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Sustainable Catalytic Cracking Technology Useful for the Energy Transition

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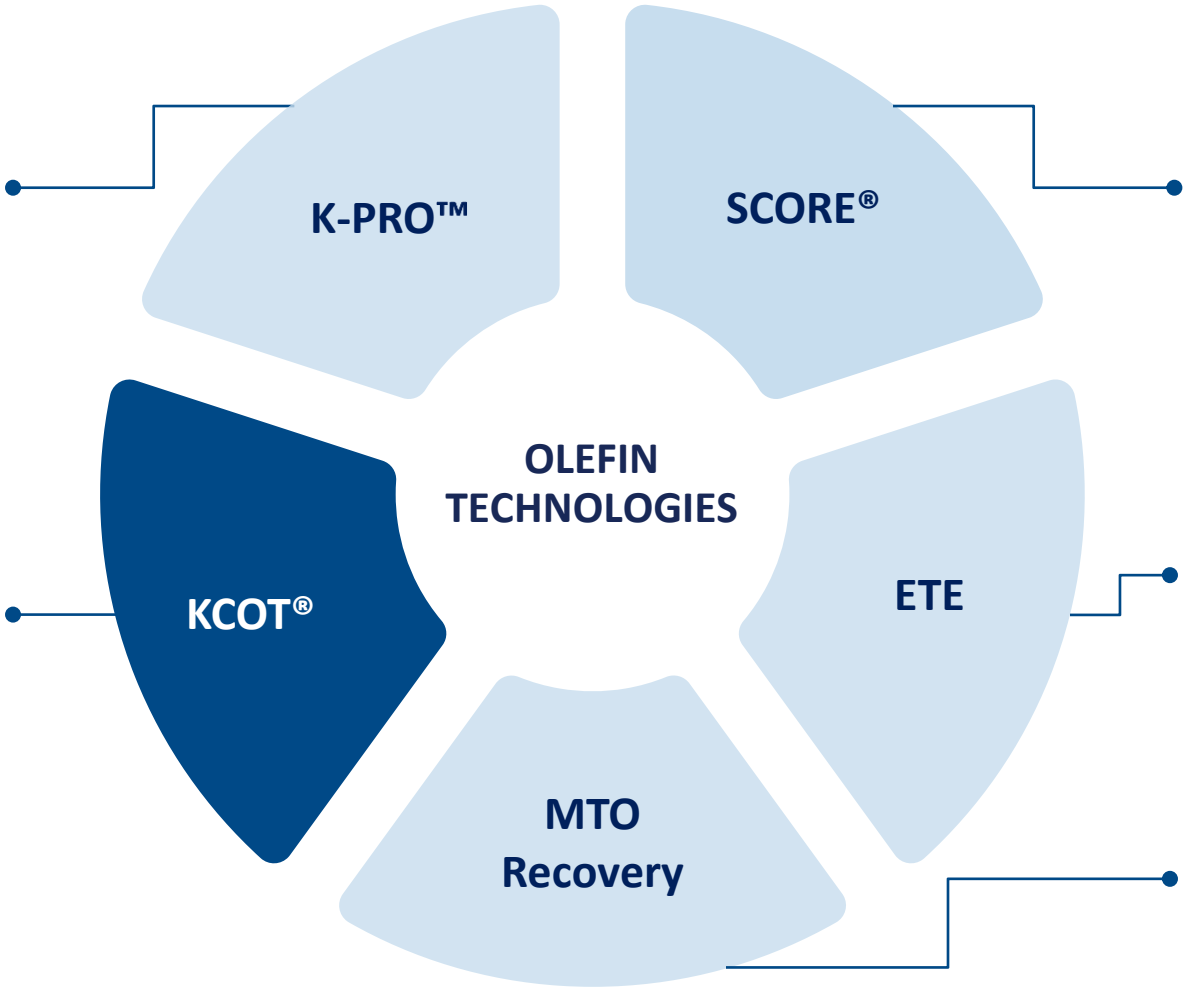
Delivering Solutions, Changing the World.℠

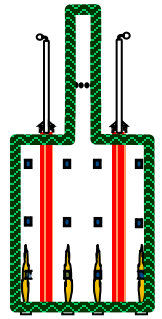
KBR Olefins Technologies

- Propane to Propylene (PDH)
- FCC based — easier to operate and more reliable
- Environmentally friendly catalyst
- Lower CAPEX and OPEX

- Catalytic Olefins Process
- C4-C10 Olefinic, Paraffinic or Mixed Feeds
- Higher Propylene-to-Ethylene Production
- Energy Transition Technology—upgrading Low Value Gasoline Streams



- Steam cracking process
- Furnace flexibility — Ethane to gas oil
- Highest yield in industry
- Lower CAPEX
- Lowest CO_2 footprint



- Ethanol to Ethylene Technology
- Newest addition to Olefins Portfolio
- Production of 'bio-ethylene'

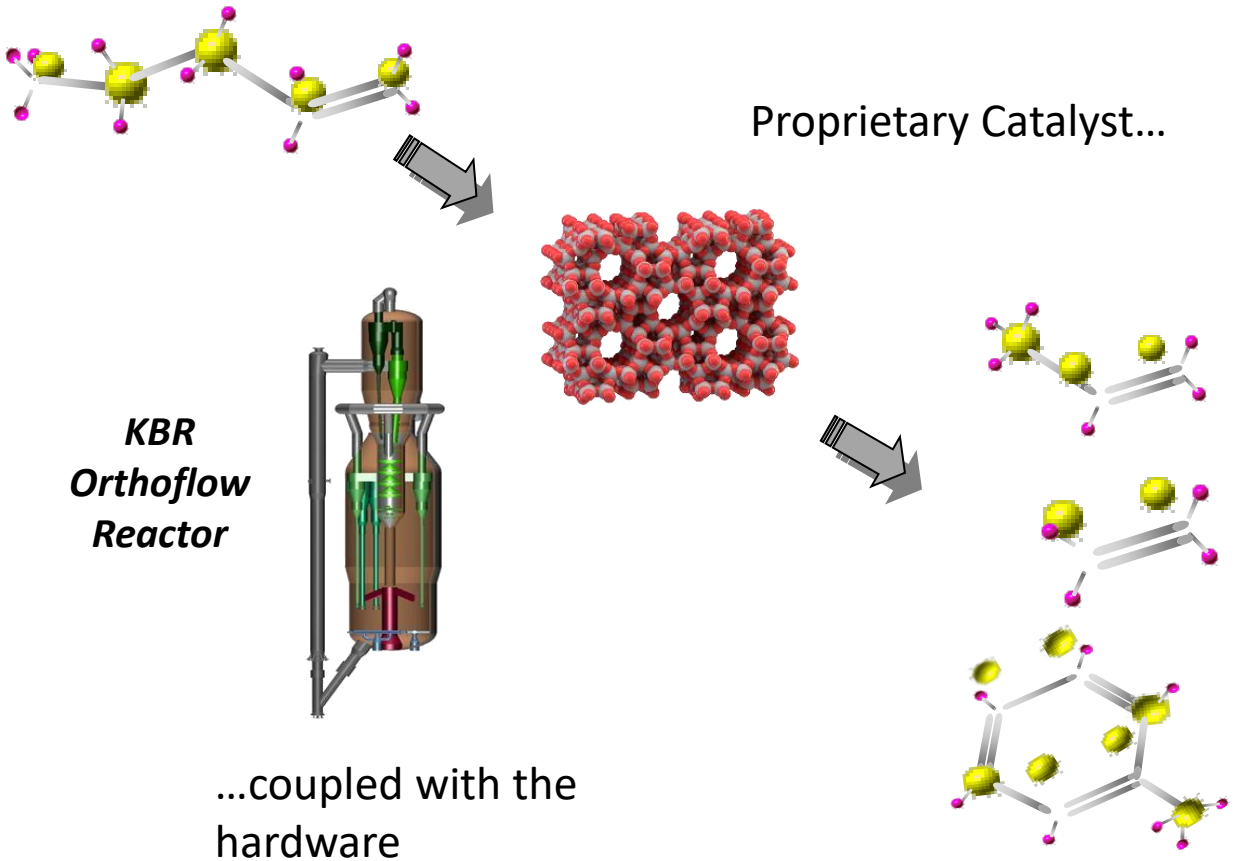
- Optimized recovery section Design
- Low CAPEX and OPEX

