VALERO
ENERGY CORPORATION

Presentation to Lehman Brothers

Refining 101: Refinery Basic Operations
Refining 201: Coking Technologies and Applications
January 16, 2007

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Executive Vice President

Refining Operations

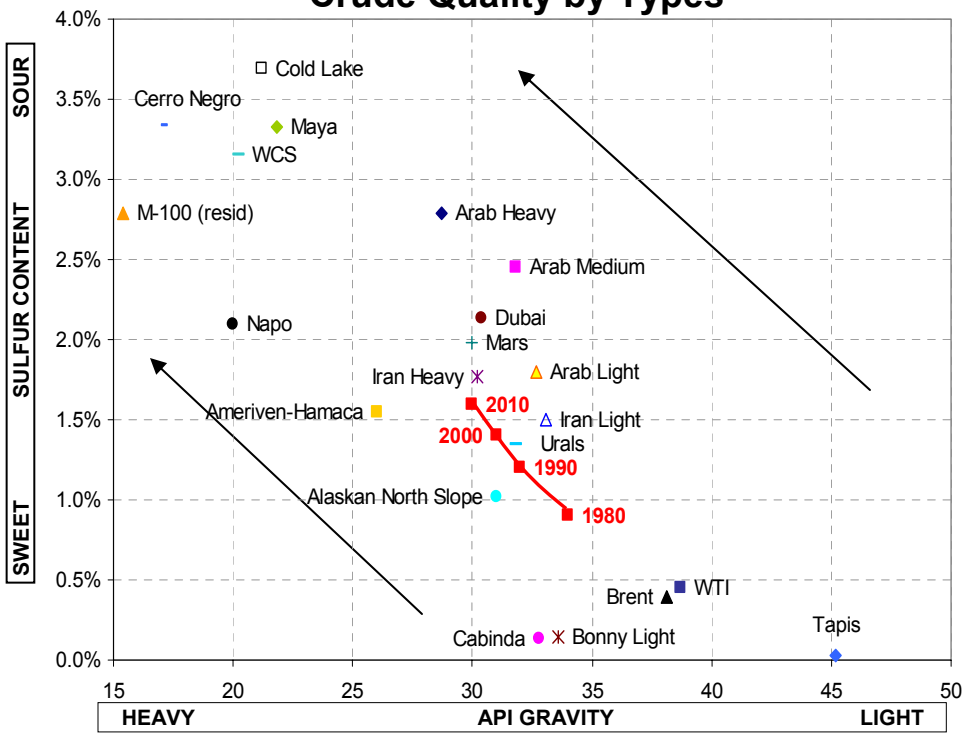
Refining 101: Refinery Basic Operations

Crude Oil Characteristics

- Crudes are classified and priced by density and sulfur content
- Crude density is commonly measured by API gravity
  - API gravity provides a relative measure of crude oil density
  - The higher the API number, the lighter the crude
    - Light crudes are easier to process
    - Heavy crudes are more difficult to process
- Crude sulfur content is measured as a percentage
  - Less than 0.7% sulfur content = sweet
  - Greater than 0.7% sulfur content = sour
  - High sulfur crudes require additional processing to meet regulatory specs
- Acid content is measured by Total Acid Number (TAN)
  - Acidic crudes highly corrosive to refinery equipment
  - High acid crudes are those with TAN greater than 0.7

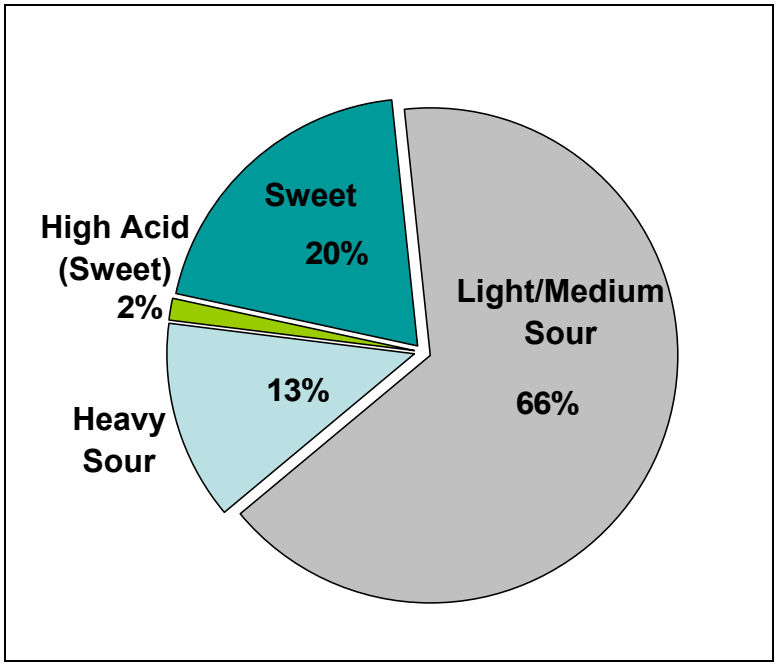
Crude Oil Basics

Crude Quality by Types



Source: Simmons & Co.
NOTE: Red line represents the average crude quality by decade (actual and projected)

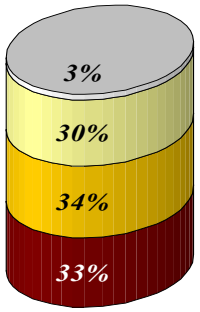
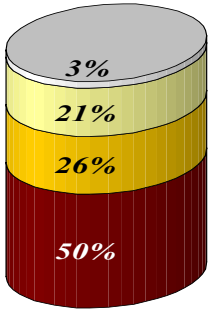
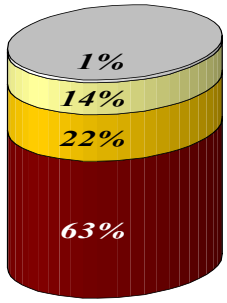
Estimated Quality of Reserves (2006)



