

E20 Supply and Demand Study

Final Report

E4tech (UK) Ltd for ePURE

November 2019

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Executive Summary

Renewable ethanol is expected to play an important role in the realisation of the EU's energy and climate ambitions to 2030. One of the main factors limiting the potential contribution of renewable ethanol to decarbonisation of the road vehicle fleet is the level at which ethanol is blended into gasoline. One option to overcome this is through the standardisation and use of mid-level ethanol blends in gasoline, such as an E20 grade which could use ethanol (up to 20% in volume) and/or other oxygenates (such as ETBE). Work ongoing over the last five years has shown that higher blends are a valid option for ethanol blending in gasoline. In this study, we investigate the potential demand for ethanol in 2030 if E20 were used across the gasoline pool in two scenarios, and how this might be supplied.

Introduction of E20 to the EU market is expected to increase the demand for ethanol in transport despite decreasing gasoline demand to 2030. In the more likely low gasoline demand scenario, with 20% market share of E20, a 58% increase (3.2 billion litres) in the volume of ethanol supplied would be required, compared with 2017 supply volumes. A high demand scenario, with a 100% market share of E20 would require almost a trebling (increase of 11.5 billion litres) in the volume of ethanol supplied to the market compared with 2017 supply volumes. Even if all of the ethanol supplied to meet the demand in 2030 was produced from crops, in none of these scenarios would the estimated crop cap set by RED II be exceeded (low demand scenario 1.7%, high demand scenario 3.1%), meaning that the crop cap would not be a barrier to the introduction of E20 to the EU market.

If demand is low, several different supply routes could almost meet the potential increase in demand alone. Whilst all routes are still likely to contribute to meeting demand, the market would be much more competitive because of this. These routes could include increased utilisation and expansion of existing plants, and potentially through new plants, which could be co-located with advanced ethanol production. There will also be an important role for advanced ethanol in supplying increased ethanol demand in 2030, contributing to advanced biofuels targets. This will rely on successful commercialisation of this technology, supported by sufficient market incentives through successful implementation of the RED II in Member State policy.

In a high ethanol demand market, it is likely that all the supply routes considered in this study may need to contribute to the supply mix, with less competition between routes. This scenario could require an additional contribution from the EU conventional ethanol industry of 7 billion litres. The feedstock requirements for this expansion would be similar to those of European ethanol production in 2017, meaning new demand for feedstock, and ultimately land.

In addition to increased EU production from conventional and advanced routes, imports of both conventional and advanced ethanol could be important to supply demand in a high scenario.

1 Introduction

1.1 Background

Renewable ethanol is expected to play a key role in the realisation of the EU's energy and climate ambitions to 2030. One of the main factors limiting the potential contribution of renewable ethanol to decarbonisation of the road vehicle fleet is the level at which ethanol is blended into gasoline. One option to overcome this is through the standardisation and use of mid-level ethanol blends. Currently two types of gasoline blends are supplied to the EU market: E5 and E10, which are characterised respectively by an oxygen limit of 2.7 and 3.7% by mass and an ethanol content of 5 and 10%. E10 is the highest ethanol-containing blend allowed according to the Fuel Quality Directive (FQD).

Other higher blends such as E85 and ED95 (for heavy duty vehicles) are also being considered by some Member States to help to decarbonise their transport sector. While there is currently a market for E85 in Sweden and France, and an emerging market for ED95 in France, Sweden, Norway and Finland, these blends' market potential will not be further explored in this report, which focuses on blends that could be used across the whole gasoline pool.

Fuel suppliers and car manufacturers are considering options to increase engine performance and decrease emissions, for example through increasing oxygenate levels. One option for this is a hypothetical E20 grade which could use pure ethanol up to 20% in volume, other oxygenates such as ETBE, or a combination of both. As this study intends to assess the maximum potential demand for ethanol, E10 and E20 are assumed to contain 10% and 20% pure ethanol by volume respectively.

Work ongoing over the last five years has shown that E20 blends are a valid option for ethanol blending in gasoline. This work includes:

- In 2015, the EC launched a Horizon 2020 project to assess the impact of mid-level ethanol blends (E20/25) on vehicles and fuel distribution. The results of this study were published in June 2019¹, concluding that there were no technical barriers to roll out of an E20 blend, but that the proportion of ethanol in the petrol blend should not exceed this in order to minimise the possibility of vehicle incompatibility and malfunctions. E20 blends were shown to decrease CO₂ and NO_x, PM and HC emissions.
- In 2017, a study on the impact of increasing the limits of the bio-content of petrol and diesel imposed by the FQD in 2020 and beyond² concluded that increased use of high ethanol blends is possible in petrol vehicles and will have generally positive emission benefits.

¹ NEN Presentations Future fuels and engine concepts

<https://www.nen.nl/Evenementen/Presentaties/20190625-Presentaties-Future-fuels.html>

² ICF International for DG CLIMA, 2017, Impact of higher levels of bio components in transport fuels in the context of the Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998, relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC

- DG CLIMA’s recent technical tender³ on transport fuel quality parameters will assess whether the limits currently included in the fuel specifications set out by the FQD could become a barrier for reaching the renewable energy in transport target under RED II.
- The Horizon 2020 Work Programme 2018-2020 includes budget for the standardisation of E20/25 in support of the implementation of RED II⁴.

Introducing E20 in Europe relies on there being sufficient volumes of ethanol to meet demand, and this supply being compatible with policy targets and requirements under RED II, such as the advanced biofuels target and cap on crop-based biofuels. It is important to consider how the additional quantities of ethanol required to meet the new demand would be supplied by 2030, and what implications this would have for resource use and for European ethanol production (EU-28). This study sets out to answer these questions and propose a theoretical ethanol supply scenario for 2030.

1.2 Objectives

The objectives for this study are to:

1. Calculate the demand for ethanol in the European transport market in 2030 resulting from introduction of E20.
2. Present a scenario of how this demand could be supplied through different ethanol supply routes including: existing EU ethanol production capacity, expansion of the current production capacity, new advanced ethanol plants, and imports of conventional ethanol and advanced ethanol.
3. Draw conclusions and highlight the implications of a move to E20 in the EU.

2 How much ethanol would be needed to meet demand for E20?

The first step is to quantify the volume of ethanol demand in 2030 that would result from introduction of E20, considering two different gasoline demand scenarios, each with two different E20 blending scenarios. One of these scenarios is intended to be an extreme demand scenario, so to test supply scenarios that could meet this demand.

