



Oil refineries in the age of energy transition

Navigating the future of energy

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Houston

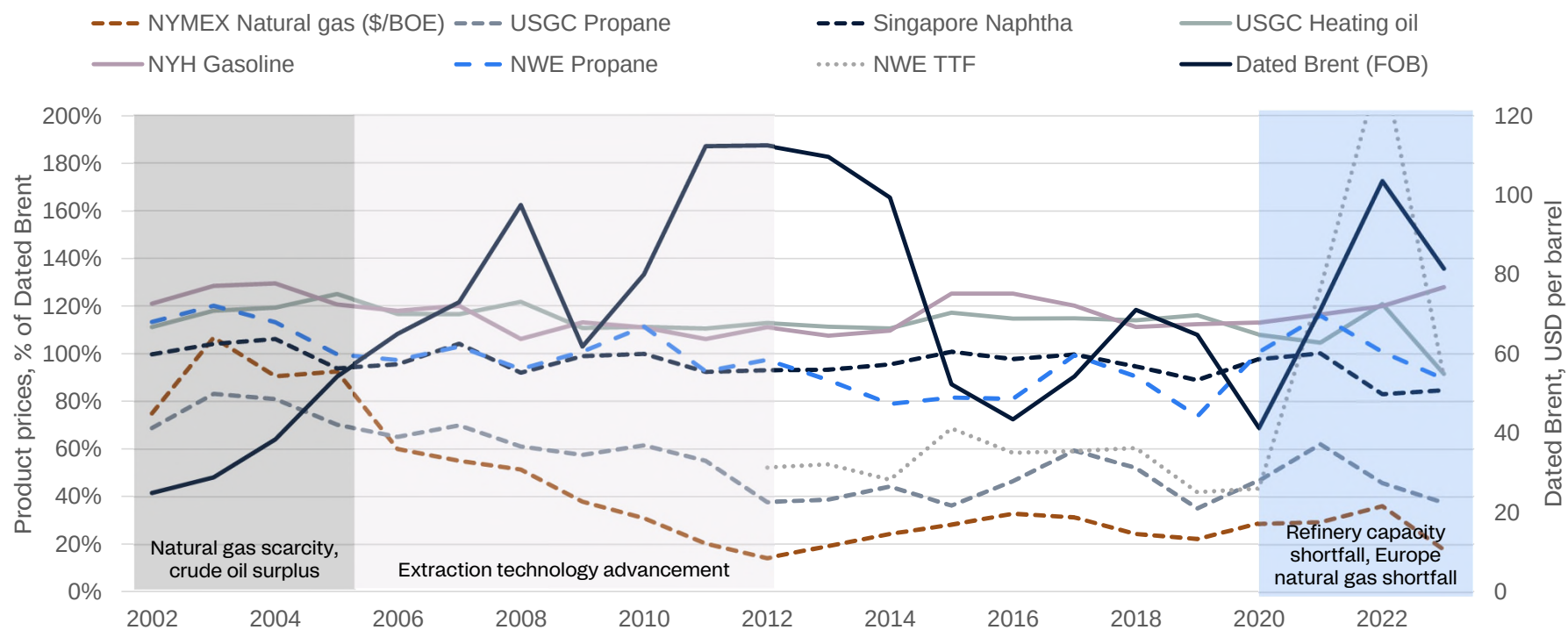
Key messages



- Petrochemical feedstock supply, currently a **byproduct** of petroleum extraction and refining, will become **bespoke** as energy transition reduces refinery throughput and petroleum extraction
- Global **refining is critical** for NGL supply, currently comprising 40% of the world's supply
- Refineries have several options to transition from primarily fuel production to petrochemical feedstock production with modest capital expenditure
- Refiners will be cautious about allocating significant capital to petrochemical feedstock production and will first need strong price signals – **supply shortages** are distinctly possible