KCOT is a Key to Address Energy Transition, or to Improve Cracker Economics

- Liquid crackers, looking to upgrade C4, C5, non-aromatic gasoline — recycle to K-COT
- Integrated refinery / petrochemical complexes looking to improve overall flexibility and value upgrade
- Refiners with excess naphtha (straight run or cracked) — upgrade to olefins, especially C3
- Upgrade by-products from FT / CTL / MTO / MTP facilities

K-COT TECHNOLOGY OVERVIEW

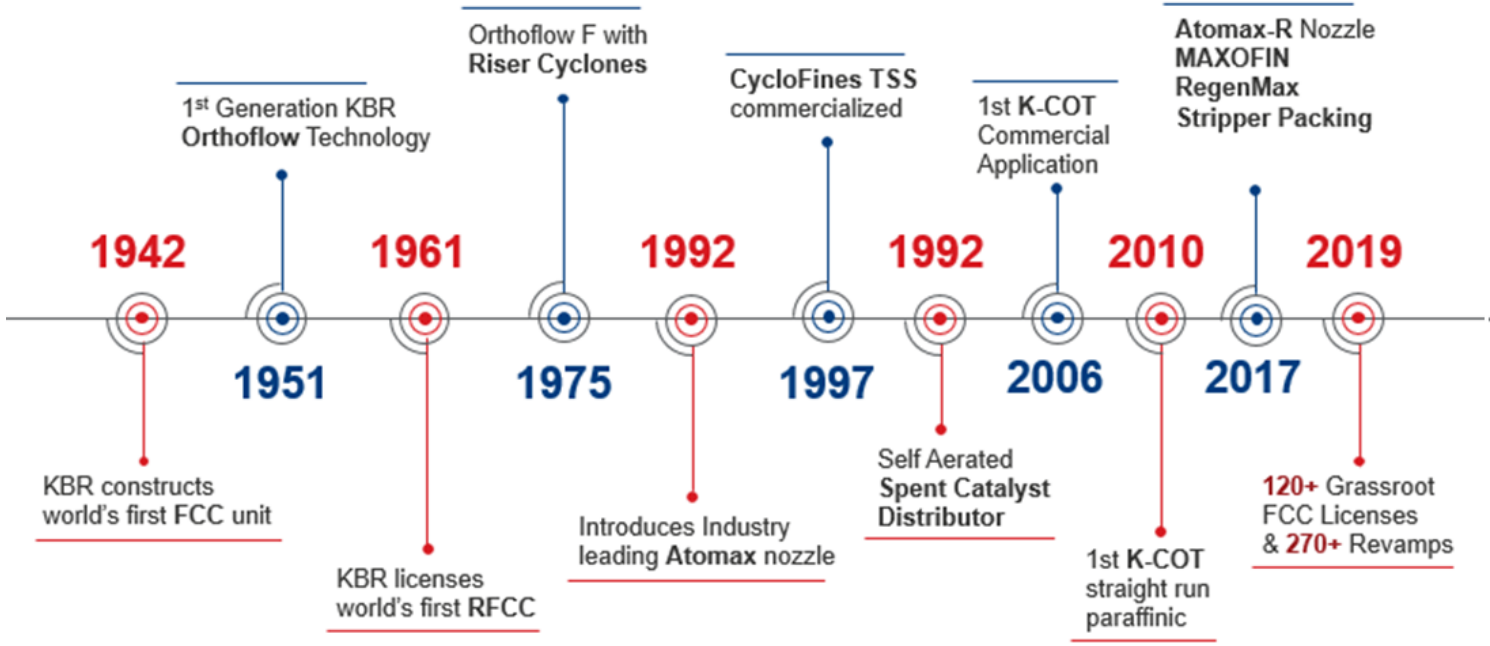
KCOT: KBR Catalytic Olefins Technology



- KBR Proprietary Modified ZSM-5 catalyst
- KBR's well-proven Orthoflow™ fast fluidized reactor with 70-year experience
- KBR's over 100 olefins plant design experience

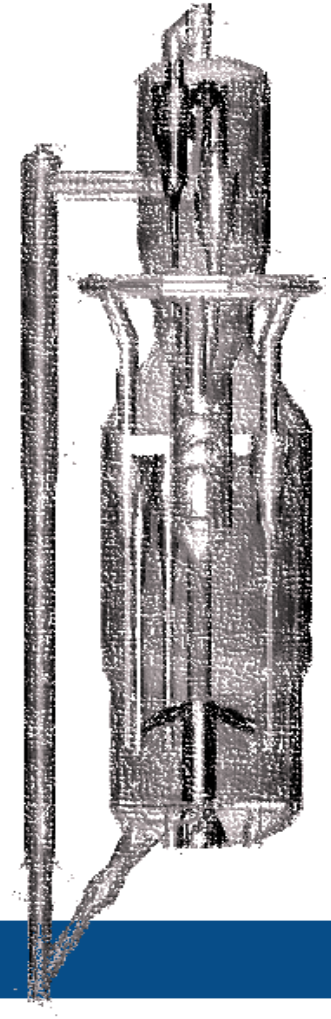
Based on Commercially Proven Technology

KCOT Technology is based on KBR's extended experience in FCC reactor design



Proven Innovation!

KBR has been on the forefront of **FCC technology** from the beginning and has consistently delivered leading-edge high performing technology to its customers **for over 70 years**.



KBR KCOT is based on over 70 years of innovation and improvements

The KCOT Advantage

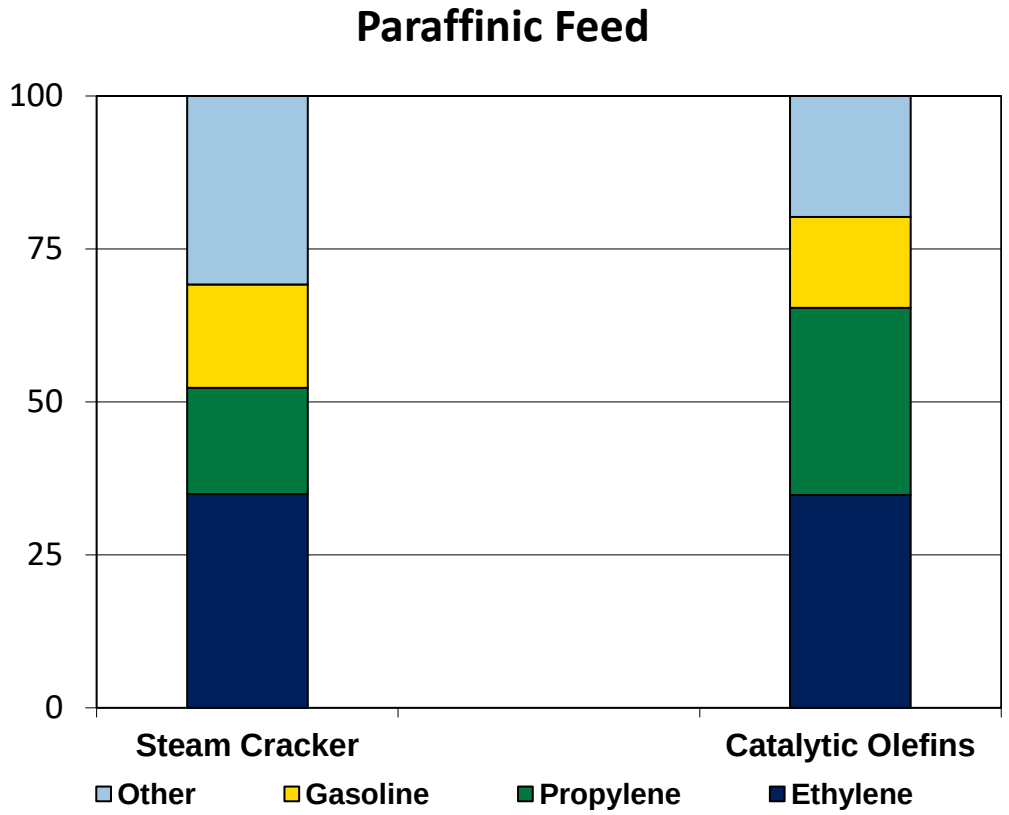
Feed Flexibility + **High Value Product** = **KCOT**

