Refining - Petrochemical Integration

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Agenda

◆ Introduction
◆ Refinery and petrochemical industries
◆ Refinery and petrochemical integration
◆ Case study
◆ Conclusions
Fluor - Executive Overview

◆ One of the world’s leading publicly traded engineering, procurement, fabrication, construction, maintenance, & project management companies

◆ #136 on the FORTUNE® 500 list in 2015

◆ Over 1,000 projects annually, serving more than 600 clients in 81 different countries

◆ 40,000+ employees executing projects globally

◆ Offices in 33 countries on 6 continents

◆ 103-year company legacy
The Energy & Chemicals business line serves the global oil and gas production/processing, chemicals, and petrochemicals industries.

- Ranks No. 1 on ENR (Engineering News-Record) magazine’s list of Top Design Firms in the Petroleum sector

- Full range of services including design, engineering, fabrication, procurement, construction, and project management

- Consulting services for feasibility studies and project financing

- Global office platform optimizes execution of all sized projects including mega-projects in remote locations with challenging environments
Energy & Chemicals
Worldwide Projects

Deep Conversion Refinery
Port Arthur, Texas

Shell Quest Carbon Capture & Storage
Alberta, Canada

TAQA Gas Storage Bergermeer
Alkmaar, the Netherlands

Shah Gas Development
Shah, United Arab Emirates

BASF Integrated Petrochemical Site II
Nanjing, China
Fluor Offices in Europe

Antwerp
Established in 2008
Industrial Services, Oil & Gas, Chemicals, Power, Manufacturing

Farnborough
Established in 1957
Energy & Chemicals, Life Sciences, Power, Infrastructure, Transportation, Telecommunications

Asturias
Established in 1989
Energy & Chemicals, Power, Life Sciences, Mining

Madrid
Established in 2002
Energy & Chemicals, Power, Life Sciences, Mining

Tarragona
Established in 2009
Industrial Services

Bergen op Zoom
Established in 1988
Industrial Services, Small Capital and Plant Engineering, Long Term Service Agreements, Operations & Maintenance

Amsterdam
Established in 1959
Energy & Chemicals & Infrastructure, EPC Execution Center for Europe, Africa and the Middle East

Moscow
Established in 1995
Energy & Chemicals, Industrial Services

Gliwice
Established in 1945
Energy & Chemicals, Power, Mining, Metals, Life Sciences, and Industrial Services

Rotterdam
Established in 2007
Industrial Services, Small Capital and Plant Engineering

Asturias
Established in 1989
Energy & Chemicals, Power, Life Sciences, Mining

Madrid
Established in 2002
Energy & Chemicals, Power, Life Sciences, Mining

Bergen op Zoom
Established in 1988
Industrial Services, Small Capital and Plant Engineering, Long Term Service Agreements, Operations & Maintenance
Fluor Office in Amsterdam

Year of establishment: 1959

Staff
630

Market Focus
Europe, Middle East, Russia

Average Years of Experience
22

Industries
Oil & Gas, Petroleum, Refining, Chemicals and Petrochemicals, Gas Processing & Underground Gas Storage

Major Clients
Shell, Tasnee, Ruhr Oel/BP, SABIC, KNPC, BASF SOCAR, TAQA, DOW, Lukoil, Exxon

Strengths
Studies, FEED, EPCm, PMC capabilities, multi-office execution, and new project execution strategies
Selected EAME Projects

- BASF SE
  BASF TDI Complex
  Ludwigshafen, Germany
  EPC

- SAPCO
  Super Absorbent Polymer Plant (SAP)
  Al-Jubail, Kingdom of Saudi Arabia
  EPC

- Repsol Petroleo SA
  C-10 Expansion
  Cartagena, Spain
  FEED, E, P, CM, PMC

- SABIC
  Confidential
  FEL

- Sasol Technology
  Multiple projects
  South Africa
  EPCM

- NATREF
  Natref Clean Fuels II Project, Sasolburg, South Africa
  FEED / EPCM

- ExxonMobil
  DCU & Flare
  Antwerp, Belgium
  EPC

- Shell
  REN
  Moerdijk, NL
  EPCm

- Esso
  RAHC Project
  Rotterdam, NL
  FEED, EPCm

- Sibur, Russia
  Multiple Projects
  PMC services

- SOCAR
  Multiple projects
  Azerbaijan
  PMC/Early Works

- KNPC
  Clean Fuels Project
  Kuwait
  EPC

- Abu Dhabi Gas Development Company
  Shah Gas Development (SGD) Program
  Abu Dhabi, UAE
  PMC services

- Kuwait Oil Company
  Multiple projects
  Kuwait
  PMC services

- QP / Shell Al Karaana Petrochemical Project
  Ras Laffan Industrial City, Qatar
  FEED

- Sadara Chemical Company
  Sadara, Location: Jubail, Kingdom of Saudi Arabia
  EPCM
Refining versus Petrochemical industry

**Refinery**
- Producing motor fuels from crude oil
- Large feedstock (crude) flexibility
- Produce a multitude of products
- High capacities
- Stand alone in power/steam
- Shortage of hydrogen
- Gas streams ($C_2$) not monetized
- Unsaturated gases & LPG not monetized
- High CO$_2$ emissions
- Tightening product specs (gasoline benzene & aromatics)
- Declining gasoline demand

