



Prospective for Non-Crude Liquids

A Report for the European Commission in the Framework of EU-OPEC Energy Dialogue

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Agenda

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 - Total Liquid Fuels
 - Non-crude Liquids
 - Impact on Crude-derived products
 - Environmental impact
- 3 Key conclusions

Project Team

The team here today:

- Jonathan Bourne – Nexant, Project Executive
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- Matthew Morton – Nexant, Fuels markets and biofuels
- Shanshan Wang – Nexant, Natural Gas Liquids
- Aiganym Murzina – Nexant, Coal-to-Liquids & Gas-to-Liquids

Introduction

Study objectives

The objectives of the study were as follows:

- To provide an overview of the current production of different types of non-crude liquids such as biofuels, NGLs, GTLs, CTLs.
- To provide a quantitative breakdown of the production in different specified regions.
- To assess the perspective for future production of non-crude liquids until 2020 and for 2030, 2035 and 2040, including a breakdown of the potential production for different types of non-crude liquids in the different producing regions.

Product definitions

The non-crude liquids assessed in the study were as follows:

- **First generation biofuels:** Ethanol and biodiesel (FAME and HVO) produced from food or feed crops (excluding crop residues).
- **Second generation biofuels:** Produced from non-food or feed feedstocks, including agricultural residues, specialty crops and waste products, excluding algal feedstocks.
- **Algae-derived biofuels:** Biofuels derived from the cultivation of algae, including potential bio-based direct substitutes for crude oil (not currently in commercial production).
- **Natural gas liquids (NGLs):** Heavier hydrocarbon components of natural gas, such as propane, butanes and condensate, excluding ethane.
- **Gas to liquids (GTL):** Liquid fuels produced from conversion of methane-rich natural gas streams via Fischer-Tropsch process, including diesel, kerosene, naphtha and LPG.
- **Coal to liquids (CTL) :** Liquid fuels produced from coal via direct or indirect liquefaction processes, including gasoline, diesel, kerosene, naphtha.

Scenario definitions

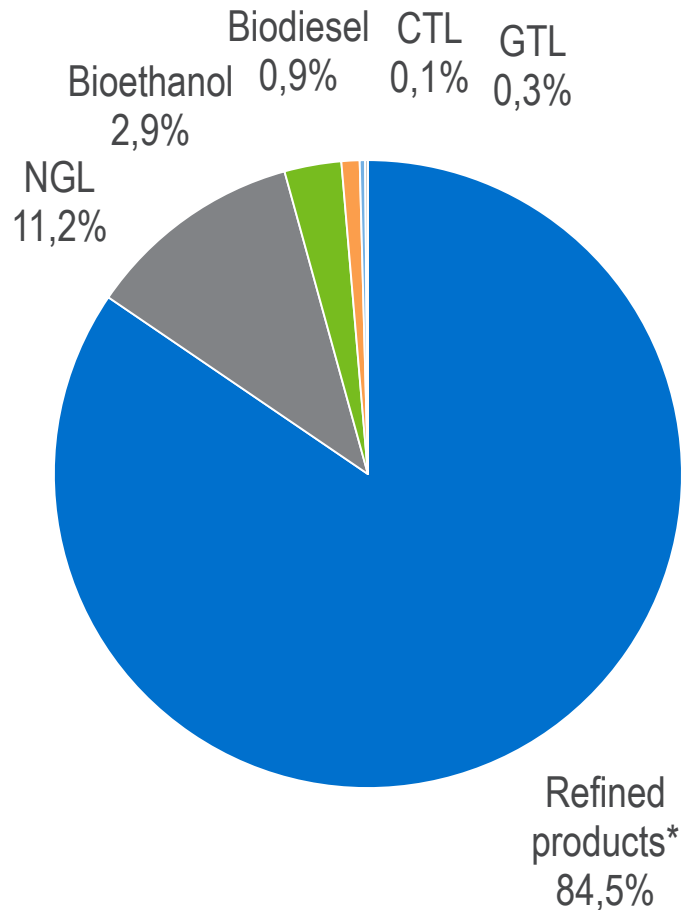
Scenario Themes – with Base, Low and High cases for each

- **Macroeconomic landscape**
 - GDP, population growth, crude oil price
- **Fuels demand**
 - transport fuel demand, vehicle ownership per capita, vehicle types, fuel split, aviation emissions policy
- **Non-Crude Liquid Specific Assumptions**
 - **Biofuels**
 - production capacity, competitiveness – incentives/subsidies, policy mandates, feedstocks
 - **Natural Gas Liquids**
 - gas pricing and production, liquids content, demand, ethane logistics
 - **Gas-to-Liquids**
 - gas pricing, planned assets, competitiveness, investment, operating rates, technology
 - **Coal-to-Liquids**
 - coal pricing, planned assets, competitiveness, CO₂ emissions, energy security, operating rates, technology

Historic & Forecast Production

Most liquid fuels are still produced from fossil fuels

2015 Production – Assessed Markets



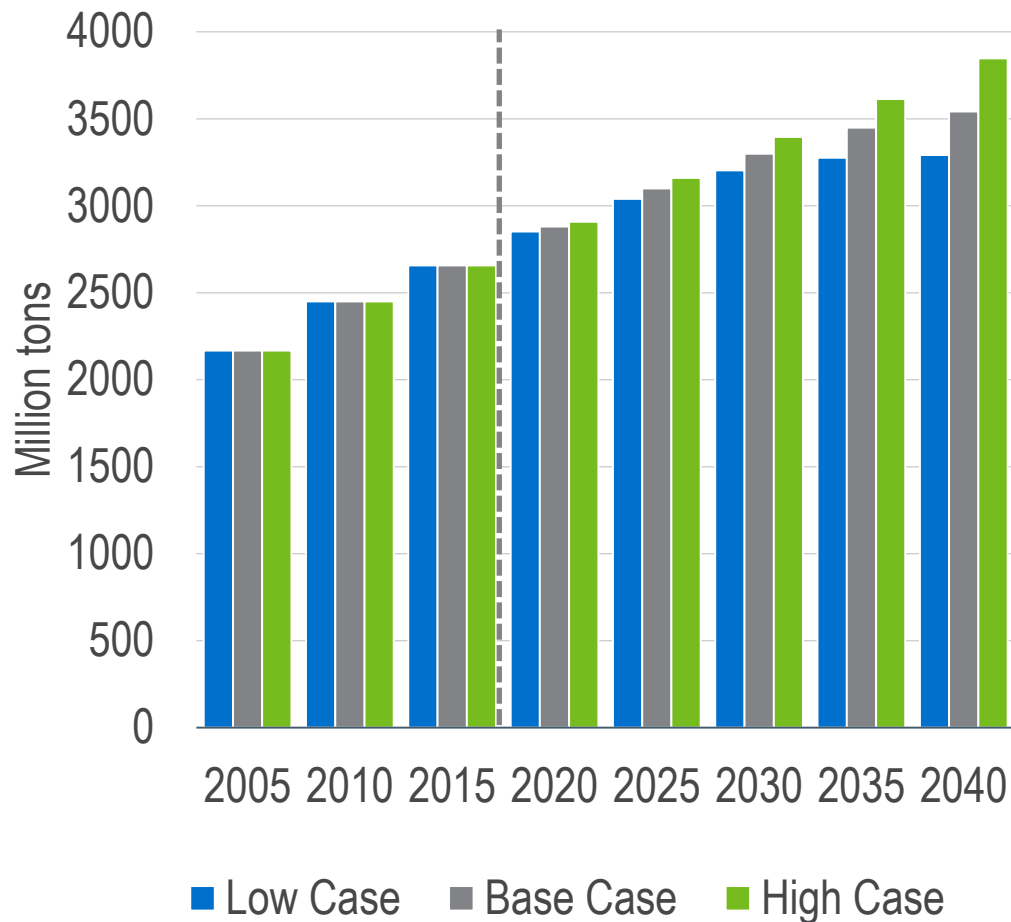
Non-crude liquids currently account for nearly 16 percent of total supply of assessed fuels

- NGLs play a major role, accounting for 63 percent of total LPG production.
- Ethanol, especially first generation, is second largest non-crude liquid and occupies 8.5 percent of gasoline supply.
- Gasoil is largely produced from crude oil, with non-crude liquids taking less than three percent share.
- GTL and CTL production plays a minor role, with supply limited to a small number of markets.