NGL price history provides a preview of what's to come

Refined product pricing, % of Dated Brent

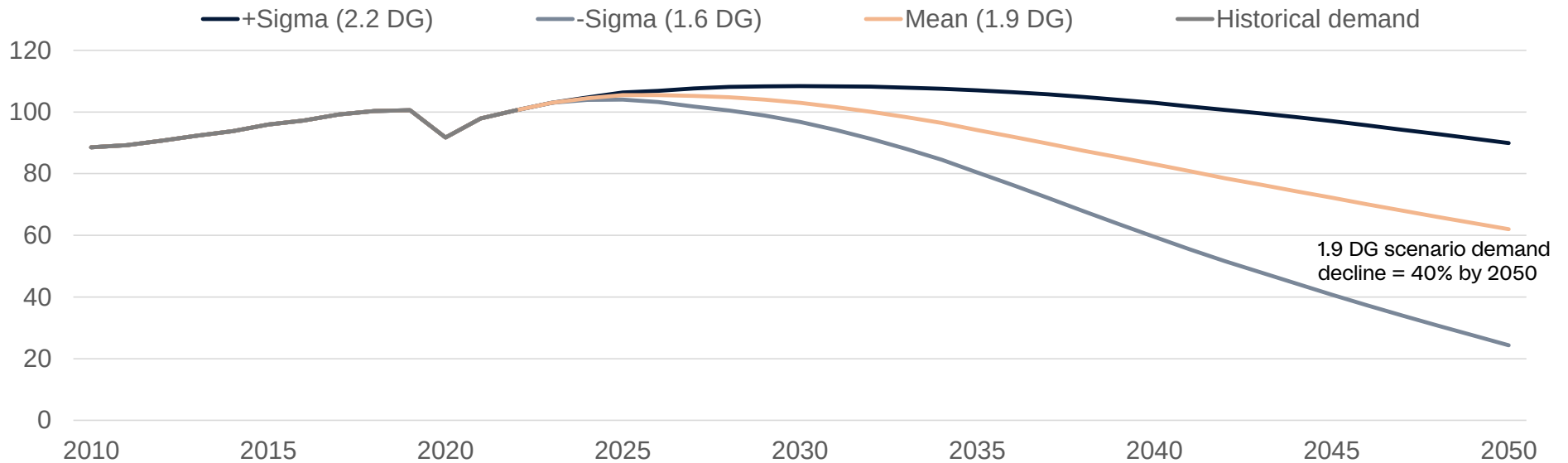


Source: Rystad Energy, Argus Media Group

Global oil demand, currently at 100 million bpd, is expected to decline and could drop between 10% and 80% by 2050 based on scenario assumptions

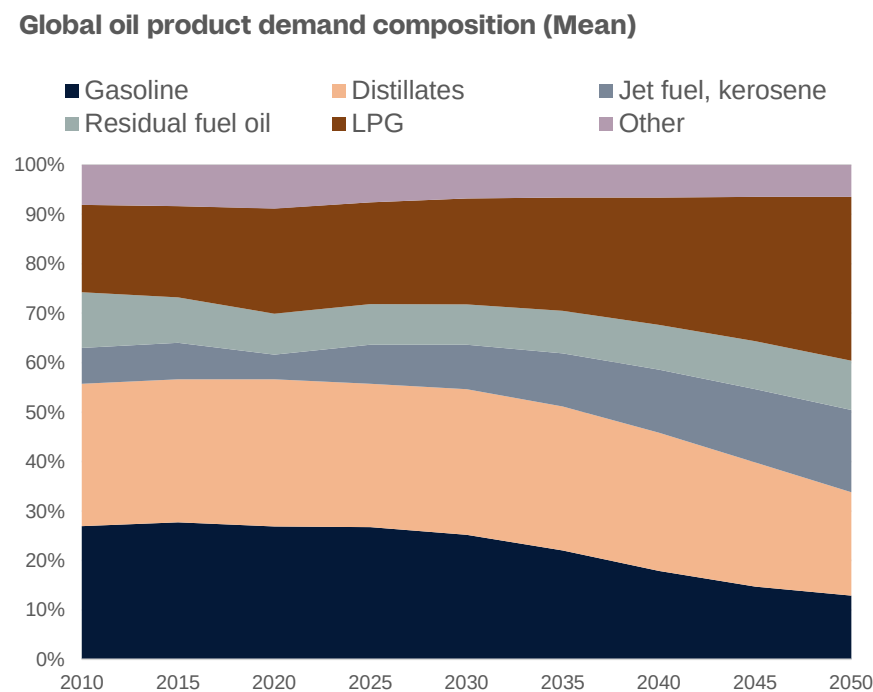
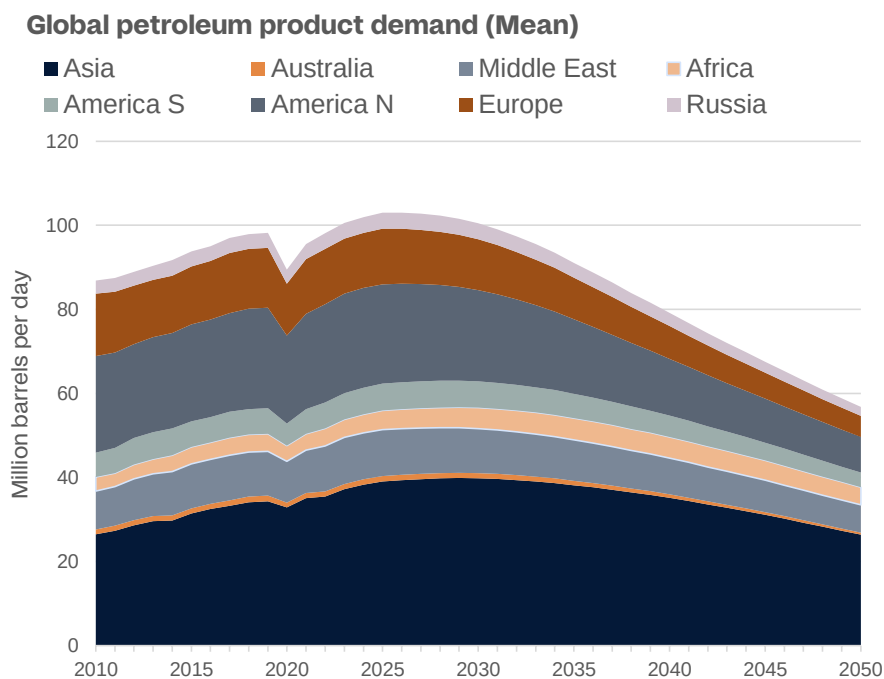
Global oil demand scenarios

