



# Basics of Refining & Renewable Diesel

CAPITAL DISCIPLINE, INNOVATION AND  
UNMATCHED EXECUTION



# Agenda

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- 1** Crude Oil Overview
- 2** Basics of Refining
- 3** Refinery Optimization and Economics
- 4** Basics of Renewable Diesel

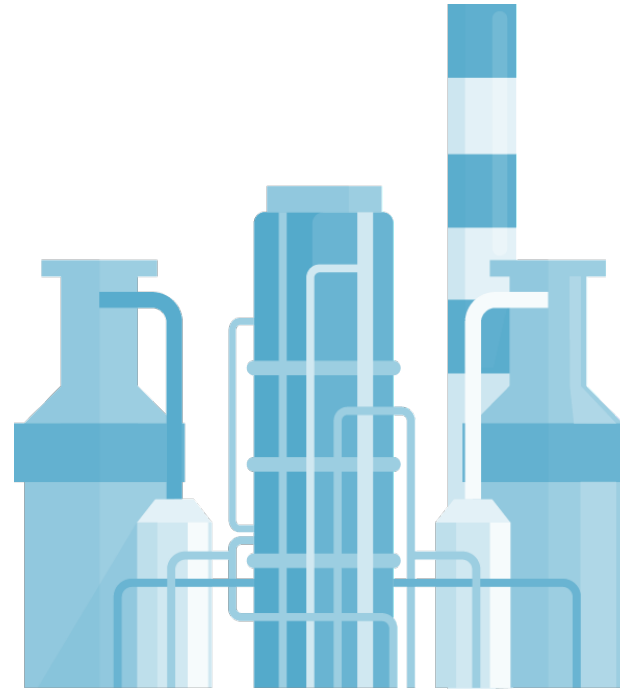


# Randy Hawkins

Vice President  
Crude & Feedstocks - Supply & Trading

# Crude oil characteristics

- Crude oils are blends of hydrocarbon molecules
  - Classified and priced by density, sulfur content and acidity
- **Density** is commonly measured in API gravity (relative density of crude oil to water)
  - API > 10: lighter, floats on water
  - API < 10: heavier, sinks in water
- **Sulfur** content is measured in weight percent
  - Less than 0.7% sulfur content = sweet
  - Greater than 0.7% sulfur content = sour
- **Acidity** is measured by Total Acid Number (TAN)
  - High acid crudes are those with TAN greater than 0.7
  - Acidic crudes are corrosive to refinery equipment and require greater investment to process significant volumes

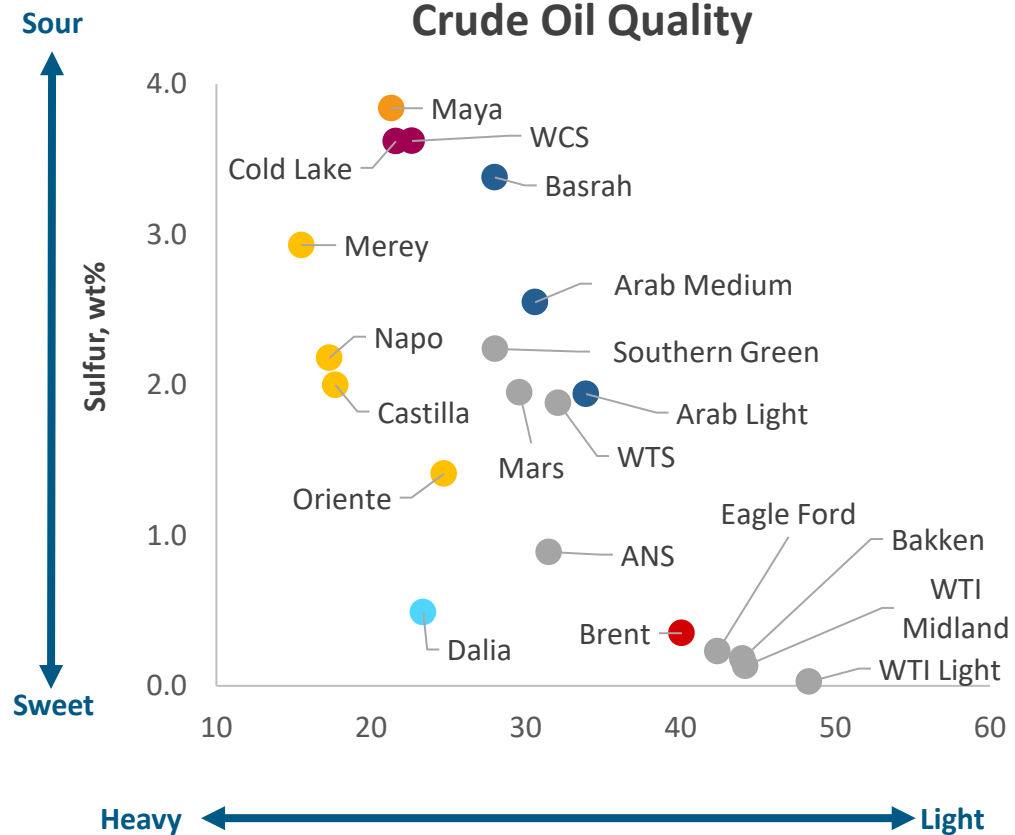
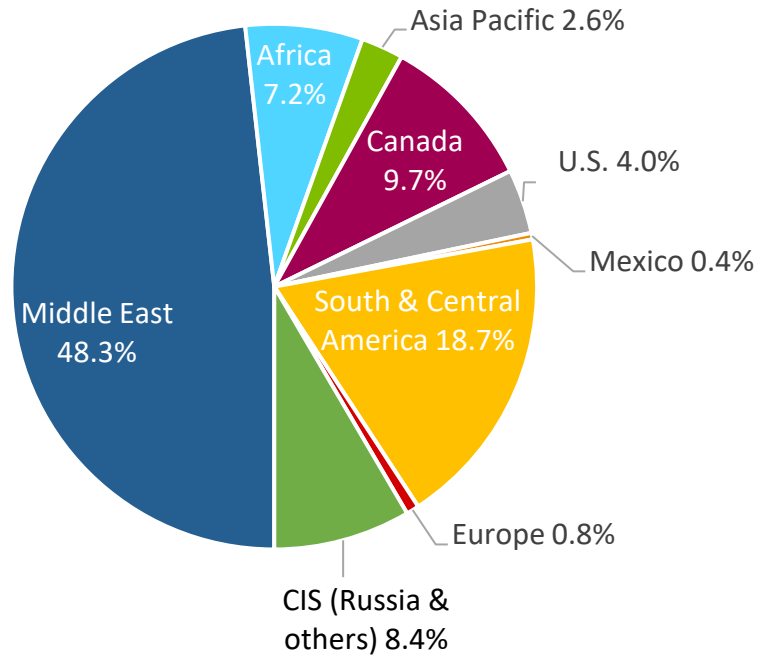


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**Heavy, sour, high acid crude oils** are more difficult to process, but **trade at a discount** relative to light, sweet, low acid crudes oils