These scenarios consider 2030 as a fixed point for assessment and do not consider the timings for roll-out of E20 or the likelihood of the two ethanol blending scenarios being achieved. We assume that all vehicles are compatible with the use of E10 and E20 by 2030, although in practice there may be a very small number of old vehicles which are not compatible. This is an assumption supported by the 2017 report² which suggests that most post-2011 vehicles are E20 tolerant.

³ DG CLIMA Technical Assessment of Transport Fuel Quality Parameters
<https://etendering.ted.europa.eu/cft/cft-display.html?cftId=4985>

⁴ Horizon 2020 Work Programme 2018-2020 10. Secure, clean and efficient energy
https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-energy_en.pdf on p. 296

2.1 Scenarios

Gasoline demand in 2030

Two scenarios for gasoline consumption in EU-28 by 2030 have been used as the basis for calculating the potential ethanol demand in 2030:

- I. **A Low Carbon scenario (LC)** – This is based on the EUCO3232.5 scenario⁵, which includes the impact of policy measures such as demand reduction, mode switching and vehicle efficiency, which could have a large impact on gasoline demand. Gasoline demand is not publicly available for this scenario. However, the scenario gives a 9.8% reduction in energy demand in the private car and motorcycles sector compared to the EU Reference Scenario 2016⁶. On top of this we considered the scenario's expectation that 2.4% of this demand will be supplied through electrification of road transport (higher than 0.9% electrification in the BaU scenario). This gives a final energy reduction of 11.2% which is applied to the EU Reference scenario 2016 gasoline demand to give the LC scenario 2030 gasoline demand. This gives a gasoline pool demand of 54 Mtoe.
- II. **A Business as Usual scenario (BaU)** – The EU Reference Scenario 2016⁷ gives projected gasoline demand in 2030, and overall biofuels demand, assuming that 2020 targets are maintained to 2030, i.e. 10% renewable energy in transport. We have used this information to estimate the size of the gasoline pool in 2030, by taking the gasoline demand figure and adding an estimate of the biofuels used in gasoline, giving a total demand of 61 Mtoe. This is a conservative i.e. high demand case, as it does not include the impact of policy measures such as demand reduction, mode switching and vehicle efficiency, which could have a large impact on gasoline demand. It therefore presents a 'worst case' scenario for ethanol demand and tests the boundaries of what could be possible and required in 2030.

Ethanol blending in 2030

Two deployment scenarios have been considered for the uptake and use of E20 by the European market:

- I. **20% E20** – an example case with lower uptake of E20, where E20 accounts for a small proportion of the gasoline market (20%). The rest of the market is supplied by E10 (80%). This is equivalent to E20 having a similar market share to premium grade gasoline today.
- II. **100% E20** – E20 is the only gasoline blend on the EU market and has 100% market share.

2.2 Resulting ethanol demand in 2030

Based on the Low Carbon and Business as Usual scenarios the energy demand in the gasoline pool is expected to decrease by 33% and 24% respectively compared with 2018⁸ (Figure 1). Within each

⁵ European Commission, Technical Note: Results of the EUCO3232.5 scenario on Member States, 2019

⁶ European Commission, EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050

⁷ European Commission, EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050

⁸ Current energy use (2017) for gasoline and ethanol used in Europe from SHARES and the USDA GAIN EU Biofuels Annual 2019

gasoline demand scenario, the total demand for the gasoline pool is constant across both E20 scenarios but the demand for ethanol varies depending on the blend being used due to the difference in energy content. In both gasoline demand scenarios, the 20% E20 scenario has a 42% lower demand for ethanol than the 100% E20 scenario.

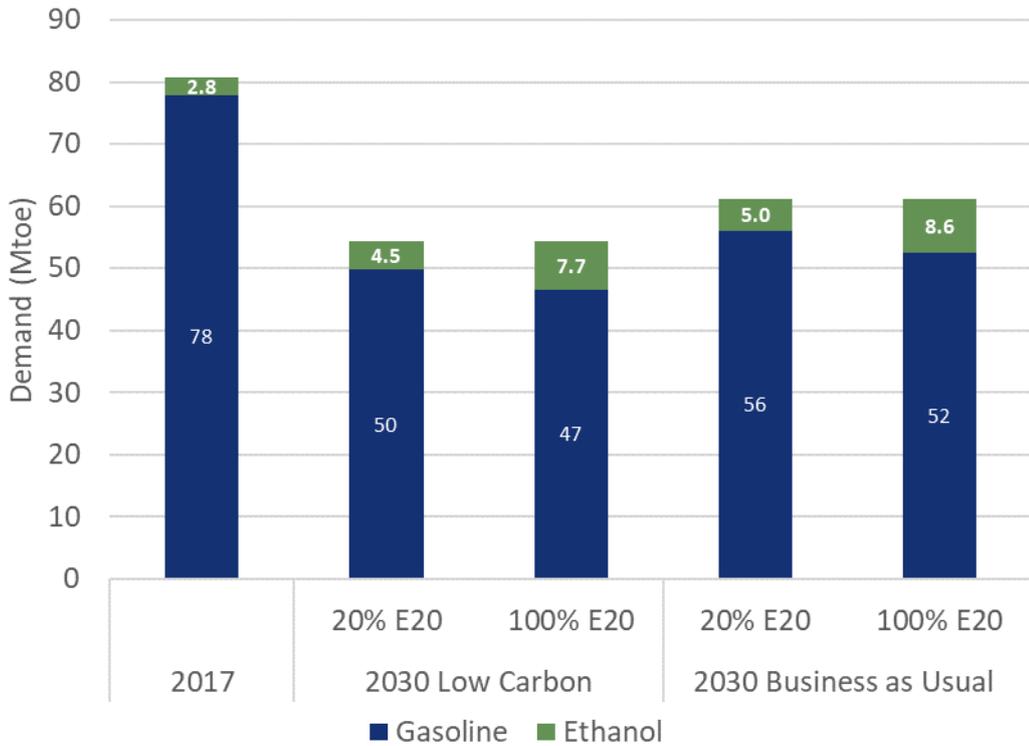


Figure 1: Energy demand in the gasoline pool for Business as Usual and Low Carbon scenarios.

Figure 2 shows the demand for gasoline and ethanol in Europe on a volume basis.

