2015 Haldor Topsoe Catalytic Forum

Refining and Petrochemicals: Challenges and Solutions

Rafael Larraz
1. CEPSA Overview

2. Refining and Petrochemical Market Outlook

3. Refinery Petrochemical Integration

4. Refinery Petrochemical Integration. Future trends

5. Conclusions

**DISCLAIMER:** The information included in this presentation has been collected from public sources and does not represent neither CEPSA strategy nor CEPSA position on these topics.
1. CEPSA Overview
Cepsa is an integrated company which operates in all the stages of the oil and gas value chain

- More than 80 years in the oil business
- More than 10,800 professionals
- Strong commitment with R&D activities
Since August 2011, Cepsa’s sole shareholder is International Petroleum Investment Company (IPIC), an investment group established in 1984 by the Government of Abu Dhabi, which has had a stake in the Company for the past 26 years.

For Cepsa, integration in IPIC represents a great opportunity for growth and international expansion, a major business challenge.
OUR ACTIVITIES

EXPLORATION AND PRODUCTION

REFINING

PETROCHEMICALS

DISTRIBUTION AND MARKETING

GAS AND ELECTRICITY
CEPSA Research Centre

• Founded in 1975
• New facilities inaugurated 2008
• Located in Alcalá de Henares (Spain)
• 9000 m² laboratories
• More than 30 pilot plants. CEPSA Technology
• Budget 2015 10 M€
• R&D activities for CEPSA Group
  • Upstream
  • Downstream
  • Petrochemicals
  • Innovation
CEPSA Oil Refining

Combined output of the refineries
(millions of metric tons)

- Liquefied petroleum gas (LPG): 0.9
- Kerosene: 1.7
- Gasoline: 2.5
- Fuel oil: 3.4
- Others: 4.1
- Diesel: 9.8
- Grand total: 22.4

Refinery Petrochemical Integration: 12.7%

ASESA
50% (asphalt refinery)
0.73 million tonnes per year

CEPSA

Other Companies

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CEPSA Petrochemistry

- PROPYLENE
- BENZENE
- TOLUENE
- XYLENES
- LAB
- PHENOL
- CUMENE
- ACETONE
- PTA/PIA
- PET
- CI CLOHEXANE

Haldor Topsoe Catalytic Forum, 2015
CEPSA Phenol & Acetone Plant, Shanghai China - CEPSA’s chemical plant in Shanghai was inaugurated in April and has been one of the biggest projects in CEPSA’s international growth and expansion strategy.
2. Refining and Petrochemical Market Outlook

Prediction is very difficult, especially if it's about the future.

Niels Bohr
World GDP Outlook

GDP GROWTH BY REGION

(Annual percent change)

<table>
<thead>
<tr>
<th>Region</th>
<th>2005</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>3.33</td>
<td>2.61</td>
<td>1.73</td>
<td>2.28</td>
<td>2.20</td>
<td>2.41</td>
</tr>
<tr>
<td>Latin America</td>
<td>4.35</td>
<td>5.97</td>
<td>4.14</td>
<td>2.57</td>
<td>2.64</td>
<td>0.93</td>
</tr>
<tr>
<td>Europe</td>
<td>2.41</td>
<td>2.29</td>
<td>2.04</td>
<td>(0.17)</td>
<td>0.30</td>
<td>1.35</td>
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<tr>
<td>CIS</td>
<td>6.59</td>
<td>4.89</td>
<td>4.70</td>
<td>3.44</td>
<td>2.00</td>
<td>0.72</td>
</tr>
<tr>
<td>Africa</td>
<td>5.47</td>
<td>5.02</td>
<td>0.92</td>
<td>5.17</td>
<td>3.93</td>
<td>3.46</td>
</tr>
<tr>
<td>Middle East</td>
<td>5.67</td>
<td>5.50</td>
<td>5.50</td>
<td>2.28</td>
<td>2.47</td>
<td>3.06</td>
</tr>
<tr>
<td>Asia Pacific</td>
<td>5.26</td>
<td>7.37</td>
<td>4.64</td>
<td>4.65</td>
<td>4.60</td>
<td>4.24</td>
</tr>
<tr>
<td><strong>Total World</strong></td>
<td><strong>3.81</strong></td>
<td><strong>4.33</strong></td>
<td><strong>3.03</strong></td>
<td><strong>2.41</strong></td>
<td><strong>2.47</strong></td>
<td><strong>2.56</strong></td>
</tr>
</tbody>
</table>

Source: WB, 2015

World GDP mainly to growth in Africa, Middle East and Asia.

