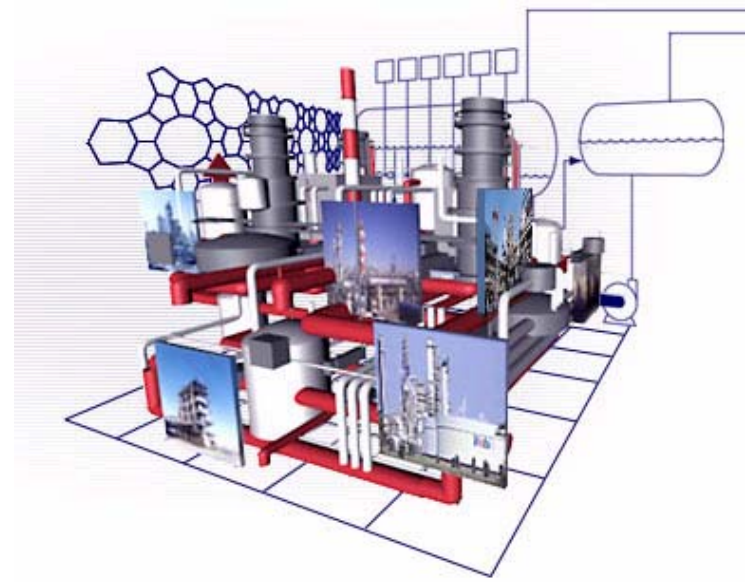


# ***Challenges and Opportunities in Managing CO<sub>2</sub> in Petroleum Refining***

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GCEP Workshop on  
**Carbon Management in Manufacturing Industries**  
STANFORD UNIVERSITY  
*Stanford, California*  
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# Outline

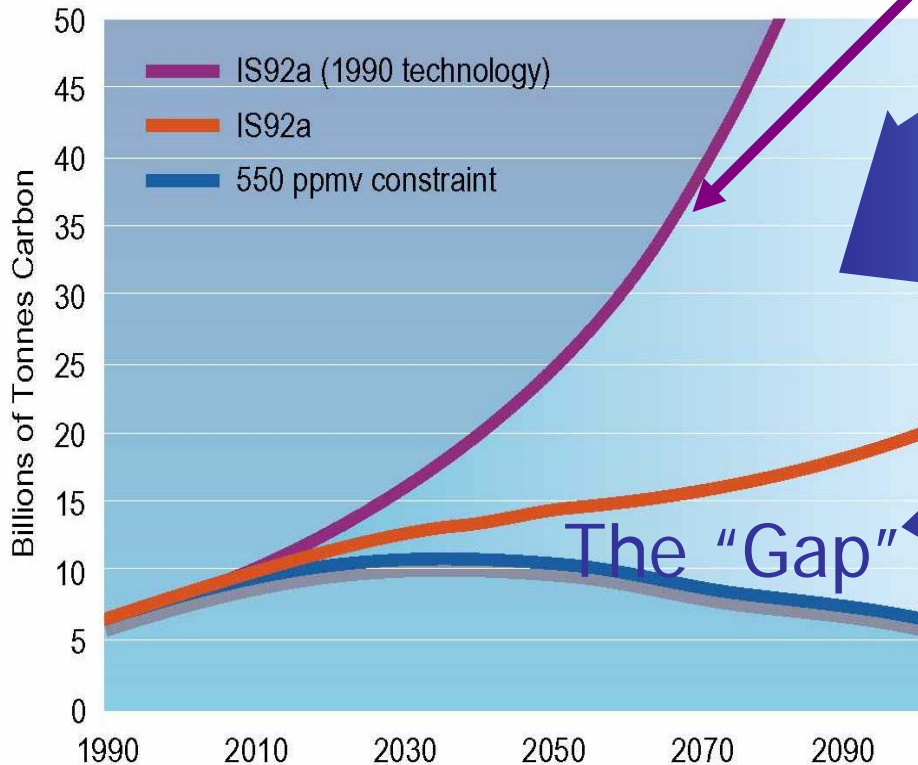
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- Overview of the Refining Challenge
- Reducing CO<sub>2</sub> Today in Petroleum Refining
- Challenges and Opportunities for Future CO<sub>2</sub> Reduction