# Crude oil reserves and quality

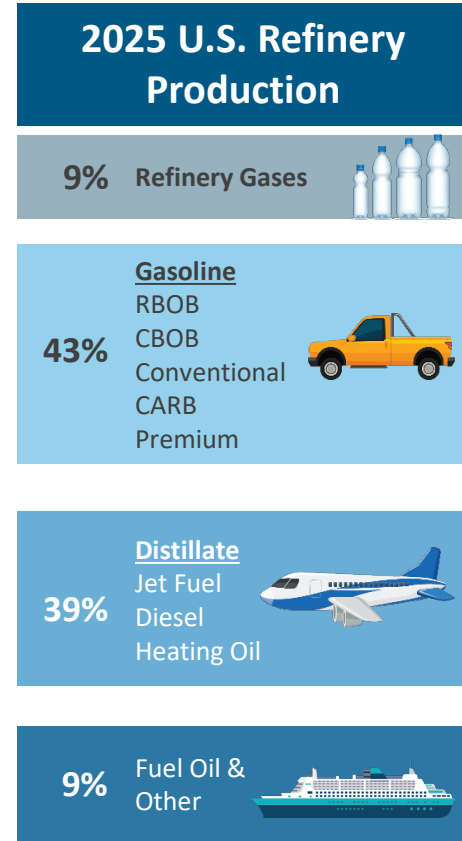
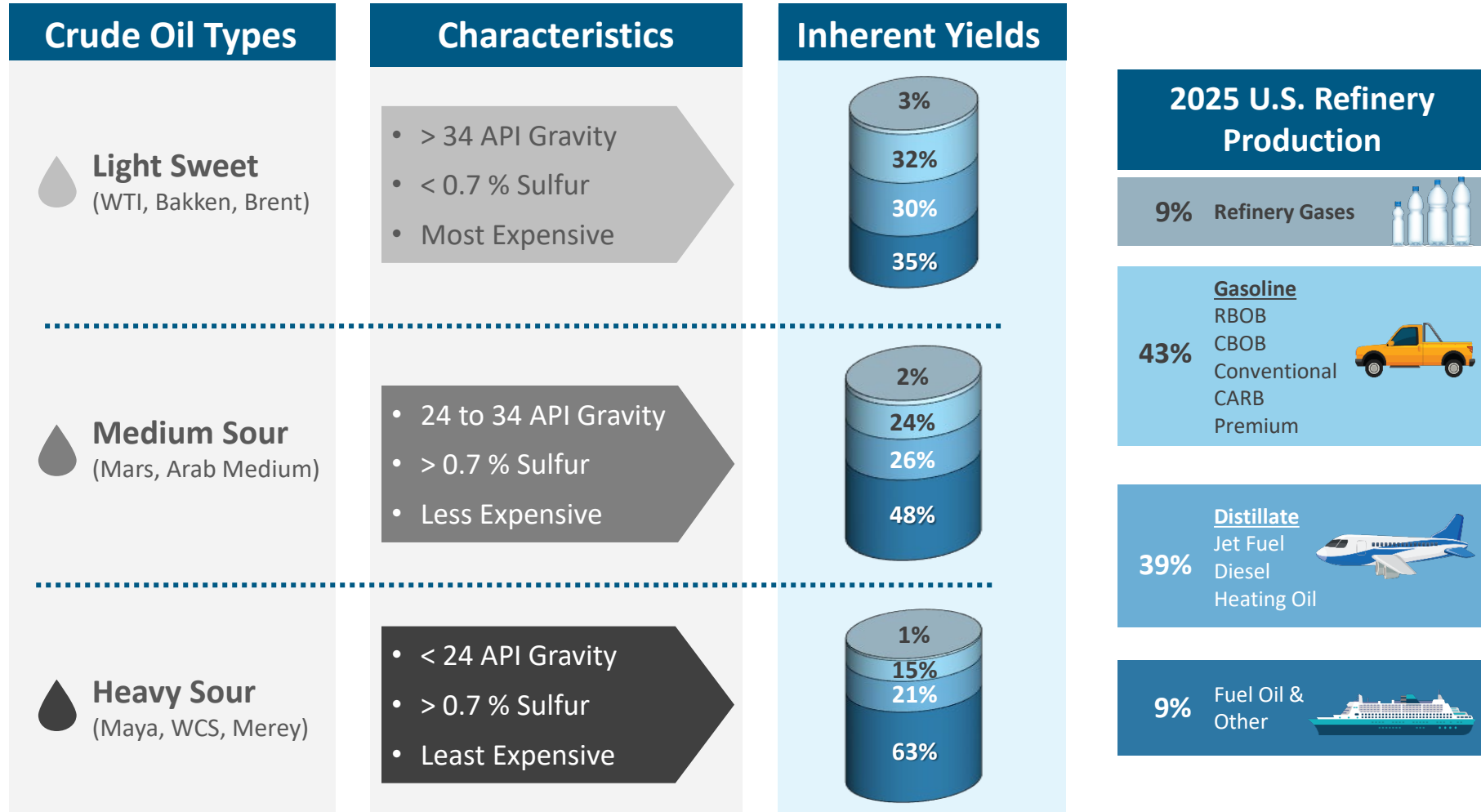
1.73 Trillion Barrels of Oil Reserves



Majority of global reserves are **sour crude oils**

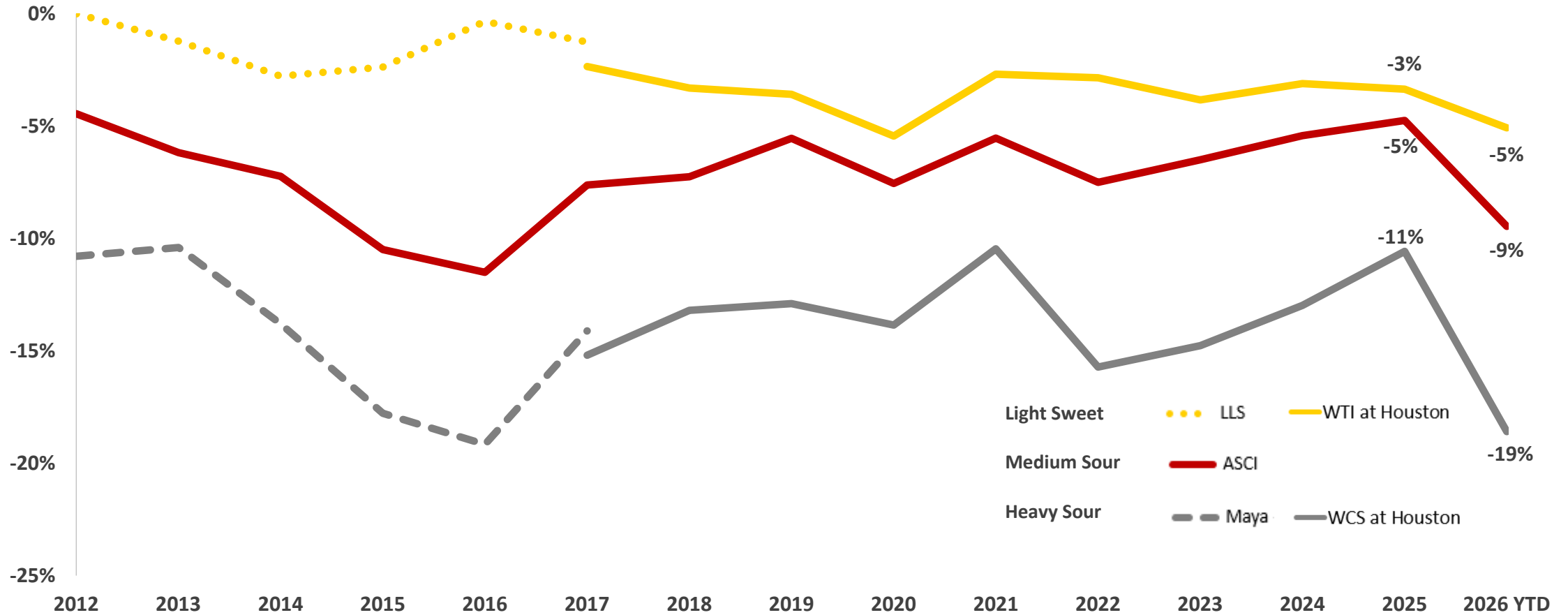
**WTI** and **Brent** are the primary light sweet crude oil **pricing benchmarks**