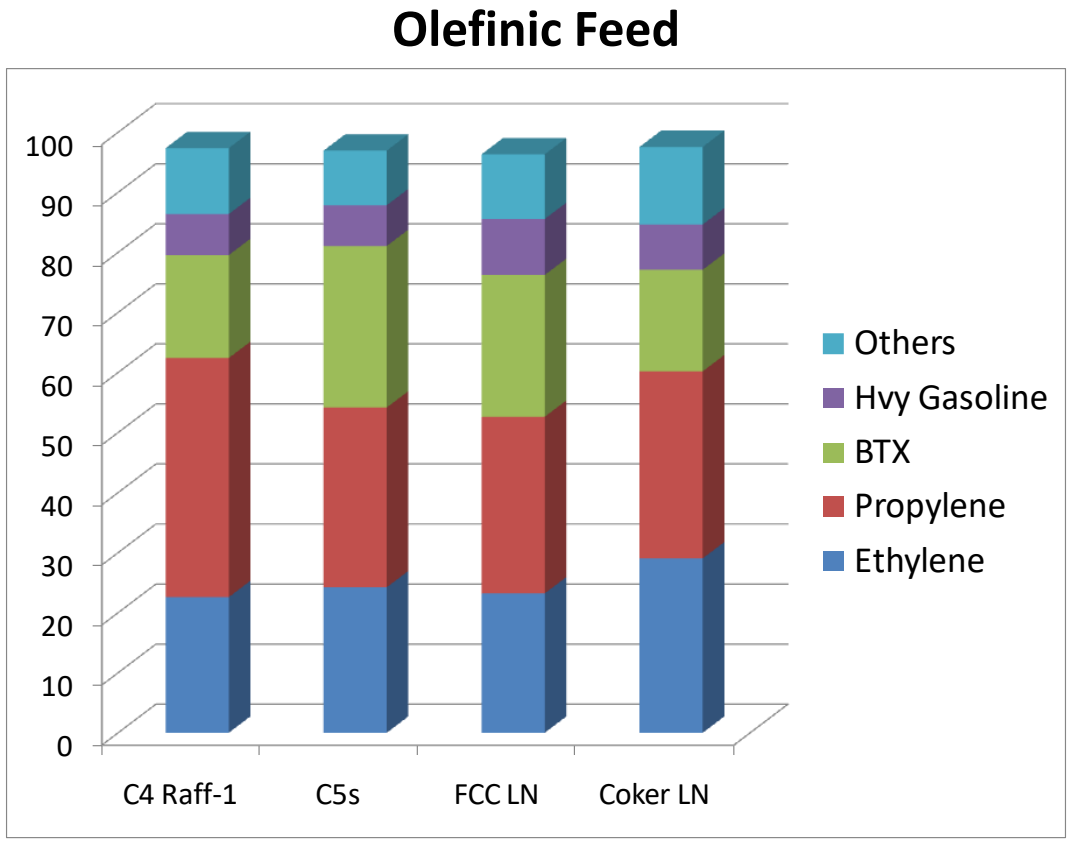
Ultimate Feed Flexibility	High Value Product
Ability to process C4-C10 olefinic, paraffinic or mixed streams, such as: ▪ Mixed C4s from refineries and conventional steam crackers ▪ Amylenes, TAME raffinate and mixed C5s ▪ Cracked naphtha from FCCs, steam crackers, cokers and visbreakers ▪ Oxygenates, such as methanol and ethanol ▪ Other low-value olefinic streams No need for feed pre-treatment	▪ Ability to convert low-value streams directly into high-value petrochemical feedstock ▪ High propylene-to-ethylene ratio compared to steam cracking (**~1:1** for straight run feed, **~2:1** for olefin-rich feed) ▪ High aromatics product credit

KCOT Feedstock Flexibility

Feed Type	KCOT *P/E Ratio Up to 2.5* *Olefins yield up to 60%*	SCORE *P/E Ratio Up to 0.65* *Olefins yield up to 60%*
Ethane		√
Propane		√
Butane	√	√
Straight Run Naphtha	√	√
Steam Cracking olefinic C4's, C5's	√	√ (hydrogenated)
Aromatics Raffinates (C6-C8NA)	√	
Refinery C4's	√	
FCC/Coker Naphtha	√	
Visbreaker Naphtha	√	
Methanol, Ethanol	√	
Other Oxygenates	√	

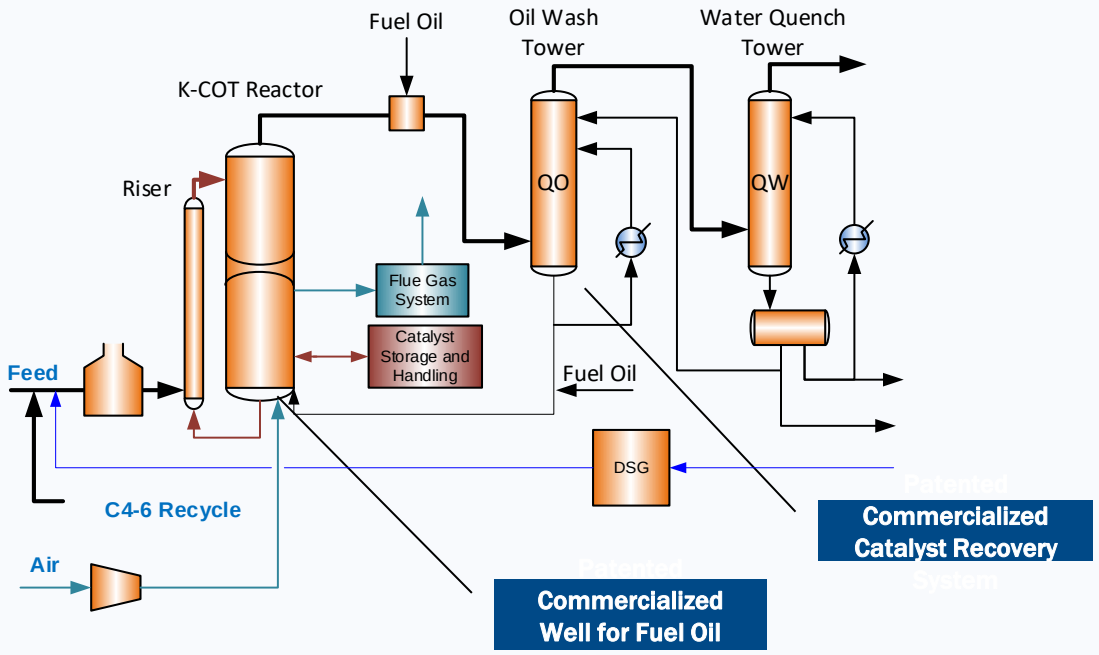
Typical Ultimate Yields Performance



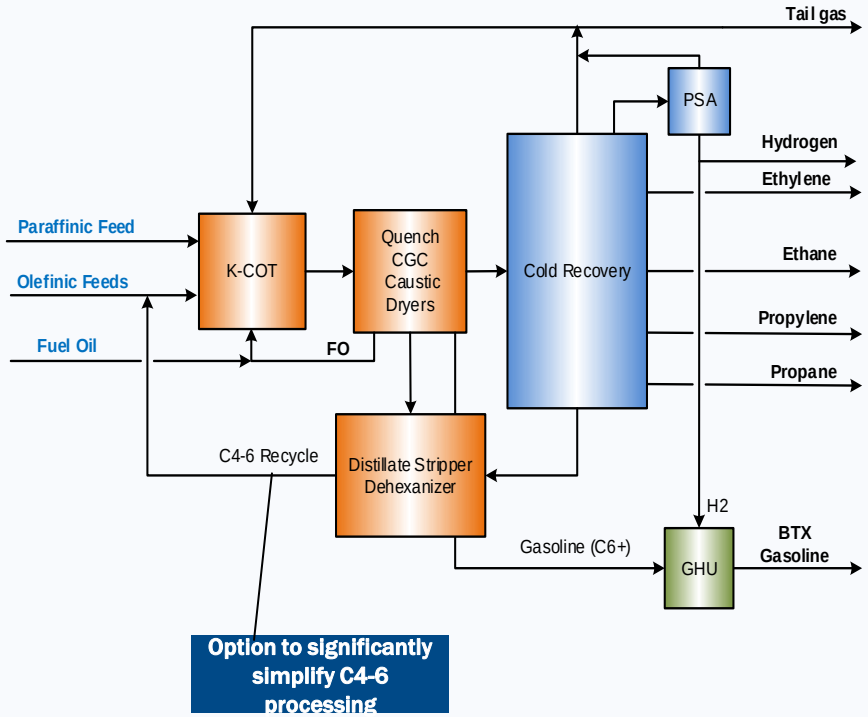


P/E Ratio = 1.0 ~2.0

K-COT - Reaction & Separation Section



- Based on KBR's 70 years experience in FCC reactor
- Large single reactor capacity up to 1200KTA of ethylene and propylene



