Long-Term Refinery Planning In An Uncertain Environment

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Gulf Downstream Association presents

TRANSFORM *Virtual Event*

The Evolving Future of Leadership and Project Management

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About this presentation…

- Developed solely for the purpose of supporting this conference
- Does not contain any material related to Saudi Aramco's market view or forward business plan
- Does not include any estimates or projections related to its operating assets
- Does not express the views or opinion of Saudi Aramco on any specific topic

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Discussion Topics

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- Market Uncertainty
- Environmental Topics
- Resid Conversion
- Petrochemicals
- Closing Remarks

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Technology Disruption In The Transportation Sector

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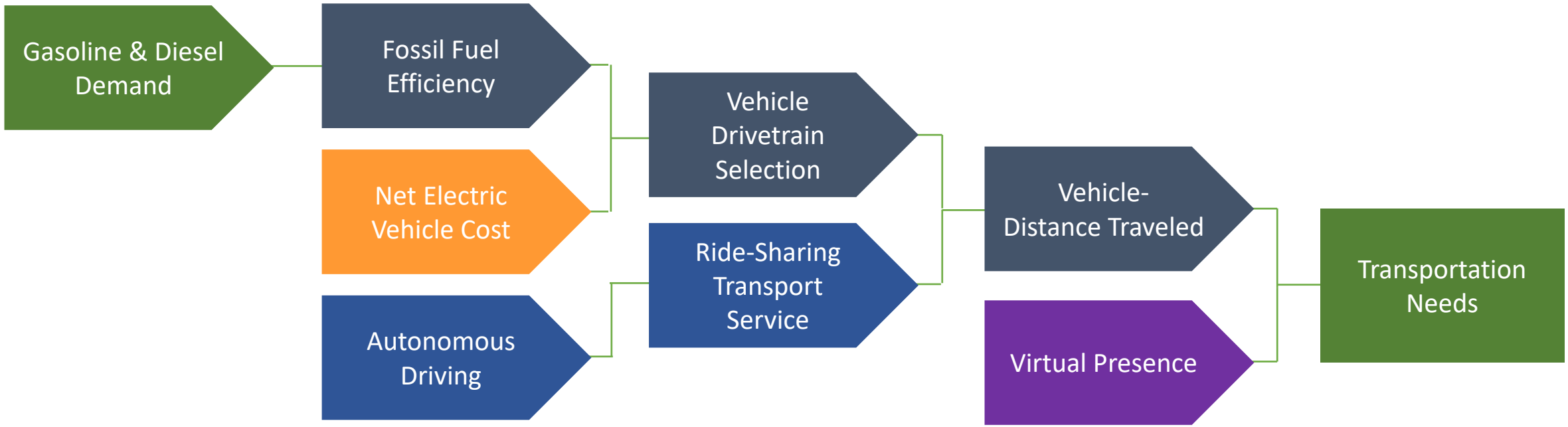
- Risk of accelerated demand decline driven by software, AI and regulatory developments
  - Traditional vehicle ownership model exposed to risk of erosion from new transport services
  - Technologies may provide support for aggressive climate change policies
- Fossil fuel displacement toughest in heavy-duty applications
  - Longer term, hydrogen may emerge as a key alternative in commercial and industrial sectors