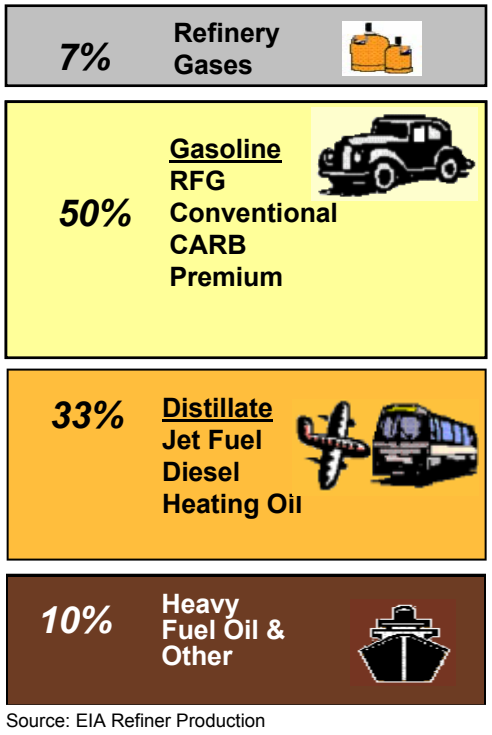
Source: Oil & Gas Journal, Company Information

- Majority of global reserves are light/medium sour
- Most quoted benchmark prices are light sweet crudes
  - WTI (West Texas Intermediate), Western Hemisphere
  - Brent (North Sea Crude), Europe
- Historical trend shows global crude supply becoming heavier and more sour

What's in a Barrel of Crude Oil?

Crude Types	Characteristics	Yields
Light Sweet Crude (i.e. WTI, Brent)	> 34 API Gravity < 0.7 % Sulfur 35% Demand Most Expensive	
Medium Sour Crude (i.e. Mars, Arab Light, Arab Medium)	24 – 34 API Gravity > 0.7 % Sulfur 50% Demand Less Expensive	
Heavy Sour Crude (i.e. Maya)	< 24 API Gravity > 0.7 % Sulfur 15% Demand Least Expensive	

