



**Asia-Pacific
Economic Cooperation**

**Case Studies Highlighting Member Economy
Experiences in Developing Their Ethanol
Sectors**

Energy Working Group

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Executive Summary

This document reviews a summary of ethanol utilization in 5 APEC economies (Canada; Peru; Philippines; Thailand; and the United States) and depicts how trade of fuel ethanol can help support the development of the overall alternative fuel infrastructure.

More importantly, the report highlights the obstacles and challenges along the supply chain- from feedstock and infrastructure challenges to policy framework that foster the creation of domestic ethanol industries.

Abbreviations & Acronyms

Case Studies:

Canada:

APEC	Asia-Pacific Economic Cooperation
CAGR	Compound Annual Growth Rate
GHG	Greenhouse Gas
MSW	Municipal Solid Waste
NAFTA	North American Free Trade Agreement
RFR	Renewable Fuels Regulations
RFS2	U.S. Renewable Fuel Standard

Philippines:

CAGR	Compound Annual Growth Rate
GFI	Government Financial Institutions

Thailand:

AEDP	Alternative Energy Development Plan
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U.S.:

CARB	California Air Resources Board
EE	Ethanol Equivalent
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
HVO	Hydrotreated Vegetable Oil
LCFS	Low Carbon Fuel Standard
MMP	Misfueling Mitigation Plan
RFA	Renewable Fuels Association
RFS2	Renewable Fuel Standard 2 (Originally authorized under the Energy Policy Act of 2005, the RFS was expanded under the Energy Independence and Security Act of 2007 and referred to as RFS2.)
RIN	Renewable Identification Number
VEETC	Volumetric Ethanol Excise Tax Credit

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Case Study - Canada

Canada's Ethanol Market in Figures (2015)

Average national blend in gasoline - **5.9% by volume**

Fuel ethanol demand - **2.75 billion liters**

Fuel ethanol production - **1.7 billion liters**

Number of plants - **17**

Industry capacity - **1.8 billion liters**

Net fuel ethanol imports - **1.1 billion liters**

Total ethanol imports - **1.1 billion liters**

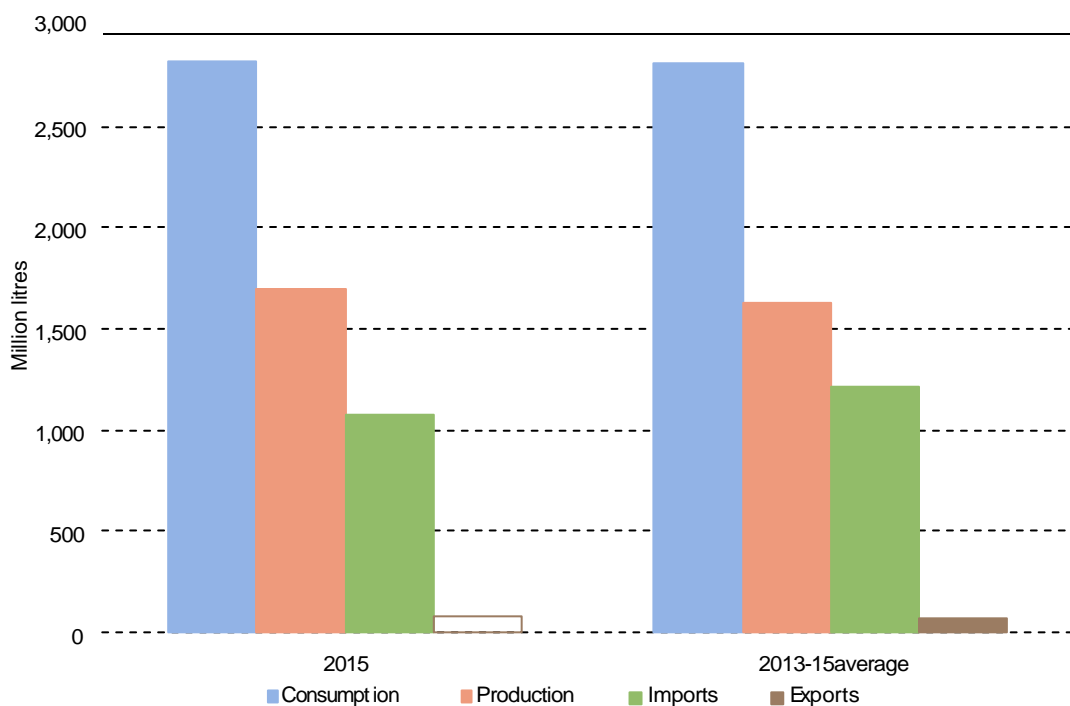
Total ethanol exports - **82 million liters**

Main import origin - **U.S.**

Snapshot - ethanol in Canada

Canada is the third largest consumer of fuel ethanol of the 21 APEC members behind the U.S. and China. Consumption in 2015 reached 2.75 billion liters driven by the nationwide blending mandate of 5% ethanol in gasoline. The industry has been stable for several years with demand and output remaining flat. Over this period the supply gap has been met with imports of around 1.1 billion liters per year from the U.S.

Diagram CA.1: Fuel ethanol balance, average 2013-15



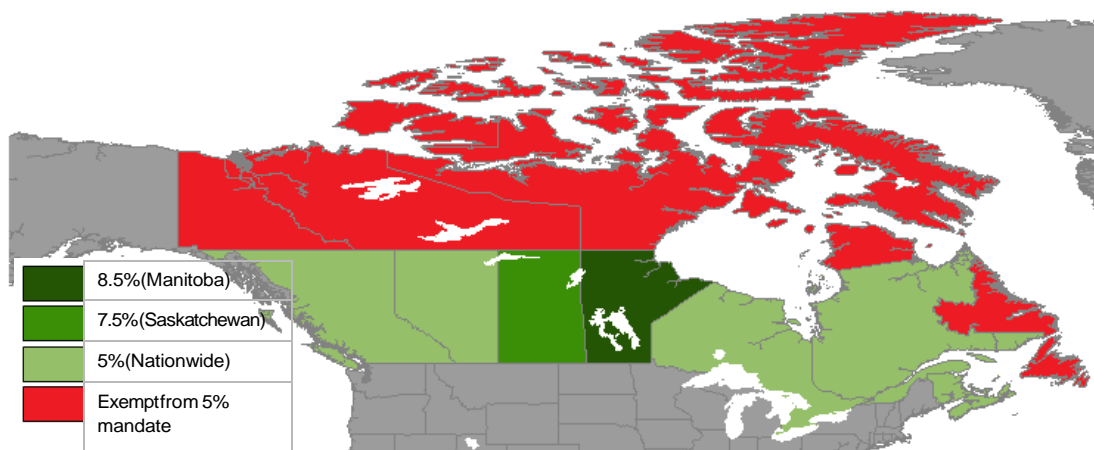
Biofuel policy history

The aim of the Canadian government in implementing biofuel targets was to reduce the greenhouse gas emissions of the economy. The implementation of a nationwide 5% ethanol mandate was announced under the federal Renewable Fuels Regulations (RFR) on September 1st 2010. The mandate came into effect on December 15th and remains in force today. However, because of logistical constraints and unfavorable climate some provinces are exempt from the mandate (Map CA.1).

The federal ethanol mandate was preceded by several provincial mandates:

- 2007: Ontario and Saskatchewan initiated 5% and 7.5% mandates, respectively.
- 2008: Manitoba implemented an 8.5% mandate.
- 2010: British Columbia initiated a 5% mandate.
- April 2011: Alberta implemented a 5% mandate.
- 2012: Quebec implemented a 5% mandate, which includes advanced renewable fuels.

Map CA.1: Ethanol mandates by province



The RFRs stipulate that each primary supplier must provide ethanol comprising at least 5% of their total gasoline pool by volume during the compliance period. Exclusions apply for aircraft fuel and for regions in the economy which are north of latitude 60°N plus Newfoundland and Labrador. There is also the option of using up to 20% of the total “biocrude” supply in the gasoline pool, towards fulfillment of the mandate. Biocrude refers to renewable drop-in fuels, which are chemically similar to petroleum-based fuels, but produced using renewable feedstocks. In the case of the ethanol mandate, the regulation therefore refers to biogasoline.

While Environment Canada considered creating specific mandates for biofuels based on GHG savings, in the mold of the advanced biofuels mandate of the U.S. Renewable Fuel Standard (RFS2), this was rejected on the basis of insufficient certainty around GHG assessments.

The maximum threshold for renewable fuels in gasoline has been set at 10%. The maximum permissible blend is set at E-85, while the blending limit is set at 80% for other fuels.

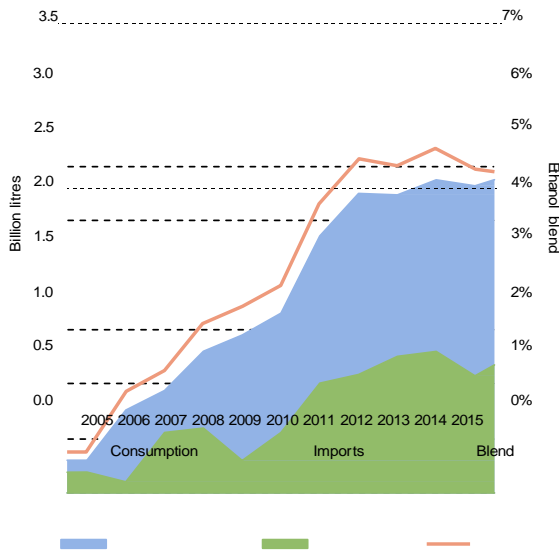
Prior to the establishment of the RFR, the most significant federal incentive for ethanol was the fuel-tax exemption. This was phased out in 2008 and replaced with a range of targeted support programs.

Supply and demand

The rapid growth in ethanol demand seen between 2005 and 2012 has slowed in recent years with the average blend of ethanol in gasoline across the economy remaining fairly stable at around 6% by volume (Diagram CA.2).

Diagram CA.2: Fuel ethanol consumption and blend

The diagram reveals:

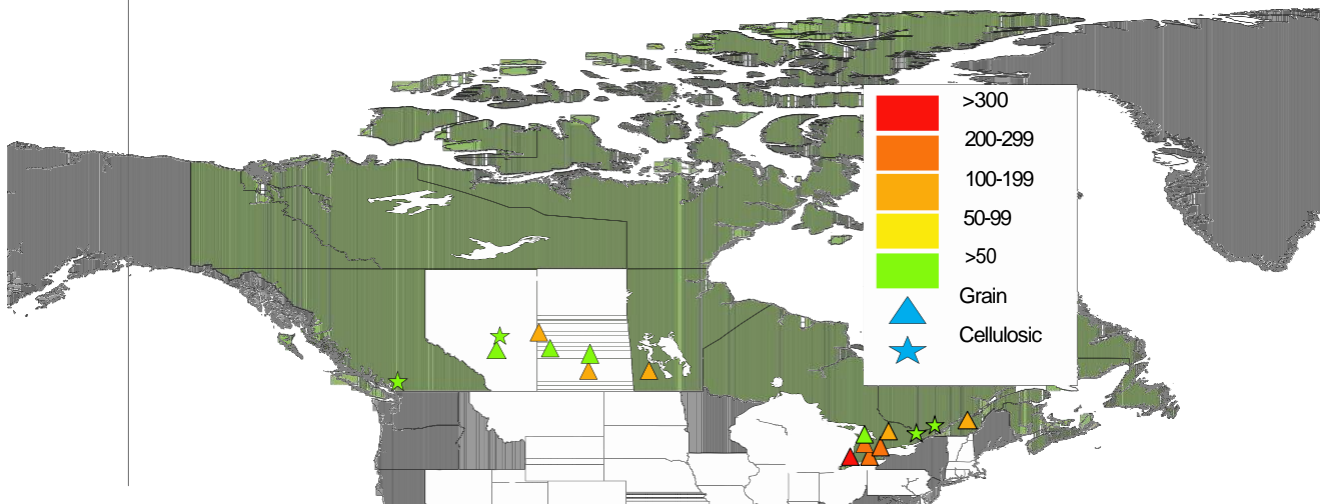


- The compound annual growth rate (CAGR) of ethanol demand between 2005 and 2012, the period that mandates were put in place, both at province and national levels, was 37%.
- The CAGR between 2012 and 2015, which saw no change in ethanol mandates, was just 5%.
- Imports have made up around 40% of ethanol used in Canada historically.

