Prospective for Future Production of Non-Crude Liquids

Publishable Executive Summary

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Executive Summary

"Non-crude" oil-derived liquid fuels are defined in this study as including biofuels, natural gas liquids (NGLs) and fuels produced by Gas-to-Liquids (GTL) and Coal-to-Liquids (CTL) processes. Over recent years the total production levels of these materials in the assessed markets grew from 250 million tons in 2005 to an estimated 410 million tons in 2015.

NGLs, which includes for the purpose of this study propane, butanes, and higher condensates but excludes ethane[1], is the largest segment investigated, with estimated production in 2015 of nearly 300 million tons, representing approximately 73 percent of the total non-crude liquid markets. NGLs production growth historically has averaged three percent per year over the period 2005 to 2015 and has been driven by the development of the global natural gas market.

The second largest non-crude liquids market segment is biofuels. Globally, production of the biofuels assessed in this report has been increasing steadily for the last decade, from a total of 28 million tons in 2005 to an estimated 101 million tons in 2015. Biofuels have been classified in this study under the following terms:

- First generation biofuels
- Second generation biofuels
- Algae derived biofuels

First generation biofuel is defined as all product produced using food or feed crop-derived feedstocks, while second generation product is defined as all biofuels produced using non-food or feed crop-derived feedstocks, with the exception of those derived from algae biomass, which are classed separately.

Within the biofuels category, first generation bioethanol and biodiesel have historically been the most significant materials. This is largely due to the significant first generation ethanol production in Latin America and North America, where domestic fuel policies in Brazil and U.S. have been strong drivers for growth.

While there have been numerous pilot and demonstration projects aimed at the production of second generation bioethanol, only a small number of commercial scale plants have been completed in recent years, and output in the assessed markets is therefore limited. Consequently, second generation biofuel production is dominated by second generation biodiesel production (generally using waste products as feedstock).

While no commercial scale production of algae-based biofuels has yet emerged, there are numerous pilot and demonstration projects in operation across a range of the assessed markets, led by Europe and the United States. As of 2016, a range of factors remain as barriers to large scale production, notably cost.

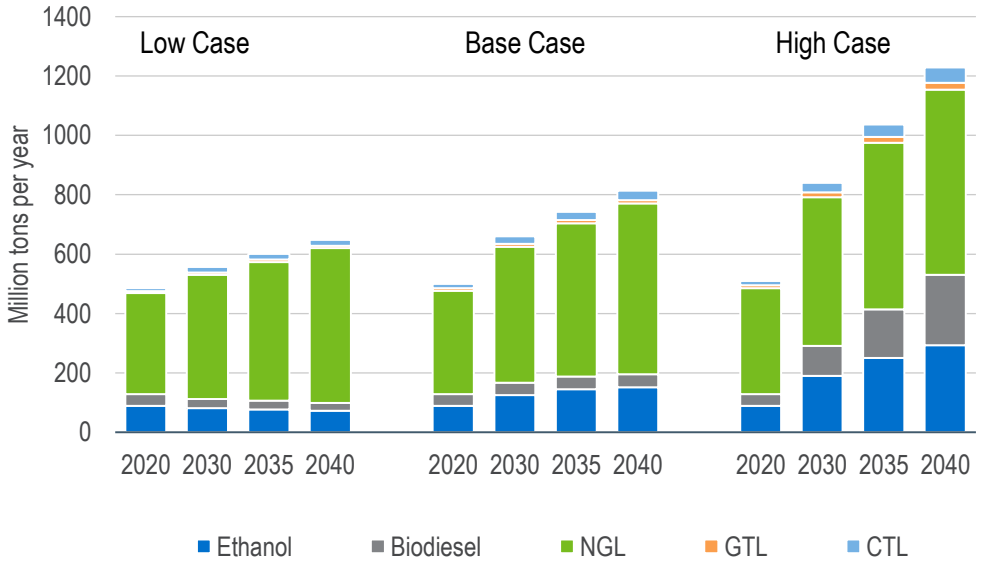
From the analysis provided, NGLs and biofuels have dominated historic non-crude liquids production, with GTL and CTL materials occupying only relatively minor positions. CTL commercial operation is limited to facilities in China and South Africa driven by a desire to exploit domestic coal reserves. Meanwhile, there are six GTL

[1] For this study, ethane is not considered a NGL component as it is not readily liquefied and overall does not compete within the conventional liquid fuels market.

plants in operation in Qatar, Malaysia, Nigeria and South Africa where new plants have been built aimed at monetising natural gas reserves.

