Quality and Conversion Capacity Upgrade

Case Study

Sébastien HUCHETTE
Prime-D & Prime-K Licensing For ULSD, ULSK & Cetane Uplift

North America
- 18 units

Central & South America
- 12 units

Europe
- 24 units

CIS
- 7 units

Middle East - Africa
- 29 units

Asia - Pacific
- 22 units

- 112 Prime-D Units Licensed for ULSD
- 62 awards over the last 4 years
- 14 units in 2010
- 32 revamps of Diesel HDT for ULSD or Cetane gain

as of December 2010
Agenda

• Performance Programs
  Axens' Consulting Services

• Case study: African refinery master plan
  • Refining context
  • Objectives and challenges
  • Technological solutions
  • Profitability study
An Organization Favoring Synergies

Jean Sentenac – CEO

Business Units
- Process Licensing
- Catalysts & Adsorbents
- Performance Programs

Support Departments
- Marketing
- Tech Service
- Technology

Subsidiaries
- Axens North America, Inc.
- Axens Far East KK
- Axens (Beijing) Trading Co Ltd
- Axens Middle East SPC
- Axens India Private Ltd
- Axens Vostok
- Axens Canada Specialty Aluminas Inc.
Agenda

• Performance Programs
  Axens' Consulting Services

• Case study: African refinery master plan
  • Refining context
  • Objectives and challenges
  • Technological solutions
  • Profitability study
Market Demand, Mbdoe

Market Structure, %

AAGR 09-20

2009

2020

3.4 Mbdoe

4.5 Mbdoe

11.8% 11.3% 3.3%

10.5% 11.2% 2.4%

21.3% 21.5% 1.1%

4.8% 4.7% 2.8%

20.8% 24.3% 2.4%

15.3% 14.4% 4.2%

14.8% 12.1% 2.2%

1.1% 2.2% 0.9%

Other* = Kerosene (≠ Jet Fuel), Refinery Gas, Petroleum Coke, NGL, Lubricants, Bitumen, Paraffin Wax, Refinery Losses, …

Source: Axens & other sources (2009)
8.5 Mt/y  
(Gasoline)  
Ex-NWE/Med

2.8 Mt/y  
(Diesel)  
Ex-NWE

5.5 Mt/y  
(Diesel/Jet)  
Ex-Middle East/India

Mt/y = Million metric tons per year
## Country & EU Gasoline Specifications

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur, ppm max</td>
<td>500</td>
<td>300</td>
<td>150</td>
<td>150</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Aromatics, vol% max</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>42</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Olefins, vol% max</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Benzene, vol% max</td>
<td>Report</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lead, ppm max</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>RON, min</td>
<td>91</td>
<td>91</td>
<td>91</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
</tbody>
</table>

**Expected transition in Local Market**

- **AFRI**: 2020
- **Euro III**: 2005
- **Euro IV**: 2005
- **Euro V**: 2009

ARA 2011 - Cape Town, South Africa
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur, ppm max</td>
<td>3500</td>
<td>500</td>
<td>50</td>
<td>350</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Polyaromatics, vol% max</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Cetane Number, min</td>
<td>46</td>
<td>46</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Cetane Index, min</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Density, @15°C, kg/m3</td>
<td>800-890</td>
<td>800-890</td>
<td>820-880</td>
<td>820-845</td>
<td>820-845</td>
<td>820-845</td>
</tr>
</tbody>
</table>

**Expected transition in Local Market**

2020
• Performance Programs
  Axens' Consulting Services
• Case study: African refinery master plan
  • Refining context
  • Objectives and challenges
  • Technological solutions
  • Profitability study
Refinery Process Configuration

Yields vs crude

- Butane Pool: 2%
- Gasoline Pool: 17%
- Kerosene Pool: 25%
- Diesel: 39%
- Fuel Oil: 13%
- Bitumen: 4%
Pre-Feasibility Study Objectives (1/2)

• Determine the most appropriate refining scheme which fits with the local market:
  • Maximize distillate production
  • Satisfy to new AFRI-4 specifications
  • Adapt residue processing based on:
    • Residue availability
    • Residue quality

• Processing scheme flexibility:
  • Conversion flexibility to process future crude slate and adapt to the demand of bitumen
  • Hydroprocessing flexibility to achieve AFRI-4 specifications on existing crude slate and future crude slate
Pre-Feasibility Study Objectives (2/2)

- Refinery Resources:
  - Electricity produced on-site but may also be purchased from utility company
  - Self-sufficiency in other energies and H₂ production
  - Import of natural gas is capped

- Selection of Refinery Scheme based on
  - CAPEX, NPV, IRR
## Strategy by Product Pools

<table>
<thead>
<tr>
<th>Product Pools</th>
<th>Local Market</th>
<th>Export Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG ($C_3/C_4$)</td>
<td>No constraint</td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>Satisfy</td>
<td>Minimize</td>
</tr>
<tr>
<td>Kerosene</td>
<td>Satisfy</td>
<td>Maximize</td>
</tr>
<tr>
<td>Jet A1</td>
<td>Satisfy</td>
<td>Maximize</td>
</tr>
<tr>
<td>Diesel</td>
<td>Satisfy</td>
<td>No constraint</td>
</tr>
<tr>
<td>Specialty GO</td>
<td>Satisfy (niche market)</td>
<td></td>
</tr>
<tr>
<td>FOD</td>
<td>Satisfy</td>
<td></td>
</tr>
<tr>
<td>VGO</td>
<td>Minimize</td>
<td></td>
</tr>
<tr>
<td>HSFO</td>
<td>Minimize</td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>Optimize</td>
<td>(cap is twice current production capacity)</td>
</tr>
</tbody>
</table>

