15

		2007	2008	2009	2010	2011	2012	2013	2014	2015
Production										
1,000 mt		500	680	885	980	1,220	1,075	1,100	1,100	1,100
Imports										
1,000 mt		190	683	714	1,078	882	647	524	330	548
% share	United States	100	100	100	100	100	100	100	100	100
	Others	0	0	0	0	0	0	0	0	0
Exports										
1,000 mt		212	171	398	488	403	414	491	489	490
% share	EU	3	6	5	1	6	9	10	7	10
	Japan	2	3	3	2	3	2	5	2	1
	United States	93	66	86	89	91	88	82	85	82
	Others	3	25	6	9	0	1	3	5	7

Note: DDGS = distillers' dried grains with solubles; mt = metric tons.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2016a) and United Nations Comtrade (UN Comtrade, 2016).

China

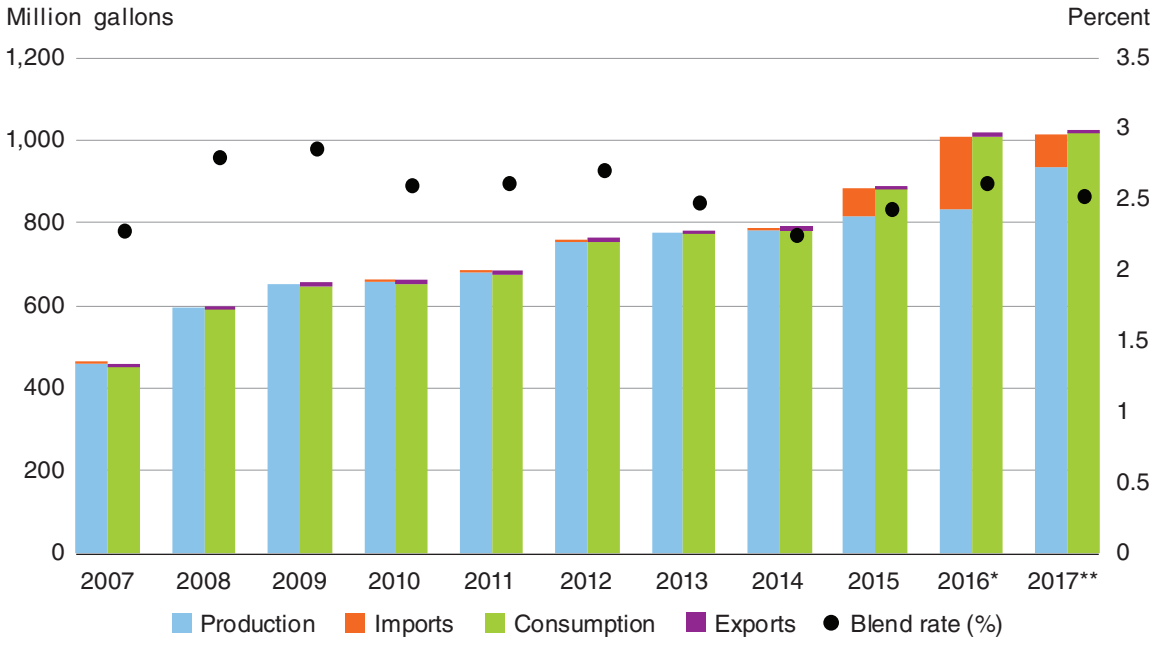
Ethanol

China is the third-largest producer of ethanol for fuel after the United States and Brazil. Biofuels are part of China's longrun strategic energy plan to help protect the environment, prevent energy shortages, and reduce dependence on imported energy (FAS, 2017b). Its 12th five-year plan (2011-16) set a goal of producing 1.3 billion gallons of fuel ethanol by 2016. It had hit 64 percent of this target by the end of 2016. The recently approved 13th five-year plan (2016-20) emphasizes the increased use of renewable energy, especially cellulosic and nongrain-based ethanol production. Cities and provinces have the authority to mandate ethanol blends. By 2016, 11 provinces and 40 cities had adopted an E10 blend mandate, although the actual blend rate in these markets varies from 7 to 20 percent. These local-use mandates translate to an estimated average national blend rate of less than 3 percent.

Chinese domestic policy dictates that fuel ethanol consumption be met almost entirely by domestic production, even though imported ethanol is significantly less expensive than domestic.[5] With ethanol consumption growing by an average rate of 7 percent over the last decade, consumption was estimated to reach a record 1 billion gallons in 2016 (fig. 6). Corn is the main ethanol feedstock (72 percent); wheat, cassava, corn cobs, and sorghum stalks are also used. To encourage the use of nongrain feedstocks (and discourage the use of grain), China has eliminated direct subsidies for grain-based biofuels and introduced a $122/ton subsidy (based on 1 Chinese Yuan Renminbi (rmb) to $0.15 conversion) for cellulosic and a $114/ton subsidy for other nongrain-based ethanol. In 2016, China modified its corn support price program, which could lead to changes in corn use. That is, domestic production of corn could be less profitable, potentially lowering domestic production. This could lead to large imports of corn, as well as DDGS.

[5]FAS (2017) notes that the price for domestic ethanol was $787/ton in 2015, while the imported price was $595.

Figure 6
China ethanol production, consumption, trade, and blend rate, 2007-17



Note: * = estimates; ** = forecasts.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017b).

The outlook for China's use of corn for ethanol production is subject to several potentially mitigating factors: the challenges facing biofuels development in China, the impact of biofuel on food security, the availability of land for feedstock production, and the economic feasibility of supplying feedstocks (Chang et al., 2012). On the other hand, China has large corn reserves that have been held in stocks for so long that they cannot be used for human consumption or animal feed. Using the corn reserves might be a viable option to increase ethanol production (Shuping and Aizhu, 2015).

