Evaluating the Techno-Economics of Retrofitting CO_2 Capture Technologies in an Integrated Oil Refinery

(Progress Report)

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Industry CCS Workshop

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IEAGHG Activities on CCS in the Oil Refining Sector

- *Initiated the study to evaluate the Techno-Economics of Retrofitting CO_2 Capture in an Oil Refining Sector.*
- *Project Partners*
  - GASSNOVA (CLIMIT Programme)
  - CONCAWE
  - Shell
- *Cost of the Project*
  - Total: ~ £850,000
  - IEAGHG: ~ £180,000 (Cash & In-Kind)

Outline of the Presentations

- *Purpose of the Presentation*
  - To present the outline of the work plans for the oil refining study
- *Oil Refining Sector Overview*
  - What are the important considerations
  - CO_2 Point Sources from Oil Refineries
- *Capture Technology Overview*
  - Post-Combustion
  - Pre-Combustion
  - Oxyfuel Combustion
- *Scope of the Work*
- *Recommendations*

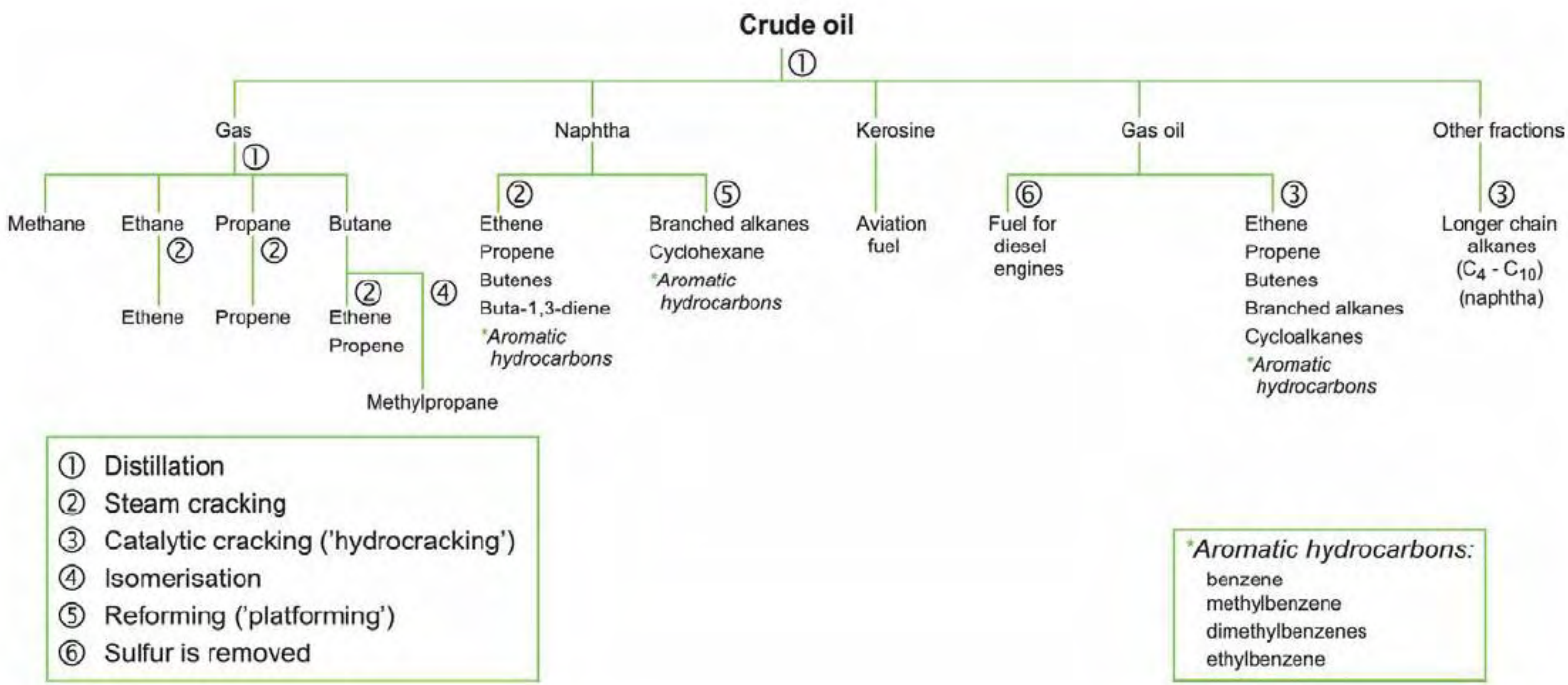
- *To thank CONCAWE in providing data & information*

World Oil Refining Sector

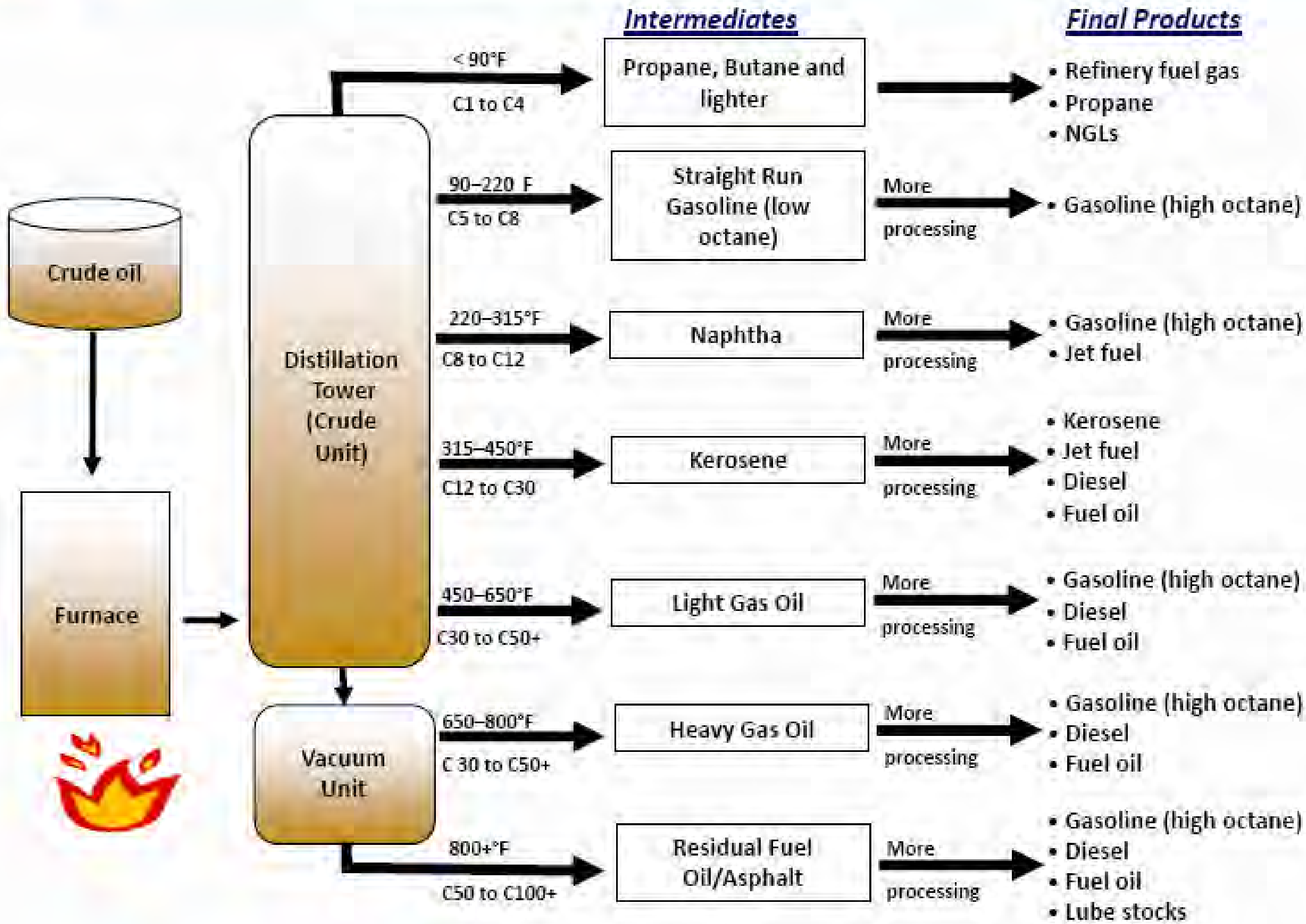
- ***In 2012, the global consumption of petroleum products reached nearly ~90 million bbl/d.***
- ***Top 10 Countries***
  - USA 17.38 mbbl/d
  - China 11.54 mbbl/d
  - Russia 5.75 mbbl/d
  - Japan 4.25 mbbl/d
  - India 4.21 mbbl/d
  - S. Korea 2.88 mbbl/d
  - Italy 2.20 mbbl/d
  - S. Arabia 2.12 mbbl/d
  - Germany 2.09 mbbl/d
  - Canada 2.06 mbbl/d