# The Need for Innovative Technology

Technology frozen at 1990 efficiency levels

## Carbon Emissions



### Assumed Advances In:

- Energy intensity
- Nuclear
- Renewables

### Gap Technologies:

- Carbon capture and storage
- H<sub>2</sub> and advanced transportation
- Bio-technologies
- Solar

Source: J. Edmonds, PNNL

# CO<sub>2</sub> in Refining – A Simplified View

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*An oversimplified simple model...*

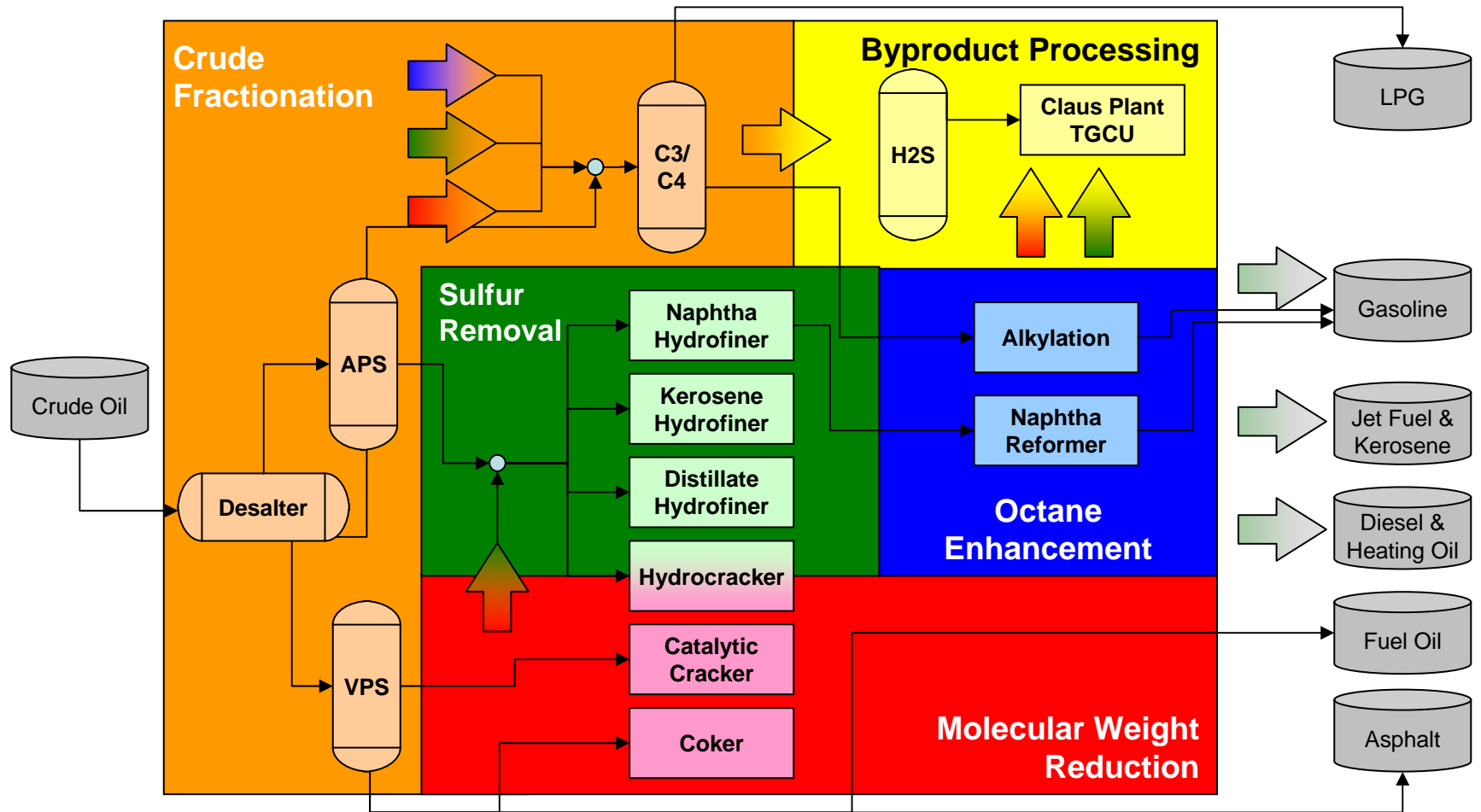
Hydrocarbon Feedstock + Energy  $\longrightarrow$  Products