Million barrels per day



Source: Rystad Energy OilMarket Cube

Electric vehicle adoption is the key risk to oil demand and will force refineries to drastically change their product mix to remain in business

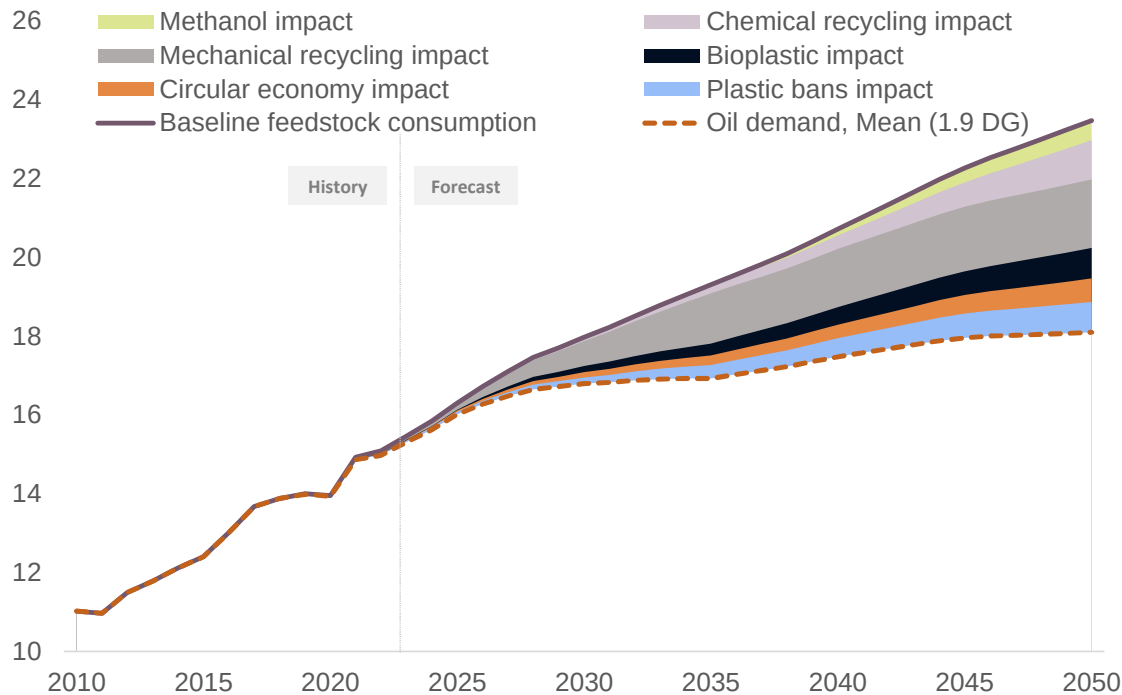


Source: Rystad Energy OilMarket Cube

Global plastics demand will almost double by 2050, supporting modest growth in petrochemical feedstock demand