* LPG, gasoline, gasoil, kerosene

Total liquid fuels: Historic & forecast production

Historic & Forecast Production – Assessed Markets



Historic Production has seen growth over last ten years

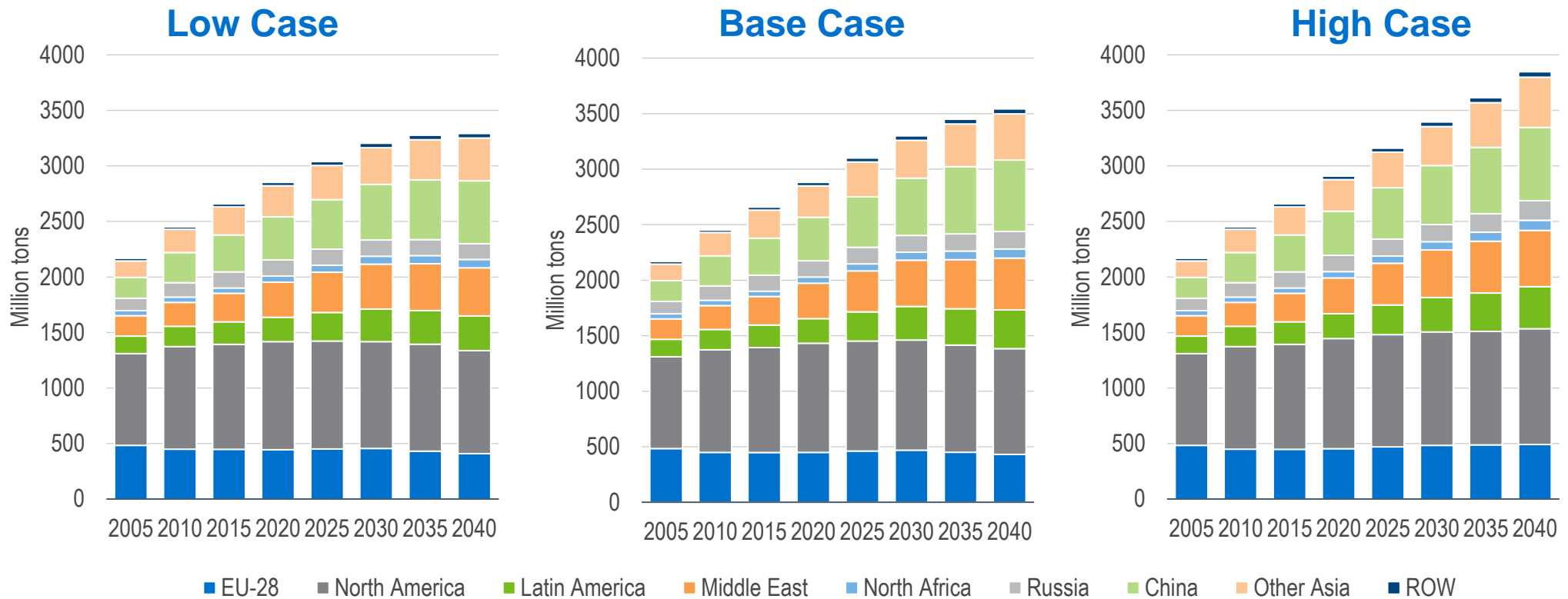
- Assessed markets see production rise from 2.2 billion tons to 2.7 billion tons between 2005 and 2015.
- CAGR 4.2 percent.

Total liquid fuels supply shows continued upward trend to 2040 in all cases

- Gasoil, LPG to slightly increase share of supply, at expense of gasoline, kerosene.

Case	CAGR 2015-2040	Incremental volume 2015-2040
Low	0.9 %	635 Mt
Base	1.2 %	888 Mt
High	1.5%	1 190 Mt

Total liquid fuels: Historic & forecast production



Low GDP, fleet growth constrains supply

- EU-28 supply falls by 40 Mt, Asia up by some 365 Mt.
- Middle East output up by almost 180 Mt.

Growth in line with recent trend

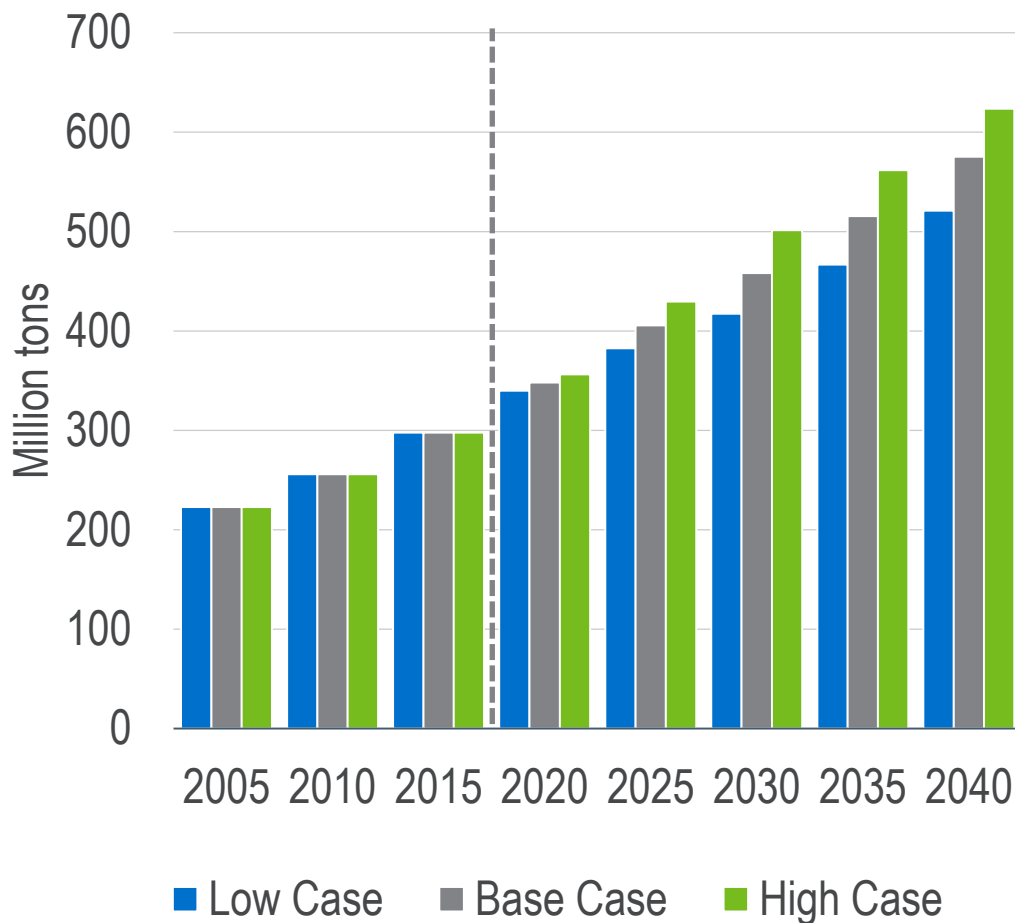
- EU-28 supply falls by 17 Mt, Asia up by over 470 Mt.
- Middle East up by 210 Mt.

