CONVERT RESIDUE TO PETROCHEMICALS

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Global primary energy outlook
Global petroleum product demand
Crude quality projections
Light olefins & their derivatives
Emerging refining scenario & challenges
Residue upgradation technologies
Technology for resid to light olefins – INDMAX
Summary
As of 2010, total primary energy supply was 235.4 MBOE/day

Projected total primary energy supply in 2035 at 355.9 MBOE/day
- Coal dominates the global energy supply followed by oil in 2035
- Contribution of oil would remain significant throughout
GLOBAL PETROLEUM PRODUCTS DEMAND: 2010 & 2035

- Total products demand in 2010 was 86.8 Million Barrels/day
- Projected products demand in 2035 at 109.7 Million Barrels/day

* Includes refinery fuel oil
** Includes bitumen, lubricants, waxes, still gas, coke, sulfur, direct use of crude oil, etc.
Global demand for Residual Fuel would decrease from 10.6% in 2010 to 5.9% in 2035
GLOBAL CRUDE QUALITY OUTLOOK

Source: World Oil Outlook, 2011
CRUDE OIL YIELDS

API Gravity

Lighter

Heavier

Refinery Complexity

Low

High

<table>
<thead>
<tr>
<th>API Gravity</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.3</td>
<td>0.3%</td>
</tr>
<tr>
<td>27.6</td>
<td>1.1%</td>
</tr>
<tr>
<td>21.3</td>
<td>3.5%</td>
</tr>
<tr>
<td>15.3</td>
<td>2.5%</td>
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</tbody>
</table>
Shares of synthetic crudes derived from oil sands would increase by 7%
- API < 10; Bottom > 60 wt%
- Condensate crude shares would increase by 1%
- Lighter sweet crude shares would drop by 4%
- Medium crude shares would drop by 2%
- Heavy crude shares would drop by 3%

Source: World Oil Outlook, 2011
EMERGING REFINING SCENARIO

- Oil continues to be major energy source up to 2035
- Era of easy oil almost over – future crudes to be heavy & extra heavy
- Increasingly stringent automotive fuel & lube specifications
  - Product finishing (HDS, Hydrotreating, Lube Hydro-finishing etc.)
  - High hydrogen demand in refinery
- Declining FO demand
  - Dedicated facilities for residue upgradation
- Environmental regulations to be in increasing order
  - Elaborate ETP, Particulate arrestor, SOX and NOX control facilities
- Fluctuations in crude & product prices resulting in frequent adjustment to refining operations
- High investment & operating cost
- Increasing competition

Intelligent Refining – Key for Survival
**PROPYLENE SOURCES & DERIVATIVES**

**Sources**
- Steam crackers: 30
- FCC: 64
- Others: 6

**Derivatives**
- Polypropylene: 62
- Propylene oxide: 12
- Acrylic acid: 4
- Acrylonitrile: 9
- Cumene: 3
- Isopropanol: 8
- Others: 2

*Source: Nexant*
ETHYLENE SOURCES & DERIVATIVES

Sources
- Polyethylene (LDPE, LLDPE, HDPE)
- Ethylene oxide/ Ethylene Glycol
- EDC/PVC
- Alpha Olefins
- Ethyl benzene/Styrene
- Others

Derivatives
- Polyethylene (LDPE, LLDPE, HDPE)
- Ethylene oxide/ Ethylene Glycol
- EDC/PVC
- Alpha Olefins
- Ethyl benzene/Styrene
- Others

Source: Nexant
## Global Propylene Sources & Production

<table>
<thead>
<tr>
<th>Source</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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<tbody>
<tr>
<td>Steam crackers, MT</td>
<td>43459</td>
<td>53743</td>
<td>66318</td>
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<tr>
<td>FCCU, MT</td>
<td>20107</td>
<td>23138</td>
<td>28349</td>
</tr>
<tr>
<td>Dehydrogenation, MT</td>
<td>1777</td>
<td>2721</td>
<td>2776</td>
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</tbody>
</table>

Propylene derivatives growth rate till 2015

- Polypropylene : 5.5%
- Propylene Oxide : 4.3%

- World ethylene demand is expected to cross 160 MMTPA by 2015 as per Global Industry Analysts.

- Asia-Pacific, Europe and North America - major consumers of ethylene (over 87% of the global ethylene market)

Source: CMAI

Source: www.pudaily.com
PROPYLENE DEMAND

C3= demand growth rate ~ 5% pa - Increasing gap between C3= demand & supply from steam cracker

Produce propylene from alternate route that gives high propylene/ethylene ratio
RESID UPGRADEATION PROCESSES

- Carbon Rejection Technologies
  - Deep Cut Vacuum Distillation (Increase VGO cut point >590°C)
  - Solvent De-Asphalting (SDA)
  - Thermal Cracking (Visbreaking, Delayed Coking, etc.)
  - Catalytic Cracking (RFCC)
  - Gasification

- Hydrogen Addition Technologies
  - Fixed Bed Catalytic Cracking
  - Ebullated Bed Catalytic Cracking

