Bottom of the Barrel Conversion

What does the future hold?

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Safety Moment

Work to live ... Not live to work

- Work life balance / stress
- Take time to move around
- Become active
- Find hobby outside of work
  - Cycling
  - Cooking
  - Reading novels
  - Community activities
- Monitor health
  - Over 45 - Get stress test / cardio review
  - Other screenings
Perspective of change: Embrace It

Time to reach 50 Million Users (years)

- Landline Telephone: 75 years
- Airplane: 68 years
- Automobile: 62 years
- Radio: 38 years
- Light bulb: 43 years
- Television: 22 years
- YouTube: 4 years
- Cell phones: 3 years
- Facebook: 3 years
- Twitter: 2 years
- Angry Bird app: 0.1 years

Technology is transforming
Bunker shifts from by-product to ‘on-purpose’ product

**TODAY**

Crude purchases to produce the highest value of regulated products at the “lowest” cost given the asset configuration

Bunker fuel is a by-product

If the refiner could make high value product they would

**TOMORROW**

- On purpose bunker production means
  - Higher priced, low sulfur crude
  - Major capital investment for bottoms upgrading and desulfurization
  - Capacity rationalization
  - Its cost $\rightarrow$ build or buy

Not all crudes are created equal, i.e. not all crudes or blends of crude make an acceptable IMO Fuel
Market Shifts Overall

Demand for heavy fuel oil, has been declining since the 1980s.

The demand growth for lighter products – such as ethane, liquefied petroleum gas (LPG) and naphtha – almost triple of total oil demand.
Global Fuel Oil Demand Outlook

Looking at the Future

Global residual fuel demand has been declining for decades.

What is the future of Heavy Carbon Rich Fuel sources?

Continuing the decline or potential trend of HS Fuel Oil considering potential Utility demand
Chemicals Market

- Petrochemicals market continue to grow globally
- US market expanding with cheap NGLs
- LNG demand continues globally

Grand View Research, Inc, North America petrochemicals market
Motor Fuels Demand

- US / EU Flat to Declining
- East of Suez – Increasing
- South of US – Slight increase
- Fleet Efficiencies are on the rise
  - Car ownership/life cycle >13 yrs
- Shift in consumer demand
Back to Front Analysis: Cyclical demand

PetCoke

Power Generation
Sharp decline switch to gas

Cement Industry
Expect 7% growth through 2025

Steel industry
Expect 8% growth through 2025

Aluminum Industry
Expect 4% growth through 2022

Biggest Players are China and India
I want to be Green!!

CO2 reduction = Energy Efficiency

The reality

- Renewables (bio diesel / ethanol) still emit CO2
- Wind / Solar power are inconsistent to a population that demands consistency
- Infrastructure does not and will not exist sufficiently for 30 years.

Oil use continue forward

- Fuel flat to decline
- Plastics increasing overall

What does this mean to bottom of the barrel?

- Light Crude vs Heavy Sour
- What options for managing the bottom of the barrel efficiently
What are the bottom of the barrel options

- Coking - Delayed or Fluid / Flexi
- Resid FCC
- SDA
- Resid Hydrotreating Eb Bed / Slurry Hydrocracking

Conversion to C3+:
- ≈ 75-78 wt% (Coking)
- ≈ 85-90 wt% (Resid FCC)
- ≈ 95-98 wt% (Resid Hydrotreating)

Additional processing required for all options

25-35 wt% Coke
5-10 wt% Coke

Fundamental Question:
What is most energy efficient and cost effective solution?
Options will include crude source and margin value

(1) Advertised
Delayed Coking
Coke yield on feed – 25-35 wt%
Can be as high as 10-15% on crude
PetCoke contributes less than 5% to refinery profit

Conversion to C3+ ≈ 75-78 wt%

Resid FCC
Feed Concarbon challenged i.e. max commercial experience is ≈ 10 wt%
Heat removal required with large steam generators
Insufficient for “total” destruction

Conversion to C3+ ≈ 85-90 wt%
What are the bottom of the barrel options

Solvent Deasphalting (SDA)
Non destructive
Concentrate the carbon for “other” processing options
Pitch can be flacked and used in road asphalt production

Vac Res

Hydrogen Addition

Conversion to C3+ ≈ 85-90 wt% (1)

Resid Hydrotreating
Eb Bed / Slurry Hydrocracking

Conversion to C3+ ≈ 95-98 wt% (1)

Hydrogen Addition
Ebulating / Slurry hydrocracking – Licensors Eni / UOP / KBR/CLG
Fixed bed Hydrotreating – Licensors Axens/ UOP / Haldor Topsoe