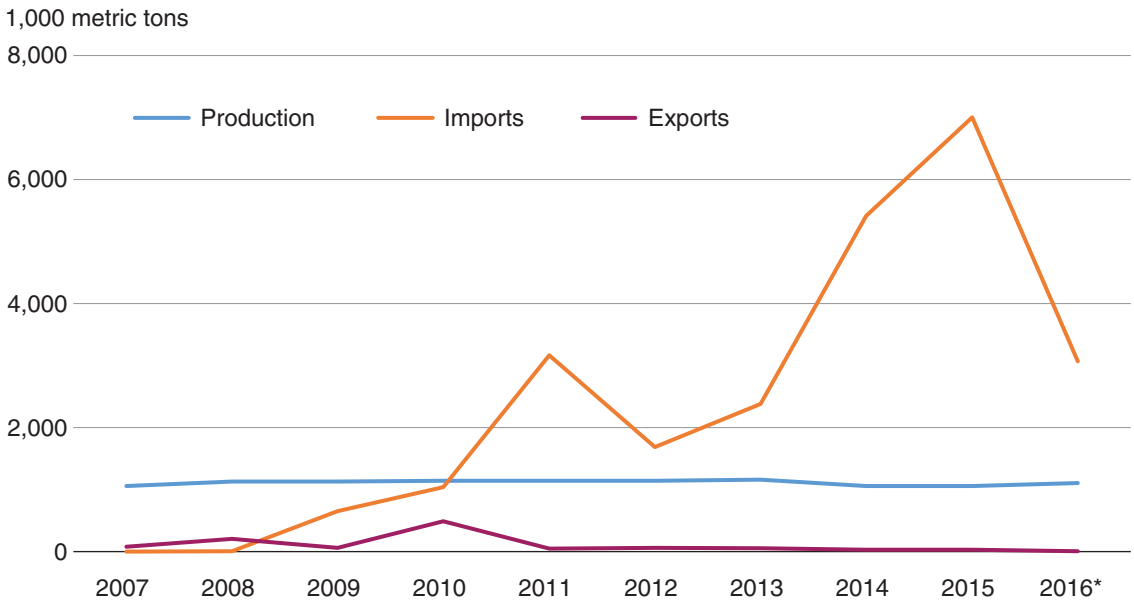
Prior to 2014, China banned ethanol imports. In 2014, it experimented with low import levels to test the market. In 2015 and 2016, it allowed imports of 69 million and 177 million gallons, respectively, mainly from the United States. Ethanol imports from 10 Association of Southeast Asian Nations (ASEAN) countries,[6] Chile, and Pakistan enter with no tariff. Imports from the United States faced a tariff of 5 percent from 2009 to 2016; the tariff was increased to 30 percent beginning in 2017. Imports in 2017 are forecast to be half of those in 2106, as government policy favors domestically produced ethanol.

DDGS

As Chinese ethanol production grew, DDGS production remained relatively the same because the use of cassava and corn cobs to produce ethanol increased. Indeed, there was no overall change from 2007 to 2015 (fig. 7). DDGS production in China peaked in 2013 at 1.16 million metric tons. However, DDGS imports increased from 2,000 metric tons in 2007 to 6.3 million metric tons in 2015, almost all of which were imports from the United States (ERS, 2016b). In 2016, as a result of a change in trade policy, U.S. DDGS exports fell by half. In January 2017, China imposed antidumping and countervailing duties on U.S. imports, which could further reduce imports.

[6]These 10 countries are Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam (ASEAN, 2016).

Figure 7
China DDGS production and trade, 2007-16



Note: * = estimates.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017b) and United Nations Comtrade (UN Comtrade, 2016).

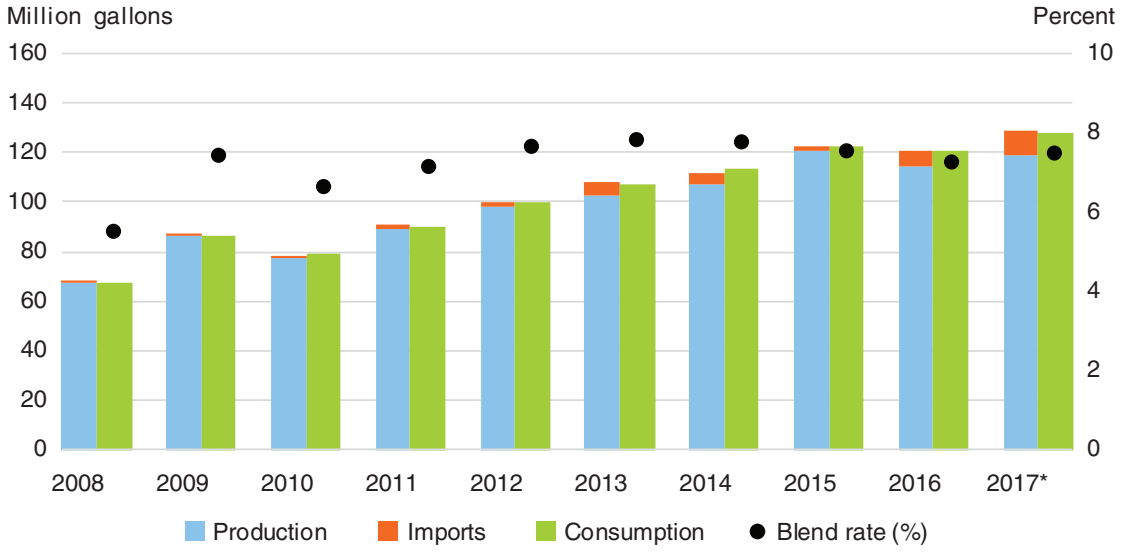
Colombia

Ethanol

Colombia's sugar-based ethanol industry was designed to reduce dependency on imported fuel, mitigate greenhouse gas emissions, and develop rural-employment-creating sugar industries. A 2001 law stipulated that gasoline consumed in Colombia must contain 10-percent ethanol by 2006. Colombia did not begin producing ethanol until 2005, and the 10-percent mandate was eventually applied only to certain cities (Toasa, 2009). In 2014, the mandate was officially set at 8 percent. Since 2008, the blend rate has varied between 8 and 10 percent, depending on the region and market conditions.

Ethanol production in Columbia has grown at an average rate of 8 percent (fig. 8). In 2016, production capacity was around 120 million gallons. The current consumption level, which is consistent with the level of domestic production, results in a blend rate of around 7.8 percent, close to the E8 target. Colombia authorizes ethanol imports, primarily from Ecuador, only if the blend mandate cannot be satisfied with domestic production. Recently, Colombia has shown an interest in importing U.S. ethanol when domestic supplies are inadequate (FAS, 2017c). In late 2016, Columbia rescinded a 2014 restriction on ethanol trade and said it will lift all restrictions on ethanol imports by 2017, as long as the ethanol attains at least a 61-percent reduction in greenhouse gases, compared to gasoline.

Figure 8
Colombia ethanol production, consumption, trade, and blend rate, 2008-17



Note: * = estimates.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017c).

DDGS

As Colombia's ethanol production is entirely from sugar, it does not produce DDGS. Colombia imports DDGS mainly from the United States. In 2016, Colombia imported 166,000 metric tons of U.S. DDGS, surpassing its previous import record of 112,000 metric tons in 2014. The high level of U.S. imports is partially due to the trade agreement between Colombia and the United States that took effect in 2012 (Feed & Grain, 2016).