There are 13 first generation ethanol plants in Canada currently operating with a combined capacity of 1.76 billion liters per year. These plants use a combination of wheat and corn as their feedstock. In addition to this there are 4 cellulosic ethanol plants that are currently in operation. These four have a combined capacity of 45 million liters and they use a variety of cellulosic feedstocks including straw, woody biomass and MSW. Almost all of this cellulosic capacity is owned by Enerkem.

Map CA.2 reveals the locations of all operating plants in Canada, it is clear that most plants are located in the south of the economy with 70% of capacity located in the provinces of Ontario and Quebec.

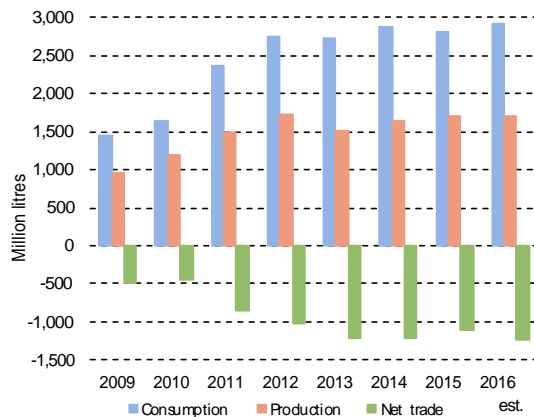
Map CA.2: Ethanol plants (capacity in million liters per year)



Trade

Although plants producing ethanol for use in Canada must register with Environment Canada there is no limit on the volume of ethanol imported into the economy or regulations on the feedstock or GHG saving required from the fuel.

Diagram CA.3: Fuel ethanol production, consumption and net trade



Imports into Canada from Mexico and the U.S. are tariff-free under the North American Free Trade Agreement (NAFTA).

Domestic production in Canada has been stable at close to 1.7 billion liters since 2012 with little new capacity coming on stream. The supply gap has not been met with growing domestic production because of the availability of plentiful supplies of cheap ethanol from the U.S. Demand for net imports has also remained flat at around one billion liters in recent years.

The vast majority of ethanol imports into Canada come from the U.S. The U.S. is the world's largest and cheapest supplier of ethanol and has obvious logistical advantages for exporting to Canada. Small volumes have

been imported from other economies, particularly Brazil which was a significant supplier between 2004 and 2009. However, since 2010 the U.S. has been the origin of 99% of all imports.

Map CA.3: Ethanol imports into Canada, average 2013-15 (billion liters)



Summary

Aims & policies	Achievements
<ul style="list-style-type: none"> • Aim: GHG emissions reduction • Policy: Nationwide blending mandate of 5% (with some regional exceptions) • Some province level blending mandates up to 8.5% • No restrictions or specifications on ethanol source or origin • Violations of the mandate are illegal and as such offending parties can be penalized in a number of ways from warnings to prosecution 	<ul style="list-style-type: none"> • Mandates: met with consumption of 2.8 billion liters • Average nationwide blend: 5.9% (2015) • Higher province mandates more than outweigh exempt northern provinces • Output of 1.7 billion liters supplies 60% of domestic demand (2015) • Free access to U.S. ethanol imports allow the mandate to be met with annual imports of around 1.2 billion liters • Operating capacity of 45 million liters of cellulosic ethanol
Challenges	Looking ahead
<ul style="list-style-type: none"> • Sparse population, cold weather and difficult logistics makes ethanol use in the northern provinces unrealistic and uneconomic • Producers struggle to compete with cheaper imports from U.S. • Cold weather means a higher blend is not possible without changes to vehicles 	<ul style="list-style-type: none"> • Increasing the mandate is unlikely due to the adverse conditions • No new production capacity in the pipeline • Potential for growth in cellulosic ethanol capacity for export to the U.S. market

Case Study - Peru

Peru's Ethanol Market in Figures (2015)

Average national blend in gasoline - **6.7% by volume**

Fuel ethanol demand - **161 million liters**

Fuel ethanol production - **125 million liters**

Number of plants - **2**

Industry capacity - **245 million liters**

Net fuel ethanol imports - **36 million liters**

Total ethanol imports - **115 million liters**

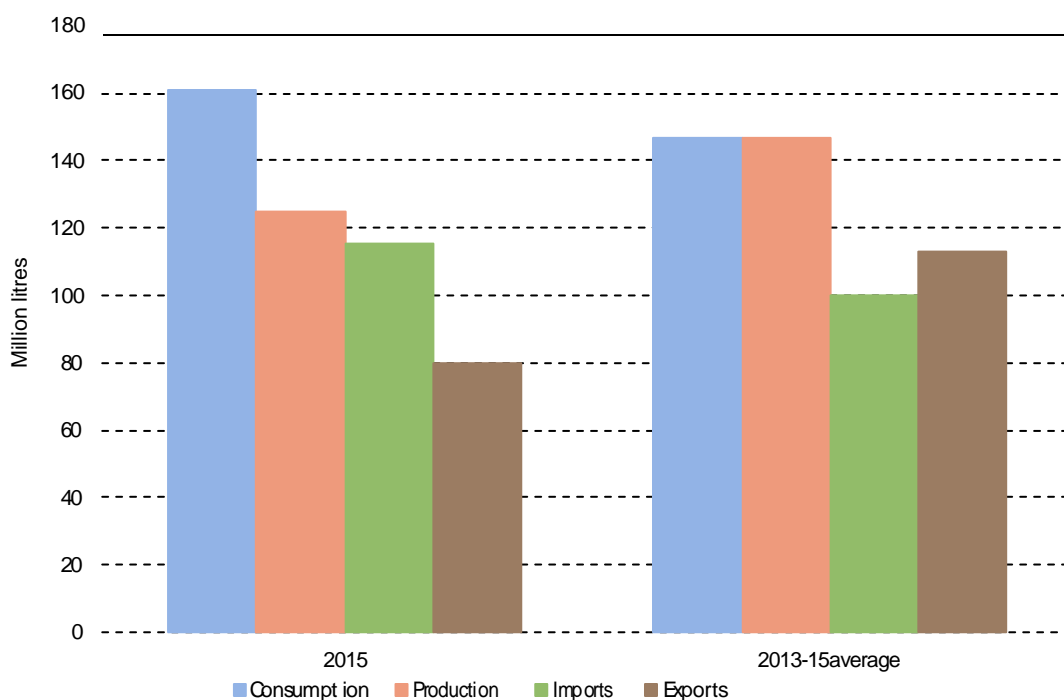
Total ethanol exports - **80 million liters**

Main import origin - **U.S.**

Snapshot - ethanol in Peru

Demand for fuel ethanol in Peru is entirely driven by the mandated blend of ethanol in gasoline set at 7.8%. The actual national blend of ethanol in gasoline is slightly below this at 6.7%. Consumption has averaged 147 million liters in the last three years (2013-15) and the economy has switched from being a net exporter to a net importer over that period. Financial difficulties for one local producer, has led to falling output in recent years with imports plugging the gap in supply.

Diagram PE.1: Fuel ethanol supply/demand, 2015 and 3 year average (2013-15)



Biofuel policy history

Peru implemented biofuel policy in order to diversify the transport fuel market, provide economic opportunities for agricultural producers, generate employment, reduce air pollution and to help tackle the large drug industry in the economy.

In 2005, the blending mandate for ethanol was announced. The mandate that all gasoline must contain a blend of 7.8% ethanol was set to be introduced gradually across the economy. The ethanol blended gasoline is referred to as “gasohol.”

The mandate was originally set to be implemented in some states in 2006. However, the roll out of the blend was delayed several times until finally coming into force in some states in April 2010. Map PE.1 reveals the progress of the mandate throughout the economy over the course of 15 months. The mandate has not been implemented in five regions (Amazonas, San Martin, Ucayali, Madre De Dois and Loreto). These regions are sparsely populated and heavily forested so the logistics of supplying the area with gasohol were deemed too difficult.

Diagram PE.2 reveals the monthly sales of ethanol over the period that the mandate was being implemented. The date of the mandate’s introduction into each region can also be seen on the diagram, highlighting the impact of policy on demand. In 2010, gasohol was introduced slowly to regions starting in the north and working south throughout the year. The marginal impact of each region was relatively small and left monthly consumption at close to 2.8 million liters. The second wave of implementation had a much larger and more immediate effect as the blend was introduced to the ten remaining regions all at once in July 2011. This saw consumption more than triple to an average of over 10.5 million liters per month in 2012.

Map PE.1: The implementation of the blending mandate across regions of Peru

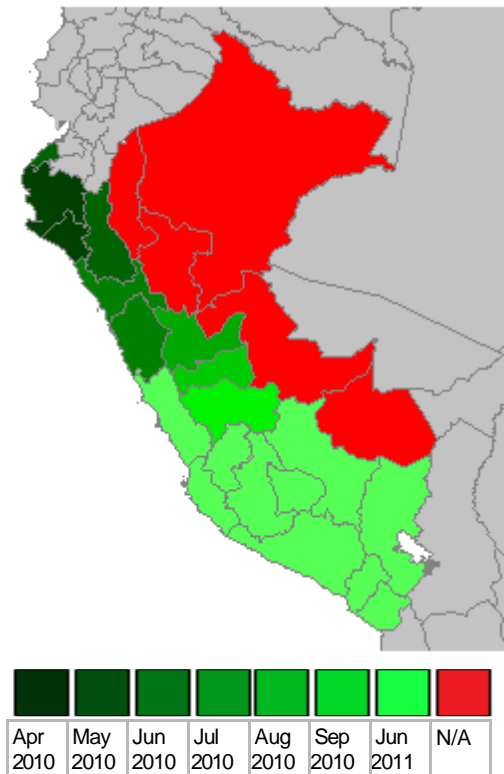
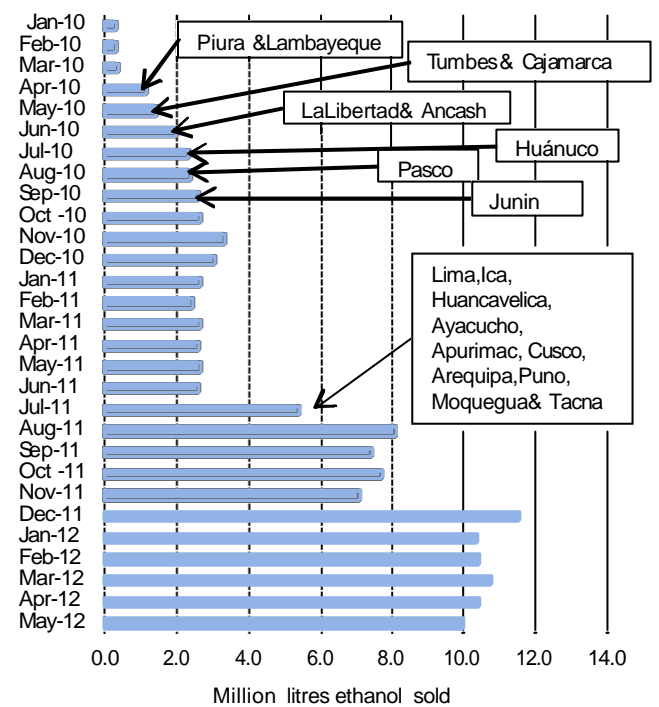


Diagram PE.2: Monthly fuel ethanol sales



Note: Regions shown linked to the month the blending mandate was implemented

Supply and demand

Since the full implementation of the blending mandate in June 2011, demand for fuel ethanol in Peru has grown in line with gasoline. The percentage of ethanol in total gasoline has been stable at around 6.7% since 2012. Growth in gasoline demand has driven rising ethanol sales with demand in the first half of 2016 reaching a total of 87.6 million liters. **2015 saw total fuel ethanol use of 161 million liters.** The region of Lima is by far the biggest consumer in the economy, responsible for almost half of total ethanol demand.