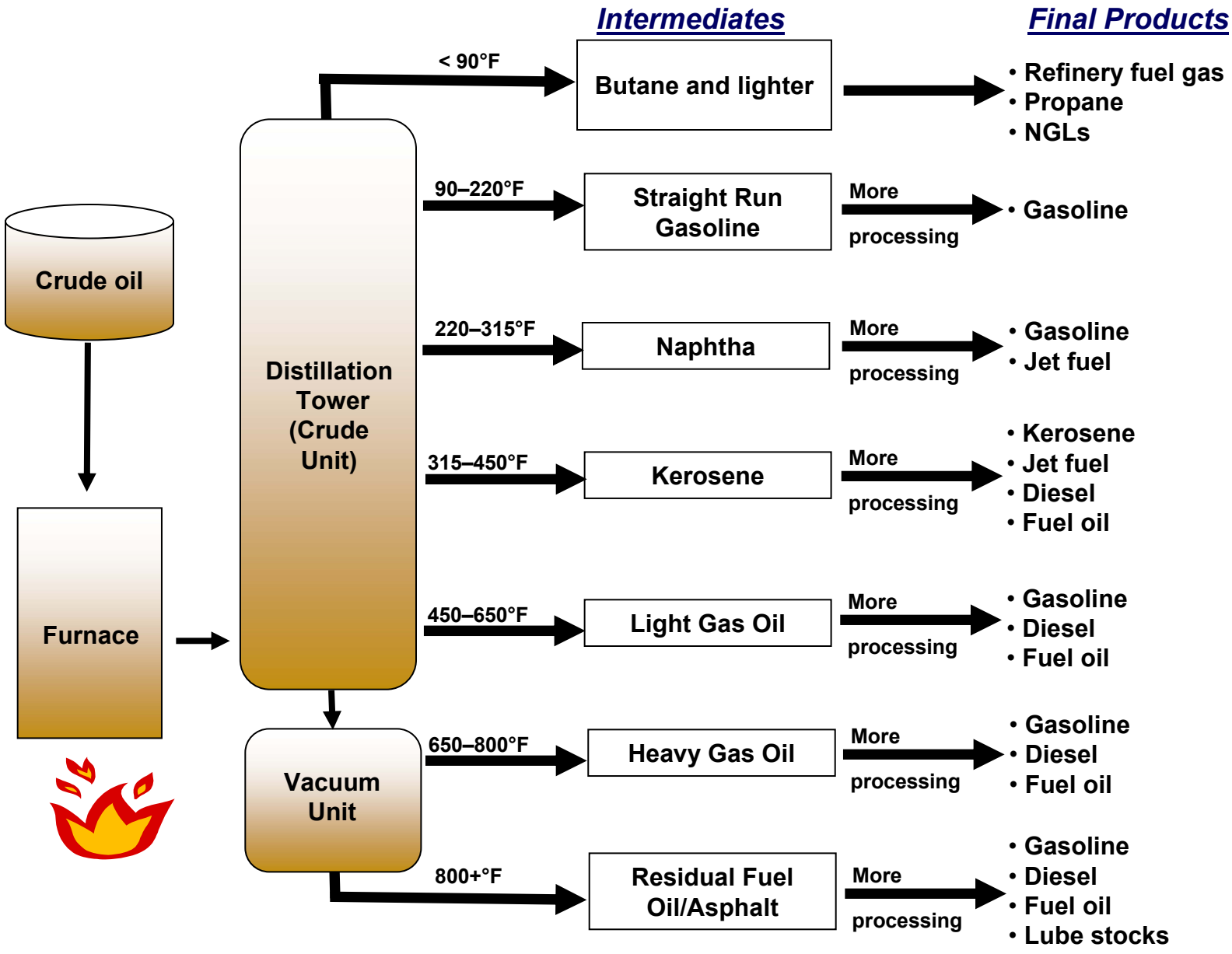
2005 U.S. Production



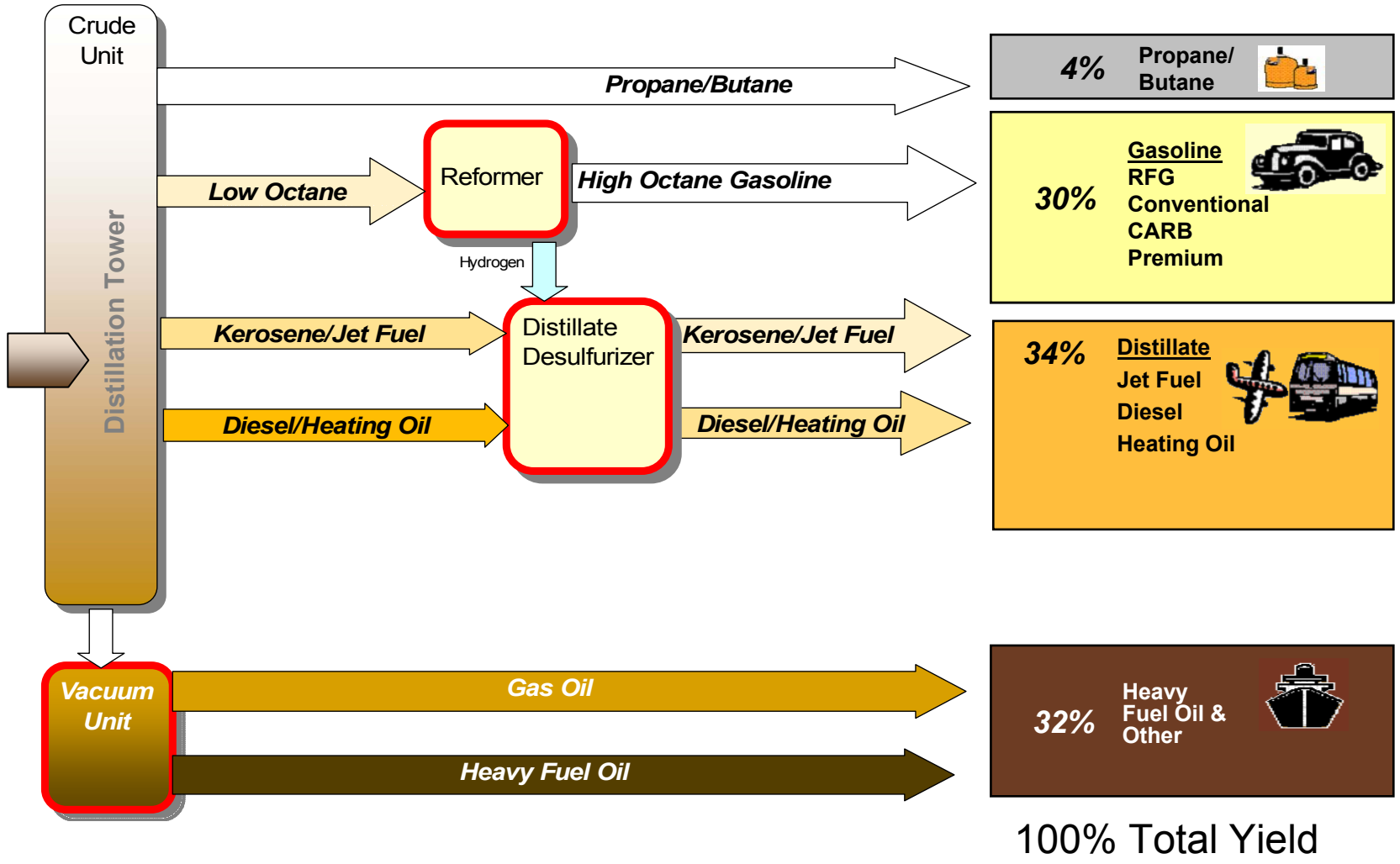
Source: EIA Refiner Production

Refineries upgrade crude oil to higher value products

Basic Refining Concepts

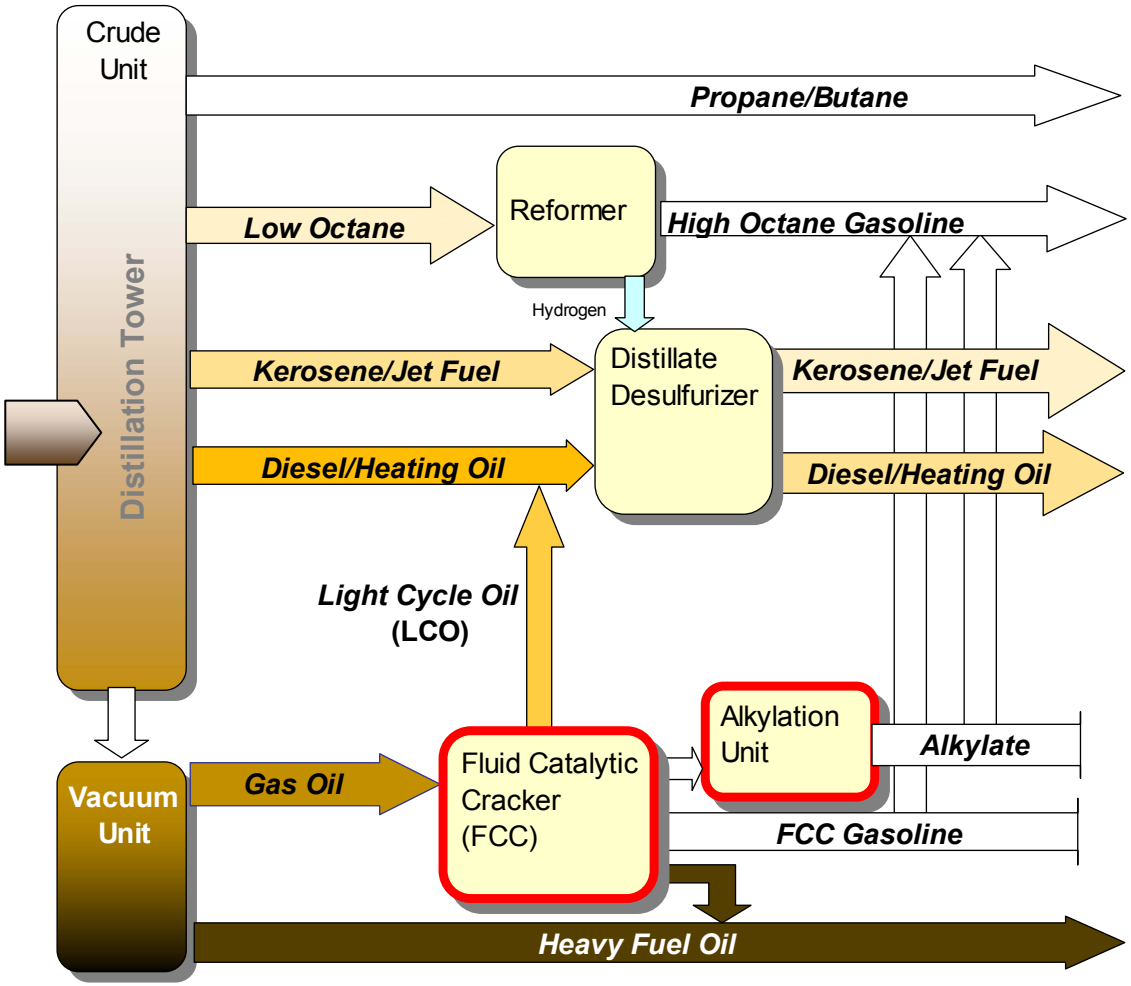


Hydroskimming Refinery



Simple low upgrading capability refineries tend to run sweet crude