# What is in a barrel of crude oil?



Refineries **upgrade** crude oil into **higher value gasoline and distillates**

# Crude oil discounts relative to ICE Brent

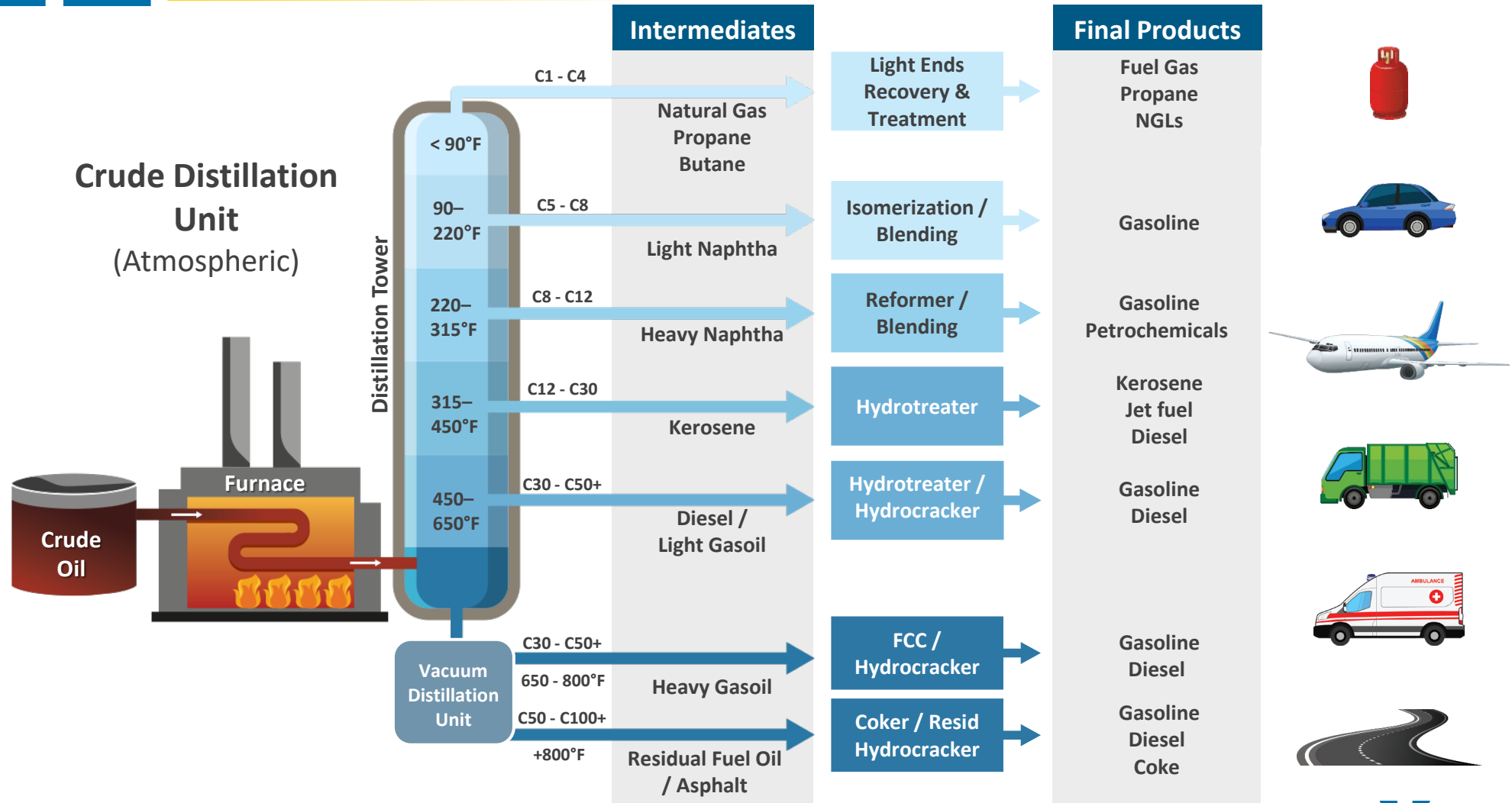




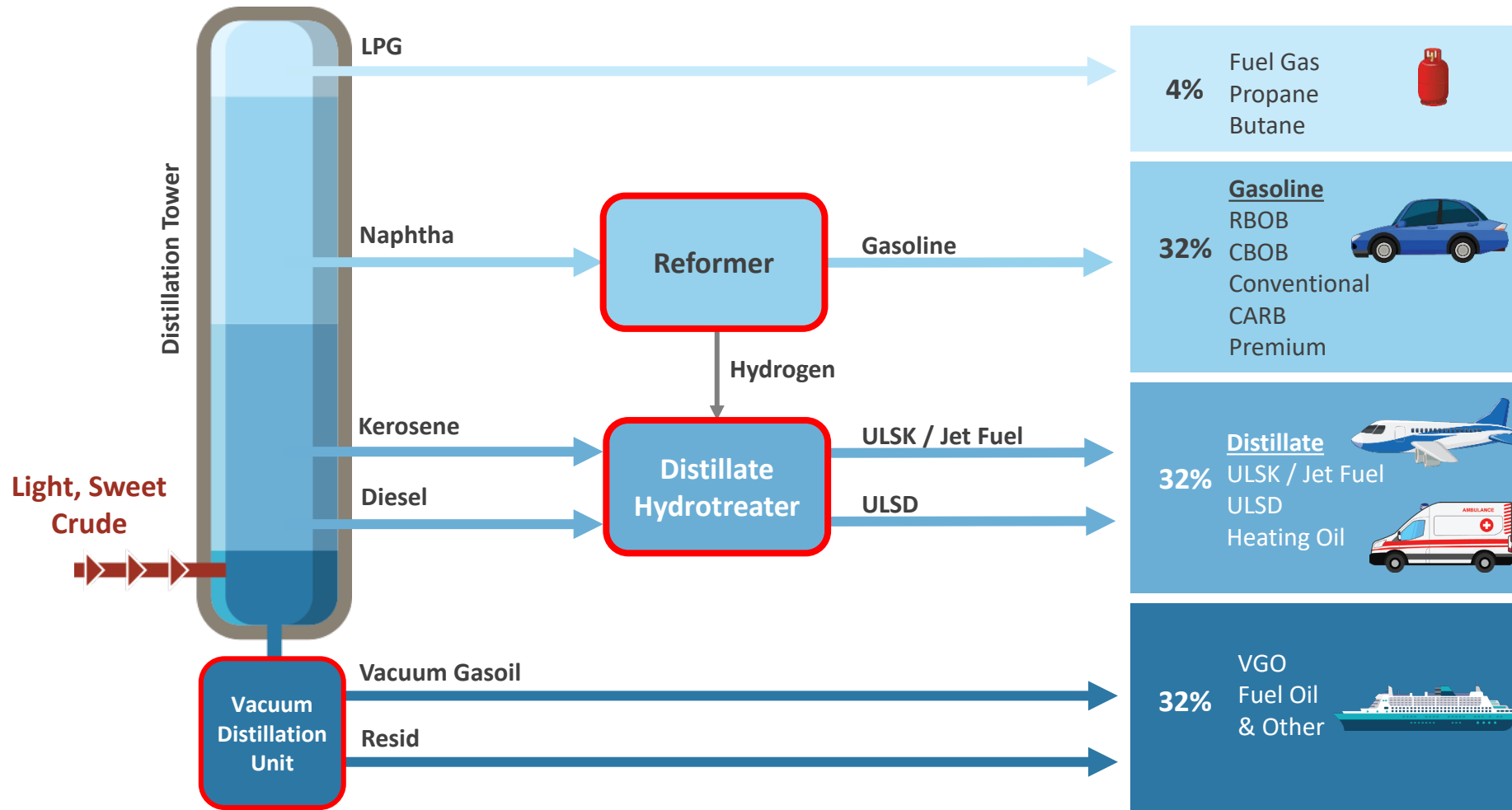
# Matt Dooley

Vice President  
Refining Services

# Basic refining concept

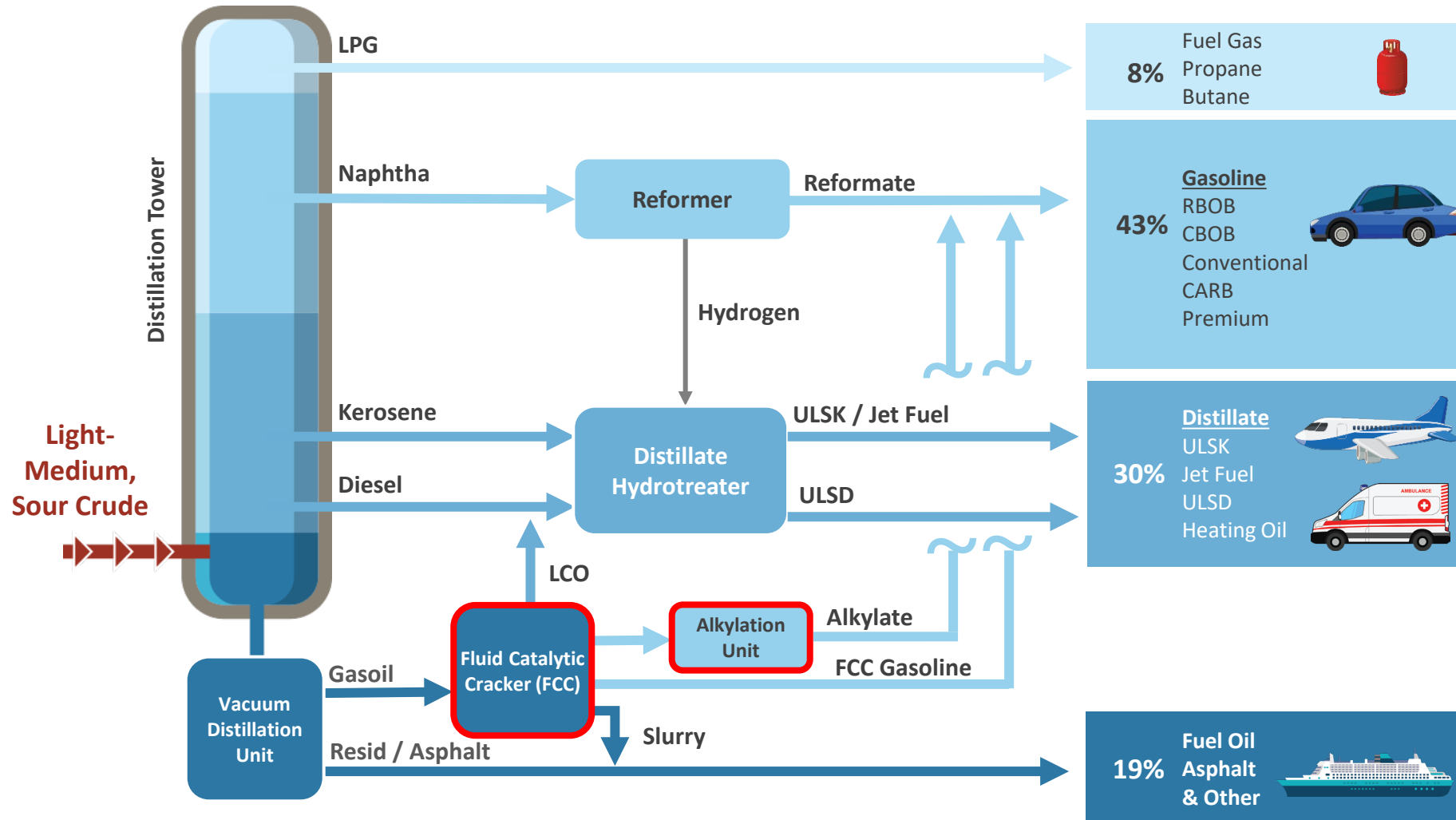