Petrochemical linked to GDP growth, specially in the emergent areas.

Source: Nexant, 2014
World Oil Production and Demand

Oil Production

Oil Consumption

Source: BP Energy Outlook, 2015
World Natural Gas Production and Demand

Source: BP Energy Outlook, 2015
World Oil Demand by sector

Refineries should improve its complexity in order to address the demand in petrochemicals and fuels.
Crude Oil Cost Curve

Source: Oil&Gas Journal Financial, 2015
Shale Gas and Oil

Directional drilling and hydraulic fracturing make tight oil and gas possible.

Recovery factor for the tight oil and gas formation is extremely low, around 10%.

Fields production periods are low in comparison with conventional oil and gas reservoirs.

Those facts make tight formation production much more expensive than Middle East fields.
Shale Gas and Oil

Source: BP Statistical Review 2015

<table>
<thead>
<tr>
<th>Crude</th>
<th>Country</th>
<th>API °</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eagle Ford</td>
<td>USA</td>
<td>44,7</td>
</tr>
<tr>
<td>Bakken</td>
<td>USA</td>
<td>40,8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Vol.</th>
<th>Marcellus</th>
<th>Barnett</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>82,1</td>
<td>91,8</td>
</tr>
<tr>
<td>Ethane</td>
<td>14</td>
<td>4,4</td>
</tr>
<tr>
<td>Propane</td>
<td>3,5</td>
<td>0,4</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0,1</td>
<td>2,3</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0,3</td>
<td>1,1</td>
</tr>
</tbody>
</table>
China produces 3874 MT of Coal out of a World production of 8165 MT.

China has huge coal reserves, much of which is used for power generation.

Coal reserves in western China are low quality and remote from consumption centres.

Source: BP Statistical Review 2015
Petrochemical Value Chain

Volume

Oil&Gas
(10^6 MT)

Upstream
(10^5 MT)

Intermediate
(10^4 MT)

Downstream

Conversion
Industries

Price

E&P

Oil Refinery

Gas Separation

Olefins:

Ethylene

Propylene

Aromatics:

Benzene

Toluene

Xylene’s

Olefins:

EDC/VCM

EO/EG

Oxoalcohols

Acrylonitrile

Aromatics:

Ethylbenzene

Styrene

Ciclohexane

Caprolactam

Cumene/Fenol

LAB

PTA/PIA

Plastic Resins:

PE, PP, PVC, PS, EPS, PET

PC, POM, PBT, Nylon 6,6, PMMA

Synthetic Fibers:

Polyester

Nylon 6

Polypropylene

Acrylic

Synthetic Rubber Elastomers:

BR, SBR, EPDM

PTA/PIA/PET

Synthetic Coating Adhesives:

PVA, Silicone

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Petrochemical Derivatives

Diagram showing the flow of raw materials and products in the petrochemical industry.
Petrochemical Business Cycle

Start of the Cycle

Demand exceeds supply
Beginning of investment in the sector
Era of high margin and expansion

End Of cycle

Era of competitive devaluation
Beginning of consolidation and closures
Manufacturers start regaining pricing power
Demand starts exceeding supply

Excess Capacity

Over investment in the sector
Manufacturers start losing pricing power
Supplies slowly start exceeding demand

Deutsche Bank, 2013

<table>
<thead>
<tr>
<th>Product</th>
<th>LTGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td>1-1,5 x GDP</td>
</tr>
<tr>
<td>Propylene</td>
<td>2 x GDP</td>
</tr>
<tr>
<td>Benzene</td>
<td>1 x GDP</td>
</tr>
<tr>
<td>P-Xylene</td>
<td>1,5 x GDP</td>
</tr>
<tr>
<td>HDPE</td>
<td>1,5 x GDP</td>
</tr>
<tr>
<td>LDPE</td>
<td>2 x GDP</td>
</tr>
<tr>
<td>PP</td>
<td>1-1,5 x GDP</td>
</tr>
</tbody>
</table>

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Petrochemical Production Process

Steam Cracking

Produce olefins and some aromatics.
Processing feedstocks include ethane, LPG and naphta.
Aromatics yields are low when natural gas is used as feedstock.