Overview of Refining Crude Oil

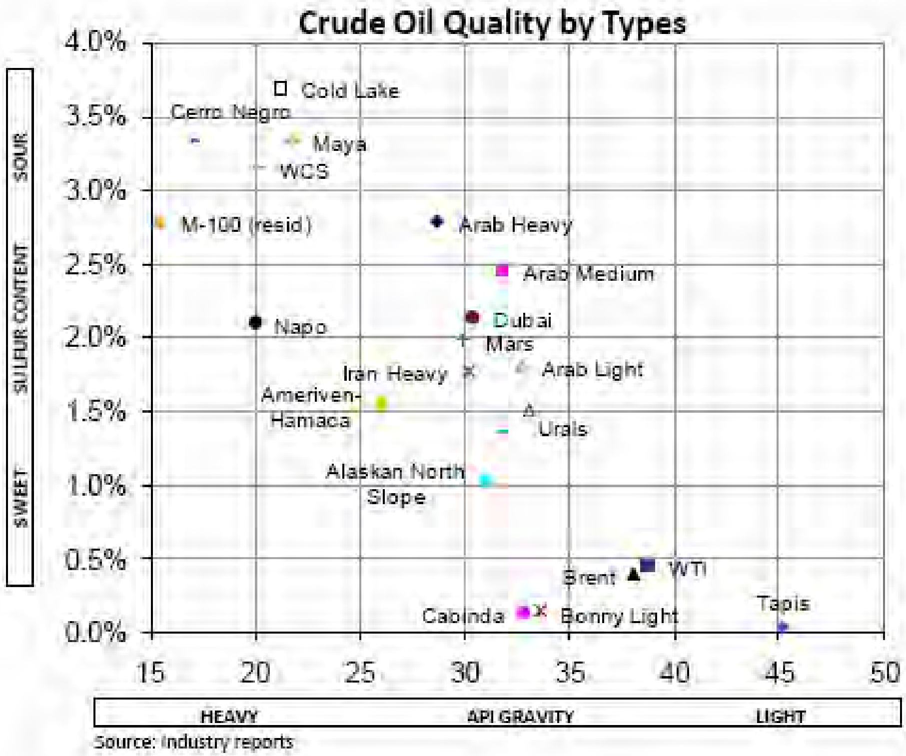
- ***The only common processing unit among all the integrated refinery is the atmospheric distillation.***