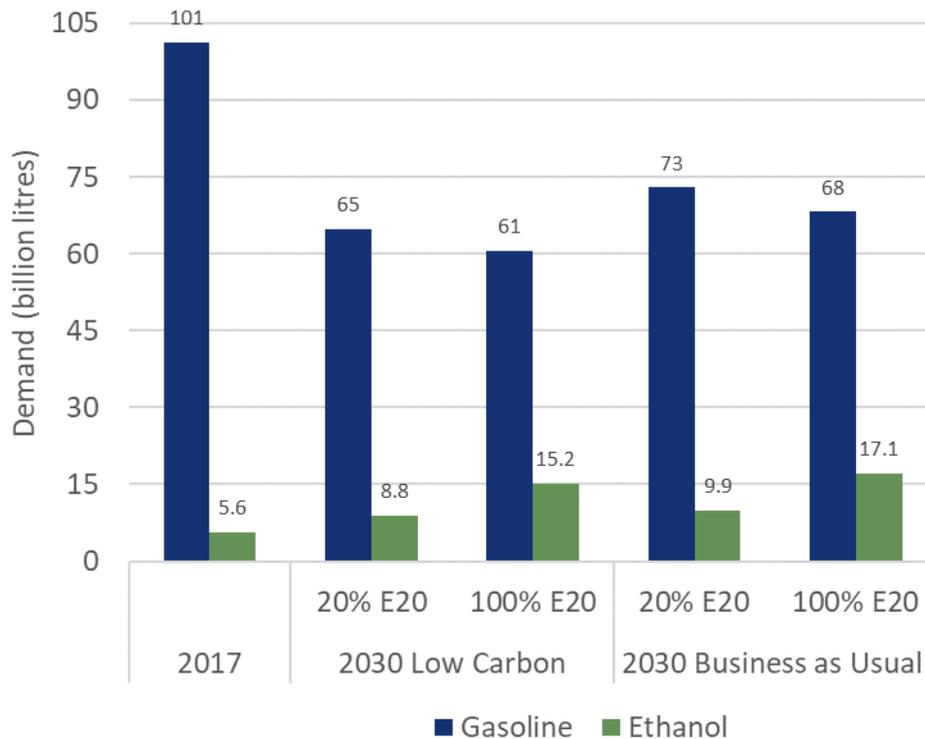


Figure 2: Volumetric demand for gasoline and ethanol under each scenario.

In 2017 gasoline demand in the EU was 101 billion litres⁹, plus 5.6 billion litres of fuel ethanol^{10,11}. Despite the decrease in demand for the gasoline pool to 2030, introduction of E2O is expected to increase demand for ethanol under all scenarios. However, the range of future ethanol demand varies greatly by scenario. The Low Carbon scenario with 20% E2O gives the lowest ethanol demand of 8.8 billion litres (3.2 billion litre increase vs. 2017) whilst the Business as Usual scenario with 100% E2O has the highest ethanol demand of 17.1 billion litres (11.5 billion litre increase vs. 2017). For comparison, the 2011 NREAPs projected a 2020 ethanol consumption of 14.4 billion litres¹².

2.3 Interaction with RED II requirements

Before considering how the 2030 ethanol demand could be supplied, we have first checked whether there are any policy constraints on meeting the levels of ethanol demand calculated above. RED II includes a cap on the contribution of crop-based biofuels produced that can count towards the 14% target for renewable energy in transport. The cap is calculated as the 2020 share of these fuels, plus

⁹ EU Commission, DG Energy, Energy datasheets: EU-28 countries 1990-2017, https://ec.europa.eu/energy/sites/ener/files/energy_statistical_countrydatasheets.xlsx

¹⁰ USDA GAIN EU Biofuels Annual 2019

¹¹ There is a small discrepancy in USDA GAIN data, instead of the reported fuel consumption number (5,624 million litres), we referenced the calculated consumption number (5,577 million litres) by summing EU production and EU import, then subtracting EU export to ensure consistency across all calculations

¹² Overview of biofuel policies and market across the EU-28 <https://epure.org/media/1758/180903-def-rep-overview-of-biofuel-policies-and-markets-across-the-eu-28.pdf>

1%, or up to 2% for Member States with a current share below 1%, within a maximum value of 7% of the total energy used in road and rail transport. Member States can choose to have a lower crop cap and consequently reduce their RES-T target. Several Member States have announced lower crop caps, such as the UK which has set its crop cap at 2.3% by 2030 or Germany with a crop cap of 6.5%. Considering the Member States that have announced lower crop caps so far, and assuming other Member States have caps at either 7% or 2% greater than their 2017 crop biofuels share (assuming 1% increase to 2020 and then 1% increase on the 2020 figure), the overall cap would be approximately 5.3%¹³.

Based on this we have assessed ethanol’s contribution to the EU’s total road and rail transport energy demand (the RED denominator) under the different scenarios. If all of the ethanol supplied to meet the demand in 2030 was met from crops (as shown in Figure 3), the demand would result in a contribution of less than half of the 7% crop cap¹⁴.