Map PE.2: Ethanol plants

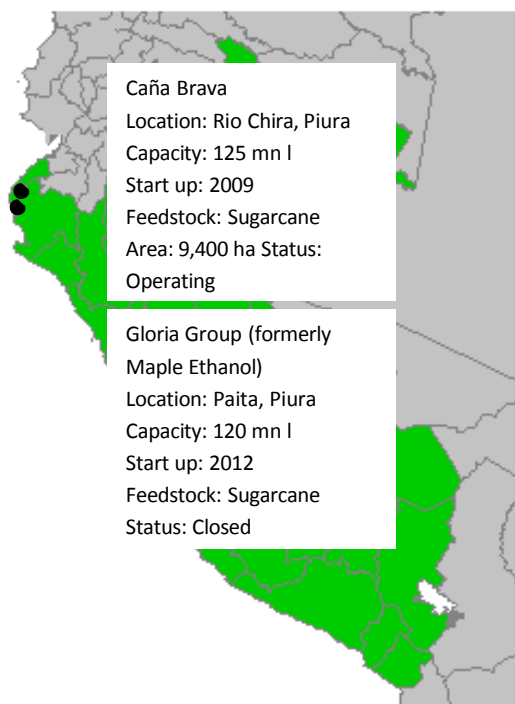
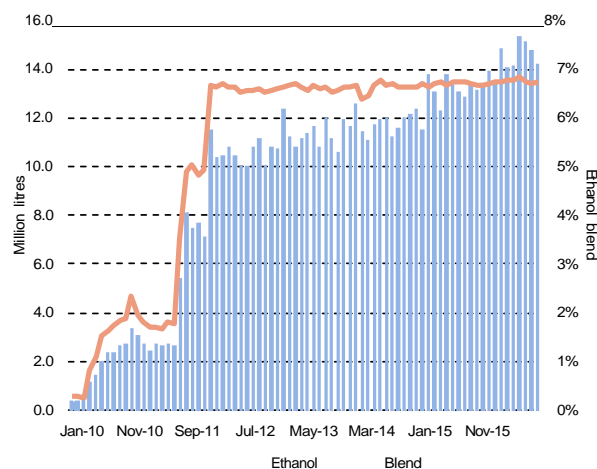


Diagram PE.3: Monthly ethanol sales and blend



The announcement of the mandate led to several companies announcing plans to build fuel ethanol production facilities. Between 2006 and 2010 six large-scale fuel ethanol plants were planned with a combined capacity of 840 million liters per year. However, four of these plants never made it past the planning stage. In 2014 investment in another ethanol plant was announced with plans to open in 2018 but since then there has been no sign of construction.

There are currently just two functional fuel ethanol plants in Peru with a combined **capacity of 245 million liters per year**, both using sugarcane as a feedstock. They are owned by Caña Brava (125 million liters) and Maple Ethanol (120 million liters) and both located in the northern region of Piura. However, the Maple Ethanol plant has been beset by problems forcing the company to sell the facility in 2015. The company was acquired by the Gloria Group but has yet to restart operations.

The capacity of these two plants is significantly above the current level of demand in Peru of around 160 million liters so there is potential for the economy to be a net exporter if it is competitive on the world market.

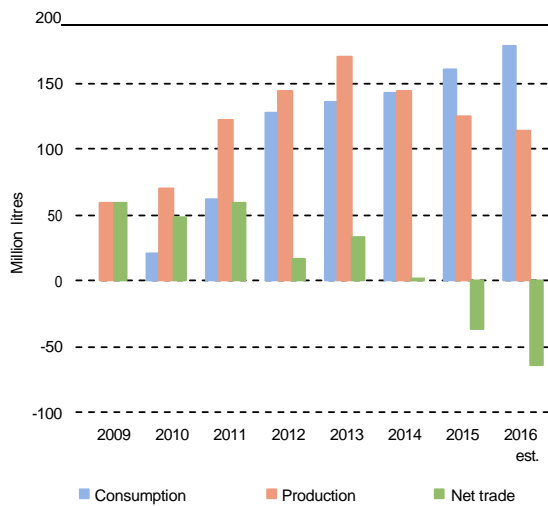
Production reached a peak in 2013 of 170 million liters when both plants were operating (Diagram PE.4). However, since then the troubles at Maple Ethanol have led to **output volumes shrinking to reach just 125 million liters in 2015.**

Trade

Peru allows ethanol from any origin to be used to meet its mandate. This brings several benefits, including:

- Competition in the market
- Access to low cost ethanol
- Sufficient supplies to meet the mandate, covering any gaps in domestic supplies

Diagram PE.4: Fuel ethanol production, consumption and net trade

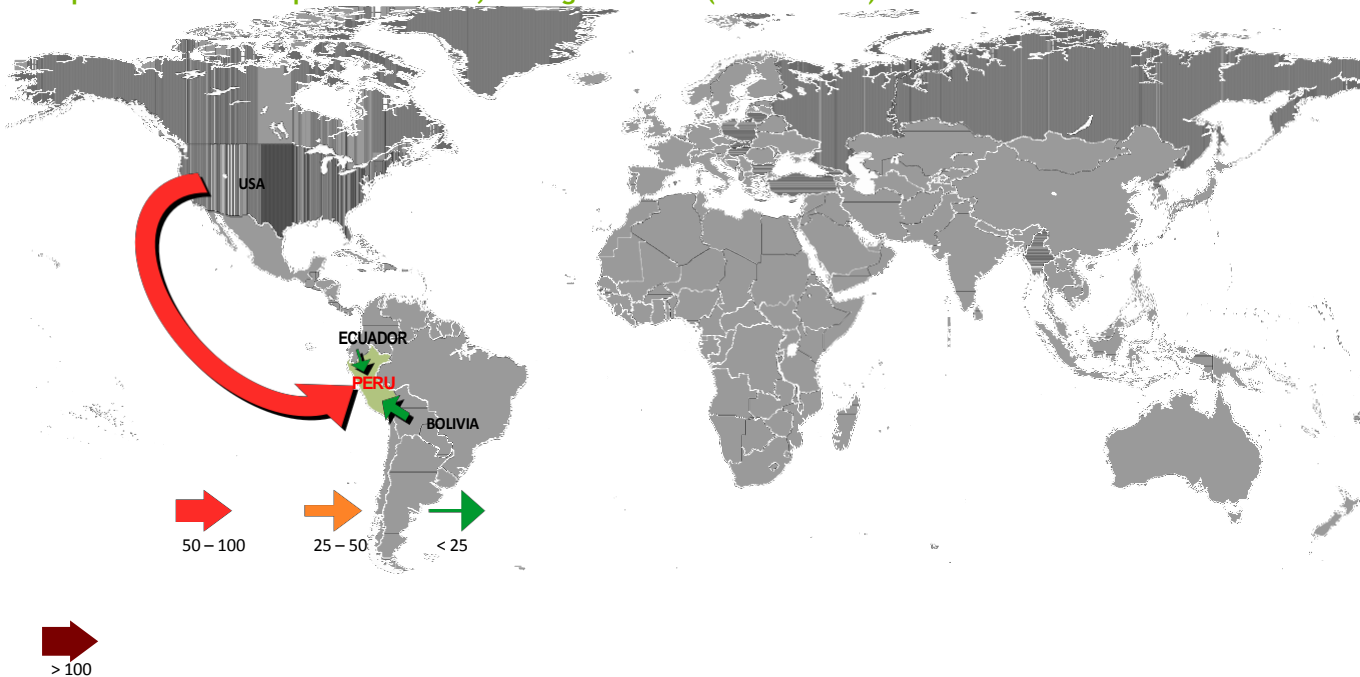


Peru has become a net importer of fuel ethanol since 2015 as domestic producers have struggled to cope with difficult economic conditions. As discussed above, production has fallen from a peak of 170 million liters in 2013, falling by 26% in the two years to 2015. Demand for ethanol has risen in line with growing demand for gasoline leading net imports to rise to over 35 million liters in 2015.

The majority of this import demand has been met with ethanol from the U.S. As the world's largest and lowest cost producer of ethanol, the U.S. is also the largest supplier of ethanol onto the world market. In 2015, Peru imported 115 million liters of ethanol (including both fuel and non-fuel grades). Of that total 105 million liters were fuel ethanol imports from the U.S. These imports have allowed the mandate to be met despite the difficulties faced by domestic producers in recent years.

Peru also exports significant volumes of ethanol to the EU and surrounding economies. Total exports in 2015 were 80 million liters.

Map PE.3: Ethanol imports into Peru, average 2013-15 (million liters)



Summary

Aims & policies	Achievements
<ul style="list-style-type: none"> • Aims: diversify the transport fuel market, provide economic opportunities for agricultural producers, generate employment, reduce air pollution and to help tackle the large drug industry • Policy: Nationwide blending mandate of 7.8% (with some states exempt) • No restrictions or specifications on ethanol source or origin • Blending is a legal requirement 	<ul style="list-style-type: none"> • Mandates: met in the states it is applied with consumption of 161 million liters (2015) • Average nationwide blend: 6.7% (2015) • Output of 125 million liters equal to 78% of domestic demand (2015) • Access to imports, particularly from the U.S., have allowed the mandate to be met in years when supply cannot meet demand
Challenges	Looking ahead
<ul style="list-style-type: none"> • Sparse population and difficult logistics makes ethanol use in the some states unrealistic and uneconomic • Producers have struggled with only two of six planned plants being built • One of the two operating plants failed to reach financial stability and had to stop operations 	<ul style="list-style-type: none"> • No plans to increase the ethanol blend however demand will rise in line with gasoline use • Despite occasional announcements of new projects, no new fuel ethanol capacity is under construction • If the financial situation improves enough for both plants to operate, Peru will return to being a net exporter with duty free access to the U.S.

Case Study - Philippines

Philippines' Ethanol Market in Figures (2015)

Average national blend in gasoline - **9.1% by volume**

Fuel ethanol demand - **509 million liters**

Fuel ethanol production - **168 million liters**

Number of plants - **13** (10 accredited, 3 awaiting accreditation)

Industry capacity - **430 million liters** (282 million liters accredited)

Net fuel ethanol imports - **341 million liters**

Total ethanol imports - **363 million liters**

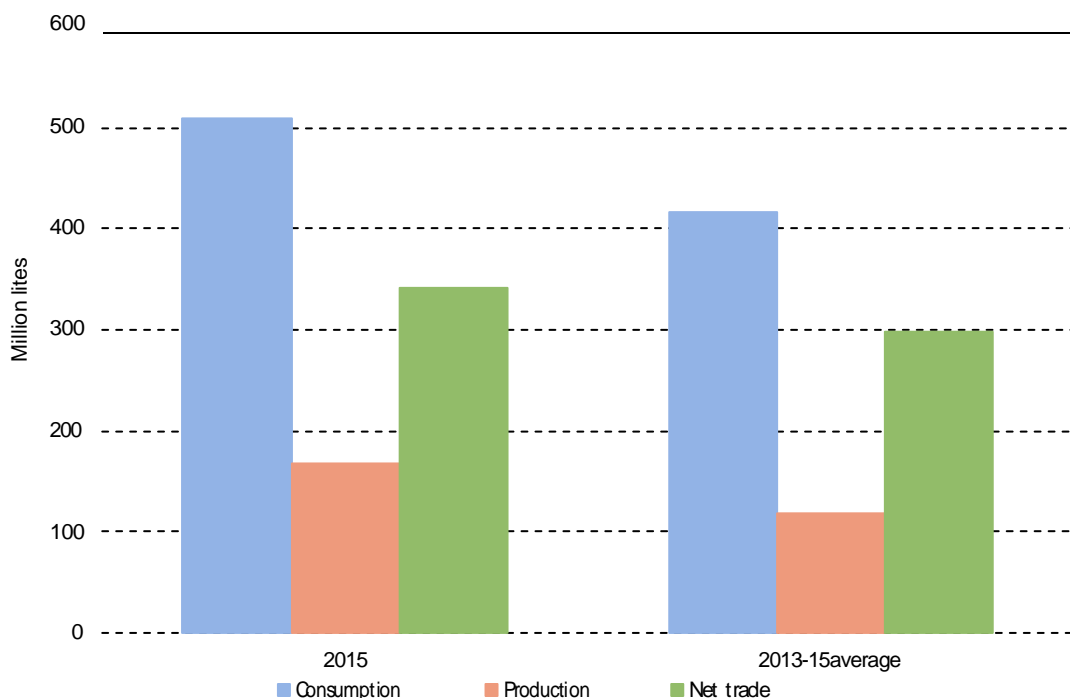
Total ethanol exports - **0 million liters**

Main import origin - **U.S., Thailand, Brazil, Pakistan, Indonesia, Singapore**

Snapshot - ethanol in the Philippines

Fuel ethanol in the Philippines is driven by a mandated blend of ethanol with gasoline. The mandate was first set at 5% and was subsequently raised to its current level of 10% in 2012. The industry is also supported by generous tax subsidies and incentives. Domestic ethanol is given first preference in the market with imported product only allowed if there is insufficient supply locally. Although domestic output has increased in recent years the market is still heavily reliant on imports to meet their mandates (Diagram PH.1).

