Achieving Process Energy Efficiency via Innovation
Agenda

- Why focus on Refining/Petrochemical for reducing CO$_2$?
- How can innovation help to reduce energy/CO$_2$?
- Real Life Examples of Energy improvement
Typical USA Refinery with FCC

Flowrates in bbl/day

Nat Gas → H₂ Plant (14,000) → to HT

H₂ Plant → Isomerization (14,000) → Naphtha HT/Spl (42,000)

Naphtha HT/Spl → Crude Column (150,000)

Crude Column → VGO Ht (45,000) → Vacuum Unit (45,000)

Vacuum Unit → Delayed Coker (32,000)

Delayed Coker → FCC (38,000) → Distillate Hydrotreater (60,000)

Distillate Hydrotreater → Reforming

Reforming → Gas Recovery → Sulfur Plant → Sulfur

Sulfur Plant → LPG

Gas Recovery → Gasoline

Gasoline → Jet

Jet → Low S Diesel

Low S Diesel → Slurry Oil

Slurry Oil → Coke

Achieving Process Energy Efficiency via Innovation
Energy & CO₂ in a Refinery

- In the US, refining contributes to ~4% of CO₂ emissions
- 8-11% of crude is consumed as energy to drive the processes
- Energy costs 50% to 60% of total variable operating costs (excluding feedstocks)
- $80 to $100 million/year on energy & 1.2 to 1.5 million metric tons/year of CO₂
- CO₂ emissions increase with heavier feedstock, cleaner fuels, conversion and complexity

<table>
<thead>
<tr>
<th>Refining Unit</th>
<th>% of Energy Consumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDU/VDU</td>
<td>17</td>
</tr>
<tr>
<td>Fluid Catalytic Cracking (FCC) Unit</td>
<td>20</td>
</tr>
<tr>
<td>Reformer</td>
<td>14</td>
</tr>
<tr>
<td>Hydrocracking</td>
<td>10</td>
</tr>
<tr>
<td>Alkylation and Hydrotreating</td>
<td>15</td>
</tr>
<tr>
<td>Coker</td>
<td>4</td>
</tr>
<tr>
<td>Utilities</td>
<td>15</td>
</tr>
<tr>
<td>Offsite</td>
<td>5</td>
</tr>
</tbody>
</table>

Basis: for a 100,000 BPSD refinery; natural gas cost @ $6/MMbtu
Solutions for Energy and CO₂ Reduction

**Reduce Energy Costs and Emissions**
- Use Energy More Efficiently in Process
- Reduce Emissions
- Managing H₂/Fuel Systems Efficiently

**Get Energy Cheaper**
- Use Carbon Credits

**Operate More Efficiently**
- Recover More Heat
- Utilize New Process Technology
- Better Manage H₂
- Better Manage Fuel Gas System

**Improve Monitoring & Operation**
- Improve Heat Integration
- Reduce Waste/Leaks
- Advanced Process Technology, Equipment & Catalysts
- Minimize H₂ to Fuel
- Manage H₂ Partial Pressure
- Maximize Recover of Valuable Components
- Minimize Fuel Gas Flare

**Online Control & Optimization**
- Improve Resource Allocation
- Boiler/Turbine Performance
- Balance Supply & Demand
- Renewable Energy Source
- GHG Capture & Storage

**CO₂ Summit: Technology & Opportunity – June 9th, 2010**
## Opportunities for Energy Savings

<table>
<thead>
<tr>
<th>Area of Savings</th>
<th>Actions</th>
<th>Energy Improvement</th>
<th>Energy Savings</th>
<th>CO(_2) Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved operation and control</td>
<td>• Improve online operation, optimization and control</td>
<td>2 to 4%</td>
<td>$1.5M to 3M/year</td>
<td>24,000 to 48,000 metric tons/year</td>
</tr>
<tr>
<td>Improved heat recovery</td>
<td>• Increase heat recovery within and across process units.</td>
<td>5 to 10%</td>
<td>$4M to 7.5M/year</td>
<td>60,000 to 120,000 metric tons/year</td>
</tr>
<tr>
<td>Advanced Process Technology</td>
<td>• Employ new process technology, design and equipment</td>
<td>3 to 8%</td>
<td>$3M to 6M/year</td>
<td>36,000 to 96,000 metric tons/year</td>
</tr>
<tr>
<td>Steam and Power Optimization</td>
<td>• Energy supply optimization for driver selection, equipment loading and utility buy/sell.</td>
<td>2 to 3%</td>
<td>$1.5M to 2.3M/year</td>
<td>24,000 to 36,000 metric tons/year</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>12 to 25%</td>
<td>$10M to 20M/year</td>
<td>144,000 to 300,000 metric tons/year</td>
</tr>
</tbody>
</table>

