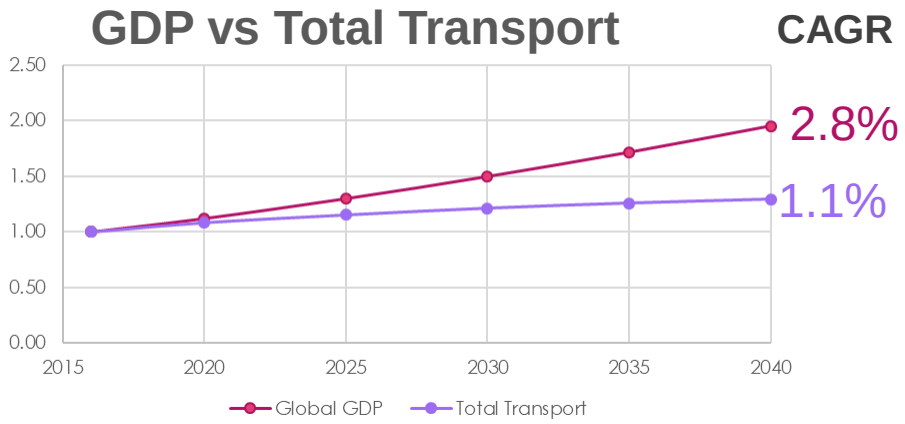
Ethylene Middle East Technology Conference

EMET CONFERENCE

Profit Pivot Points in in a Crude to Chemicals Integrated Complex

Brian S. Muldoon
Vice President - Petrochemicals
Lummus Technology – McDermott

Challenges Facing Refiners

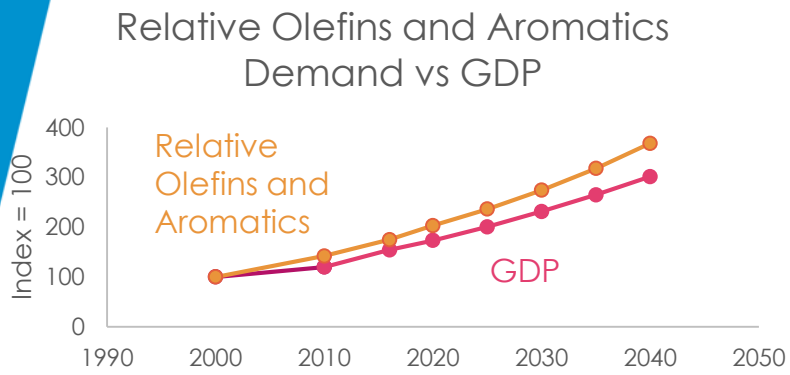


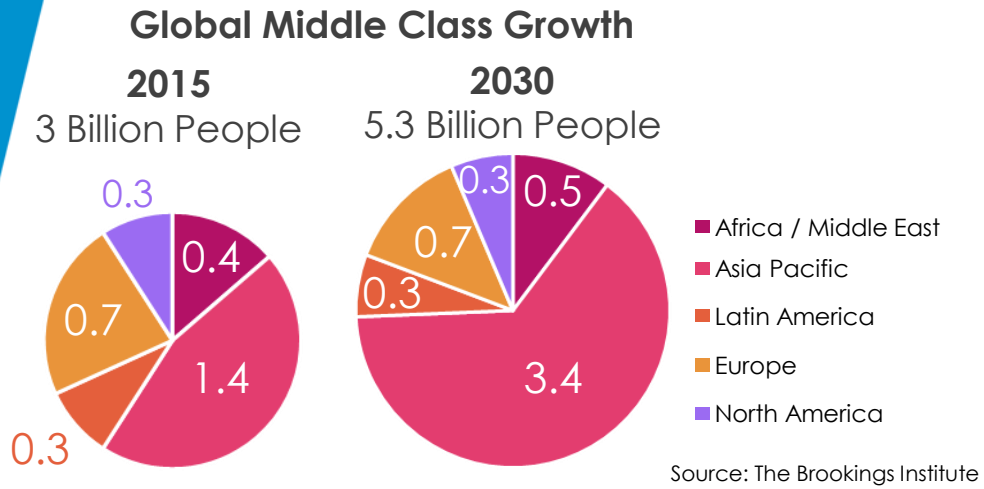
- **Total Transport:** Oil, Biofuels, Gas, Other

Reduced growth in fuel demand

- Extended fuel mileage
- Enhanced Electric Vehicles
- Environmental Headwinds

Drivers of Rapid Petrochemicals Growth





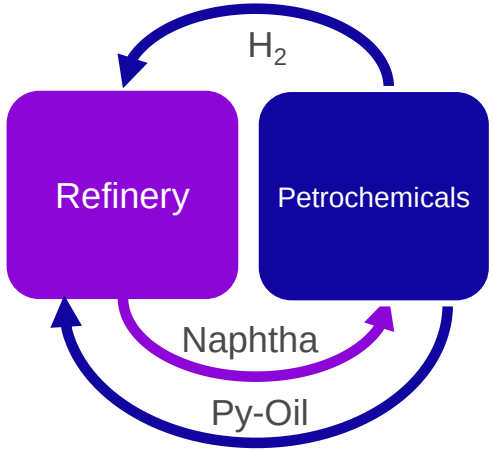
Source: The Brookings Institute

- From 2016 to 2040, 40% chemicals sector growth
  - Quality of life improvement
  - Rising prosperity
  - Development of Middle Class
- Petrochemical growth exceeds GDP growth
  - Emerging Markets unprecedented Growth

