

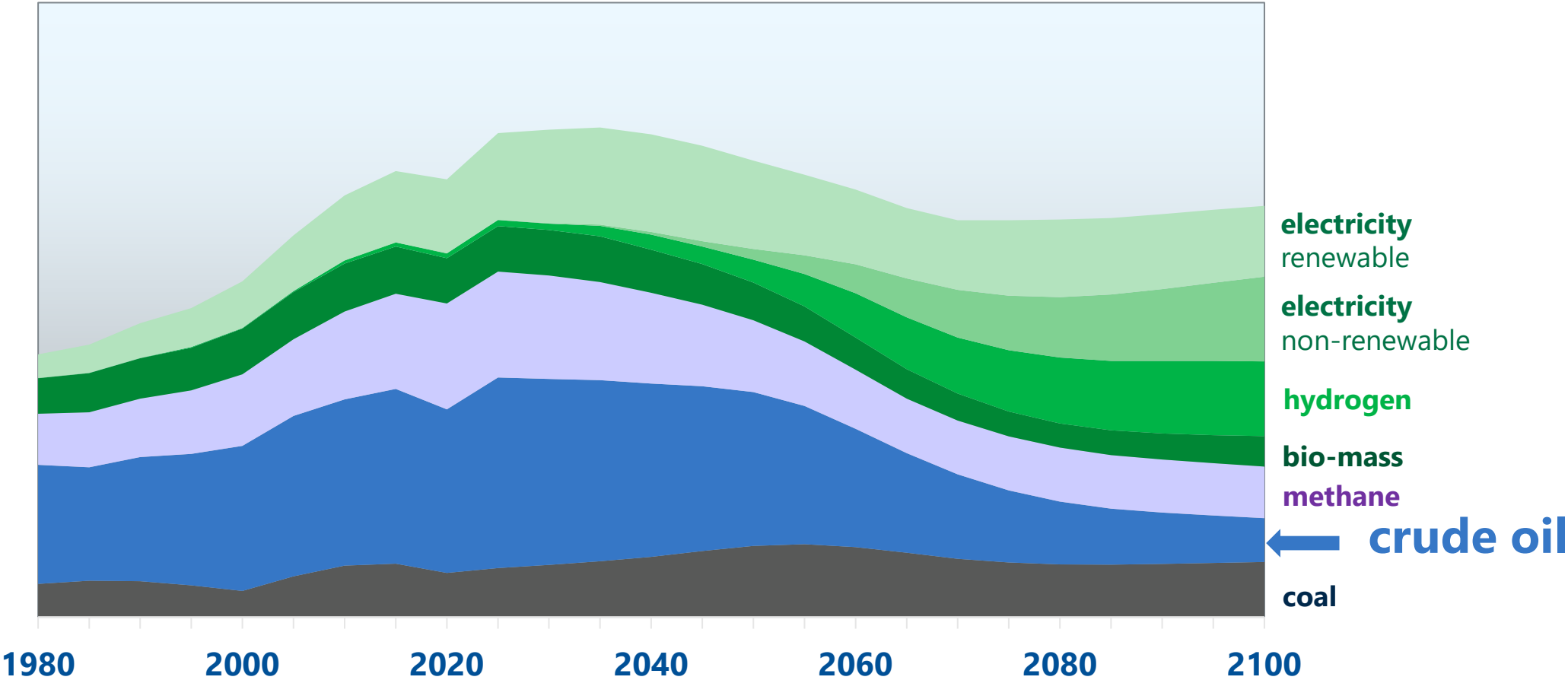
Converting Increasing Amounts of Crude Barrels to Chemicals - The Future of Refining

Dan Gillis, Technology Director, CLG
September 12-14, 2023

The Big Dilemma for Refiners: Crude Oil Derived Transportation Fuels Will Decrease