ARA 2011 - Cape Town, South Africa
**Crude Slate**

<table>
<thead>
<tr>
<th>Quality</th>
<th>Current Blend</th>
<th>Future Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>29.5</td>
<td>28.3</td>
</tr>
<tr>
<td>Sulfur, wt %</td>
<td>0.24</td>
<td>0.32</td>
</tr>
<tr>
<td>Nitrogen, ppm</td>
<td>1,200</td>
<td>1,600</td>
</tr>
<tr>
<td>Nickel, ppm</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Vanadium, ppm</td>
<td>Nil</td>
<td>4</td>
</tr>
<tr>
<td>CCR, wt %</td>
<td>1.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

⇒ Heavier crude

**Distillation yields (wt%)**

- Refinery Gases
- Light Naphtha (LN)
- Heavy Naphtha (HN)
- Kerosene
- Gas Oil (GO)
- Heavy Gas Oil (HGO)
- Vacuum Gas Oil (VGO)
- Vacuum Residue (VR)
**Crude Slate**

### Quality

<table>
<thead>
<tr>
<th>Quality</th>
<th>Current Blend</th>
<th>Future Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>29.5</td>
<td>28.3</td>
</tr>
<tr>
<td>Sulfur, wt %</td>
<td>0.24</td>
<td>0.32</td>
</tr>
<tr>
<td>Nitrogen, ppm</td>
<td>1,200</td>
<td>1,600</td>
</tr>
<tr>
<td>Nickel, ppm</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Vanadium, ppm</td>
<td>Nil</td>
<td>4</td>
</tr>
<tr>
<td>CCR, wt %</td>
<td>1.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

- **Heavier crude**

### Distillation yields (wt%)

<table>
<thead>
<tr>
<th></th>
<th>Current Blend</th>
<th>Future Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **VGO + VR: ~ +10 wt%**
Agenda

• Performance Programs
  Axens' Consulting Services

• Case study: African refinery master plan
  • Refining context
  • Objectives and challenges
  • Technological solutions
  • Profitability study
Conversion scheme enables slightly improved refinery yields even with heavier crude.
Objectives related to heavy fractions are met
Euro-V Variant

- Evaluate flexibility to achieve Euro-V specs
- Diesel pool constraints
  - AFRI-4: Sulfur
  - Euro-V: Density
- Middle distillates quality is poor (high aromatics content)

Current Distillate distribution (wt%)
- Conv. GO 10%
- SR Kero 29%
- SR GO 50%
- Conv. Kero 11%

Future Distillate distribution (wt%)
- Conv. GO 13%
- SR Kero 26%
- SR GO 47%
- Conv. Kero 14%

Density gain achieved with HDS unit
- Medium Pressure HDS unit
- High Pressure HDS unit

Density gain achieved with kerosene blending
• Performance Programs
  Axens' Consulting Services

• Case study: African refinery master plan
  • Refining context
  • Objectives and challenges
  • Technological solutions
  • Profitability study
• 15 cases studied
  • various technological solutions
  • various crude blends
• Typical decision-making tool provided
Financial results
- NPV (@ WACC)
- IRR
- Pay Back Time (PBT)
- Discounted PBT
- Equity Rate of Return
- … and other criteria

Capital Investment Breakdown
- Process Units (+ eng.)
- Storage
- Utilities
- Building
- Infrastructure
- Physical Contingency
- Owner’s Cost
- Pre – Production Expenditure
- Interest D.C.
- Increase in Working Capital
Economic Results

**CASH FLOW EVOLUTION - Nominal & cumulative discounted**

```
Net Cash Flow (nominal)  Discounted Cumulative
```

**Financial Ratios**

ADSCR 0.96  LLCR 1.34  PLCR 1.84

**CASH FLOW BREAKDOWN**

```
Equity  Credit  Operating Costs  Principal  Interest  Taxes  Increase in current assets  Shareholders account
```

**Samples**

Typical deliverables

**WTI 74 $/bbl - Escalated**

**Samples**

Typical deliverables
Risk Analysis of Selected Scheme (1/2)

TORNADO DIAGRAM - Single Parameter Sensitivity +/- 30%

Net Present Value MM$(discounted)

Samples
Typical deliverables

- Gasoline RON 95
- Crude #1
- Fuel M100
- P-Xylene
- Gasoline RON 92
- Jet A1
- Diesel (Summer)
- Investment
- Gasoline RON 80
- Diesel (Winter)
• Optimized refinery processing scheme
  • Aligned with expected demand in high quality fuels (AFRI 4 specs)
  • Aligned with expected crude supply
  • Consistent with overall corporate strategy

• Economic study
  • Overall CAPEX estimates
  • Financial & Risk analysis

...A project that fit the refiner’s requirements
Quality and Conversion Capacity Upgrade

Case Study
Prime-D & Prime-K Licensing
For ULSD, ULSK & Cetane Uplift

112 Prime-D UnitsLicensed
Cum. Capacity > 4,500 kbpsd

Units Number

Capacity, kbpsd

Level Pressure, barg

as of December 2010