India

Ethanol

Biofuels in India are viewed as a means to provide a higher degree of national energy security in an environmentally friendly, cost-effective, and sustainable manner (FAS, 2017d). India first established an E5 mandate for 9 States in 2003, expanded it to 20 States and 4 territories in 2006, and nationwide in 2008. But mandates have not been met due to a lack of political will, inadequate procurement pricing, and insufficient feedstock (molasses, which is a byproduct of the sugar industry). FAS (2017d) also notes that high taxes in certain States and procedural hurdles have restricted production growth. India instituted an ambitious national policy on biofuels in 2009 that targets the replacement of 20 percent of petroleum fuel consumption with biofuels (ethanol and biodiesel) by the end of 2017. However, the effective 3.3 percent blend rate for ethanol in 2016 was below the 5-percent mandate. Individually, 13 of the 29 Indian States have a blending mandate of 2.5 percent.

As most sugar mills in India are unprofitable because of high production costs and low sugar prices, the availability of sugar molasses for ethanol production is an issue. Around 45 percent of ethanol is used to produce liquor, 40 percent is used by the chemical industry, and the rest is for fuel and other uses (Ray et al., 2011). In addition, ethanol faces competition with cattle feed and

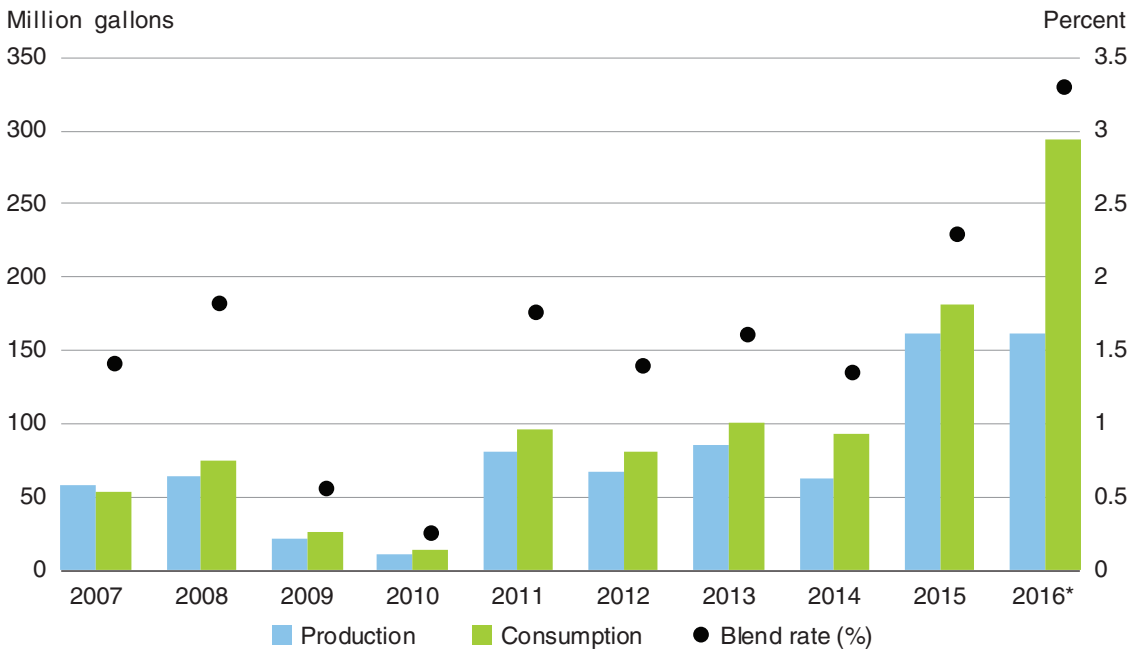
exports for the use of molasses. Overall, fuel ethanol production is estimated at about 161 million gallons in 2016. Fuel ethanol consumption has outpaced production since 2008, with a difference of 130 million gallons in 2016 (fig. 9).

With consumption exceeding domestic production, India is a net importer of ethanol. However, the trade balance for ethanol has diminished over the last 5 years as production has increased (FAS, 2017d). India also uses ethanol for industrial purposes; however, the lack of an explicit tariff code for ethanol used for fuel in the Harmonized Commodity Description and Coding System (HS) makes it difficult to determine how much is actually used for fuel.[7] Rather, all ethanol is grouped into two categories (anhydrous and hydrous) in the HS. According to the U.S. Energy Information Administration (EIA), the United States exported 37 million and 84 million gallons of ethanol for fuel to India in 2015 and 2016, respectively (EIA, 2017). In addition to the United States, which provided the majority of ethanol imported for all uses in 2015, India also imports ethanol from Brazil, the EU, Bhutan, and Pakistan.

DDGS

As India's ethanol production is entirely from sugar, it does not produce DDGS. India imported a small amount of a product classified under HS Code 230330 (Brewing or Distilling Dregs and Waste), which is the code in which DDGS is placed, but it was from Nepal, which does not produce ethanol for fuel (dregs and waste can be produced via other processes, such as alcohol brewed and distilled for human consumption).

Figure 9
India ethanol production, consumption, and blend rate, 2007-16



Note: * = estimates.

Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017d). FAS (2017d) does not report ethanol for fuel production; we estimate this by applying the percentage of total ethanol consumption that is used for fuel to production.

[7]The Harmonized Commodity Description and Coding system, often called Harmonized System (HS), is a six-digit standardized numerical method of classifying traded products.