Medium Conversion: Catalytic Cracking



Light Sour Crude

8%	Propane/ Butane
45%	Gasoline RFG Conventional CARB Premium
27%	Distillate Jet Fuel Diesel Heating Oil
24%	Heavy Fuel Oil & Other

104% Total Yield

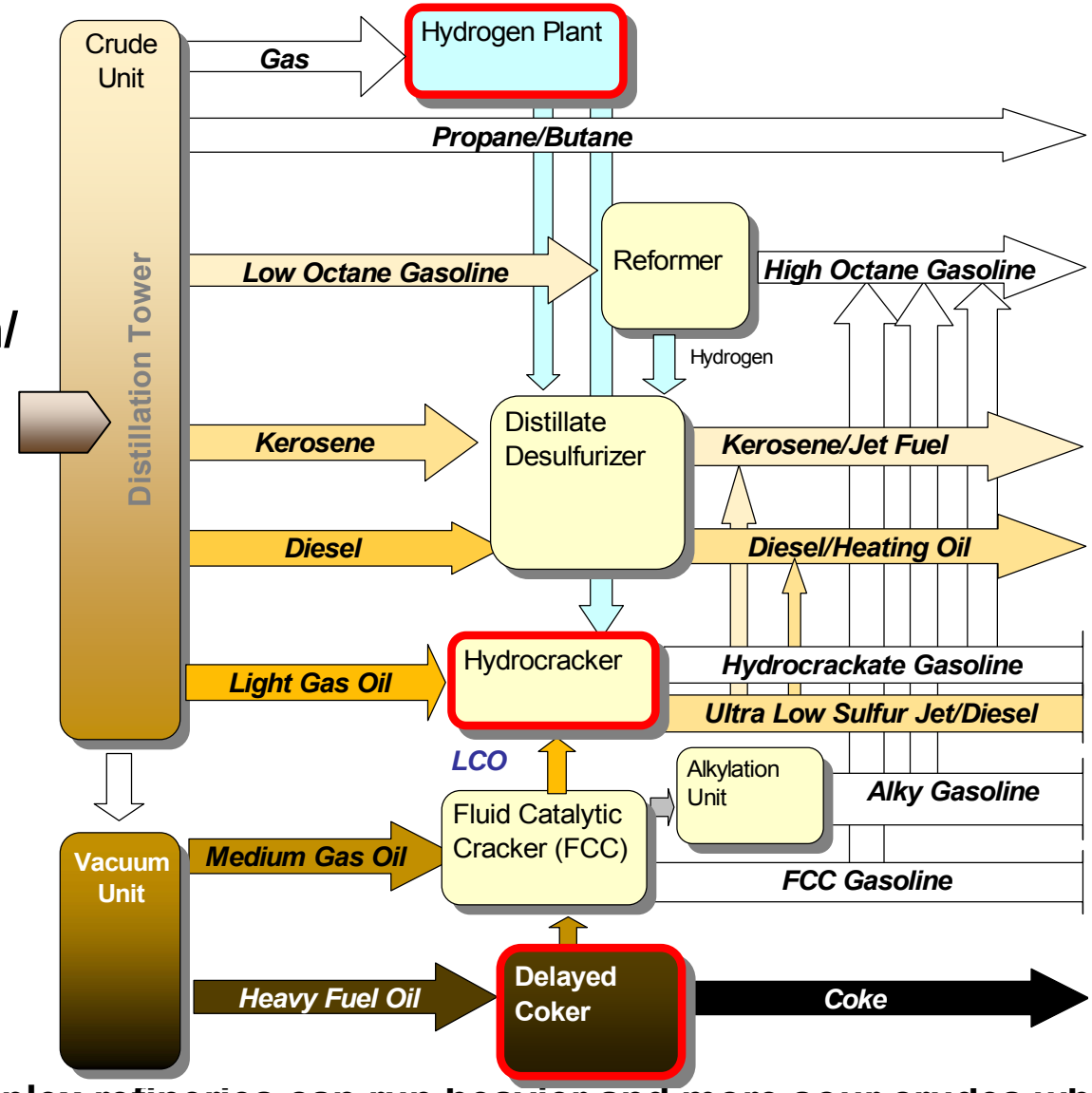
Moderate upgrading capability refineries tend to run more sour crudes while achieving increased higher value product yields and volume gain