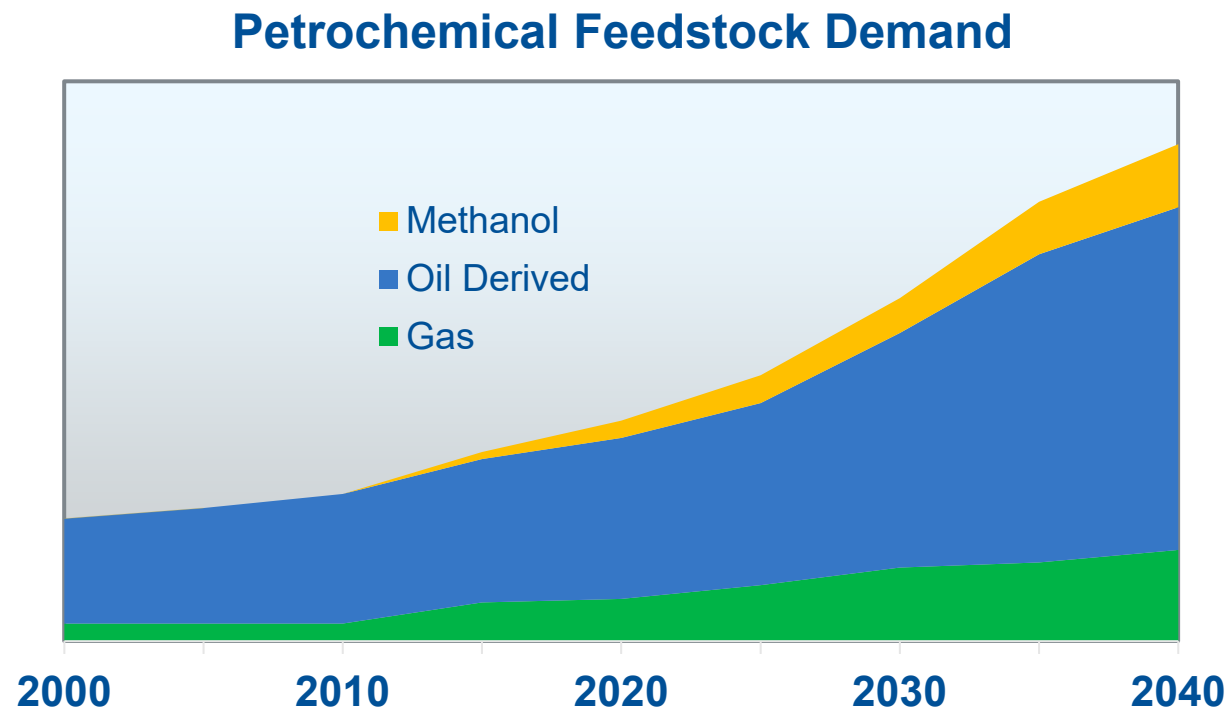


Relative Energy Transition Carbon Emissions



Refiners' Opportunity: Growth in Petrochemicals Will Drive Demand for Crude Derived Feedstocks

- Demand will grow by 125% over the next 20 years
- Supply from other sources will be limited
- Crude derived liquids will have to significantly increase