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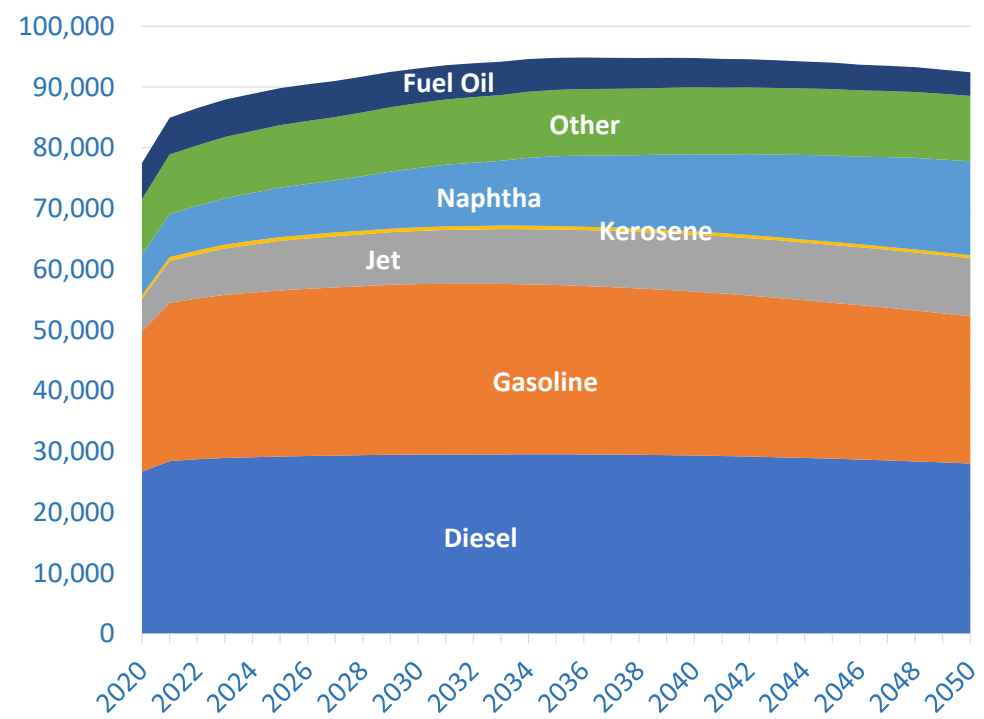
Long-Term Demand Scenarios

- IHSM forecast outlook for fuel demand remains relatively flat in post-2030 period.
- Major differences in market outlooks are usually attributed to:
  - Greenhouse gas regulations
  - Technology disruption in transportation sector
  - Global economic growth projections
- Well defined long-term view is critical to planning function

IHSMarkit Global Demand Forecast



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Refineries Play Central Role In Hydrocarbon Transition

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Production	Refining	End Use
• Crude Oil • Gas/NGL	• Product Slate • Configuration	• Fuel to CO_2 • Chemicals & Non-Fuels

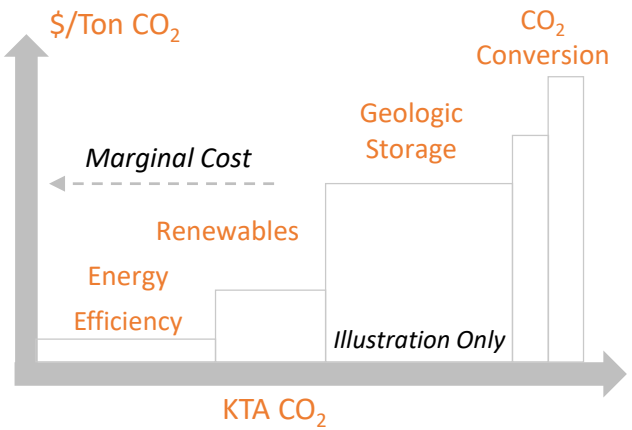
New Drivers

CO_2 Emission Reporting

- Baseline
- Scope 1 & 2 CO_2
  - Own facility (Scope 1)
  - Supplier facility (Scope 2)
- Product Slate (Scope 3) CO_2
  - End use emissions

CO_2 Abatement Cost Curve

- Applies to Scope 1 and 2 CO_2



Refinery Optimization Under CO_2

- Hydrogen Sourcing
  - Blue H2: Produced from hydrocarbons with carbon capture
  - Green H2: Produced from electrolysis and renewable power
- Product slate focus
  - Maximization of petrochemicals

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Potential Refinery De-Carbonization Approaches

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Energy Efficiency

- Energy Management Systems
  - Operational efficiency
- Refinery process technology
  - Power & heat recovery systems
  - Anti-fouling agents
  - Catalyst improvements
- Heat Integration
  - Pre-heat train integration
  - Low-grade heat improvement/export
- Optimization with other facilities
  - H2 and steam integration
  - Shared power generation
  - Process synergies (C2 recovery)

Low Carbon Energy Sources

- Avoidance of coke/liquid fuel
  - Fuel oil: 0.08 CO_2 T/MMBTU
  - Methane: 0.06 CO_2 T/MMBTU
- Power Generation
  - Combined cycle
- Renewable Power
  - Solar, Wind, Nuclear (green)
  - Blue power via gas with CCS
- Methods for Low Carbon Hydrogen
  - SMR with CCS
  - H_2 via petrochemicals