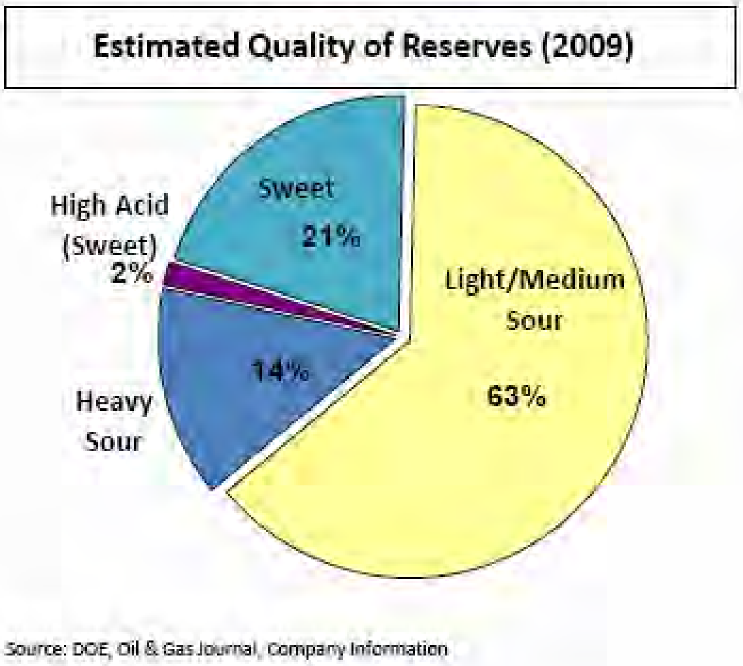


Basic Refining Concepts



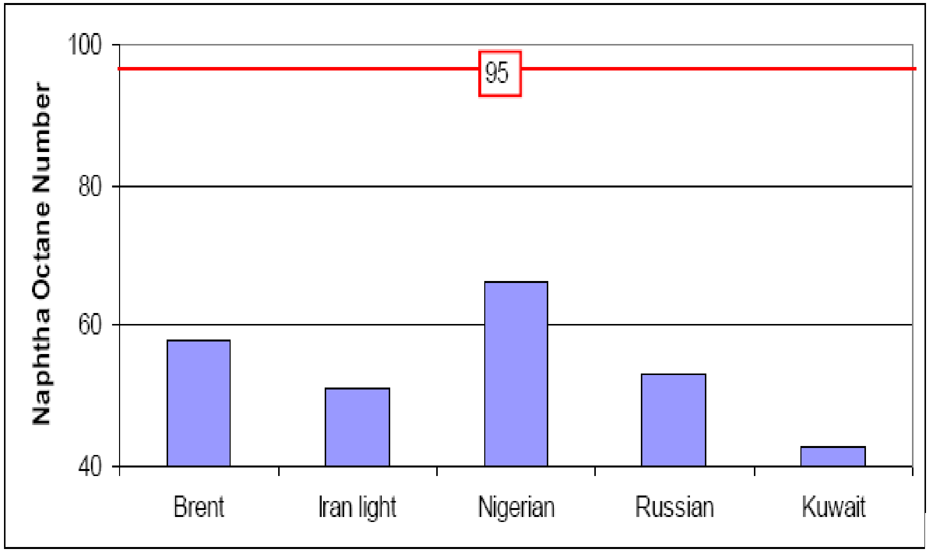
Feedstock Variation

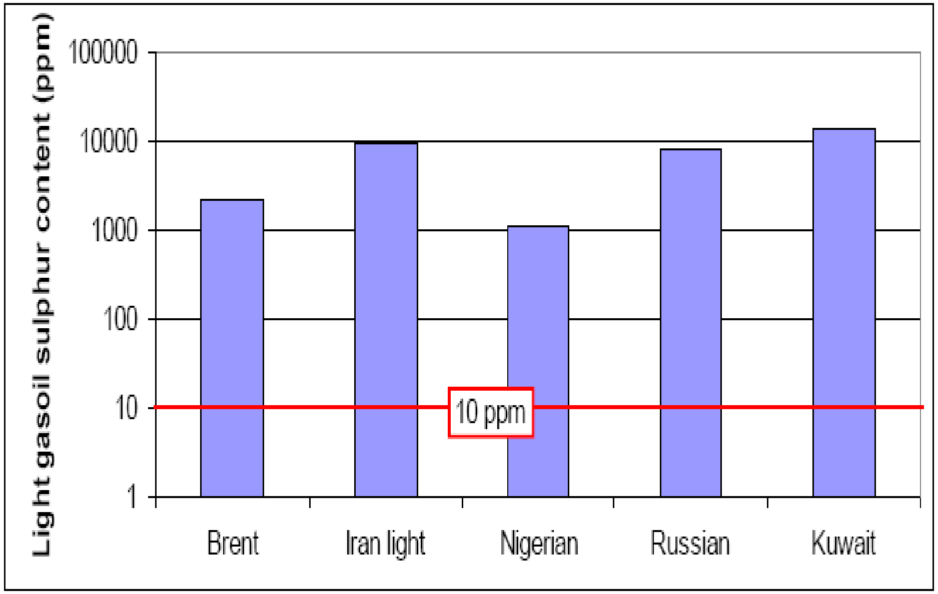




Data from Valero 2010

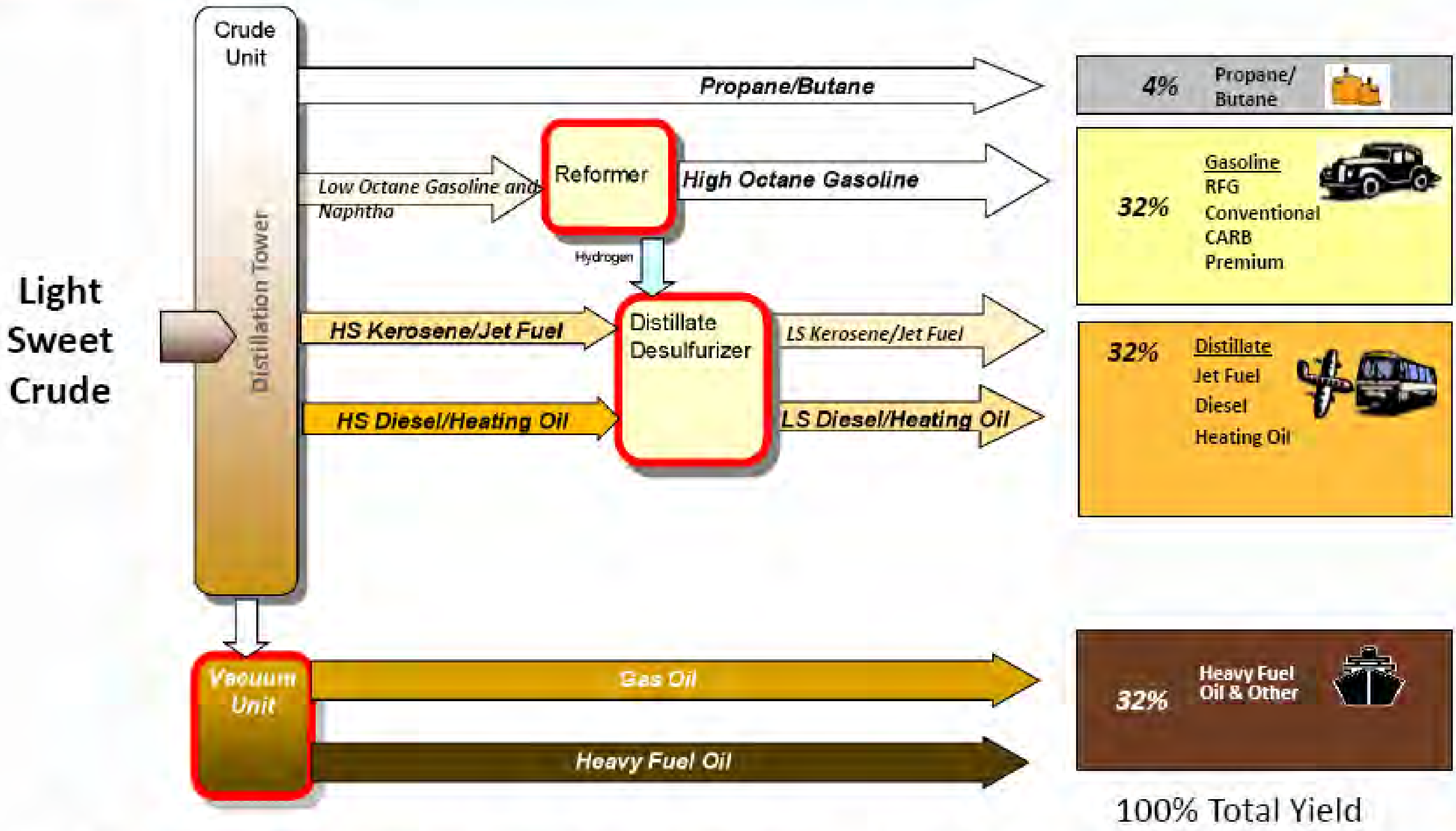
Product Quality Requirements





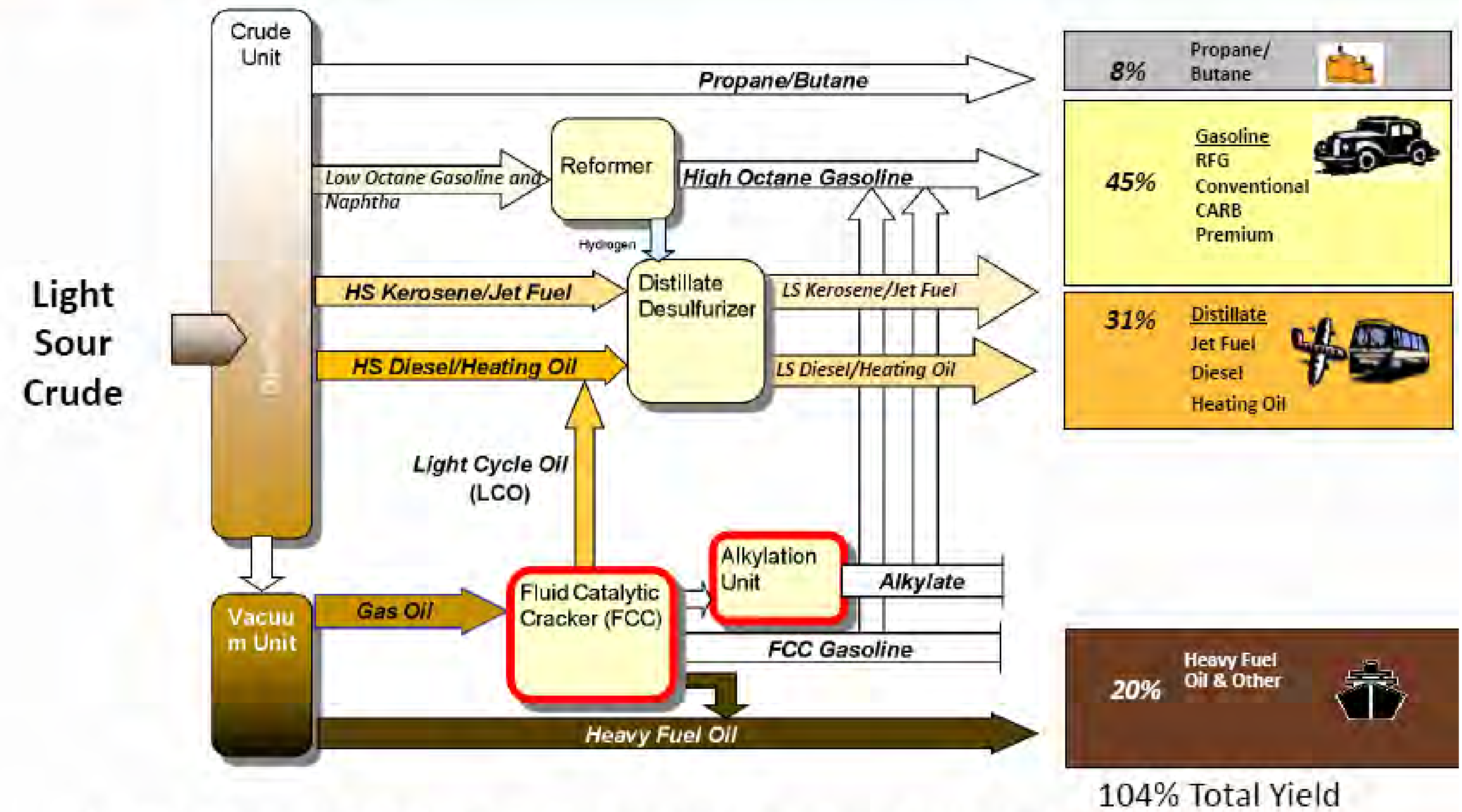
Data from CONCAWE 2011

Hydroskimming/Topping Refinery



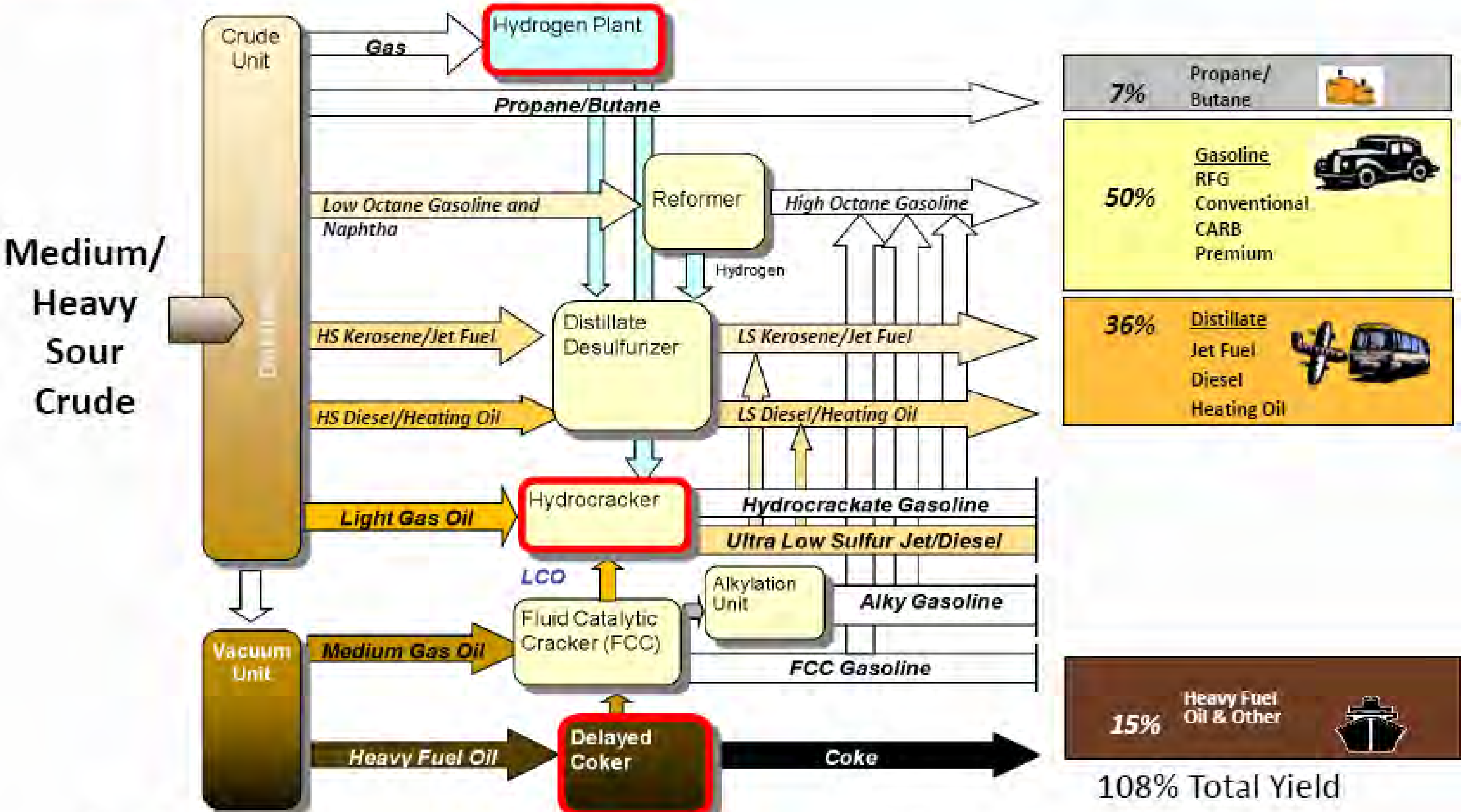