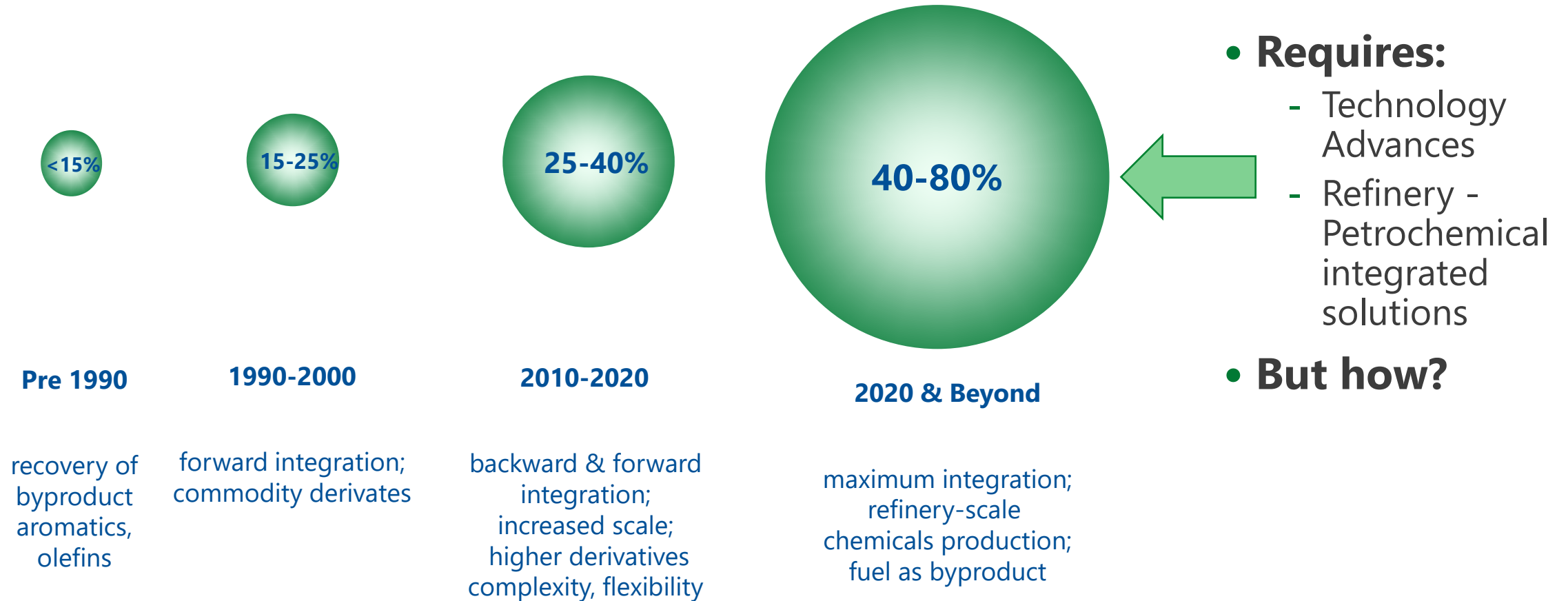


Source: Woodmac, IHS Markit, 2019

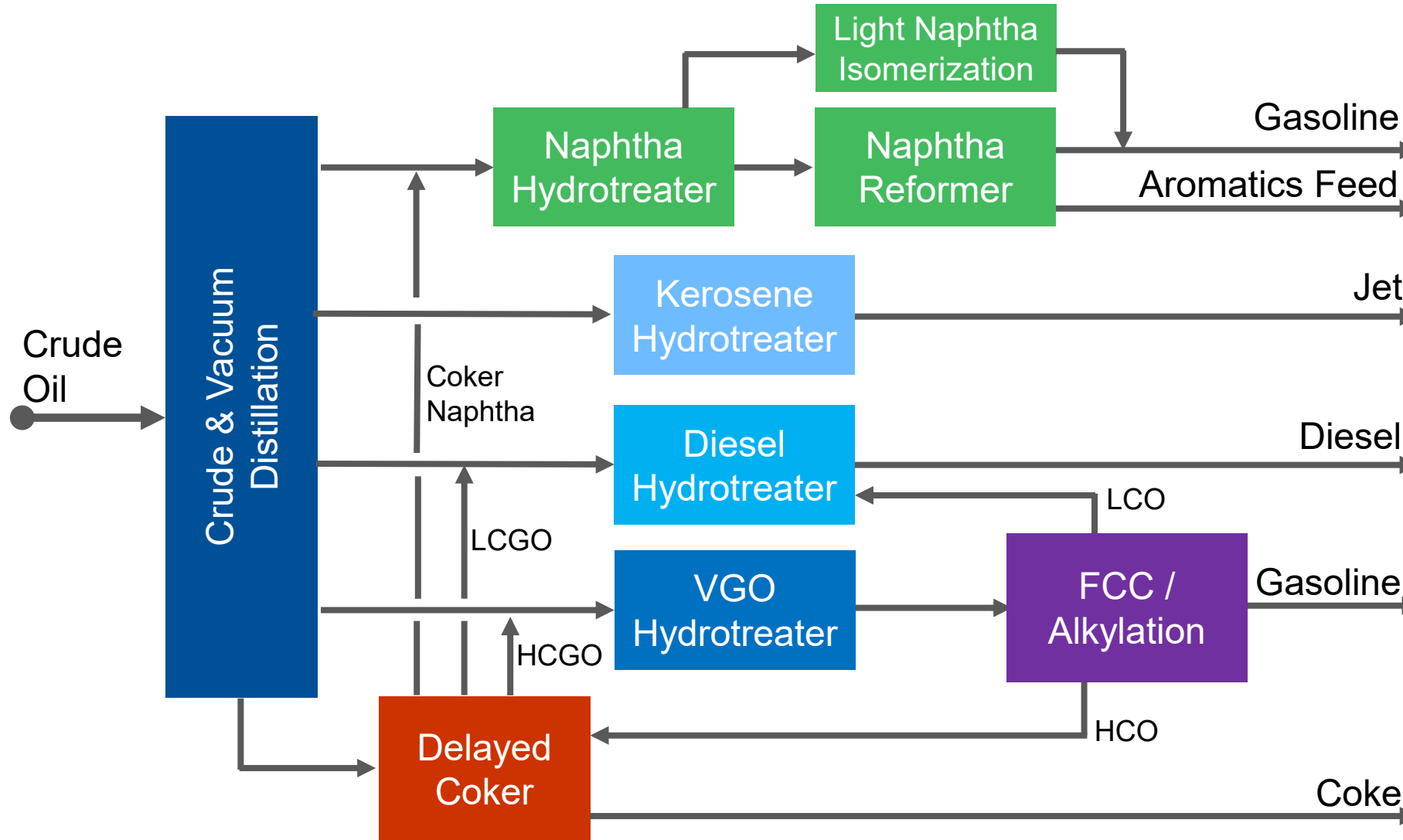
***Shifting product demands require
integrated refinery / petrochemical solutions***