(1) Advertised
**Refiners: Pinched in from all sides**

**Emissions Regulated**
- Fuels – Low sulfur, lower GHG (VOC, NOx, SOx, Benzene)
- Stack Emissions – CO2, VOC, NOx, SOx

**Market Shifts**
- Diesel demand in EU falling faster than expected
- Green push for EV and Hybrids increasing globally
- Petrochem demand continues to increase

**Investment Challenges**
- Proven Technology vs Emerging Technology that is disruptive
- ROCE is critical and cash not readily available

**Efficiency Demands**
- Corporate Average Fuel Economy (CAFE) standards increasing
- Gasoline demand and octane increasing
- Crude to Chemicals Drive
Crude capacity growth

Example of East of Suez Growth

- ME
- China
- India / Indonesia
- Total

Year:
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023

Millions bpd:
- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35

KBC Proprietary Work
Shift In global refining

Decreasing crude quality, increasing hydro-processing / conversion / maximum value lift

Simple Hydroskimming Economics unfavorable
- Crude diet limited to sweet options
- Nelson CI 5 or less

Cracking refinery complex with HS Bunker product at risk
- Crude diet low to medium sour to blending to HS Bunker
- Nelson CI 6 to 9

Full conversion refinery positioned for profit
- Crude diet only limited by metallurgy and hydroprocessing assets
- Nelson CI 9 to 12

Full conversion integrated Petrochemical complex insulated from nearly all threats
- Complete crude diet flexibility
- Nelson CI 13 plus
Some of the projects for DCU

- Add to the list
  - Singapore 100 kbpd
  - Gunvor 30 kbpd
  - Lukoil
  - India

- The total delayed coking capacity starting 2018 to be near 1.00 MMbpd name plate
  - Cokers can do 20% of name plate w/o mods

- Three ENI slurry hydrocrackers
### Capital investment risks: Bottoms conversion

<table>
<thead>
<tr>
<th>Technology</th>
<th>Crude Flexibility?</th>
<th>Secondary Processing Required?</th>
<th>Commercially Proven?</th>
<th>Specific Bottoms Stream</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Coking</td>
<td>++</td>
<td>Yes</td>
<td>Yes</td>
<td>Coke</td>
<td>$$</td>
</tr>
<tr>
<td>RFCC</td>
<td>+</td>
<td>Yes</td>
<td>Yes</td>
<td>Decant Oil</td>
<td>$$</td>
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<tr>
<td>SDA</td>
<td>++</td>
<td>Yes</td>
<td>Yes</td>
<td>High Viscosity Residue</td>
<td>$$$</td>
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<tr>
<td>“Slurry-Rx” Hydrocracking</td>
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<td>Yes</td>
<td>No</td>
<td>Residue w/Metals</td>
<td>$$$$</td>
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<tr>
<td>Residue Hydrotreating</td>
<td>+</td>
<td>Yes</td>
<td>Yes</td>
<td>Residue</td>
<td>$$$$</td>
</tr>
<tr>
<td>Gasification</td>
<td>++</td>
<td>Yes (flue)</td>
<td>Yes</td>
<td>None</td>
<td>$$$$</td>
</tr>
</tbody>
</table>

$ Relative cost including secondary system investments

- Take a carbon rich stream and either produce coke or attempt to add hydrogen to upgrade
  - Hydrogen addition on slurry or residua systems are 210 to 310 barg without accounting for additional hydrogen demand, metals on catalyst and cycle length and other aspects
- Sulfur recovery systems upgrades
**Choices Emerging**

- **Delayed Coker Expansions in US / EU**
  - Proven Technology
  - Access to Discounted sour crude
    - US is Canadian WCS
    - EU will be discounted Urals (IMO impact)

- **East of Suez**
  - Mix of Technologies
  - Delayed Coking in India
  - Slurry Hydrocracking in China / Russia
    - Even shutting down Cokers?
  - Flexicokers re-emerging

- **Factors**
  - Cost
  - Reliability of technology
  - Disposition of coke (will it be banned)
The solution involves industry becoming more efficient

- Reduced variable costs and energy efficiency
- Consider raw material to finished product and the value chain optimization
- Being responsive and agile through Digitalization
In closing

• Decisions forward will be based upon margin value
• Near term in US may see more tight oil consumption
• Technology cost and maturity is limiting pathway to adapting hydrogen approach
• Hydrogen addition pathway will reduce the “overall” demand of crude by converting more to a liquid product
Excellence

is never an accident. It is always the result of high intention, sincere effort, and intelligent execution; it represents the wise choice of many alternatives - choice, not chance, determines your destiny.