Petrochemicals demand and energy transition impact

Million barrels per day



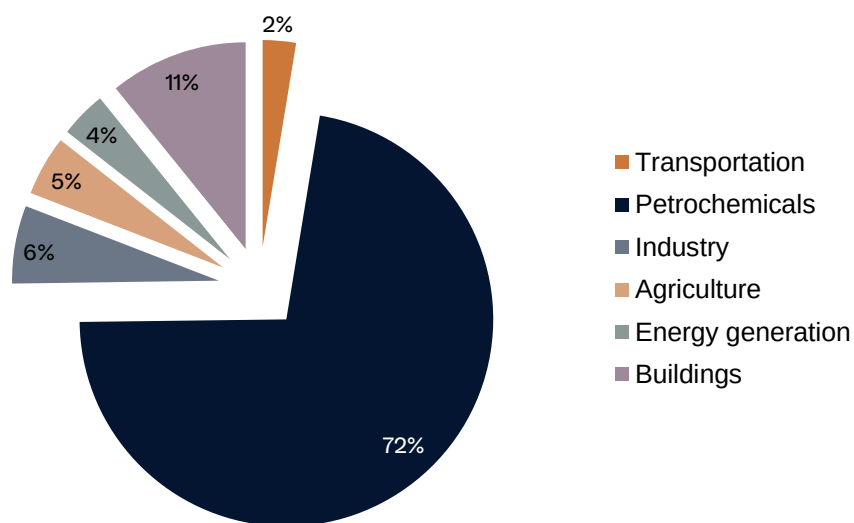
Source: Rystad Energy Oil Market Transition Solution

Key risk factors to this forecast:

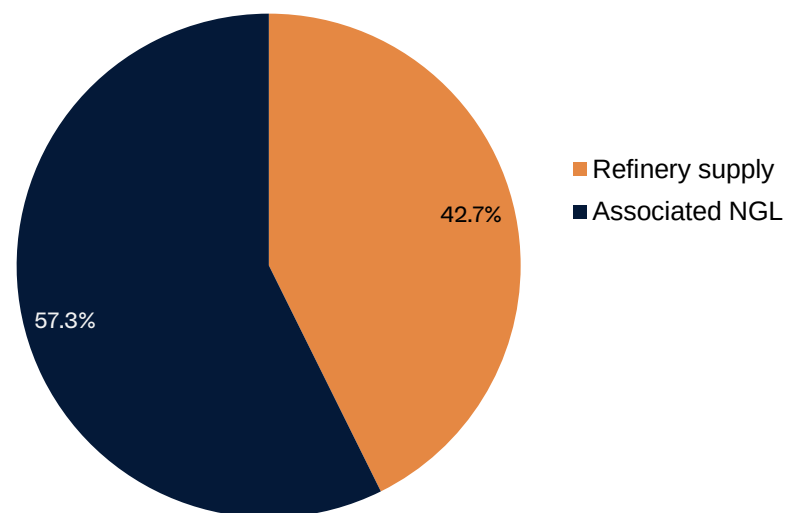
- ↓ Governmental action
- ↑ Chemical/mechanical recycling efficiency gains
- ↓ Disruptive technology, such as renewable methanol, increases hydrogen's role in plastics manufacture