Synergies of Refinery / Petrochemical Integration

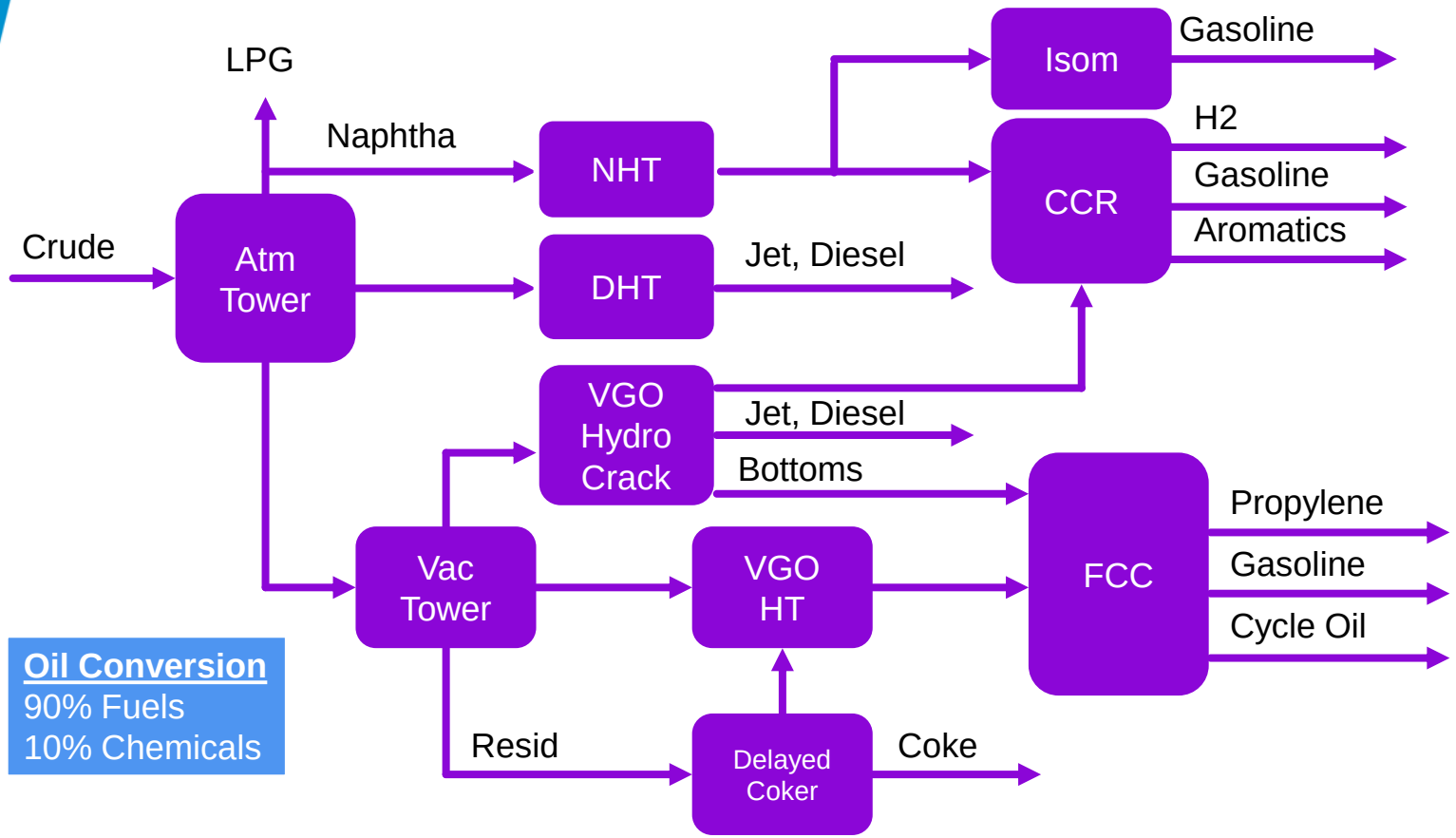
- ***Recent Trend:*** Greater integration not just co-location
- Position petrochemicals plants near:
  - Low-cost feedstock
  - Lower transportation costs for feedstocks
  - Fuel Sources
  - Existing Infrastructure
  - Downstream Markets: PE / PP / PET

Complimentary Units



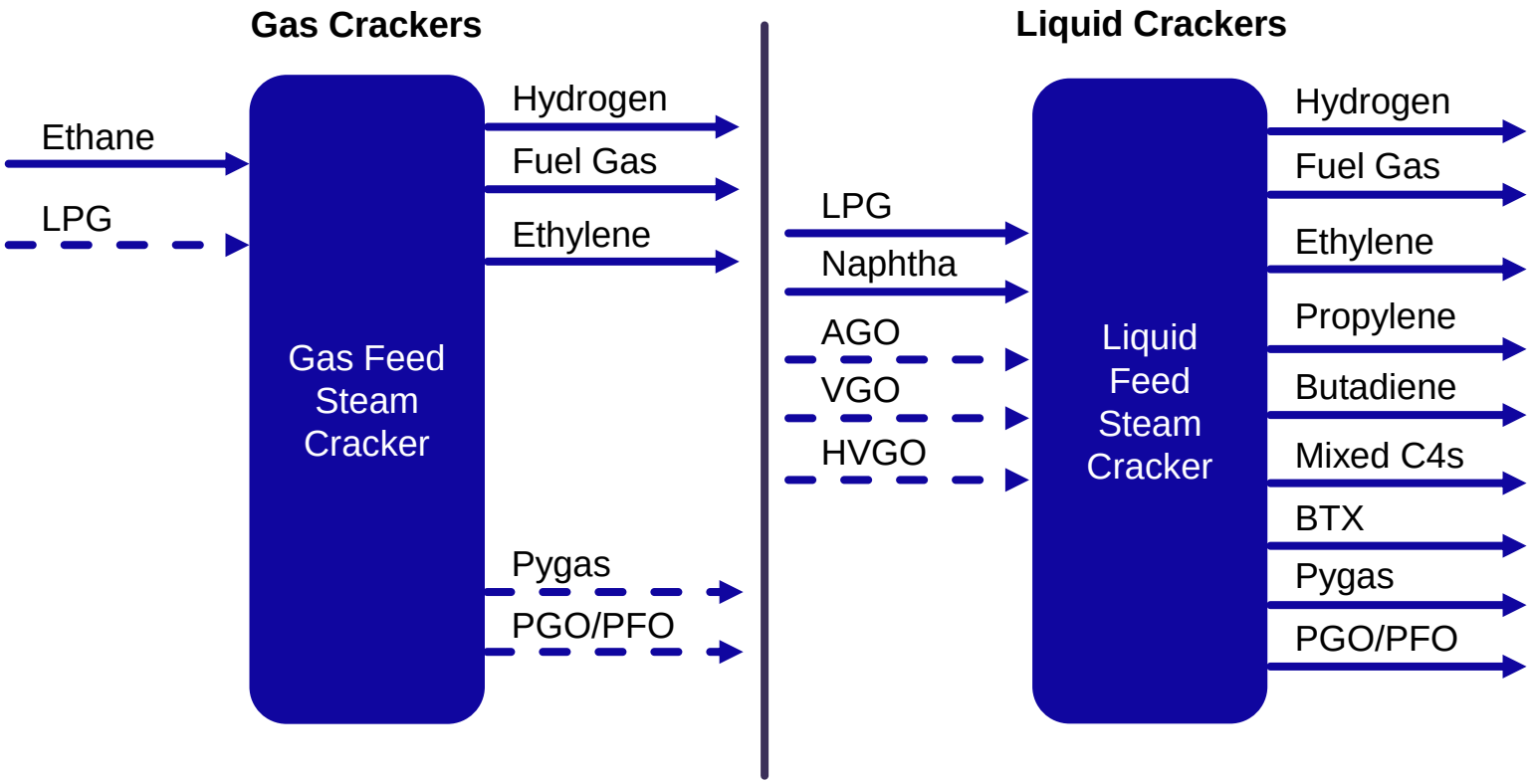
- Petrochemicals provide high value outlet for refiners

