Challenges and Opportunities in Managing CO_2 in Petroleum Refining

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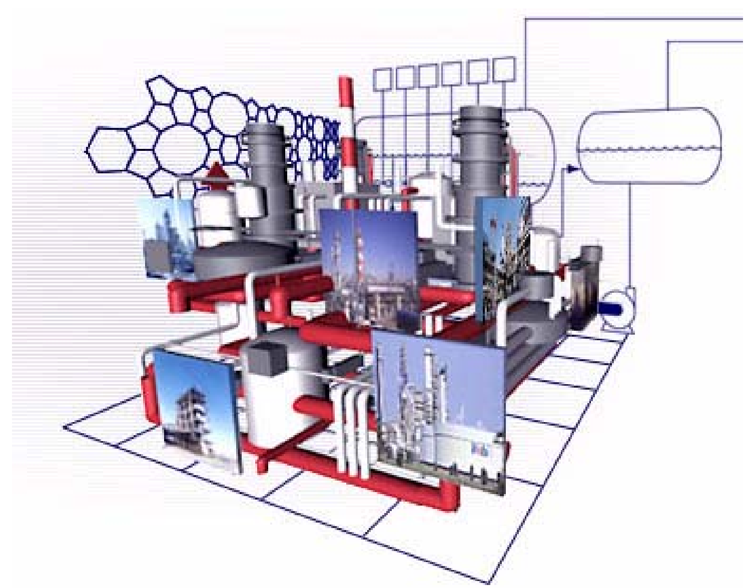
GCEP Workshop on

Carbon Management in Manufacturing Industries

STANFORD UNIVERSITY

Stanford, California

April 15 - 16, 2008



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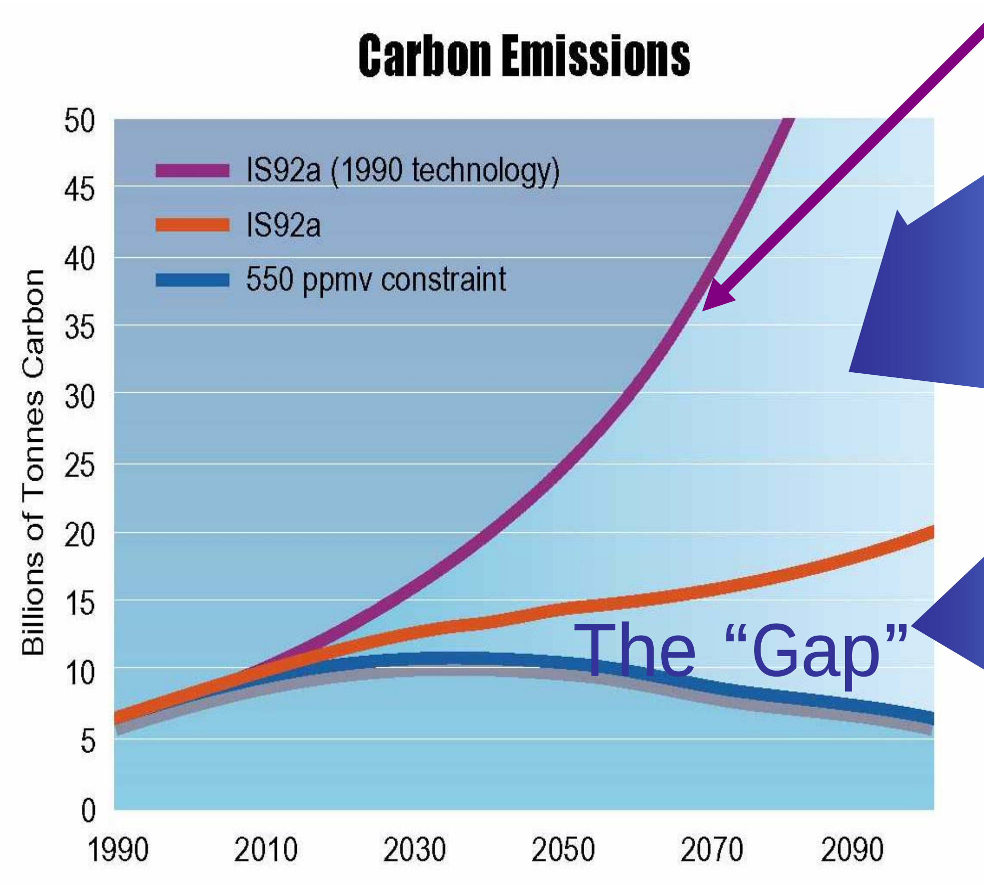
Outline