Fluidized Catalytic Cracking

Produces Propylene as a by product
After some years of low margins, propylene production might turn it into a key process for refinery petrochemical integration.

Catalytic Reforming

Produces Aromatics as a by product.
New catalyst generations focused on xylenes

Refiner has to consider petrochemicals as a high priced alternative option, but for a small market.
Petrochemical Feedstocks

Most Petrochemicals are made from ethane, propane or naphta, that come from oil refineries and gas processing.

Regions with surplus, low priced ethane are attractive for steam cracking.

Olefins (ethylene, propylene, butadiene) and aromatics (benzene, toluene and xylenes) make up 90% of the petrochemical production, and are building blocks for almost all other petrochemicals and polymers.

These petrochemicals are commodities and its market is cost driven and very price sensitive.

Source: Nexant, 2015
Petrochemical Feedstocks Prices

† Source: ICIS Heren Energy Ltd.
‡ Source: Energy Intelligence Group, Natural Gas Week.
BP Statistical Review, 2015
Petrochemical Products Prices

Credit Suisse. Benchmark Prices, 2015

Haldor Topsoe Catalytic Forum, 2015
Petrochemical Products Prices

Credit Suisse. Benchmark Prices, 2015

Haldor Topsoe Catalytic Forum, 2015
Basic Petrochemical Market and Trends

World Petrochemical market value estimation is 1300 US$ billion.

Basic Petrochemical Market size is around 423 MMT and 530 US$ billion value.

World Oil Consumption in 2014 4211 MMT

Aromatics (BTX) represents 119 MMT and 130 US$ billion value. Paraxylene market represents 38 MMT

Additional Ethylene capacity expansions (2015-17) represents 15 MT mainly is USA and ME.

On purpose propylene capacity will increase from 17 MMT to 42 MMT by 2020.

Additional world BTX demand (2015-2020) is around 17 MMT, of which 85% of new BTX supply is dominated by Asia (63%) and ME (22%).
Petrochemical Trends by Geographic Region

**North America**, Shale gas boost petrochemicals, mainly ethylene. Propylene and aromatics a possible issue. Today ethane accounts for 55% of the olefin slate and propane 20%. Shale gas is bringing cheap feed stocks and more ethane cracking.

**Western Europe**, Petrochemicals threatened by lack of cheap feedstocks. Refinery naphtha is the main cracker feed. Naphtha and condensates provided about 75% of the feed to the European ethylene crackers. 12.5% came from ethane, propane and butane and the balance from gasoil and other sources.

**Middle East**, Feedstock availability, expansion projects in refining and petrochemicals. Ethane is the primary cracker feedstock. Some countries has promoted, through incentive pricing, LPG cracking. ME has been leading the petrochemical expansion due to the rich hydrocarbon availability in the region

**Asia**, China is the main player. Coal an alternative feedstock. Refinery naphtha is the main cracker feed. This area is driving the global petrochemicals demand.
3. Refinery Petrochemical Integration
Oil Refining Business

<table>
<thead>
<tr>
<th></th>
<th>Market Demand 2015</th>
<th>SAHARAN BLEND</th>
<th>ARABIAN LIGHT</th>
<th>SAFANI YAH</th>
<th>BOSCAN</th>
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</thead>
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<tr>
<td><strong>GAS 3,3</strong></td>
<td>0,806</td>
<td>0,855</td>
<td>0,893</td>
<td>0,995</td>
<td></td>
</tr>
<tr>
<td><strong>GASOLINE 30.2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DISTILLATES 56.4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FUELS 10.3</strong></td>
<td>44</td>
<td>34</td>
<td>27</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td><strong>SULFUR % P</strong></td>
<td>0,2</td>
<td>1,7</td>
<td>2,8</td>
<td>5,27</td>
<td></td>
</tr>
<tr>
<td><strong>º API</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DENSITY</strong></td>
<td>0,806</td>
<td>0,855</td>
<td>0,893</td>
<td>0,995</td>
<td></td>
</tr>
</tbody>
</table>

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Oil Refining Trends

World Refining Capacity 96 MBbl/d

World Oil refined Products Demand

Source: BP Statistical Review 2015

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The Refining Market. Refining Margin Evolution

RM = Products - Petroleum - Operating Costs

Source: BP Statistical Review 2015
Oil Refining Cost Curve

Residue Conversion Units. **VB, Coker, RFCC, RHCK Refinery**

VGO Conversion Units. **FCC/HCX Refinery**

Catalytic Reformer. **Hydroskimming**

Distillation. **Topping.**

Source: BCG, 2014
Oil Refining in Europe. Refinery closures

Reported Refineries in trouble are those with:
- Capacity < 200 kBPSD and Nelson Complexity < 8
- Difficult access to crude supply, i.e. inland refineries

Only complex refineries will capture the market opportunities and remain competitive.
Oil Refining in Europe. Homogeneous Specifications to come.