Technology Advances Will Drive the Shift to Chemicals

% Chemicals Produced Per Ton Of Crude In An Integrated Refinery



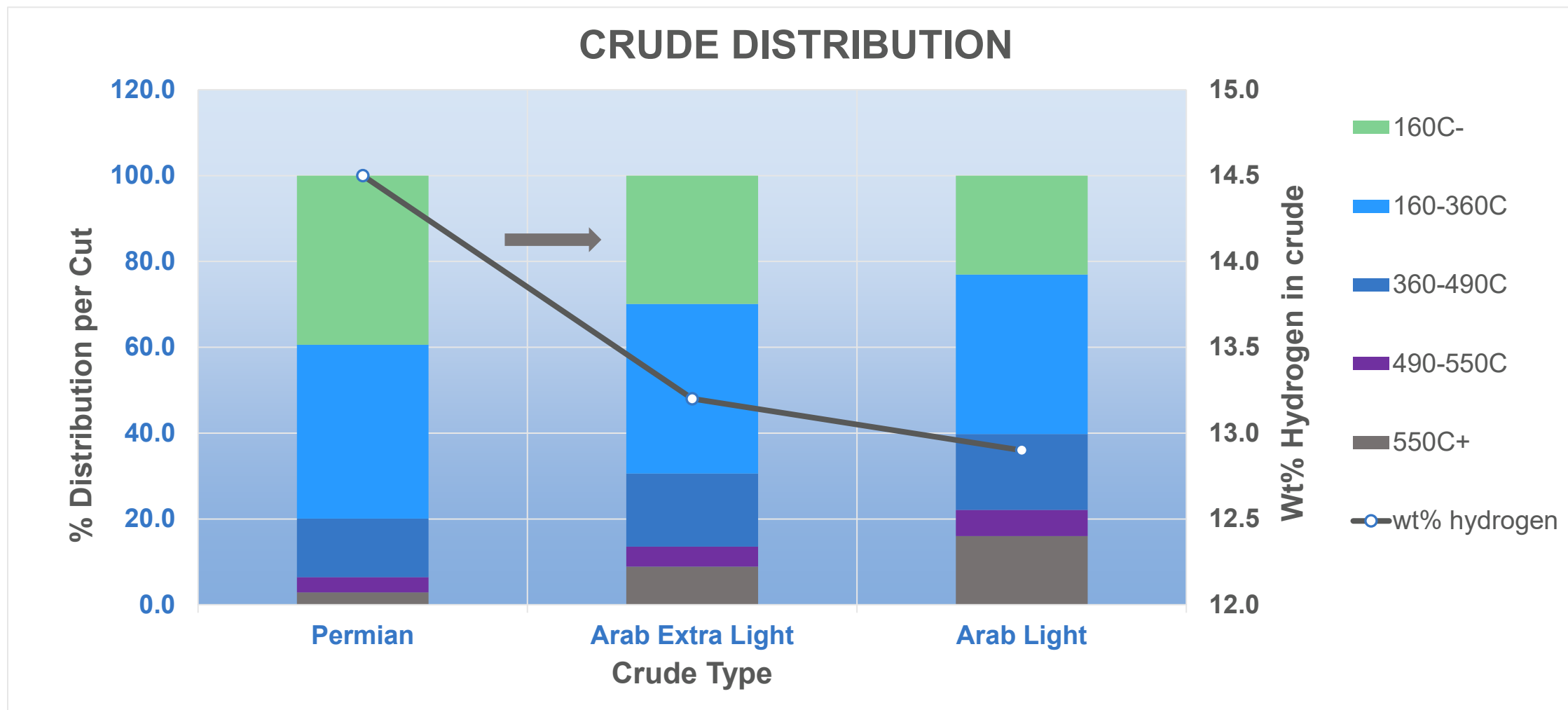
Many Current Refinery Configurations



Refinery mindset:

- Focus is on transportation fuels
- Crude type and product Flexibility
- Meeting ever increasing tighter specifications
- Crack spread, margins drivers

Crude to Chemicals Solutions: CAPEX/OPEX/CO2 Emissions All Dependent On Crude Source



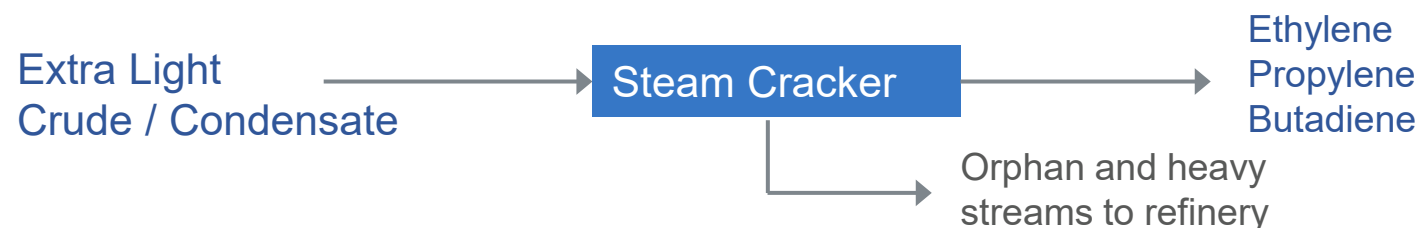
Challenges increase in making chemicals as crudes get heavier

The heaviest material (residue) must be removed before steam cracking

Lummus Provides Refiners With All Pathways To Petrochemicals Depending on Crude Type