- Overview of the Refining Challenge
- Reducing CO_2 Today in Petroleum Refining
- Challenges and Opportunities for Future CO_2 Reduction

The Need for Innovative Technology

Technology frozen at 1990 efficiency levels



Source: J. Edmonds, PNNL

Assumed Advances In:

- Energy intensity
- Nuclear
- Renewables

Gap Technologies:

- Carbon capture and storage
- H_2 and advanced transportation
- Bio-technologies
- Solar

CO_2 in Refining – A Simplified View

An oversimplified simple model…

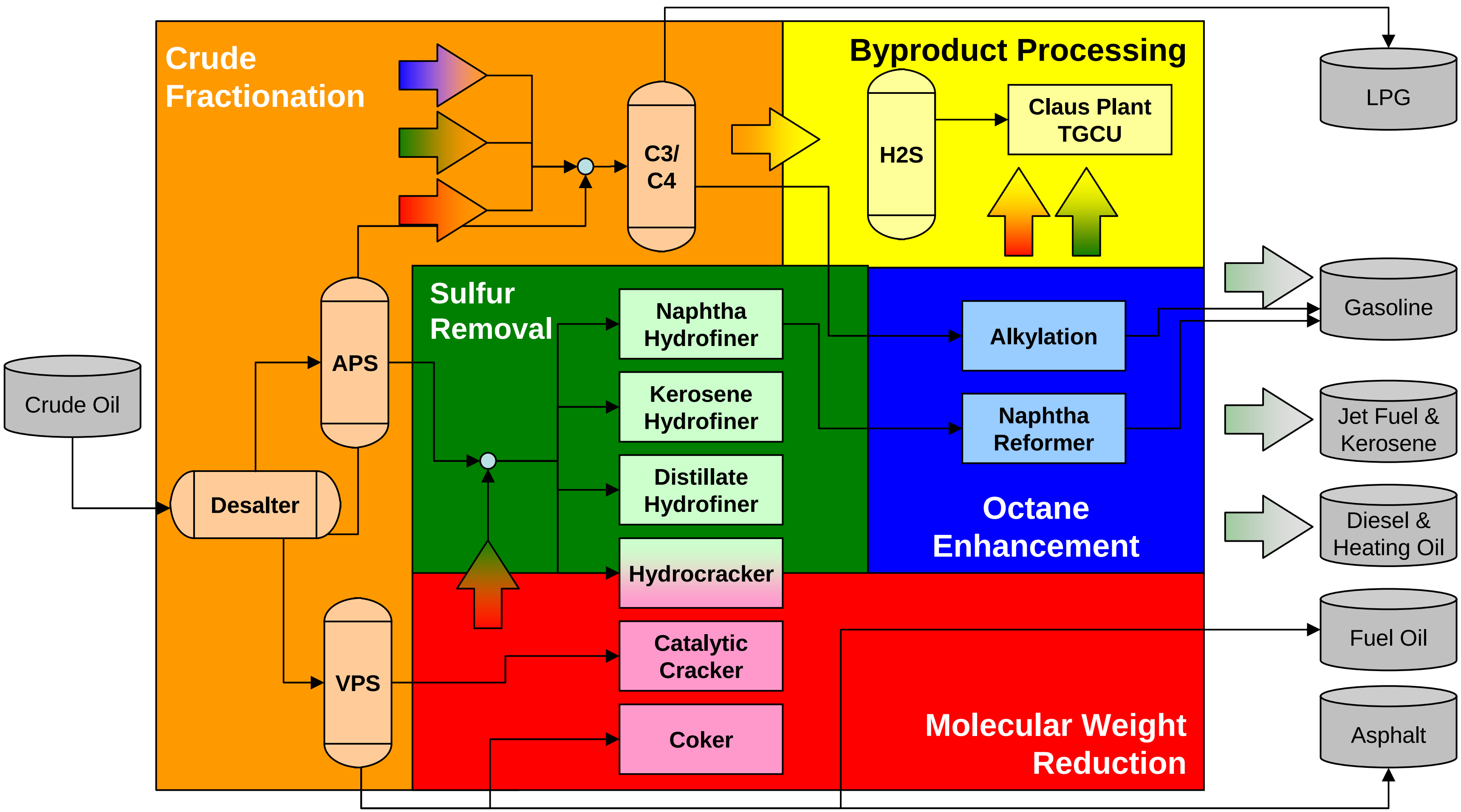
Hydrocarbon Feedstock + Energy ⟶ Products