$$\text{Energy} \propto \text{CO}_2$$

$$\text{Energy} \propto \text{CO}_2 = f(\text{Feedstock, Products, Source of Energy})$$

- **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

# Simplified Refinery Flow Scheme



*Refinery configurations differ and produce different product slates*

*Adding units for Octane Enhancement and/or Molecular Weight Reduction increase refinery complexity*

# ***CO<sub>2</sub> in Refining – Impact of Complexity***

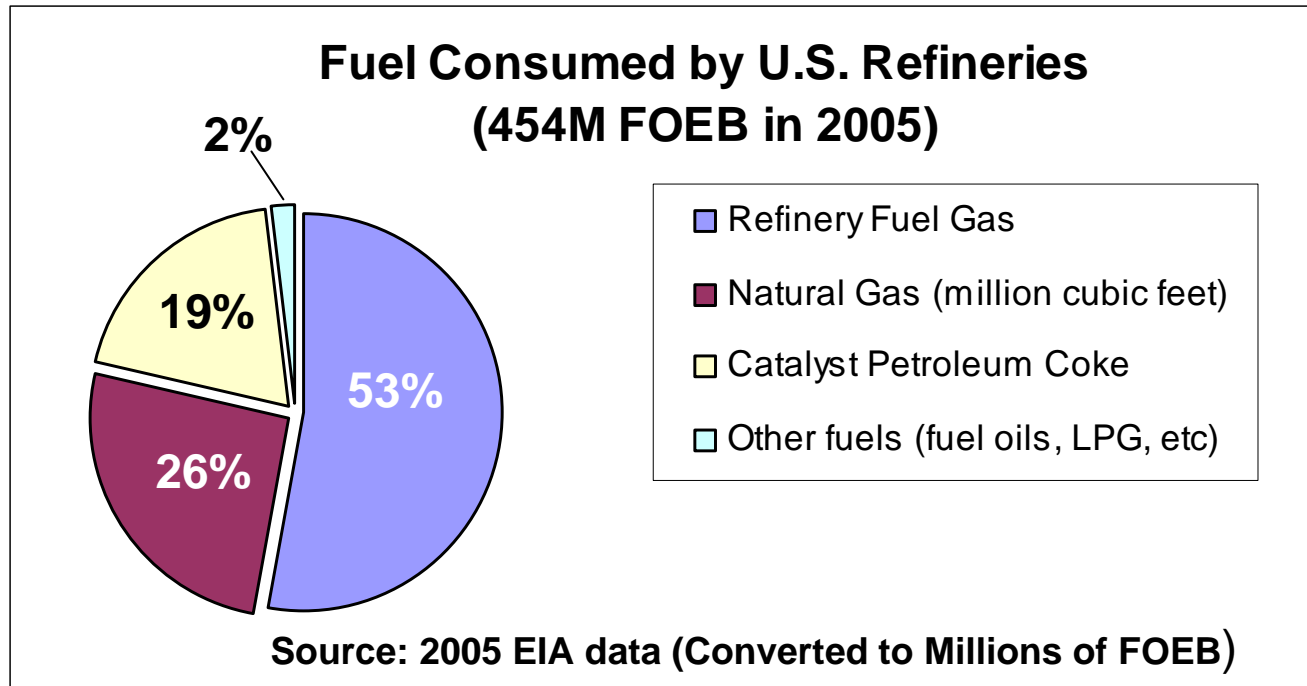
- A refinery’s complexity (and resulting energy usage) determines products
  - **Simple refinery** – crude distillation, cat reforming, distillate hydrotreating
  - **Complex refinery** – cat cracking, alkylation, gas processing, sometimes coking