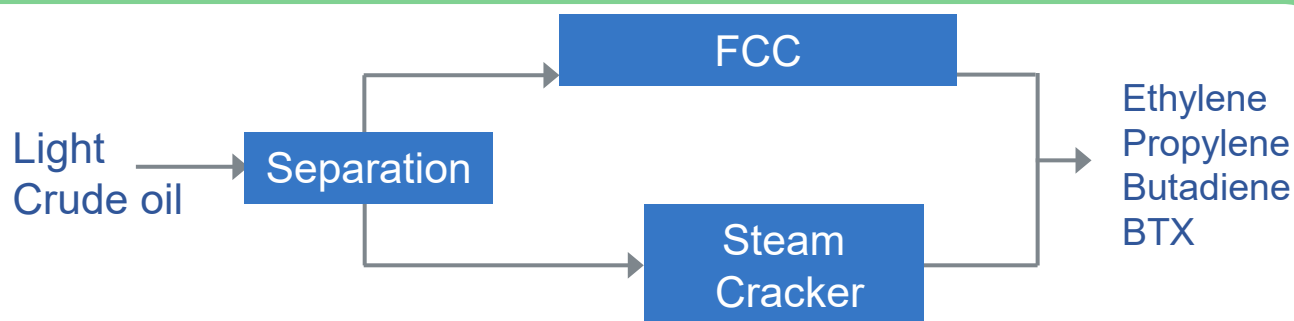
- **Direct Cracking**

- Lummus HOPS technology



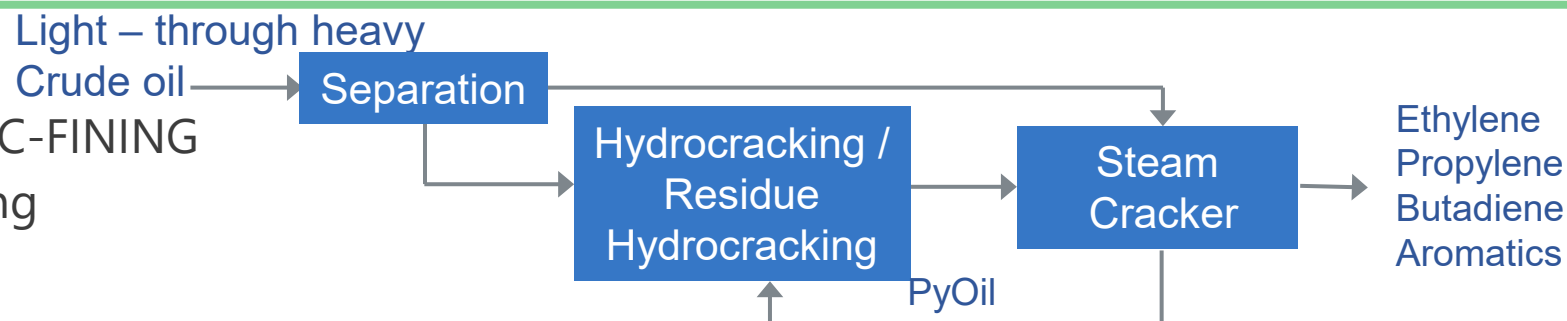
- **High Propylene FCC / Cracking**

- Lummus FCC
- Lummus Steam Cracking



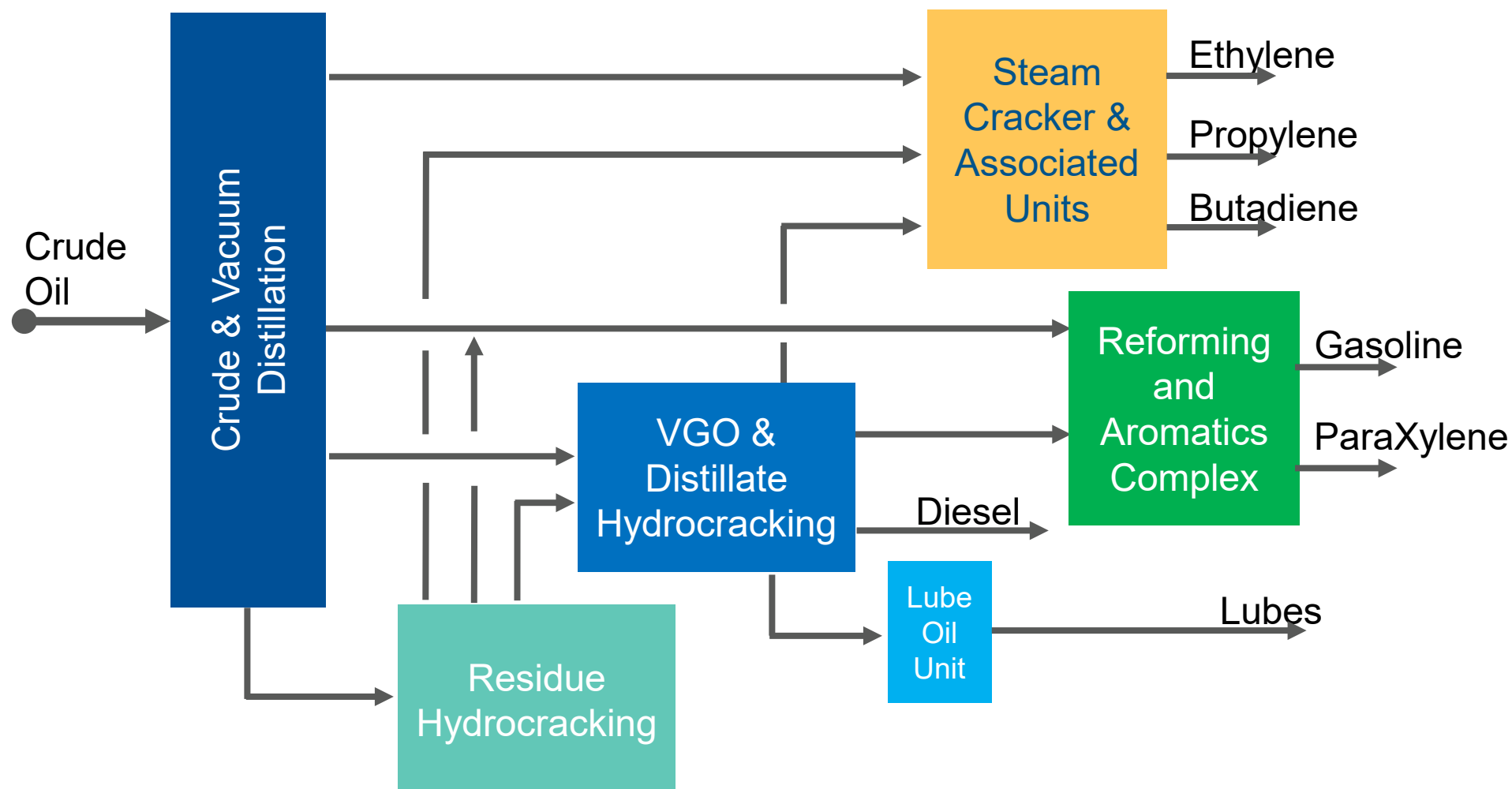
- **Crude Oil to Chemicals**

- CLG ISOCRACKING / LC-FINING
- Lummus Steam Cracking
- TC2C™



Most refineries will want to use some form of COTC to make chemicals

Crude Oil to Chemicals: High Content of Hydroprocessing Required to Maximize Chemicals