$$\text{Energy} \propto CO_2$$

$$\text{Energy} \propto CO_2 = f(\text{Feedstock, Products, Source of Energy})$$

- **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 <u>Octane Enhancement</u> and/or <u>Molecular Weight Reduction</u> increase refinery complexity

CO_2 in Refining – Impact of Complexity

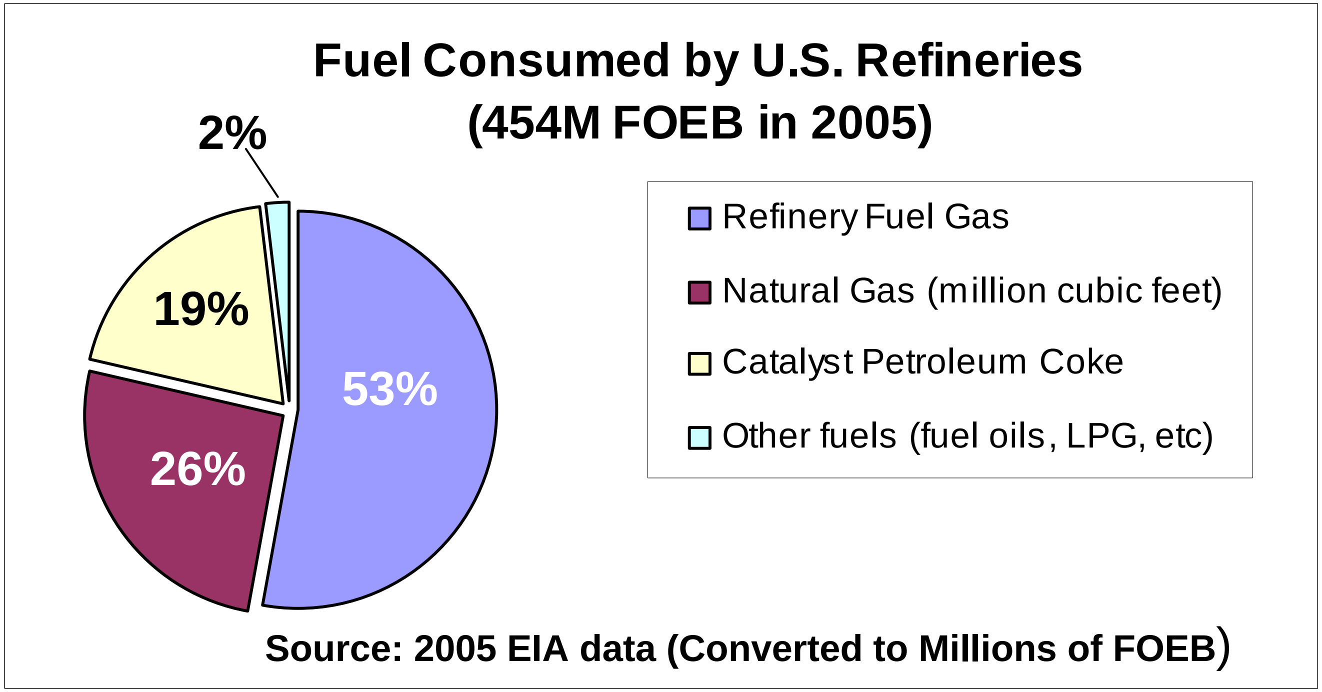
- A refinery's complexity (and resulting energy usage) determines products
  - **Simple refinery** – crude distillation, cat reforming, distillate hydrotreating
  - **Complex refinery** – cat cracking, alkylation, gas processing, sometimes coking

