Exploiting Refinery and Petrochemical Integration (RPI)

Tom Kers
KBC Background
Global Perspectives
KBC Views on RPI
KBC RPI Methodology
RPI Examples
Conclusions

Refinery Petrochemical Integration (RPI) is the efficient use of resources between the refiner and the petrochemical plant operator to create greater value jointly than the two entities could separately achieve.
KBC History

1979
KBC founded as independent consulting company, specialising in energy improvement in refineries

1983
Release of DISTOP & CATOP; First yield & energy study applied to petrochemicals (ethylene plant)

1986
Development of Petrofine software leads to first refinery-wide flowsheets and Yield & Energy Surveys

1993
Y&E Survey develops into comprehensive Profit Improvement Program (PIP)

1995
Developed Reliability, Availability & Maintenance services

1996
On-site Implementation Services take KBC’s profit improvement deliverable to a new dimension

1997
KBC goes public - listed as plc on London Stock Exchange

1998
Purchase of Profimatics SIM models software

1999
KBC adds Strategic and Environmental consulting capabilities to the portfolio

2002
KBC extends into Oil and Gas market analysis with PEL acquisition and enhances Energy services with Linhoff March acquisition

2004
KBC releases Petro-SIM™ – Plant-Wide Flowsheet Simulation

2006
KBC enhances Operational Excellence and Human Performance improvement services with TTS Performance Systems and Veritech acquisitions

2009
KBC enhances Operational Excellence and Human Performance improvement services with TTS Performance Systems and Veritech acquisitions

2012
KBC acquires Infochem, adding strength in physical properties, PVT and flow assurance

2014
KBC acquires FEESA to further develop upstream capabilities with Maximus

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KBC acquires FEESA to further develop upstream capabilities with Maximus

People
Technology and Tools
Methodology
KBC Office Locations
Global Client Base

Aramco Asia, China
Bin Son Refinery, Vietnam
CNOOC, China
Cosmo Oil, Japan
Formosa Petrochem, Taiwan
FREP, China
Fuji Oil, Japan
InterOil, PNG
IRPC, Thailand
Koa, Japan
PetroChina, China
Petron, Malaysia
Petron, Philippines
Petronas, Malaysia
PTTES, Thailand
Samsung Total, Korea
Sinopec, China
SK Corporation, Korea
SPRC (ARC), Thailand
Thaioil, Thailand
Tonen General, Japan

Global Client Base

Alon, USA
Ancap, Uruguay
BP, USA
Coastal, USA
ConocoPhillips, USA
Ecopetrol (REFICAR), Ecuador
El Paso, Aruba
ENAP, USA
Flint Hills Resources LP, USA
Hess Oil Trading Company, USA
Hovensa, St. Croix
Husky Energy, Canada
Irving Oil, Canada
Lyondell-Basell, USA
Lyondell-Citgo, USA
Marathon, USA
Mobil, USA
National Oil Company, South America
NCRA, USA
Nova Chemicals Corporation, Canada
Parkland Income Fund, Canada
Pemex, Mexico
Petrobras, Brazil
Petro-Canada, Canada
Refining Process Services, USA
Rio Tinto, Americas
Sinclair, USA
Suncor, Canada
Teso Refining & Marketing Co, USA
Texaco, UK

ADM, Europe
BP, Nerefco, Netherlands
ConocoPhillips, UK
Engen, South Africa
Essar Oil, UK
GALP, Portugal
Grupa Lotos, Poland
Hellenic Petroleum, Greece
Holborn Europa Raffinerie GmbH, Germany
INA, Croatia
Koch, Netherlands
KPRL, Kenya
Kuwait Europort, Netherlands
Murphy Oil Corporation, UK
Oil Planning Service, Africa
Oman Oil RPI, Oman
OMV Aktiengesellschaft, Austria
PCK, Germany
Petrogal, Portugal
PetroPlus, France
PetroSA, South Africa
PKN Orlen, Germany
Raffineria di Milazzo, Italy
Rompetrol, Romania
Sasol Synfuels Ltd, South Africa
Slovneft, Russia
Total, France
Tupras, Turkey
Vitol, UK
Global Energy Perspectives
# Global Energy Perspectives