Simple, low upgrading capability refineries run sweet crude

Medium Conversion: Catalytic Cracking



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

High Conversion: Coking/Resid Destruction



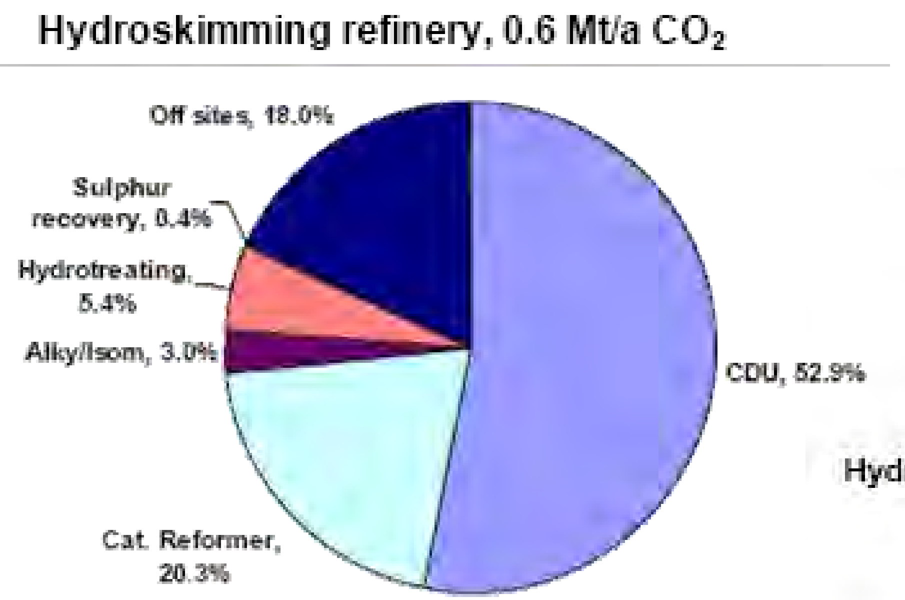
Complex refineries can run heavier and more sour crudes while achieving the highest light product yields and volume gain

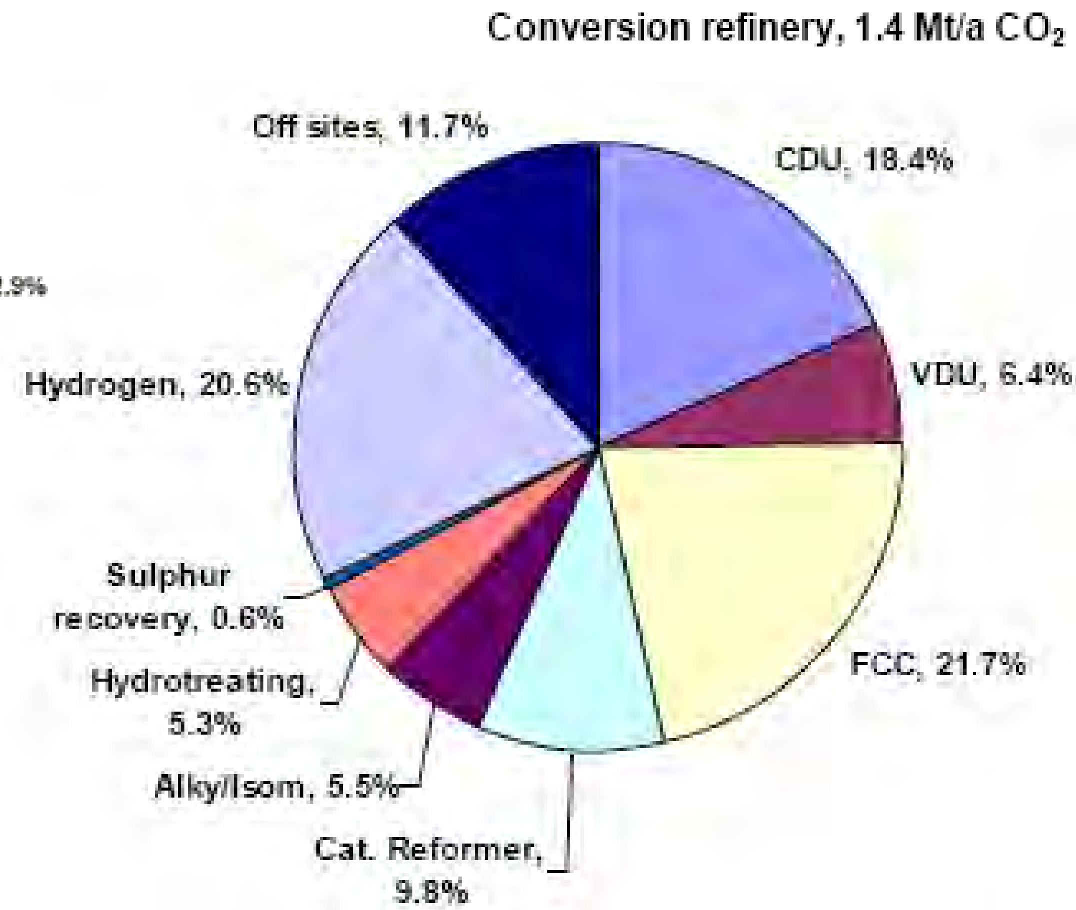
Deployment of CCS in Oil Refining Sector...

