Design of a Modern Olefins Production Facility

IPRO 304-d
http://www.iit.edu/~olefin
Objectives

• To model and analyze a modern ethylene production process
• To understand the economic aspects of building and running a facility and the worldwide market of feedstocks, products, and product derivatives
• To identify environmental and safety concerns and develop sustainability
Approach

• Team arranged in four groups
  – Production Process Team
  – Economic Analysis Team
  – Environmental Responsibility Team
  – Web Site Team

• Obtaining information
  – Work regularly with Faculty Advisors
  – Use experience and resources from other coursework
  – Learn to search for information in new ways
Process Overview

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Design of a Modern
Furnace and TLE

Diagram showing the flow of Initial Feed through the Furnace and Transfer Line Exchanger.
Quench Tower

IPRO 304-d  Design of a Modern
Compressor Train
Design of a Modern Olefins Production Facility
Refrigeration Train
Design of a Modern Olefins Production Facility
Recovery Train

IPRO 304-d Design of a Modern...
World Ethylene Feedstock

- Naphtha
- NGL
- Refinery Gas
- Gas Oil
- Others
World Ethylene Feedstock Demand - 2000

- **North America**: Naphtha (146.5 MTPY), NGL (36.9 MTPY), Others (4.1 MTPY)
- **Middle East**: Naphtha (5.92 MTPY), NGL (5.56 MTPY), Others (0.04 MTPY)
- **FSU**: Naphtha (0.22 MTPY), NGL (0.03 MTPY), Others (0.02 MTPY)
- **Europe**: Naphtha (69.1 MTPY), NGL (1.43 MTPY), Others (0.05 MTPY)
- **Asia-Pacific**: Naphtha (50.77 MTPY), NGL (3.82 MTPY), Others (0.08 MTPY)
- **Africa**: Naphtha (0.08 MTPY), NGL (0.01 MTPY), Others (0.01 MTPY)

**Million Tons Per Year**
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US vs World Ethylene Feedstock Demand - 2000

- **World**
  - Natural Gas Liquid (NGL): 29.87%
  - Refinery Gas: 6.65%
  - Naphtha: 59.83%
  - Gas Oil: 8.5%
  - Others: 0.9%

- **US**
  - Natural Gas Liquid (NGL): 66.65%
  - Refinery Gas: 2.93%
  - Naphtha: 24.45%
  - Gas Oil: 5.69%
  - Others: 0.0%
Ethylene Capacity & Demand: 2001

- Asia-Pacific: Moderate demand, significant capacity additions.
- Europe: High demand, moderate capacity, with announced and speculative additions.
- Middle East: Lower demand, moderate capacity.
- South & Central America: Low demand and capacity.
- FSU: Low demand and capacity.
- Africa: Very low demand and capacity.
Global Ethylene Demand By Region, 2000

- US: 27%
- Canada: 4%
- Latin America: 5%
- Eastern Europe: 4%
- Western Europe: 20%
- Middle East: 8%
- Africa: 1%
- Japan: 1%
- East Asia: 7%
- Oceania: 1%

Design of a Modern Olefins Production Facility
Global Ethylene Production

<table>
<thead>
<tr>
<th>Region</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
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<tr>
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<td>24848</td>
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<td>3586</td>
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<td>4767</td>
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<tr>
<td>Western Europe</td>
<td>19400</td>
<td>19486</td>
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<tr>
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<td>6419</td>
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<td>1134</td>
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<tr>
<td>Japan</td>
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<td>7610</td>
<td>7382</td>
</tr>
<tr>
<td>East Asia</td>
<td>15106</td>
<td>16964</td>
<td>18198</td>
</tr>
<tr>
<td>Oceania</td>
<td>430</td>
<td>445</td>
<td>451</td>
</tr>
</tbody>
</table>