## Owner’s – Current Challenges

### Strategic
- Consolidation; Bankruptcy
- Ability to attract capital investment
- When to build grassroots/ expand
  ✓ Requirements that “drive projects”

### Market
- Current supply / demand changes
- Price volatility
- Credit availability
  ➔ General economic recession ongoing

### Operational
- Energy reduction
- Yield improvement / capacity increase
- Delayed / cancelled capital investment
- Aging assets
  - Operational availability
  - Process safety
- Skill retention / demographic changes

✓ **There are some simple things that drive projects**

1. Fill rate – Most chemical plants break even above a 60% capacity utilisation; some as high as 70-80%
2. Break even point – Must be profitable by year two, which implies a high fill rate is required
3. Prices / Margins – Depend on macro economic factors
4. Capital costs – can be controlled somewhat; relatively high in Japan

### Environmental / Regulatory
- Uncertain regulatory environment
  - Air emissions
  - Water emissions
- Required capital investments
  - Remain in operation
  - Increase capacity
Global Petrochemical Profitability

Profitability is Cyclical in the Petrochemical Business

Average Return on Replacement Capital

-10%
-5%
0%
5%
10%
15%
20%
25%
30%


Average cash margins were at all-time lows
- Now cycling up, are expected to peak in 2015

Refining Challenge – to increase historically low margins

Petrochemical Challenge – to maintain acceptable margins during the downturns

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KBC Views on RPI

KBC Conducted a Global Industry RPI Survey

- Hydrocarbon stream transfer is implemented, to some degree, at most refinery-petrochemical complexes
- Shared utilities were implemented to a much lesser extent for many reasons
- Shared logistics and services were only done at a few locations with common parent company owners on a single site
KBC Views on RPI

Effective Implementation of RPI Depends Heavily on Local Managerial Factors

Common Ownership

Develop the maximum benefit for the overall organisation even though it requires action by separate divisions

Separate Companies

The managerial challenge is even greater when achieving RPI with no common ownership Conflicting Profit Requirements
KBC Views on RPI

The U.S. and Singapore have the highest degree of RPI

Europe has only a moderate amount of RPI in place

Japan and Korea now showing increased interest in RPI

China, other Asia, and Middle East are increasing the extent of RPI from a low base

New mega projects will be integrated petrochemical refineries

- Example – PETRONAS “RAPID” scheduled to start up in 2017
# Refinery-PC Stream Dispositions

1. Refinery-derived cracker feeds can be:

<table>
<thead>
<tr>
<th>Standard Feeds</th>
<th>Non-standard Feeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>• LVN, HVN, FRN</td>
<td>• FCC Offgas – ethylene &amp; propylene</td>
</tr>
<tr>
<td>• Raffinate - BTX Recovery</td>
<td>• FCC Ethane and Propane</td>
</tr>
<tr>
<td>• AGO</td>
<td>• Alkylation Unit Butane Purge</td>
</tr>
<tr>
<td>• VGO</td>
<td>• Reformer LPG</td>
</tr>
<tr>
<td>• LSWR</td>
<td>• Reformer Fuel Gas</td>
</tr>
<tr>
<td>• Coker Light Ends</td>
<td>• Hydrocracked Gas Oil (HVGO)</td>
</tr>
<tr>
<td>• Hydrocracker Light Ends</td>
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</tbody>
</table>

2. Crackers generate by-product hydrogen

- Refineries consume hydrogen to remove sulfur and to saturate olefins and aromatics; ideal transfer stream

3. Refinery & cracker produce common aromatics & gasoline

4. Steam and fuel gas from the cracker are utilised in the Refinery

5. Heavy HC streams are used in a common Co-gen
Uncomplicated RPI Opportunities

Recovery of Cracker Hydrogen
Sell to Refinery to Replace Expensive Manufactured H2

Optimum Use of Storage and Logistics
Convert under-utilised tanks to other products/intermediates

Can be by a single company or between separate Cracker / Refinery
KBC Views on RPI

Complicated RPI Opportunity

For recovery of ethylene and ethane
This upgrade in value over fuel gas can be achieved in all ownership situations
KBC RPI Methodology