Traditional Refinery

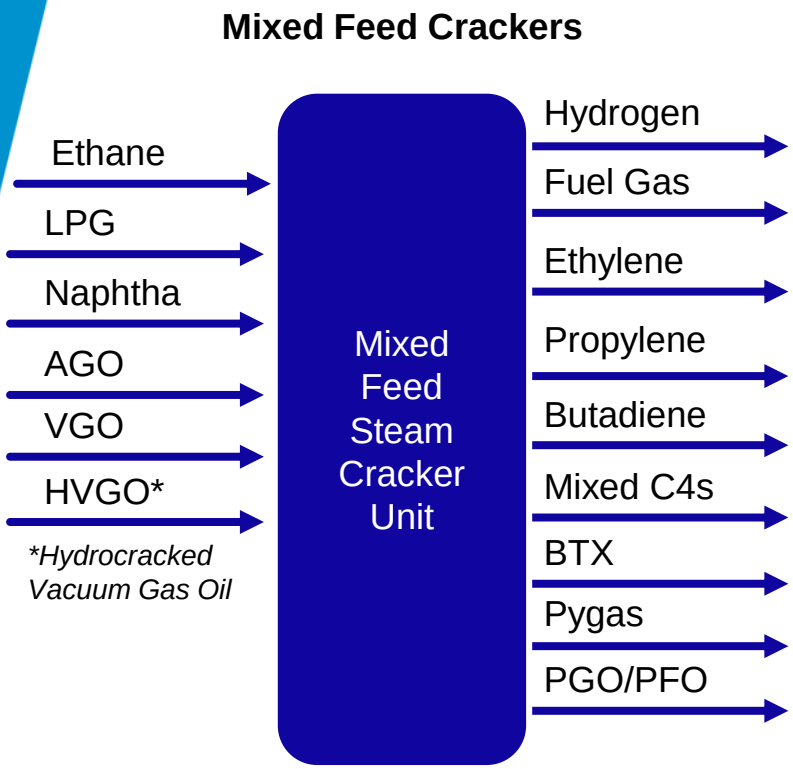


Oil Conversion
90% Fuels
10% Chemicals

Traditional Petrochemicals



Feed Flexible Petrochemicals Complex



- **Mixed Feed Steam Crackers provide ultimate flexibility**
  - Multiple Feeds and Products
  - Larger capacity: 1.5 to 2.0 Million Tons per Annum

McDermott Technology – One Stop Shop

Lummus Technology

- Leading technology licensor
  - Refining
  - Petrochemical
  - Gas Processing
  - Coal Gasification Technologies
- 120+ Licensed Technologies
- 3000+ Patents, Applications, Trademarks
- Industry Leading Ethylene technology

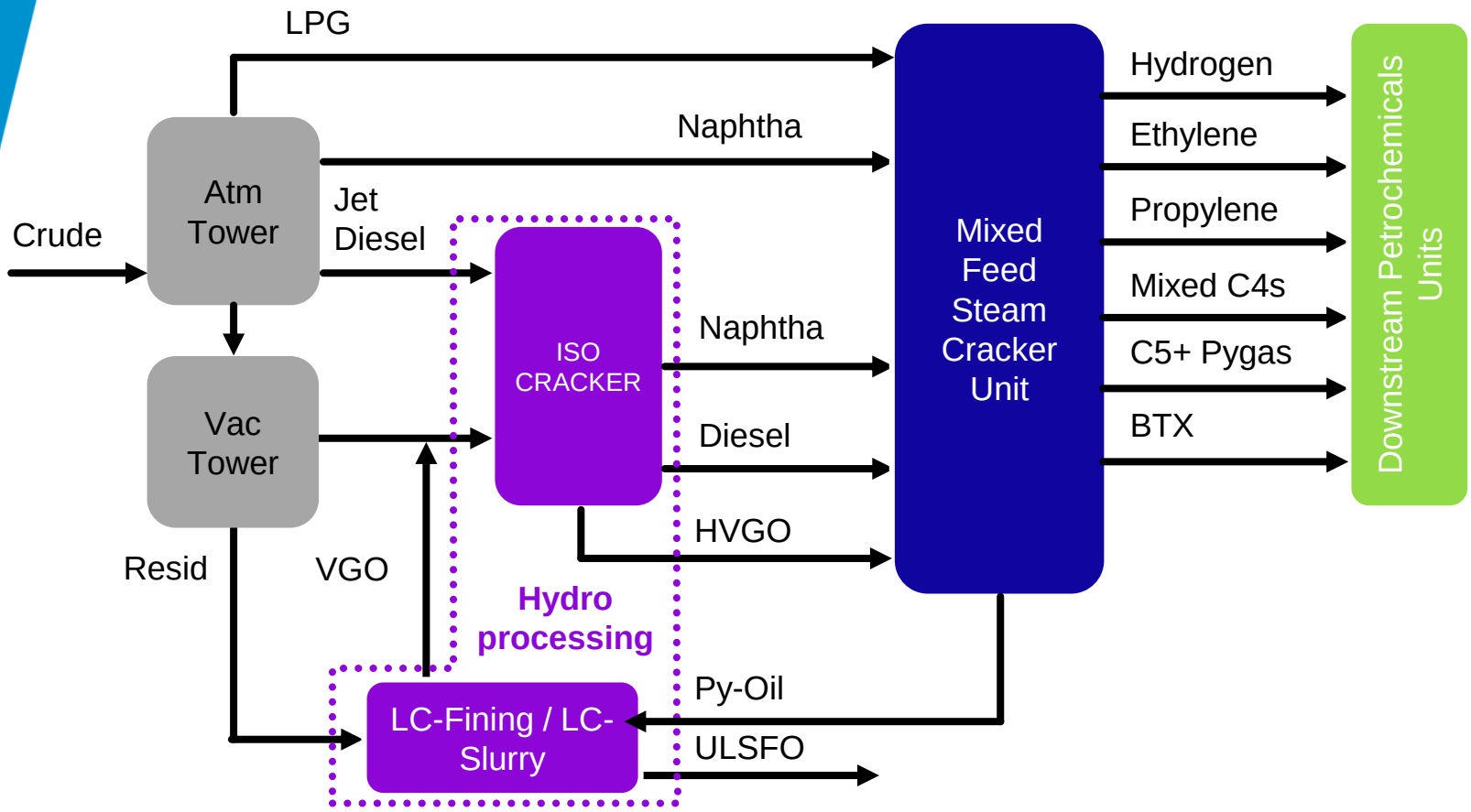
Chevron Lummus Global (CLG)