- ***Oil Refinery has high level of process integration***
- ***Fuel/energy required by the complex refinery is met by using the used of by-product gases or low quality liquid fuel, and balanced by using natural gas or other external fuel.***
- ***No oil refineries are alike...***
  - Very site specific conditions
- ***Benchmarking is necessary...***

Difference between Simple vs Complex Refineries

(Refinery with 150K bbl/d Capacity)

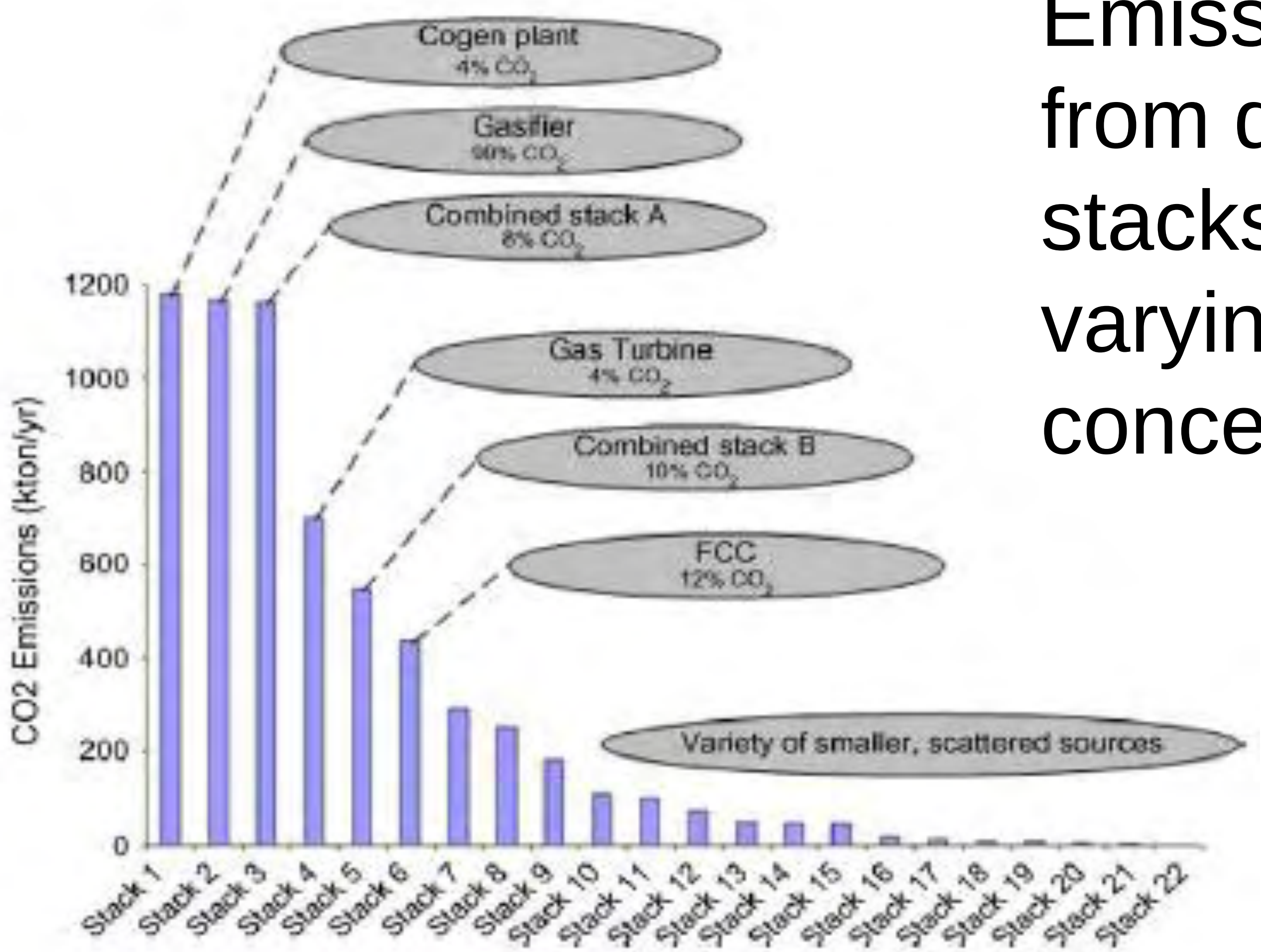




Data from CONCAWE 2011

An Example of CO_2 Emissions Profile of a Complex Oil Refinery

(Shell Pernis Refinery ~400K bbl/d – data from van Straelan, 2010)