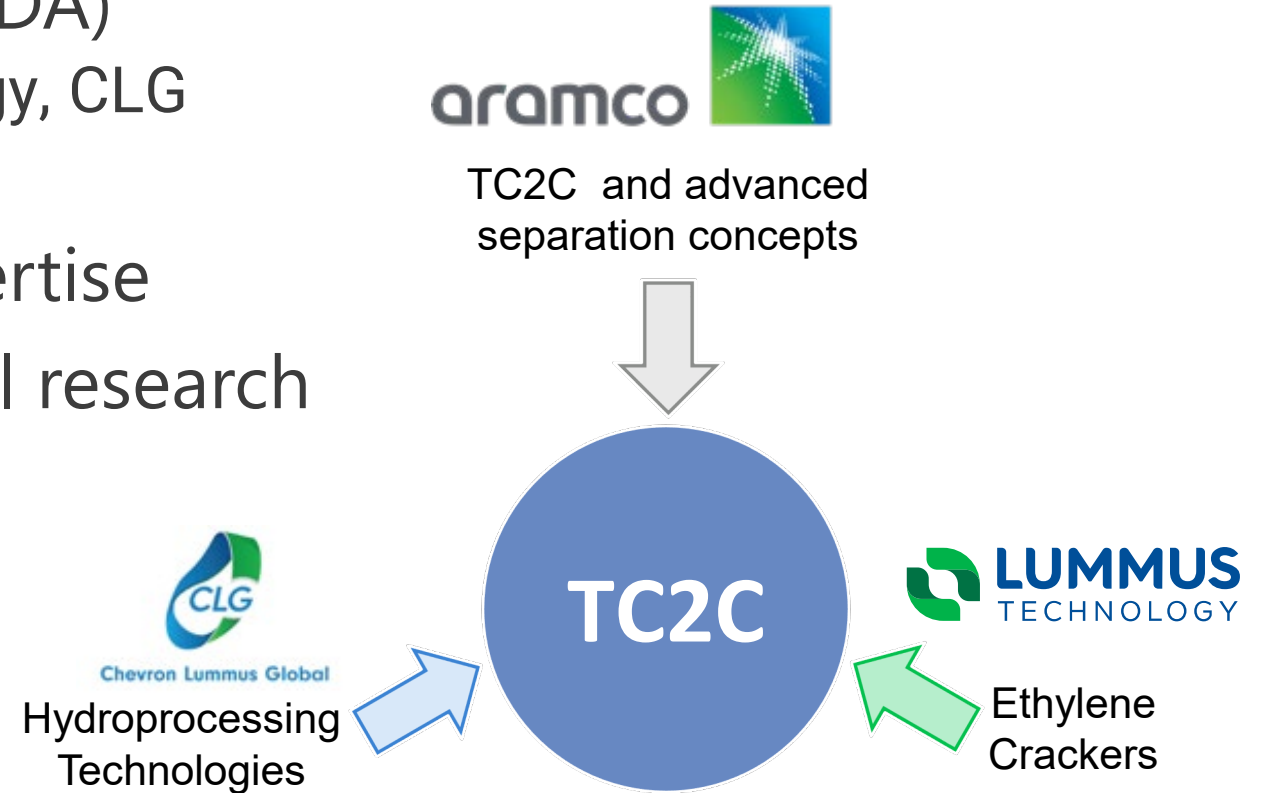


Required Mindset:

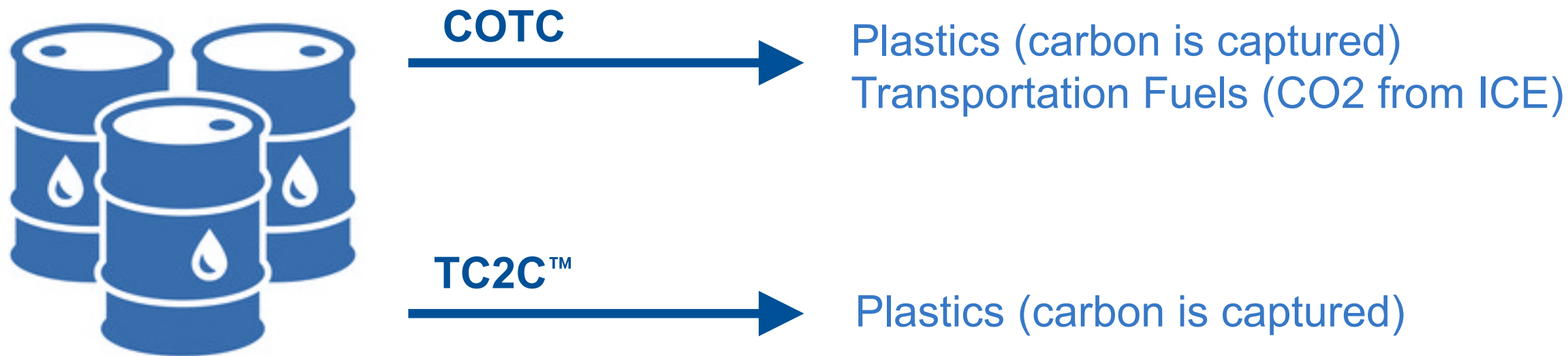
- Focus on high-value chemical production
- Chemical prices drive product slate
- Process light to medium crudes
- Less need for product flexibility
- Opportunistic produces fuel byproducts

Thermal Crude to Chemicals (TC2C™) Technology Quest: More Chemicals, Less Crude, Lower Energy Intensity

- Joint Development Agreement (JDA)
 - Saudi Aramco, Lummus Technology, CLG
 - Signed in 2018
- Combines technologies and expertise
- Built on 4 + years of fundamental research
- Key benefits:
 - Increased chemicals yields
 - Reduced CAPEX
 - Lower energy intensity
 - Feedstock and product flexibility