- Joint Venture – Chevron and McDermott
- 100+ Hydroprocessing Plants designed worldwide
- Active R&D Programs, Pilot Plant in Richmond, CA and Pasadena, TX

CLG
Chevron Lummus Global

MCDERMOTT
TECHNOLOGY

Integrated Refinery and Petrochemicals Unit



Profit Pivot Points for an Integrated Complex

Hydroprocessing

- Optimize cracker feeds
- Balance Hydrogen consumption to optimize production of chemicals
- HVGO excellent Lubes or Cracker feedstock

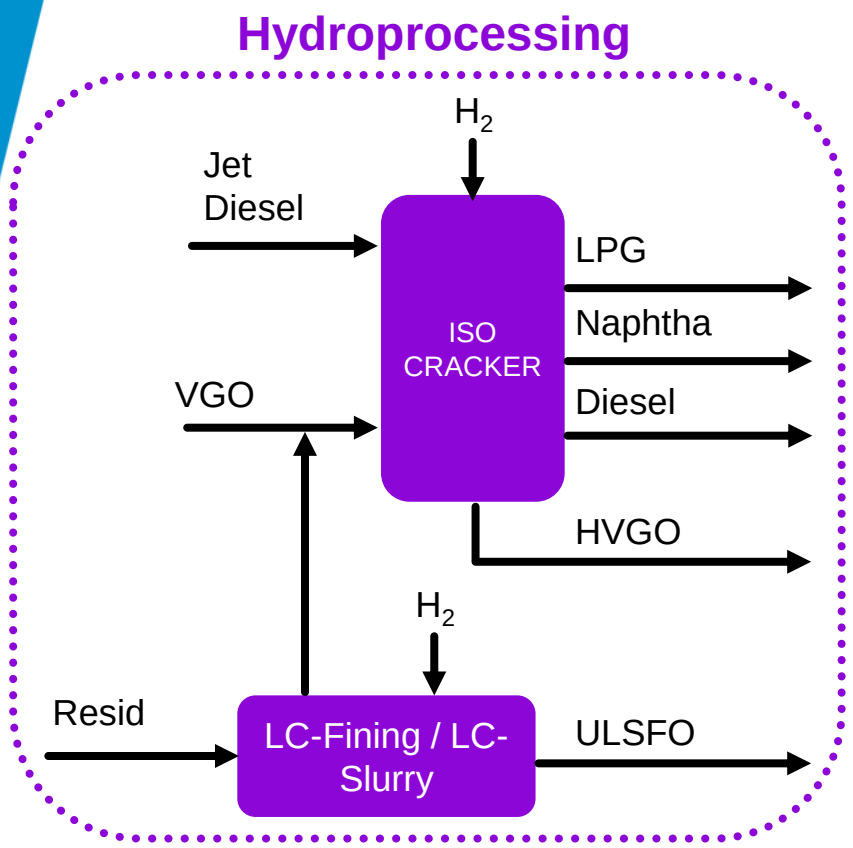
Mixed Feed Steam Cracker

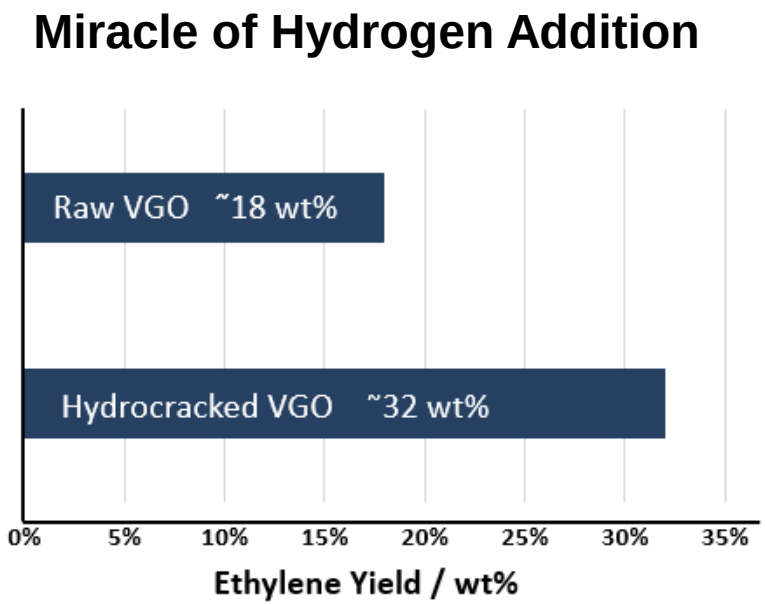
- Feed Flexibility
- Cracking Severity determined by Propylene to Ethylene (P/E) Ratio

Co-Product Selectivity

- Monetize valuable co-products such as Butadiene, Paraxylene, BTX
- Olefins Conversion Technology maximizes C2-C3-C4 Product flexibility