# Low conversion: Hydroskimming (Topping)



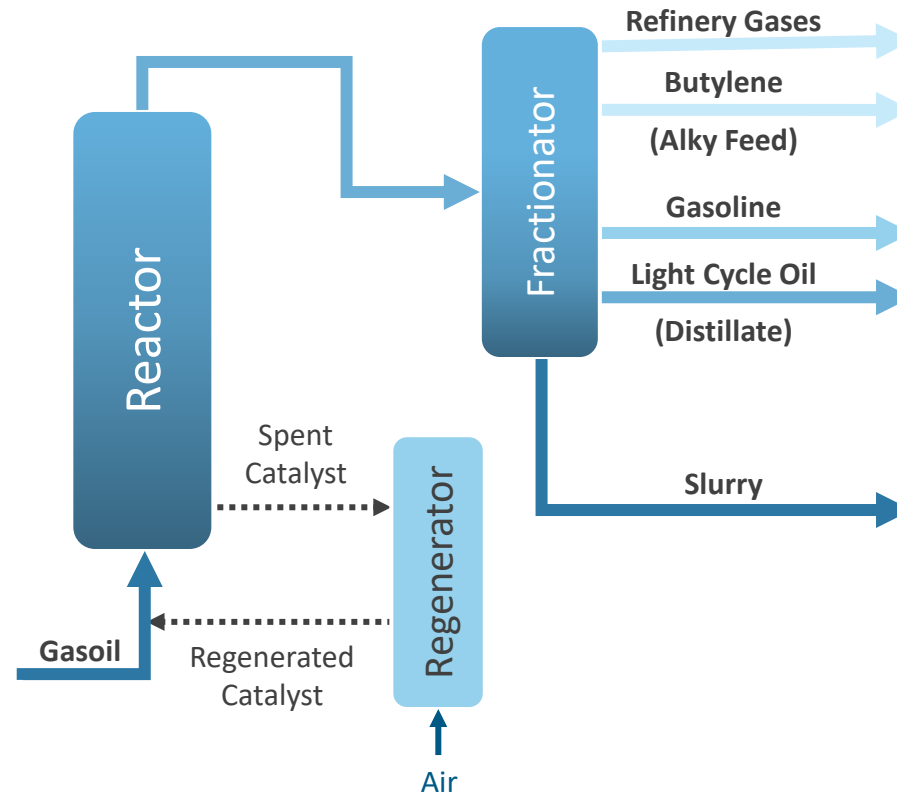
Low complexity refineries process **sweet crude oils**

# Medium conversion: Catalytic Cracking



Moderate complexity refineries tend to run more **sour crudes**, yield more **high value products** and achieve **higher volume gain**