Carbon Capture & Sequestration

- Middle East region advantages from carbon sinks
  - Access to geologic CO_2 storage
  - Varying costs & capacity for CO_2 disposal
  - Large infrastructure programs
- Technologies for CO_2 conversion
  - Capture and storage via mineralization/carbonates
  - Emerging technologies require development
- Petcoke alternatives
  - 6-12% of crude oil carbon
  - Cavern or minefill storage (?)
  - Conversion

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Circular Refinery Concept For Waste Conversion

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Refineries provide important platform for elimination of waste hydrocarbons from environment

Waste Oil

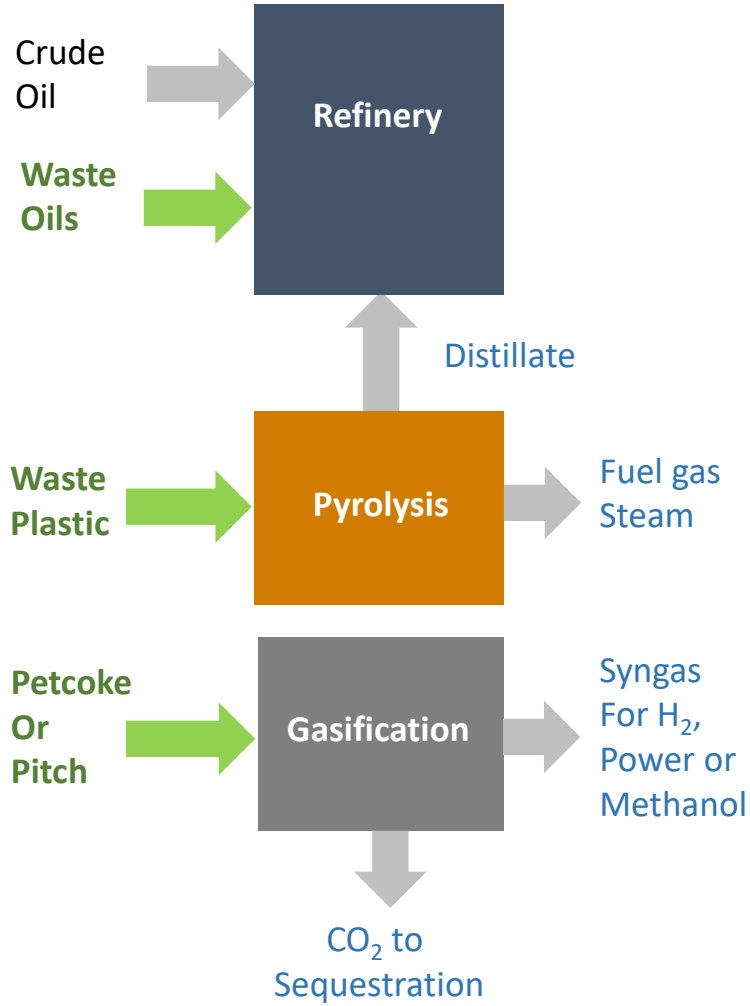
- Includes recycled lube oil and cooking oils
- Fed to refinery hydroprocessing units
- Eliminates contaminated waste and offsets crude oil

Waste Plastics

- Dedicated pyrolysis unit produces raw distillate
- By products may supplement refinery fuel balance
- Eliminates plastic landfill and offsets crude oil

Petcoke & Pitch

- Gasification unit produces utilities, H2 or methanol
- Process CO_2 sent to geologic sink
- Reduces product slate CO_2 emissions



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Resid Upgrading Technology Overview

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	Key Attributes	Investment Driver	Opportunities
Delayed Coking	• Relatively low capital & energy intensity • Yield loss to petcoke	• May be favored in Asia due to LNG costs and/or capital availability	• Petcoke is emerging focal point for CO_2 management at end use
Ebullating Bed	• Higher capital & energy intensity • Volumetric yield gain	• Large SR resid availability • Low fuel costs	• Strong integration cases with existing delayed coking and FCC units.
Resid Slurry	• Similar to ebullating bed • Highest conversion & yield • Emerging technology case	• Desire for higher feed flexibility & scale • Low fuel costs	• Cracked resid conversion • Maximize scale through resid transfers (Conversion Hub)
ARDS RFCC	• Many supporting process blocks • Direct propylene production • Strong gasoline focus	• Large crude expansion for petrochemical production	• Strong petrochemical integration cases • Additional focus on C2 and C4 optimization