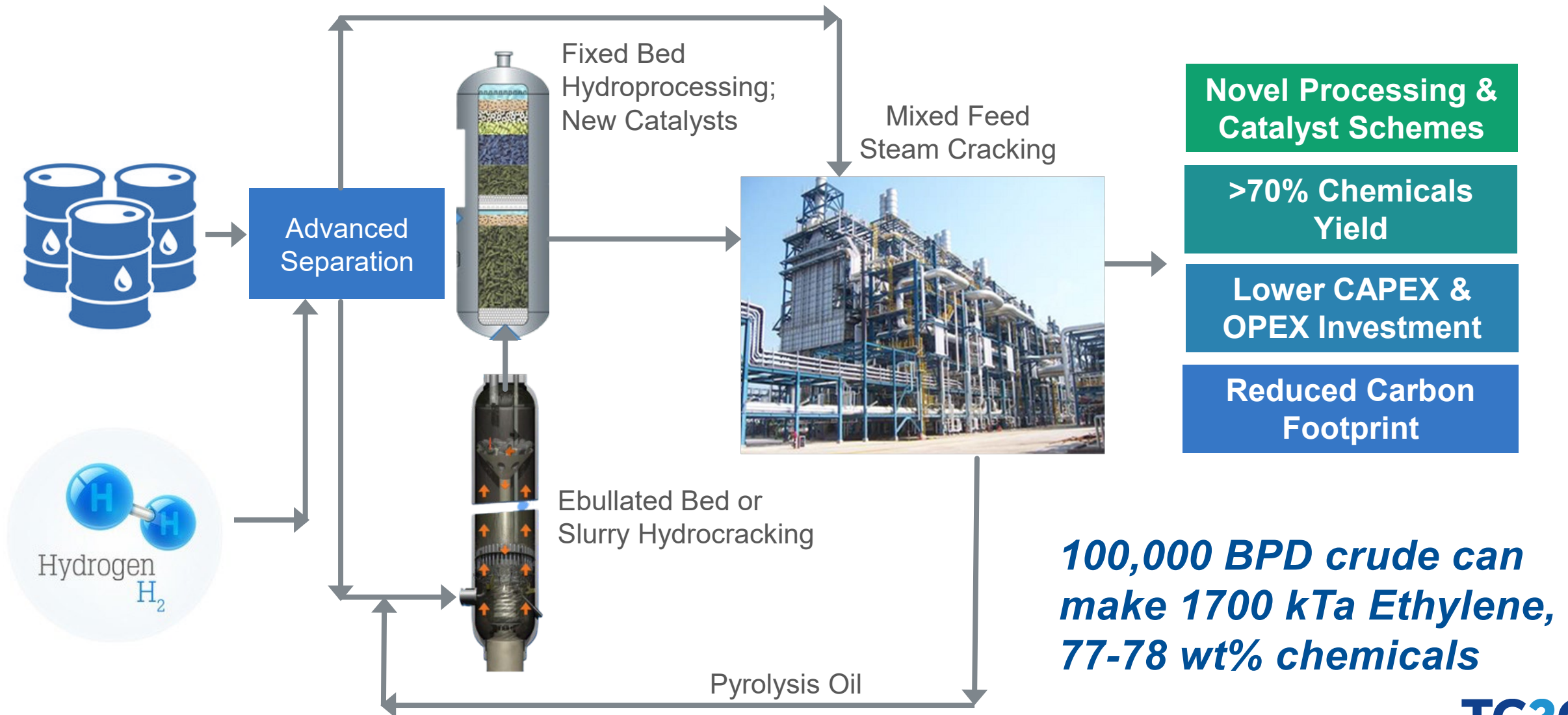


TC2C™ – Why is it different?