➤ With increasing complexity, comes increasing energy usage

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

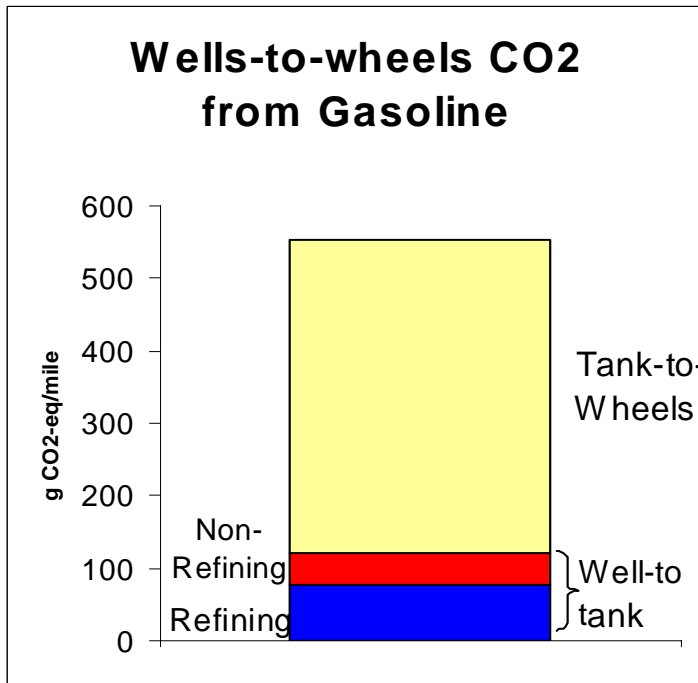
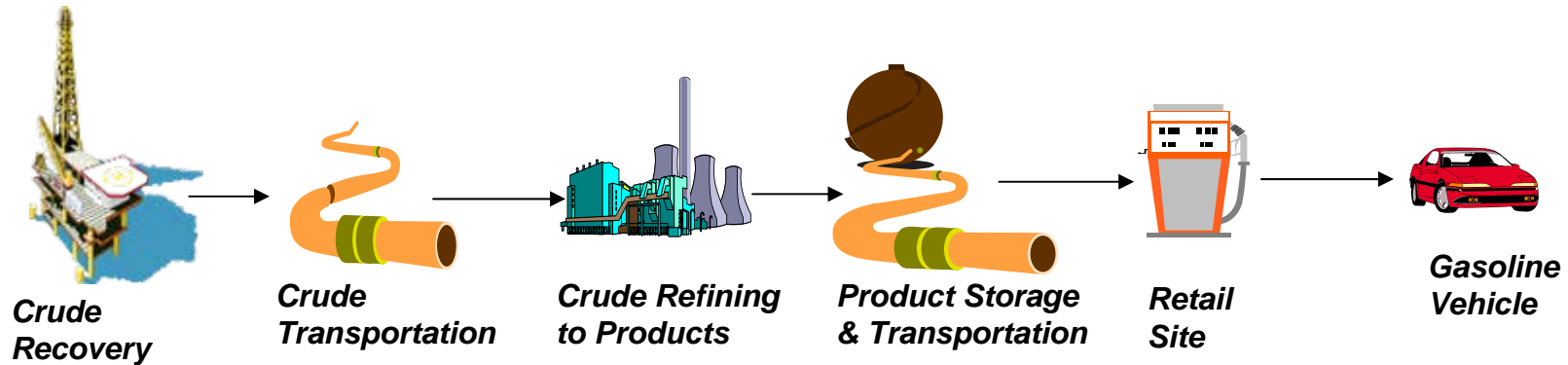
*Product breakdown source: Petroleum Refining in Nontechnical Language, William Leffler, 2000*

# Fuel Usage in a Refinery



- 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

# Relative Energy Usage in Refining



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

- ~80% of the CO<sub>2</sub> emitted is due to combustion of gasoline
- ~60% of the remaining CO<sub>2</sub> is due to refining (~10% of total)
- <10% of refining CO<sub>2</sub> emissions are concentrated
- Most (>90%) of refinery CO<sub>2</sub> 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 – CO<sub>2</sub> 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 CO<sub>2</sub> from Hydrogen production