Thousand Metric Tons Per Year
Design of a Modern Olefins Production Facility

Derivatives Commercially Produced From Ethylene

- Ethylene
  - Polyethylene
    - Ethylene dibromide
      - Ethylene Cyanohydrin
        - Acrylonitrile
    - Ethylene Glycol
    - Ethanolamine
    - Acetaldehyde
      - Acetic Acid
        - Vinyl Acetate
    - Ethylene Oxide
      - Ethyl Alcohol
      - Acetic Anhydride

- Ethyl Benzene
  - Ethyl Chloride
  - Ethylene dichloride
    - n-Alpha Olefin
    - Diethyl Ether
  - Styrene
    - Vinyl Chloride
      - Polyvinyl Chloride
  - TEL
    - Ethyl Cellulose
Ethylene Derivatives Demand: 1995-2005

- Low Density Polyethylene
- Linear Low-Density Polyethylene
- High Density Polyethylene
- Polyvinyl Chloride
- Ethylene Dichloride
- Ethylene Glycol
- Ethylene Oxide

Million Tons Per Year

2005:
- Low Density Polyethylene: 16.1
- Linear Low-Density Polyethylene: 11.5
- High Density Polyethylene: 25.5
- Polyvinyl Chloride: 35.3
- Ethylene Dichloride: 55.4
- Ethylene Glycol: 14.2
- Ethylene Oxide: 15.3

2000:
- Low Density Polyethylene: 15.3
- Linear Low-Density Polyethylene: 12
- High Density Polyethylene: 20.6
- Polyvinyl Chloride: 27.1
- Ethylene Dichloride: 42.9
- Ethylene Glycol: 10.8
- Ethylene Oxide: 12.1

1995:
- Low Density Polyethylene: 14.1
- Linear Low-Density Polyethylene: 8.2
- High Density Polyethylene: 16.7
- Polyvinyl Chloride: 20.9
- Ethylene Dichloride: 33.3
- Ethylene Glycol: 3.3
- Ethylene Oxide: 10.2
Costs Analysis

Capital Costs
ISBL Fixed Capital = 202.02 $MM
OSBL Fixed Capital = 50.50 $MM
Total Fixed Capital = 252.52 $MM

Startup Costs
Thirty Days of Variable Costs – Fresh Feed and Utilities = 37.0 $MM
Fixit Costs at 5% of Total Fixed Capital = 13.0 $MM
Total Startup Costs = 49.0 $MM

Working Capital
Product Inventory : 30 Days Storage = 59.0 $MM
Raw Material Inventory : 30 Days Storage = 35.0 $MM
Cash, Stores, Accounts Payable 1% TFC = 3.0 $MM
Total Working Capital = 97.0 $MM
Variable Operating Costs
Fresh Feed  305.0  MLbs / Hr  At 16.0 Cents / Lb  = 406.0 $MM / Yr
Utilities  900.0  MMBtu/Hr  At 2.50 $ / MMBtu  = 19.0 $MM / Yr
Total Variable Operating Costs = 425.0 $MM / Yr

Fixed Operating Costs
Fixed Costs At 30% of Total Fixed Capital = 76.0 $MM / Yr

Production Schedule
Ethylene  195983.0 Lbs / Hr  At 34.0 Cents / Lb  = 555.0 $MM / Yr
Propylene  59214.0 Lbs / Hr  At 26.0 Cents / Lb  = 128.0 $MM / Yr
Fuel  383.0 MMBtu / Hr  At 2.50 $ / MMBtu  = 8.0 $MM / Yr
Total Revenue  = 691.0 $MM / Yr

Salvage Value
Salvage Value = 25.0 $MM

Discounted Cash Flow Profitability Index = 25.0
## Optimization

<table>
<thead>
<tr>
<th>High Ethane - Propane Conversion</th>
<th>Low Ethane - Propane Conversion</th>
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<tbody>
<tr>
<td>Low Recycle of Ethane - Propane</td>
<td>High Recycle of Ethane - Propane</td>
</tr>
<tr>
<td>Reduced Equipment Size</td>
<td>Increased Equipment Size</td>
</tr>
<tr>
<td>Reduced Capital &amp; Operating Costs</td>
<td>Increased Capital &amp; Operating Costs</td>
</tr>
<tr>
<td>Reduced Yield of Ethylene &amp; Propylene</td>
<td>Increased Yield of Ethylene &amp; Propylene</td>
</tr>
</tbody>
</table>