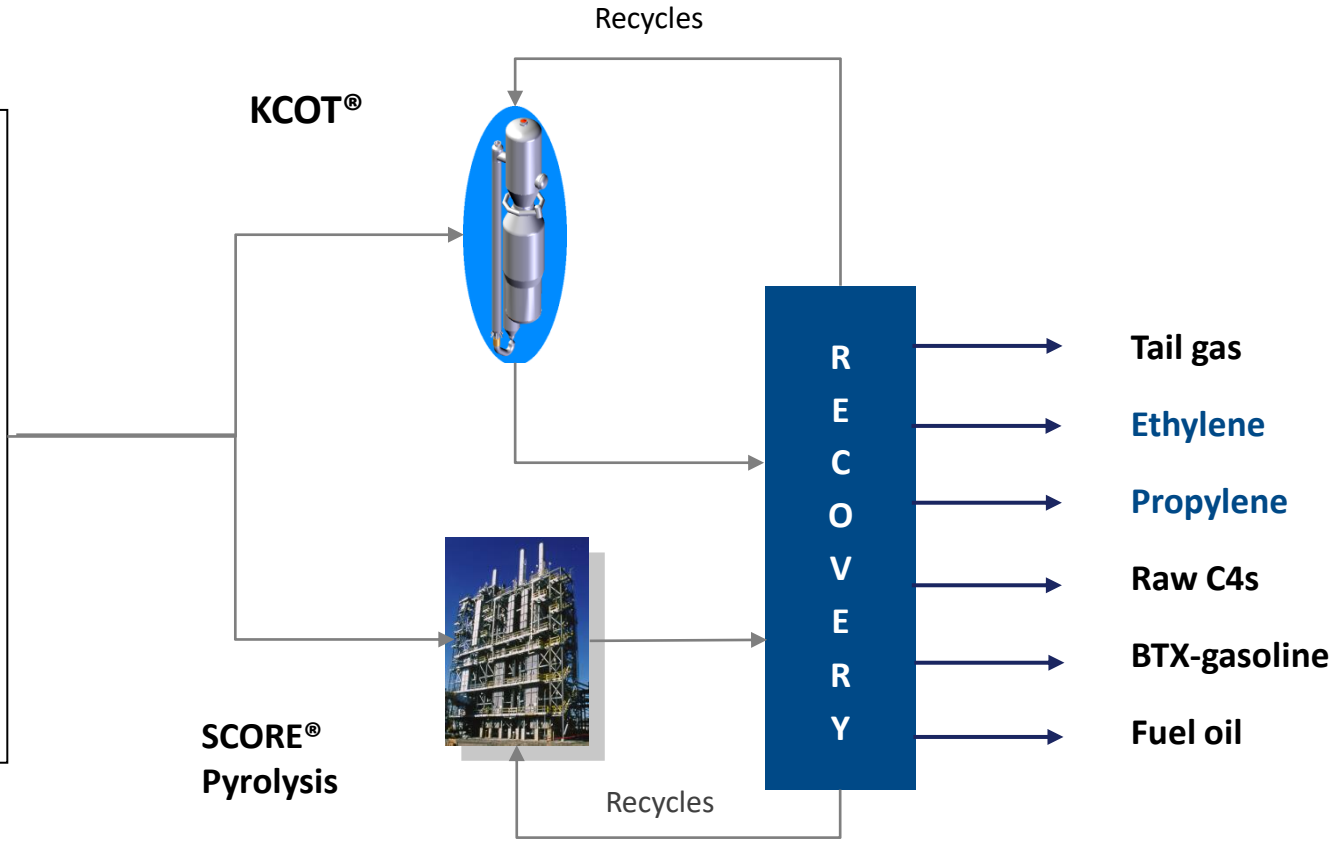
- Based on KBR's over 100 olefins plant design experience with additional features
  - Removal of trace impurities such as oxygen in addition to acetylene
  - Unique Quench Oil column design with catalyst recycle scheme
  - Simplified C4 – C6NA recycle circuit
- Low CAPEX

IMPROVE CRACKER ECONOMICS

KBR Combined Olefins Process

Fresh Feeds:

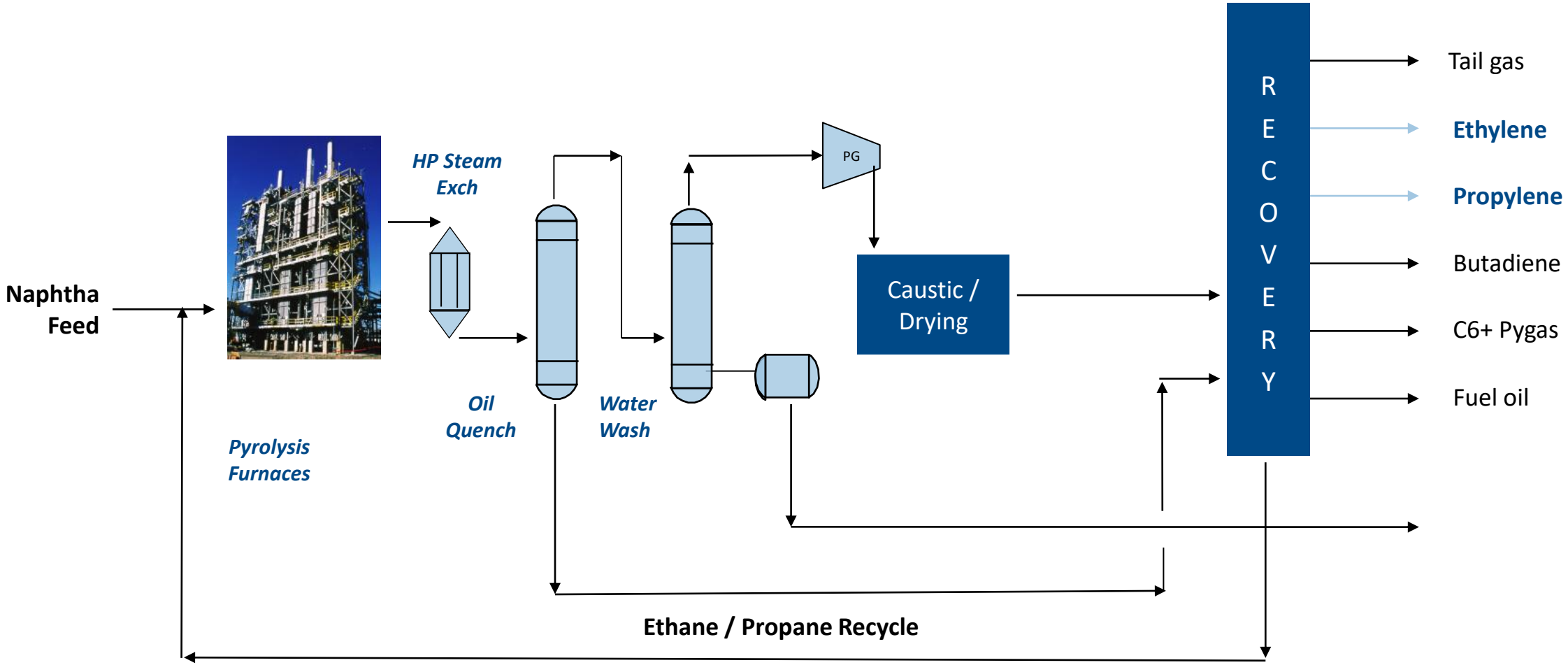
- Ethane
- LPG
- Mixed Refinery C4s
- Straight-run Naphtha
- Cracked Naphtha (FCC, Coker, Visbreaker)
- Raffinate from Aromatics Complex
- Gasoil/HGO/VGO/Unconverted Oil
- By-products from FT/MTO/MTP facilities
- Oxygenates
- Other low value olefinic streams