# Fluid Catalytic Cracker (FCC)

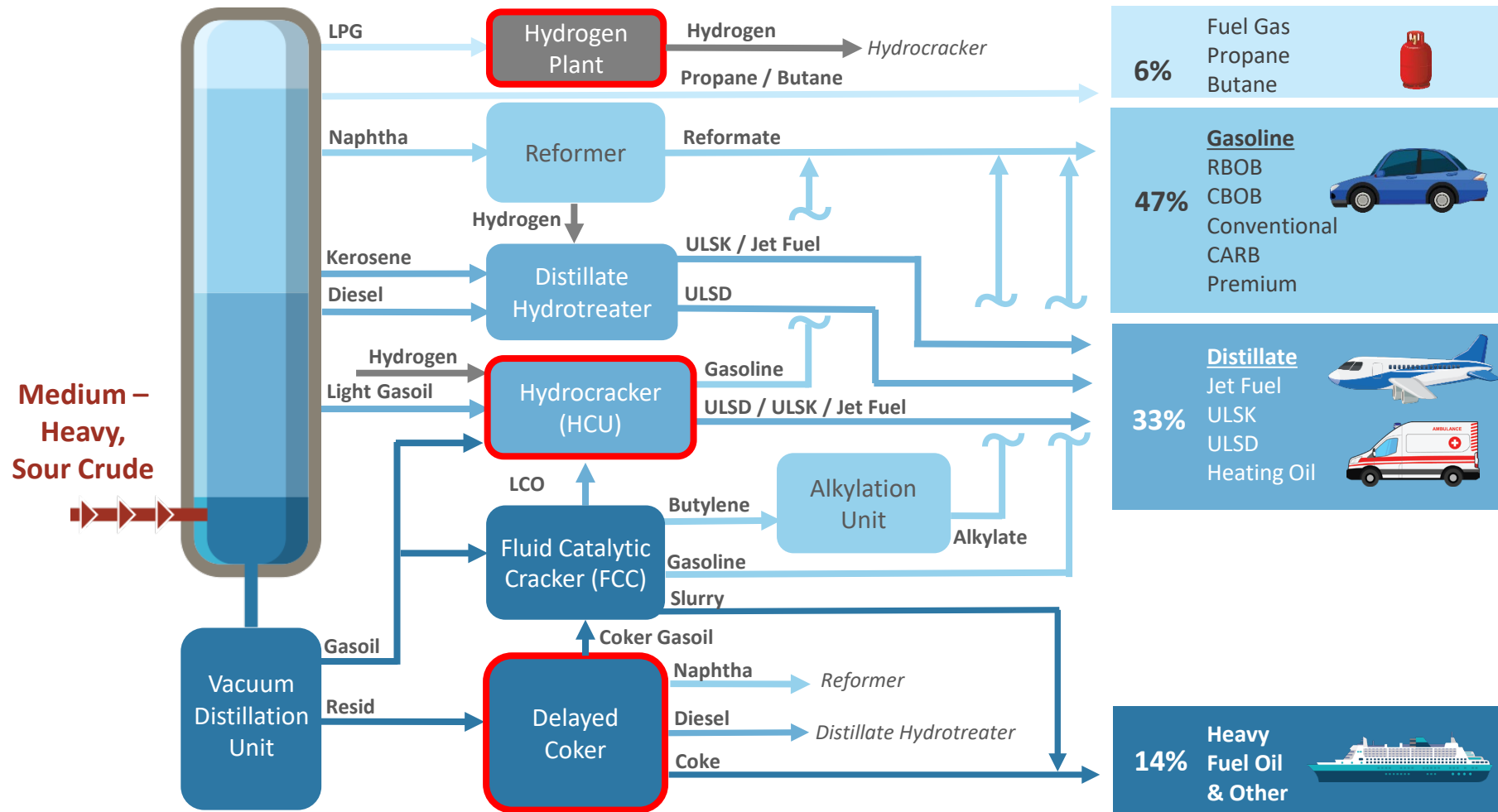


Total FCC liquid volume yield is approximately 110% of throughput



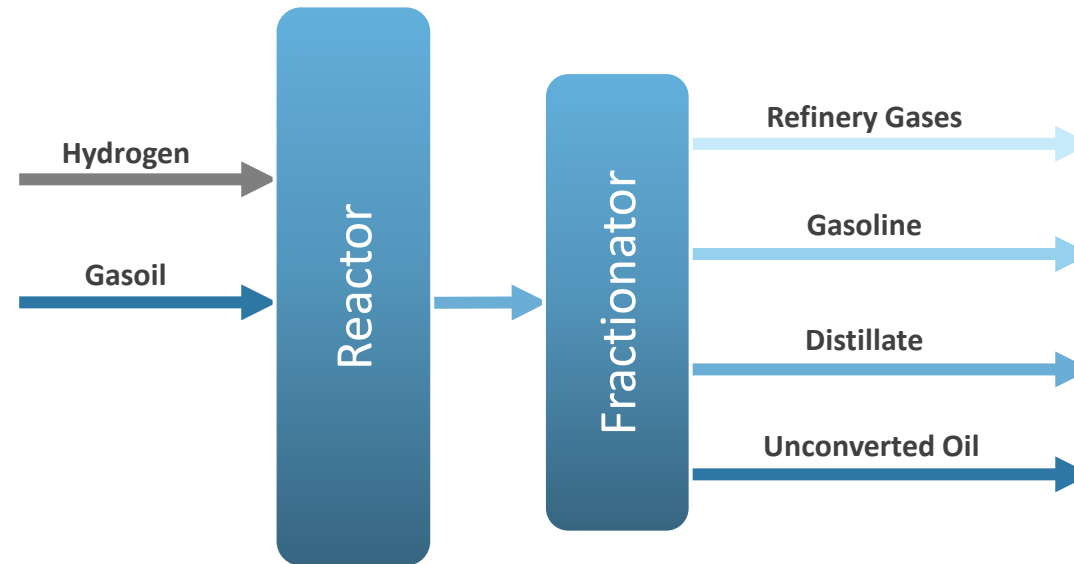
FCC converts **low-value gasoils** into **higher value light products**

# High complexity: Coking / Resid Destruction



High complexity refineries can run **heavier**, more **sour** crudes oils while achieving the **highest light product yields** and **volume gain**

# Hydrocracker Unit (HCU)

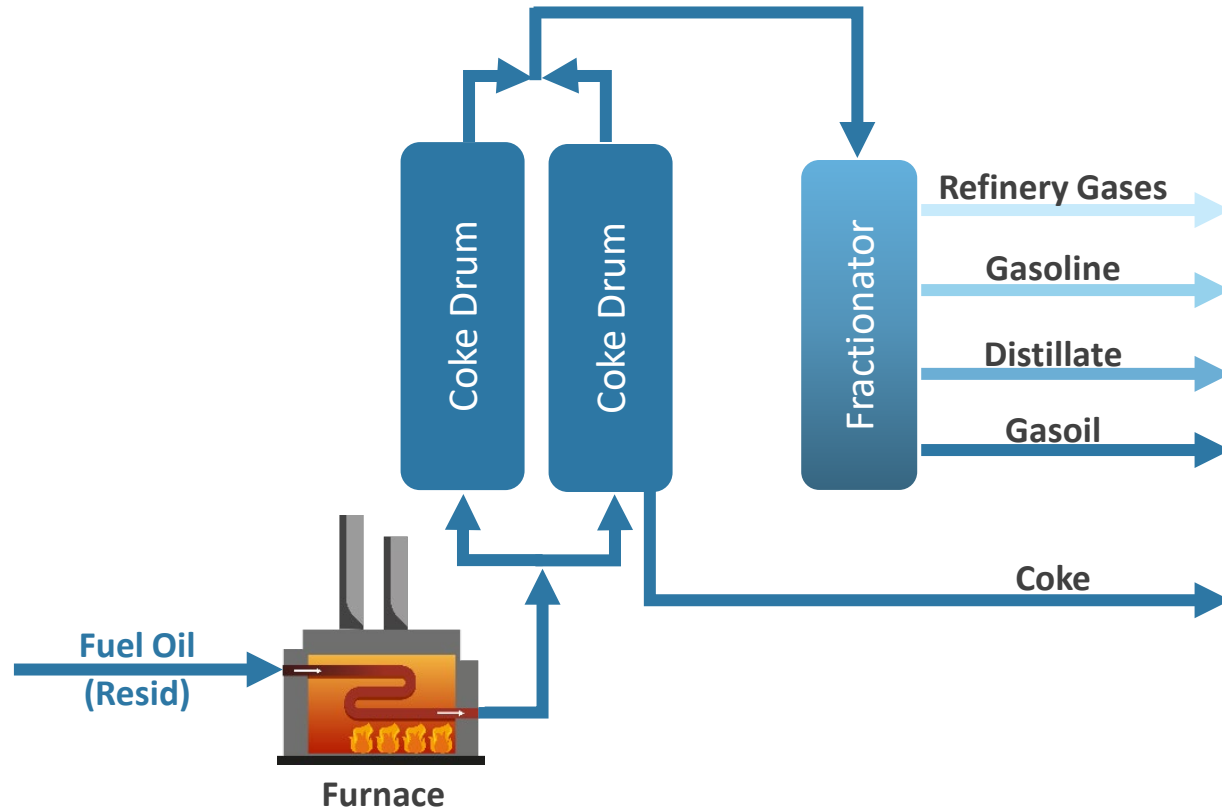


Total Hydrocracker liquid volume yield is approximately 110% to 115% of throughput