Crude Unit and Catalytic Cracker

Aruba Crude Towers

Memphis Cat Cracker

High Conversion: Coking/Resid Destruction

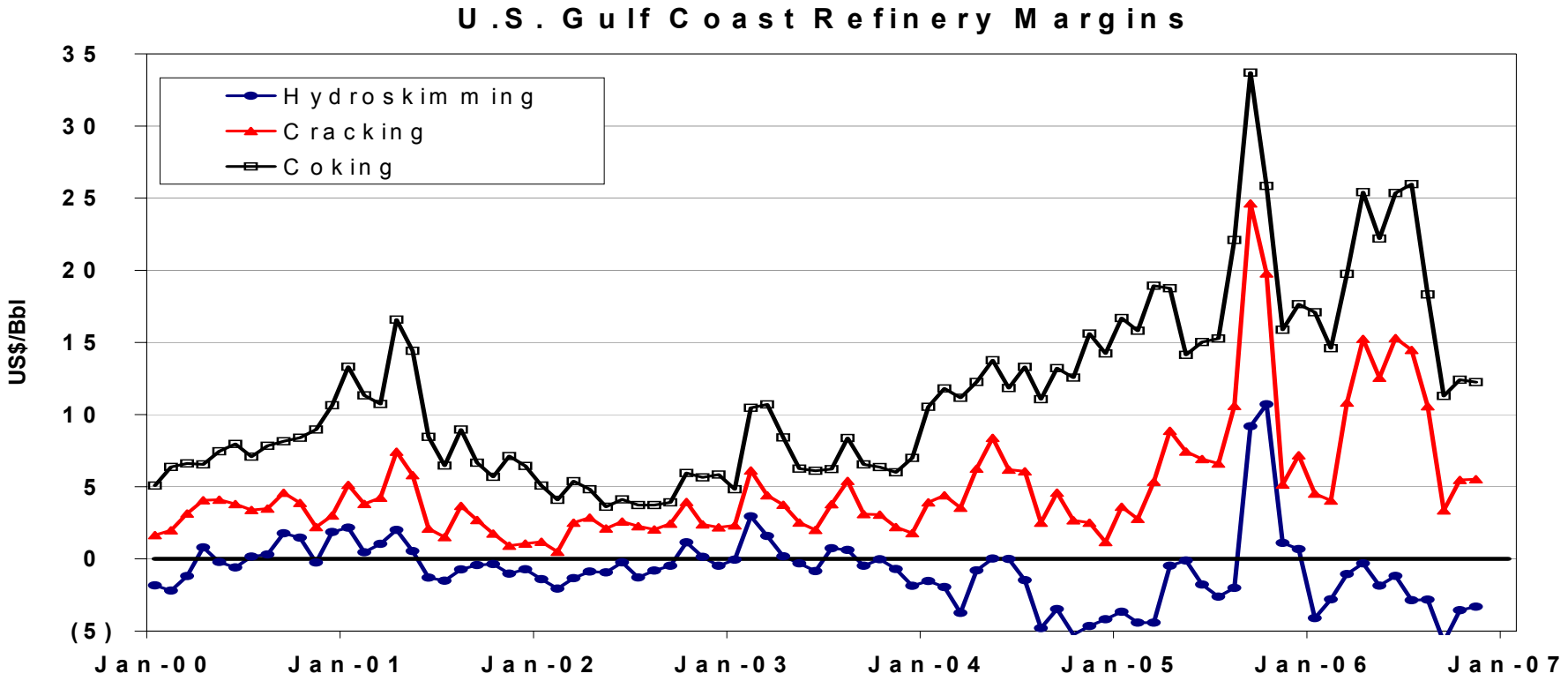


7%	Propane/ Butane
58%	Gasoline RFG Conventional CARB Premium
28%	Distillate Jet Fuel Diesel Heating Oil
15%	Heavy Fuel Oil & Other

108% Total Yield

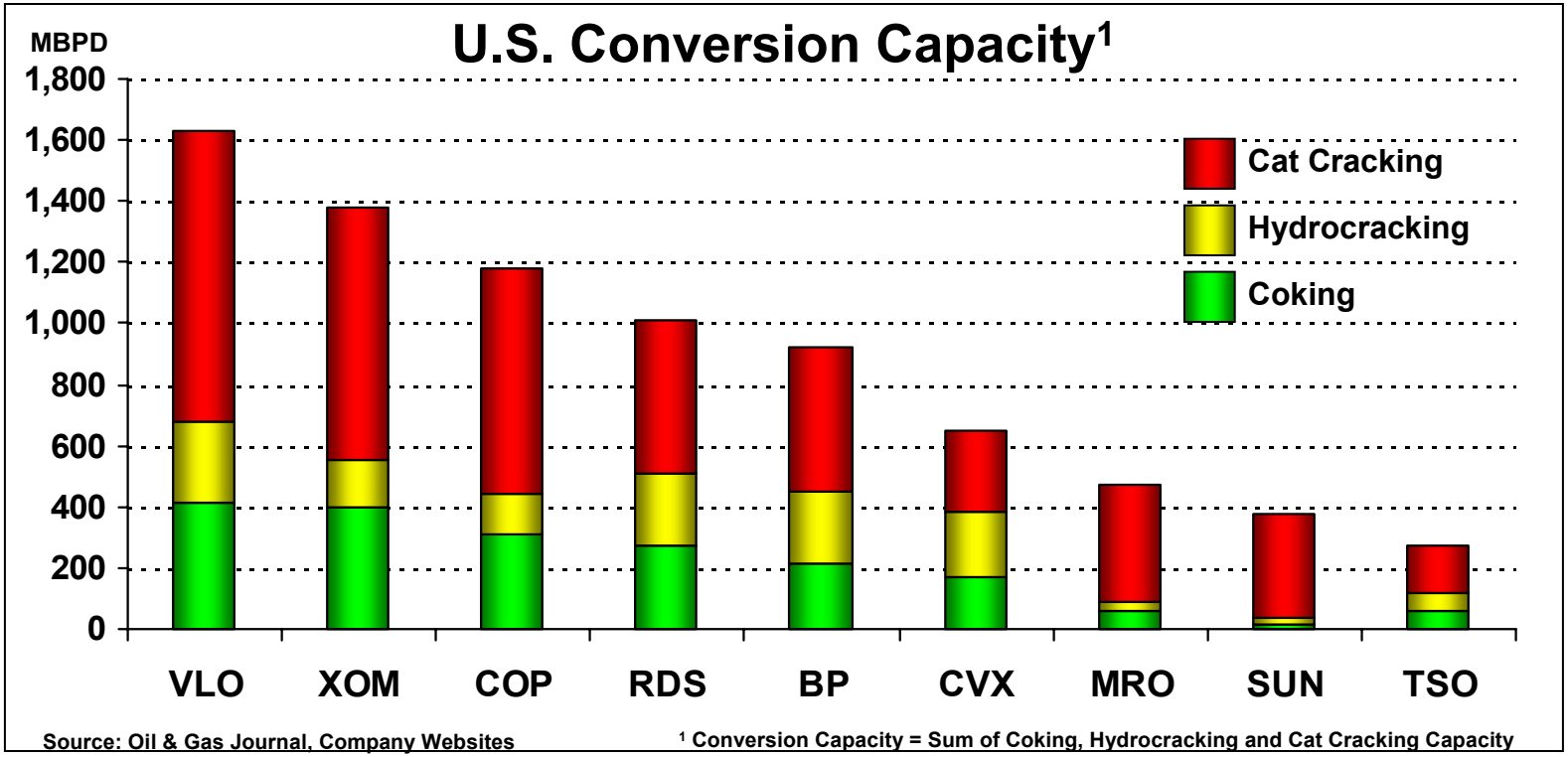
Complex refineries can run heavier and more sour crudes while achieving the highest light product yields and volume gain