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Innovations to Save Energy & Reduce CO₂

- Apply new technology, equipment, and catalysts
  - High selectivity/activity catalyst
  - High efficiency reactor internals
  - High capacity fractionator internals
  - Enhanced heat exchangers
  - Modern power recovery turbines
  - Novel process design
Load new distillate catalyst in Unicracking Unit
Energy Impact from Higher Distillate Selectivity

Benefits of Catalyst Change

1. Lower chemical H2 consumption reduces natural gas consumed at H2 Plant
2. Lower chemical H2 consumption reduces makeup gas compression energy
3. Higher distillate selectivity reduces heat release in the new distillate catalyst; less quench is required
4. Lower quench requirement reduces the recycle gas compressor utilities
What makes a refinery more efficient? -- Equipment selection optimization

- Helical baffle exchanger for fouling services?
- High-con tubes for column overhead condensers?
- Dividing wall column for fractionators/separators?
Conventional Separation – 2 Columns

Dividing Wall Column
- Vertical wall separates column sections
- Eliminates separation inefficiency
- 3 products using a single column
- Typically 25-40% savings in capital and energy costs
Integration of Separation Processes

FEED

Column 1

Product 1

Condenser

Column 2

Product 2

Condenser

Column 3

Product 3

Product 4

Reboiler

Reboiler

Reboiler

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Achieving Process Energy Efficiency via Innovation
Conventional Design – Pinch Representation
-Requires High Utility Demand for Reboiling

Composite Curves

- Steam & Fuel: 300 MMBtu/h
- Cooling Utility: 320 MMBtu/h

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Achieving Process Energy Efficiency via Innovation
Optimized Design – Pinch Representation
- Minimizes Utility Needs for Reboiling

**Composite Curves**

- **Process-Process Heat Recovery:**
  - 200 MMBtu/h
  - 330 MMBtu/h

- **Steam & Fuel:**
  - 200 MMBtu/h

- **Cooling Utility:**
  - 220 MMBtu/h

**Temperature (°F)**: 0, 100, 200, 300, 400, 500, 600

**Enthalpy (MM Btu/hr)**: 0, 100, 200, 300, 400, 500, 600, 700, 800
Enhanced Heat Transfer Tubing - Boiling

- Porous metal coating applied to boiling side
  - Maximizes boiling coefficient
  - Extends boiling to very low LMTD’s
- Overall coefficient 2 to 4 times that of bare tube
- Conventionally used to reduce equipment size and installation cost
- Can be leveraged to enable better heat integration between process operations for significant energy savings
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Example: Refinery Wide Energy Study

- Energy study identified energy savings potential of $61.3 million/yr at capital cost of $75.5 million.
- Refinery selected 31 projects out of 73, with overall benefit of $33 million/yr at the capital cost of $30 million for the next six years.
- Main units where savings were identified were Hydrotreaters, Crude & Vacuum Fractionation, Delayed Coker and Naphtha Reforming.
- Basis: Large refinery.
Example: Refinery Energy Retrofit

- 19 projects identified at refinery with throughput of 110,000 barrels per day
- Units include CDU, HCU, DHT, Platforming, Steam and Power system
- Total energy saving: 330 MMBtu/h (17%)
- Total energy cost saving: $27 million/yr
- Overall simple payback less than two years
- Total CO$_2$ reduction: 230,000 metric tons/yr (19%)
- The refinery decided to move many of these energy projects forward into implementation
FCC Energy Efficiency Trend

- Significant energy reduction realized through innovation and application of other design improvements

Comparison for FCC Energy Efficiency

20% Reduction

20% corresponding to energy savings of $8-10 M/yr and CO2 reduction of 80~10 kMt/yr CO2
Aromatics Complex Energy Reduction

- Current technology employs significant heat integration
- Recent energy reduction program undertaken to identify potential for further improvement

**Result → Energy Savings >30%**

- Application of innovative equipment/strategies enables change to heat integration for a reduction in low level heat rejected
- Energy saving: 400 MMBtu/h
- Cost saving: $20 million/yr
- Simple payback: < 2 years
- Total CO\(_2\) reduction: 200 kMt/yr

Basis: Current world scale aromatics complex and natural gas cost @ $6/MMbtu
25% energy saving for refining industry:

Savings of 391,000 BPD fuel eqv for US refining
- $5 Billion/year saving in energy operating cost
- 48 MMt/year of CO2 reduction

Savings of 1.8 MMBPD fuel eqv for global refining
- $25 Billion/year saving in energy operating cost
- 240 MMt/year of CO2 reduction

Basis: US refining: 17 MMBPD; Global: 79 MMBPD; 2Q as the average; natural gas cost @ $6/MMbtu
Thank You!

Q & A