Two Phase Program
Tools, Experience, Objectivity
Refinery/Petrochemical Integration (RPI)

Benchmarking and Optimisation

- Model plant operations using rigorous simulation

Challenge Plant Constraints

- Implement Best Practices Throughout the Plant Organization

Evaluate Options Using Models

- Identify Opportunities with Quick Payouts

Develop & Implement Projects

- Constantly Monitor the Implementation Results – Profit Tracker

Sustain the Benefits

- Continuous Improvement with Appropriate KPIs

Primary Focus of RPI Study

- Implement Best Practices Throughout the Plant Organization
- Identify Opportunities with Quick Payouts
- Constantly Monitor the Implementation Results – Profit Tracker
- Sustain the Benefits with Continuous Improvement

The less well-integrated producers will be the marginal producers and price setters

Asian facilities cannot be as competitive as the Middle East but RPI is critical to Margin
Manage the Molecules - Rigorously

Full Complement of Rigorous Models

Olefin-SIM™ Rigorous Furnace Model

Olefins, iC₄

Gas Plant

ALK

H₂

ISOM

AROM

Light Naphtha

Heavy Naphtha

Kero

Diesel

CDU

VDU

Atmospheric Residue

Gasoil

Vacuum Residue

COKER / VISBREAKER

RHDS

Coker Model

Ethylene Plant

N HTR

K HTR

D HTR

HCR

VGO

HTR

FCC

Blender

KBC Petro-SIM™

Industry-leading Process Simulation Software Suite

Full set of Aromatics Models

Full Complement of Rigorous Models

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KBC Methodology – Phase 1

Data Input
- Clarifications
- Details
  - Business
  - Operations
  - Maintenance
  - Logistics
- Benchmarks

Activity
- Kick-Off Meetings
- Site Visits
- Benchmarking
- Opportunity Generation
- Quick Wins Test Runs
- Report Generation

Outcome
- Inception Report
- Base Case Report Petro-SIM Models
- Implement
- Early Benefits
- Recommendations

KBC & Owner(s) Internal Reviews

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KBC Methodology – Phase 2

Typical Scope for Phase 2 Implementation

**Step 1**
Upgrade the combined LP’s to represent ongoing exchange of process streams

**Step 2**
Use LP’s and rigorous process models to estimate detailed economics of opportunities and effect on overall operation

**Step 3**
Conduct rigorous opportunity evaluations including plant tests if they are required

**Step 4**
Perform pinch technology studies to evaluate hydrogen and utility integration opportunities

**Step 5**
Evaluate operating and or capital savings by integrating planned or potential strategic project synergies

Total Benefits $17.5 MM/yr

- Ethylene Yield
- Ethylene Energy
- Aromatics Yield
- Aromatics Energy
Rigorous Simulation Tools are Used

Flow sheet modelling
- Process simulation software suite
- Understanding process impacts
- Confidence that predicted results will match the plant operations
- Estimates potential economic benefits of process and operational changes
- Rigorous Petro-SIM models of conventional or step out processes

- Steam System Modelling

- Pinch Analysis

KBC’s ProSteam™ & SuperTarget™
Technical Evaluation - Overview

- **Process Technology**: Measure of quality of unit process design & incorporated technology
- **Licensor Experience**: Measure of technology/ licensor commercial experience for similar size & application
- **Licensor Package**: Measure of quality of licensor package; guarantees and liabilities; engineering and license fees
- **Global Technical Assistance**: Ability of licensor to provide technical assistance during start-up/normal operations
- **Design Complexity & Construction Schedule**: Assessment of investment costs and schedule implications; long-lead equipment
- **Operations and Maintenance**: Comparison of criteria affecting the operability of the plant such as Shut-downs, Reactor Conditions, Design Complexity
Economics Evaluation - Overview

- **Utility Consumption**
  - Quantitative comparison of utilities consumptions from guarantee figures

- **Yield Performance**
  - Quantitative measure of guaranteed feed consumption and product/ by-product production

- **Catalyst Performance**
  - Quantitative measure of initial cost of catalyst + inert materials + annual catalyst costs

- **Chemicals and Solvents**
  - Comparison of annual cost for Chemicals and Solvents from guaranteed Licensor figures