Conversion Economics



- Conversion capacity needed to capitalize on sour crude discounts
  - Hydroskim – Breakeven or moderate margins; High resid yield
    - When margins are positive – increase crude runs
    - When margins are negative – decrease crude runs
  - Cracking – Better margins; Lower resid yield
  - Coking – Best margins; Lowest resid yield
    - Maximize heavy crudes

Comparison of Sour Conversion Capacity



- Valero is an industry leader in upgrading capacity
- Valero's upgrading capacity provides superior operational flexibility
- Significant capital investment and long lead time required to add conversion capacity

Refining 201:

Coking Technologies and Applications

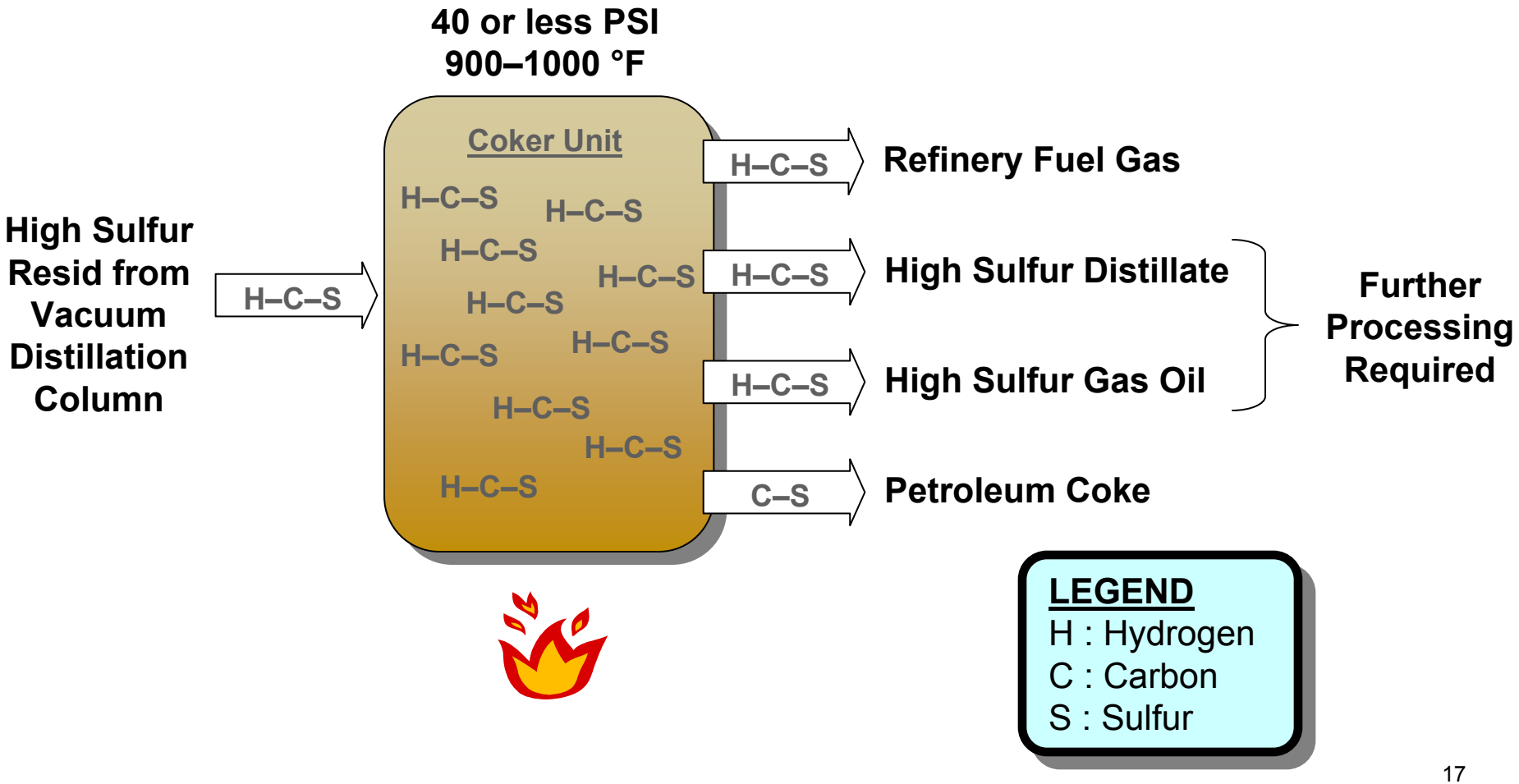
Industry Context

Cokers are found in two different refinery configurations:

- Sweet crude refineries (e.g. Lima)
  - Produce needle or anode–grade coke (low metals, low sulfur)
  - Smaller capacity due to lower resid content of crude
- Medium to heavy sour crude refineries (e.g. Port Arthur, Texas City)
  - Produce fuel grade coke (high metals, high sulfur)
  - Larger capacity
  - Require additional refinery infrastructure:
    - Vacuum tower capacity
    - Sulfur processing and handling capacity
    - Proper metallurgy

Coking Basics

Value-added thermal cracking of resid to distillates and gas oils, primarily for further upgrading in fluid catalytic crackers or hydrocrackers



Delayed Coking

Port Arthur

Texas City

St. Charles

- Most common process used in over 80% of world coking capacity
- Semi–batch process
- Advantages include lower capital cost and longer run–lengths