Japan

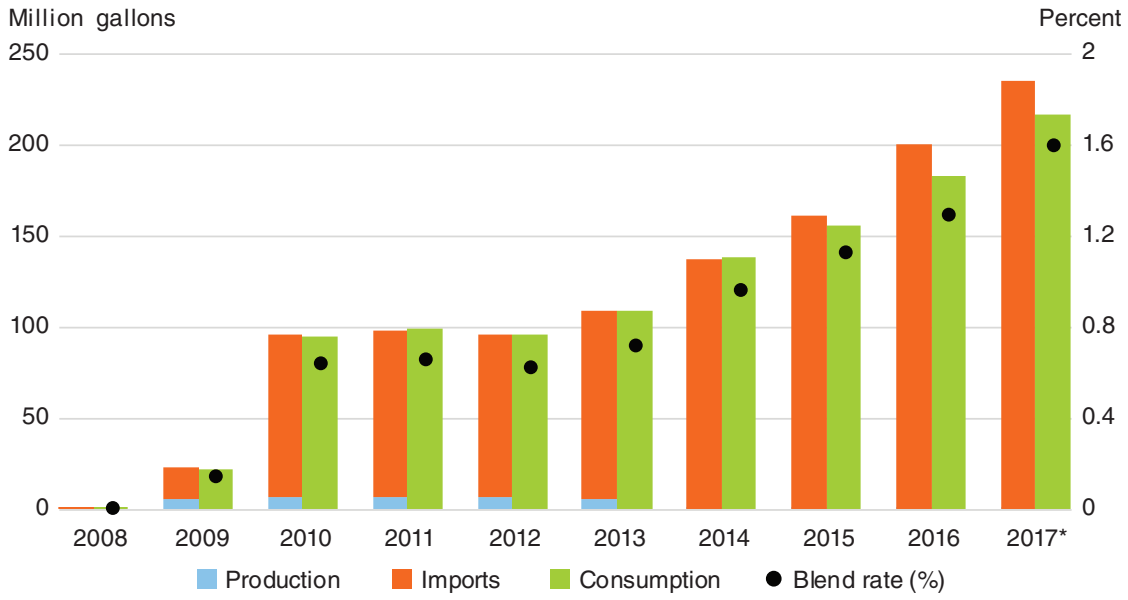
Ethanol

Japan's current energy policy focuses on generating power from renewable sources. There is no specific ethanol mandate; however, there is a total biofuel mandate of 218 million gallons for 2017. Note that the other biofuel component, biodiesel, is very limited. However, Japan restricts the amount of ethanol that can be directly blended to 3 percent, although ethanol can be blended at a higher rate (7 percent) through a blend that uses ethanol as an octane enhancer. Since Japan has a low food self-sufficiency rate, production of ethanol is very small. Rather, Japan depends on imports that are subject to a sustainability standard. Initially, the Government determined that only Brazilian sugarcane ethanol met this standard.[8] In 2016, Japan imported around 200 million gallons of ethanol (fig. 10); the blend rate was less than 2 percent (FAS, 2017e).

DDGS

With low levels of ethanol production, Japan's DDGS production is relatively low. However, Japan has been one of the 10 largest importers of DDGS from the United States, with imports totaling around 300,000 metric tons since 2012 (table 2).

Figure 10
Japan ethanol production, consumption, trade, and blend rate, 2008-17



Note: * = estimates.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017e).

[8]Japan is considering including U.S. ethanol under the standard by the end of 2017 (USGC, 2016c).

Philippines

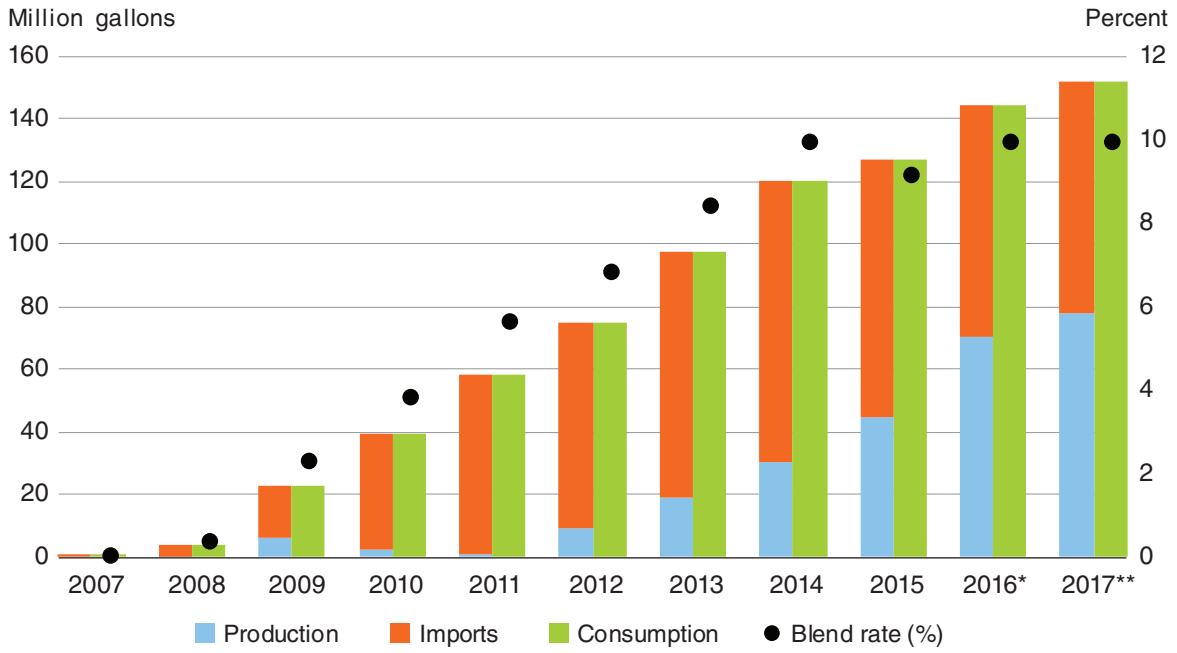
Ethanol

The Philippines was the first Southeast Asian country to pass biofuel legislation. Its 2007 Biofuels Act sought to reduce dependence on foreign oil, mitigate greenhouse gas emissions, and increase rural employment and income. It set the mandated blend rate at 10 percent in 2011, rising to 20 percent by 2020. To encourage domestic production, the Biofuels Act provides domestic producers tax exemptions and favorable financing. In 2015, the Philippines passed a law that promotes the sugarcane industry, the main ethanol feedstock, by providing financial support for infrastructure programs, research and development, credit, grants to farms, and scholarship grants (FAS, 2016b).

Ethanol production has grown in the Philippines from 0.3 million gallons in 2008 to 44 million gallons in 2015 (fig. 11). Despite this increase, it has not met the mandate, and hitting the 20-percent blending target by 2020 with domestically produced ethanol will be challenging. Production is limited by the inadequate capacity of existing sugarcane distilleries, low productivity in the sugarcane industry, high production costs, and damage from frequent typhoons (ITA, 2016).

The Philippines has not exported ethanol and is not expected to in the near future, with domestic production and capacity falling short of the required consumption level. To help meet the mandates, it imported 82 million gallons of ethanol in 2015. In 2015, it received 57 percent of its total imports from the United States, down from a 73-percent share in 2014.

Figure 11
Philippines ethanol production, consumption, trade, and blend rate, 2007-17



Note: * = estimates; ** = forecasts.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2016b).

DDGS

The Philippines' ethanol production is entirely from sugar-based sources, thus, it does not produce DDGS. However, it is a large importer of DDGS, primarily from the United States. The Philippines has imported an average of more than 100,000 metric tons a year since 2007 (table 2). Its DDGS imports from the United States are expected to double in the coming years as China restricts imports (USGC, 2016a).