Refineries are critical suppliers of feedstocks for high-value chemicals

World NGL demand share by sector, 2022



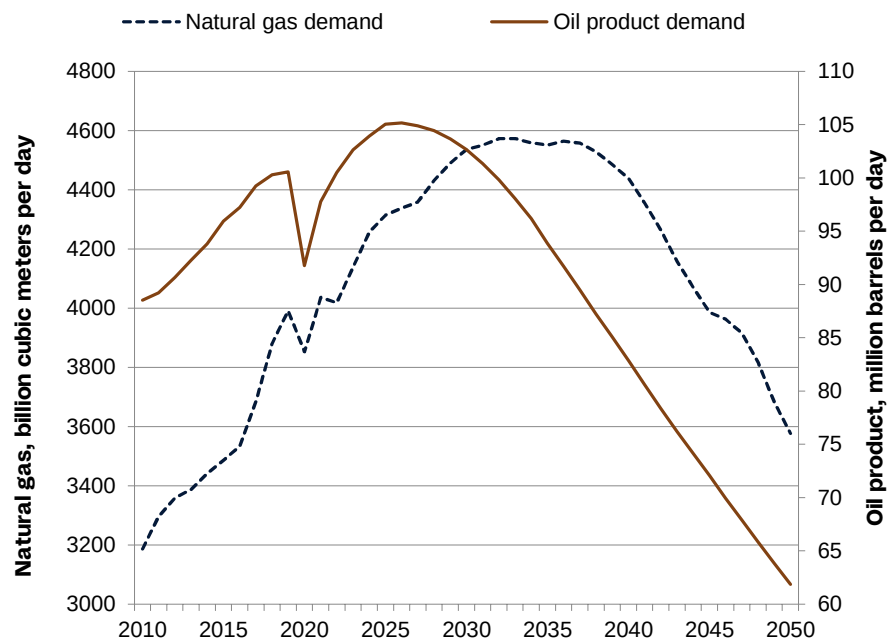
World NGL supply -2022



Source: Rystad Energy OilMarket Cube

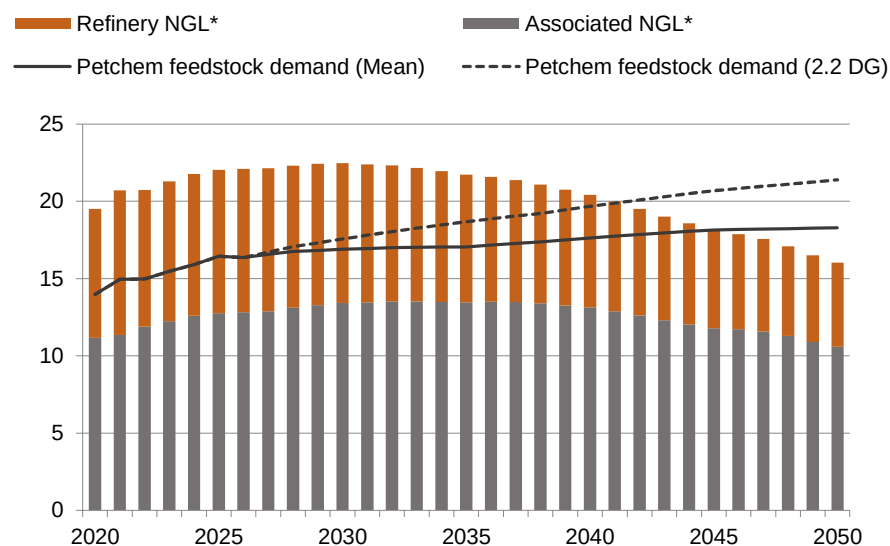
Refinery and associated NGL supply are challenged by energy transition – intense competition is likely

Global petroleum demand



Source: Rystad Energy

Global NGL balance, million bpd



* Assumes constant production ratio to global oil product demand and global natural gas demand