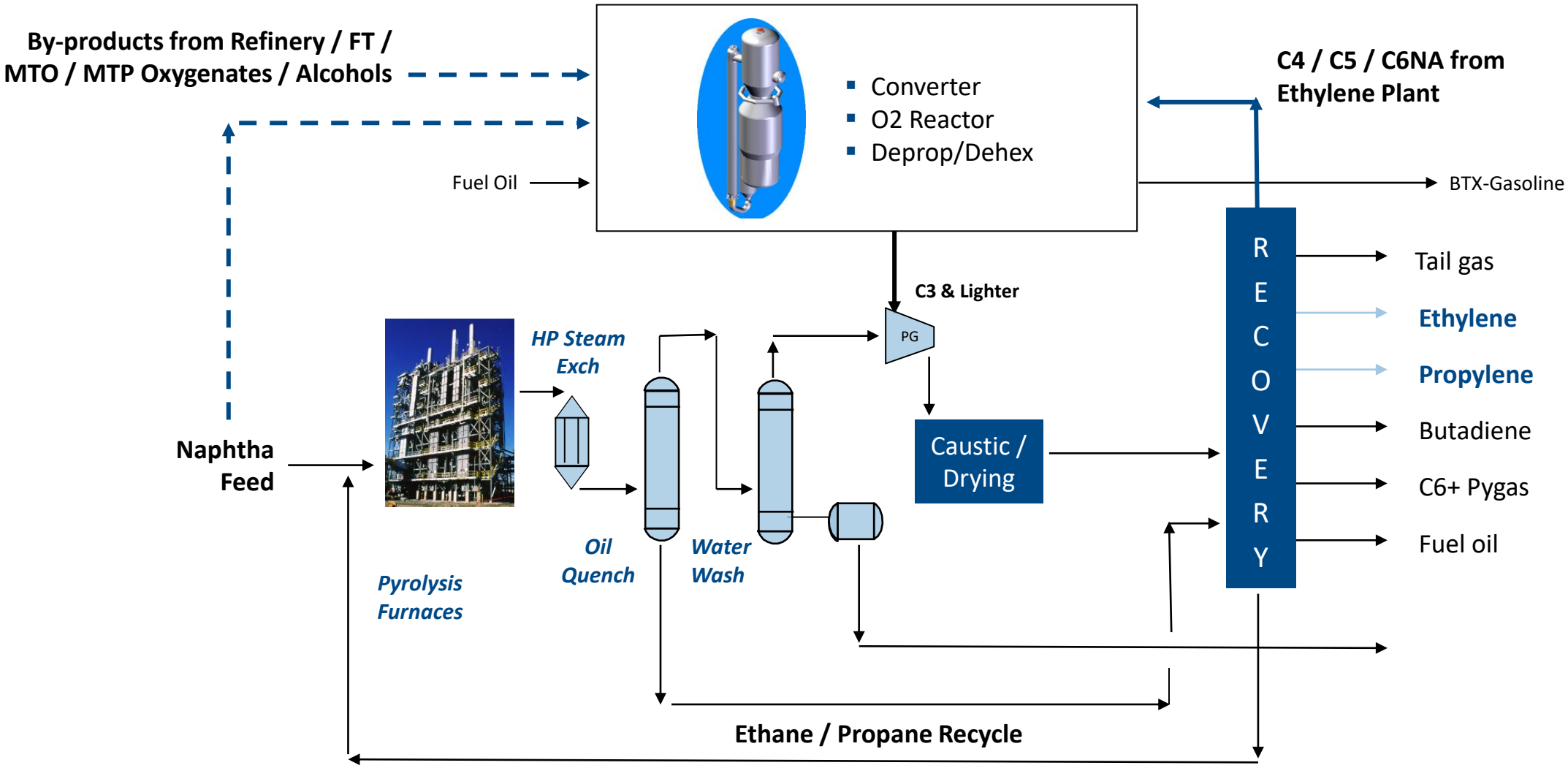
- Highest flexibility on feed side
- Highest flexibility on product side