Diagram PH.1: Fuel ethanol balance, average 2013-15



Biofuel policy history

The Filipino government signed into law the Biofuels Act of 2006 on January 12th 2007. The aim of the Act was to:

- Increase the contribution of biofuels in the economy's energy mix
- Develop and utilize domestic renewable and sustainable sources of energy
- Reduce dependence on imported fossil-based fuels
- Improve the quality of the environment
- Create opportunities for rural socio-economic development

The Act set out blending mandates for ethanol in gasoline and biodiesel in diesel making the Philippines the first South East Asian economy to have biofuels blending legislation.

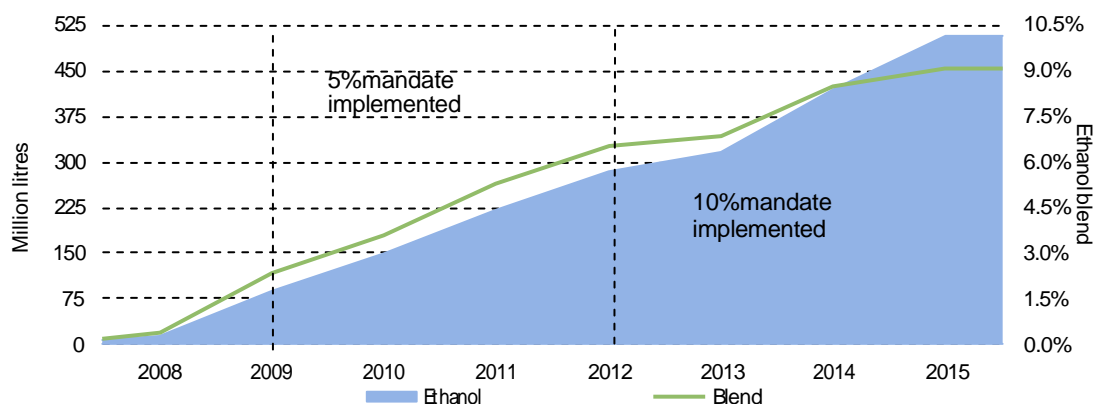
The ethanol blending mandate was set at 5% from 6th February 2009 and increased to 10% on the February 6th 2012. There are plans to increase the blend again to 20% in 2020.

To reach the goal of using domestic resources the ethanol used to meet the mandate must be domestically sourced. Imports are only permitted when there is a shortage of supplies of local product as decided by the National Biofuel Board.

Incentives

- Specific tax per liter of blended ethanol set at zero.
- Raw materials used in the production of biofuels are exempt from Value Added Tax (VAT).
- Exemption from Wastewater Charges of all water effluents from the production of biofuels under Philippine Clean Water Act.
- High priority from Government Financial Institutions (GFIs) to entities that engage in production, storage, handling and transport of biofuel and biofuel feedstock, including the blending with petroleum as certified by the Department of Energy.

Diagram PH.2: Fuel ethanol consumption and blend

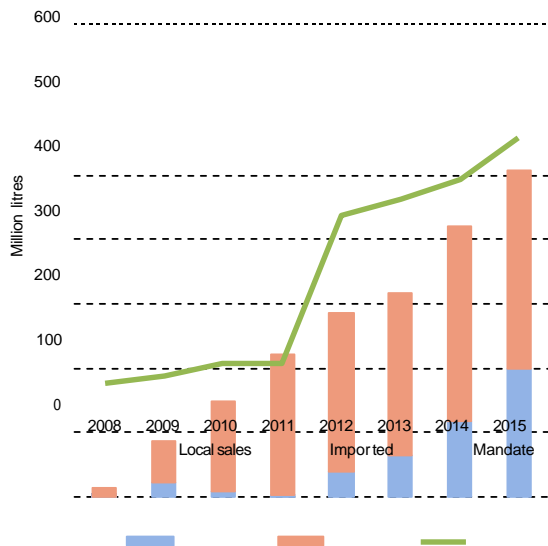


Supply and demand

Since the implementation of the blending mandate in February 2009 demand for fuel ethanol in the Philippines has risen steadily, **reaching over 500 million liters in 2015**. Diagram PH.3 reveals the annual sales of fuel ethanol compared to the volume needed to meet the mandate. The split between domestic and imported ethanol sales are also shown.

Diagram PH.3: Ethanol sales by fuel type

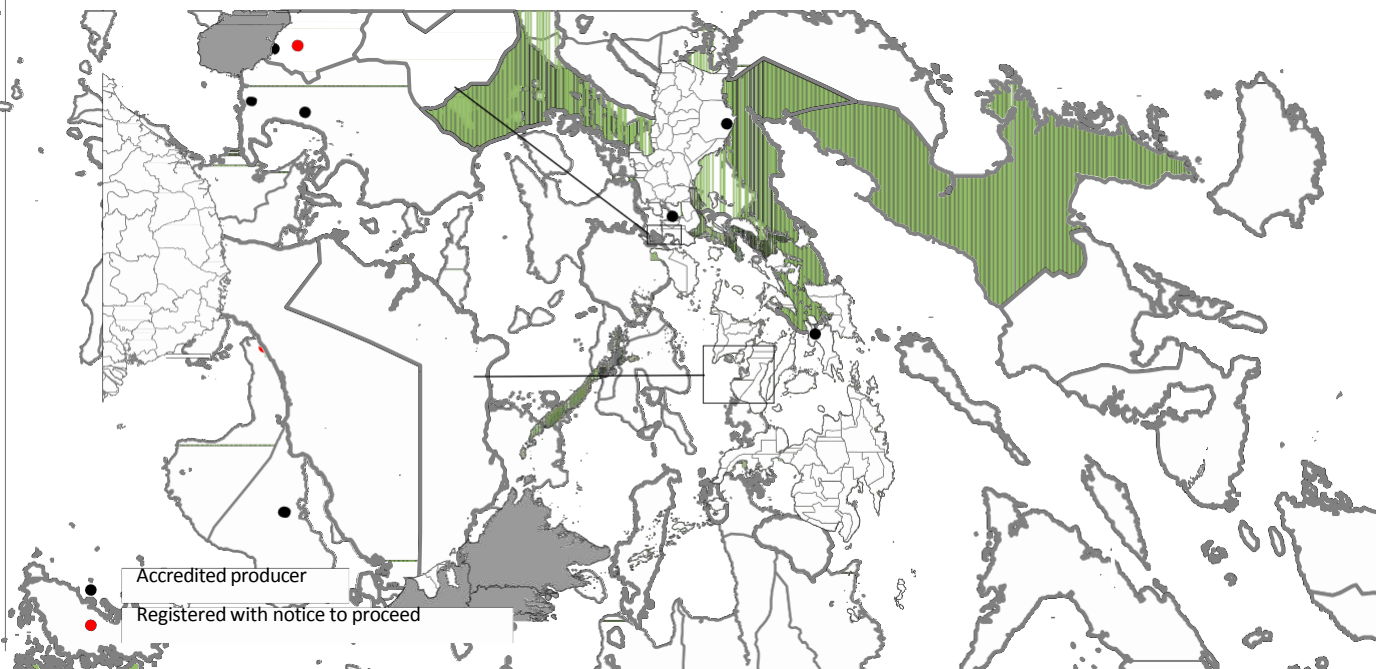
The diagram reveals:



- Sales have grown with a compound annual growth rate (CAGR) of 34% between 2009 and 2015.
- The mandate has only been met in one year so far (2011).
- The proportion of sales from imported ethanol has shrunk over recent years.
- Domestic production only began to provide significant volumes in 2012 but has increased quickly to provide almost 40% of total sales in 2015.

Imports have played a key role in allowing the Philippines to meet their targets as domestic infrastructure and facilities have taken time to come online. Domestic fuel ethanol producers must register with the Department of Energy in order to become an accredited supplier. There are currently ten accredited plants with a combined capacity of just over 280 million liters. A further two plants are registered with the ministry and have received notice to proceed and there is one plant which is currently in the process of registration. These three plants will add an additional 147 million liters of capacity.

Map PH.1: Ethanol plants

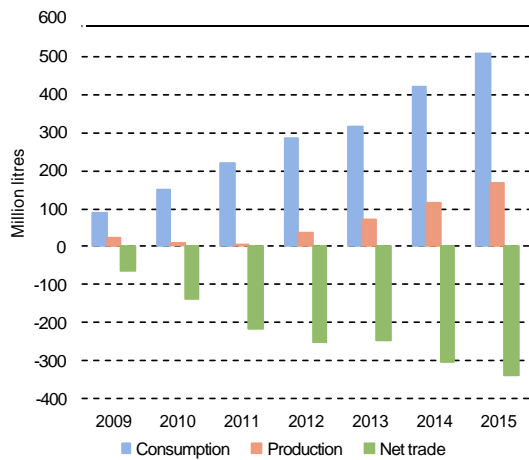


Trade

The Philippines only allow imported ethanol to be used toward the mandate when there are insufficient supplies domestically. This:

- Supports the domestic industry, and
- Allows the mandate to be met in years of domestic shortage

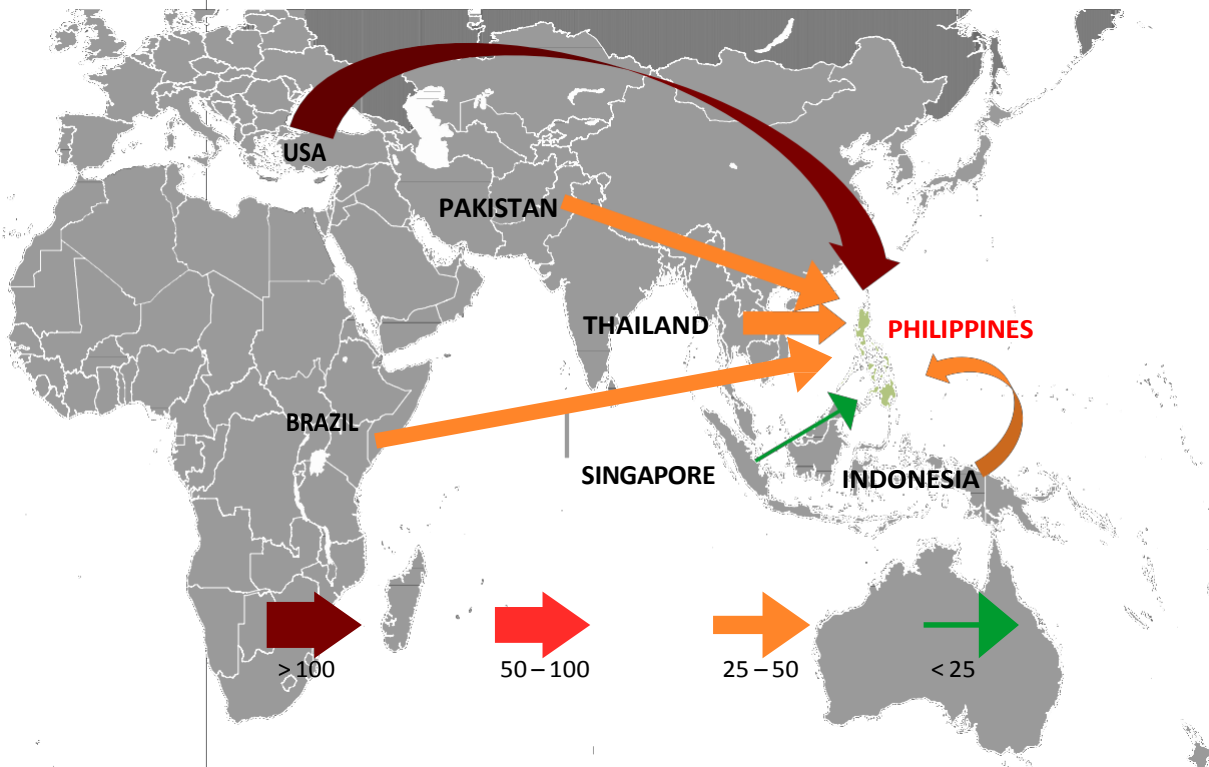
Diagram PH.4: Fuel ethanol production, consumption and net trade



Domestic production of fuel ethanol has increased over the period since 2009 when the mandate was introduced. However, there was a lag of several years between the announcement of the policy and capacity coming on stream which necessitated the import of ethanol in order for the mandate to be met. Although output has increased demand for imports has also risen, reaching 350 million liters in 2015. There are no exports of ethanol from the Philippines as all production is used toward the mandate.