Upgrades high sulfur gasoil into **low sulfur gasoline, jet and diesel**

**Increases volumetric yield** of products through hydrogen saturation

# Delayed Coker

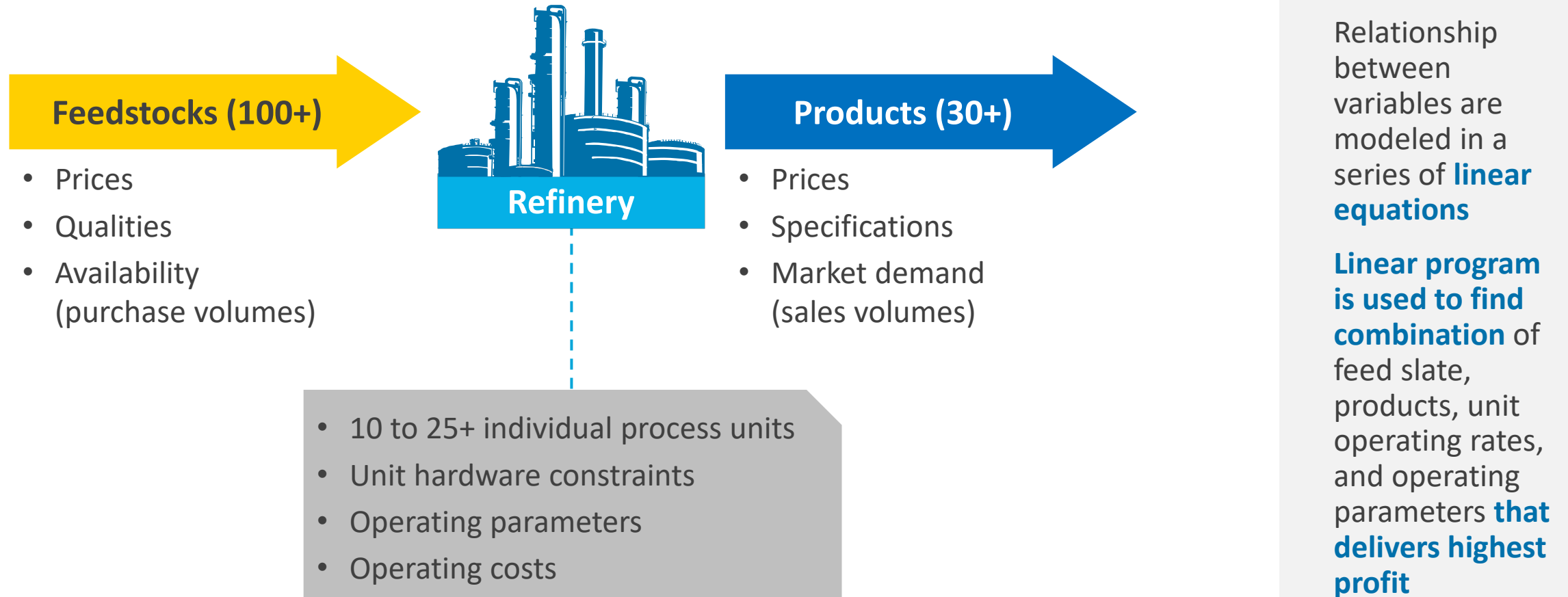


Total Coker unit liquid volume yield is approximately 80% of throughput

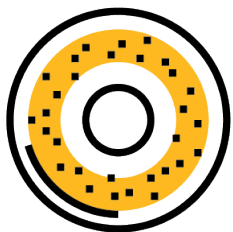


Upgrades **low value residual fuel oil** into **higher value light products**

# Maximizing refinery profit – Linear Programming (LP) Model



# Linear Program (LP) example: What's for breakfast?

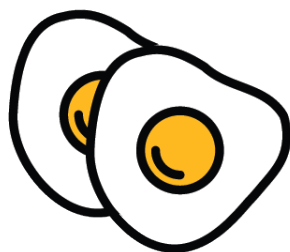


**1 LARGE BAGEL**

\$2.00

3 g protein

1 g fat



**2 LARGE EGGS**

\$3.50

6 g protein

5 g fat



**3 BACON SLICES**

\$4.00

8 g protein

8 g fat



**1 CUP OATMEAL**

\$2.50

4 g protein

1 g fat



**1 CUP ORANGE JUICE**

\$2.50

2 g protein

0 g fat



Your **goal** is to consume at **least 18 grams of protein**, but **not more than 10 grams of total fat** for the **lowest price**

# Optimizing breakfast from an engineer's point of view

*Solve for number of servings of each item:*

Consume at least 18 grams of protein

$$\left[ \text{Donut} \times 3 \text{ g} \right] + \left[ \text{Mug} \times 4 \text{ g} \right] + \left[ \text{Eggs} \times 6 \text{ g} \right] + \left[ \text{Bacon} \times 8 \text{ g} \right] + \left[ \text{Juice} \times 2 \text{ g} \right] \geq 18 \text{ grams protein}$$

Consume no more than 10 grams of total fat






$$\left[ \text{Donut} \times 1 \text{ g} \right] + \left[ \text{Mug} \times 1 \text{ g} \right] + \left[ \text{Eggs} \times 5 \text{ g} \right] + \left[ \text{Bacon} \times 8 \text{ g} \right] + \left[ \text{Juice} \times 0 \text{ g} \right] \leq 10 \text{ grams total fat}$$

Minimize the cost of breakfast

$$\left[ \text{Donut} \times \$2.00 \right] + \left[ \text{Mug} \times \$2.50 \right] + \left[ \text{Eggs} \times \$3.50 \right] + \left[ \text{Bacon} \times \$4.00 \right] + \left[ \text{Juice} \times \$2.50 \right] = \text{Minimum}$$


Even with only five food choices, there are so **many possible combinations** that using trial and error to find the one with the lowest cost is not efficient

# What's the optimal breakfast?

	<u>Servings</u>	<u>Unit Cost</u>	<u>Protein (g)</u>	<u>Total Fat (g)</u>
	0			
	2.7	✖ \$2.50 = \$6.75	✖ 4 = 10.8	✖ 1 = 2.7
	0			
	0.9	✖ \$4.00 = \$3.60	✖ 8 = 7.2	✖ 8 = 7.2
	0			

## Meal

\$10.35  
GOAL = Lowest
18 g  
Min protein
10 g  
Max fat



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**Linear programming** is a branch of applied mathematics concerned with **problems of constrained optimization**

**Price and “quality”** of each variable drives the **optimum solution**



# Eric Honeyman

Senior Vice President  
Renewables Operations & Low Carbon Fuels

# Global low-carbon fuel policies are driving demand growth for renewable diesel

	2030 GHG Emissions Reduction Target	Net-zero GHG Emissions Target	Primary Transportation Fuel Policy Mechanism	2030 Transportation Fuels Goal
California	40%	Net-zero by 2045	Low Carbon Fuel Standard (LCFS)	Reduce the carbon intensity of transportation fuels by at least 30%
Canada	40 to 45%	Net-zero by 2050	Clean Fuel Regulations (CFR)	Reduce the carbon intensity of transportation fuels by 15%
EU	55%	Net-zero by 2050	Renewable Energy Directive III (RED III)	Replace 29% of transport fuels with renewable energy, or reduce sector GHG intensity by 14.5%
UK	68%	Net-zero by 2050	Renewable Transport Fuel Obligation (RTFO)	Replace 19% of transport fuels with renewable fuels
Oregon	Clean Fuels Program requires a 20% carbon intensity reduction by 2030 and a 37% reduction by 2035			
New Mexico	Clean Transportation Fuel Standard, targeting a 20% carbon intensity reduction by 2030			
Washington State	Clean Fuel Standard requires a 45% carbon intensity reduction by 2038 (may be as high as 55% if certain conditions met)			
British Columbia	Low Carbon Fuel Standard requires a 30% carbon intensity reduction by 2030			
Norway	Biofuel for road transport mandated at 20% in 2026 and 21% in 2027			
U.S. Federal Policies	Renewable diesel demand is also driven by the EPA's Renewable Fuel Standard (RFS) and the IRS Production Tax Credits (PTC) included in the One Big Beautiful Bill (OBBB)			