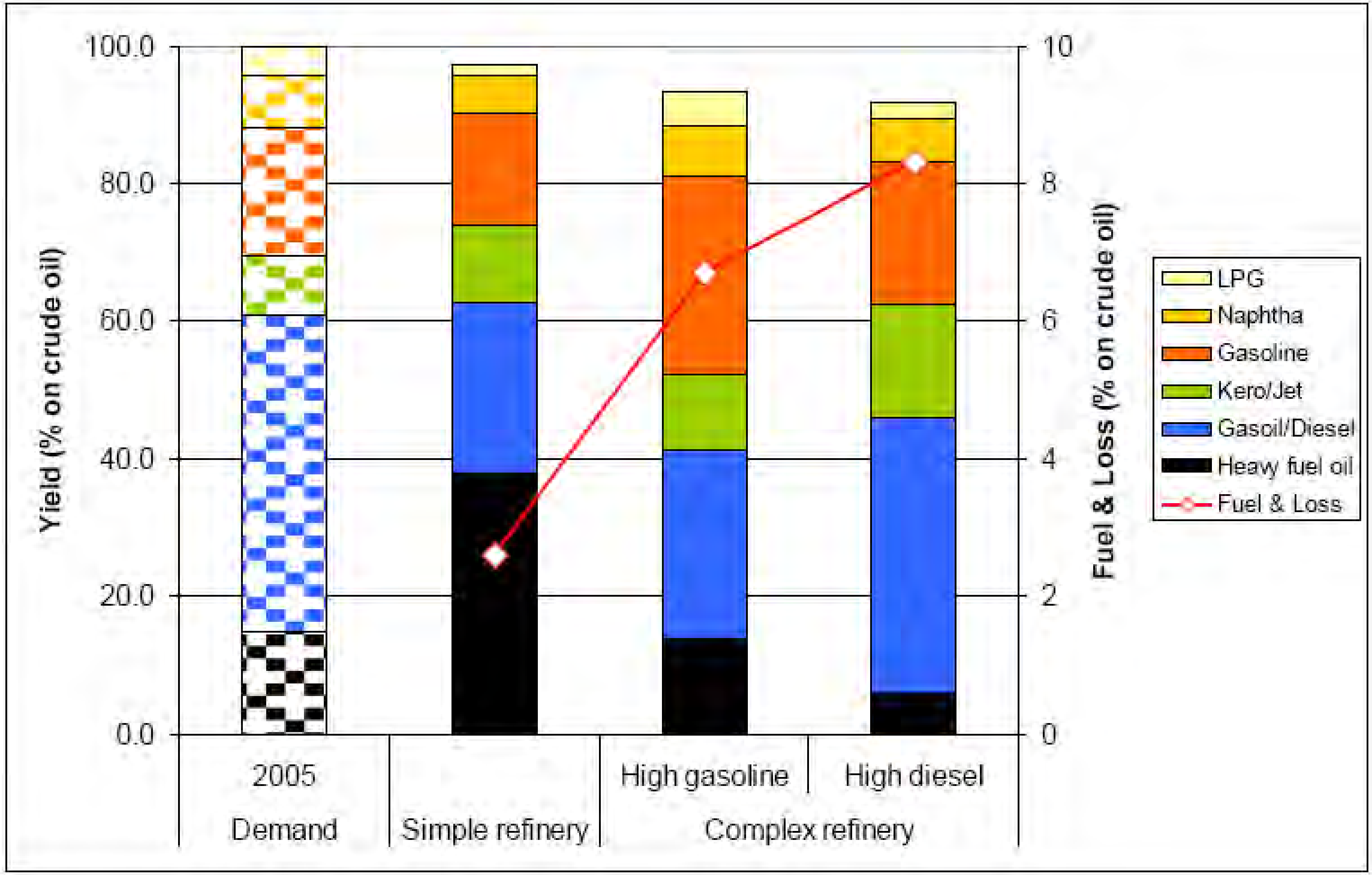


Emissions comes from different stacks and have varying CO_2 concentration

Challenges to Oil Refinery to Reduce CO_2 Emissions (1)

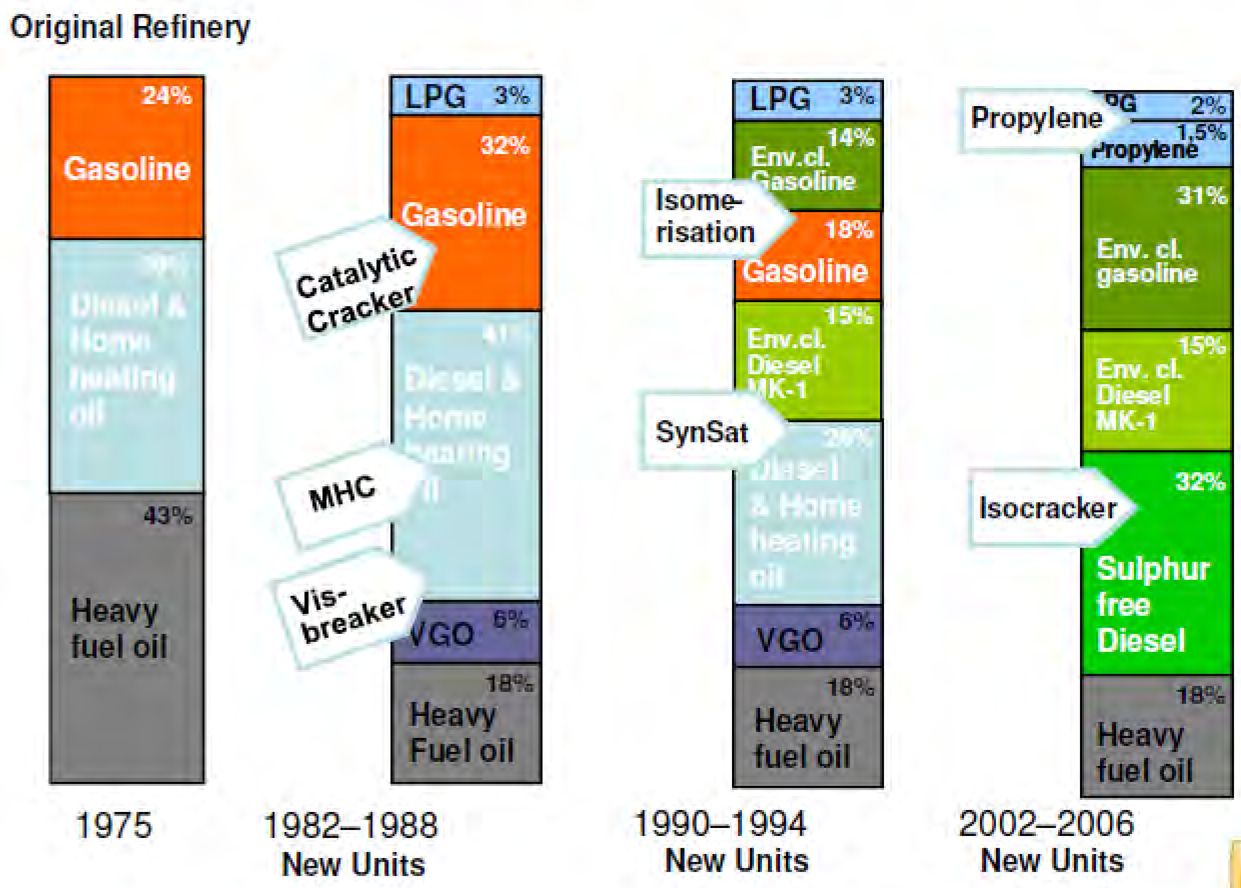
- ***CO_2 emissions varies from site to site.***
  - Comes from different stacks
  - Depends on process complexity
- ***Regulations based only on site's direct CO_2 emission tends to discriminate complex refineries.***
  - Low CO_2 Emissions from simple refinery are not necessarily "good" and high CO_2 Emissions are not always "bad".
  - They are simply performing different jobs
  - Differences in emissions are due to complexity, not to CO_2 efficiency