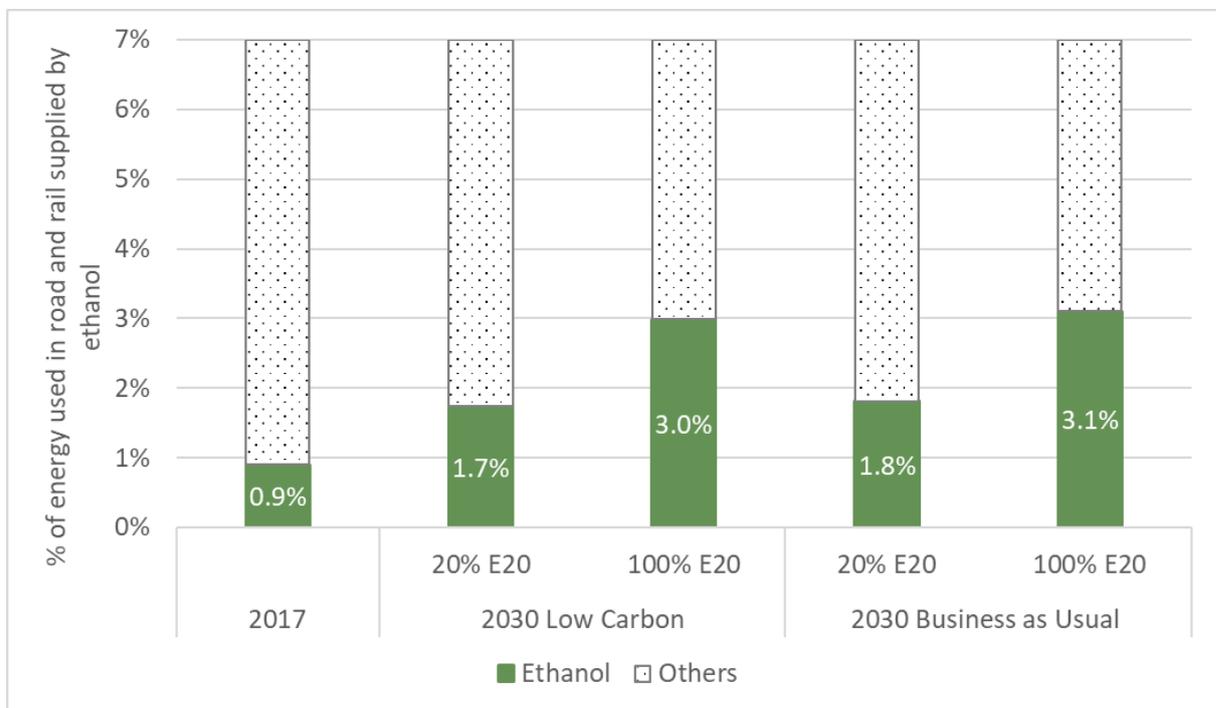


Figure 3: Ethanol demand, on an energy basis, as a percentage of the total energy used in road and rail in the EU.

In practice, this is unlikely to be the case, as more ethanol is expected to be supplied via advanced routes, as discussed in the next chapter. On this basis, we have not considered the crop cap as a limiting factor on ethanol use in the rest of this analysis.

¹³ E4tech estimate

¹⁴ 2017 total EU energy demands in road and rail, the RED II denominator, have been sourced from the EC’s Energy Statistics Energy datasheets (European Commission DG Energy, Energy Statistics Energy datasheets: EU-28 countries), whilst forecasted energy use in road and rail transport were sourced from the EU Reference Scenario 2016 and EUCO3232.5 scenarios.

3 How could this ethanol demand be supplied?

This chapter shows how the additional demand for ethanol resulting from E20 use in 2030 could be supplied, based on two illustrative scenarios for low and high ethanol demand. We discuss the factors that underpin these scenarios and the implications that these may have for the future market.

There are several ways in which future ethanol demand might be supplied by the market:

- Continued supply from today's plants in Europe
- Increase utilisation of today's plants in Europe
- Increase in conventional ethanol production capacity through expansion of the current plants or building new plants in Europe
- Increase advanced ethanol production capacity in Europe. This could be through plants at greenfield sites or co-located with conventional ethanol plants or other industrial sites.
- Imports of conventional and advanced ethanol

To build the scenarios we have sequentially assessed the ethanol volumes that the different supply routes could provide starting with those routes with the least uncertainty as to their contribution, such as current conventional ethanol production, and working to the routes with the highest uncertainty, such as advanced ethanol imports. However, this is in no way intended as a hierarchy of uptake: in practice, the relative contribution of these routes will depend on policy targets, and the relative competitiveness of these options with each other and with other fuels that can meet the same targets. The assumptions used for the supply scenarios are shown in Appendix A.

3.1 What potential routes could supply ethanol?

We have taken the demand scenarios for 2030 that have the lowest and highest levels of ethanol demand:

- The Low Carbon demand scenario with 20% E20, supplied as a mix of E10/E20, provides the lowest ethanol demand.
- The Business as Usual demand scenario with 100% E20 provides the highest potential ethanol demand.

As a reminder, the BaU 100% E20 represents the maximum ethanol demand that could be needed in the EU for E20 in 2030 and is seen as a test whether even an extremely high E20 demand could be met.

3.1.1 Supplying low ethanol demand in 2030

Figure 4 shows an illustrative example for ethanol supply in the case of low ethanol demand, based on the Low Carbon gasoline scenario with 20% uptake of E20. In this scenario the EU market would require 8.8 billion litres, which is an additional 3.5 billion litres above 2017 EU production volumes.

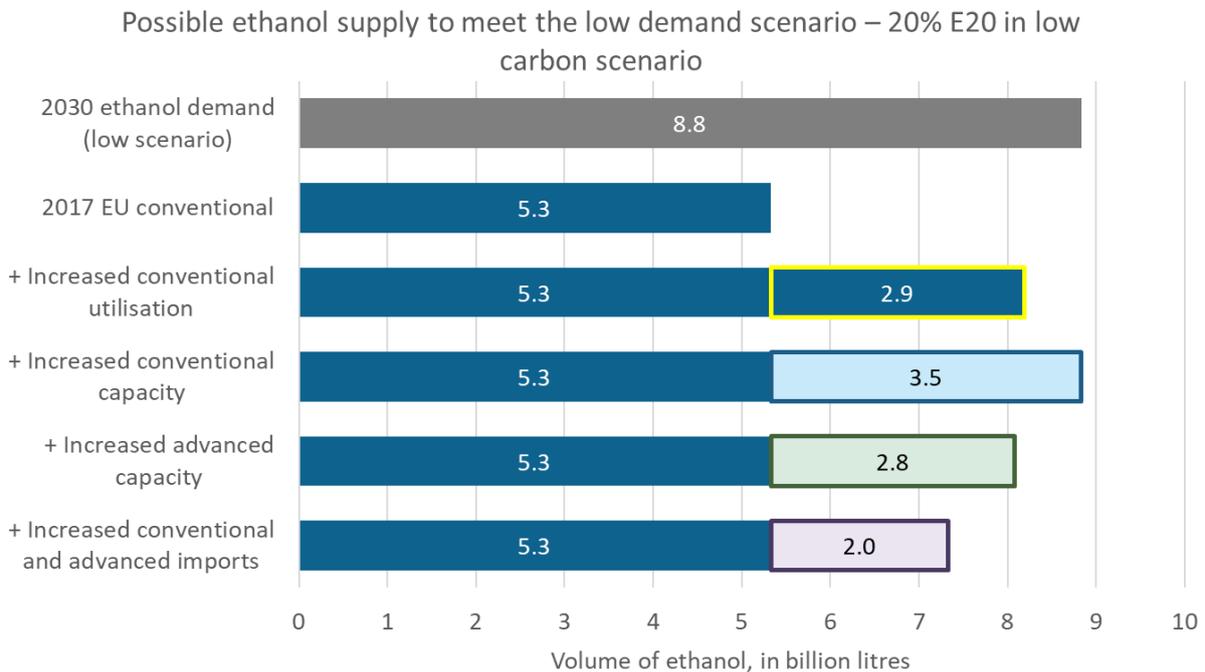


Figure 4: Ethanol supply scenarios for a 2030 low ethanol demand market

The starting point is the 2017 EU production of conventional ethanol for fuel, which accounts for 5.3 billion litres of the 8.8 billion litre total. Beyond this, we have considered supply from the other options based on the assumptions below.