- Ultrasonic Treatment Technologies
  - Cavitation Induced Hydrocarbon Cracking
FCC as Resid Processing Option
PROBLEMS WITH RESID PROCESSING IN FCC

- Ni → More H₂, Dry Gas & Coke
- S → SOx Emmission, ‘S’ in Product
- V & Na → Zeolite Destruction
- Basic N₂ → Zeolite Acidity Neutralization
- Aromatics → More Coke & Low conversion
- Con. Coke → High Regen temp, Low Cat/Oil

High catalyst consumption to maintain activity
Nickel (Ni) & Vanadium (V) deposit on outer layer of catalyst particles and catalyze dehydrogenation & condensation reactions

- More Dry gas - can limit WGC capacity
- More Coke - can limit coke burning capacity

- Higher regn. temp.
- Lower cat/oil ratio
- Loss in conversion

Ni is about four times more active than V as dehydrogenation catalyst

V has both inter & intra- particle mobility

V destroys zeolite structure resulting reduced catalyst surface area & activity
Main Contaminant metals: V, Ni, Na

V - Reduces catalytic activity & enhance DG, coke

Ni - Enhances DG, hydrogen, coke by dehydrogenation

Na - Reduces catalytic cracking
TECHNOLOGICAL GAP

- Deteriorating crude quality producing more residue per barrel of feed
- Declining demand of fuel oil
- Growing gap between propylene demand & supply from steam cracker
- Delayed coking
  - Highly suitable for processing heaviest residues
  - LPG /light olefins yield: low; Naphtha – poor quality
  - High yield of low value fuel grade coke

Fluid catalytic cracking (FCC/RFCC)
- LPG yield : ~ 15-20 wt% 
- Propylene in LPG : ~ 28-35 wt%
- Gasoline octane (RON) : ~ 90
- Limitation in processing resid feedstocks
  - CCR up to 5 wt%; Metal poisons (Ni+V) up to 35 PPM

Conventional refining processes have limitations in converting heavy feedstock to high yield of light olefins & high octane gasoline
INDMAX

A breakthrough technology for direct conversion of Residue to high yields of Light olefins & High octane gasoline rich in BTX
High severity operation
- Riser outlet temperature (> 550°C)
- Catalyst to oil ratio (wt/wt) (>12)

High steam to feed ratio (> 0.1)

Low delta coke - Excellent heat integ
- Relatively lower regenerator temp. (650 - 730°C)

Proprietary tailor-made catalyst formulation
- Higher propylene selectivity
- Superior metal tolerance
- Lower coke make

Excellent coke selectivity & metal tolerance of Indmax catalyst allows high severity operation
Hardware - Simple configuration

- Simple configuration of circulating fluidized bed riser – reactor – stripper – regenerator configuration
- Single riser - multiple diameter
- Single stage regenerator with total combustion - No CO boiler
- No catalyst cooler (Feed CCR <6%)
- No feed furnace (Feed CCR >2 %)

Feed: Wide range of feedstocks from heavy residue, fuel oil, gas oil & naphtha

- Up to 11 wt% feed CCR
- (Ni+V) up to 100 ppm

Products:

- LPG yield : 30-55 wt% on feed
- Propylene in LPG : 40-55 wt%
- Ethylene in Dry gas : 45 – 60 wt%
- High octane gasoline : RON > 95
- (Tolune + Xylene) in Gasoline up to 40 wt%
**CATALYTIC CRACKING REACTIONS**

**Paraffins**
- Cracking → Paraffins + Olefins

**Olefins**
- Cracking → LPG Olefins
- Cyclization → Naphthenes
- Isomerization → Branched Olefins → H Transfer → Branched Paraffins
- H Transfer → Paraffins
- Cyclization → Coke
- Condensation → Coke
- Dehydrogenation → Coke

**Naphthenes**
- Cracking → Olefins
- Dehydrogenation → Cyclo-olefins → Dehydrogenation → Aromatics
- Isomerization → Naphthenes with different rings

**Aromatics**
- Side chain cracking → Unsubstituted aromatics + olefins
- Trans alkylation → Different alkyl aromatics
- Dehydrogenation → Polyaromatics → Alkylation → Coke
- Condensation → Dehydrogenation
- Condensation

*Hydrogen transfer → Naphthene + Olefin → Aromatic + Paraffin*
Coke burning reactions

\[ \text{C} + \frac{1}{2}\text{O}_2 \rightarrow \text{CO} \ (\Delta H = -2200 \text{ kcal/kg}) \]

\[ \text{CO} + \frac{1}{2}\text{O}_2 \rightarrow \text{CO}_2 \ (\Delta H = -5600 \text{ kcal/kg}) \]

\[ \text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O} \ (\Delta H = -28900 \text{ kcal/kg}) \]