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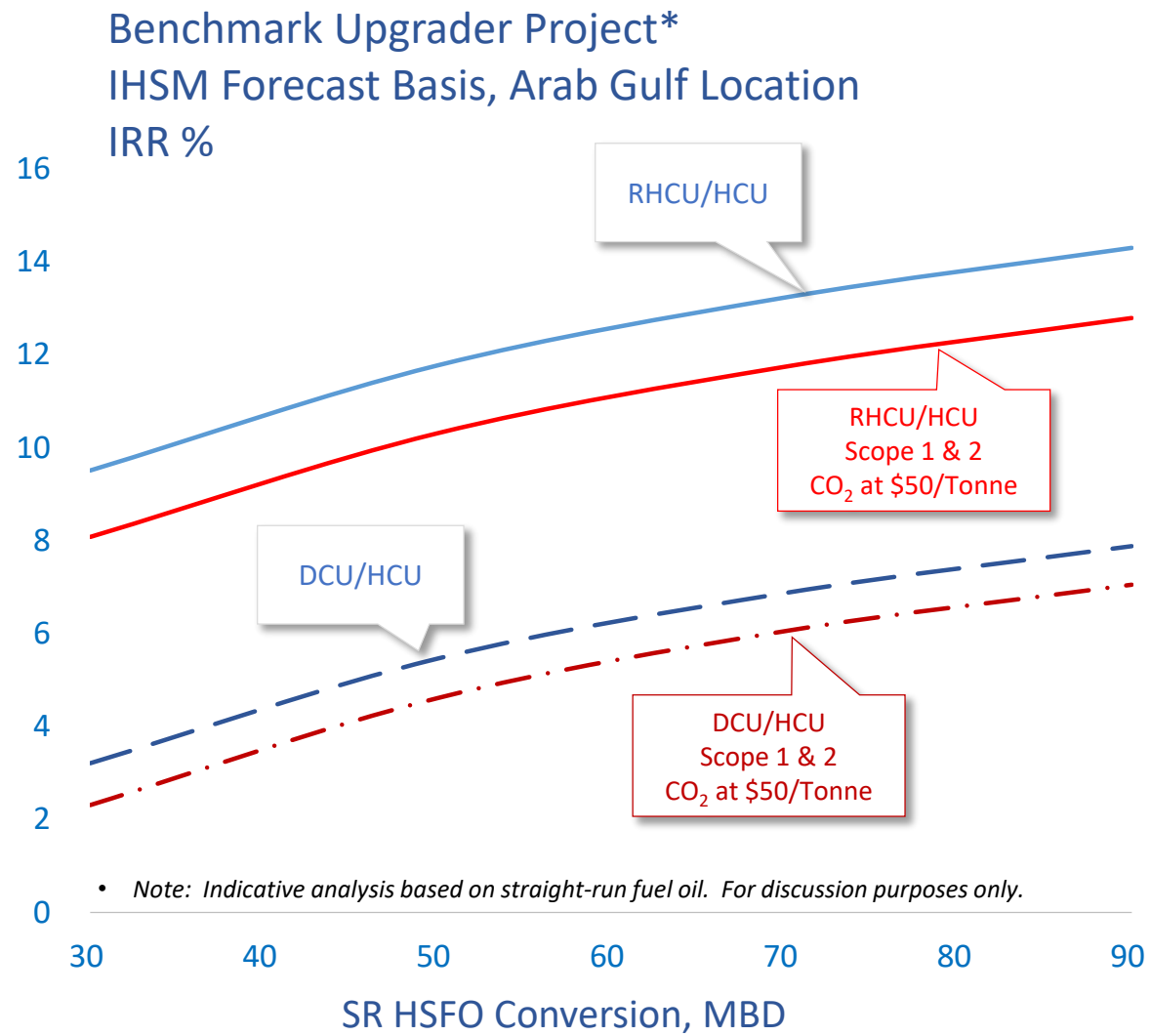
Fuel Oil Conversion



- Fuel oil upgrading economics dependent on scale
- Key development challenge includes capital and feedstock availability
- Where applicable, visbreaker closures may be needed to support straight-run feedstock supply
- RHCU cases slightly advantaged in Mid-East vs Far East locations (excl. China)
  - Lower fuel and CCS cost