An option with a relatively low degree of uncertainty is based on use of current plants:

- Increasing utilisation of current EU conventional ethanol plants – A comparison of 2017 production volumes against total EU production capacity (for both transport and traditional use) shows that there is significant underutilisation. 2.9 billion litres of unused capacity could be brought on-line to supply a future expansion of the fuels market assuming a stable demand for traditional uses and the possibility of swinging the production to fuel ethanol.

The remaining supply options, consisting of the ramp-up of EU advanced ethanol production, expansion of conventional ethanol production, and future imports of both conventional and advanced ethanol, bring a higher degree of uncertainty as to their contribution by 2030:

- **EU advanced ethanol plants** – previous work investigating the ramp-up of lignocellulosic ethanol in Europe estimated that EU (EU27) advanced ethanol plants would contribute 2.8 billion litres of ethanol to the market in 2030 in the central scenario. This will be driven by RED II, assuming successful implementation of RED II advanced biofuels mandates, considering the high level of maturity of lignocellulosic ethanol compared with other advanced biofuels pathways. For context, this would represent 0.54% of the low carbon scenario RED II denominator (taken as EUCO3232.5 EU-28 total road and rail transport demand) and 0.50% of the BaU scenario RED II denominator in 2030 without multipliers (taken as EU Ref 2016 EU-28 total road and rail transport demand), compared with the 1.75% Annex IX A biofuels subtarget).

- **Additional advanced ethanol supply** – This could be supplied by additional EU production, or by imports, or by a combination of both. Imports are a potential source of supply as a result of stronger policy support in Europe for advanced ethanol than in many regions with potential for production. E4tech modelling estimates that in a central scenario the rest of the world (non-EU) supply of advanced ethanol could reach 3.6 billion litres by 2030. Around half of this global supply is expected to be developed in the US. Due to the US's incentives for advanced ethanol it is reasonable to assume that none of this ethanol will be available for import into the EU. Half of the remaining RoW supply is assumed to be available for import into Europe, contributing 0.9 billion litres to the EU market. Overall, EU advanced ethanol consumption (supplied by increased EU production capacity and imports) totals 3.7 billion litres in this scenario, or 0.72% in the Low Carbon scenario of the total energy used in road and rail transport (without multipliers, LC RED II denominator), or 0.66% in the Business as Usual scenario, compared with the 1.75% advanced biofuel target (without multipliers) under RED II.
- **Imports of conventional ethanol** – Imports are expected to play a role in Europe meeting its demand for ethanol. In 2017, Europe imported 0.2 bn litres of conventional ethanol, which was 4% of total ethanol demand. Changes to the regulations concerning ethanol imports, such as a repeal of anti-dumping duties on US imports and a change to the Mercosur tariff quota, could give easier access to the EU market. To account for these changes an additional 0.9 billion litres has been included in the supply scenario (along with 2017's 0.2 bn litres of ethanol imports). This would match the 20% level of imports experienced in 2012¹⁰ which was the last time the anti-dumping measures were not in place. This is also supported by the current US overproduction.
- **Increased conventional ethanol production** – The required 3.5 billion litres of additional demand could be supplied by an increase in conventional ethanol production in the EU, through increasing the capacity of existing plants or building new plants. This would be a ~66% increase in production volume compared with 2019 and would most likely be achieved through expansion of existing plant capacity.

Three of the supply routes could come close to supplying this volume of ethanol on their own. This includes:

- Increasing the utilisation of the EU's current conventional ethanol plants – the graph above shows the potential for this from current plants.
- Increasing conventional production capacity through expansion of the current plants or building new plants - this is limited by demand, so is shown here at a level to match total demand.
- Increasing advanced ethanol production capacity in Europe – this could be through plants at greenfield sites or co-located with conventional ethanol plants or other industrial sites. This depends on the rate at which this industry could expand in response to market and policy drivers for advanced fuels, as explained above.

Overall low ethanol demand is likely to limit the growth of the different ethanol supply routes in 2030.

3.1.2 Supplying high ethanol demand in 2030

Figure 5 shows an illustrative example for ethanol supply in the case of high ethanol demand (17.1 billion litres), based on the Business as Usual gasoline scenario with 100% uptake of E20.