→ **Optimization based on market conditions**

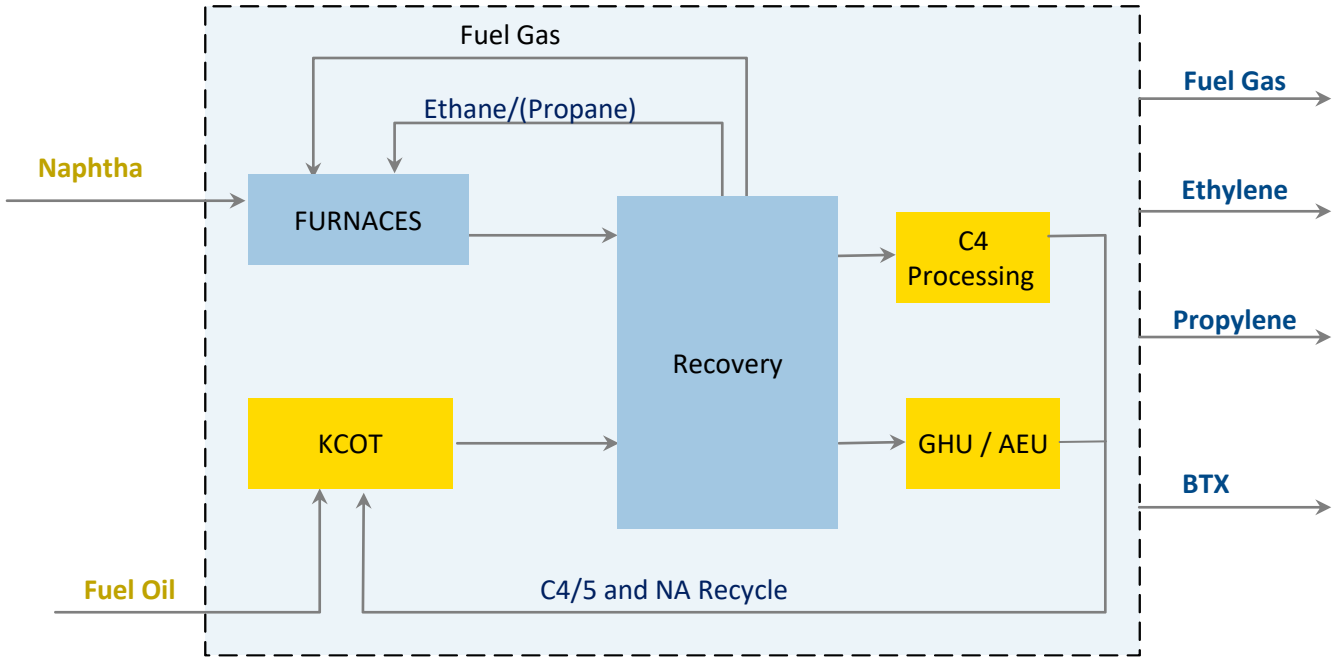
Typical Steam Cracker

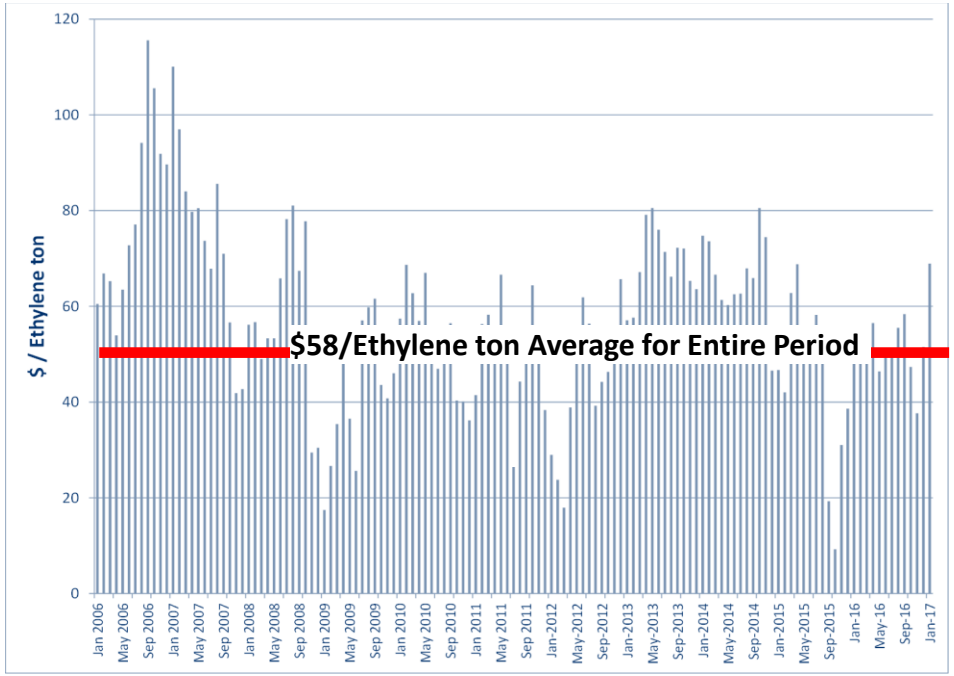


K-COT / Recycle Converter Configuration



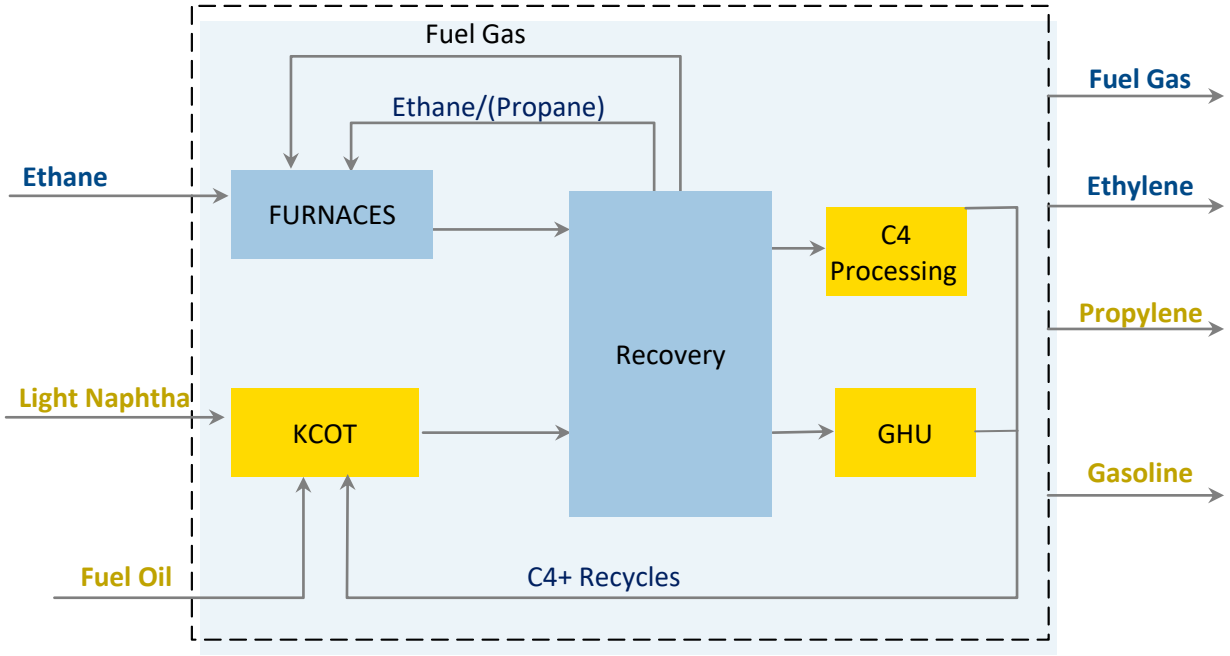
KCOT Integration with Liquid Cracker- Relative Economic Impact





Simple Payout <3 Years

KCOT Integration with Gas Cracker - Relative Economic Impact



Capex and annual E+P production*	Relative ISBL TIC	Relative Ethylene	Relative E+P	Relative TIC/ton E+P
Standalone 1800 KTA Ethane Cracker	**100**	**100**	**100**	**100**
Integrated KCOT + C2 Cracker	103	84	119	87
Int. KCOT + C2 Cracker + C4 Proc.	118	81	131	91

*USGC basis

Integrated KCOT solution advantage

- Better capital efficiency
- Increased high-value propylene production (especially with C4 processing)
- Solution flexible to include broader feed mix to adapt to changing market conditions

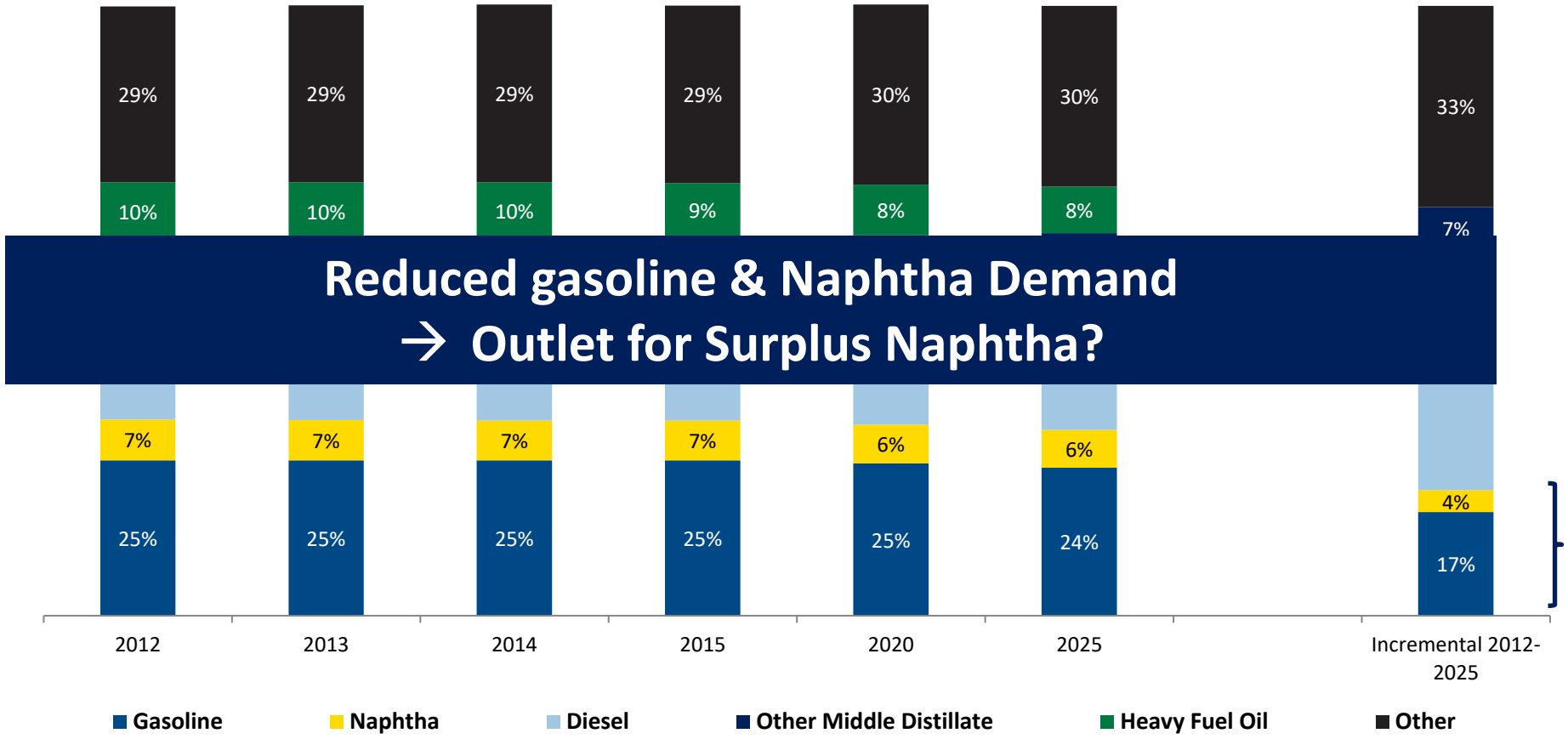
ENERGY TRANSITION

Market Trends

- Global gasoline demand expected to peak in approximately ten years, then decline thereafter
  - More electric and hybrid vehicles
  - Fleet to become more fuel efficient
  - More renewables (such as ethanol) in fuel pool
- Propylene and ethylene demand continues to grow, and yearly growth is expected to exceed GDP over the coming years
- Many refiners are considering technology to convert fuels into petrochemicals