GDP growth, low EV take-up boosts market

- EU-28 supply rises by 40 Mt
- Asia/Middle East add combined output of some 780 Mt.

Natural gas liquids: Historic & forecast production

Historic & Forecast Production – Assessed Markets



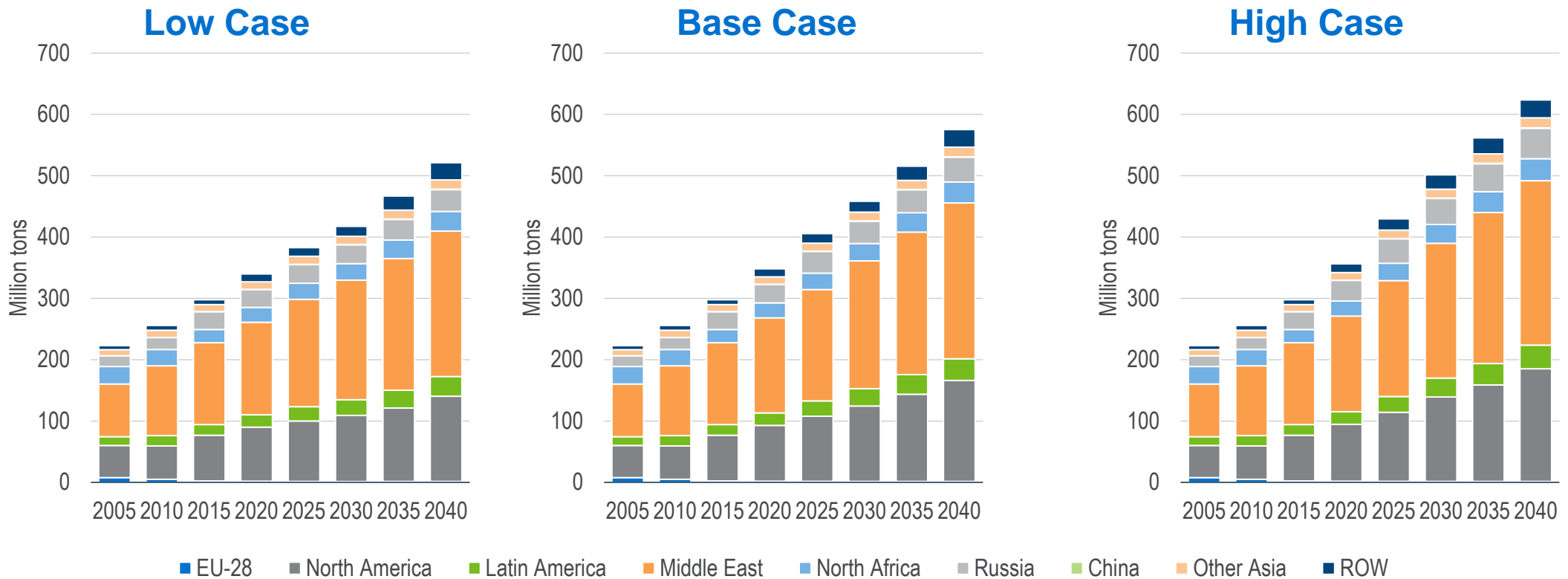
Natural gas liquids (NGLs) production driven by overall natural gas production

- Historic Production rose from 223 to 298 Mt between 2005 and 2015
- CAGR 2.9 percent.

NGLs forecast supply shows less variation between cases to 2040

Case	CAGR 2015-2040	Incremental volume 2015-2040
Low	2.3 %	223 Mt
Base	2.7 %	278 Mt
High	3.0%	326 Mt

Natural gas liquids: Historic & forecast production by region



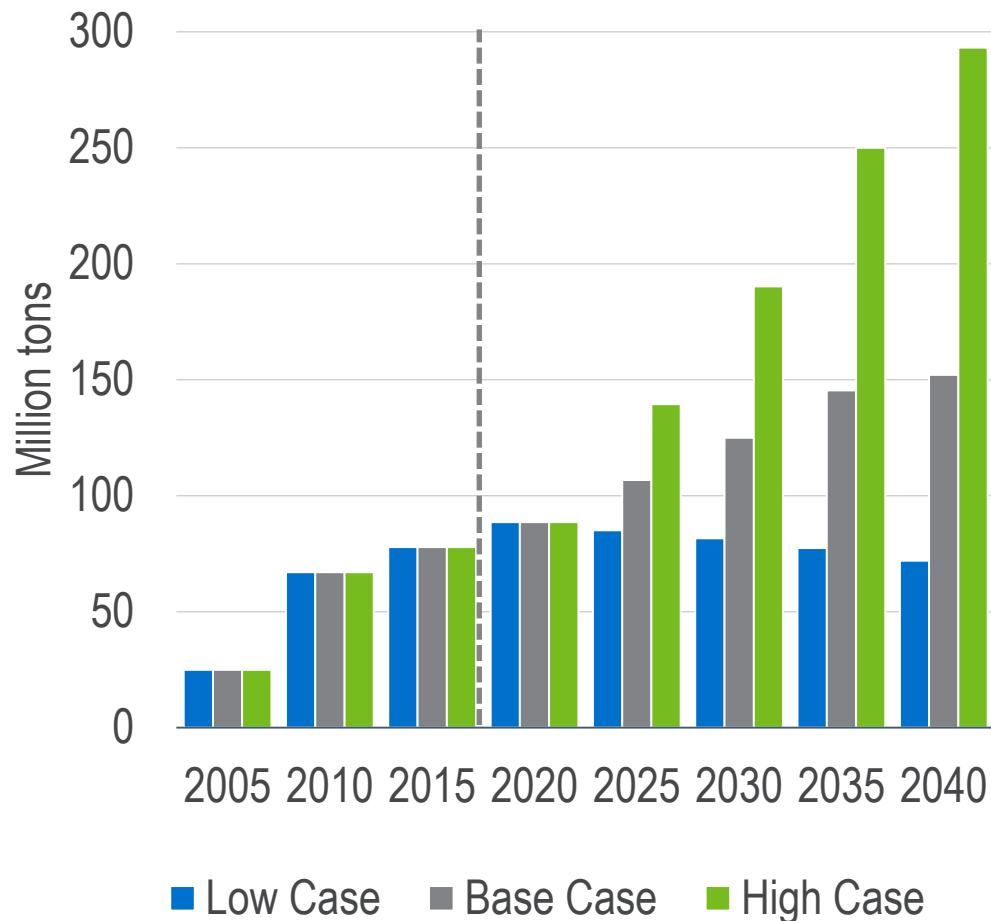
- U.S. production less than Base case due to lower GDP growth
- Middle East also sees lower volumes with less demand for its exports
- EU-28 largely unaffected

- Middle East and North America lead production
- EU-28 declining NGL production
- OPEC countries high growth in NGL production

- Middle East production rises with demand for its gas exports
- Flaring reduction (e.g. Russia) see increased production.
- No meaningful change to EU-28 production