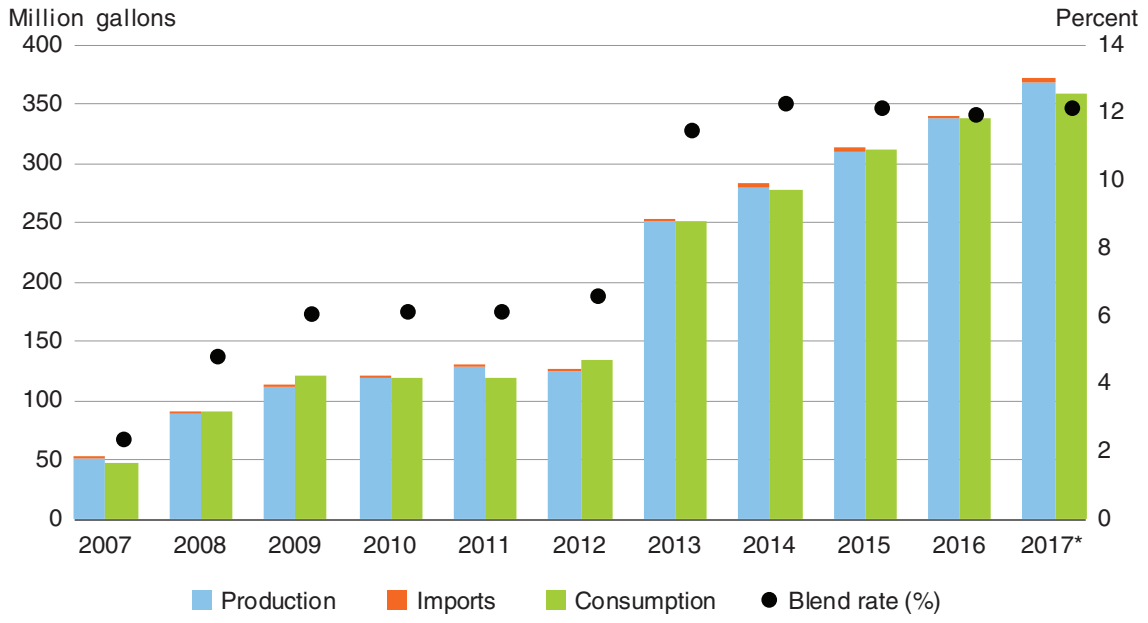
Thailand

Ethanol

Thailand's biofuel policy is guided by its Alternative Energy Development Plan (running from 2015 to 2036). But it has repeatedly revised its ethanol targets as petroleum prices fell and feedstock supplies were limited. Rather than mandate a percentage of ethanol in total gasoline use, Thailand's goal is to produce 871 million gallons of ethanol by 2021 (table 3 converts the mandate into a percentage) and 1.08 billion gallons by 2036. To encourage ethanol use, the country subsidizes blends that contain 20- or 85-percent ethanol (and provides incentives for the purchase of cars that use those blends). These fuels can be 20- to 40-percent cheaper than fuel that contains a 10-percent blend (FAS, 2017f).

Ethanol production has grown more than 25 percent per year for the last 5 years, reaching more than 310 million gallons in 2015, double its 2012 production (fig. 12). The main feedstocks are molasses and sugarcane (70 percent) and cassava (30 percent). To reach its ethanol production goals, Thailand wants to increase sugarcane yields by 25 percent and is encouraging farmers of less productive rice farms to convert to sugarcane production. Thailand did not export or import ethanol for fuel in 2014 or 2015. However, it exported a small amount of ethanol for industrial uses to the Philippines in those years.

Figure 12
Thailand ethanol production, consumption, trade, and blend rate, 2007-17



Note: * = estimates.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service (FAS, 2017f).

DDGS

As with the Philippines, Thailand does not have domestic production of DDGS, given its use of sugarcane and cassava, rather than grains, as feedstocks. However, it imports DDGS, mainly from the United States. After gradually increasing from 2005-08 (USGC, 2016b), imports were largely stagnant until 2011, when they declined, followed by a rebound in 2012 (table 2). In 2015, Thailand imported 587,000 metric tons of DDGS from the United States, making it the sixth-largest importer of DDGS from the United States, despite a 9-percent import duty. Imports from ASEAN nations enter duty-free.

Other Countries

Some countries without ethanol mandates nonetheless consume ethanol. Fifteen percent of all U.S. ethanol exports in 2016 went to Nigeria, Oman, Singapore, South Korea, Tunisia, the United Arab Emirates, and several other countries that do not necessarily have national blend mandates (EIA, 2017). These countries import ethanol for a variety of reasons. Nigeria, for example, has a 10-percent ethanol blend target, but it also subsidizes cooking stoves that use ethanol (Ohimain, 2012). South Korea uses imported fuel-grade ethanol for industrial inputs. And, depending on the relative price of gasoline and ethanol, Singapore and the United Arab Emirates use ethanol as an oxygenate in gasoline and blend it with gasoline to redistribute to other countries, such as Iraq (ITA, 2016). Since 2013, Tunisia, too, has imported U.S. ethanol as an oxygenate in gasoline. Mexico also imports U.S. ethanol. According to some estimates, Mexico could become a significant market for U.S. ethanol, especially if it were to substitute the fuel additive Methyl tertiary-butyl ether (MTBE) with ethanol (Schill, 2014).

Summary of Progress in Meeting Mandates

To illustrate how ambitious some of the ethanol mandates and targets are, we estimated the mid-term (2020-21) ethanol supply and use for eight selected countries that have midterm blend targets—Argentina, Canada, China, Colombia, India, Japan, the Philippines, and Thailand (table 5). Using data from country-specific *Global Agricultural Information Network* (GAIN) reports issued by USDA's Foreign Agricultural Service, we calculated the average expected ethanol-blended gasoline consumption, production, and exports in 2020-21, based on the average growth rates in 2012-14. We estimated imports as the amount needed by each country to meet ethanol consumption mandates, after accounting for production and exports.[9] The difficulties in achieving these targets are likely indicated by the extent to which the expected midterm blend rate exceeds the current blend rate.

Thailand and Argentina have, perhaps, the most potential to reach their medium-term targets (fig.13). These countries have production capacity that meets their domestic consumption, and ethanol imports play a small role in achieving their targets. Colombia is almost at its 8-percent target, but several others—China, India, Japan, and the Philippines—would need to double their current blending to reach their goals. Canada would need to increase its blending rate from 6 to 10 percent. The Philippines, which achieved its target of 10-percent ethanol in 2016, now has an ambitious blend target of 20 percent in 2020. Unlike Thailand and Argentina, the Philippines and Canada depend on a large volume of ethanol imports, mainly from the United States. India and China have a long road ahead to reach their medium-term blend targets, thus there is a possibility for imports from the United States and other sources.