Lotte Titan KCOT Converter

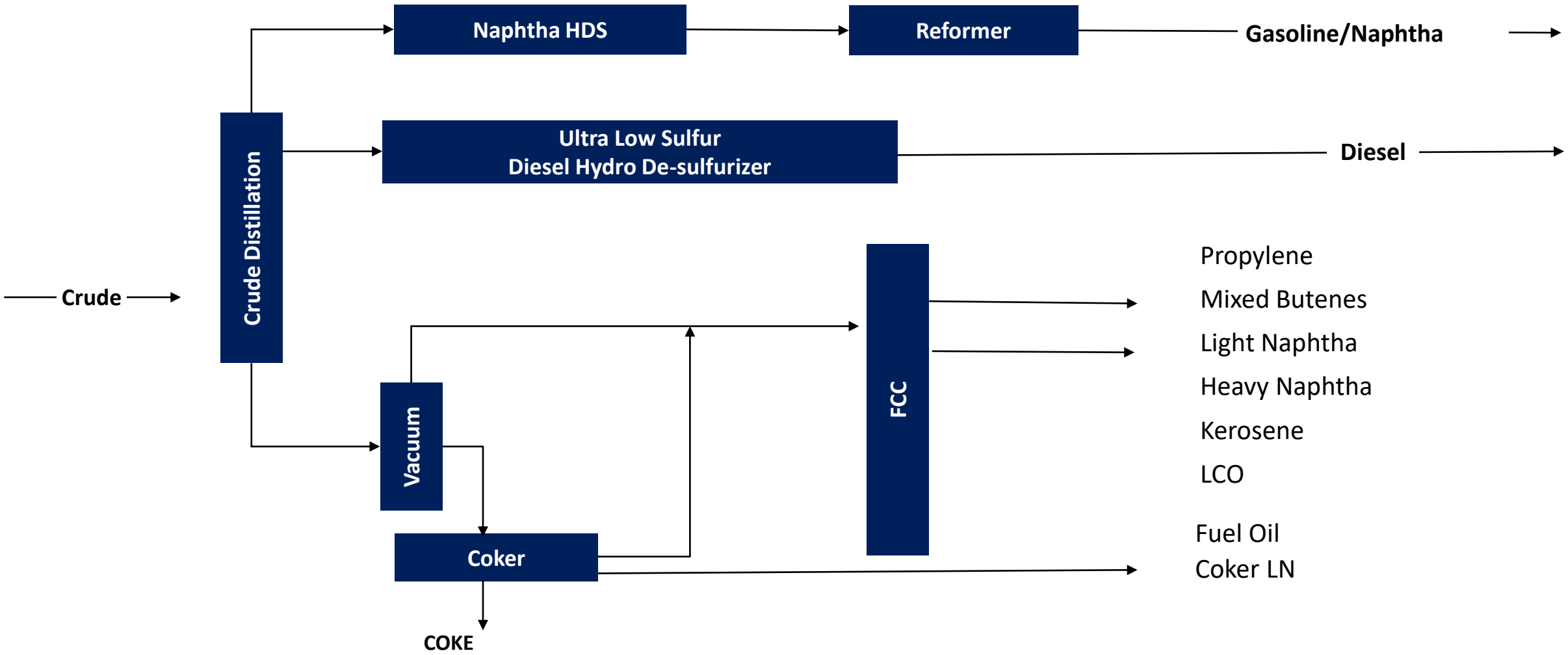
Global Refined Products Demand Mix



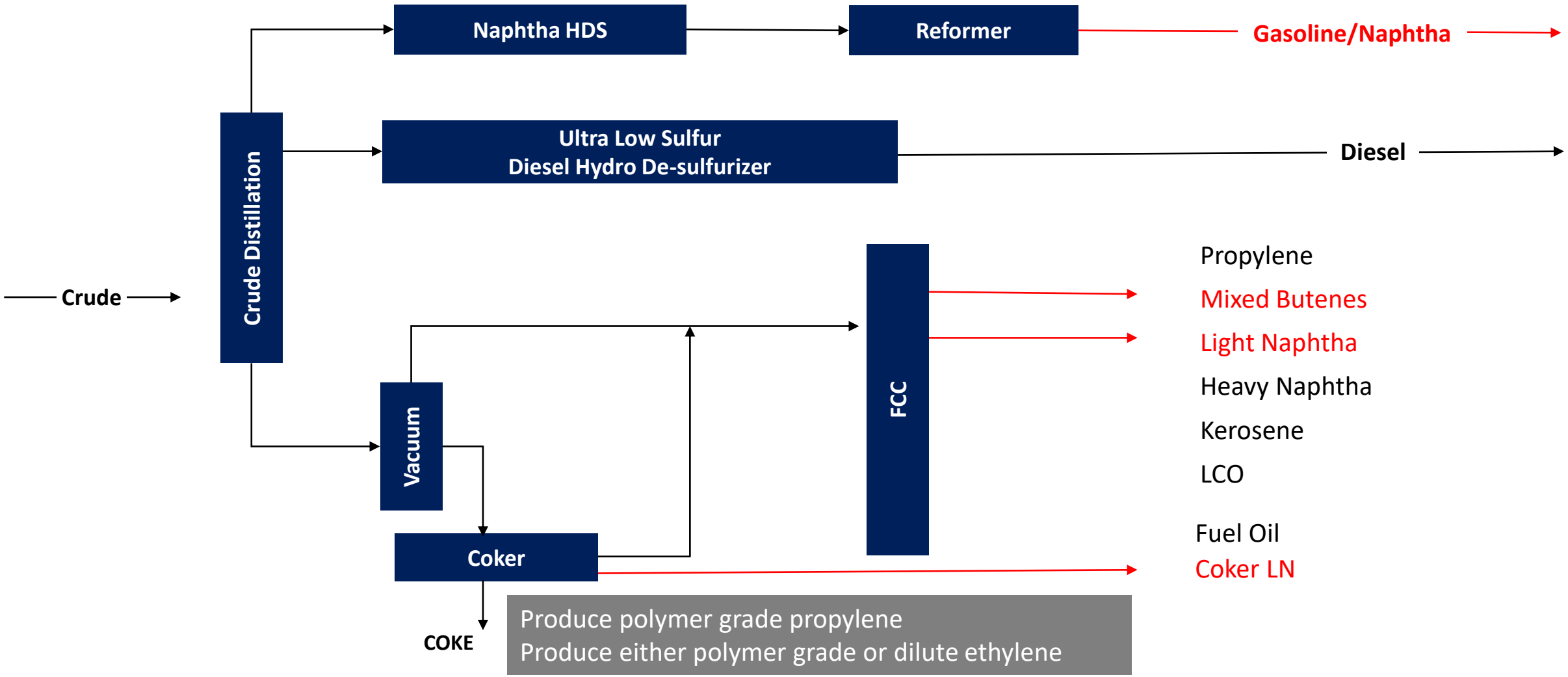
Reduced gasoline and naphtha demand

Source: Hart Energy Research & Consulting, 2013

Refinery Configuration



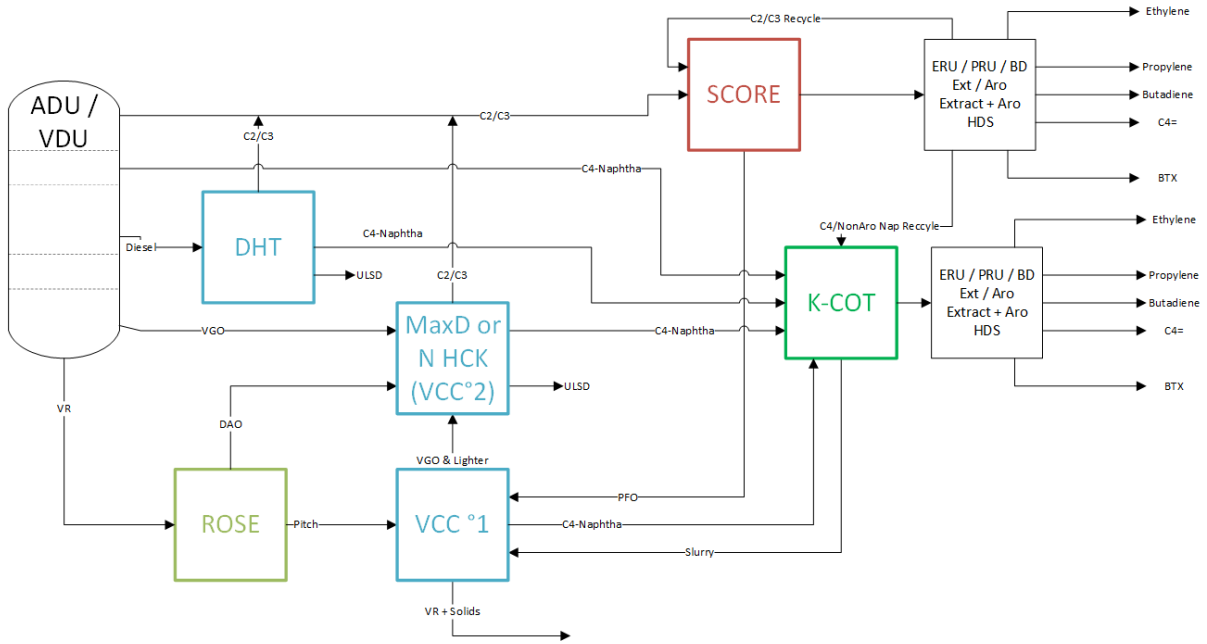
Refinery Configuration



KCOT Can Simplify Refiners' Growth to Petrochemicals

- Stand-alone K-COT minimizes investment in downstream units
  - All C4's and light C5/C6NA gasoline can be recycled without hydrogenation to minimize by-products and enhance light olefins yields
  - Only ethylene and propylene derivatives together with either aromatics or high-octane gasoline
- Stand-alone K-COT can be economic even for small naphtha feed quantities or ethylene/propylene production rates
- KBR is already working on such projects in China

Energy Transition – Maximize Chemicals Production from Crude



- Key technology to address KBR's solution for Crude to Chemicals to improve capital efficiency
- Key technology to minimize investment in downstream units
  - All C4's and light C5/C6NA gasoline can be recycled without hydrogenation to minimize by-products and enhance light olefins yields
  - Only ethylene and propylene derivatives together with either aromatics or high-octane gasoline
- Good small scale economics (China)

SUSTAINABILITY – THE PATH TO NET ZERO

A Net-Zero Carbon Future is Built on a Foundation of KBR Innovation

BLUE/GREEN AMMONIA

K-GreeN, a fully developed end-to-end green ammonia solution spanning electrolyzer to production

Commercial-scale, proven blue ammonia solutions

Carbon Capture Storage and Utilization

Innovative carbon capture and sustainability solutions (e.g., Monolith and LanzaTech projects)

Designed and delivered the world's largest carbon sequestration project

Hydrogen Expertise

Extensive hydrogen expertise with NASA range and launch operations

Expertise in designing complex cryogenics and LNG storage facilities

DECARBONIZATION OF EXISTING ASSETS

Proprietary software and tools to monitor and optimize output and efficiency and reduce emissions

Design modernization solutions to improve energy efficiency and output

Circular economy

Exclusive licensing partner for proprietary, innovative plastics recycling technology, enabling the plastic circular economy