Export Oriented Refineries will have to deal with complex logistics derived from the different specifications to handle

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>2025</td>
<td>435</td>
<td>45</td>
</tr>
<tr>
<td>Diesel(*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>2025</td>
<td>870</td>
<td>40</td>
</tr>
</tbody>
</table>

Further Investments in quality improvements will be needed.

-Refiners to produce low sulphur bunker fuel

- Ships sulphur emissions to be abated by on board SOx scrubbers

-Natural Gas engines

(*) On-road Diesel

Sources: OPEC World Oil Outlook 2013; DNV, Shipping 2020
Oil Refining in Europe. Oil Refining Fitness Check

Economic impact on refinery sector of directives analysed in Fitness Check

Has EU legislation contributed to increased refining energy costs?

EU ETS increases costs of purchased electricity

Increased energy consumption due to FQD

Switch to low-sulphur crude oil for refinery energy due to pollution legislation (IED/LCPD/IPPCD)

Demand impacts (RED, ETD, IED) reduce utilization rate, which can negatively affect refineries' energy efficiency

Source: EU Commission
Refinery Petrochemical Integration Drivers

No transportation costs. Specially for olefins

Resilient Value Chain
  - Market demand and prices flexibility
  - Regional clusters

Feedstock and product flexibility
  - Feedstock Availability
  - By Products streams

Hydrogen balance management

Maximise the potential value of hydrocarbon streams, upgrading from fuel value to higher value transport fuels or petrochemical feedstock.

Capital, OPEX and Resource Optimization
  - Shared Infrastructure, Storage & Utilities
  - Lower Logistic & Energy cost
  - Minimize overhead and waste
  - Trained workforce and contractors
Refinery Petrochemical Integration Scheme

- Natural Gas
- Crude Oil
- Condensate Splitter
  - Methane
  - Ethane
  - NGL
- Condensates
- Refinery
  - Hydrogen
  - Naphtha
  - Reformate
  - Gasoline Blend
  - VGO / Residue
- Steam Cracker
  - Ethylene
  - Propylene
  - Butadiene
- FCC Complex
  - Benzene
  - Toluene
  - (O, P, M)-Xylene
  - HCN
  - Propylene
- Aromatics Recovery
  - ETBE
  - Gasoline Blend
  - Diesel Blend

- Ethylene
- Propylene
- Butadiene
- Ethane
- NGL
Refinery Petrochemical Integration. Steam Cracker

Steam Cracking yields strongly rely on the kind of feedstock

**Naphtha**
Is the most common feedstock for crackers
Produces a broad range of products
For each ton of ethylene produced, 3.3 tons of naphta are needed

**Ethane**
Present a very high selectivity to ethylene
Negligible aromatics and propylene production
For each ton of ethylene produced, 1.2 tons of ethane are needed

<table>
<thead>
<tr>
<th>% Weight</th>
<th>Ethane</th>
<th>Propane</th>
<th>Butane</th>
<th>Naphtha</th>
<th>GasOil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen&amp;Methane</td>
<td>13</td>
<td>28</td>
<td>24</td>
<td>26</td>
<td>18</td>
</tr>
<tr>
<td>Ethylene</td>
<td>80</td>
<td>45</td>
<td>37</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Propylene</td>
<td>2</td>
<td>15</td>
<td>18</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Butadiene</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mixed Butenes</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>C5+</td>
<td>2</td>
<td>9</td>
<td>13</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Benzene</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>2</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

Source: Chemistry of Petrochemical Processes. Matar, Hatch, 2005
Refinery Petrochemical Integration. Propylene Gap

High propylene world demand.

Propylene Gap, more than 10 MMT/y.

Steam Cracker. The increase in US ethane cracking has led to a drop in propylene production.