Ethanol: Historic & forecast production

Historic & Forecast Production – Assessed Markets



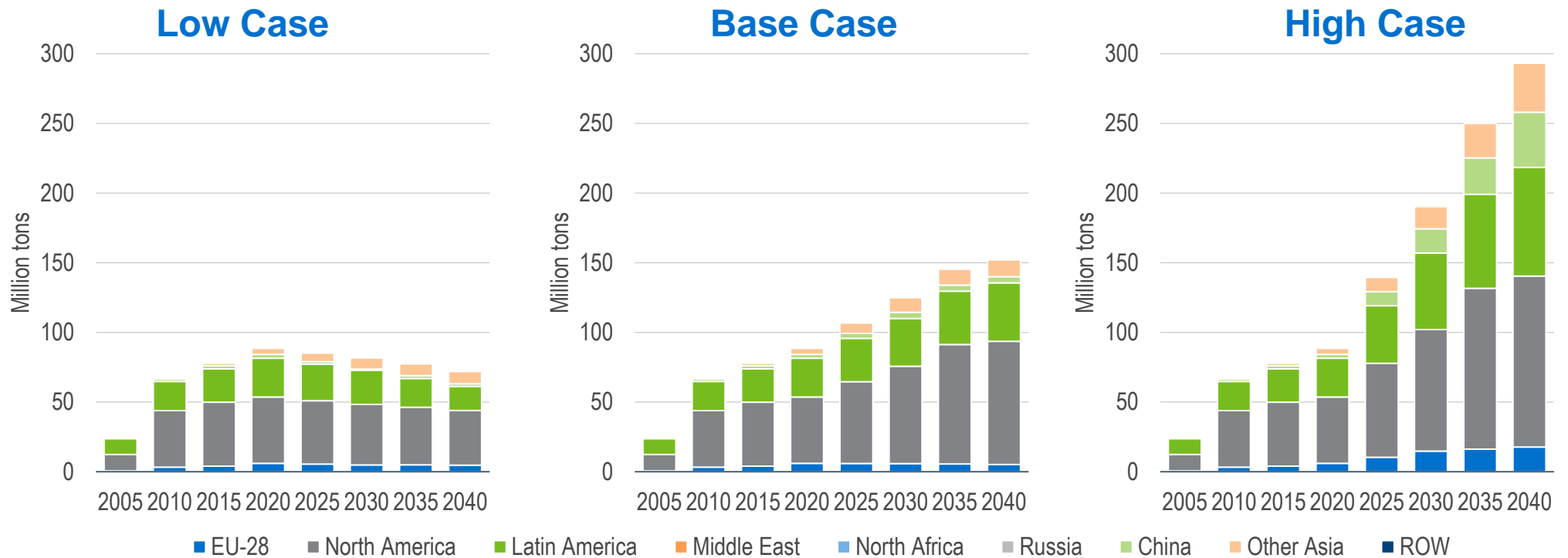
Historic production

- Extensive 1G production, mainly Brazil & USA
 - Driven by blending mandates, relatively low cost production
- Small volumes of 2G ethanol in US, China, Brazil and Italy

Forecast production

- Growth dependent on crude oil prices, long-term policy support and fuel standards
 - Proportion of 2G ethanol expected to increase in all scenarios
- Bioethanol production costs vary widely, depending on region, feedstock & technology
 - 190-530 \$US per ton (1G)
 - 380-920 \$US per ton (2G)
- Ethanol expected to continue to have largest share of overall biofuel market to 2040

Ethanol: Historic & forecast production by region



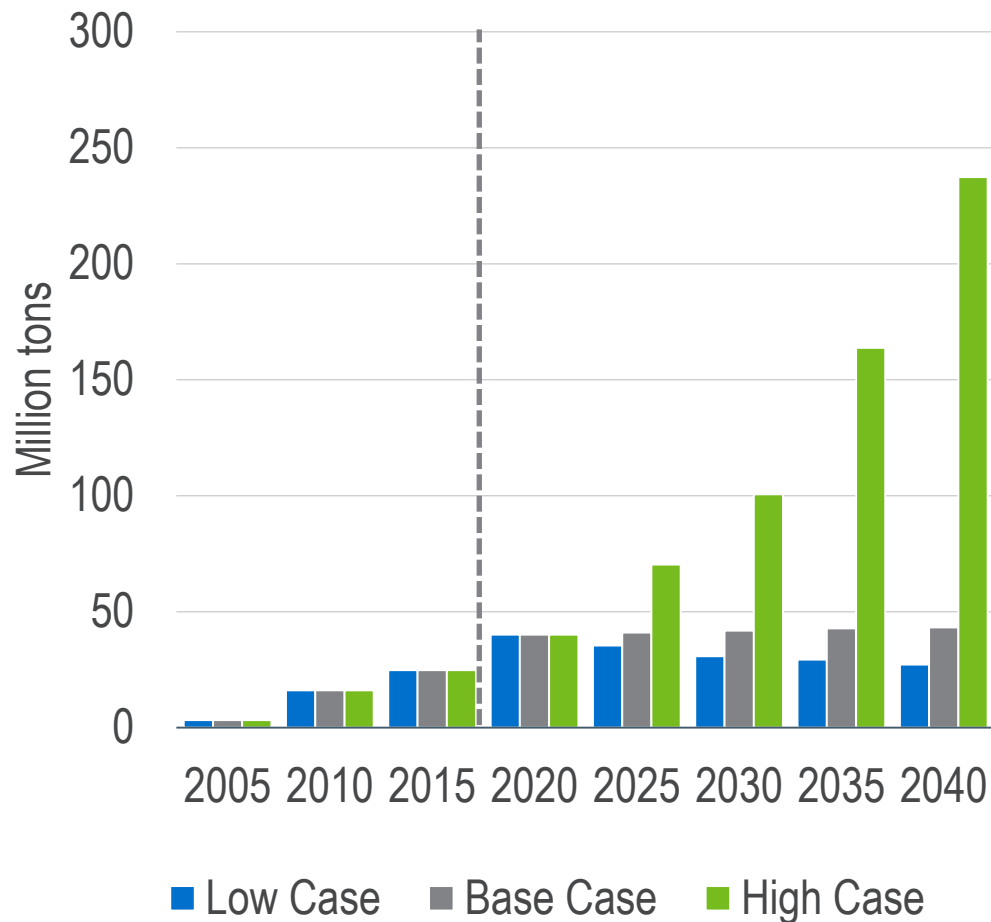
- Low demand for liquid fuels; low crude oil price → scaled back biofuel mandates
- Increased resource constraints
- Overall decrease; continued 1G dominance
 - Reduced investment in 2G capacity due to reduced fuel demand

- Existing (2020/30) mandates met and extended to 2040
- Growth to 2040 in 1G and 2G
 - Biggest growth in Brazil and Asia
 - 2G growth driven by USA
- 2G constrained by technical & commercial challenges, lack of policy support (not feedstock)

- Increasing demand for liquid fuels; high oil price → biofuel supply potential maximised
- Uptake limited by fuel standards & infrastructure
- 1G market share reduced by 40% to 57% in 2040
 - 2G growth driven by USA & China, which also import to meet demand