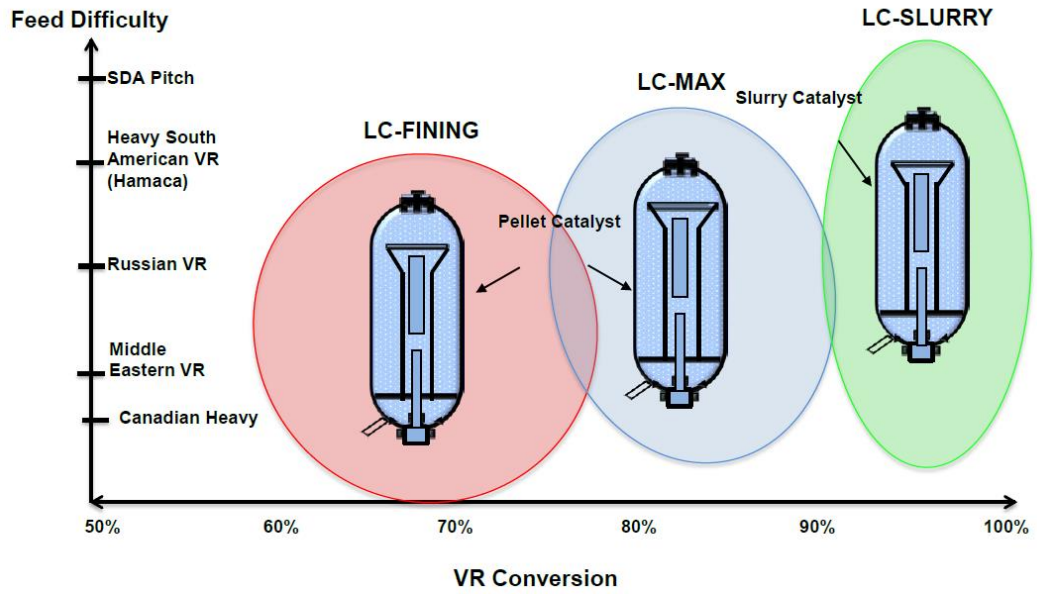
Hydroprocessing Pivot Point





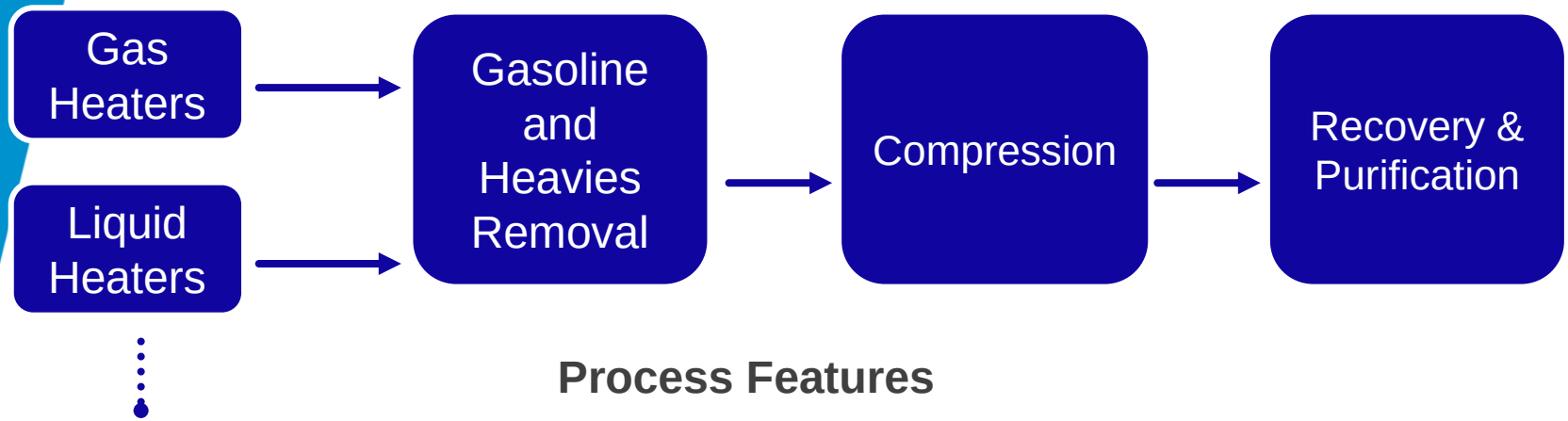
Effectively prepares feed to Mixed Feed Steam Cracker in terms of **Feed Flexibility, Conversion, and Yield**

Upgrading the Bottom of the Barrel



- Catalyst and reactor configurations determine range of conversion
- Outlet for Py-Oil upgrading from Steam Cracker