Table 5
Ethanol midterm (2020/21) supply and use in selected countries based on meeting blending targets

Country	Current blend rate	Midterm target blend rate	Estimated midterm			
			Gasoline fuel consumption	Ethanol		
				Consumption	Production	Net import needed to meet target
	%		in million gallons			
Argentina	10.7	12	2,734	373	450	0
Canada	6.3	10	11,615	1,291	471	819
China	3	10	47,072	5,230	873	4,357
Colombia	7.7	8	1,996	174	159	15
India	3	10	11,980	1,331	540	791
Japan	1.4	4.5	12,223	576	0	576
Philippines	10	20	1,801	450	120	330
Thailand	12.6	15	3,481	614	575	39

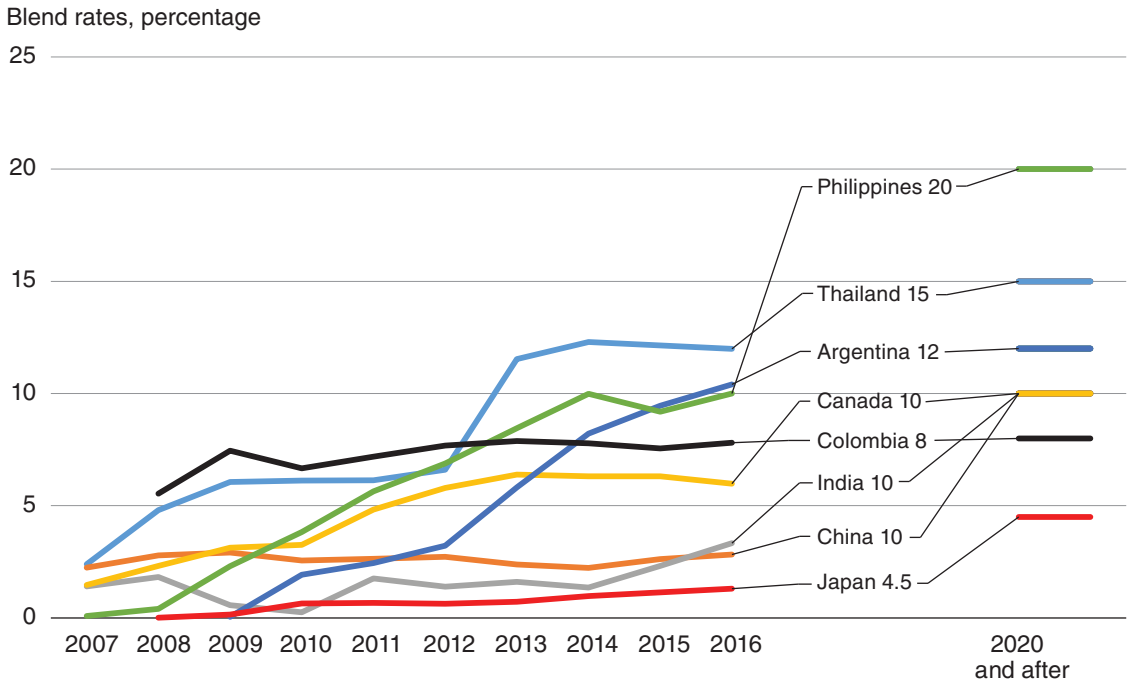
Note: Midterm blend rates and gasoline consumption are from USDA, Foreign Agricultural Service Global Agricultural Information Network (GAIN) reports. Estimated ethanol consumption is the amount of ethanol needed to be blended with gasoline to achieve the midterm blend rate. Estimated midterm (2020/21) ethanol production and export are projected based on the average growth rate of ethanol production and export from 2012-14. Given the current stock level, estimated ethanol import is the difference between estimated use (consumption and export) and production.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service GAIN reports.

[9]In practice, these mandated levels are not likely to be achieved by most of the countries. Nonetheless, the amounts needed to achieve these mandates provide useful information.

Based on our estimates, the eight countries would need net imports of more than 6.9 billion gallons of ethanol by 2020/21, assuming that they meet their existing ethanol mandates/targets and open their borders to trade. China and India are among the countries with the biggest need for imports to meet mandates. In addition, among the current largest markets, Canada and the Philippines could continue to rely on imported ethanol, mainly from the United States.

In the individual country case studies, this report discussed the feedstocks used in each profiled country to produce ethanol. Of nine selected countries/regions listed in table 6, seven currently allocate more than 25 percent of production of the feedstock to ethanol production. Share-of-production estimates indicate that seven of the nine countries could increase the share of feedstocks used for ethanol, even though production of those feedstocks increases in almost all countries. The projected total production of each feedstock is taken from the USDA Baseline (ERS, 2017). The amount of a feedstock necessary to meet estimated ethanol production by 2020 is based on a linear projection of feedstock demand for biofuel between 2017 and 2020, except for the United States, where the projection of the corn used for ethanol is from the USDA Baseline. The USDA Baseline indicates that ethanol production in the United States is projected to increase over the first couple of years of the projection period, then decline through the rest of the decade. The share of U.S. corn expected to go to U.S. ethanol production falls over time.

Figure 13
Historical ethanol blend rates and medium-term targets



Note: Data for 2007-2015 are actual blends rates; data for 2016 are estimated blend rates; data for 2020 targets are the blend rates set by government mandates. Thailand's production targets are converted to a percentage.
Source: USDA, Economic Research Service calculations from USDA, Foreign Agricultural Service reports.

Table 6

Share of agricultural commodity production allocated to ethanol production

		Production (1,000 mt)		Used for Biofuels (1,000 mt)		Share of Production (%)	
Country	Feedstock	Current	Projected	Current	Projected	Current	Projected
Argentina	Corn	29,640	39,661	650	1,357	2.19	3.42
	Molasses	680	NA	1,125	2,350	165.44	NA
Brazil*	Sugarcane	742,108	NA	343,582	440,905	46.30	NA
Canada*	Corn	12,914	13,725	3,278	3,388	25.38	24.68
	Wheat	31,339	30,497	963	995	3.07	3.26
China*	Corn	213,384	222,321	3,495	4,301	1.64	1.93
	Wheat	123,058	133,337	1,050	1,292	0.85	0.97
	Other	NA	NA	735	904	NA	NA
EU*	Wheat	145,999	156,578	2,745	3,015	1.88	1.93
	Corn	68,264	70,100	5,092	5,592	7.46	7.98
	Barley	58,519	58,343	539	592	0.92	1.01
	Rye	9,299	NA	667	733	7.18	NA
	Sugar beet	117,749	NA	9,819	10,782	8.34	NA
	Other	NA	NA	270	296	NA	NA
India*#	Molasses	11,772	NA	8,861	7,901	75.27	NA
Philppines*	Sugarcane	32,113	NA	235	636	0.73	NA
	Molasses	975	NA	336	909	34.45	NA
Thailand*	Sugarcane	100,731	NA	803	1,488	0.80	NA
	Molasses	4,465	NA	2,734	5,068	61.22	NA
	Cassava	30,033	NA	1,893	3,510	6.30	NA
United States	Corn	362,839	362,856	129,832	135,255	39.40	37.28

Note: mt = metric tons; * indicates total ethanol production (where a small proportion of ethanol production in the country may be from nonagricultural feedstocks); # indicates that country has a sizeable industrial ethanol-demand component; NA indicates baseline data/projections not available.