→ GHG emissions  
>48 ktonnes/kbd

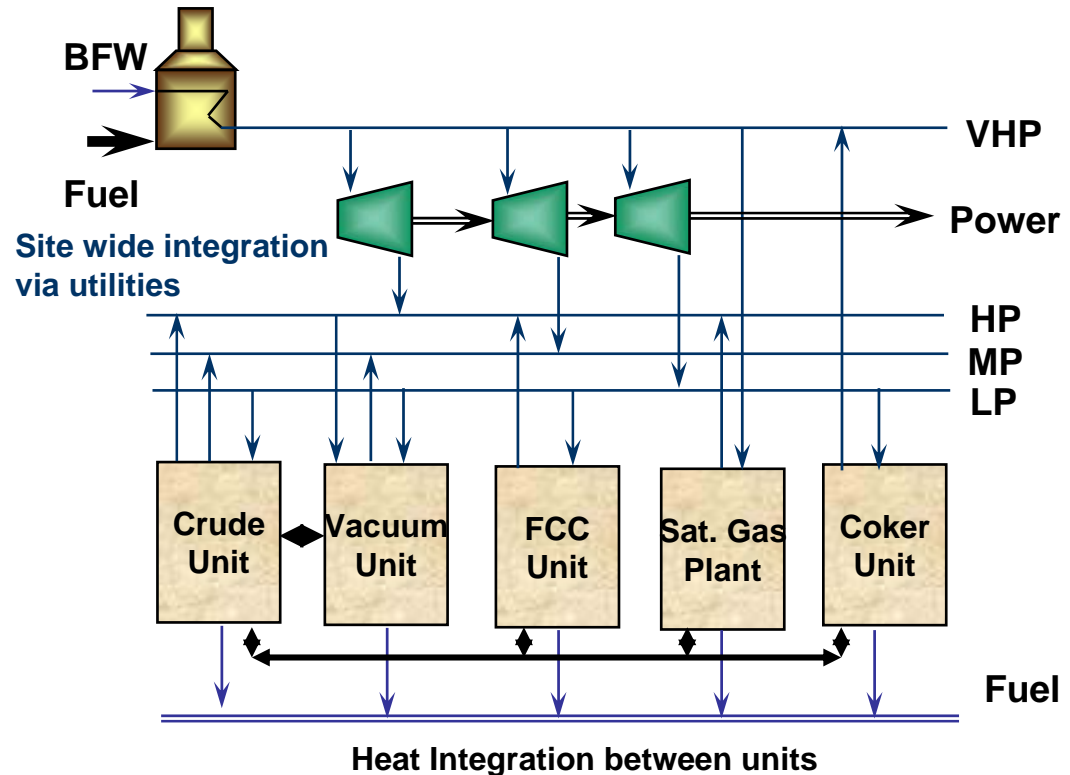
**Conclusion:** Two refineries with similar throughputs could have very different CO<sub>2</sub> emissions. Not simple to equitably track refining GHG intensity.

# Reducing Refining CO<sub>2</sub> – Current Options

- Three ways to reduce CO<sub>2</sub> 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