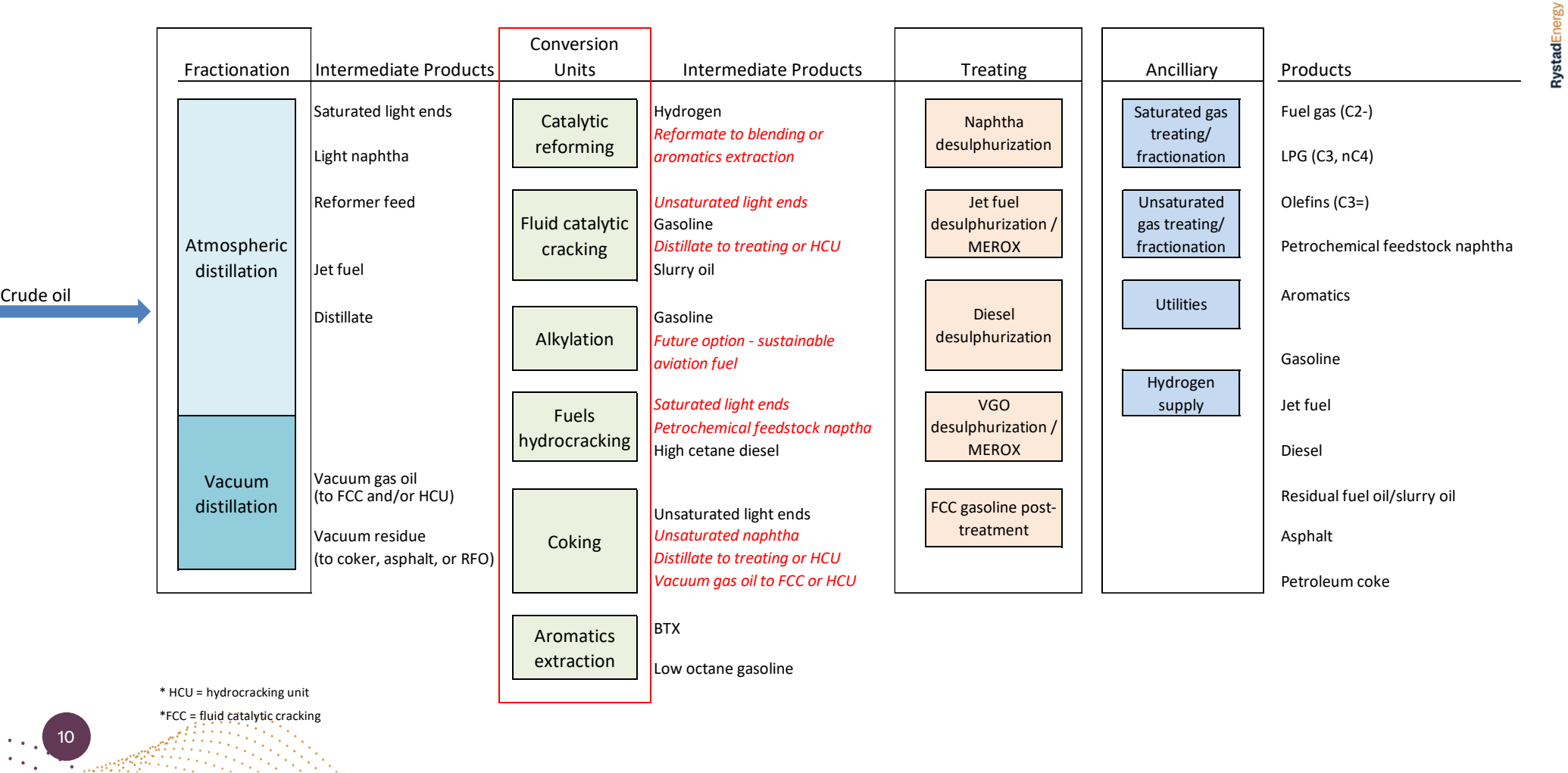
Source: Rystad, Energy OilMarket Cube

Refiners will need to plan for an increasingly critical role in supplying petrochemical feedstocks

- Declining fuels demand creates **opportunities** to increase byproduct yield to sustain refinery utilization
- **High conversion refineries** with excellent market access **are strong candidates** to compete against greenfield crude oil to chemicals facilities
- Refiners will need to develop **strategic plans around** global **NGL** balances to assess on-purpose petrochemical feedstock production



Refinery conversion units are key to increased petrochemical feedstock supply, byproduct gasoline is unavoidable