Looking forward, Nexant and E4tech have produced supply projections for the assessed non-crude liquids for the period from 2016 to 2040. These projections have been developed using three separate scenarios – a Base Case, a Low Case and a High Case – each of which is grounded in a consistent set of assumptions. Key metrics included in these scenarios are macroeconomic factors, the role of policy in driving biofuels markets, developments in the global natural gas markets, and the competitiveness of coal and gas feedstocks in comparison with crude oil. A key input in defining these Cases has been the long term availability of sufficient feedstocks to supply the volumes of demand for biofuels envisaged by many government mandates; assumptions in this regard have also driven long term projections on the development of first generation, second generation and algae-based biofuels to 2040.

Figure 1 Total Non-Crude Liquids Production Summary



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Based on these scenarios, forecast production of non-crude liquids in 2040 is projected to stand at some 814 million tons under the Base Case scenario, accounting for approximately 23 percent[2] of the total production of the liquid fuels under assessment (gasoline, gasoil/diesel, LPG and jet kerosene). This level of supply represents an annual average growth of some 2.8 percent between 2015 and 2040.

Under the Low Case, total non-crude liquid supply would stand at approximately 650 million tons in 2040, accounting for some 20 percent of total liquid fuels supply (reflecting the fact that the Low Case scenario implies significantly lower overall fuel demand and production). Non-crude liquids production under this scenario would see annual average growth of some 0.9 percent.

[2] 23 percent is based on the total non-crude liquids supply including the entirety of NGL production. Condensates in NGLs are not currently used in fuel applications considered in this study. Therefore, the actual percentage of non-crude liquids displacing the liquid fuels under assessment would be lower than 23 percent.

Under the High Case, non-crude liquids supply would increase to a significantly greater extent, reflecting scenario assumptions on the rollout of second generation biofuels as well as macroeconomic and competitiveness impacts on other products. Under this scenario, non-crude liquid supply is projected to reach over 1 200 million tons by 2040, representing an average annual growth of 4.5 percent per year. Growth along these lines – against a background of generally stronger fuels demand and production – would see non-crude liquids accounting for 32 percent of total liquids fuels supply in 2040.

The three Cases show the structure of the total production of non-crude liquids shifting in different ways. In the Base Case scenario, non-crude supply remains dominated by NGL volumes along the same lines as the current situation, i.e. with NGLs accounting for over 70 percent of total production. Under this scenario, the share of total supply taken by biofuels will also remain broadly stable, with ethanol accounting for 19 percent, and biodiesel five percent, of total in 2040. CTL and GTL technologies are moderately competitive leading to investment of 34 million tons in CTL and modest further investment in GTL plants.

Under the High Case, the structure of non-crude liquids supply will shift more dramatically, as significant growth in biofuels – led in part by second generation biodiesel – brings these products up to a 43 percent share of non-crude liquids (of which 25 percent ethanol, 18 percent biodiesel). In the High Case, CTL and GTL technologies are strongly competitive and provide attractive investment returns. However, overall, in spite of high capacity growth, these technologies still remain niche in volume terms.

The Low Case, meanwhile, would see – against a background of weak overall fuels demand – biofuels volumes actually declining in the assessed markets, outpacing the negative impact of this scenario on NGL supply, and leading to an increased share for NGLs of total non-crude liquids supply, at 80 percent by 2040. Under the low scenario, CTL and GTL technologies are not competitive and this leads to limited capacity development.

Overall, these scenarios are projected to impact on the market for crude-derived liquid fuels by displacing varying volumes of incremental required supply by 2040, as underlying macroeconomic trends drive total fuel consumption upwards. This impact can be assessed in terms of the scale of output (of the assessed end-use liquid fuels) of an assumed European marker[3] refinery, defined in this study as having an annual total crude oil processing capacity of around 15 million tons, and featuring Fluid Catalytic Cracking capacity, but lacking more advanced deep conversion capacity (such as Hydrocracking or Delayed Coking technology).