Govt/C-Suite advisory

Renewable Biofuels

Developing and designing innovative biofuel solutions for clients spanning start-ups to established players

Renewables & Renewable Integration

Automated Tools, to drive efficiency in repetitive designs. EV Charging and Offshore Wind.

Patented floating turbine hulls

Trusted Advisory services

Industry leading Project and Program Management

Delivering a cleaner, greener future with KBR energy transition *expertise* and *proprietary technologies*

Approaches to Reduce CO_2 Emissions

CARBON CAPTURE

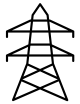
- End of Pipe Solution
- CAPEX Intensive
- CO2 Disposition Issues

Easier to implement on K-COT:
- **Only one flue gas point source**
- **Equipment synergies**

ENERGY EFFICIENCY

- Modern Grassroots Facilities Highly Energy Efficient
- Incremental Improvements
- Minor Impact on CO2 Emissions

Plants are already highly efficient



ELECTRIFICATION

- E-Drives for all Compressors
- Significant reduction in steam generation demand, CW load
- Electrification of Regenerator

Motor drivers could be applied; KBR has commercial experience with this in KCOT

HYDROGEN AS FUEL

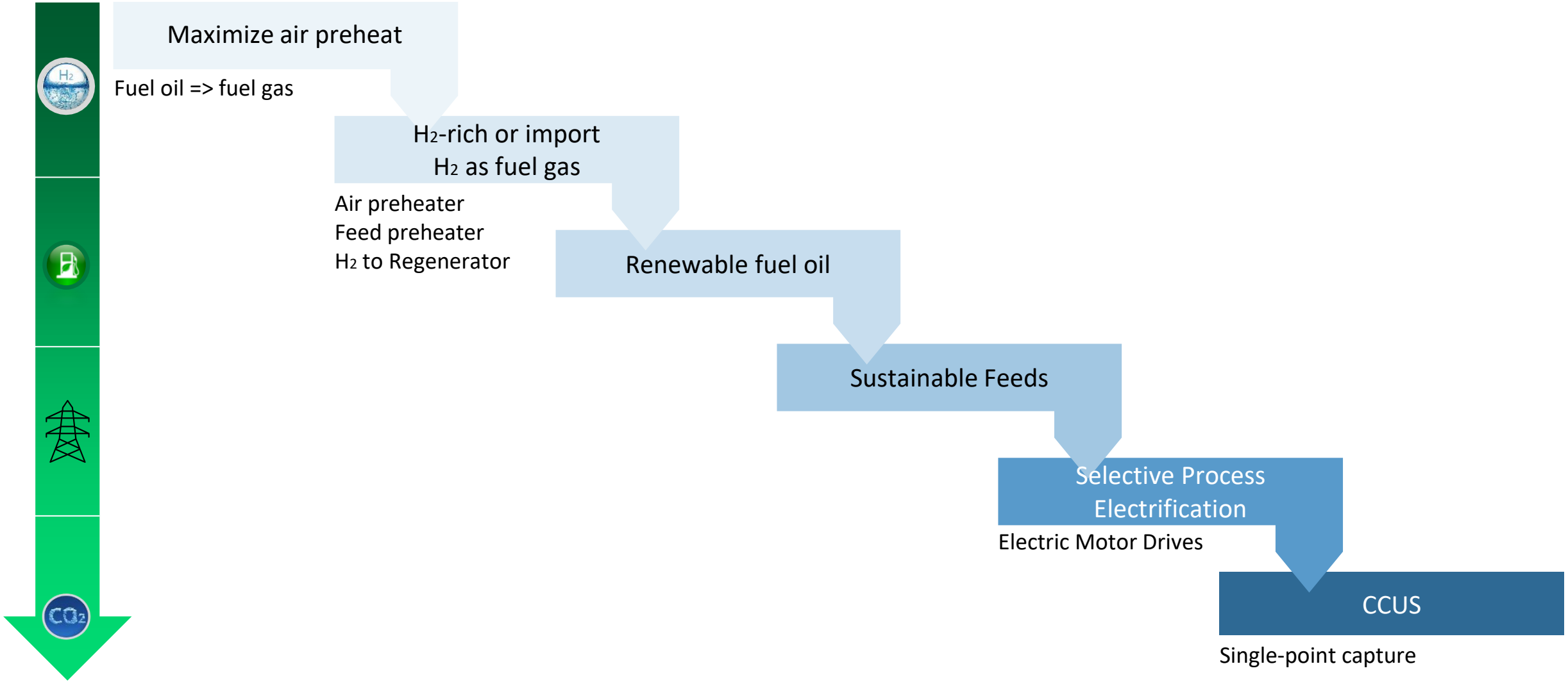
Shift from Fuel Oil use to H2-rich fuel gas
- Maximize fuel gas (vs. fuel oil)
- H2-rich fuel gas
- Pure H2 as fuel (Sourcing Challenges, Fuel Gas Disposition)

KBR has demonstrated "proof of concept" via CFD modeling – seeking commercial demonstration

RENEWABLE BIOFUELS

Alternative feeds
- Ethanol & Methanol as feed to K-COT
- Bio-oil as fuel
- Plastics recycle pyrolysis oil as feed (some by-products may be processed without treatment)

KCOT Path to Net-Zero



KCOT Advantages

- Higher Propylene and Aromatics
  - High propylene and Aromatics product credit from various low-value liquid feed
- Ultimate flexibility
  - Feed and product flexibility for olefins production
- Economy of scale across wide range of capacity
  - Large capacity range – 200 KTA up to 1200 KTA olefins from single reactor
  - Small capacity – economy of size for both PE and PP, simplified recovery
- Based on well proven technologies
  - Catalyst performance
  - Orthoflow reactor
  - Backend separation

Lotte Titan K-COT Reactor

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