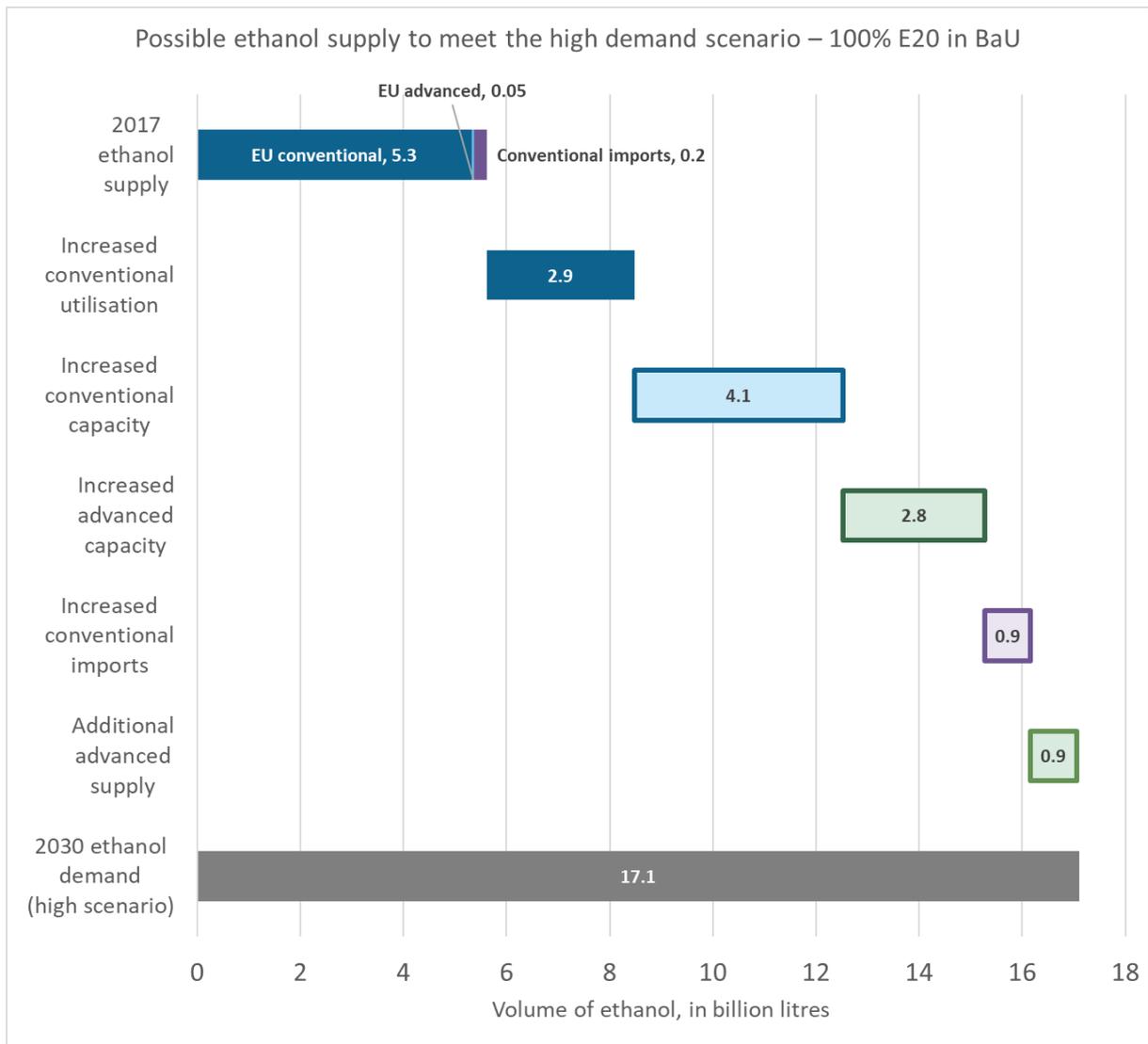


Figure 5 Ethanol supply to meet high demand scenario

This high ethanol demand scenario has very different implications for ethanol supply in 2030. As a result, a different approach is needed to show how supply could be met compared with in the low ethanol demand scenario. The starting point is the 2017 EU production of conventional and advanced fuel ethanol along with 2017 ethanol imports, which accounts for 5.6 billion litres of the 17.1 billion litre total. 2017 EU supply of advanced ethanol was very limited, accounting for only 0.05 billion litres and there is no global trade in advanced ethanol. Beyond this, we have considered supply from the other options based on the assumptions used in section 3.1.1. A combination of all supply routes, including imports, are used to meet demand.

As stated above, this supply scenario is not intended to be prescriptive. Shifts in availability and cost of different supply routes could influence demand for other routes.

3.2 How feasible is this level of supply?

It is important to ensure that the levels of ethanol supply estimated above can be sourced sustainably. The high demand scenario presents a ‘worst case’ scenario for ethanol demand and has been used to understand the feasibility of supplying this volume of ethanol in Europe by 2030. Obviously if this high volume can be supplied sustainably then lower demand scenarios will not be an issue. Increased production in the EU will also require investment in new plants.

3.2.1 Feedstocks and land needed for conventional ethanol production in Europe

Sourcing sufficient amounts of sustainable crops to meet ethanol demand is essential for future supply. We have calculated the amount of crops and corresponding land requirement to supply the additional conventional ethanol in Europe needed to meet high ethanol demand in 2030. This assumes that new plants are based on the 2018 mix of crops.

Table 1: Assumptions and feedstock requirements for additional conventional ethanol in 2030

Crop type	Share of conventional ethanol production by feedstock 2018 ¹⁵	Ethanol production from these feedstocks, Mt	Ethanol yield (t wet feedstock/t ethanol) ¹⁶	Wet feedstock required, Mt
Corn	44%	2.4	3.0	7.2
Wheat	27%	1.5	3.4	5.0
Sugar beet	22%	1.2	12.9	15.6 ^b
Other cereals	7%	0.4	3.9	1.4
Total Cereals		4.2		13.6
TOTAL^a		5.4		29.1

a, due to rounding, above figures do not add exactly

b, equivalent to 2.5 Mt of sugar at 16% sugar content and moisture content 76.5%

To put this figure into context:

- The increased cereal demand is equivalent to 4.4% of Europe’s average 2014-2018 supply of cereal crops. The EC’s 2018 agricultural outlook indicates that total EU production of cereal crops is expected to increase to 325 million tonnes in 2030 compared with an average of 308 million tonnes in 2014-2018¹⁷. The additional demand would be 4.2% of this figure.

¹⁵ ePURE, European renewable ethanol – key figures 2018 <https://epure.org/media/1920/190828-def-data-statistics-2018-infographic.pdf>

¹⁶ JRC, Definition of input data to assess GHG default emissions from biofuels in EU legislation, Version 1d – 2019 <https://ec.europa.eu/jrc/en/publication/definition-input-data-assess-ghg-default-emissions-biofuels-eu-legislation>

¹⁷ European Commission, 2018. EU agricultural outlook 2018-2030. Available at: https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/medium-term-outlook-2018-report_en.pdf

- The increased sugar beet demand is equivalent to about 12.5% of EU sugar beet production (both average 2014-2018 and in 2030)¹⁷. The EU currently exports significant amounts of sugar beet in the form of sugar. The increased sugar beet demand for conventional ethanol is equivalent to 89% of the projected sugar export in 2030.

Table 2 Assumptions and land requirements for additional conventional ethanol in 2030

Crop type	Wet feedstock required, Mt	Wet yield (t/ha) ¹⁸	Land requirement, million ha
Corn	7.2	7.13	1.0
Wheat	5.0	5.80	0.9
Sugar beet	15.6	80.76	0.2
Other cereals	1.4	4.55	0.3
TOTAL^a	30.2		2.4

^a due to rounding the above figures do not add exactly

Overall an additional 2.4 million hectares of land would be needed to cultivate crops to supply the additional 6.9 billion litres of ethanol, from full utilisation of current plants and development of new plants, needed in the high demand scenario i.e. BaU demand with 100% E20.