<table>
<thead>
<tr>
<th>Mode</th>
<th>Total Combustion</th>
<th>Partial Combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke on regenerated catalyst, wt%</td>
<td>&lt; 0.05</td>
<td>&gt; 0.05</td>
</tr>
<tr>
<td>Effective catalyst activity</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Regenerator temperature, °C</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>CO in flue gas, ppm</td>
<td>&lt; 1000</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Requirement of CO Boiler</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Chances of Afterburning</td>
<td>Lower</td>
<td>Higher</td>
</tr>
</tbody>
</table>
HEAT BALANCE

Flue Gas to WHRU

Heat of coke combustion

Heat loss

Regenerator

Exothermic

Endothermic

Heat of reactions

Products to Fractionator

Riser

Feed preheater

Heat loss

Steam

Feed

Reactors

Stripper

Steam
Commissioned 2000 BPSD plant in June 2003 for processing residue (CCR: 4 wt%)

Products: Propylene/LPG, High octane Gasoline component

Currently in regular operation

Successfully processed feed CCR of 5 wt% & demonstrated 17 wt% propylene yield (once through)

Flexible to operate in MS or light olefin maximization mode
<table>
<thead>
<tr>
<th></th>
<th>Test run After start up</th>
<th>Test run Current operation</th>
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</thead>
<tbody>
<tr>
<td>Feed rate, MT/hr</td>
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<td>11</td>
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<tr>
<td>Heavy feed, wt%</td>
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<td></td>
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<tr>
<td>API gravity</td>
<td>80</td>
<td>91.5</td>
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<tr>
<td>CCR, wt%</td>
<td>18.1</td>
<td>18.5</td>
</tr>
<tr>
<td>Sulfur, wt%</td>
<td>3.74</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>0.38</td>
<td>0.43</td>
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<tr>
<td>Coker Gasoline feed, wt%</td>
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<td></td>
</tr>
<tr>
<td>API gravity</td>
<td>20</td>
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<tr>
<td>Sulfur, wt%</td>
<td>66</td>
<td>65.3</td>
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<tr>
<td></td>
<td>0.14</td>
<td>0.12</td>
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<tr>
<td>Riser top temp, °C</td>
<td>588</td>
<td>580</td>
</tr>
<tr>
<td>Regen dense temp, °C</td>
<td>700</td>
<td>706</td>
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<tr>
<td>CRC, wt%</td>
<td>0.05</td>
<td>0.06</td>
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<tr>
<td>Propylene, wt%</td>
<td>17.1</td>
<td>17.3</td>
</tr>
<tr>
<td>CLO, wt%</td>
<td>3.5</td>
<td>7</td>
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<tr>
<td>Gasoline RON</td>
<td>&gt; 98</td>
<td>&gt; 98</td>
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</table>
Agreement exist between IndianOil & Lummus Technology Inc., USA for worldwide marketing & licensing of INDMAX Technology

**IndianOil R&D**
- Provides Basic Process Design data/information to Lummus

**Lummus**
- Worldwide marketing & licensing of INDMAX Technology
- Prepares & provides the Process Design Package to the clients
- Required know-how, experience & credibility in building commercial large FCC units
- Possesses design know-how of FCC internals / subsystems
  - Micro-jet feed injector, Packed bed catalyst stripper, Direct coupled cyclone, etc.
**INDMAX-FCC REACTOR-REGENERATOR**

- **Direct-Coupled Cyclones**
- **Reaction Riser** (Short Contact Time)
- **Cyclone Containment Vessel (CCV)**
- **Micro-Jet Feed Injection Nozzles**
- **Turbulent Regenerator Bed**
- **External Regenerated Catalyst Hopper**
- **Micro-Jet Feed Injection Nozzles**
- **Cyclone Containment Vessel (CCV)**
- **MG Stripper**
- **Turbulent Regenerator Bed**
- **Direct-Coupled Cyclones**
- **Turbulent Regenerator Bed**
- **External Regenerated Catalyst Hopper**
- **MG Stripper**
- **Direct-Coupled Cyclones**
- **Cyclone Containment Vessel (CCV)**
INDMAX - CONTINUAL DEVELOPMENT

Improvement of light olefins yield

Setting up 85000 BPSD unit

Collaboration with Lummus for global marketing & licensing

Scale up & Commercialization

Process development & pilot plant demonstration

INDMAX Technology

Yields of light olefins with paraffinic VGO feed (wt%):
- Propylene: 27
- Butylenes: 15
- Ethylene: 14

Highly attractive yields for integration with petrochemicals
IndianOil’s proven INDMAX technology can meet Refiner’s objectives of propylene maximization & residue upgradation in cost effective manner.
A novel technology for direct conversion of residue to high yields of light olefins & high octane gasoline rich in Toluene & Xylene developed, designed and demonstrated indigenously

- Feed CCR up to 11 wt%
- Very high Vanadium tolerance of catalyst (feed Ni+V up to 100 ppm)
- Excellent heat balance due to low delta coke & high cat/oil ratio
- Simple hardware configuration for residue conversion
  - No feed furnace, CO boiler & catalyst cooler (upto 6% CCR)

INDMAX provides unique opportunity to address the underlying issues in the emerging refining scenario
Questions?

Thank You