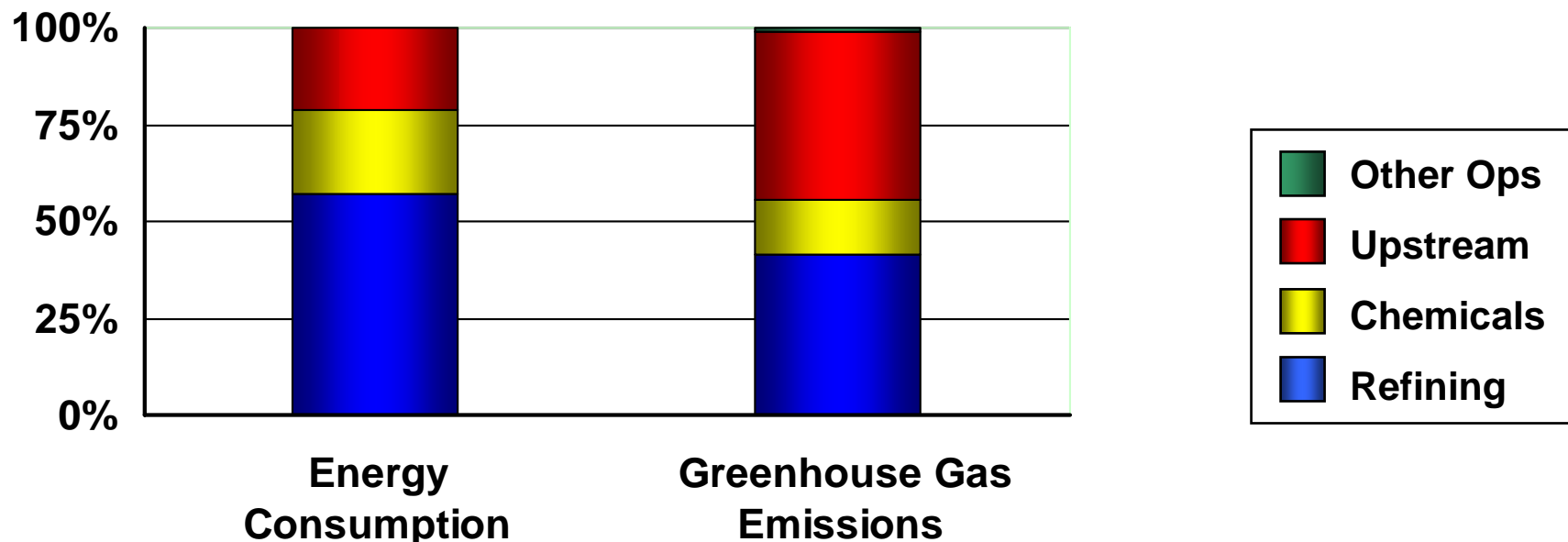
- **Fuel switching – natural gas for fuel oil**

- Natural gas – 0.0531 tonnes/MBtu (HHV)
- Fuel Oil – 0.0762 tonnes/MBtu (HHV)

- **Throughput Reduction**

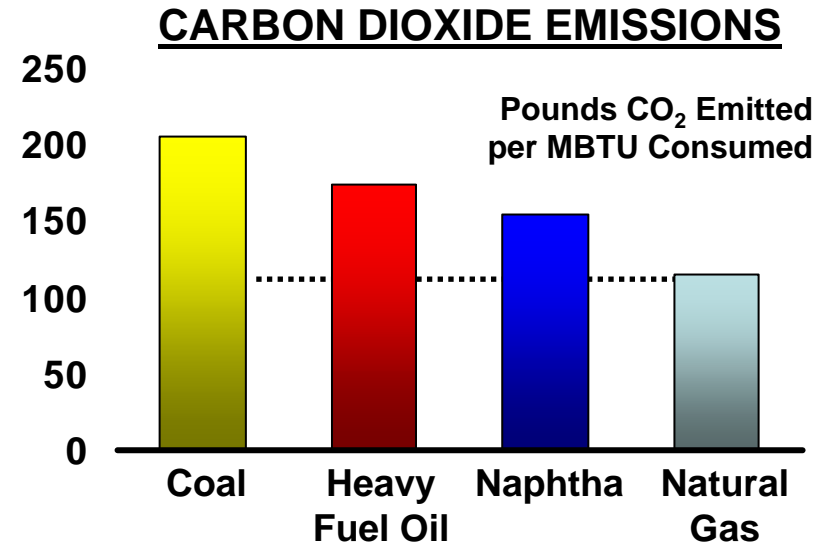
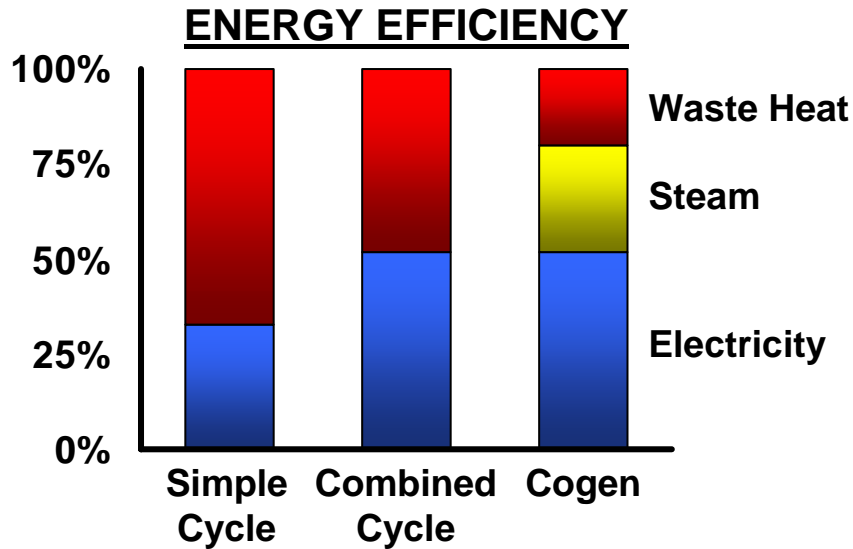
- Reduces overall supply