**Up to 80% reduction in life cycle GHG emissions**

**Cost-effective fuel that can be used with existing vehicles**

**Drop-in fuel that does not require infrastructure investments**

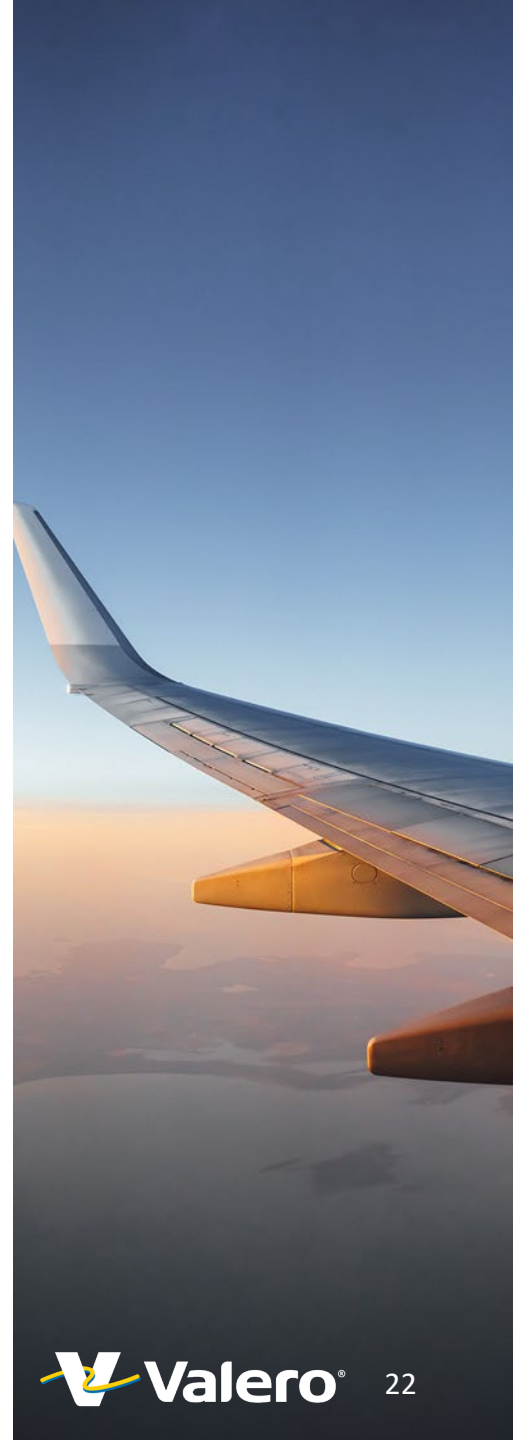
# SAF mandates are expanding globally

	SAF Mandates
<b>CORSIA</b>	Program aims to offset growth in CO <sub>2</sub> emission from international aviation above 85% of 2019 emissions. Participation is voluntary over 2021-2026 and becomes mandatory for participating nations starting in 2027 <sup>(1)</sup>
<b>EU<sup>(2)</sup></b>	2% in 2025, 6% in 2030, 20% in 2035, 34% in 2040, 42% in 2045, and 70% in 2050
<b>France<sup>(3)</sup></b>	1.5% in 2024, 2% in 2025 and 5% in 2030
<b>Sweden<sup>(3)</sup></b>	1% in 2021 and increasing to 30% in 2030
<b>Switzerland</b>	2% in 2026 and increasing to 6% by 2030
<b>Norway</b>	2% in 2026, expected to increase to 30% in 2030
<b>UK</b>	2% in 2025, increasing linearly to 10% in 2030 and then to 22% in 2040
<b>British Columbia</b>	1% in 2028, 2% in 2029 and 3% in 2030
<b>Brazil</b>	GHG emission reduction of 1% in 2027, progressively increasing to 10% by 2037, through the use of SAF
<b>India</b>	Target of 1% by 2027, 2% by 2028, and 5% by 2030
<b>Japan</b>	10% by 2030
<b>Singapore</b>	1% in 2026, possibly increasing to 3%-5% in 2030
<b>South Korea</b>	1% in 2027, increasing to 3-5% in 2030 and 7-10% in 2035
<b>Thailand</b>	1% in 2026, increasing to 1-2% over 2027-29, 3-5% over 2030-32, and 5-8% over 2033-37
<b>Potential Policies</b>	Indonesia, Malaysia, Iceland <sup>(2)</sup> , Liechtenstein <sup>(2)</sup> , and Netherlands <sup>(3)</sup>

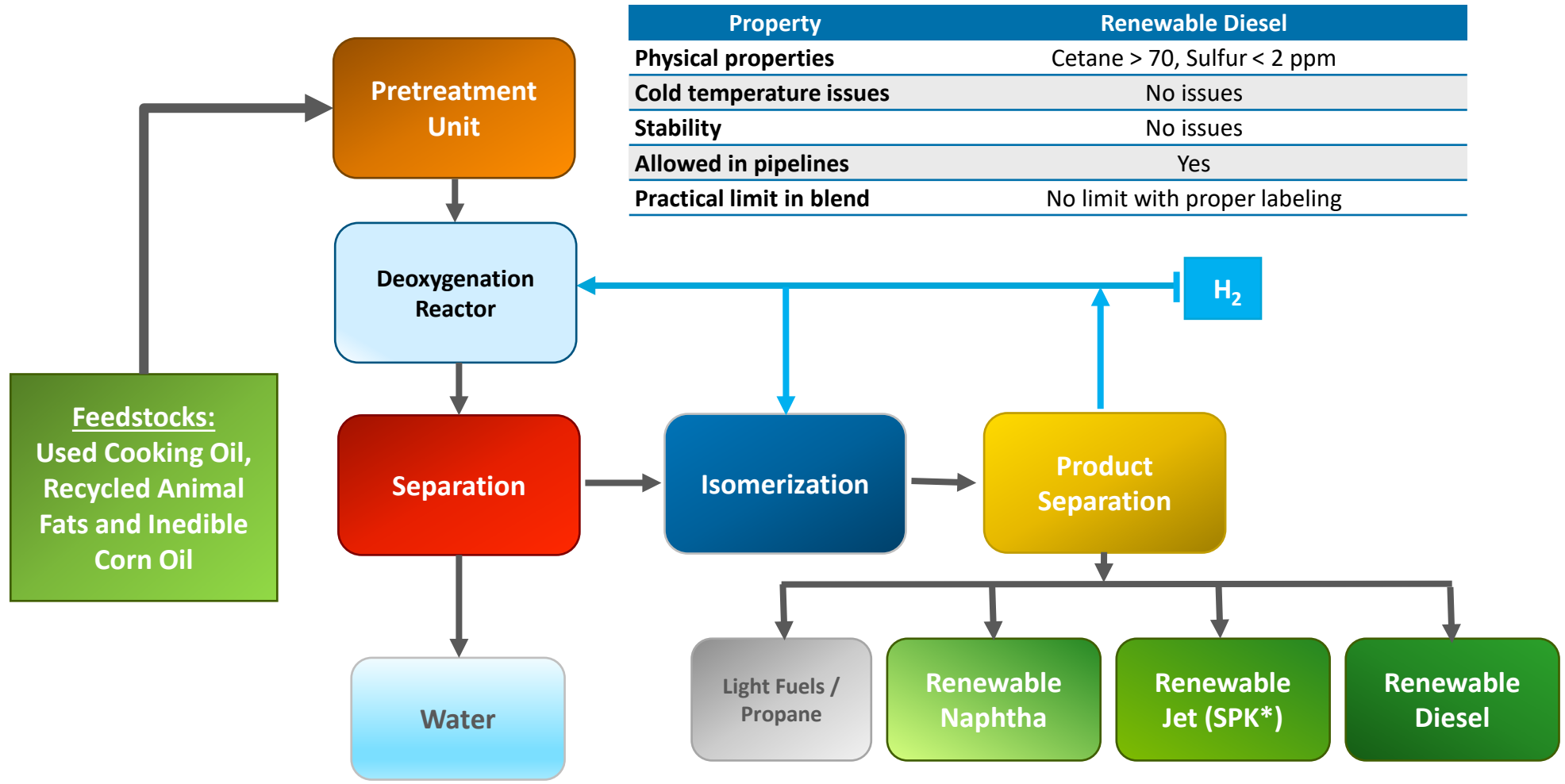
<sup>(1)</sup>Currently 130 nations voluntarily participate