On purpose production: Propane Dehydrogenation
Olefin Metathesis
Methanol to Propylene

Petrochemical FCC

Propylene Cost curve

Source: Booz&Allen, 2012
On purpose Propylene. Propane Dehydrogenation

Propane dehydrogenation produces propylene with rather high selectivity.

The economics of dehydrogenation of propane to propylene depends on the differential among propane and propylene.

Most of today’s activity in dehydrogenation is centered in the US, Middle East and China.
China is using its low value coal reserves to feed Coal to Liquids and Methanol to Olefin (MTO) technologies to produce ethylene and propylene.

In China metanol consumption for olefins production ramps up to more than 8 MMT/y. China is the biggest metanol producer in the world with a share of 50%.

At low oil prices economics of MTO are weak.

No economic direct routes for converting methane to propylene.

Methane from Natural Gas must first be converted to methanol (or DME), and then it can be converted to ethylene and propylene.

High capital intensity for such Methane (or Methanol) to Olefins (MTO) processes.
On purpose Propylene. Olefin Metathesis

Metathesis is the reaction of ethylene with 2-butene to form propylene, the reaction is equilibrium limited. Feasibility depending on ethylene vs. propylene prices (typical historical value for the P/E price ratio has ranged from 0,7 – 0,8)

Propylene Gap make this unit competitive under some specific scenarios

Grass roots steam crackers, which incorporate metathesis as a method to increase propylene production must over-produce ethylene feed to unit, increasing the overall capital expenditure.
**Propylene Splitter**
- Propylene Polymer Grade 99.5%
- Chemical Grade 94.5%
- Propylene Refinery grade 60%

**Alkylation Unit**
- Alkylates

**Etherification Unit**
- ETBE

**Oligomerization Unit**
- Diesel blending

**HDT/S Unit**
- Diesel blending

**C4=**

**Naphtha**
- Gasoline blending

**VGO/ Resid**

**Etherification**

**SHT Unit**
- BioEthanol

**Alkylation**
- C4=

**Refinery**
- Propane
- Isobutane

**FCC**
- C4=
- Naphtha

**Propylene Splitter**
- C4=

**C4=, C5=**

**LCO**

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Refinery Petrochemical Integration. The Petrochemical FCC

Shift FCC operation to olefin production:

ZSM5 addition convert C7-C10 molecules to olefinic LPG.

Send Light Naphtha to a dedicated FCC riser or to the steam cracker. Depending on the energy vs. yield balance.

High severity FCC, propylene from 4% to 25% yield. Naphtha Aromatics content to increase.

Significant changes to the gas and lighter product recovery sections are necessary

Residue FCC
Refinery Petrochemical Integration. Aromatics Complex

- HT Naptha (
  - Catalytic Reforming
  - Coke Oven Lt. Oil
  - Py Gasoline
)

- Naphtha/ Ethane/ LPG
  - Steam Cracker Py Gas

- % Aromatics Source
  - Reforming 68%
  - Coke Oven Lt. Oil 29%
  - Py Gasoline 3%

- Naphtha Petrochemical Use 41%
- Naphtha Gasoline Use 59%

- World Naphtha demand 817 MMT

- Production / Demand / Isomer
  - Benzene
    - 23% 18% o-Xylene
    - 53% 2% m-Xylene
    - 24% 80% p-Xylene

- Paraxylene
- Toluene
- Xylene
- o-Xylene
- m-Xylene
- p-Xylene
- A9
- A10+
### Refinery Petrochemical Integration Energy

Typical Steam Cracking energy consumption varies from 12 GJ/t to 18 GJ/t

<table>
<thead>
<tr>
<th>Product</th>
<th>Electricity (GJ/t product)</th>
<th>Feedstock* (GJ/t product)</th>
<th>Fuel (GJ/t product)</th>
<th>Steam (GJ/t product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene (SC)</td>
<td>0.3</td>
<td>0</td>
<td>13.1</td>
<td>-1.4</td>
</tr>
<tr>
<td>Benzene (AE)</td>
<td>0.1</td>
<td>45</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ethylene</td>
<td>0.3</td>
<td>45</td>
<td>13.1</td>
<td>-1.4</td>
</tr>
<tr>
<td>Propylene (SC)</td>
<td>0.3</td>
<td>45</td>
<td>13.1</td>
<td>-1.4</td>
</tr>
<tr>
<td>Propylene (FCC)</td>
<td>0.1</td>
<td>45</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Toluene (AE)</td>
<td>0.1</td>
<td>22.5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Xylene</td>
<td>0.1</td>
<td>45</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>P-Xylene</td>
<td>0.2</td>
<td>0</td>
<td>6.3</td>
<td>0.8</td>
</tr>
</tbody>
</table>

*Feedstock consumption is accounted for by means of the calorific value of the basic chemicals following the first conversion of fossil fuels to chemicals.

