Challenges and Opportunities in Managing \( \text{CO}_2 \) in Petroleum Refining

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Outline

- Overview of the Refining Challenge
- Reducing CO₂ Today in Petroleum Refining
- Challenges and Opportunities for Future CO₂ Reduction
The Need for Innovative Technology

Technology frozen at 1990 efficiency levels

Assumed Advances In:
- Energy intensity
- Nuclear
- Renewables

Gap Technologies:
- Carbon capture and storage
- H₂ and advanced transportation
- Bio-technologies
- Solar

Source: J. Edmonds, PNNL
CO$_2$ in Refining – A Simplified View

An oversimplified simple model…

Hydrocarbon Feedstock + Energy → Products

Energy ∝ CO$_2$

Energy ∝ CO$_2$ = f(Feedstock, Products, Source of Energy)

- **Feedstock**: Energy increases as the “Heaviness” (API Gravity) of the Feedstock increases
- **Products**: Energy increases as the products are more highly desulfurized and as they become lighter (e.g., gasoline vs. diesel)

- **Refinery Energy Sources**
  - Refineries typically make their own fuel gas, but may need to import fuel gas to balance energy needs
  - Fuel oil vs. natural gas dictated by cost and availability
Refinery configurations differ and produce different product slates

Adding units for Octane Enhancement and/or Molecular Weight Reduction increase refinery complexity
**CO₂ in Refining – Impact of Complexity**

A refinery’s complexity (and resulting energy usage) determines products

- **Simple refinery** – crude distillation, cat reforming, distillate hydrotreating
- **Complex refinery** – cat cracking, alkylation, gas processing, sometimes coking

*With increasing complexity, comes increasing energy usage*

<table>
<thead>
<tr>
<th>Product (100 kbd)</th>
<th>Simple Refinery</th>
<th>Complex Refinery (with coker)</th>
<th>Typical Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>30</td>
<td>60</td>
<td>Transportation</td>
</tr>
<tr>
<td>Jet fuel</td>
<td>10</td>
<td>10</td>
<td>Transportation</td>
</tr>
<tr>
<td>Distillate</td>
<td>20</td>
<td>25</td>
<td>Transportation, Residential</td>
</tr>
<tr>
<td>Residual fuel</td>
<td>35</td>
<td></td>
<td>Steam, Power, Bunker</td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td>4</td>
<td>Residential</td>
</tr>
<tr>
<td>Coke</td>
<td></td>
<td>3</td>
<td>Fuel, Power</td>
</tr>
<tr>
<td>Refinery Fuel Gas</td>
<td>8</td>
<td>13</td>
<td>Refinery Heat</td>
</tr>
</tbody>
</table>

*Product breakdown source: Petroleum Refining in Nontechnical Language, William Leffler, 2000*
Fuel Usage in a Refinery

Fuel Consumed by U.S. Refineries
(454M FOEB in 2005)

- Refineries produce most of their own fuel – only use purchased fuel as supplement
  - Purchased energy may include fuel gas or fuel oil
  - About 10% of the crude’s energy is used in refining (worldwide range is 2-14%)
    + Energy consumption is primarily dependent upon product slate
    + Typically, low energy use corresponds to a low yield of transportation fuel

Source: 2005 EIA data (Converted to Millions of FOEB)
Relative Energy Usage in Refining

Based on a “wells-to-wheel” analysis, refining produces a relatively small portion of the GHG emissions.

- ~80% of the CO₂ emitted is due to combustion of gasoline
- ~60% of the remaining CO₂ is due to refining (~10% of total)
- <10% of refining CO₂ emissions are concentrated
- Most (>90%) of refinery CO₂ emissions are dilute (e.g. from FCC’s and dozens of heaters/boilers)

Data from Argonne National Labs, Well-to-wheels Study, 2005.