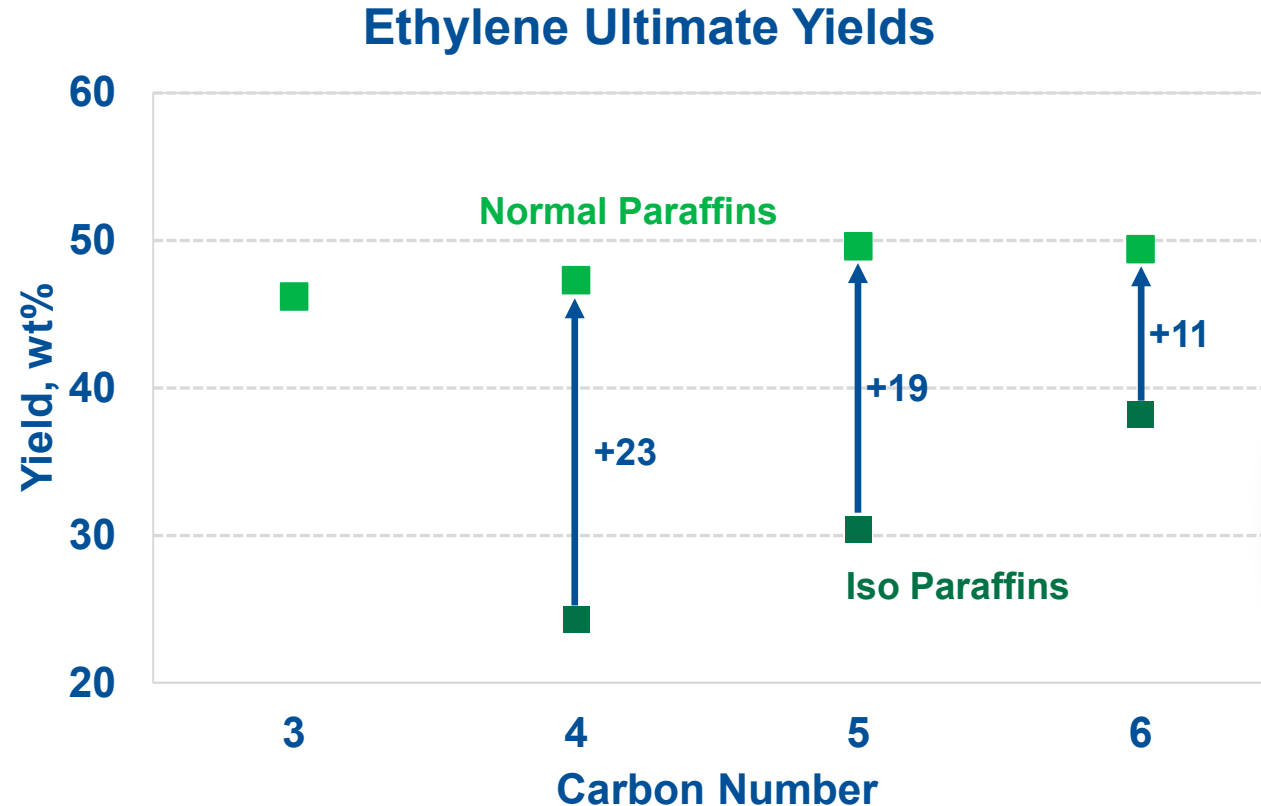


Conversion of crude oil into chemicals places carbon into plastics and other products as opposed to burning the crude oil for energy.

TC2C™ - Selective Processing of Crude and Cracker Components in Optimized Reaction Platforms



CLG New Hydrocracking Catalysts Designed to Maximize High-Quality Cracker Feedstocks



Enables high conversion of VGO's and Distillates without shift to iso-paraffins in light products

“Bolt-On” TC2C™ Benefits for an Existing Refinery

Dramatic Increase in Chemicals,
Decrease in Fuels Production

Debottlenecks Refinery,
Optimizes Unit Operations

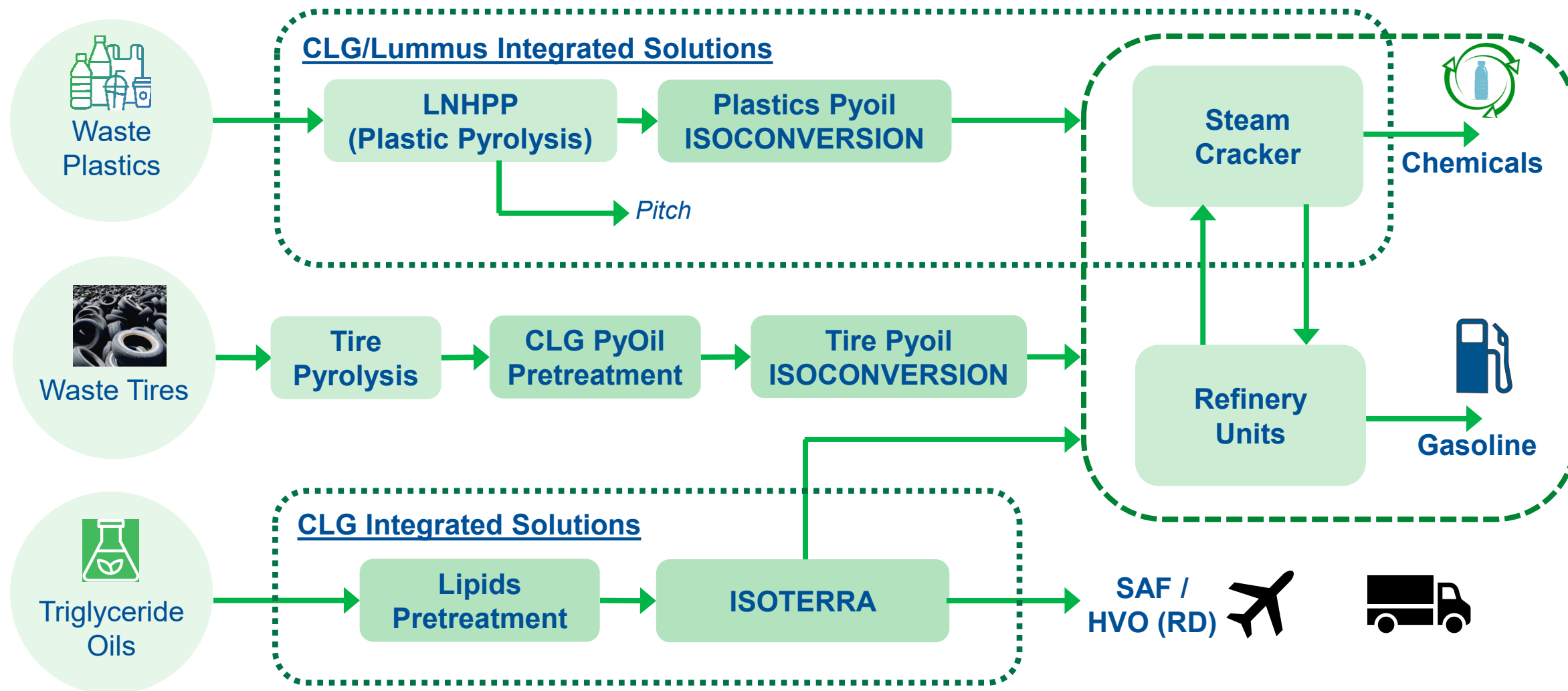
Can be “bolted on” during
regular turnaround

Upgrades low-value orphan
streams into petrochemicals

Reduces refinery's
carbon footprint



Renewables Feedstocks And Their Processes Can Also be Integrated Into Refinery and Chemical Plants



In Summary



- Refineries will transition from transportation fuels hubs to chemical feedstock generators
- Several pathways available depending on your feedstock sources and existing infrastructure
- All pathways must be low in carbon intensity to meet stakeholders expectations
- Powerful solutions such as TC2C now available to meet these challenges
- Renewables processing can also be a key ingredient for your transition

**We are here to help you
find your pathway to the
refinery of the future
Thank You**

**www.lummustech.com
daniel.gillis@lummustech.com**