Source: Current feedstock production data are from FAO (2017) and are an average of 2013-15 production. Other information for the United States is based on USDA baseline projections (ERS, 2017). Feedstocks used for biofuels are based on information from USDA, Foreign Agricultural Service Global Agricultural Information Network (GAIN) reports; projected feedstock production data are from USDA baseline projections (ERS, 2017).

Opportunities for U.S. Exports

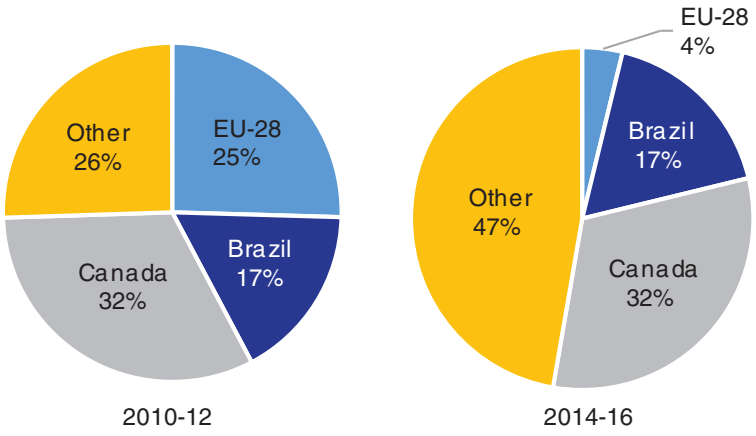
Ethanol

The United States is the world's largest producer of ethanol. Although most U.S.-produced ethanol is consumed domestically, the United States exported 1.05 billion gallons of ethanol in 2016, the second-highest amount on record. The opportunity to export stems partly from ethanol plant capacity exceeding blend wall limits (the physical limit to how much ethanol can be blended with gasoline). In 2016, production capacity at U.S. plants was almost 16 billion gallons, about 1.6 billion gallons more than 2016 domestic consumption (fig. 2).

As domestic consumption is constrained by the blend wall, as well as by the limit on the amount of corn-based ethanol that can be applied to the ethanol mandate under RFS2, U.S. ethanol producers have found abundant export opportunities. In 2015, U.S. ethanol was exported to more than 50 countries (EIA, 2017). And in the past 5 years, more than 100 countries have imported U.S. fuel ethanol (ITA, 2016). If major economies start implementing their existing target blend rates, U.S. ethanol producers would have much larger foreign market opportunities, as domestic production in some countries (e.g., China and India) may not be sufficient to meet the required ethanol levels.

Traditionally, Canada, Brazil, and the EU were the main importers of U.S. ethanol. Today, Canada continues to be the leading destination for U.S. ethanol exports, with a 32-percent share in 2014-16 (fig. 14). Brazil's share of exports dropped in 2012-15, when the price of gasoline compared to ethanol fell, but rose again in 2016. However, Brazil introduced a tariff-rate quota (TRQ) on ethanol imports in August 2017, which could impact U.S. exports. In 2016, the U.S. exported 267 million gallons of ethanol to Brazil; however, the TRQ would apply a 20-percent tariff on Brazilian imports above 159 million gallons (Agri-Pulse, 2017). After the EU imposed an antidumping duty on U.S ethanol imports for 5 years starting in 2013, U.S. ethanol exports to the EU fell from a 25-percent share in 2010-12 to around 4 percent in 2014-16.

Figure 14
Share of U.S. ethanol exports by destination

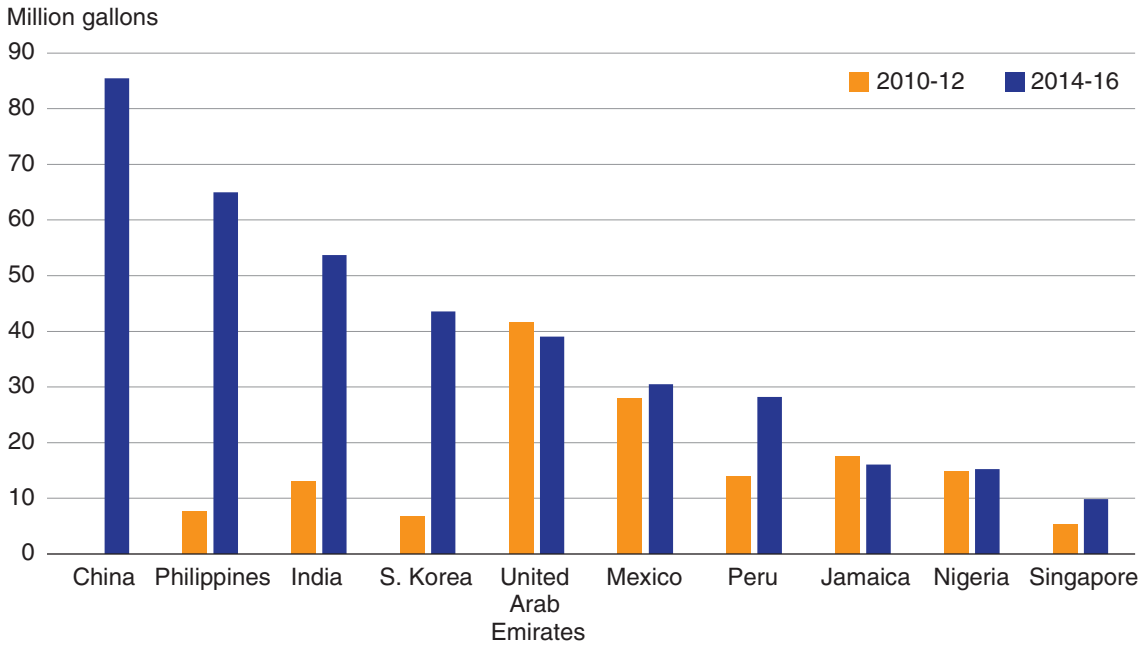


Source: USDA, Economic Research Service calculations from U.S. Department of Energy, Energy Information Administration (EIA, 2017).