# 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!

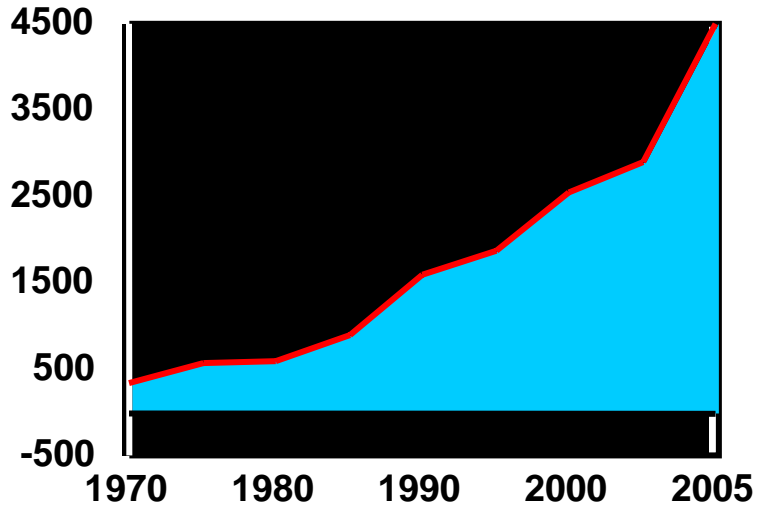
# Cogeneration Benefits



- 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 CO<sub>2</sub> of conventional coal-fired utility plants