➢ With increasing complexity, comes increasing energy usage

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

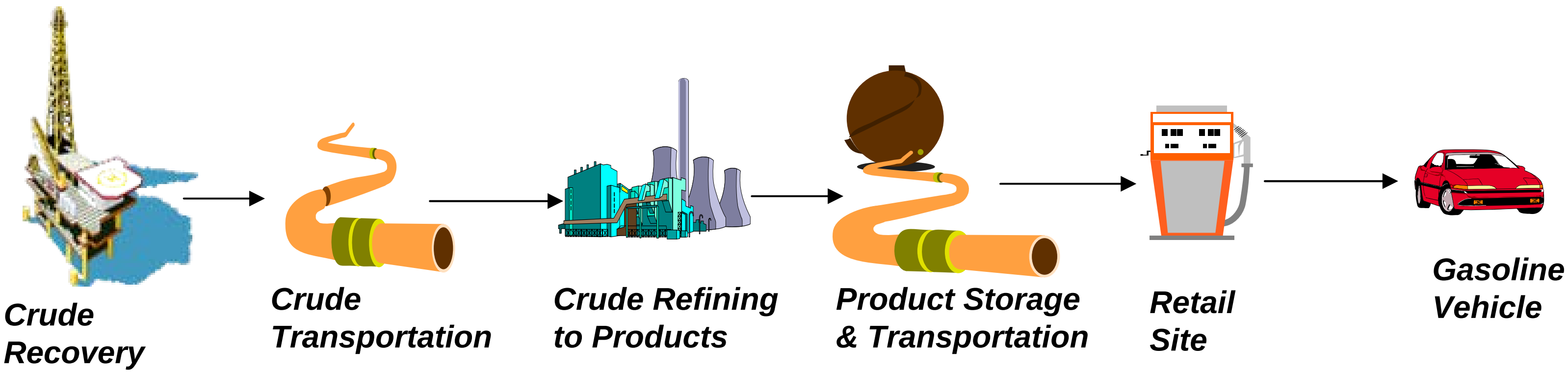
Product breakdown source: Petroleum Refining in Nontechnical Language, William Leffler, 2000

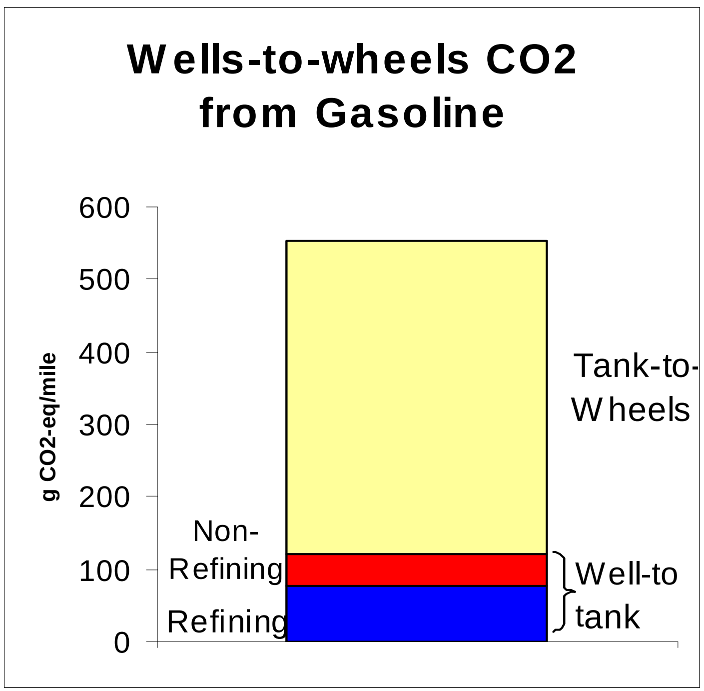
Fuel Usage in a Refinery



- 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_2 emitted is due to combustion of gasoline
- **~60%** of the remaining CO_2 is due to refining **(~10%** of **total)**
- **<10%** of refining CO_2 emissions are concentrated
- Most **(>90%)** of refinery CO_2 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