Biodiesel: Historic & forecast production

Historic & Forecast Production – Assessed Markets



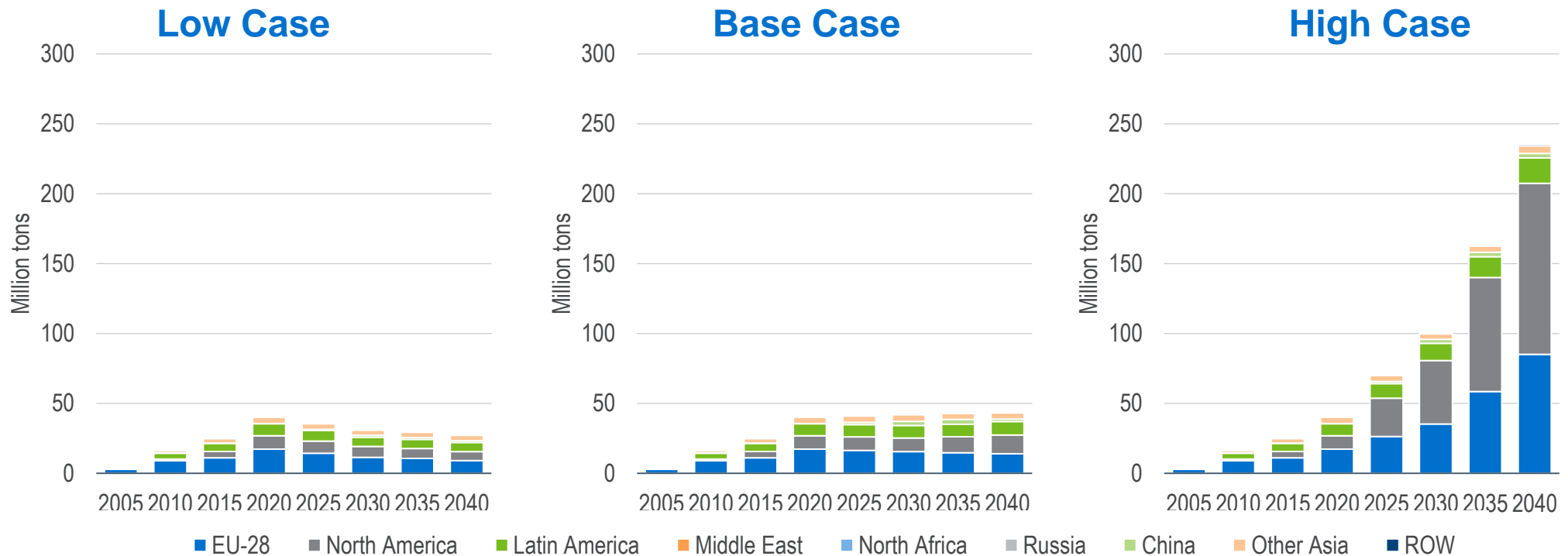
Historic production

- Smaller volumes than ethanol (25% total market)
- Production concentrated in the EU, but rapid growth from North America, Latin America & Asia

Forecast production

- Growth dependent on crude oil prices, long-term policy support and market-based mechanisms, and overall fuel demand
 - Proportion of 2G biodiesel expected to increase due to increased competitiveness of advanced technologies and feedstocks
- Biodiesel production costs vary widely, depending on region, feedstock & technology
 - 460-890 \$US per ton (1G)
 - 490-1,250 \$US per ton (2G)
 - 2,630-3,030 \$US per ton (3G)

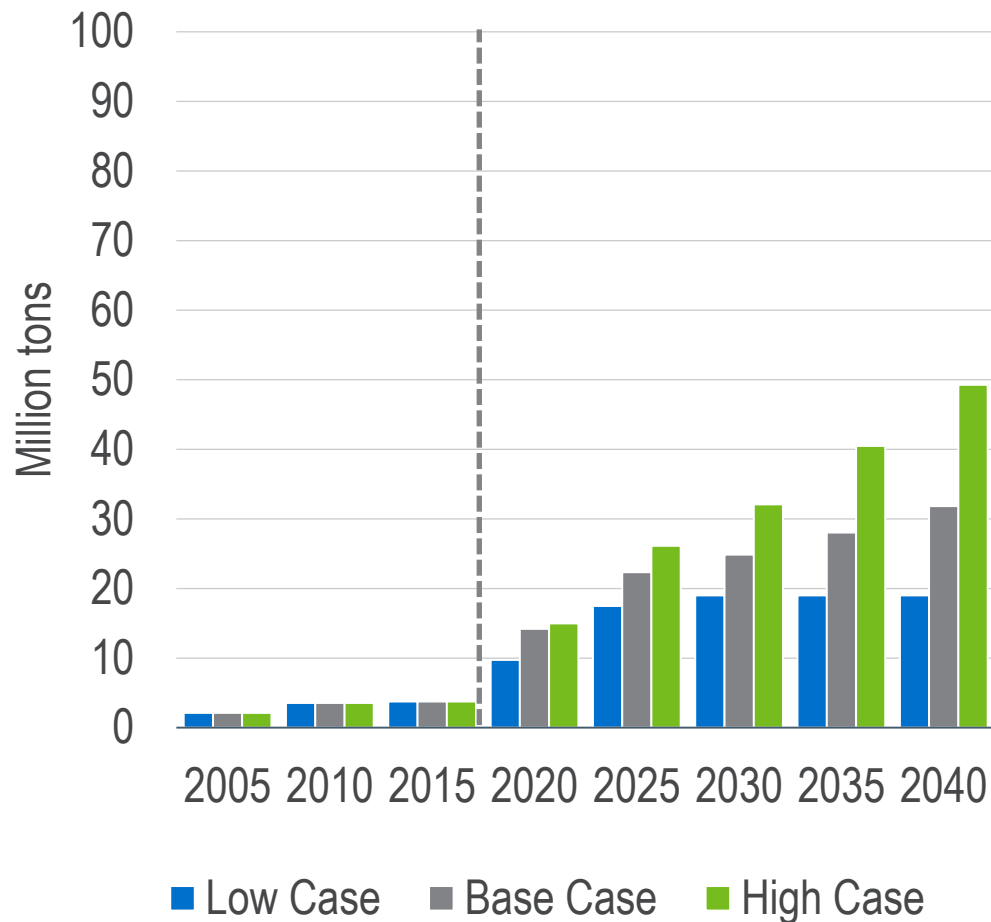
Biodiesel: Historic & forecast production by region



- Low demand for liquid fuels; low crude oil price → scaled back biofuel mandates
- Limited 1G feedstock availability
- Overall decrease; but 1G demand outstrips supply by 2040
 - Small growth in 2G production to meet local demands
- Existing (2020/30) mandates met and extended to 2040
- Very gradual overall growth
 - 1G production declines after 2030; shifts to 2G production (US, EU)
- 1G/2G shift driven by competitive production costs
 - Commercial rollout of gasification & pyrolysis platforms by 2040
- Increasing fuel demand; high oil price → biofuel mandates met and maximised
- No uptake capacity constraints
- 2G biodiesel is dominant biofuel globally; rapid deployment of gasification & pyrolysis (EU, US)
- Small volumes of 3G from 2030 (US, Middle East)