**Base Petrochemical site**
- Steam Cracker based
  - base petrochemicals from NGL and/or naphtha
- Aromatics based
  - base petrochemicals from naphtha
- World scale
- High electricity consumption
- Excess hydrogen & gas
- Some streams not monetized
  - $C_4$=s
  - Py-gas
  - Py-oil
  - $C_9$ aromatics

Different industries but great synergy opportunities
Integrated refinery/petrochemical sites, operating margin

◆ Higher operating margin
  – Depressed products from one are valuable feedstock to the other
    ◦ Refinery gases and LPG as feedstock to petrochemicals
    ◦ Benzene rich stream from refinery to petrochemicals
    ◦ Petrochemical C4’s, py-gas/py-oil, hydrogen as feedstock to refinery
  – Reduced transportation costs
  – Energy savings
    ◦ Hot feeding
    ◦ More potential for combined cycle operation
    ◦ Bigger size -> higher efficiency
  – Lower staffing levels
    ◦ Centralized control room etc
    ◦ Synergy in support functions (maintenance, HR, security, admin.)
Lower investment cost

- Synergistic effects due to integration
  - Less equipment due to hot feeding and/or allowing reduced recovery
- Less redundancy
  - in steam/power generation
  - In hydrogen production
- Reduced storage volume of feed & products
- Reduced design margins
- Single site benefits
Integrated refinery/petrochemical sites, other issues

- Lower emissions
  - Only excess methane/import natural gas as fuel

- Increased flexibility
  - Choice of feed streams to the petrochemicals section to adjust to demand
  - Possibility to optimize crude cocktail to meet refinery & petrochemical needs
  - Back-up hydrogen supply to the refinery

There are multiple benefits in integrating refineries with petrochemical sites; how do we determine what makes sense?

Let’s develop a case study to shed some light on operating margin versus investment cost
Case study - I

Gas Processing Plant
- 12 BCMA capacity (9.1 million ton per year)

Petrochemicals
- Steam cracker
- Poly olefins
  - Poly ethylene (LLDPE & HDPE)
  - Poly propylene
- Butene 1 as co-monomer
- Butadiene
Gas Processing Plant and Petrochemical Complex

CASE 1

Gas Plant
- Export Treated Gas
- C2
- C3
- C4s
- C5+

Petrochemical Complex
- HDPE
- LLDPE
- Poly Propylene
- Butadiene
- Py-Gas
- Py-Oil

Natural Gas
Case study - II

◆ Gas Processing Plant
  – 12 BCMA capacity (9.1 million ton per year)

◆ Petrochemicals
  – Steam cracker
  – Poly olefins
    • Poly ethylene (LLDPE & HDPE)
    • Poly propylene
  – Butene 1 as co-monomer
  – Butadiene

◆ Refinery
  – 10 Million ton per year (200,000 bpd)
  – Producing Jet, Gasoline (Euro5) and Diesel (Euro 5)
  – FCC (incl. Alkylation & MTBE), Hydrocracker, Delayed Coking unit

<table>
<thead>
<tr>
<th>Stream</th>
<th>Minimum Production (kta)</th>
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<tbody>
<tr>
<td>LPG</td>
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<td>Jet Fuel</td>
<td>1300</td>
</tr>
<tr>
<td>Diesel</td>
<td>3000</td>
</tr>
<tr>
<td>Lubes</td>
<td>100</td>
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Stand alone case

CASE 1+2

Gas Plant

Export Treated Gas

C2
C3
C4s
C5+

Petrochemical Complex

HDPE
LLDPE
Poly Propylene
Butadiene

Py-Gas
Py-Oil

REFINERY

Methanol

Crudes

LPG
Gasoline R95
Gasoline R98
Jet Fuel
Diesel
Blown Bitumen
Asphalt
Sulphur
Anode Coke
Stand-alone versus integrated cases
Integration with respect to exchanging ‘non‐monetized’ streams
LP model required
  – multiple routings
  – product property constraints (motor fuel pools)
Evaluate operating margin
  – Gross margin minus Utility cost minus Cost of catalyst & chemicals
Expand with investment cost
  – AACE Class 5 basis
  – Consider maximum / optimized train sizes
Other synergy benefits (scaled down U&O systems, operating cost saving etc.) have not yet been considered
Cases 1-9: increasing level of integration

Operating margin increases with level of integration
Operation Margin

Operation Margin = Gross Margin – Utility Cost – Catalyst & Chemical Cost

But Operation Margin does not tell you everything you need to know ...

Propylene FCC further increases operating margin
Operating margin increases for either price set
Simple payback

Simple payback varies with options chosen: but some integrations make more sense than others
Conclusions I

- Integrating refineries with petrochemical complexes offers attractive benefits

- Based on this case study
  - monetizing stranded streams can increase operating margin by between 45 and 70%
  - However the net effects (after investment cost changes) are much lower; however simple payback can still improve by between 10 and 25%

- LP model results alone are insufficient; need to consider investment cost changes

- A full study needs to consider
  - miscellaneous synergy benefits
  - project execution effects
  - risk profiles
A proper study needs
- Marketing studies (feed and product pricing, demand patterns)
- Engineering contractors (LP work, financial modeling, investment cost, project execution strategy, risk profile)
- Customer (local and company specific criteria, operating cost, financing schemes)

And above all: TEAMWORK between all parties involved!

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