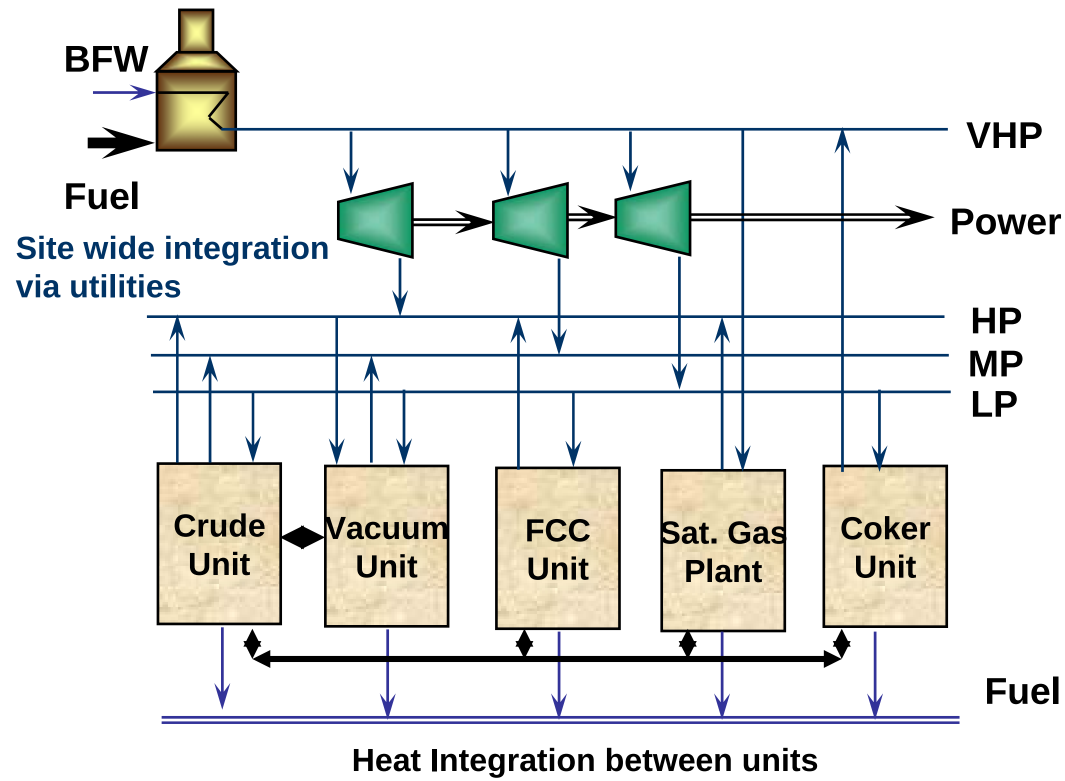
- Feedstock is heavy crude
- Products include low sulfur gasoline, jet fuel, chemical feedstock, etc.
- Fuel source is fuel oil
- ~50 heaters/boiler
- <15% of CO_2 from Hydrogen production

→ GHG emissions
>48 ktonnes/kbd

Conclusion: Two refineries with similar throughputs could have very different CO_2 emissions. Not simple to equitably track refining GHG intensity.

Reducing Refining CO_2 – Current Options

- Three ways to reduce CO_2 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