The Table below summarises the degree of non-crude liquid fuel supply penetration at an aggregate level and by fuel type. Under the Base Case scenario, non-crude liquids are projected to account for some 23 percent of total liquid fuels supply in 2040, compared to an estimated 15 percent in 2015, equivalent to the output of 35 marker refineries.

[3] A marker refinery is a generic large scale European refinery with an annual capacity of 15 million tons per year and having a product yield as follows: LPG 4.8 percent, Gasoline 35.4 percent, Jet Kerosene 10.2 percent, Diesel/Gasoil 32.5 percent, Other products 17.1 percent.

In the Base case, there is little penetration of non-crude liquids into the diesel/gasoil supply reflecting the limited increase in biodiesel production in this scenario. There is more modest impact on gasoline supply where non-crude penetration of total gasoline supply, including from ethanol, GTL and CTL, is set to account for some 13.7 percent of total supply by 2040, compared to an estimated 8.5 percent in 2015. In this Base Case, this is heavily driven by first-generation bioethanol supply. Meanwhile, there is a high impact of non-crude liquids on LPG supply, driven almost entirely by NGLs production

Table 1 Non-Crude Liquid Supply Penetration

		2015	2040
Total	High Case	15.0%	32.0%
	Base Case		23.0%
	Low Case		20.0%
Gasoline	High Case	8.5%	24.0%
	Base Case		13.7%
	Low Case		7.0%
Gasoil/diesel	High Case	2.7%	15.0%
	Base Case		4.3%
	Low Case		2.8%
LPG	High Case	63.0%	81.0%
	Base Case		80.0%
	Low Case		93.0%

Under the Low Case scenario, non-crude liquids' share of total supply is projected at 20 percent in 2040, equivalent to the output of 17 marker refineries. Non-crude penetration of total gasoline supply, including from ethanol, GTL and CTL, is projected to only account for some 7.0 percent of total supply in 2040. This is down from 8.5 percent in 2015 due to the poor competitiveness of biofuel production in a low crude oil price environment and the scaling back of fuels mandates in the longer term. Meanwhile, there is little further penetration into the diesel/gasoil supply.

However, there is even further penetration on NGLs into the LPG supply as non-crude liquids penetration in 2040 is projected at some 93 percent. While the volume of LPG produced from NGLs will fall under the Low Case scenario, as gas production is less robust, the total volume of end-use LPG supply will fall more sharply, resulting in a higher percentage share for non-crude LPG.

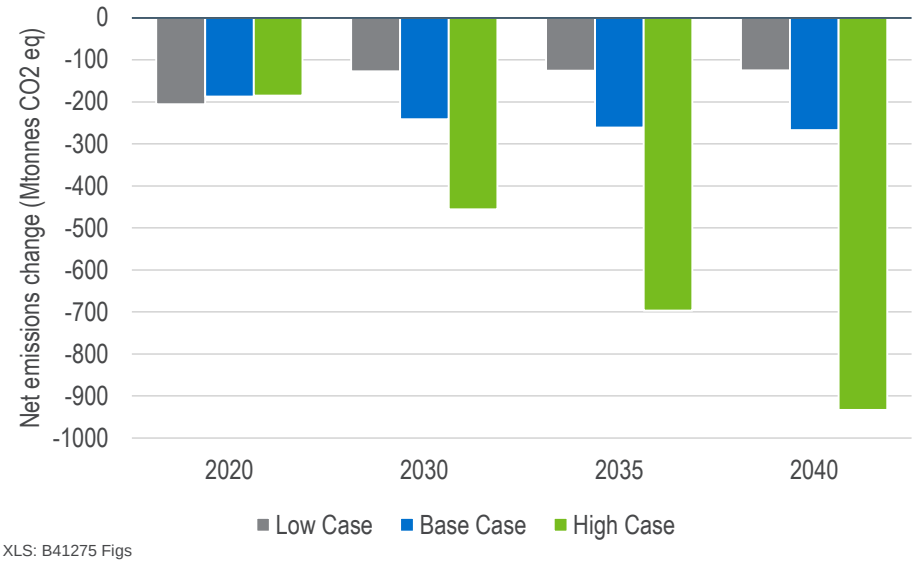
Under the High Case scenario, non-crude liquids are projected to account for 32 percent of total liquids supply, equivalent to the output of 71 marker refineries. Non-crude penetration of total gasoline supply is set to account for some 24 percent of total supply in 2040 as a strong ramp up in second generation biofuel production is seen. For gasoil, non-crude liquids are projected to account for over 15 percent of total supply in 2040 driven by high growth in biodiesel production. Meanwhile for LPG,