Fluid Coking and Flexicoking

Delaware City

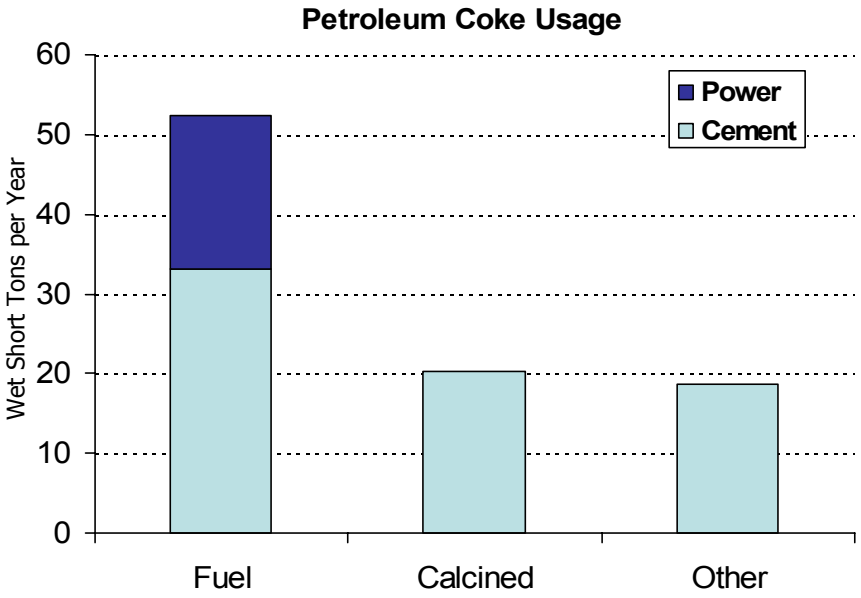
Benicia

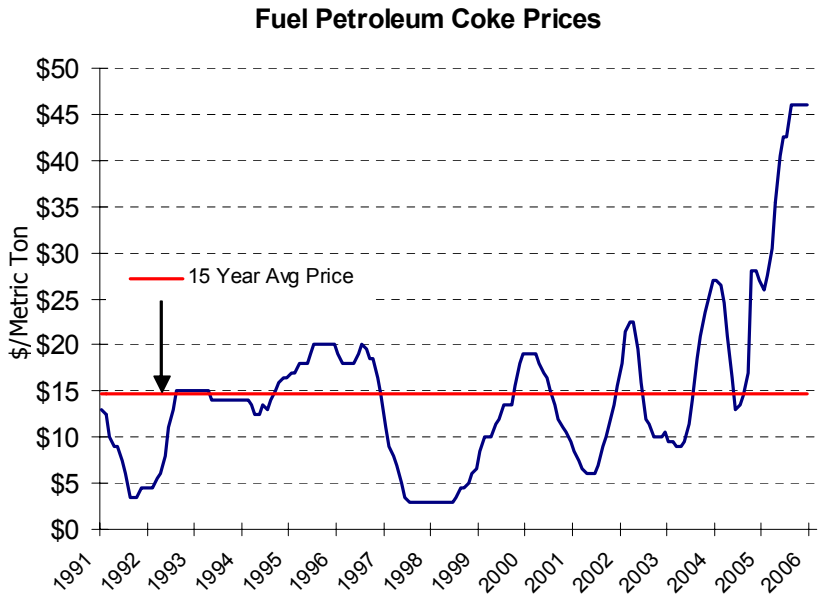
- 13 commercial units (8 Fluid and 5 Flexi) in service worldwide
- Continuous process
- Advantages include better liquid yield and use of coke for heat
- Flexicokers have additional gasification step to upgrade coke to low BTU fuel

Petroleum Coke Demand

Primary markets for petroleum coke include:

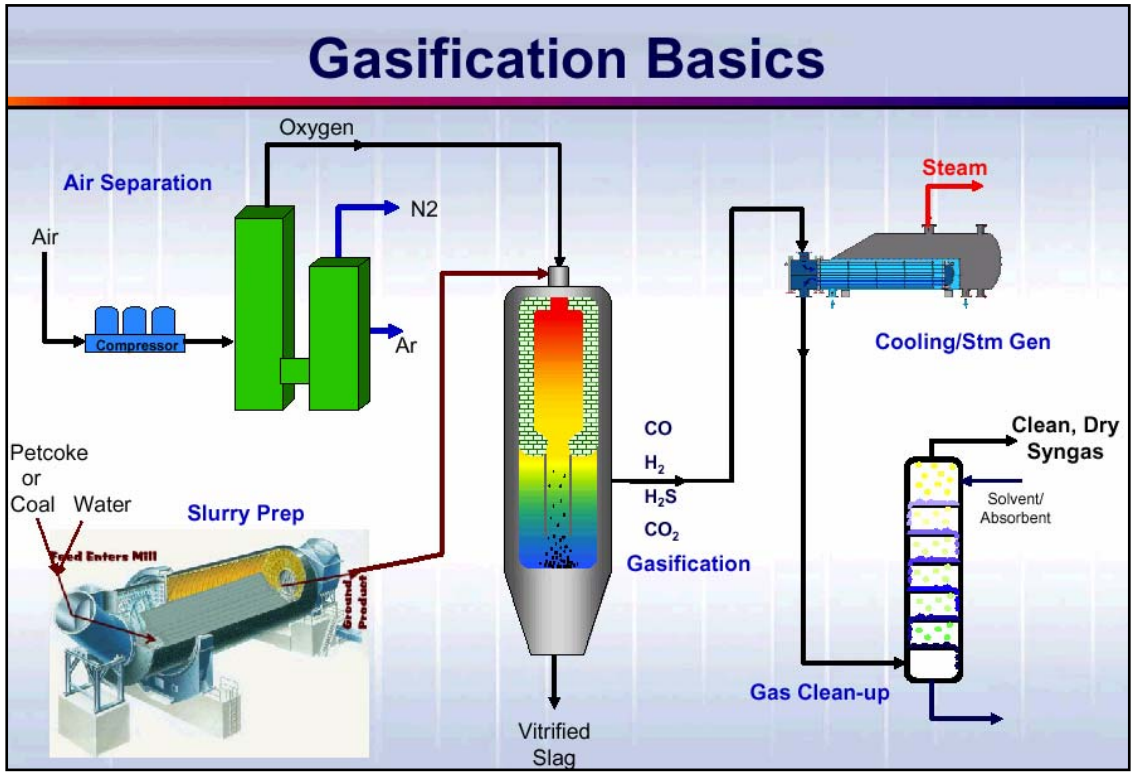
- Fuel coke
  - Cement kilns and electric power production
- Calcined
  - Aluminum anodes, titanium oxide, graphite equipment and electrodes
- Other uses
  - Steel production, chemicals, furnace refractory lining