For comparison:

- The 2017 land area used for cereal crop cultivation in EU-28 was 55.5 million ha, with 1.8 million ha used for sugarbeet¹⁷. The areas above are equivalent to 3.9% of this area for cereals and 10.7% for sugar beet.
- The EC's 2018 agricultural outlook projects that improvements in crop yields and agricultural technology are expected to decrease the land needed for cereal crop cultivation by ~1 million hectares by 2030, which could mean additional area available for crops for ethanol.
- In 2018, JRC estimated¹⁹ that in the period 2015-2030 11% of agricultural land in the EU is under high potential risk of abandonment. This is due to factors including land suitability, farm structure and agricultural viability, population and regional specificities. Although this is expected to be avoidable in many places, the incremental abandonment 2015-2030 is projected to reach 4.2 Mha (about 280 kha/yr on average) of agricultural land, bringing the total abandoned land to 5.6 Mha by 2030, the equivalent of 3% of total agricultural land. 70% of this land (4 Mha) is expected to be arable land, with very little of the land that is abandoned then subsequently used for re-cultivation, conversion to forestry and natural areas, or conversion to built-up area. Of this arable land, around 1 Mha is estimated to be in mountainous areas which could have challenges for mechanisation, meaning that around 3 Mha may be suitable.

¹⁸ Average of 2009 and 2014 moist yield, CAPRI Modelling System, http://www.ilr.uni-bonn.de/agpo/rsrch/capri/capri_e.htm

¹⁹ JRC, 2018, Agricultural Land Abandonment in the EU within 2015-2030 <https://ec.europa.eu/jrc/sites/jrcsh/files/jrc113718.pdf>

It should also be noted that conventional ethanol production also leads to production of high protein animal feed co-product. As an example, assuming each tonne of co-product could replace a tonne of wheat feed, the additional ethanol supply in the maximum demand scenario i.e. BaU 100% E2O scenario would reduce land required for feed by 0.7 million hectares¹⁶.

3.2.2 Availability of wastes and residues for advanced ethanol production

It is also important to ensure there would be enough waste and residue feedstocks in the EU to support the level of expansion that is envisioned in the supply scenario for advanced ethanol. For this we have used data from S2Biom²⁰ to provide the volumes of corn stover, other straws, forestry residues and wood mill residues that could be available in 2030 as feedstocks for advanced ethanol production. This takes into account sustainability constraints such as: sustainable removal rates to maintain soil carbon level for agricultural residue, no harvesting in protected area for forestry residue, soil and water protection and biodiversity, avoidance of competition with existing uses (food, feed and urbanisation, material production, and indirect land use change). Using an estimated process yield of 37% for an advanced ethanol plant²¹ a total of 58 billion litres of advanced ethanol could be produced from this material each year, as shown in Table 3. An alternative source gives similar potentials, of 139 Mt crop residues and 40 Mt forest residues in 2030²².

Table 3: Potential for advanced ethanol from wastes and residues in 2030

Feedstock	Available amount for bioenergy (Mt/yr) – Low estimate	Advanced ethanol potential (PJ/yr)	Advanced ethanol potential (Bn litres/year)
Corn stover	29	159	7.5
Other straws	115	637	30.1
Forestry residues	31	178	8.4
Wood mill residues	79	459	21.7
Total^a	253	1432	67.6

^a due to rounding, above figures do not add exactly

Both supply scenarios above includes 2.8 billion litres of European advanced ethanol in 2030. To produce this would require 4.1% of the potential waste and residue feedstocks available in 2030 (Figure 4) – a very small proportion even if these feedstocks are also in demand for other energy uses. Supply of advanced ethanol is therefore unlikely to be constrained by feedstock availability.

²⁰ Data from S2Biom (Annexes)

https://s2biom.wenr.wur.nl/doc/S2Biom_D1_8_v1_1_FINAL_19_04_2017_CP.pdf + Country Data (FR, DE, ES)

²¹ BioGrace – List of standard values, Version 4 – Public

²² Wasted: Europe’s Untapped Resource, 2014 <https://europeanclimate.org/wp-content/uploads/2014/02/WASTED-final.pdf>



Figure 4: EU advanced ethanol supply in comparison to ethanol potential from available wastes and residues

3.2.3 Availability of ethanol for import in 2030

Supply of conventional ethanol into the EU via imports could be constrained by the volume of ethanol available on the global market. The IEA estimates that global ethanol production will reach 121 billion litres by 2030²³, an increase of 23% on 2015’s value of 98 billion litres. This could grow through new plant capacity, and increased production from existing plants: for example, plants in the US have been producing at >105% plant rated capacity and could have the potential to go up to 120% rated capacity through debottlenecking. The high ethanol demand scenario includes 12 billion litres of conventional production in the EU which would mean the Rest of the World producing 108 bn litres in 2030. The volume of imports used in the high demand scenario above of 1.2 billion litres is 1% of this estimated Rest of World production. For comparison, EU import of ethanol (fuel and industrial use) was 1.6% of Rest of World production in 2012^{10,24}. This level of imports therefore seems reasonable, although there is the potential for increasing shares of demand from other regions, for example through introduction of mandates in China.

Supply of advanced ethanol by imports from the rest of the world will be limited by the global capacity, which in turn depends on the time taken to rollout new technologies and plants. It will also depend on the strength of policy in other countries, and whether this provides a greater revenue than the policy support in Europe, taking into account transport costs. However, it is also important to understand whether this supply could also be constrained by the availability of wastes and residues from the agricultural and forestry industries. The 2014 IRENA report on global bioenergy supply and demand

²³ International Energy Agency, 2017. Energy Technology Perspectives 2017. Available from: <https://webstore.iea.org/energy-technology-perspectives-2017>

²⁴ Renewable Fuels Association. <http://www.ethanolrfa.org/resources/industry/statistics/#1454098996479-8715d404-e546>

projections²⁵ estimates that by 2030 the rest of the world could supply enough lignocellulosic wastes and residues to produce 718 billion litres of advanced ethanol. This is taking into account of sustainability constraints, e.g. sustainable removal rates to maintain soil carbon level for agricultural residue and avoidance of competition with existing uses (food, feed and urbanisation, material production, and indirect land use change). The estimated import volume into the EU of 0.9 billion litres would require 0.12% of the available feedstock. This would indicate that future imports of advanced ethanol are unlikely to be constrained by feedstock availability.