- **Capital Cost**
  - Quantitative comparison of Capital Cost based on KBC estimates and validated by Licensor figures

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Examples

*Industry Implementation of RPI*
<table>
<thead>
<tr>
<th>RPI Activity</th>
<th>Type of Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock Flexibility</td>
<td>Crack NGLs Through Gas Oil</td>
</tr>
<tr>
<td></td>
<td>Crack Conditioned Crude Oil</td>
</tr>
<tr>
<td></td>
<td>Crack LPG Opportunistically</td>
</tr>
<tr>
<td></td>
<td>Crack Raffinates</td>
</tr>
<tr>
<td>BTX Raffinate Optimisation</td>
<td>Crack or Blend in Gasoline</td>
</tr>
<tr>
<td>Crude and Cracker Feedstock Selection &amp; Optimisation of Operating Parameters</td>
<td>Optimise with a Single Linear Programming Model for Refinery &amp; PetChem Consider Refinery &amp; Cracker in Optimisation but Run in Separate Models</td>
</tr>
<tr>
<td>FCC Propylene Optimisation – production and recovery</td>
<td>Select Catalyst &amp; Operating Conditions for Increased Olefins Production Run Deep Catalytic Cracking</td>
</tr>
<tr>
<td>Condensate Optimisation</td>
<td>Crack Condensate in Furnaces (as-is or after treating)</td>
</tr>
<tr>
<td>Hydrocracker Unconverted Oil Optimisation</td>
<td>Crack Unconverted Cycle Oil (from Hydrocracker)</td>
</tr>
<tr>
<td>Use LCO as Primary Fractionator’s Quench Oil</td>
<td>Use LCO in Primary Fractionators</td>
</tr>
<tr>
<td>Recover Light Gases from Coker Overheads</td>
<td>Recover Coker Dry Gases and Separate the Olefins; Crack the Paraffins</td>
</tr>
<tr>
<td>Recover Light Gases from FCC Overheads</td>
<td>Recover FCC Dry Gases and Separate the Olefins; Crack the Paraffins</td>
</tr>
<tr>
<td>Recover Light Gases from Fuel Gas</td>
<td>Recover Paraffins from Fuel Gas Systems; use as Cracker Feeds</td>
</tr>
<tr>
<td>C₄ Optimisation/ Recovery</td>
<td>Produce C₄ Products such as Alkylate; Butadiene; MTBE; Propylene</td>
</tr>
<tr>
<td>Aromatics Optimisation</td>
<td>Recover and Produce Benzene; Toluene; Xylenes</td>
</tr>
<tr>
<td>Cutpoint Optimisation</td>
<td>Consider Petrochemicals when Optimising Reformer Cutpoint</td>
</tr>
<tr>
<td>Hydrogen Optimisation</td>
<td>Maximize Hydrogen Recovery in Cracker for Use in Refinery</td>
</tr>
<tr>
<td>Share C₃ Splitter – Maximize Propylene Recovery</td>
<td>Aggregate all Mixed C₃ Streams and Process in One C₃ Splitter</td>
</tr>
<tr>
<td>C₅ Optimisation – Cracking versus Gasoline</td>
<td>Consider Recovery of C₅ Molecules such as Isoprene; DCPC; Piperylenes</td>
</tr>
<tr>
<td>Pyrolysis Gas Oil Optimisation</td>
<td>Recover Aromatics from Pyrolysis Gasoline; Recycle Crack C₆-C₈ NA</td>
</tr>
<tr>
<td>Pyrolysis Tar Optimisation</td>
<td>Optimise PyTar to Cutter Stock, Carbon Black Feed or Needle Coke Feed</td>
</tr>
<tr>
<td>Plan Operations with Neighbors</td>
<td>Develop Operating Plans with Separately Owned Neighbors</td>
</tr>
<tr>
<td>BTX Heavies Optimisation</td>
<td>Optimise C₉+ Molecules to Blending or to Fuel</td>
</tr>
<tr>
<td>Integrate Waste Handling/ Effluent Treating</td>
<td>Ensure Full Compliance to All Regulations</td>
</tr>
<tr>
<td>Site-Wide Utility Complex; No Reliance on Grid</td>
<td>Maximum Utilization of All Heavy HC Streams</td>
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<tr>
<td>Optimum Use of Storage and Logistics</td>
<td>Convert Under-utilized Tanks to Other Products/ Intermediates</td>
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Case Study