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Growth In Petrochemicals Demand Expected To Remain Robust

IHSMarkit Demand Forecast Basis

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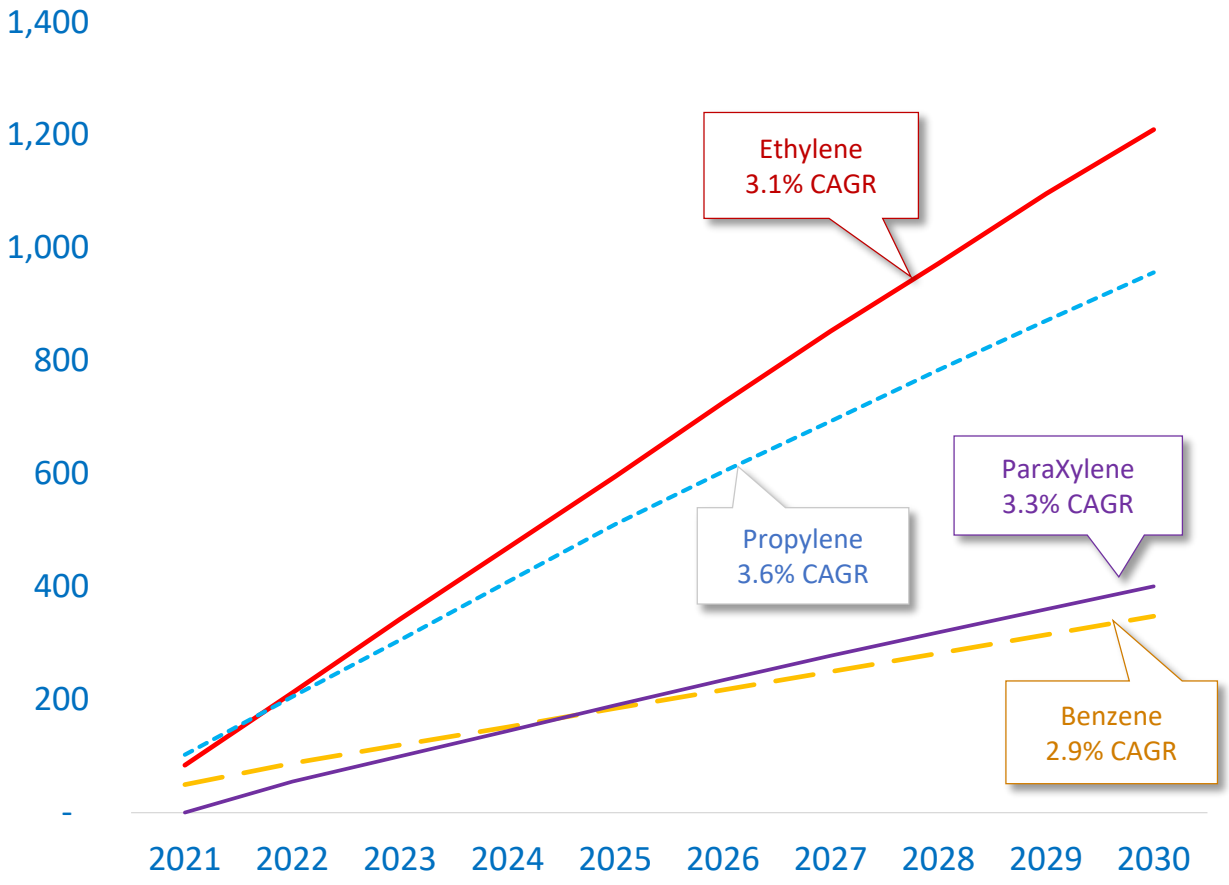
Cumulative Demand Growth
MBD Crude Equivalents*



** Note: Crude oil equivalents based on carbon content.*

Global Demand Growth*, KTA	2021-25 Average	2026-30 Average
Ethylene	5,050	4,780
Propylene	4,040	3,490
ParaXylene	1,780	1,560
Benzene	1,240	1,200
Total	12,110	11,020

** Note: Based on IHSMarkit Forecast*

- Ethane feed is expected to account for approx. 20% of ethylene supply growth
- Growth in total liquids placed into chemicals expected to be near 2.5 MMBD of crude oil equivalents by 2030
- After COVID recovery, overall fuel demand growth projected to be 0-1% CAGR