Wells-to-wheels analysis dependant on methodology and assumptions
- Assumptions should fit how data should be used
- Argonne used allocation methodology – CO₂ allocated based on assumptions on quantity and quality of refinery products
- Results show trend for today’s discussion
A Tale of Two Refineries

**Refinery A**
- Feedstock is light crude
- Products are fuels from distillation only
  - No cracking or conversion
  - No Sulfur reduction
- Fuel source is natural gas
- Less than a dozen heaters/boilers
- No Hydrogen production

→ GHG emissions <12 ktonnes/kbd

**Refinery B**
- Feedstock is heavy crude
- Products include low sulfur gasoline, jet fuel, chemical feedstock, etc.
- Fuel source is fuel oil
- ~50 heaters/boiler
- <15% of CO₂ from Hydrogen production

→ GHG emissions >48 ktonnes/kbd

**Conclusion:** Two refineries with similar throughputs could have very different CO₂ emissions. Not simple to equitably track refining GHG intensity.
Reducing Refining CO₂ – Current Options

- Three ways to reduce CO₂ using commercial technology
  - **Energy Efficiency**
    - Cogeneration
      - More efficient energy
      - Increases site’s direct emissions (more than offset on grid)
    - Other Energy Efficiency Improvements
      - Impacts multiple units due to utilities integration
  - **Fuel switching – natural gas for fuel oil**
    - Natural gas – 0.0531 tonnes/MBtu (HHV)
    - Fuel Oil – 0.0762 tonnes/MBtu (HHV)
  - **Throughput Reduction**
    - Reduces overall supply
ExxonMobil’s Corporate Focus

- Refining and Chemicals account for over 75% of corporate energy consumption and nearly 65% of corporate greenhouse gas emissions.
- Energy the single largest cash operating expense -- about 50% of total.
- Improving energy efficiency is a win-win-win …
  - Extends supply and affordability of conventional energy sources.
  - Reduces greenhouse gas emissions and plant operating costs.
- Benefits companies, consumers, and the environment … Now!

![Energy Consumption and Greenhouse Gas Emissions Chart]

### Chart Explanation:
- **Other Ops**: Green
- **Upstream**: Red
- **Chemicals**: Yellow
- **Refining**: Blue

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Cogeneration Benefits

- Cogeneration nearly twice as efficient as traditional technologies
  - State-of-the-art gas and steam turbine electricity generation
  - Coupled with efficient recovery and utilization of waste heat
- Natural gas is the fuel of choice for reducing carbon dioxide emissions
  - Generates 25-45% less carbon dioxide per B.T.U. consumed
- Gas-fired cogeneration units utilize about 1/2 of the fuel and generate less than 1/3 of the CO₂ of conventional coal-fired utility plants

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ExxonMobil Cogeneration Capacity

- Over 100 units at 30 locations provide 4500 MW of capacity
  - Efficiency gain sufficient to service about 1.5 million U.S. residential households
  - Capacity to reduce CO₂ emissions more than 10 million tonnes per year versus alternatives, at full utilization
  - Refinery direct emissions increase but savings on utility grid more than offset
Improving ExxonMobil’s Energy Efficiency

- Plant energy efficiency improved over 35% from 1973 to 1999
  - Saved cumulative equivalent of 1.8 billion barrels of crude oil
  - Translates to over 200 million tonne decrease in GHG emissions
- Ongoing initiatives expected to provide continuous improvement
  - Additional investment in highly-efficient cogeneration capacity
  - Further implementation of Global Energy Management System (GEMS)
Challenges and Opportunities for Further Reducing CO$_2$ Levels in Refining

• Applying commercial capture technologies is challenging
  – CO$_2$ is dilute
  – Involves low pressure
  – Potential complications from other contaminants (SOx, NOx, particulates)

• Most CO$_2$ comes from combustion of refinery fuel gases, natural gas, fuel oil, etc. in multiple refinery heaters
  – A large, complex refinery may have dozens of stacks

• Retrofitting for capture technology can be difficult.
  – Amine technology requires ~3 vessels (scrubber, regenerator, amine storage)
  – Space on unit may not be available

• Consolidation of stacks raises operational issues
The Need for Innovation

Technology frozen at 1990 efficiency levels

Assumed Advances In:
- Energy intensity
- Heat integration
- Fuel switching

Gap Technologies:
- Carbon capture and storage
- ???

Source: J. Edmonds, PNNL
Meeting The Challenge

• ExxonMobil is engaged on a number of fronts to meet tomorrow’s energy needs ...

  – Energy conservation and efficiency
  – New exploration and enhanced production
  – New technologies and improved products
  – Actions now and research for the future

ExxonMobil
Taking on the world’s toughest energy challenges.