Aromatics Integration with an Adjacent Cracker
## Olefins Process Optimisation

- Feed selection, $0.5M/yr identified
- Plant constrained by “unrealistic” propylene specification requested by customer, $3.5M/yr identified
- Optimisation of Ethylene plant Steam:Hydrocarbon ratio’s, $1.5M/yr identified
- Increase throughput by relaxing appropriate Deethaniser column constraints, $1.2M/yr identified

## Aromatics Process Optimisation

- Increased Paraxylene production, $7.0M/yr identified
- Paraxylene Unit, Isomerisation Unit, Ethylene & Benzene conversion optimised, 0.5M/yr identified
- Hydrogen usage optimised, $1.0 M/yr identified

**Additional Optimisation Points:**
- Increase Paraxylene unit feedrate
- Xylene Isomerisation feed rate increased against heater constraint
- Hydrogen savings identified to allow increase in Cyclohexane production
Case Study - Energy

SuperTarget™ – Heat Integration of Processes & Utilities

**Aromatics** $1.5M/yr savings
- Energy savings on recycle gas compressor, $1M/yr identified
- Energy savings on BTX extraction section resulting from improved feed pre-fractionation, $0.5M/yr identified

**Ethylene** $1M/yr savings
- Shortfall in performance of major turbine drivers, $0.7M/yr identified
- Opportunity to install turbo-alternator on steam let-down stream, $0.3M/yr identified

**Utilities** $1M/yr savings
- Setting correct marginal energy prices
- Optimise against cooling constraints
- Power generation from steam let-downs
- Attention to steam traps
Case Study - Planning

Developed a Standalone LP Model for the Complex

- All process units
- Showing integration with the 2 neighboring power plants
- Evaluation of feedstock, Production processing severity alternatives

Standalone LP Projects were Identified Based on the Model

- Seasonal effects
  - LP allowed fine tuning of operations to capture 10 to 20% of the $4M/yr difference in ethylene margin between Optimum Summer/Winter
- Product demand scenarios
  - LP allowed client to be able to vary unit severity based on ethylene and propylene demand worth $0.7~1.4M/yr
Case Study – Results Summary

$3.75 M/yr implemented before the end of the 6-month Phase 1

• Increase in the paraxylene production demonstrated in two test runs

Yield & Energy Benefits by Process

- Ethylene Yield
- Ethylene Energy
- Aromatics Yield
- Aromatics Energy

$17.95 / ton ethylene

$12.95 / ton total aromatic products

Total Benefits $17.5 MM
Conclusions

- Keys to Successful Project Development
- Systems Required for RPI Success
- Is RPI a Option or a Necessity?
Keys to Successful Project Development

Conduct Preliminary Economic Screening

- Identify viable integration options and technologies
- Embrace Capital Project Excellence (CapX™) and Operational Excellence (OpX™) throughout the project
- Methodology - keep up with the latest licensor and vendor offerings
- Tools – undertake rigorous simulations of the configurations being studied
- Experience – familiarity based on diverse industry experience

Project Evaluation & Execution

- Process Licensor Technology Comparisons
- Ranking Based on Detailed Methodology – Technical and Commercial Considerations
- Implementation Issues – Planning; FEED; PMC Services; Construction During Operation

Current Market Size | Raw Material Costs | Product Prices | SWOT & Barriers | Opportunity Ranking

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Is RPI an Option or a Necessity?

RPI is Being Implemented in Essentially all Grassroots Complexes Worldwide

Simple RPI Activities are not Enough to Compete Against Highly Integrated Mega Sites

Effective RPI Implementation Requires Strong Managerial Support

Rigorous Study & Implementation → Requires Methodology, Tools and Expertise

→ RPI is a necessity to be competitive

Agreed Identified Benefit (¢/bbl)

- 20.8 ¢/bbl
- 3.6 ¢/bbl
- 106.6 ¢/bbl

Yield & Energy Benefits by Process

Total Benefits $17.5 MM

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Thank You
감사합니다

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