Coal-to-Liquids: Historic & forecast production

Historic & Forecast Production – Assessed Markets



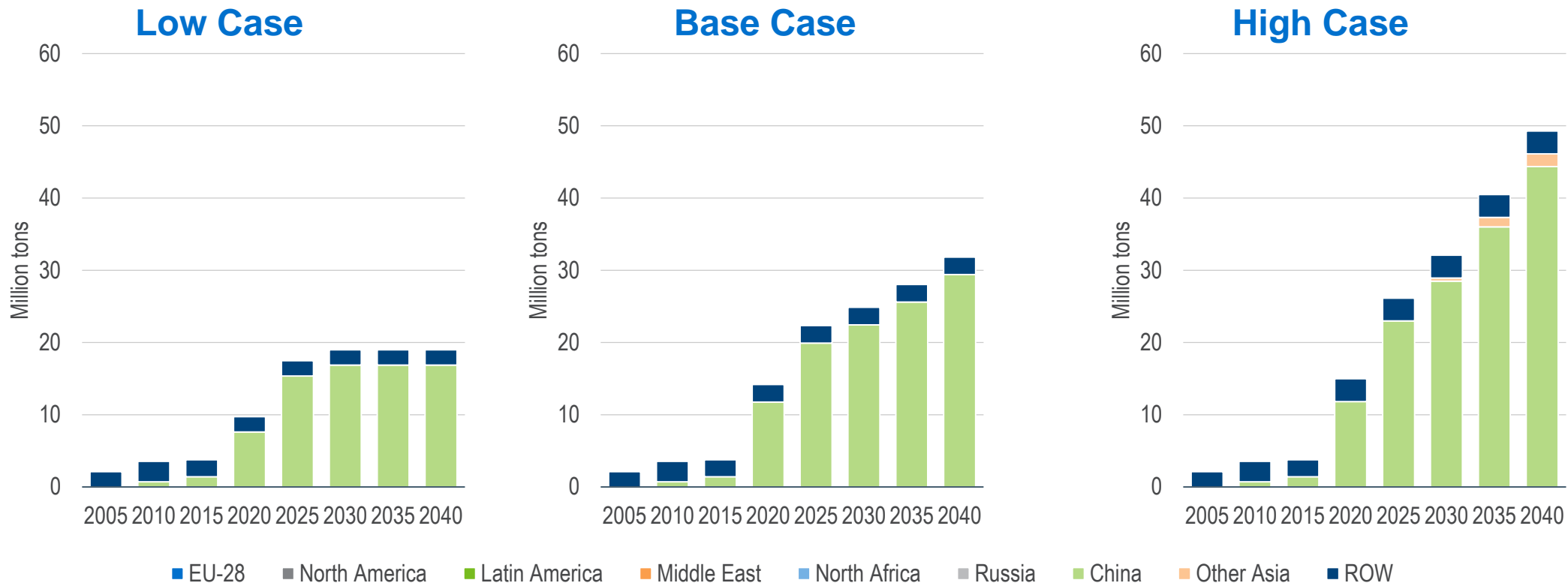
Historical Coal-to-Liquids (CTL) production has been niche

- Production rose from 2.1 Mt to 3.8 Mt between 2005 and 2015.
- CAGR 5.9 percent.
- Coal reserves and energy security are drivers for growth

CTL supply outlook has wide spectrum of outcomes

Case	CAGR 2015-2040	Incremental volume 2015-2040
Low	6.7 %	15Mt
Base	8.9 %	28Mt
High	11.0%	48 Mt

Coal-to-Liquids: Historic & forecast production by region



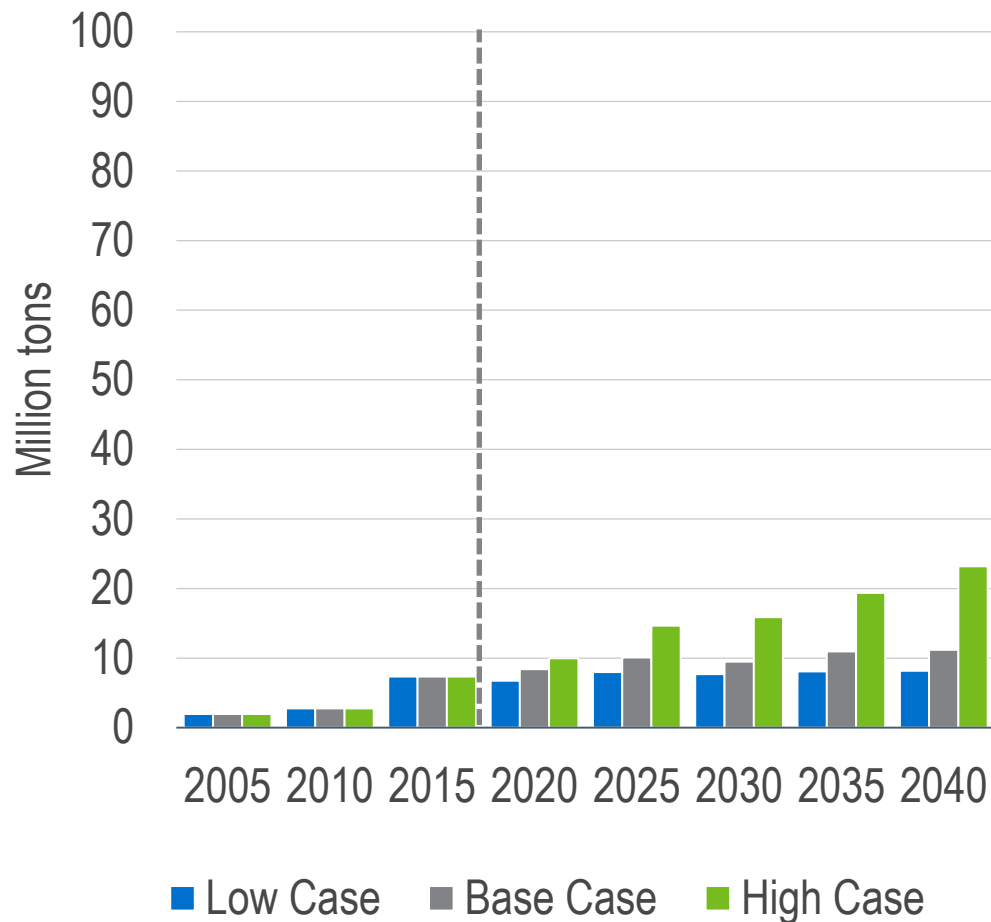
- Investment unattractive to lack of competitiveness at \$40 per barrel.
- Planned projects in China are implemented but no further capacity addition
- South African plants at lower operating levels

- Investment modestly attractive at \$70 per barrel crude oil
- New projects in China dominate increased supply (34 Million tons)
- South African production stable at existing levels

- CTL production competitive at \$100 per barrel
- Chinese production grows with 16 new plants over the outlook period
- India enters as a new entrant
- EU-28 and OPEC not active

Gas-to-Liquids: Historic & forecast production

Historic & Forecast Production – Assessed Markets



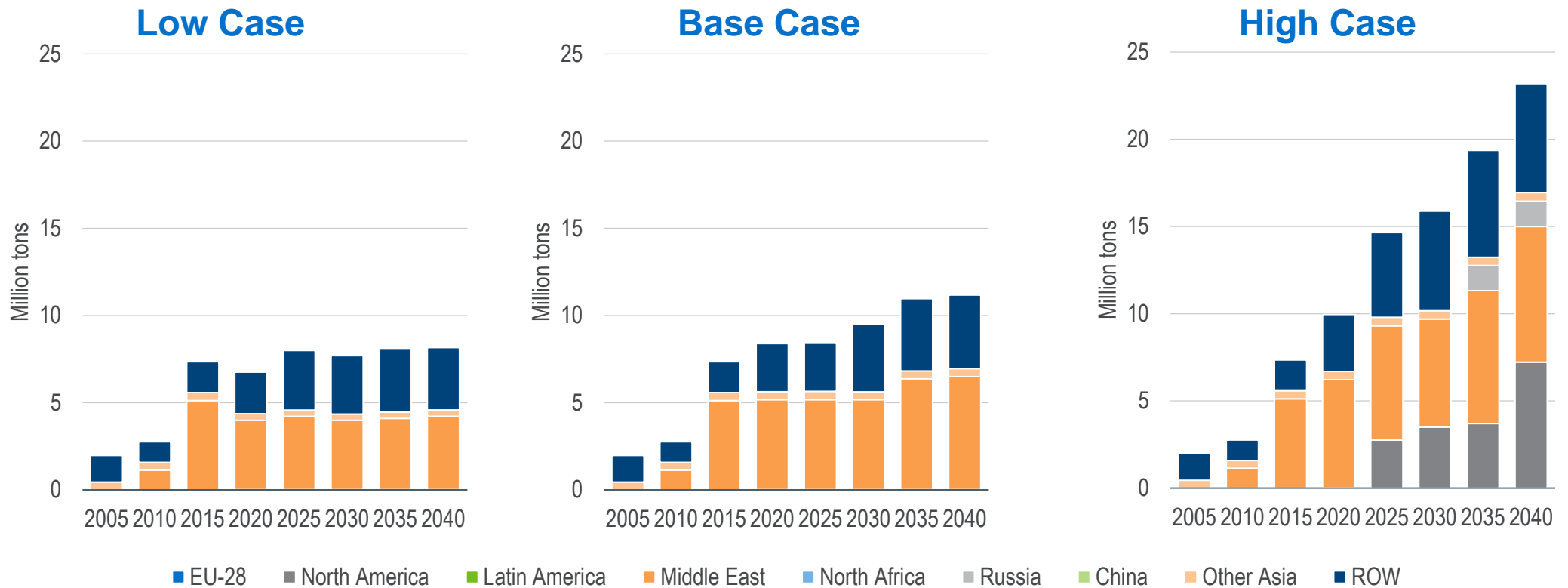
Gas to liquids (GTL) historic production limited in scale