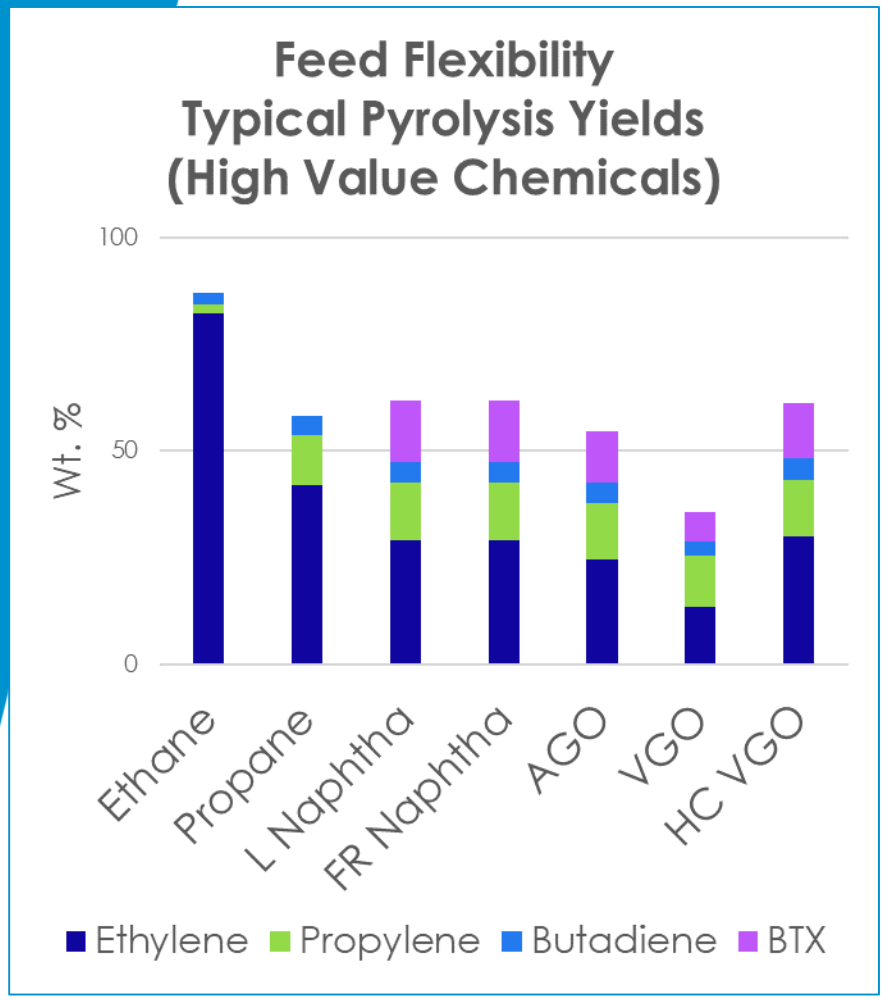
Mixed Feed Steam Cracker



Process Features

- SRT® Pyrolysis Furnace Module
  - High Yield
  - Long Run Length
- Optimized CAPEX / OPEX
  - Low Pressure Design vs conventional plants
  - Multi Component Refrigeration
  - Reduced Compressor Casings and Equipment Count