<sup>(2)</sup>European Union's ReFuelEU Aviation regulation

<sup>(3)</sup>Member of the EU and will be covered by ReFuelEU Aviation



# Renewable diesel process and properties



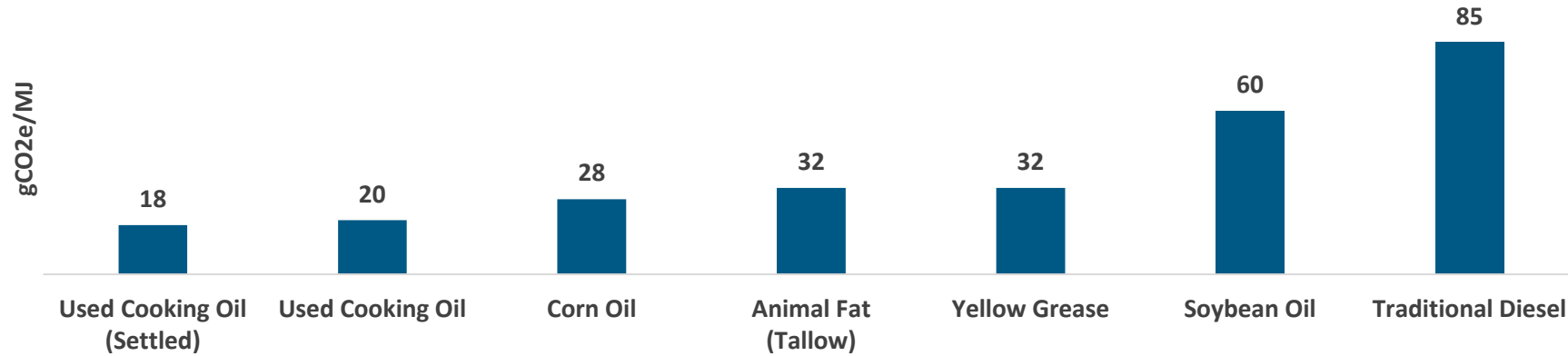
Property	Renewable Diesel
Physical properties	Cetane > 70, Sulfur < 2 ppm
Cold temperature issues	No issues
Stability	No issues
Allowed in pipelines	Yes
Practical limit in blend	No limit with proper labeling

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**Pretreatment Unit** allows the plant to process advantaged, low carbon intensity feedstocks

# DGD utilizes a variety of renewable feedstocks

DGD St. Charles Renewable Diesel California Carbon Intensity



Renewable diesel derived from UCO has a **\$0.85 per gallon** LCFS credit value, compared to soybean oil at **\$0.33 per gallon\***

\*Assuming \$100 per metric ton carbon price, UCO CI of 20 and soybean oil CI of 60

# Questions and Answers



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# Major refining processes – Crude processing

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- **Definition**

- Separating crude oil into different hydrocarbon groups.
- The most common means is through distillation.

- **Process**

- **Desalting** – Prior to distillation, crude oil is often desalted to remove corrosive salts as well as metals and other suspended solids.
- **Atmospheric distillation** – Used to separate the desalted crude into specific hydrocarbon groups (straight run gasoline, naphtha, light gas oil, etc.) or fractions.
- **Vacuum distillation** – Heavy crude residue (“bottoms”) from the atmospheric column is further separated using a lower-pressure distillation process. Means to lower the boiling points of the fractions and permit separation at lower temperatures, without decomposition and excessive coke formation.



# Major refining processes – Cracking

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- **Definition**

- Breaking down large, heavy hydrocarbon molecules into smaller hydrocarbon molecules through application of heat (thermal) or the use of catalysts.

- **Process**

- **Coking** – Thermal non-catalytic cracking process that converts low value oils to higher value gasoline, gas oils and marketable coke. Residual fuel oil from vacuum distillation column is typical feedstock.
- **Visbreaking** – Thermal non-catalytic process used to convert large hydrocarbon molecules in heavy feedstocks to lighter products such as fuel gas, gasoline, naphtha, and gas oil. Produces sufficient middle distillates to reduce the viscosity of the heavy feed.
- **Catalytic cracking** – A central process in refining where heavy gas oil range feeds are subjected to heat in the presence of catalyst, whereby large molecules crack into smaller molecules in the gasoline and lighter boiling ranges.
- **Catalytic hydrocracking** – Like cracking, used to produce blending stocks for gasoline and other fuels from heavy feedstocks. Introduction of hydrogen in addition to a catalyst allows the cracking reaction to proceed at lower temperatures than in catalytic cracking, although pressures are much higher.



# Major refining processes – Combination

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- **Definition**

- Linking two or more hydrocarbon molecules together to form a large molecule (e.g. converting gases to liquids) or rearranging to improve the quality of the molecule.

- **Process**

- **Alkylation** – Important process to upgrade light olefins to high-value gasoline components. Used to combine small molecules into large molecules to produce a higher octane product for blending into gasoline.
- **Catalytic reforming** – The process whereby naphthas are changed chemically to increase their octane number. Octane number is a measure of whether a gasoline will knock in an engine. The higher the octane number, the more resistance to pre or self-ignition.
- **Polymerization** – Process that combines smaller molecules to produce high octane blendstock.
- **Isomerization** – Process used to produce compounds with high octane for blending into the gasoline pool. Also used to produce isobutene, an important feedstock for alkylation.



# Major refining processes – Treating

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- **Definition**

- Processing of petroleum products to remove some of the sulfur, nitrogen, heavy metals, and other impurities

- **Process**

- **Catalytic hydrotreating and hydroprocessing** – Used to remove impurities (e.g. sulfur, nitrogen, oxygen, and halides) from petroleum fractions. Hydrotreating further upgrades heavy feeds by converting olefins and diolefins to paraffins, which reduces gum formation in fuels. Hydroprocessing also cracks heavier products to lighter, more saleable products.

# Refining and renewable diesel acronyms

- **AGO** – Atmospheric Gasoil
- **API** – American Petroleum Institute
- **ATB** – Atmospheric Tower Bottoms
- **B–B** – Butane-Butylene Fraction
- **BBLs** – Barrels
- **BPD** – Barrels Per Day
- **BTC** – Blenders Tax Credit
- **BTX** – Benzene, Toluene, Xylene
- **CARB** – California Air Resource Board
- **CCR** – Continuous Catalytic Regenerator
- **CI** – Carbon Intensity
- **DAO** – De-Asphalted Oil
- **DCS** – Distributed Control Systems
- **DHT** – Diesel Hydrotreater
- **DSU** – Desulfurization Unit
- **EPA** – Environmental Protection Agency
- **ESP** – Electrostatic Precipitator
- **FCC** – Fluid Catalytic Cracker
- **GDU** – Gasoline Desulfurization Unit
- **GHT** – Gasoline Hydrotreater
- **GOHT** – Gasoil Hydrotreater
- **GPM** – Gallon Per Minute
- **HAGO** – Heavy Atmospheric Gasoil
- **HCU** – Hydrocracker Unit
- **HDS** – Hydrodesulfurization
- **HDT** – Hydrotreating
- **HGO** – Heavy Gasoil
- **HOC** – Heavy Oil Cracker
- **H<sub>2</sub>** – Hydrogen
- **H<sub>2</sub>S** – Hydrogen Sulfide
- **HF** – Hydrofluoric (acid)
- **HVGO** – Heavy Vacuum Gasoil
- **kV** – Kilovolt
- **kVA** – Kilovolt Amp
- **LCFS** – Low Carbon Fuel Standard
- **LCO** – Light Cycle Oil
- **LGO** – Light Gasoil
- **LPG** – Liquefied Petroleum Gas
- **LSD** – Low Sulfur Diesel
- **LSR** – Light Straight Run (Gasoline)
- **MON** – Motor Octane Number
- **MTBE** – Methyl Tertiary-Butyl Ether
- **MW** – Megawatt
- **NGL** – Natural Gas Liquids
- **NOX** – Nitrogen Oxides
- **P–P** – Propane-Propylene
- **PSI** – Pounds per Square Inch
- **PTC** – Production Tax Credit
- **RBOB** – Reformulated Blendstock for Oxygenate Blending
- **RDS** – Resid Desulfurization
- **RFG** – Reformulated Gasoline
- **RFS** – Renewable Fuel Standard
- **RIN** – Renewable Identification Number
- **RON** – Research Octane Number
- **RVP** – Reid Vapor Pressure
- **SMR** – Steam Methane Reformer (Hydrogen Plant)
- **SAF** – Sustainable Aviation Fuel
- **SOX** – Sulfur Oxides
- **SPK** – Synthetic Paraffinic Kerosene
- **SRU** – Sulfur Recovery Unit
- **TAME** – Tertiary Amyl Methyl Ether
- **TAN** – Total Acid Number
- **UCO** – Used Cooking Oil
- **ULSD** – Ultra Low Sulfur Diesel
- **ULSK** – Ultra Low Sulfur Kerosene
- **VGO** – Vacuum Gasoil
- **VOC** – Volatile Organic Compound
- **VPP** – Voluntary Protection Program
- **VTB** – Vacuum Tower Bottoms
- **WTI** – West Texas Intermediate
- **WWTP** – Waste Water Treatment Plant

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and make a **better future**  
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