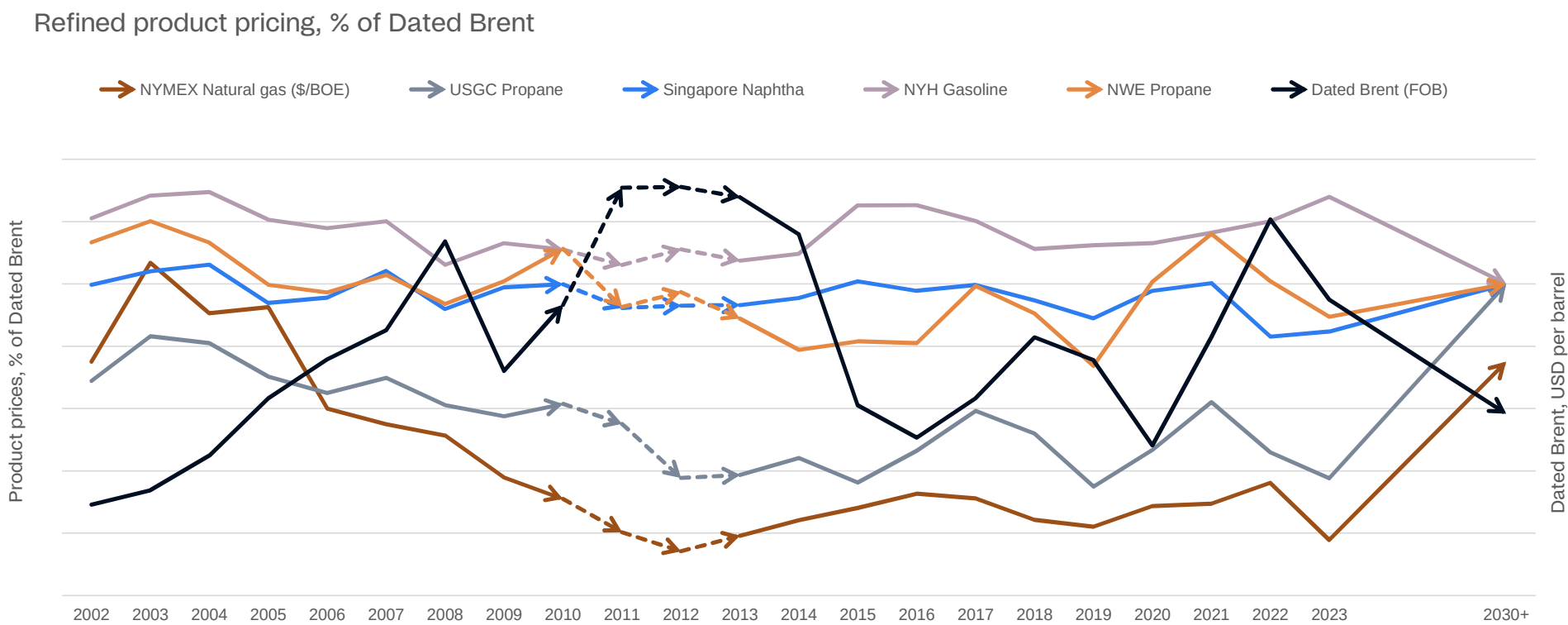
Simple first steps - North America refinery yields have room to move with minimal capital required

- Redirect light naphtha from gasoline blending to petrochemical feedstock markets
 - Gasoline prices must fall, and naphtha prices must increase relative to crude oil to liberate the almost 1 million bpd of naphtha cracker feedstock potentially available from US refineries
- Increase ZSM-5 use in fluid catalytic crackers (FCCs) to maximize olefin yield
 - US Gulf Coast refinery olefin yield is about 5 wt% on FCC feed but could move towards 10 wt% with modest capital and potentially >30 wt% with significant capital
 - Lower gasoline values and higher olefin values are required to support FCC operational changes, but tag-along gasoline production is unavoidable
- Optimize BTX production by adjusting feed cut points and using more naphthenic crude oils. Gasoline octane blending values affect refinery BTX yields
 - Lower octane blending values are required to support reformer operational changes – increasing ethanol content in gasoline drives octane blending values down

Complex next steps come with significant capital cost and challenging economics

- “Crude-oil-to-chemicals” starts with refining
 - Incremental investment at refineries to maximize carbon rejection and/or hydrogen addition will be site-specific and likely not widespread across the industry
 - Conversion of fuels FCCs to petrochemical FCCs
 - Idling FCCs and investing in brownfield vacuum gas oil hydrocracking
 - Atmospheric residue coking + additional distillate hydrocracking
 - Aromatics extraction units
 - Hydrogen supply becomes even more critical to convert crude oil to NGLs
 - The entire value proposition to refiners must be up-ended to justify significant capital expenditure
- Hydrogen-rich hydrocarbons that have historically been discounted to crude oil on an energy-parity basis will need to be valued differently in the future

Many factors influence the future – scenario planning is key



Source: Rystad Energy, Argus Media Group

Signposts

Crude oil and natural gas energy values

Gasoline and light naphtha prices/cracks

Electric vehicle uptake

Environmental policy announcements (federal, state/provincial, municipal)

Grid infrastructure announcements and permits

Agricultural commodity prices (renewable fuel competitiveness)

GHG emissions costs (social and mandated)

Technology breakthrough announcements





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