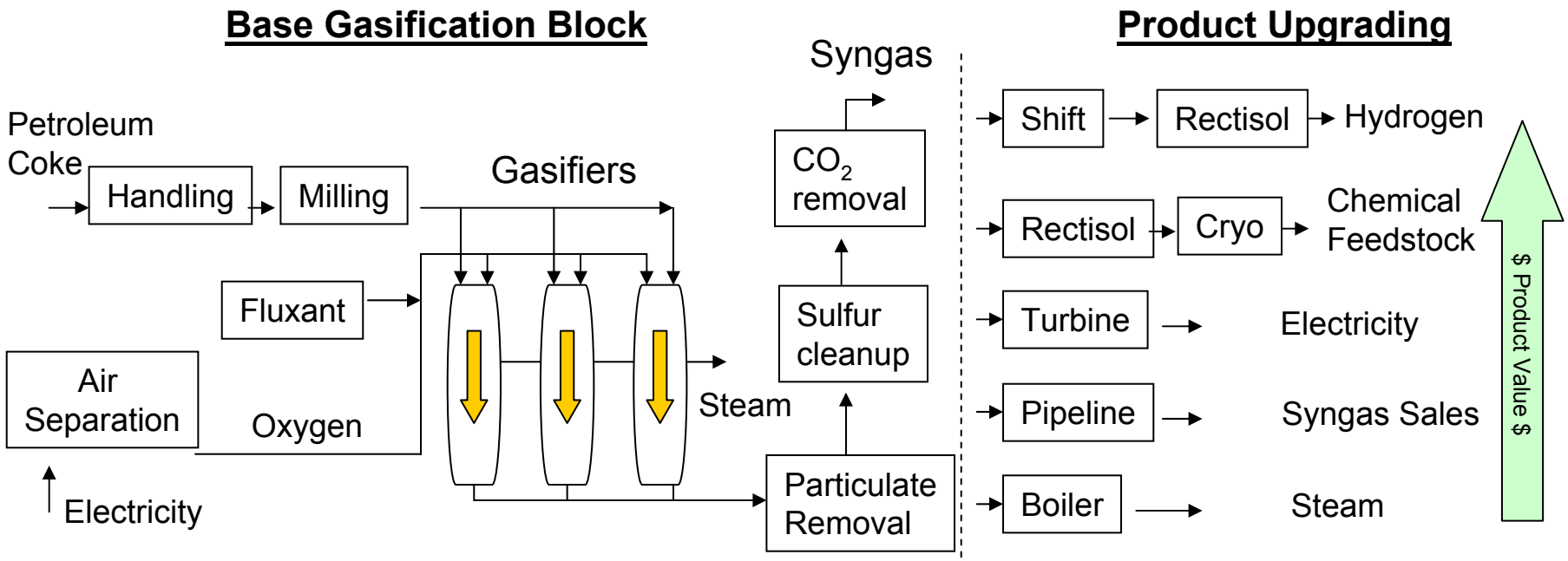
Petroleum Coke Gasification

- Gasification of heavy oil is common worldwide with over 50 plants
- With higher world energy prices, interest has been renewed in gasification of solids (coal and petroleum coke) for power
  - Coal-based plants are common with over 40 plants worldwide
  - Only 5 plants worldwide use petroleum coke as feed



Petroleum Coke Gasification Process

- Solids gasification offers environmental benefits vs. coal-fired boilers
  - Low-sulfur fuel (syngas)
  - Potential for CO2 sequestration
- Pathways exist to upgrade syngas to higher value products



Q&A

Appendix

Major Refining Processes – Topping

- **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

- **Definition**
  - **"Cracking" or breaking down large, heavy hydrocarbon molecules into smaller hydrocarbon molecules thru application of heat (thermal) or through 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 and large molecules crack into smaller molecules in the gasoline and surrounding 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

- **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 with gasoline.
  - Catalytic Reforming – The process whereby naphthas are changed chemically to increase their octane numbers. Octane numbers are measures 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 blending stock.
  - 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

- **Definition**
  - **Processing of petroleum products to remove some of the sulfur, nitrogen, heavy metals, and other impurities**
- **Process**
  - **Catalytic Hydrotreating, Hydroprocessing, sulfur/metals removal – 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 parafins, which reduces gum formation in fuels. Hydroprocessing also cracks heavier products to lighter, more saleable products.**

List of Refining Acronyms

- AGO – Atmospheric Gas Oil
- ATB – Atmospheric Tower Bottoms
- B–B – Butane–Butylene Fraction
- BBLS – Barrels
- BPD – Barrels Per Day
- BTX – Benzene, Toluene, Xylene
- CARB – California Air Resource Board
- CCR – Continuous Catalytic Regenerator
- 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 – Gas Oil Hydrotreater
- GPM – Gallon Per Minute
- HAGO – Heavy Atmospheric Gas Oil
- HCU – Hydrocracker Unit
- HDS – Hydrodesulfurization
- HDT – Hydrotreating
- HGO – Heavy Gas Oil
- HOC – Heavy Oil Cracker (FCC)
- H2 – Hydrogen
- H2S – Hydrogen Sulfide
- HF – Hydroflouric (adic)
- HVGO – Heavy Vacuum Gas Oil
- kV – Kilovolt
- kVA – Kilovolt Amp
- LCO – Light Cycle Oil
- LGO – Light Gas Oil
- 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
- NO_X – Nitrogen Oxides
- P–P – Propane–Propylene
- PSI – Pounds per Square Inch
- RDS – Resid Desulfurization
- RFG – Reformulated Gasoline
- RON – Research Octane Number
- RVP – Reid Vapor Pressure
- SMR – Steam Methane Reformer (Hydrogen Plant)
- SO_X – Sulfur Oxides
- SRU – Sulfur Recovery Unit
- TAME – Tertiary Amyl Methyl Ether
- TAN – Total Acid Number
- ULSD – Ultra–low Sulfur Diesel
- VGO – Vacuum Gas Oil
- VOC – Volatile Organic Compound
- VPP – Voluntary Protection Program
- VTB – Vacuum Tower Bottoms
- WTI – West Texas Intermediate
- WWTP – Waste Water Treatment Plant