Complex Refineries is Required to Meet Demand of the Products

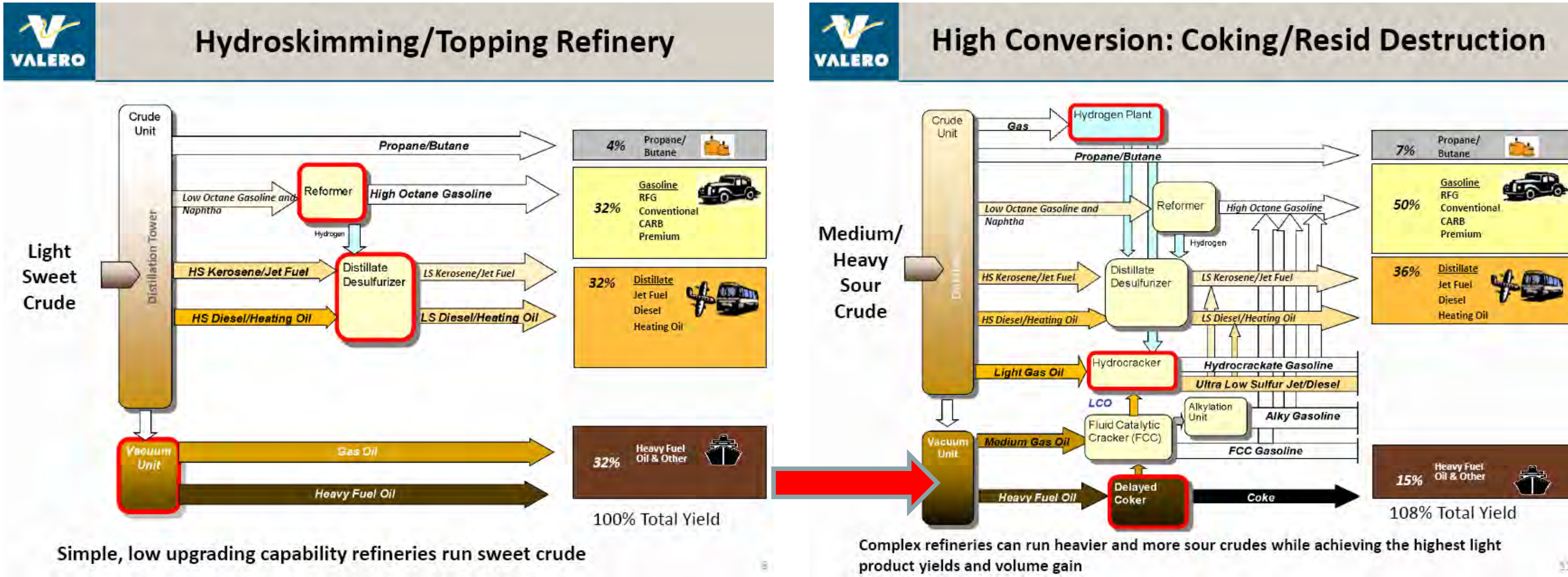


Data from CONCAWE 2011

Demand of Products lead to Evolution of Refineries' Landscape



Simple and Complex Refineries are complementary to each other

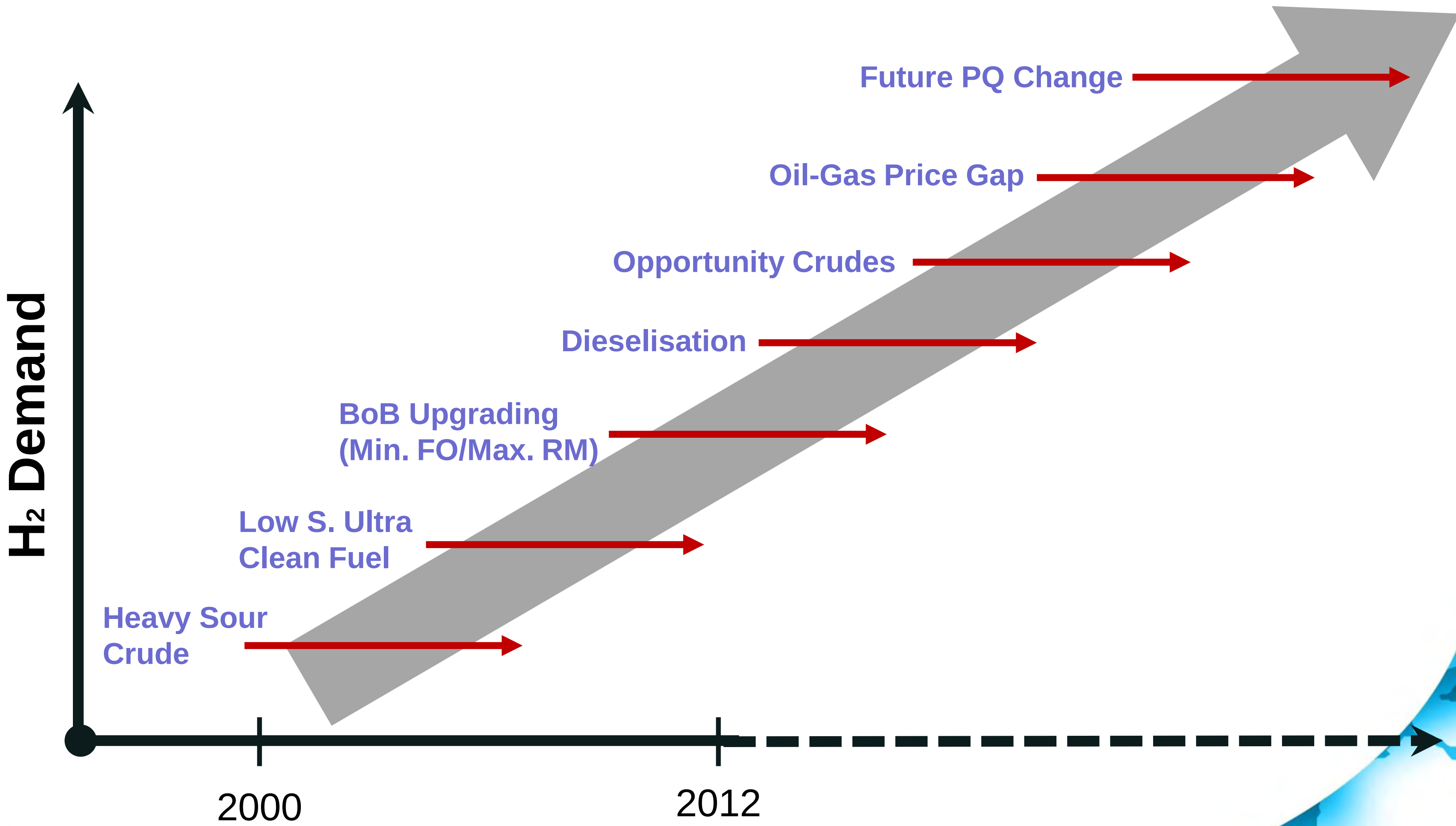


This illustrates that simple refinery could sell bottom products (HFO) to other complex refineries to further processing to lighter products.

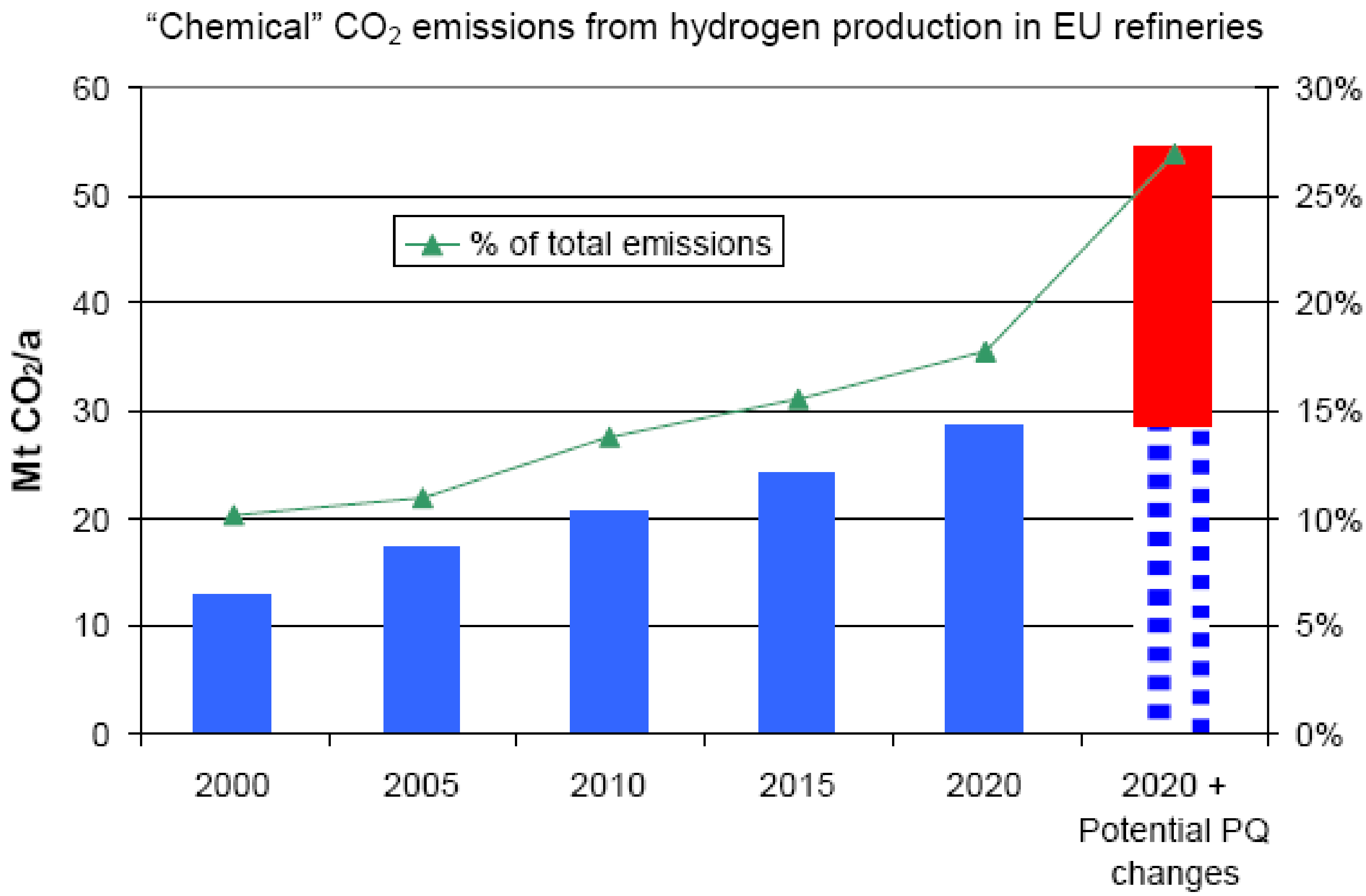
CO_2 Emissions accounting is important.