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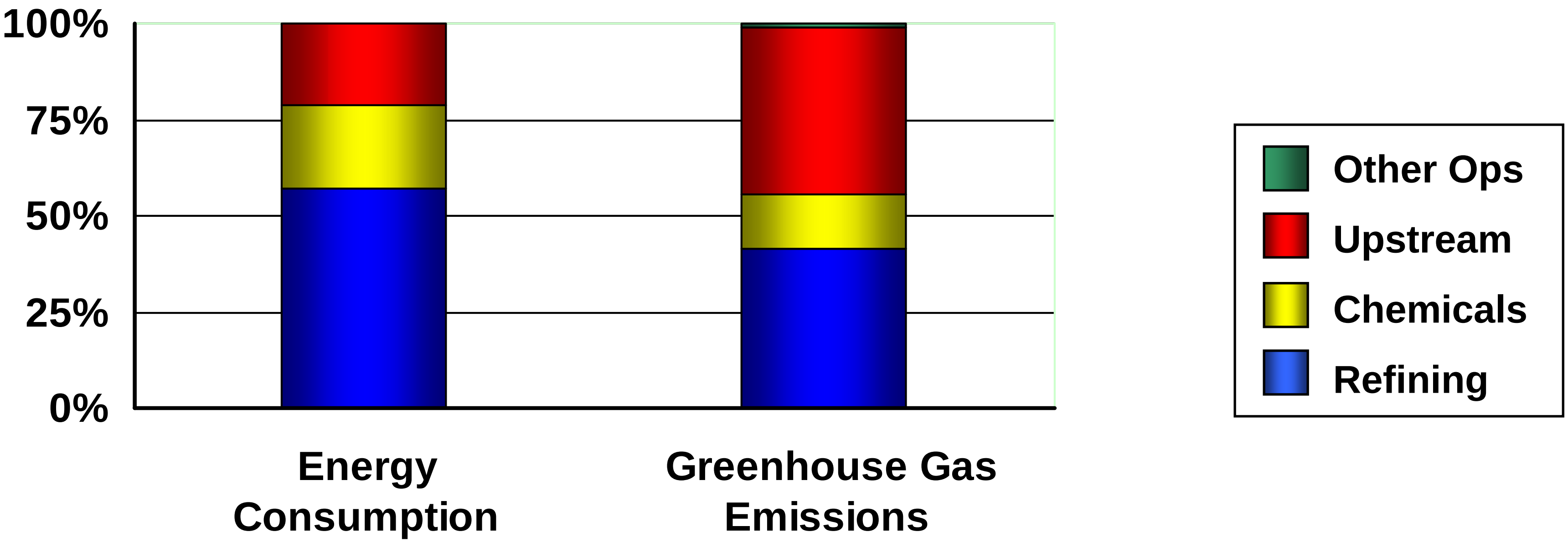
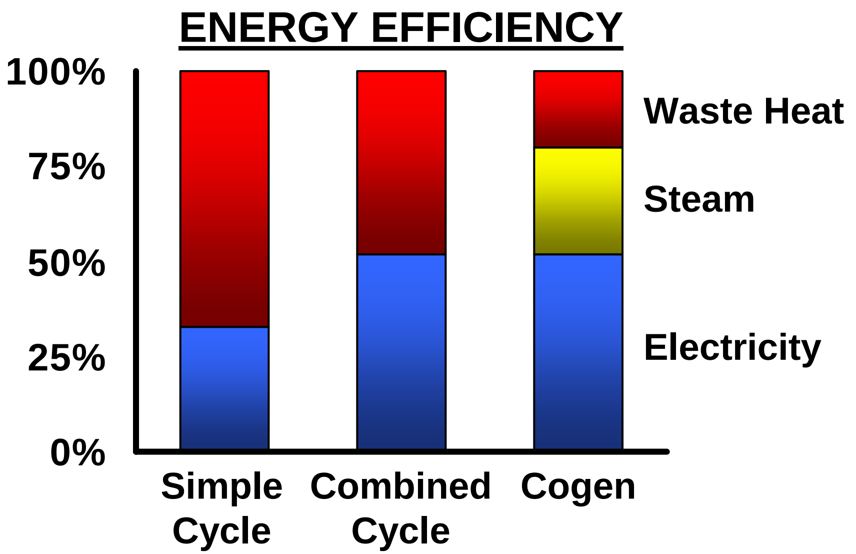
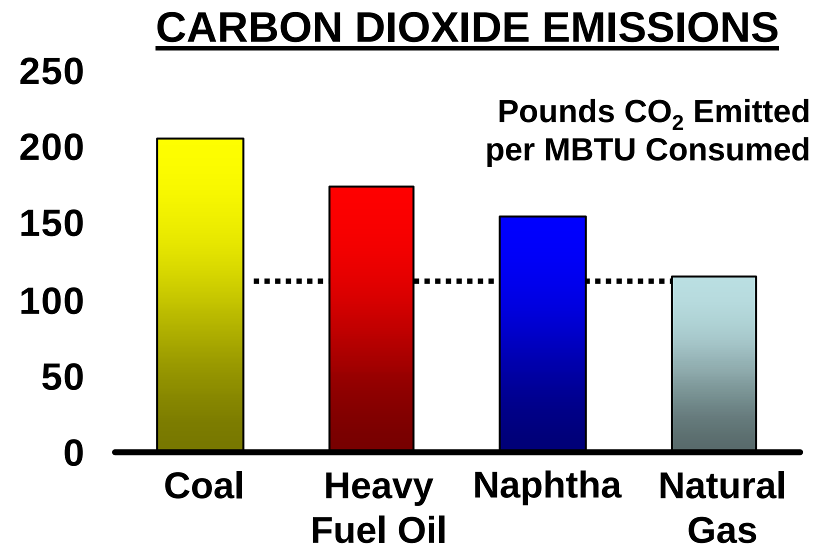
ExxonMobil's Corporate Focus



- 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!