- 6 Facilities operating in Qatar, Malaysia, South Africa and Nigeria
- Production rose from 2 Mt to 7.4 Mt between 2005 and 2015.
- CAGR 14 percent.

GTL supply set to remain low compared to other non-crude liquids

Case	CAGR 2015-2040	Incremental volume 2015-2040
Low	0.4 %	0.8 Mt
Base	1.7 %	3.8 Mt
High	4.7 %	15.8 Mt

Gas-to-Liquids: Historic & forecast production by region



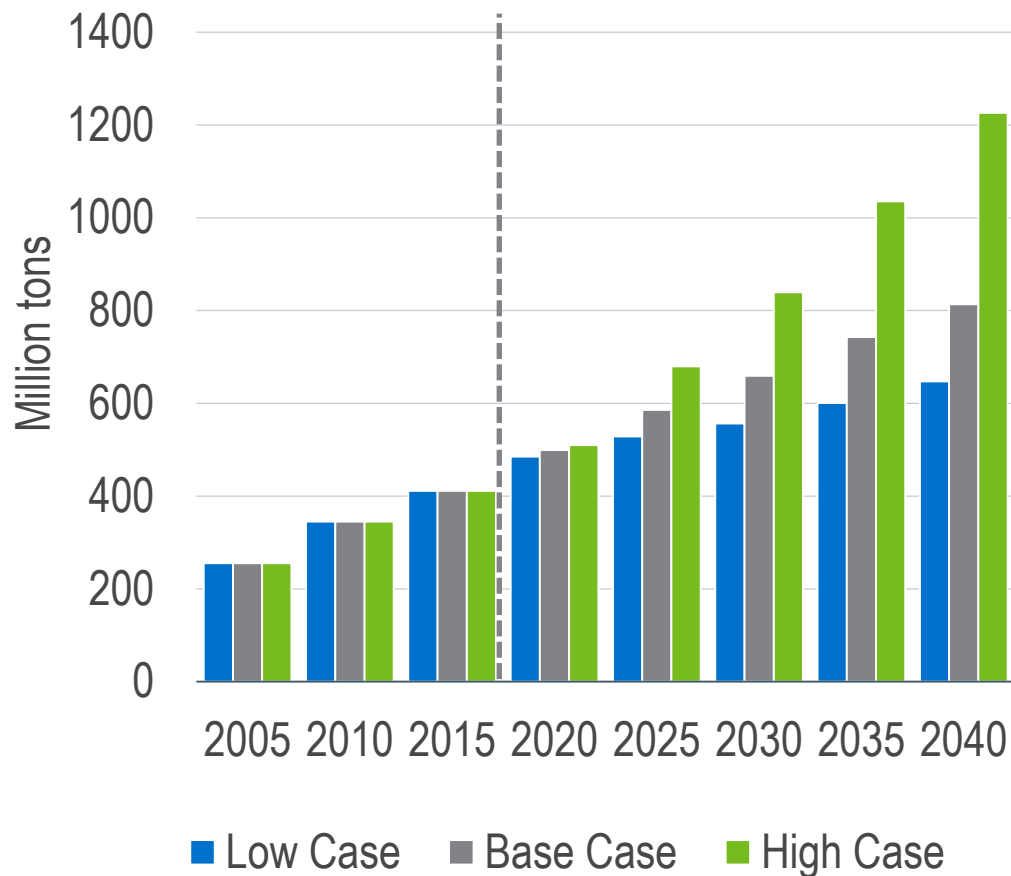
- GTL not cost competitive at \$40 per barrel crude oil
- Modest capacity investment through existing planned projects
- Plant operating rates impacted by lack of competitiveness

- GTL cost competitive at \$70 per barrel crude oil
- Middle east production grows with assumed new capacity in Qatar
- RoW capacity grows through new plants in Turkmenistan
- OPEC countries leading in GTL

- GTL highly cost competitive at \$100 per barrel crude oil.
- New capacity comes through in Qatar, Russia, U.S.
- Higher operating rates also driven up by high margins.

Total Non-crude Liquids: Historic & forecast production

Historic & Forecast Production – Assessed Markets



Historic sizeable increase in non-crude liquids production

- Total non-crude liquid supply up from 255 Mt to 411 Mt between 2005 and 2015.
- CAGR: 4.9 percent.

Non-crude liquid supply to rise in all scenarios

- Second generation biofuels, GTL and CTL materials still play minor roles.

Case	CAGR 2015-2040	Incremental volume 2015-2040
Low	1.8 %	236 Mt
Base	2.8%	402 Mt
High	4.5 %	815Mt

Refined product market impact

Share of current & projected total liquid fuels supply*

		2015	2040
Non-crude liquids	Low Case		20%
	Base Case	15%	23%
	High Case		32%
Gasoline	Low Case		7%
	Base Case	8.5%	14%
	High Case		24%
Gasoil/diesel	Low Case		3%
	Base Case	2.7%	4%
	High Case		15%
LPG	Low Case		93%
	Base Case	63%	80%
	High Case		81%