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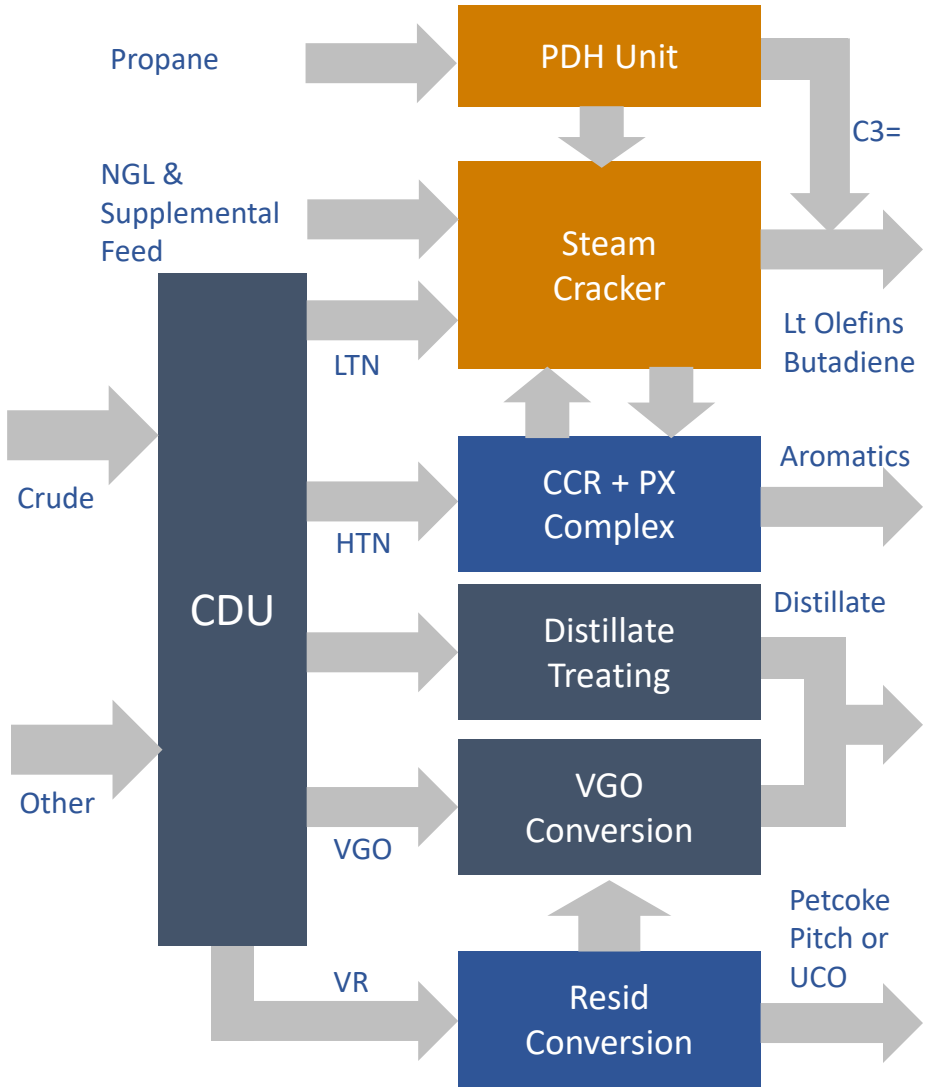
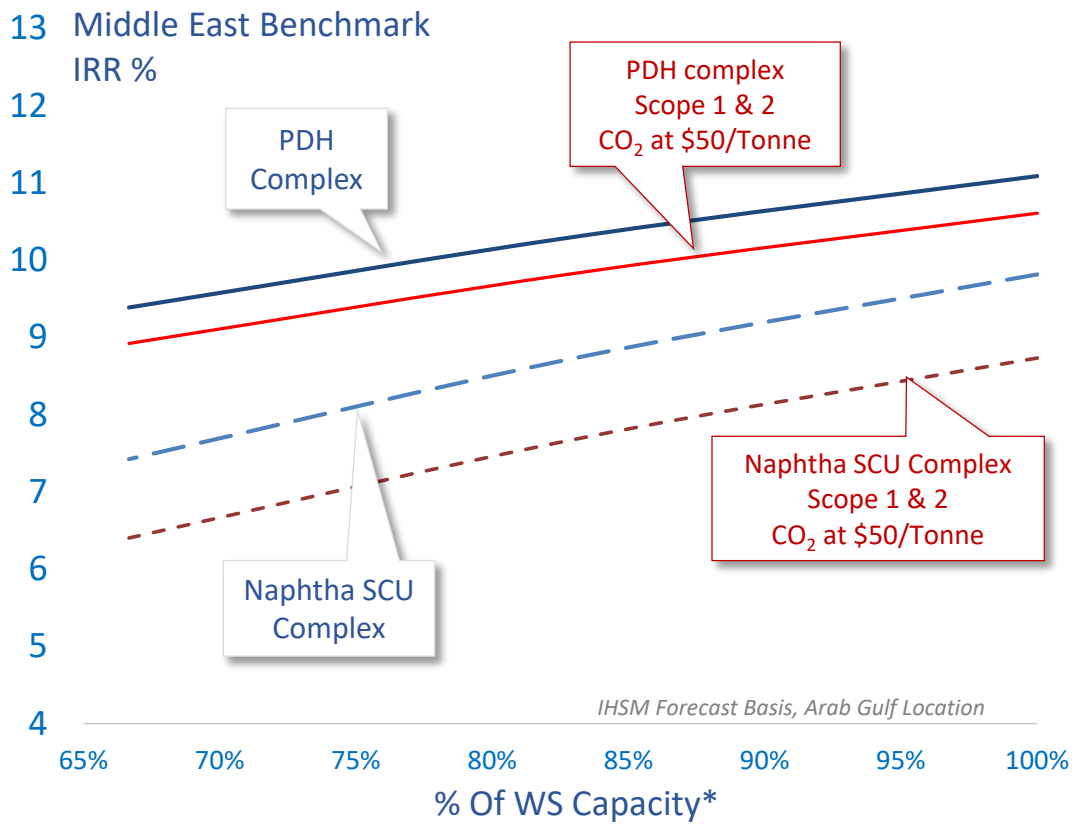
Deep Refinery – Petrochemical Integration