# ExxonMobil Cogeneration Capacity

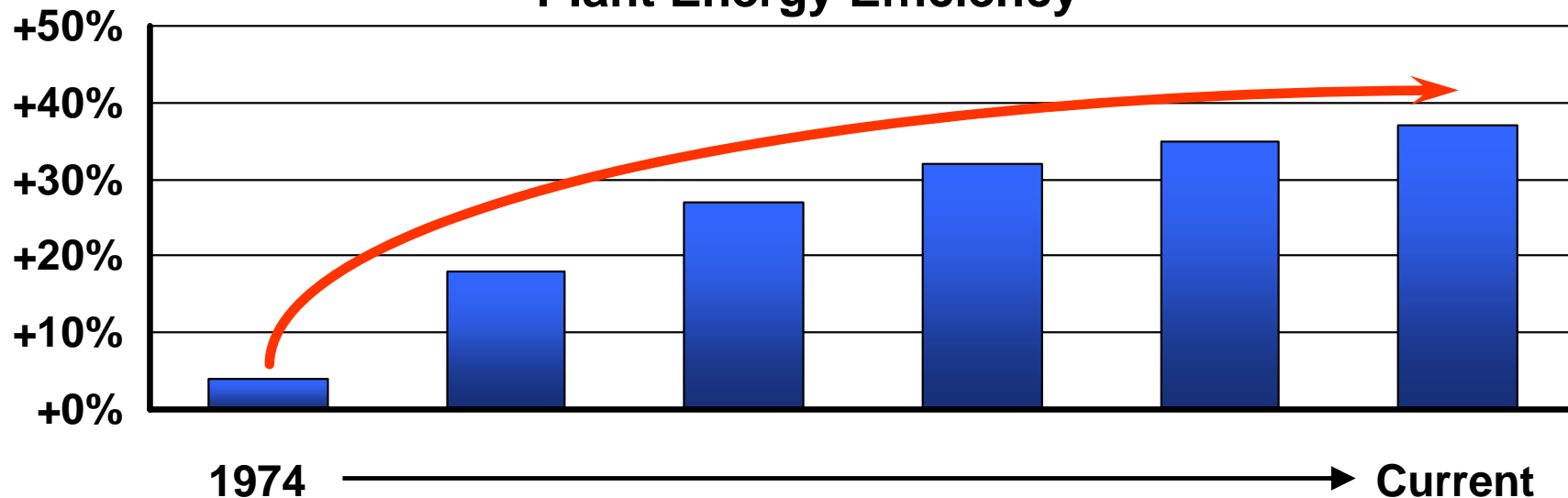
XOM Cogen Capacity



- 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 CO<sub>2</sub> 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



- 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<sub>2</sub> Levels in Refining***

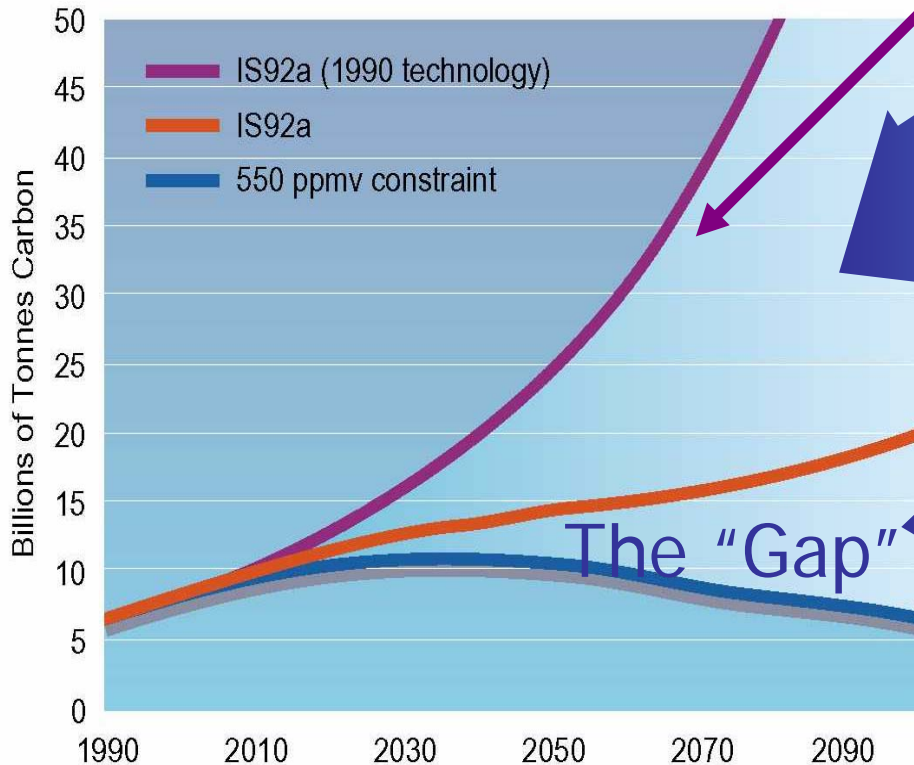
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- Applying commercial capture technologies is challenging
  - CO<sub>2</sub> is dilute
  - Involves low pressure
  - Potential complications from other contaminants (SO<sub>x</sub>, NO<sub>x</sub>, particulates)
- Most CO<sub>2</sub> comes from combustion 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

## Carbon Emissions



### 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