non-crude penetration in 2040 is projected at some 81 percent. This reflects the opposite dynamics seen for LPG in the Low Case scenario.

Overall, the impact of non-crude liquids supply projections has the potential to discourage significant new refinery investment globally in the coming 25 years.

In terms of environmental impact, the summary net Greenhouse Gas (GHG) emissions change for each scenario is shown in the Figure below. The principal contributors to the reduction in GHG emissions are the biofuels. The annual emissions reduction caused by biofuels is 316 million tons CO_2 in the Base Case, ranging from 126 to 1063 million tons CO_2 in the Low and High Cases. An emissions reduction of 316 million tons CO_2 is equivalent to taking around 67.3 million passenger cars off the road. However, CTL leads to an increase in GHG emissions leading to a reduced aggregated impact.

Figure 2 Net GHG Emissions Change due to Non-Crude Liquids Supply



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In December 2015, at the Paris climate conference (COP21), 195 countries adopted the Paris Agreement to tackle climate change. Through the Paris agreement, all countries aim to hold global average temperature increase to well below 2°C above pre-industrial levels, to reach peak global GHG emissions as soon as possible, and to be producing net zero emissions by the second half of this century. Achievement of these aims will require dramatic changes in many sectors of the economy.

The transport sector constituted 14 percent[4] ($7GtCO_2eq$) of global GHG emissions in 2010 and therefore must play a significant part in reducing emissions in line with a 2°C scenario. There are a wide variety of options open to the transport sector to decarbonise, including incremental changes to existing technologies, novel fuels or propulsion systems, and behaviour change including choice of transport mode.

[4] Intergovernmental Panel on Climate Change (IPCC) (November 2014). Climate Change 2014: Mitigation of Climate Change

A greater focus on reduction of GHG emissions in the transport sector could have some implications for production of non-crude liquids to 2040, including:

- More favourable biofuels policy and mandates could drive greater uptake, suggesting that the High Case deployment of biofuels could be more likely
- Reduced use of coal, leading to less production of CTL, would support the Low Case CTL scenario
- Limited impact on production of GTL fuels, as emissions are similar to those of crude oil
- NGL production is driven by natural gas production and the impact of stringent GHG emissions mitigation scenarios on natural gas production uncertain, although natural gas use may increase in the medium term to 2040. In this case NGL production would also increase in the medium term.
- The development of Carbon Capture and Storage (CCS) technology could be important for non-crude liquids, by enabling a reduction in GHG intensity of non-crude fossil-derived fuels. Use of CCS technology could reduce the GHG intensity of CTL fuel from 200.9 gCO_{2eq}/MJ to 110.8 gCO_{2eq}/MJ and could reduce the emissions intensity of GtL fuel from 94.3 gCO_{2eq}/MJ to 84.2 gCO_{2eq}/MJ (JEC, 2014a).

The Paris climate agreement is one factor amongst many in driving production of non-crude liquids. However, the outcome of the Paris conference may increase the importance of GHG emissions reduction relative to other drivers of road transport fuel choice such as cost, availability and energy security.

Finally, it is stressed that very different market drivers will ultimately determine the overall production of non-crude liquids. Production of NGLs is fundamentally driven by the demand for gas and the requirement to extract the heavier NGLs prior to distribution and use. Meanwhile, biofuels production is heavily influenced by regulation, incentives and political mandates driven by underlying environmental considerations. CTL production is limited to those regions where energy security is a concern and where coal reserves are abundant. GTL is also limited and adoption is driven by the desire to monetise natural gas reserves. In conclusion, these four non-crude liquid types are driven by four fundamentally different strategic influences and this impacts their future production potential.