Source: IEA OECD, 2009

### Graph

- **Y-axis:** GJ/t Feedstock
- **X-axis:** Nelson Index
- **Legend:**
  - High Efficiency
  - Low Efficiency

Source: Ocic, 2005
The “Antifragile” Refinery

**Capacity:**
A minimum size to reach economy of scales

**Complexity:**
Ability to deliver high value light products

**Flexibility on feedstocks:**
Ability to process different slates of crudes thanks to an efficient trading unit and an adapted logistics system

**High distillate yield:**
Adapted to the European market with a strong demand for diesel

**Energy efficiency:**
Integration of the different units with efficient energy use

**Petrochemical Integration:**
Combined optimization of the feedstock streams, sharing units and transfers of products between refining and petrochemicals.

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*Source: BP Statistical Review 2015, Credit Suisse, 2015*

*Jacobs, 2009*
4. Refinery Petrochemical Integration. Future trends
Refinery Petrochemical Integration. FCC and Aromatics Complex

Maximum aromatics recovery. Significant technology challenges.

Source: Jechura, 2011
Oxidative Coupling of Methane

The oxidative coupling of methane has been the target of intense scientific and commercial interest for more than thirty years due to the tremendous potential of the technology to reduce costs, energy, and environmental emissions in the production of ethylene. In OCM, methane (CH₄) and oxygen (O₂) react over a catalyst exothermically to form ethylene (C₂H₄), water (H₂O) and heat, according to the following reaction:

\[ 2 \text{CH}_4 + \text{O}_2 \rightarrow \text{C}_2\text{H}_4 + 2 \text{H}_2\text{O} + \text{Heat} \]

While the benefits of OCM have been known since the early 1980s, past efforts did not result in a viable catalyst with performance needed for commercialization. These catalysts, while at times achieving promising yield and selectivity, were hampered by very high operating temperatures, low activities, and short lifetimes on the order of hours to days.

Recognizing this, Siluria applied a combination of new innovations in catalyst development, a thorough definition and understanding of the problem, and a highly motivated, creative research and engineering team to develop a unique catalyst to enable OCM to be commercialized.
Refinery Petrochemical Integration. Crude Cracking

ExxonMobil builds crude cracker in naphtha-reliant Asia

08 January 2014 [Source: ICIS news]

ExxonMobil, 2010

SCP Process Overview

* Selective Hydrogenation Unit
** Gasoline Hydrogenation Unit
*** Partial Oxidation Unit

ExxonMobil, 2010
Biofuels accounts for 1.4 MBboe/d % the 1.5% of the world demand. 10% by 2020
Refinery Petrochemicals Integration. Biofuels and Biochemicals

- **BioEthanol**
  - Dehydration → BioEthylene
  - Deoxygenation

- **BioPropanol**
  - Deoxygenation

- **BioButanol**
  - Deoxygenation
  - Hydrocracking → Bio-Naphtha
  - FCC
  - Bio-Butylene
  - Bio-Propylene

- **Sugars**
  - Vegetable Oil
  - Glycerine
  - Lignocellulosics
  - Furfural
  - Furfural Derivatives

**Technology Development Status**

- **Research**
- **Industrial**
- **Commercial**
5. Conclusions
CONCLUSIONS

• Petrochemicals is a cyclical market of high value products. Petrochemicals market size is 10% of the whole oil market.

• Petrochemicals strongly rely on feedstocks cost and availability. Shale gas boom and present oil glut, strongly affect the market dynamics.

• USA, ME and Asia are the most favored locations for petrochemicals production due to feedstock costs and product demand.

• Petrochemicals integration improves refinery’s economics despite the required investments are significant. The FCC seems to be the most promising unit for petrochemical integration.

• Petrochemical strongly contribute to improve refinery economic performance on a disparate set of economic environments
Thank you for your attention