The supply gap is filled with imports from a number of economies. The U.S. is primary source of ethanol globally. However, significant volumes have also come from Thailand, Brazil, Pakistan and Indonesia.

Map PH.2: Ethanol imports into the Philippines, average 2010-15 (million liters)



Summary

Aims & policies	Achievements
<ul style="list-style-type: none"> • Aims: <ul style="list-style-type: none"> – Increase the contribution of biofuels in the economy's energy mix – Develop and utilize domestic renewable and sustainable sources of energy – Reduce dependence on imported fossil-based fuels – Improve the quality of the environment – Create opportunities for rural socio-economic development • Policy: Nationwide blending mandate of 10% • Imports only allowed if domestic supplies are insufficient • Tax incentives and exemptions available to all stages of ethanol supply chain 	<ul style="list-style-type: none"> • Mandates: consumption around 10% below mandate at 509 million liters (2015) • Average nationwide blend: 9.1% (2015) • Output has risen steadily over recent years with more plants in the process of being accredited • Output of 168 million liters supplies 33% of domestic demand (2015) • Fulfillment of mandates has only been possible thanks to imports which have grown over recent years to meet rising demand • Imports predominantly from surrounding economies, Brazil and the U.S.
Challenges	Looking ahead
<ul style="list-style-type: none"> • Production has been slow to come online resulting in growing demand for imports • Actual demand has lagged the mandate in every year except 2011 	<ul style="list-style-type: none"> • There are plans to increase the mandate to 20% in 2020 • Almost 150 million liters of capacity is in the process of registering with the government and should be able to supply the market soon

Case Study - Thailand

Thailand's Ethanol Market in Figures (2015)

Average national blend in gasoline - **12.5% by volume**

Fuel ethanol demand - **1.2 billion liters**

Fuel ethanol production - **1.2 billion liters**

Number of plants - **22**

Industry capacity - **1.6 billion liters**

Net fuel ethanol imports - **negligible**

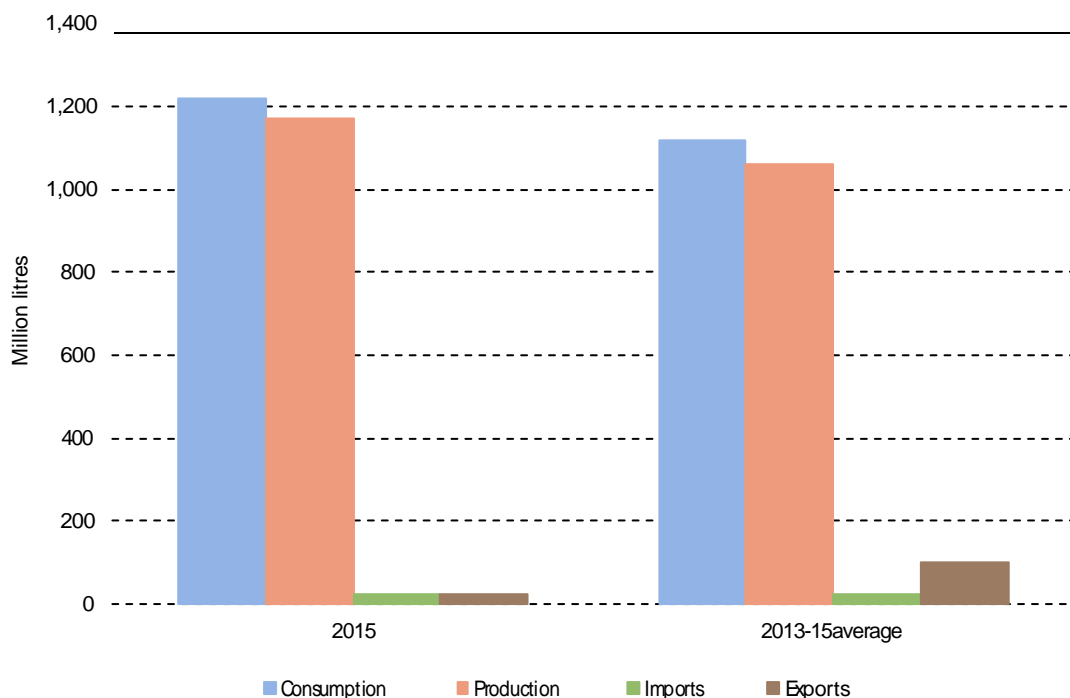
Total ethanol imports - **22 million liters**

Total ethanol exports - **20 million liters**

Snapshot - ethanol in Thailand

Fuel ethanol in Thailand is supported by generous government subsidies as well as mandates that require the replacement of regular gasoline with E-10 and E-20 gasohol. There is also growing consumption of E-85 in flex fuel cars. With a current market size of 1.2 billion liters, Thailand is largely self-sufficient with only small quantities of ethanol being traded (Diagram TH.1). However, the mandate is set to increase from 3.3 billion liters in 2012 to 4.1 billion liters in 2034. Imports will be needed to meet these targets as current domestic capacity is just 1.6 billion liters. Around 65% of fuel ethanol is produced from molasses, with the remainder coming from cassava.

Diagram TH.1: Fuel ethanol supply/demand, 2015 and 3 year average (2013-15)



Biofuel policy history

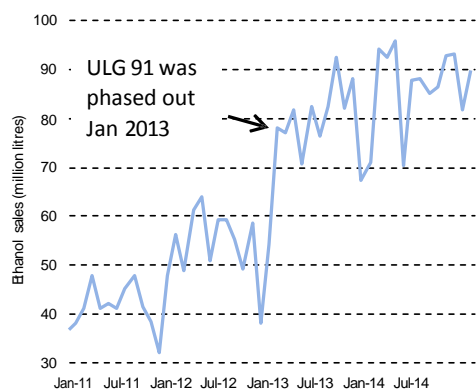
Thailand's biofuel policy is aimed at promoting energy security, supporting the economy and benefiting the environment. The economy has been supporting fuel ethanol with legislation since 2003 when it first passed the National Ethanol Program and Gasohol Strategic Plan. The 10 year Alternative Development Plan (2012-2021) was replaced by Thailand's 20-year National Energy Plan (2015-2036) in October 2015 which brought energy policy into alignment with the 11th National Economic and Social Development Plan. Like the 2012 plan, the new plan includes an Alternative Energy Development Plan (AEDP), Oil Plan and Gas Plan. Under the AEDP, the share of renewable energy and alternative energy from biofuels is targeted to increase from 7% in 2015 to 25% in 2036. Specifically, **the government aims to increase ethanol consumption to 4.1 billion liters and biodiesel consumption to 5.1 billion liters by 2036**. The 2012 ADP sets interim targets of 3.3 billion liters for ethanol and 2.2 billion liters for biodiesel in 2021.

Ethanol consumption is promoted through the use of incentives provided by the State Oil Fund, making gasohol 20 to 40% cheaper than regular gasoline (Table TH.1). The price subsidy rises with the ethanol blend, making higher blends cheaper at the pump. In addition, the government increased the marketing subsidies to gasoline stations to 5 baht/liter (\$0.14/liter) to persuade them to increase sales of E85. In addition, the government offers a 3% reduction in excise tax for the production of flex fuel cars which use E85. These subsidies do not have an official end date but as the proportion of gasoline falls and ethanol rises the burden on the government will increase, as tax revenues fall while increasing subsidies are needed.

Table TH.1: Price structure of petroleum products in Bangkok (June 2016, Baht per liter)

	Premium gasoline (Octane 95)	Gasohol E10 Octane 95	Gasohol E10 Octane 91	Gasohol E20	Gasohol E85
Ex-refinery price	13.78	14.79	14.55	15.79	20.53
Excise tax	6.00	5.40	5.40	4.80	0.90
Municipal tax	0.60	0.54	0.54	0.48	0.09
State oil fund	6.31	0.25	0.21	-2.75	-9.30
Conservation fund	0.25	0.25	0.25	0.25	0.25
Wholesale price	26.94	21.23	20.95	18.57	12.47
VAT @ 7%	1.89	1.49	1.47	1.30	0.87
Wholesale price+VAT	28.82	22.72	22.41	19.87	13.35
Marketing margin	2.65	1.85	1.74	2.12	4.71
VAT	0.19	0.13	0.12	0.15	0.33
Retail price	31.66	24.70	24.28	22.14	18.39
Gasohol subsidy		6.96	7.38	9.52	13.27

Diagram TH.2: Monthly ethanol sales, 2011-2014

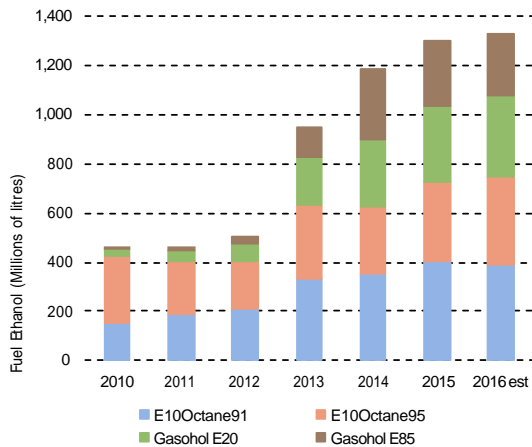


- The fuel ethanol market received a huge boost when unleaded gasoline 91 (the main market for gasoline) was replaced in January 2013 with gasohol (E-10) 91. The impact of this was to increase monthly ethanol sales from around 60 million liters to around 80 million liters.
- The government announced plans in early 2016 to further boost ethanol demand by phasing out gasohol 91 and 95 (E10) by 2018 and 2027, respectively leaving only higher blends (E20 and E85) of ethanol available.

Supply and Demand

Thailand's fuel ethanol market has grown consistently year-on-year and is estimated to reach 1.3 billion liters in 2016, slightly up on the previous year. As noted earlier, a major boost to demand came in 2013 when regular gasoline 91 was replaced with gasohol (E10) 91.

Diagram TH.3: Ethanol sales by fuel type

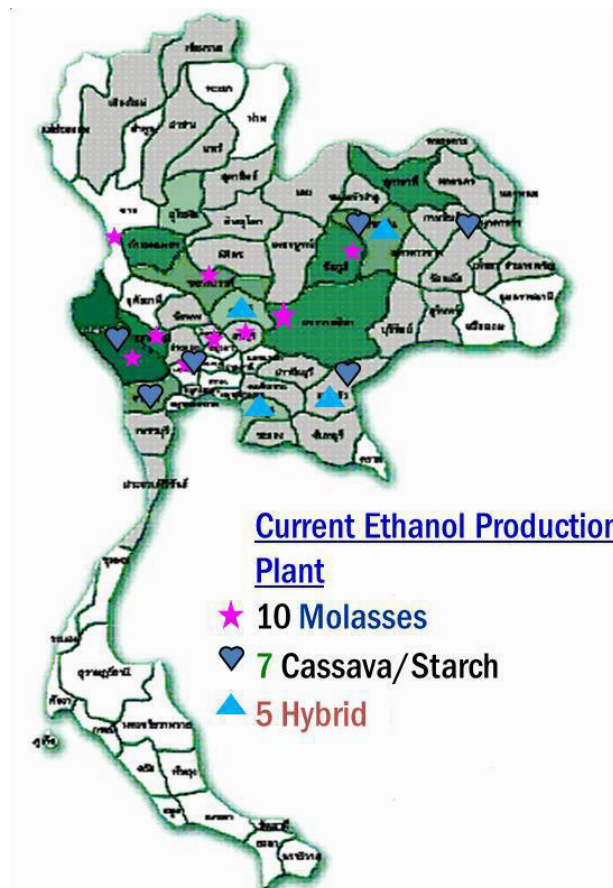


- Diagram TH.3 shows the distribution of ethanol sales by market. This reveals that in 2015, 56% of fuel ethanol sales were of E-10. A further 23% were of E-20 while E-85 accounted for the remaining fifth of the market.
- The contribution of E-20 continues to grow strongly and is expected to rise by over 10% in 2016 compared to the previous year.

Thailand has 22 fuel ethanol plants and a total installed industry capacity of 1.6 billion liters. 10 plants are based on molasses, 8 are based on cassava while 5 process a mixture of molasses and cassava (Map TH.1). One plant also has the capacity to use sugarcane juice.

In 2015, production of fuel ethanol reached 1.2 billion liters, with an estimated 759 million liters coming from molasses, 69 million liters from sugarcane and 346 million liters being produced from cassava. As supplies of molasses are limited by sugar production, and cane juice (valued at its opportunity cost of sugar) is expensive, future growth in output is expected to come from cassava.