- ***CO_2 emitted per tonne of crude or refined product is an indicator of "what refinery does" rather than "how efficiently it is done".***
- ***Need to evaluate cost of CO_2 capture deployment for oil refineries on a comparable basis.***
- ***The use of newly established "CWT" method based a common refinery activity parameter could allow comparable techno-economic analysis for CO_2 capture deployment in an integrated oil refinery.***

Reasons for Refinery Hydrogen Intensification



Identifying the Future Growth of CO_2 Emissions of the Oil Refineries



Data from CONCAWE 2011

Scope of the Study

- ***Work will include the following:***
  - To establish the boundary of the battery limit and the techno-economic information of the reference Oil Refinery (both Simple and Complex Refinery Configuration).
    - This cover 3 different capacities (100K, 250K and 500K bbl/d)
  - To look onto options for Retrofitting CO_2 Capture in an integrated refinery (both Simple and Complex Refinery Configuration)
    - Post-Combustion CO_2 Capture Option (Capture Rate between 30 to 70%)
    - Pre-Combustion CO2 Capture Option based on Hydrogen Enriched Fueled Refinery (Allow centralised CO_2 capture)
    - Oxy-Fired FCC Technology (Capture Rate below 30%)
  - Should cover between 20-22 Cases (Much more complex than the Integrated Steel Study)

CO_2 Capture Technologies Options to be considered

- ***Pre-, Post- & Oxyfuel Combustion Options for Fired Heaters and Boilers***
  - Considerations for natural draft stack
  - Considerations for multi-stack and common stack configurations
  - And many others…
- ***Oxygen Blown FCC Regenerator***
- ***Use of H_2 enriched refinery fuel***

Cost of CO_2 Capture

(Data from various literature)

Reference	Estimation year	Process Unit/Technology	Cost (€/t CO_2 avoided)	Cost ($/t CO_2 avoided)
RCI [26]	2009	Post-Combustion (Heaters)/Amines	110-130	
CCP2 [14]	Mid2008	Post-Combustion (Boiler)/Amines	96	
ERM [27]	2009	Post-Combustion (Heater, Boiler)/Amines		114-192
CCP2 [14]	Mid2008	Post-Combustion (FCC)/Amines	85-112	
Shell [19]	2007	Post-Combustion/Amines	90-120	

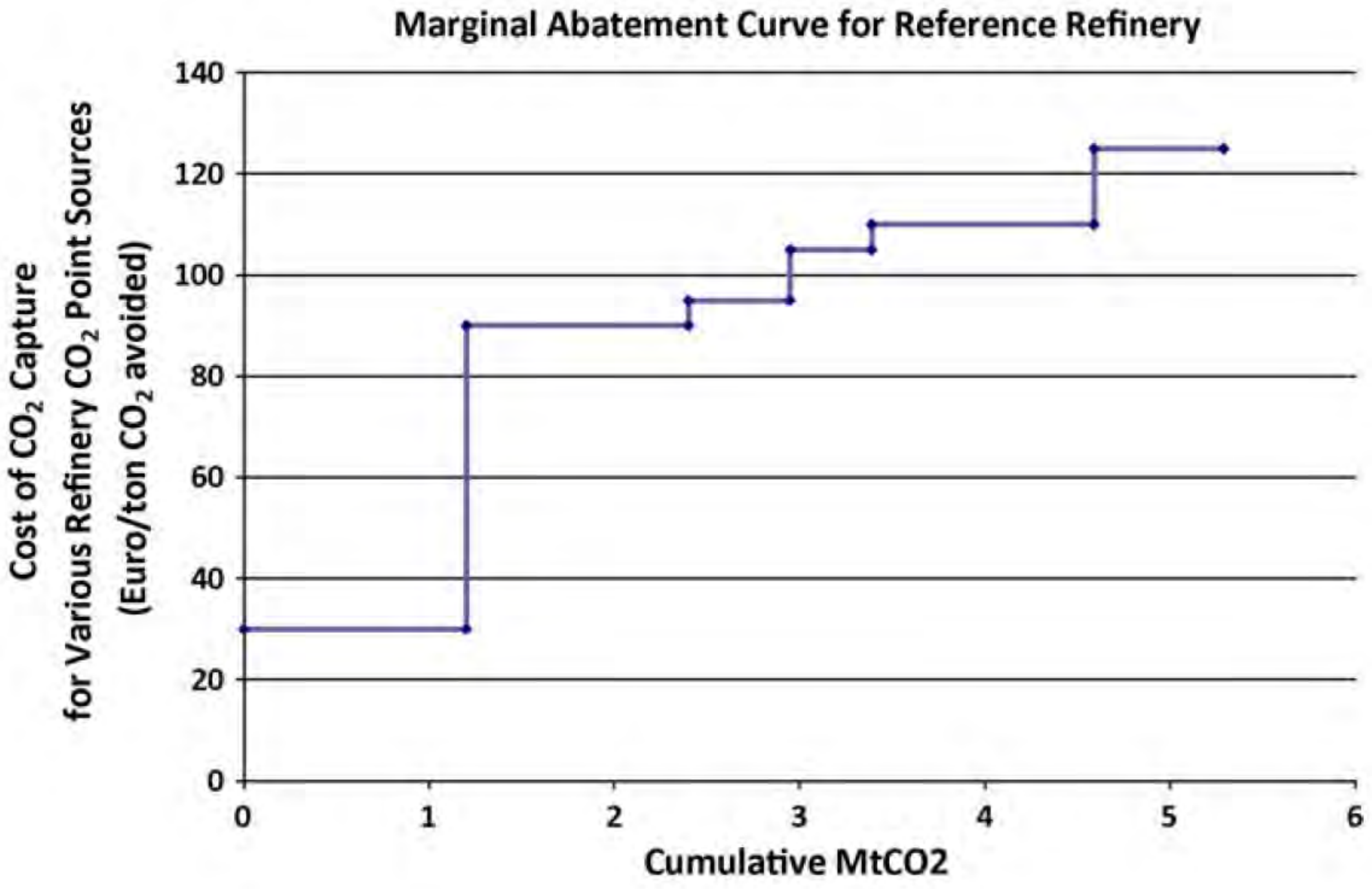
Data Compiled from CONCAWE 2011

Cost of CO_2 Capture (Data from Mello et. al. 2009)

Table 3: Comparative CO_2 avoidance cost for Post- and Oxyfuel combustion CO_2 capture reported by CCP Project (Mello et. al., 2009)

Process Unit	Technology	Cost ($/t CO2 avoided)
Refinery Boiler (Retrofit)	MEA	77
	Oxyfuel	44
Refinery Boiler (New Build – Single Unit)	MEA	96
	Oxyfuel	50
FCC	MEA	85-112
	Oxyfuel	52-55

Cost of CO_2 Capture (Data from van Straelen, 2010)



Concluding Remarks

- ***Reported cost (i.e. CO_2 avoidance cost for oil refineries) in various literature are not comparable. It is likely comparing an apple and orange. This is due site to site variation of process complexity and capacity.***
- ***No literature is available that analyses the CO_2 avoidance cost to the Refinery Margin (an important index to viability of refineries)***
- ***There are significant uncertainties with CCS cost estimates, since the technology has not been built to similar scale previously.***
- ***For refiners deep CO_2 reduction (greater than 90%) may be physically impossible or impractical due to multiple source types and capture efficiency limits***
- ***Piggybacking on a larger CO_2 transport network will be crucial***

Progress - Current Status of this Work

- ***Proposal submitted to CLIMIT / GASSNOVA for co-funding application - This has been approved.***
- ***Agreement with SINTEF to provide project management and interface to CLIMIT application.***
  - Subcontractor chosen for the project – Contract Negotiation in-Progress
- ***Agreement with CONCAWE – Agreed in principle***
  - Provide technical expertise
  - Provide small cash contribution to this study
- ***Invite other potential partners for co-funding.***
  - Shell has agreed to provide both cash and in-kind contribution.
  - Discussion on-going with other stakeholders
- ***Development and discussion of Scope – to be finalised potential partners***

Thank You

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