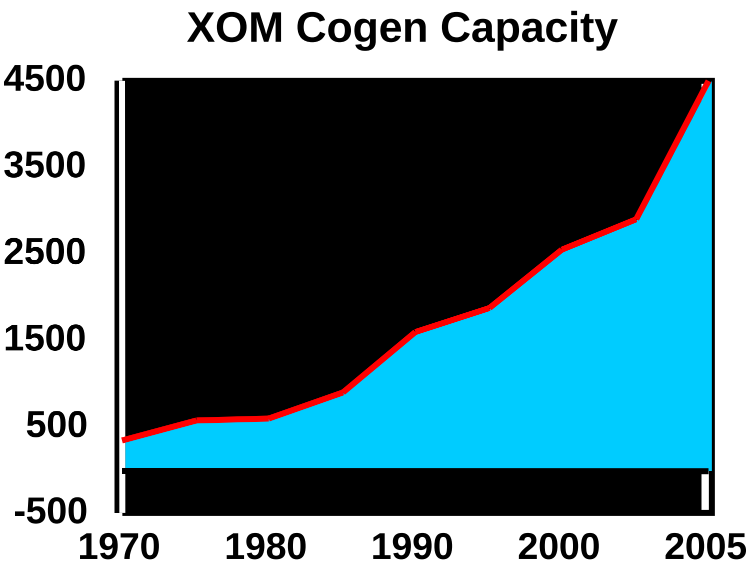
Cogeneration Benefits





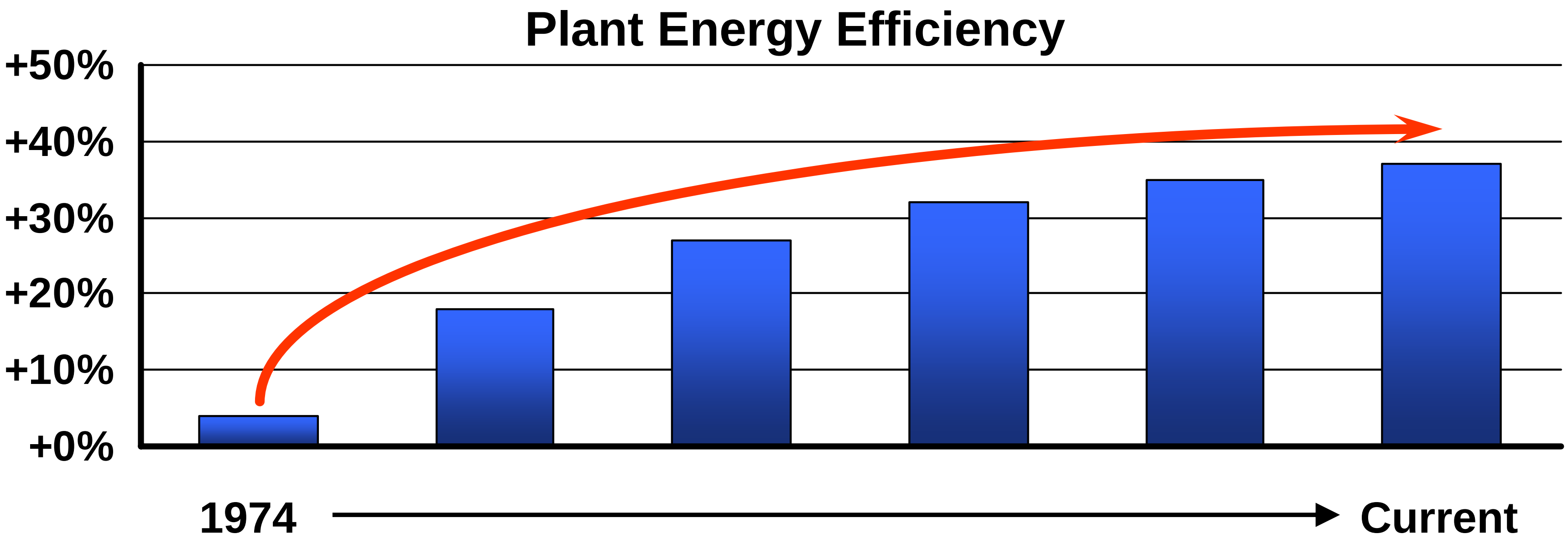
- Cogeneration nearly twice as efficient as traditional technologies
  - State-of-the-art gas and steam turbine electricity generation
  - Coupled with efficient recovery and utilization of waste heat
- Natural gas is the fuel of choice for reducing carbon dioxide emissions
  - Generates 25-45% less 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_2 of conventional coal-fired utility plants