- Investments for increased petrochemicals production are expected to continue
- By-product hydrogen may be considered as a fuel to offset CO_2 concerns



- *Note: 1500 KTA ethylene for WS steam cracker. 750 KTA propylene for WS PDH unit. Indicative analysis based on single train derivative units.*

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Overview Of Key Petrochemical Integration Options

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	Key Attributes	Capital Cost /Annual Ton Feed	Scope 1 & 2 Impact Ton CO_2 / Ton Feed	End Use Impact Ton CO_2 / Ton Feed
Steam Cracking + Derivatives	• Versatile feed set for ethylene • Challenged by feed & capital availability • H_2 yield: 3-5 MSCFD / ton feed • 73-78% wt yield of petrochemicals	Base	+ 0.6	- 2.4
Propane De-hydro + Polypropylene	• Propane to propylene derivative only • Lower complexity & overall scale • H_2 yield: 15 MSCFD / ton feed • 83% wt yield of petrochemicals	+35%	+ 0.4	- 2.6
ParaXylene* Complex	• Fit within gasoline balance • Lower complexity • Net CCR H_2 yield: 14-16 MSCFD / ton feed • 25-30% wt yield of BNZ and PX	-70%	+ 0.3	- 1.6
ParaXylene* + Trans-alkylation Complex	• Shift away from gasoline • Requires alternative for lt. naphtha • Net CCR H_2 yield: 14-16 MSCFD / ton feed • 65% wt yield of petrochemicals	-60%	+ 0.4	- 2.2

- *Note: Indicative estimates. Capital is based on approximate Total Installed Cost at worldscale capacity level. PX complex includes CCR and NHT units.*

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Closing Remarks

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- **Future Focus on Improved Environmental Performance**
  - New emphasis on energy efficiency may be driven by CO_2 control
- **New Approaches to Resid Upgrading**
  - Middle East region advantages may stem from low cost fuel and CCS infrastructure
  - New strategies to increase upgrader scale may come to the forefront
- **Petrochemical Integration Likely To Expand**
  - Continued demand growth and placement of hydrocarbons
  - Hydrogen by-product may play expanded role in low carbon economy
- **Despite challenges, the 'right' refineries are more important than ever**
  - Performs critical role in integrated value chain for committed industry players

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Thank You!

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