Map TH.1: Ethanol plant locations



Trade

According to the Thai Customs Department, fuel ethanol is a controlled product and traders must have a license to either import or export the product. To date, the Ministry of Industry has never approved the import of fuel ethanol as domestic supplies have always been deemed to be sufficient. However, the economy imports small quantities of industrial and beverage alcohol. These are liable to an import duty of 2.5 baht/liter (\$0.07/liter) which is applied to all ethanol imports under HS code 2207.

Diagram TH.4: Trade in ethanol

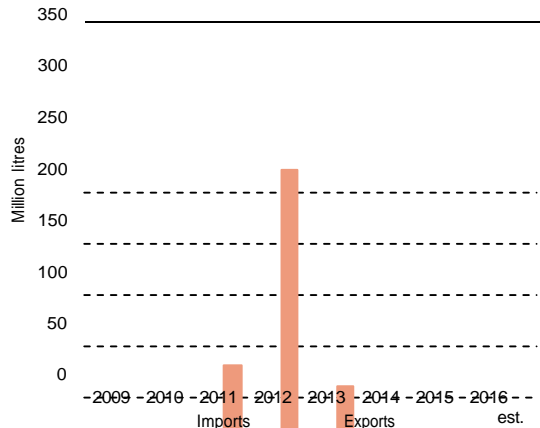
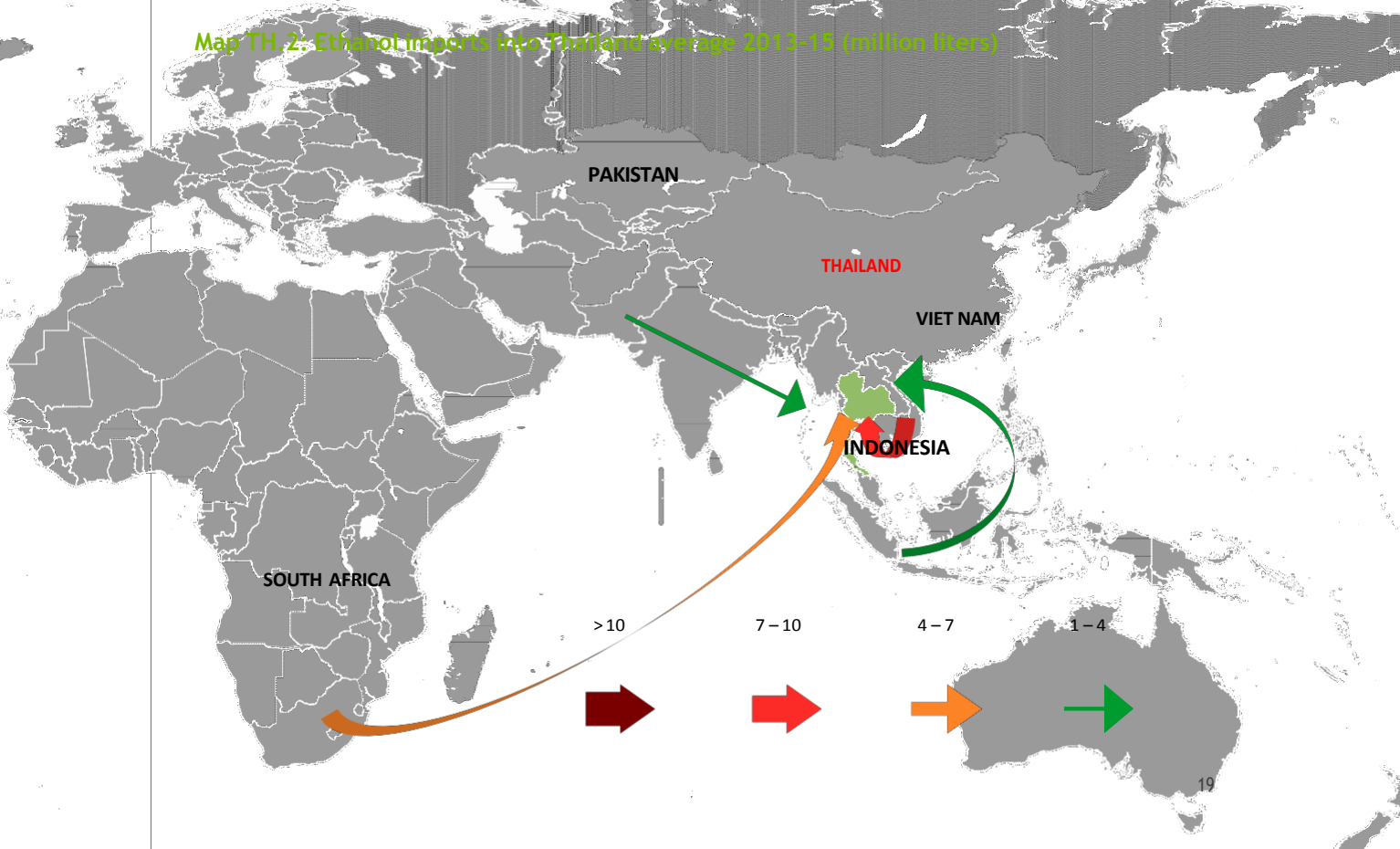


Diagram TH.4 highlights trade in ethanol since 2009. Imports have been consistently low at just 20-25 million liters for most of the period. It is thought that 11 million liters were destined for industrial uses mainly in pharmaceuticals and cosmetics.

Over the past three years exports have reached 20 million liters per annum. These exports are destined for the industrial market as producers do not have the storage facilities that would allow them to make fuel ethanol exports in bulk.

The economy exported over 300 million liters of ethanol in 2012 thanks to record molasses production. This generated a surplus of ethanol for export. As the domestic fuel market continues to grow, the economy is unlikely to export much ethanol in the next few years.

Map TH.2: Ethanol Imports into Thailand average 2013-15 (million litres)



Summary

Aims & policies	Achievements
<ul style="list-style-type: none"> • Aims: promoting energy security, supporting the economy and benefiting the environment • Policy: 20-year National Energy Plan (2015-2036) • The Plan aims to increase ethanol consumption to 4.1 billion liters by 2036 • Ethanol consumption is promoted through the use of incentives provided by the State Oil Fund, making gasohol 20 to 40% cheaper than regular gasoline at the pump 	<ul style="list-style-type: none"> • Mandates: incentives have seen consumption rise to 1.3 billion liters (2015) • Average nationwide blend: 12.5% (2015) • Output has closely matched demand
Challenges	Looking ahead
<ul style="list-style-type: none"> • The generous subsidies on ethanol make the program expensive to run • Limits on imports of fuel ethanol will make increasing mandates difficult to meet • Limited availability of molasses means that future growth will have to come from cassava. Sugarcane juice is generally too expensive as a feedstock for ethanol 	<ul style="list-style-type: none"> • The government intends to phase out E-10 in favor of E-20. Gasohol 91 will be phased out in 2018, followed by gasohol 95 in 2027 • E-85 is expected to comprise a growing portion of the market • Meeting the growing mandates will be difficult if the government continues to exclude imported fuel ethanol

Case Study - U.S.

U.S.'s Ethanol Market in Figures (2015)

Average national blend in gasoline - **10.0% by volume**

Fuel ethanol demand - **52.9 billion liters**

Fuel ethanol production - **56.0 billion liters**

Number of plants - **195**

Industry capacity - **56.4 billion liters (fuel only)**

Net fuel ethanol exports - **3.1 billion liters**

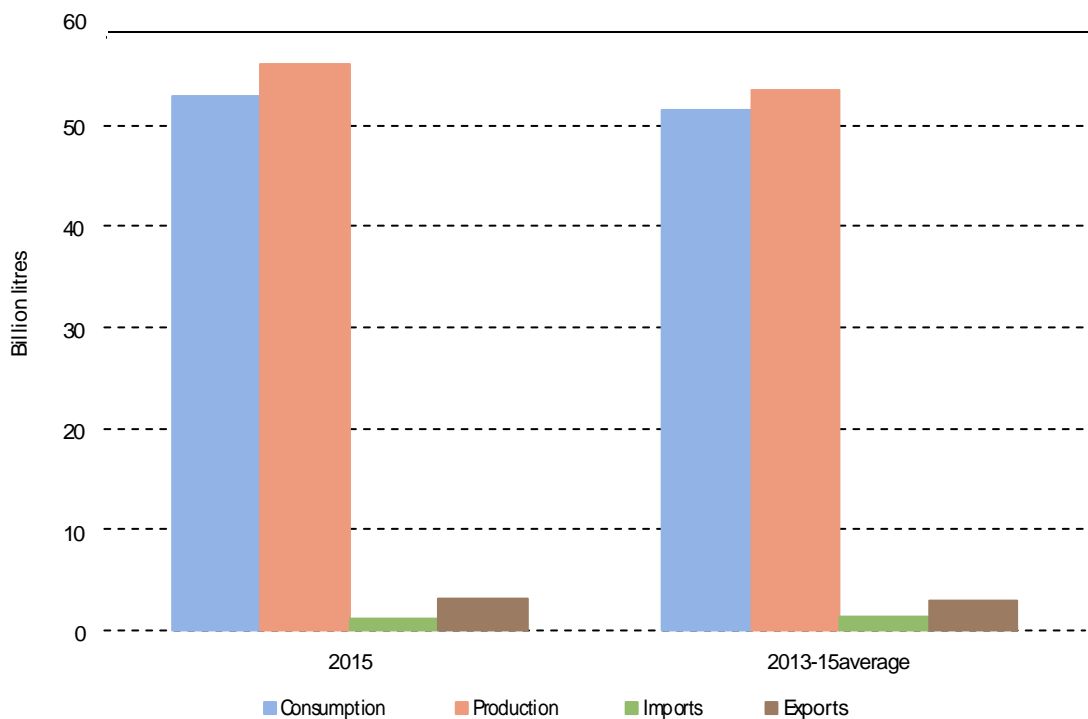
Total ethanol imports - **1.1 billion liters**

Total ethanol exports - **3.2 billion liters**

Snapshot - ethanol in the U.S.

The U.S. is the world's largest producer and consumer of fuel ethanol with annual demand of over 50 billion liters. Use of renewable fuels have been driven by the program of volumetric mandates originally put in place in 2007 with the aim of increasing renewable fuel use to 136 billion liters in 2022. Although cellulosic biofuels have taken longer to develop than expected, use of conventional corn ethanol has seen rapid growth and established the U.S. as the major exporter of fuel ethanol to the world market.

Diagram U.S.1: Fuel ethanol balance, average 2013-15



Biofuel policy history

The U.S. is the world's leading producer and consumer of fuel ethanol with production rising from 6.1 billion liters in 2000 to almost 53 billion liters in 2015. Policy supports have been key in the development of this industry. The main aims of the policy were to reduce GHG emissions, increase fuel security and support the domestic biofuel and agricultural industries.

The main driver of demand for fuel ethanol in the U.S. has been the Renewable Fuel Standard (RFS2). The RFS2 was created by the Energy Independence and Security Act (EISA) of 2007 and is administered by the Environmental Protection Agency (EPA). The policy mandates a rising volume of biofuels that must be consumed each year out to 2022.

The mandate is divided into conventional and advanced biofuels, which differ according to their feedstock and greenhouse gas (GHG) savings:

- Conventional renewable fuel makes up the majority of the mandate. These fuels must have a lifecycle GHG reduction of at least 20% compared to their fossil counterpart. Historically this section of the mandate has been met almost entirely with domestically produced corn ethanol.
- Advanced biofuels make up the remainder of the mandates. These fuels must have a lifecycle GHG reduction of at least 50% compared to their fossil counterpart. However, corn is specifically excluded from qualifying as an advanced biofuel. The advanced section is further subdivided into three parts:
 - **Cellulosic biofuel.** Fuels made from cellulosic feedstocks such as corn stover and woody biomass with a GHG reduction of at least 60%.
 - **Biomass-based diesel.** Biodiesel or renewable diesel made from vegetable oils or waste oils (tallow and used cooking oil) with a GHG reduction of at least 50%.
 - **Undifferentiated advanced biofuels.** This section is calculated as the remainder of the total advanced mandate minus the other two advanced categories and has the least stringent criteria. This has been met with a combination of domestic non-corn biofuels and imported sugarcane ethanol.