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 CO_2 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

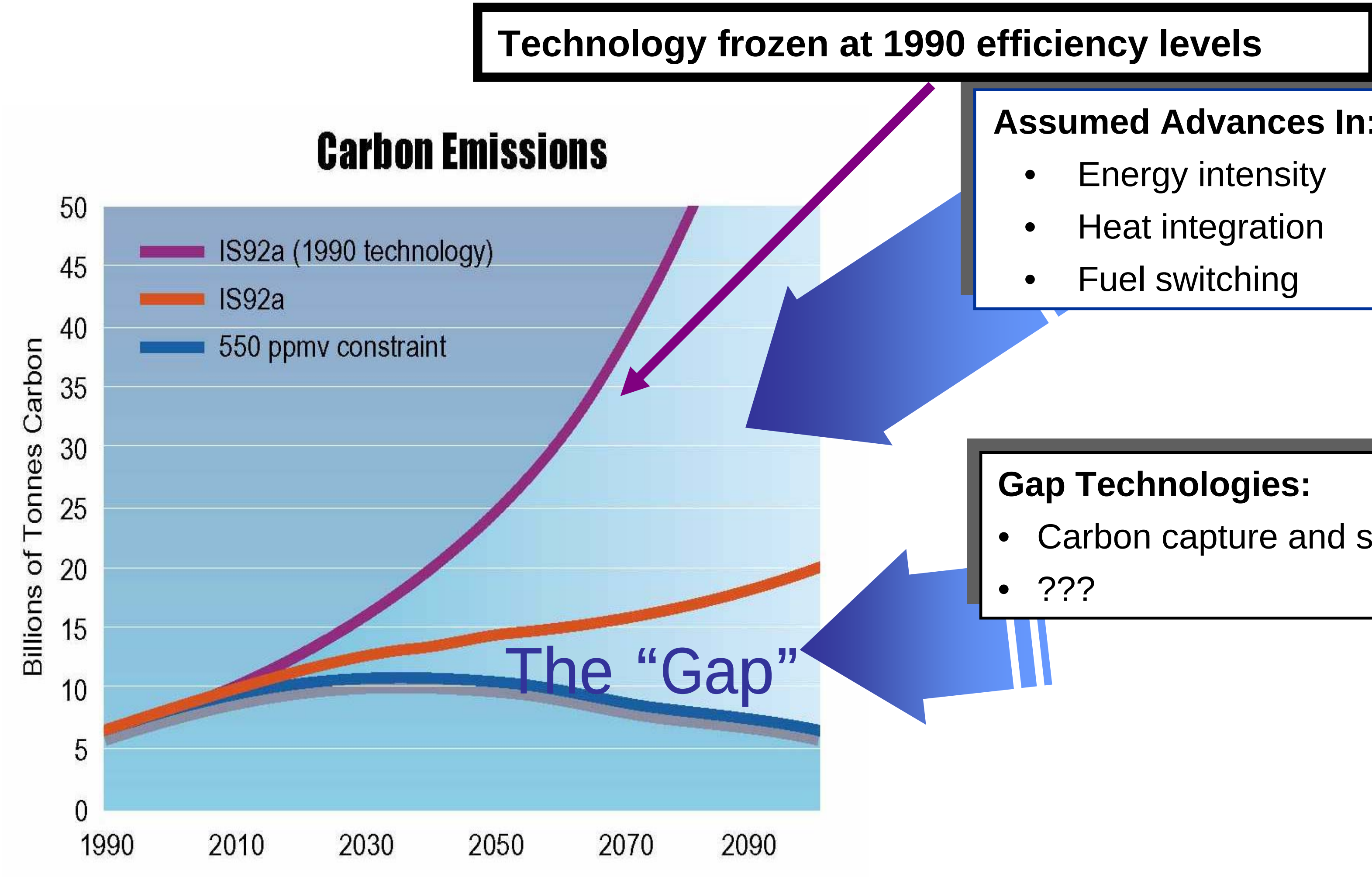
- Applying commercial capture technologies is challenging
  - CO_2 is dilute
  - Involves low pressure
  - Potential complications from other contaminants (SOx, NOx, particulates)

- 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



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