The amount of U.S. ethanol exported to other countries has increased between 2010-12 and 2014-16. The top 10 in 2014-16 were China, the Philippines, India, South Korea, the United Arab Emirates, Mexico, Peru, Jamaica, Nigeria, and Singapore (fig. 15). Some may not have blending mandates or targets, but use ethanol as an additive to increase octane in gasoline. Some may be importing ethanol for nonfuel uses, even when the product shipped is identified as fuel ethanol.

An increase in global demand for ethanol and the opening of borders could lead to export opportunities for the United States. However, two factors could limit the ability of the United States to increase the rate of exports: ethanol plant capacity and feedstock availability.[10] U.S ethanol plants have been operating at more than 90 percent of capacity since 2013 (fig. 3), so short-term expansion could be limited. However, given the rapid expansion that took place in 2006-08, growth in the number of ethanol plants is possible if the mandate is increased or if the export market is attractive. Then the question of feedstock availability comes into play. In 2016, 38 percent of U.S. corn production was used for feed and residual, 15 percent for export, and 38 for feedstocks for ethanol production. If corn production remains constant, further expansion of ethanol production could be achieved by increasing the share going to ethanol production, improving efficiency, or using stocks. An increase in the availability of DDGS for animal feed could partially offset a reduction in the amount of corn used for feed.

Figure 15
Destinations outside Canada, Brazil, and the European Union for U.S. ethanol, by average volume 2010-12 and 2014-16



Source: USDA, Economic Research Service calculations from U.S. Department of Energy, Energy Information Administration (EIA, 2017).

[10]The potential for exports is influenced by the relative price of corn to gasoline. That is, if the ratio of corn to oil price is low, we might expect more corn will go to ethanol to substitute for gasoline.

Adoption of adverse trade policies, such as the 30-percent tariff imposed in China or the recent Brazilian ethanol TRQ, could also restrict U.S. exports. And the United States could face fierce competition for export markets, particularly from Brazil, the second-biggest producer and exporter of fuel ethanol. Before 2010, Brazil was the primary source of ethanol on the world trade market. Its ethanol exports peaked at 800 million gallons in 2008. However, it experienced a decline in production after 2009 until 2013 (Beckman, 2015) and, during that time, began importing ethanol, mainly from the United States. Although it continues to export ethanol, Brazil appears to be focusing more on the domestic market, increasing the blending rate in its mandate to match the increased production. Currently, its blending rate is 27.5 percent, up from 20-25 percent in 2010 and 18 percent in 2011.

DDGS

The United States also has diversified its DDGS export destinations. Exports went to 50 countries in 2015 and more than 70 countries over the last 10 years (ERS, 2016b). If an expansion in ethanol exports resulted in an expansion in ethanol production, all else being equal, the amount of DDGS produced would also increase. According to the Nebraska Corn Board (NCB, 2010), 5.3 pounds of DDGS are produced by dry-mill ethanol plants for every gallon of ethanol. If ethanol production is increased to take advantage of export opportunities then, for example, a 1 billion gallon increase in ethanol production would lead to an additional 2.77 million metric tons of DDGS. The question then would be: What would happen to the DDGS? As table 1 indicates, the amount of U.S.-produced DDGS exported has increased over time, from 12 percent in 2005 to 31 percent by 2015. The extent to which DDGS are consumed domestically or exported is based on transport costs, both domestically and internationally; any extra profit to be made by exporting; the saturation rate for the U.S. domestic market; and trade policies, such as the ban imposed by China.

Hoffman and Baker (2011) conclude that the domestic potential for DDGS consumption based on 2010 livestock numbers is between 35 million to 55 million metric tons. In addition, they note that potential exports range from 20 million to 52 million metric tons. In 2015, 26 million metric tons of DDGS were consumed domestically, and 12 million metric tons were exported. Thus, the answer to whether the DDGS would be consumed domestically or exported will likely be based on relative profit potential in each market. The United States has found export opportunities for DDGS in countries beyond its traditional partners: Canada, China, the EU, and Mexico. In particular, South Korea and Vietnam have increased their imports of U.S.-produced DDGS (table 2). South Korea more than doubled its imports from 2012-13 to 2015/16, from 376,000 metric tons to 845,000 metrict tons; Vietnam, similarly, doubled its imports in two years to become the third-largest destination for U.S.-produced DDGS in 2015/16.

Conclusions

Favorable market conditions and government policies led to a large global expansion in ethanol production from 2001-10. Although much of this growth was in Brazil, the European Union, and the United States, these regions have experienced a slowing rate of production growth caused by policy changes and infrastructure limitations. At the same time, 26 other countries have implemented blending mandates, although most have not met them. If these countries actively strive to fulfill their mandates, strong export market opportunities for U.S. ethanol could be possible, assuming that the United States can sufficiently expand production.

At the same time, the blend wall has become a real presence in the United States, limiting how much ethanol can be consumed. Stagnant domestic growth could present further export opportunities. Given that the U.S. ethanol industry operates at nearly full capacity, additional large-scale investments in ethanol plant capacity would be needed to increase exports.[11] Current capacity under construction is small, but the large increase in ethanol production from 2007-10 demonstrates that economic factors can influence ethanol plant expansion. In addition to being the largest exporter of ethanol, the United States is the largest exporter of DDGS. If the United States can increase grain-based ethanol production for export, it would probably also need to find a destination for the additional DDGS produced. Currently, the United States has more than 50 export destinations for DDGS and more than 70 for ethanol, thus opportunities might be found. However, trade barriers hamper current exports, and may limit them in the future. Many countries promote policies designed to utilize their own domestic production and import only a small amount. If major markets continue to block trade, export opportunities could be limited.

At this time, large amounts of agricultural feedstocks are being used for ethanol, and this could increase if ethanol production continues to grow in countries with newer mandates. Current feedstock issues, including the competition between ethanol and food use for feedstocks such as corn, sugar, oilseeds, and wheat, would be addressed when countries start aggressively using nontraditional feedstocks (i.e., cellulosic feedstocks) for ethanol production. Like the United States, China and India have been trying to find economically feasible ways to produce ethanol from feedstocks that do not compete with food production for the use of land. Large-scale production of cellulosic-based ethanol could allow the United States to meet future global export opportunities for corn, corn-based products, and ethanol.

[11]RFA (2016b) notes that there is 91 million gallons worth of plant capacity under construction.

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