### Operating Control Variable

<table>
<thead>
<tr>
<th>Furnace Coil Outlet Temperature (Deg F)</th>
<th>Conversions Per Cent</th>
<th>Yields Per Cent</th>
<th>Process Profitability Index Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ethane</td>
<td>Propane</td>
<td>Ethylene</td>
</tr>
<tr>
<td>1400</td>
<td>15.5</td>
<td>32.3</td>
<td>79.5</td>
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<tr>
<td>1450</td>
<td>31.1</td>
<td>51.1</td>
<td>79.2</td>
</tr>
<tr>
<td>1500</td>
<td>56.5</td>
<td>73.6</td>
<td>79.1</td>
</tr>
<tr>
<td>1550</td>
<td>81.9</td>
<td>90.0</td>
<td>77.0</td>
</tr>
<tr>
<td>1600</td>
<td>87.9</td>
<td>98.3</td>
<td>76.7</td>
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<tr>
<td>1650</td>
<td>99.9</td>
<td>99.9</td>
<td>74.5</td>
</tr>
</tbody>
</table>
Environmental Responsibility

• Energy and Materials Efficiency
• Emissions Management
• Uses for By-products
• Health and Safety
• Sustainable Development
Efficiency

- Increased Energy Efficiency (Shell)
- Energy conserved in process
- No alternative energy sources currently feasible
Emissions Management

• Reduce greenhouse gases by:
  – Natural solutions (carbon sinks)
  – Reduce to 90% emissions by 2010
  – Kyoto Protocol’s Emissions Trading Scheme
By-products: 1,3-Butadiene

- 39% Styrene-butadiene rubber comonomer
- 23% Monomer for polystyrenes
- 11% Adiponitrile
- 9% Styrene-butadiene latexes
- 7% Neoprene elastomers
- 5% Acrylonitrile-butadiene-styrene resins
- 3% Nitrile rubber comonomer
- 2% Other polymer and copolymer uses
By-products: Benzene

- Benzene
- Styrene
- Cyclohexane
- Polystyrene
- Caprolactam
- Nylon
- Clothing
- Paint
- Plastics
- Everyday Products

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By-products: Raffinate 1

- 4-carbon paraffins and olefins without butadiene
- Feedstock for:
  - Polyisobutenes (PIB)
  - Methyl tertiary butyl ether (MTBE)
  - Butyl rubber
  - Adhesives and sealants
Health and Safety

• Employee Training:
  – Emergency procedures
  – Safe handling of toxic substances
  – On-site safety

• Company Responsibilities:
  – Provide adequate training for personnel
  – Risk Management and Crisis Management
  – Comply with federal safety standards
  – Workman’s Compensation
Sustainable Development

• Environmental, economic, and social responsibility

• Responsible care:
  – Focus on global environment
  – Resource management
  – Recognizing impact of plant operations on global issues

• UN 10 Priorities:
  • Changing unsustainable patterns of consumption and production
  • Promoting health through sustainable development
  • Providing access to energy and energy efficiency
  • Managing ecosystems and biodiversity in a sustainable way
  • Providing financial and technology transfer
Conclusion

• We have learned that our facility:
  – Has a competitive and efficient modern design
  – Is economically profitable and can be optimized
  – Can achieve sustainability and responsibility

• Our approach enabled us to:
  – Analyze and understand all important aspects of the project
  – Achieve a rewarding experience together
  – Share our results in a meaningful way
Special Thanks To:

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  - Interim Associate Dean for Public Services/Instruction Coordinator
  - Paul V. Galvin Library
  - Information Expert

- JohnPaul Kusz
  - Acting Director, Center for Sustainable Enterprise at Stuart Graduate School of Business

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Design of a Modern Olefins Production Facility
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  – Faculty Advisor
• Professor J. Abbasian
  – Faculty Advisor
Thank You!
Discussion

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