Table U.S. 1: RFS2 mandates (billion liters ethanol equivalent)

	Conventional biofuel	Biofuel Advanced	Advanced Biofuel Cellulosic	Biomass-based diesel	Undifferentiated advanced	Total RFS
2008	34.1	0.0	0.0	0.0	0.0	34.1
2009	39.7	2.3	0.0	2.8	0.0	42.0
2010	45.4	3.6	0.0	3.7	0.0	49.0
2011	47.7	5.1	0.0	4.5	0.5	52.8
2012	50.0	7.6	0.0	5.7	1.9	57.5
2013	52.2	10.4	0.0	7.3	3.1	62.6
2014	51.5	10.1	0.1	9.3	0.7	61.6
2015	53.2	10.9	0.5	9.8	0.6	64.1
2016	54.9	13.7	0.9	10.8	2.0	68.6
2017	56.0	15.1	1.2	11.4	2.6	71.2
2018	56.8	41.6	26.5	11.9	3.2	98.4
2019	56.8	49.2	32.2	11.9	5.1	106.0
2020	56.8	56.8	39.7	11.9	5.1	113.6
2021	56.8	68.1	51.1	11.9	5.1	124.9
2022	56.8	79.5	60.6	11.9	7.0	136.3

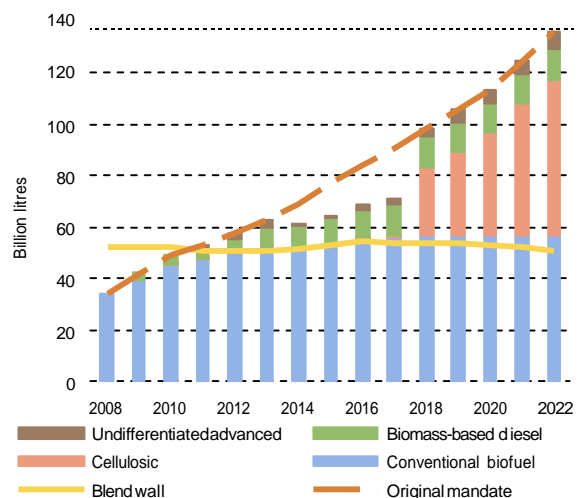
Note: One gallon of biomass-based diesel is worth 1.5 RINs, which are allocated on an ethanol equivalent basis. Mandates for 2017 are based on proposed volumes to be finalized by the end of 2016.

The RFS obligation applies to refiners, blenders and importers. A Renewable Identification Number System (RINS) is used to ensure compliance. RINS are unique identification numbers comprising 38 characters, which are assigned by the producer or importer to every gallon of renewable fuel produced or imported. Each year, refiners, blenders and importers must show that they have acquired the appropriate number of RINS to demonstrate compliance with their volumetric obligation.

Diagram U.S.2 demonstrates that much of the future growth in the total RFS mandate will be from advanced biofuels. In previous years, as the cellulosic mandate has been decreased due to a lack of supply, prior to 2014 the shortfall was been made up by undifferentiated advanced biofuel. However, since 2014 the overall mandate has been cut so the total target is below the original mandate.

The volume of biomass-based diesel (biodiesel and hydro-treated vegetable oil or HVO) has not yet been set past 2018; the EPA will set it through future rulemakings, but it will not be less than one billion gallons.

Diagram U.S.2: RFS2 mandates (ethanol equivalent)



The latest mandate for 2018 is 2.1 billion gallons (7.9 billion liters) of biodiesel (equal to 3.15 billion gallons (11.9 billion liters) of ethanol equivalent), so we have set it as constant until future mandates are announced. One gallon of biomass-based diesel receives 1.5-1.7 RINs depending on its higher energy content. The vast majority, in the form of biodiesel, receives 1.5 RINs, with smaller quantities of renewable diesel receiving 1.6-1.7 RINs. Therefore, assuming a RIN value of 1.5 on an ethanol equivalent (EE) basis, the biomass-based diesel mandate from 2018 is 3.15 billion gallons (EE).

In November of each year, the Energy Information Administration (EIA) must report to the EPA to outline the quantities of biofuels that will be available to meet the RFS. This information is then used to decide on the level of the RFS for the following year.

The EPA has the power to grant a RINS waiver in the event of severe economic or environmental harm. Furthermore, an obligated party can carry a deficit over for one year, hence the time limit for meeting the 2015 RFS is the end of 2016. If an obligated party has a surplus of RINS, they are allowed to carry over 20% into the following year. The penalty for non-compliance has been set at US\$32,500/day per violation. The general consensus is that the cost of the penalty for failure to meet a firm's obligation is sufficiently large to ensure compliance, either by blending the required amount of biofuel or by purchasing RINS on the open market.

Blend wall

One significant obstacle in the ability for the U.S. to meet the growing mandates is the so-called "blend wall." This refers to the maximum level of blending that can take place. All gasoline cars in the U.S. are able to use gasoline blended with up to 10% ethanol. However, falling gasoline demand and rising mandates meant that this wall was reached in 2014 as the

proposed volume of conventional biofuels implied ethanol blending above the 10% blend wall. Given the weak roll-out of E-15 and low uptake of high-level blends such as E-85, this ceiling limits ethanol blending to 10% of gasoline. As a result of this, in 2013, the EPA proposed cuts in the 2014 mandate for all categories of biofuels except biomass-based diesel. Mandates for 2014 and 2015 were not finalized until the end of 2015 when mandates for 2016 were also released. The EPA has said that it will finalize mandates for the following year by the end of November of the current year. The introduction of E-15 is seen as a solution to the problem of the blend wall.

E-15

In the second quarter of 2011, several policy changes brought the rollout of E-15 a step closer. Firstly, the EPA approved the use of higher blends of ethanol (up to 15%) for 2001 and newer cars, as well as releasing labelling to appear on E-15 fuel pumps to try to avoid misfueling. Many groups have responded adversely to this waiver, claiming that data testing into the effects of higher blends on these cars is not yet complete and that the labelling is insufficient. In February 2012, the EPA approved Tier 1 and 2 health effects testing data.

Significantly, the EPA announced in April its approval of the first E-15 registrations, permitting twenty ethanol producers to provide ethanol for use in E-15.

Several obstacles are yet to be overcome. The EPA remains concerned and wants to ensure that retailers and consumers are aware of the risks of misfueling, as well as other E-15 related requirements. To this end, a misfueling mitigation plan (MMP) and fuel survey must be implemented by producers and retailers. The Renewable Fuels Association (RFA) has created drafts in both cases and is further distributing an E-15 Retailers Handbook to assist retailers in compliance with E-15.

Another problem concerns gasoline standards. Blending gasoline causes a rise in vapor pressure. E-10 has been granted a 1 lb. waiver for vapor pressure. However, there is no waiver for E-15. This means that in the summer fuel producers would have to change the formulation of their gasoline blend stock for E-15 blending. For these reasons, it is likely to take time for E-15 to become widely available and its progress may be hindered by further objections from car and oil companies.

Ethanol tax credits

When the industry was still in its early stages the government supported ethanol through the use of a tax credit. The Volumetric Ethanol Excise Tax Credit (VEETC) gave blenders of ethanol US\$0.45 per gallon (US\$0.12/liter) of ethanol blended. This was intended to increase the attractiveness of ethanol to blenders.

As the industry has grown, ethanol production has benefitted from economies of scale, becoming cheaper than gasoline without the tax credit. Therefore, despite some strong opposition to the credit expiring, the credit was stopped at the end of 2011 as the cost of continuing the credit was deemed too high at a time when government debt is at record levels.

Cellulosic ethanol policy

The cellulosic ethanol producer tax credit of US\$1.01 per gallon has expired and been reinstated several times since its introduction.

Although there is a mandate for cellulosic ethanol, blenders are able to exercise a buy-out option. When the projected volume of cellulosic ethanol is less than the mandate required by EISA, the EPA is required to make Waiver Credits available for sale to obligated parties in order to allow them to meet the renewable volume obligations under the Energy Independence and Security Act (2007).

EISA (2007) requires the EPA to sell the Waiver Credits at an inflation-adjusted price that is the higher of (1) US\$0.25 per gallon (\$0.7/liter) or (2) the amount by which US\$3/gallon (\$0.79/liter) (inflation adjusted) exceeds the average wholesale price of a gallon of gasoline in the U.S.¹.

Table U.S.2: The cost of the cellulosic ethanol buy-out option (US\$/liter)

	Cellulosic Waiver	Gasoline Price ¹	Waiver Cost
2010	0.41	0.56	0.97
2011	0.30	0.75	1.05
2012	0.21	0.77	0.98
2013	0.11	0.75	0.86
2014	0.13	0.70	0.83
2015	0.17	0.43	0.60
2016	0.35	0.30	0.66

Note: 1. Gasoline price is basis ex-refinery U.S. average. The price for 2016 is the average from Jan-Aug.

In general, an obligated party should be indifferent between buying a gallon of cellulosic biofuel for a price equal to or less than the price of a gallon of gasoline plus the cost of the Waiver Credit. Table U.S.2 reveals what an obligated party would need to pay (the price of gasoline plus the waiver credit) to comply with its renewable volume obligation. In 2015, the waiver was set at US\$0.17/liter, while the average ex-refinery price of gasoline was US\$0.43/liter, making the total cost of the buy-out US\$0.60/liter. This sets an effective ceiling for the cellulosic ethanol price.

As shown above in Diagram U.S.2, the RFS mandate implies that cellulosic biofuels will comprise an increasing proportion of total biofuels, representing the majority of the growth from 2018. However, the cellulosic mandate has been revised down every year due to lack of production. Although the mandate should guarantee demand for any cellulosic ethanol production in the next few years, the willingness of the EPA to reduce the mandate adds more uncertainty to the market. This highlights the importance of a firm mandate to allow for investment in the market.

State level policy

In addition to the nationwide renewable fuel mandates, California has implemented a Low Carbon Fuel Standard (LCFS). The aim of the LCFS regulation is to reduce the carbon intensity of transport fuels used in California by at least 10% by 2020 relative to a 2010 baseline. The program is administered by the California Air Resources Board (CARB) and the original regulation was adopted in April 2009. Various amendments have been made to the legislation, including an amendment in February 2015 which slightly altered the trajectory of the target.

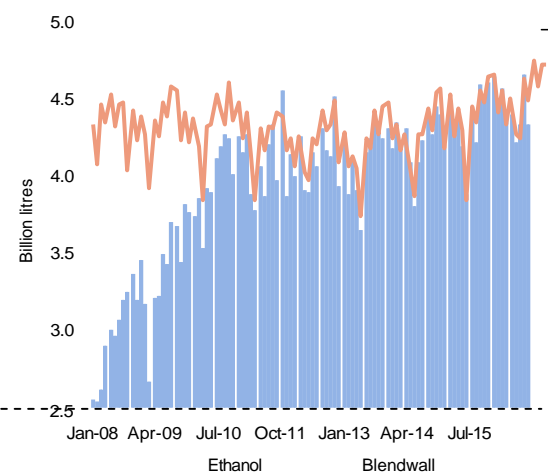
¹ The EPA will use the average monthly bulk refinery price of gasoline based on the most recent twelve months of data from the Energy Information Administration at the time it develops the cellulosic biofuel standard when determining the average wholesale price of gasoline for the purpose of pricing Waiver Credits.

The ability of ethanol to meet the mandate will fall as the GHG reduction target increases. Assuming a maximum blend of 15% ethanol in gasoline, only cellulosic ethanol has a GHG saving high enough to satisfy the target beyond 2017.

Supply and demand

Over the first years of the RFS, monthly fuel ethanol demand in the U.S. grew from around 2.5 billion liters in early 2008 to over 4 billion liters by 2010. Sales were boosted by discretionary blending, which saw fuel providers blending more ethanol than needed to meet the mandate because it was competitive with gasoline. Since 2010 growth has been restricted by the blend wall. The blend wall is the maximum blend of ethanol in gasoline that can be sold for use in regular gasoline cars. Although there have been moves to increase this by allowing the use of E15 in newer cars, higher blend fuels are not widely available so the maximum amount of ethanol that can be used is capped at around 10%. The only way to consume a larger volume is to use higher blends like E85, however, the flex-fuel car fleet is still fairly small as a proportion of the total fleet.