Mixed Feed Steam Cracker Profit Pivot Points

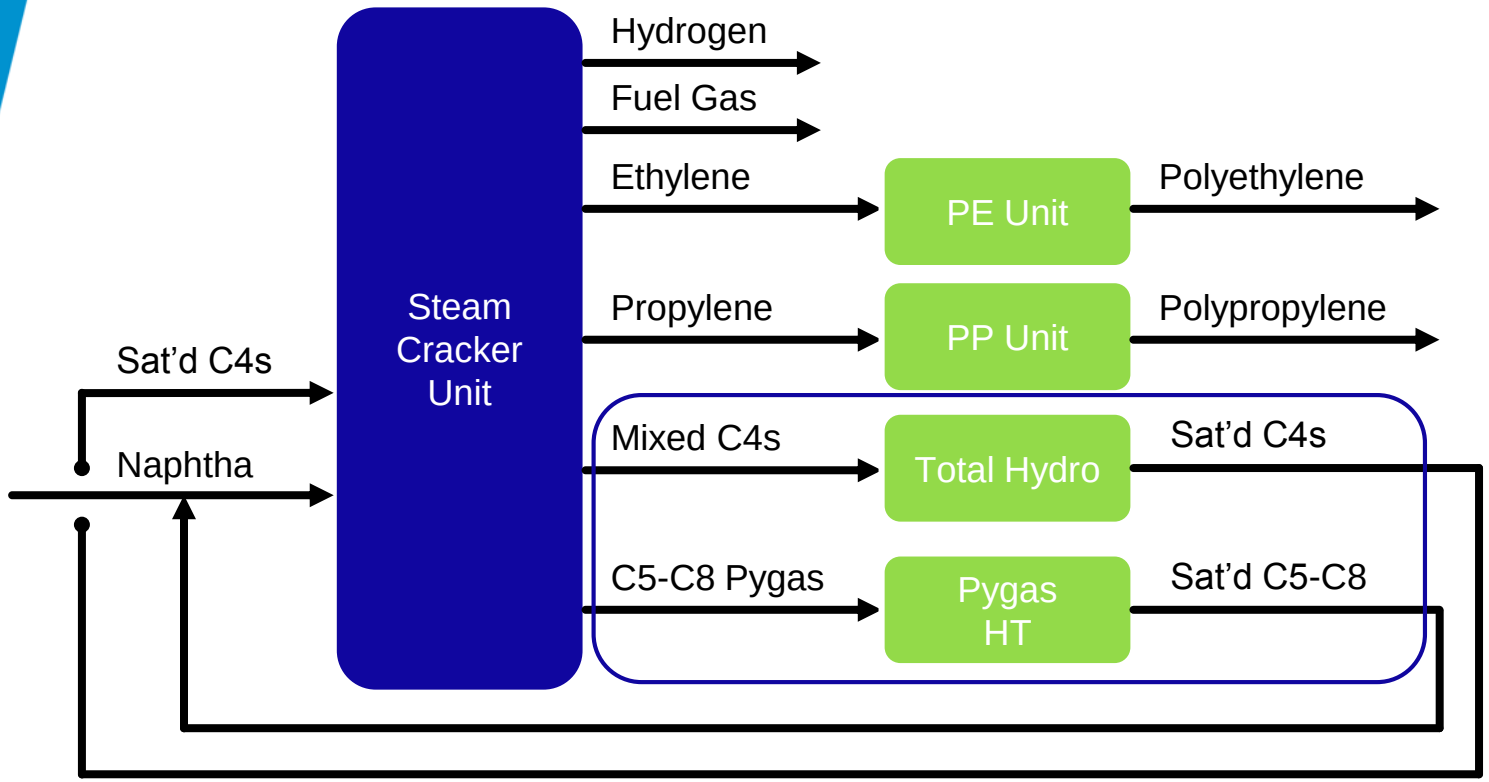


Cracking Severity

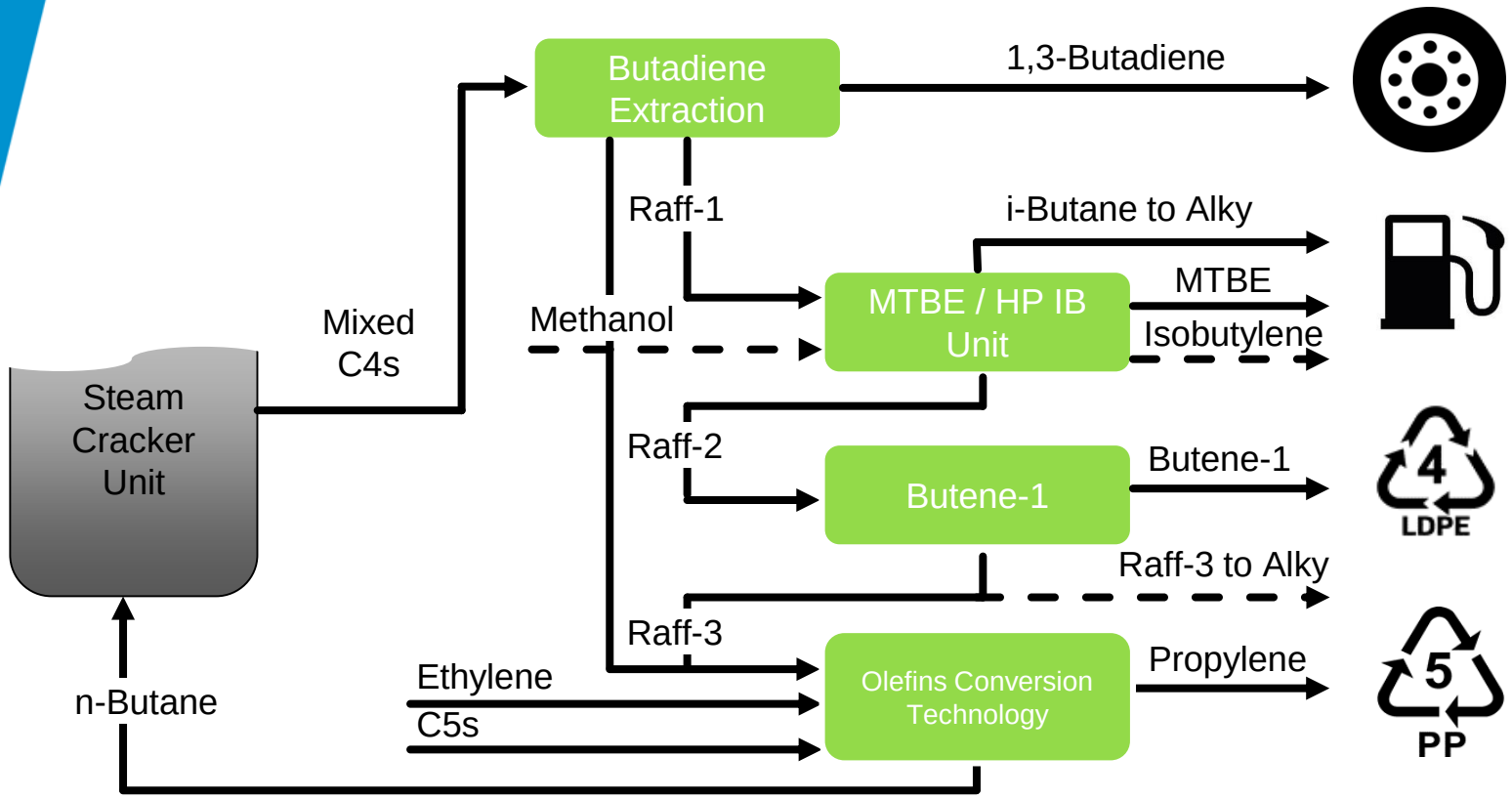
Cracking Severity	High	Low
P/E Ratio	0.45	0.65
Energy / kg Ethylene	Base	+ 16%
Feed Rate	Base	+ 14%
Ethylene Production	Base	Base
Propylene Production	Base	+ 46%

P/E Ratio defined as Propylene / Ethylene Ratio

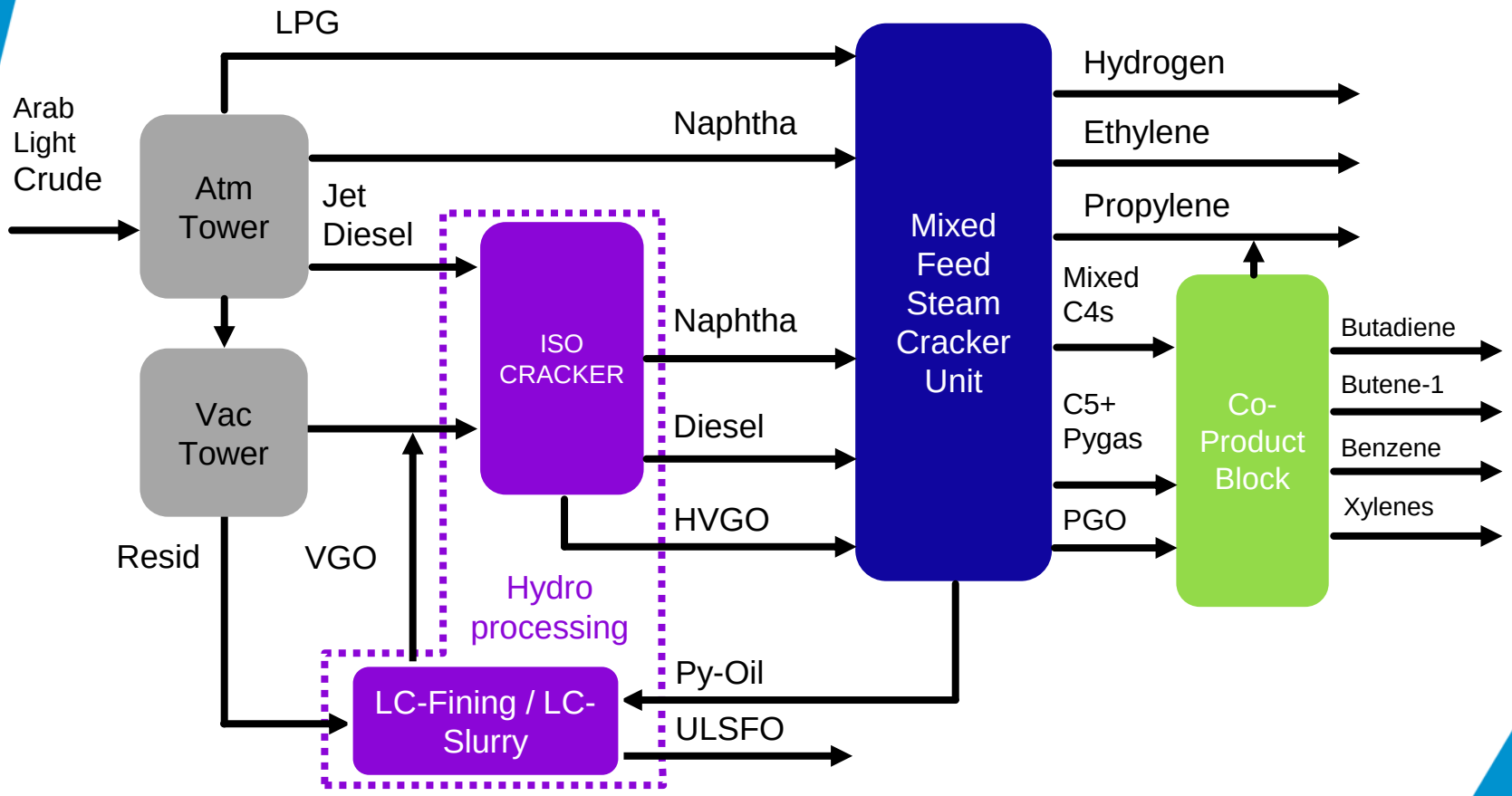
Co-Product Profit Pivot Point



Co-Product Profit Pivot Point C4 Train (Optimized)