3.3 Investment in European production

Increasing the European supply of conventional and advanced ethanol would require investment in new plants, as well as increased supply from today's plants. For the high scenario (BAU, 100% E2O) an additional 4.1 billion litres of ethanol would be needed from new conventional ethanol plants/or the expansion of existing plants and 2.8 billion litres from new advanced plants. Table 4 shows the assumptions used for average plant size and plant capex to calculate an equivalent number of plants and investment costs to meet high ethanol demand in 2030. These are based on plants commissioned since 2009 for conventional plant, and from a previous study for advanced plants. However, new conventional plants are most likely to be at least twice the size of recent plants, which would halve the number of plants needed. Additionally, volume would likely be supplied mainly by the expansion of current units.

Table 4: Assumption used for average plant capacity and capex cost for conventional and advanced ethanol plants

	Plant size (million litres)	Plant cost (million EUR)
Conventional ethanol	200	174
Advanced ethanol	63	200 ^a

^a this assumes new plants are greenfield developments and includes costs for onsite combined heat and power production.

To supply these volumes, the equivalent of 21 new conventional ethanol plants would be needed alongside 44 new advanced ethanol plants (Table 5). Feedstock supply logistics constraints mean the average size of an advanced ethanol plant is considerably smaller than a conventional ethanol plant, which accounts for the difference in the number of plants needed. The costs and size of the plants could evolve positively over time as the technology matures, and while capital costs will remain higher compared to conventional plants, the cost gap will decrease. To build this new production capacity would require investment of 3.5 billion EUR and 8.7 billion EUR for conventional and advanced ethanol respectively. This would bring benefits to European technology developers, project developers and

²⁵ IRENA (2014) Global Bioenergy Supply and Demand Projections, A working paper for Remap 2030, Available from: http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/IRENA_REmap_2030_Biomass_paper_2014.pdf

agricultural supply chains. To put this in context, the total investment required is about 5% of the EU’s annual spend on imported petroleum oils, and less than 0.1% of EU GDP²⁶.

Table 5: Number of plants and associated investment needed to meet high ethanol demand in 2030.

	Conventional ethanol		Advanced ethanol	
	Number of plants	Investment required (billion EUR)	Number of plants	Investment required (billion EUR)
High demand scenario - BaU 100% E20	21	3.5	44	8.7 ^a

^a this assumes new plants are greenfield developments and includes costs for onsite combined heat and power production.

The conventional ethanol industry is mature, with an established technology base, and as such, investments in new and existing plants are most likely to be sourced solely from the private sector. In contrast, the advanced ethanol production is at the early stages of commercialisation and it could be expected that the investment needs will be provided from both the public and private sectors.

4 Implications of E20 supply in Europe for the ethanol industry

Introduction of E20 to the EU market is expected to increase the demand for ethanol in transport despite decreasing gasoline demand to 2030. In a low gasoline demand scenario, with 20% E20 market share, the market requires a 58% increase (3.2 billion litres) in the volume of ethanol supplied compared with 2017 supply volumes. A high demand scenario, with a 100% market share of E20 requires almost a trebling (increase of 11.5 billion litres) in the volume of ethanol supplied to the market compared with 2017 supply volumes. Even if all of the ethanol supplied to meet the demand in 2030 was produced from crops, in none of these scenarios would the estimated crop cap set by RED II be exceeded (low demand scenario 1.7%, high demand scenario 3.1%), meaning that the crop cap would not be a barrier to the introduction of E20 to the EU market.

If demand is low, several different supply routes could almost meet the potential increase in demand alone. Whilst all routes are still likely to contribute to meeting demand, the market would be much more competitive because of this. These routes could include increased utilisation and expansion of existing plants, and potentially through new plants, which could be co-located with advanced ethanol production. There will also be an important role for advanced ethanol in supplying increased ethanol demand in 2030, contributing to advanced biofuels targets. This will rely on successful

²⁶ In 2018 the EU imported ~530 million tonnes of petroleum oils and oils obtained from bituminous minerals, crude which corresponds to a value of ~234 billion EUR. EC, 2019. EU imports of energy products – recent developments: Statistics explained. Available at: <https://ec.europa.eu/eurostat/statistics-explained/pdfscache/46126.pdf>

commercialisation of this technology, supported by sufficient market incentives through successful implementation of the RED II in Member State policy.

In a high ethanol demand market, it is likely that all the supply routes considered in this study may need to contribute to the supply mix, with less competition between routes. This scenario could require an additional contribution from the EU conventional ethanol industry of 7 billion litres. The feedstock requirements for this expansion would be similar to those of European ethanol production in 2017, meaning new demand for feedstock, and ultimately land.

In addition to increased EU production from conventional and advanced routes, imports of both conventional and advanced ethanol could be important to supply demand in a high scenario.

5 Annex

Table 6: Assumptions underpinning the high ethanol demand supply scenario

Factor	Assumption	Value (billion litres)
Current conventional supply	2017 production volume of conventional fuel ethanol ²⁷	5.3
Current advanced ethanol supply	2017 production volume of advanced fuel ethanol ¹⁰	0.05
Current conventional ethanol imports	2017 import volumes for conventional ethanol ¹⁰	0.2
Utilisation ramp-up of conventional ethanol plants	Potential increase in utilisation of 2017 conventional ethanol plants in Europe. This has been calculated as the difference between 2017 ethanol production volumes (transport and traditional use) ¹⁰ and the 2018 total European conventional ethanol production capacity.	2.9
Future conventional ethanol plants	Added to make up the difference between the other routes and total 2030 demand.	4.1
Future advanced ethanol plants	Central scenario for ramp-up of advanced ethanol plants, based on ramp up modelling from projects in development.	2.8
Future conventional ethanol imports	Future imports are expected to increase due to reductions in anti-dumping duties on US imports and a change to the Mercosur tariff quota, allowing easier access to the EU market. To account for these changes the total volume of conventional ethanol imports has been doubled, by adding an additional 0.9 bn litres of ethanol for future imports.	0.9
Future advanced ethanol imports	Rest of world (non EU) advanced ethanol production is expected to reach 3.6 billion litres by 2030 ²⁸ . We expect 1.8 billion litres to be produced in the US and therefore not be available on the export market. Of the remaining 1.8 billion litres we expect 0.9 billion litres to be available for import into Europe.	0.9

²⁷ Current energy use (2017) for gasoline and ethanol used in Europe from SHARES and the USDA GAIN EU Biofuels Annual 2019

²⁸ Internal E4tech calculation