Diagram U.S.3: Fuel ethanol sales and E10 blend wall

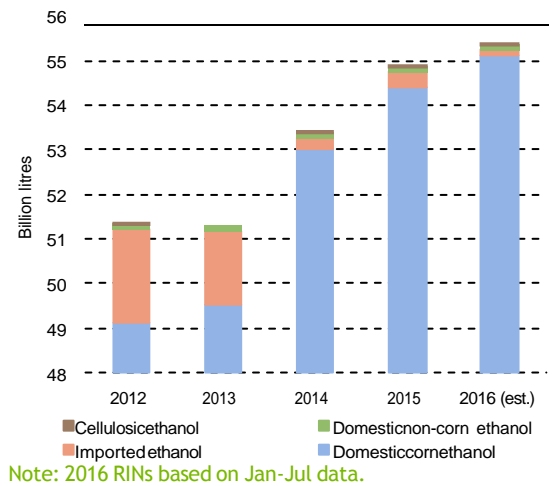


- The low price of gasoline in recent years has increased demand for transport fuels, which translates directly into higher ethanol sales.
- In the first half of 2016, average monthly ethanol sales have reached 4.5 billion liters.
- Demand for higher ethanol blends remains low with just 1.4 billion liters of ethanol consumed as E85 in 2015, less than 3% of total fuel ethanol demand.

Diagram U.S.4 reveals the split between different types of ethanol used in the U.S. based on RIN data. Every month the EPA releases data on the number of RINs produced under each category and different fuel types. This reveals that the vast majority of ethanol RINs are from U.S. corn ethanol.

An important change in the market seen in recent years is that imports of ethanol have fallen. Imported ethanol was historically used to fill the undifferentiated advanced biofuel mandate, but use of it has fallen since the blend wall was reached in 2014. Blenders now prioritize the use of corn ethanol to fill the volume within the blend wall as it is by far the cheapest option, choosing to meet the advanced mandate with wider use of biodiesel. It is clear from the diagram that use of non-corn domestic and cellulosic ethanol are both still very low.

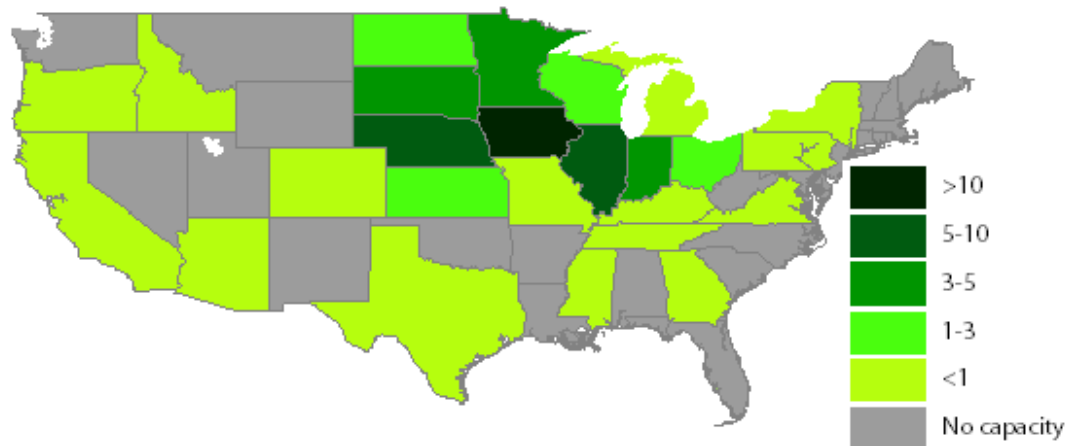
Diagram U.S.4: Annual ethanol RIN production by ethanol type



Note: 2016 RINs based on Jan-Jul data.

Ethanol output in the U.S. has followed the same trend as demand with **total production reaching 56 billion liters in 2015**. The bulk of ethanol capacity in the U.S. uses corn as the feedstock and Map 2 reveals that the distribution of capacity across the economy is centered on the major corn producing states. There are 195 fuel ethanol plants currently operating in the U.S. with a combined capacity of 56.4 billion liters; 52% of this capacity is located in just three states: Iowa, Nebraska and Illinois, across 80 facilities.

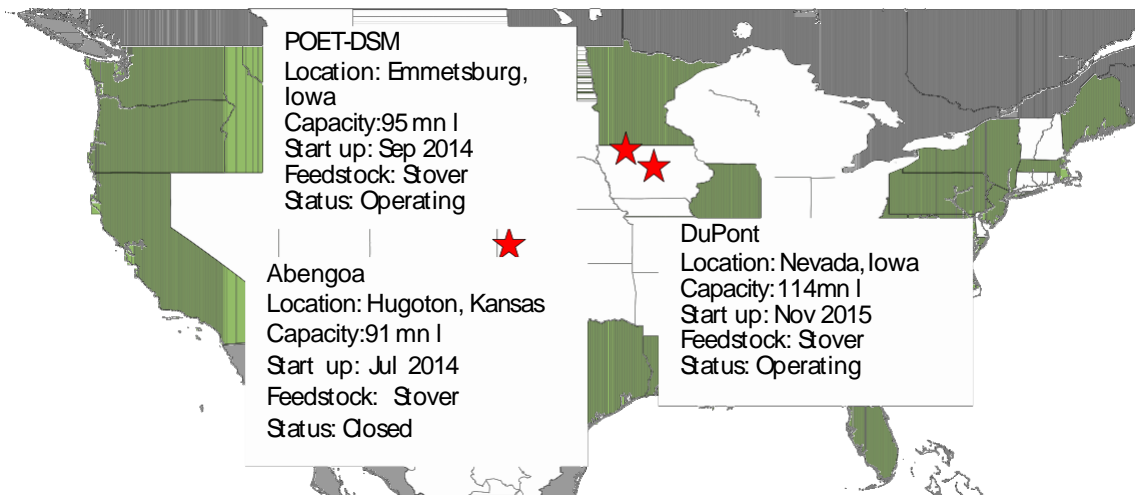
Map U.S.1: Ethanol plants (capacity in million liters per year)



Cellulosic capacity

Development of cellulosic ethanol technology has been slower than originally anticipated when the RFS was set out in 2007. While huge amounts of research and resources have been poured into this development over the last decade, actual output remains very small.

Map U.S.2: Cellulosic ethanol plants

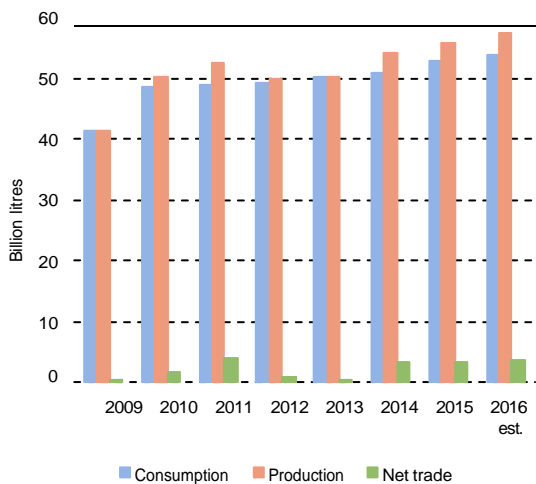


By the start of 2016, three commercial scale cellulosic ethanol plants had commenced operations with a combined capacity of around 300 million liters. All of these plants use corn stover as their feedstock. However, they have all been plagued with problems at the commissioning stage and no plant has managed large scale output so far. Furthermore, the plant owned by Abengoa ceased operating and was put up for sale in early 2016 following the company entering administration. Abengoa’s problems are unrelated to cellulosic ethanol.

Trade

As the world's largest and often most competitive producer of fuel ethanol, the U.S. has become the main source for ethanol exports to the global market. Although exports are only a small part of the overall market with 6% of production exported in 2015, it is still a key part of the industry. Imports have also played a significant role historically, particularly cane ethanol from Brazil as it is classed as an advanced biofuel and therefore counts toward the undifferentiated advanced biofuel section of the mandate. Imports have fallen since 2013 as the undifferentiated mandate has been cut in line with the ethanol blend wall, leaving biodiesel to increasingly fill the advanced mandate.

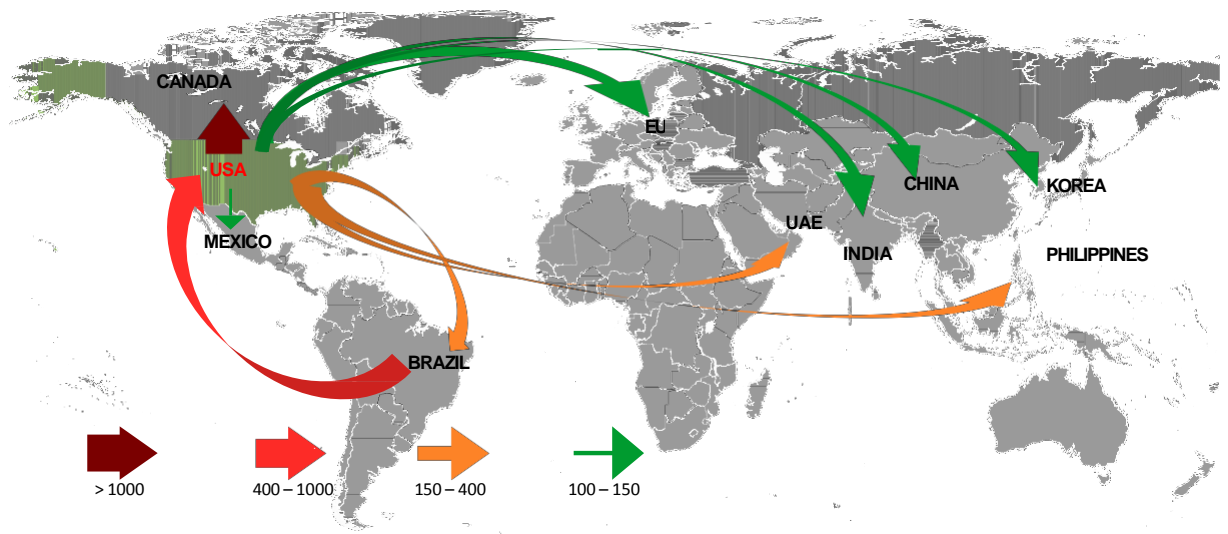
Diagram U.S.5: Fuel ethanol production, consumption and net trade



The destination of ethanol exports from the U.S. has shifted over the last decade due to a number of factors:

- Historically, the EU was a major destination but exports have been very low since the implementation of anti-dumping duties on U.S. ethanol in 2013.
- Exports to Asia have increased markedly in recent years, rising from 40 million liters in 2012 to 660 in 2015, a volume already surpassed in the first 6 months of 2016. This is due to rising imports into China, although this is expected to be short-lived.
- Brazil has fluctuated from being a net exporter to the U.S., peaking in 2012 1.4 billion liters, to being a net importer. Since 2014 U.S. imports have fallen leaving Brazil a net importer, although the volumes are relatively small at around 100-200 million liters.

Map U.S.3: Ethanol trade in the U.S., average 2013-15 (million liters)



Summary

Aims & policies	Achievements
<ul style="list-style-type: none"> • Aims: reduce GHG emissions, increase fuel security and support the domestic rural agricultural producers • Policy: RFS2 schedule sets out volumetric mandates for four categories of biofuel • Mandates are nested and are defined by GHG savings, feedstock and biofuel type • The conventional biofuel mandate is the largest at 53.2 billion liters in 2015 • Imports of fuel ethanol are allowed but producers must be registered with the EPA and prove they comply to fuel and feedstock specifications • Large penalties are imposed if obligated parties do not meet their compliance target 	<ul style="list-style-type: none"> • Mandates: met, with fuel ethanol consumption reaching 52.9 billion liters (2015) • Average nationwide blend: 10.0% (2015) • Output of 56.0 billion liters supplies all of the domestic market and makes the U.S. the largest exporter to the global market (2015) • Imports were historically important in meeting higher GHG reduction categories but have declined in recent years • Several commercial scale cellulosic ethanol plants have been built in response to the cellulosic mandate
Challenges	Looking ahead
<ul style="list-style-type: none"> • The 10% blend wall is restricting the volume of ethanol that can be consumed • Attempts to introduce higher blends of E-15 and E-85 have so far had little impact • The cellulosic mandate has been cut due to limited supply • The blend wall has led to the EPA to revise down the conventional and undifferentiated mandates since 2014 causing uncertainty in the market 	<ul style="list-style-type: none"> • RFS schedule for 2022 requires 136 billion liters of biofuels to be consumed, of which 61 billion liters are cellulosic • The cellulosic volume is unlikely to be achieved given progress to date and will result in further cuts to the mandate • The market for conventional ethanol is could decline if the traditional decline in gasoline consumption resumes. The prospects for E-15 and E-85 are still uncertain