Profit Pivot Points: Putting it all together



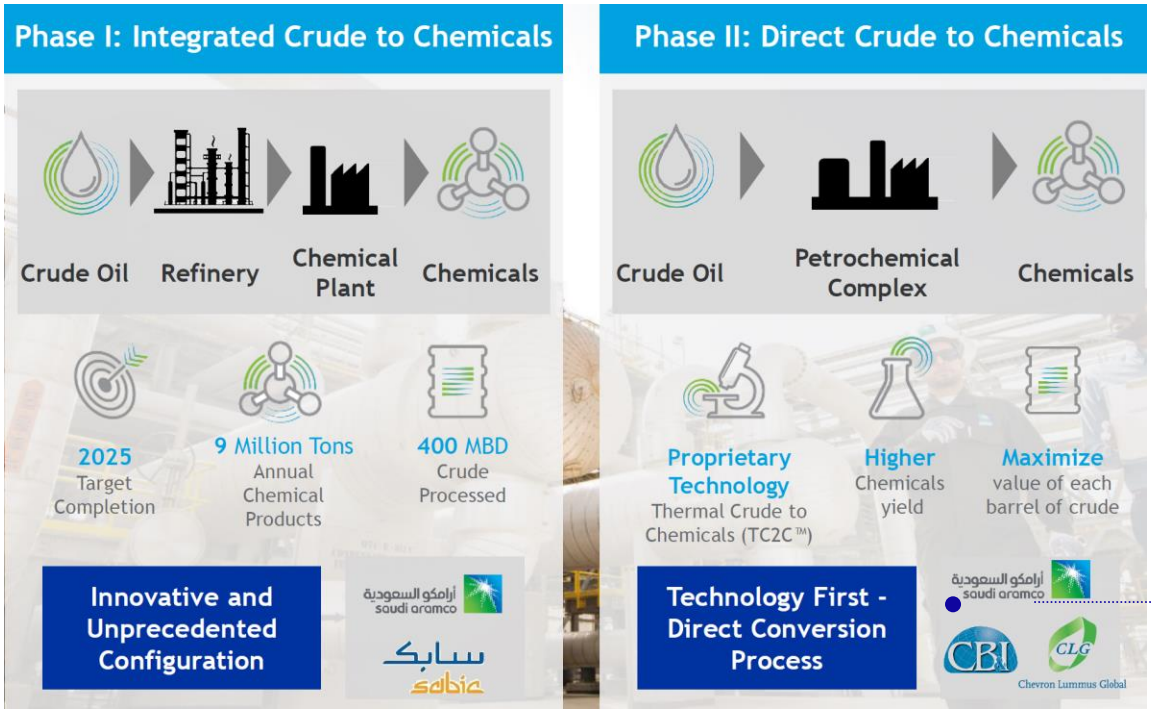
Case Study - Refinery / Petrochemicals Integration

Case	1	2	3	4	5
Reside Upgrading	No	LC-FINING	LC-FINING	LC-FINING	LC-SLURRY
Fuels Production	No	No	Yes	Yes	Yes
Fuel Oil Type	3% HSFO	1% LSFO	1% LSFO	1% LSFO	0.1% ULSFO
Crude (Arab Light), BPD	195,000	162,000	227,000	400,000	246,515
Ethylene, KTA	2,000	2,000	2,000	4,000	2,000
Propylene, KTA	1,480	1,493	1,469	2,805	1,489
Butadiene, KTA	357	357	347	774	326
Euro VI Diesel, BPD	0	0	74,500	94,265	106,000
Fuel Oil, BPD	54,000	25,000	20,000	36,935	8,500
Anode Coke, KTA					
Chemical Yield on Crude, %	58%	70%	49%	57%	45%
% IRR	Base	+7.8%	+9.8%	+18.4%	+10.4%

Notes

1. All cases includes Hydrocracker + Olefins Conversion Technology
2. All cases produce MTBE, Butene-1, Benzene, Xylenes
3. 3% HSFO priced at $21/Bbl less than crude

Crude to Chemicals: A Disruptive Technology

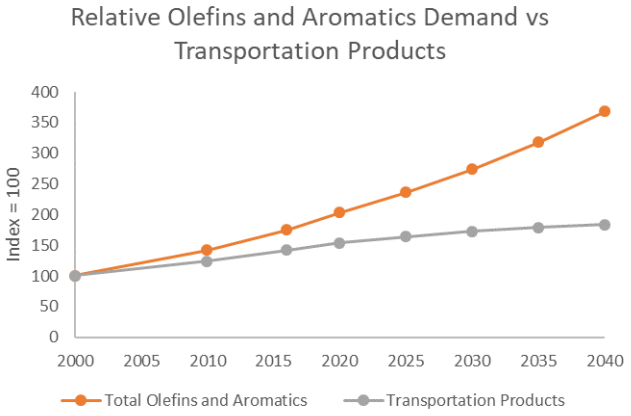


MCDERMOTT TECHNOLOGY

Source: Saudi Aramco Presentation At Baker Hughes (GE) 2018 Annual Meeting, Mr. Abdulaziz Al-Judaimi

Conclusion

- Focus on integration of refinery and petrochemicals units
- Rapid petrochemicals demand provides opportunities for refiners to shift to chemicals
- Profit Pivot Points will allow producers to pivot to meet changing market demands:
  - Hydrocracker
  - Mixed Feed Steam Cracker
  - Co-Product Management



Source: EIA and Global Data

Technology solutions exist to upgrade refined products to valuable petrochemicals

Contact Information:
Brian S Muldoon
Vice President
Brian.muldoon@mcdermott.com

Lummus Technology LLC
1515 Broad Street
Bloomfield, NJ, 07003 USA