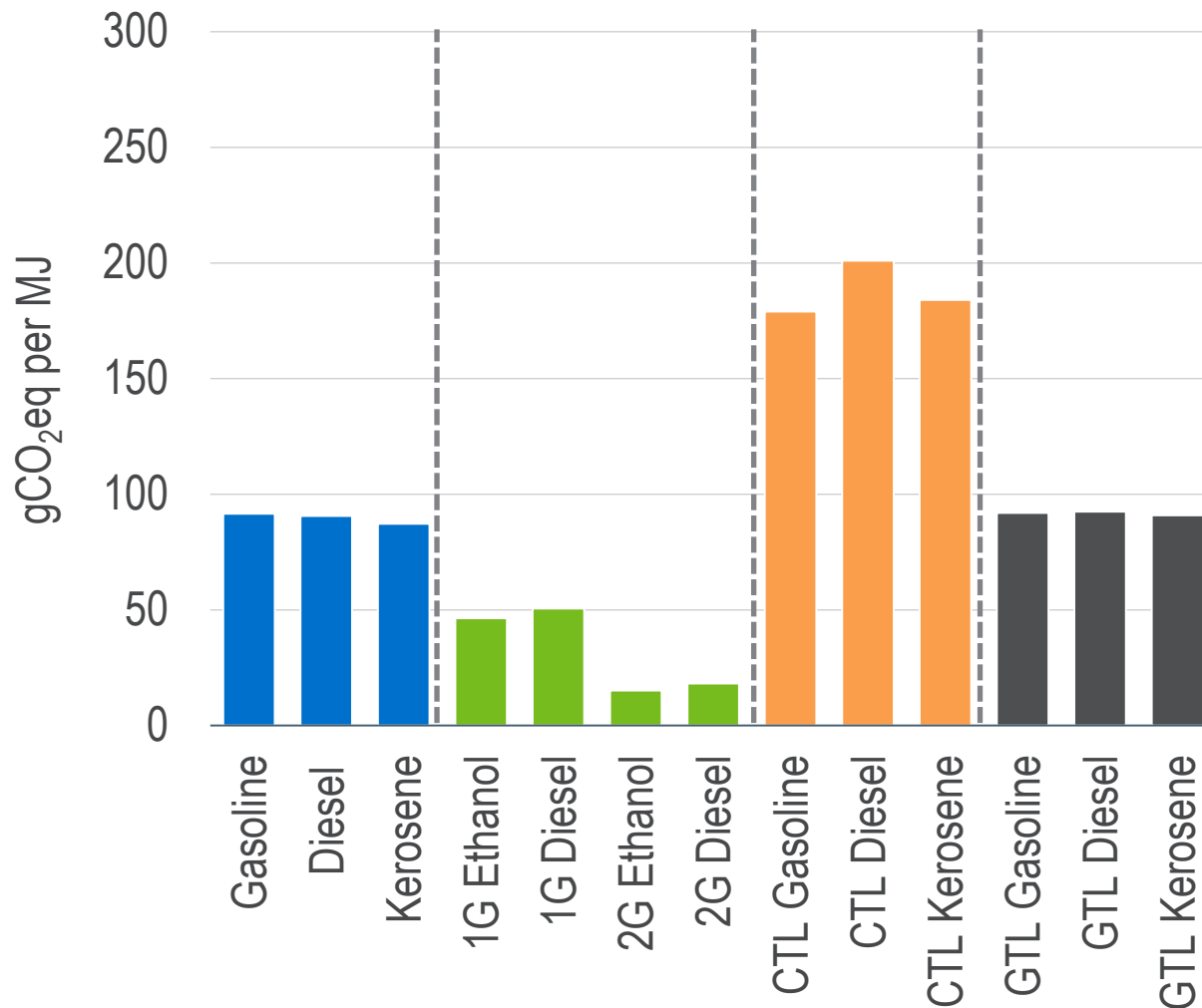
* LPG, gasoline, gasoil, kerosene

Non-crude Liquids already account for 15 percent total liquids supply in 2015

- Market impact assessed in terms of displacement of refinery production.
 - “Marker” refinery: Generic FCC refinery in Europe, with 15 Mt/year output of gasoline, gasoil, kerosene and LPG.
- Base Case: Non-crudes take 23 percent of total liquids supply in 2040.
 - Equivalent to 35 marker refineries.
- Low Case: Non-crudes take 20 percent of total liquids supply in 2040.
 - Equivalent to 17 marker refineries.
- High Case: Non-crudes take 32 percent of total liquids supply in 2040.
 - Equivalent to 71 marker refineries.
- Potential to discourage significant new refinery investment globally.

Environmental Impacts

Well-to-Wheel GHG Emissions Values

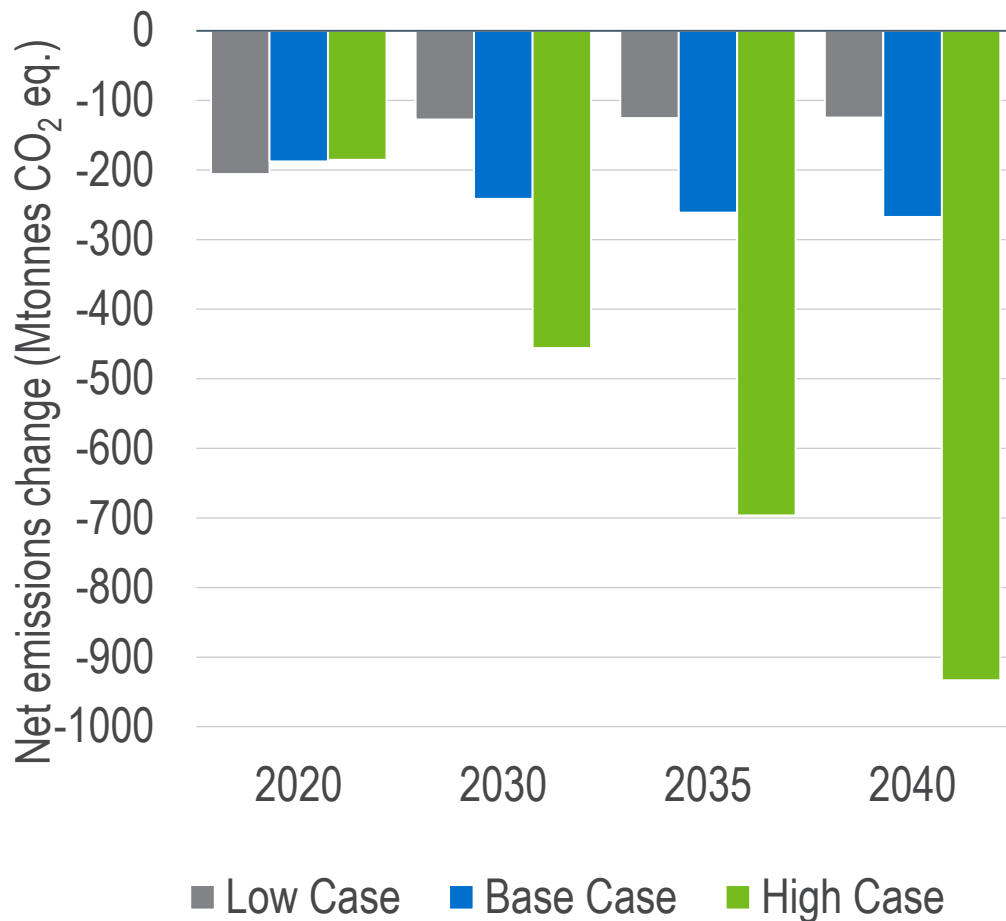


Strongly contrasting environmental impacts

- Biofuels only non-crude liquid offering significant GHG reduction.
- CTL has adverse GHG impact
- GTL relatively little change
- NGLs approach is alternative methodology:
 - Based on displacement of refinery LPG.
 - Benefit is approximately 6 gCO₂eq per MJ.

Net Emissions Change

Comparison of Net CO₂ eq. emissions across scenarios



Substantial reduction in net CO₂ eq. emissions only seen for High Case






- Base Case:
 - Biofuels major benefit contributor followed by NGLs
 - CTL negative impact grows

- Low Case:
 - Scaling back of biofuel production but still increase in CTL short term
 - Little impact from CTL longer term with limited investment.

- High Case:
 - Major benefit from Biofuels with higher second generation effect
 - CTL has more negative impact.
 - Reduction equivalent to 200 million cars off the road by 2040.

Key Conclusions

Conclusions (I) – Product Perspective

	Market	Scale (2015) (Million tons)	Scale (2040) Base Case (Million tons)	Environmental Impact
NGL	LPG	298	575	
Bioethanol	Gasoline	77	152	
Biodiesel	Gasoil	21	43	
CTL	Mixed	4	32	
GTL	Mixed	7	11	

Key conclusions (II)

Markets – EU-28

- Non-crude liquids production led by biofuels
- Small and mostly diminishing NGLs production
- No CTL or GTL activity planned or expected.

Markets - OPEC

- OPEC countries lead the way in NGLs production
- Significant market share in GTL

Crude-oil derived liquid fuel supply impact

- As NGLs largest non-crude liquid, major penetration of LPG market
- Crude oil-derived Gasoline and Diesel impacted significantly in High scenario by biofuels production



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