Coal-to-Power and Coal-to-Liquid Fuels Technologies Used in a Technoeconomic Study of the Hydrogen Economy

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Basis of the Study: President's Vision of the Hydrogen Economy

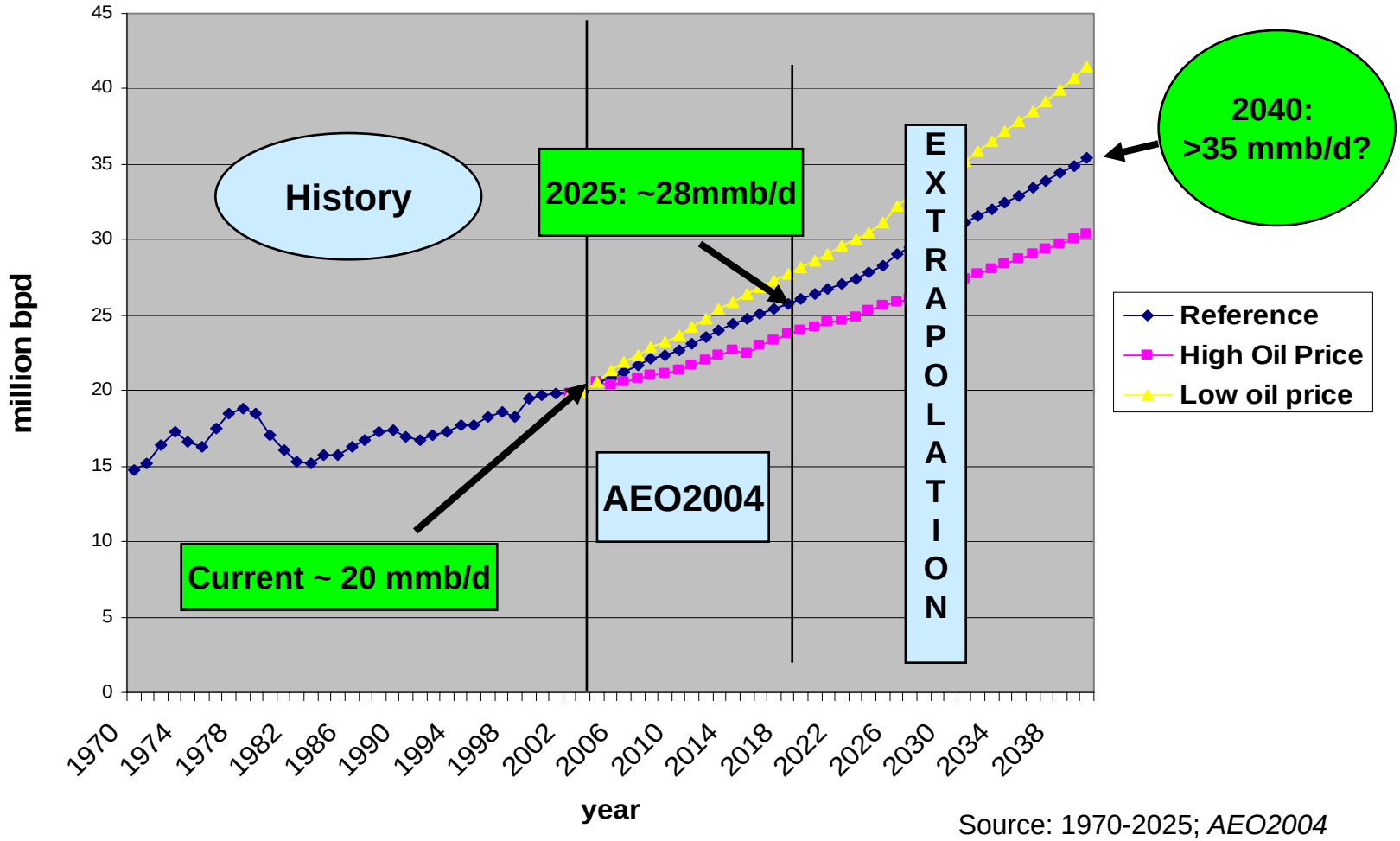
- **From speech of President George W. Bush, February 2003: "Hydrogen Fuel: A Clean and Secure Energy Future"**
  - "……If we develop hydrogen power to its full potential, we can reduce our demand for oil by over 11 million barrels per day by 2040. That would be a fantastic legacy to leave for future generations of Americans."

- From White House web site, February 2003:
  - "…..The hydrogen fuel and FreedomCAR initiatives may reduce America's greenhouse gas emissions from transportation alone by more than 500 million metric tons of carbon equivalent each year by 2040."

Primary Drivers: Oil and Carbon

- **Reduction of Petroleum Consumption**
  - 11 million barrels per day, by 2040
- **Reduction of Carbon Equivalent**
  - 500 million metric tons per year, by 2040

US Petroleum Consumption, 1970-2040, NEMS



Source: 1970-2025; *AEO2004*
2025-2040, author calculation

All Sectors and All Fossil Fuels Contribute to Carbon Emissions

CO_2 Emissions from Fossil Fuel Combustion

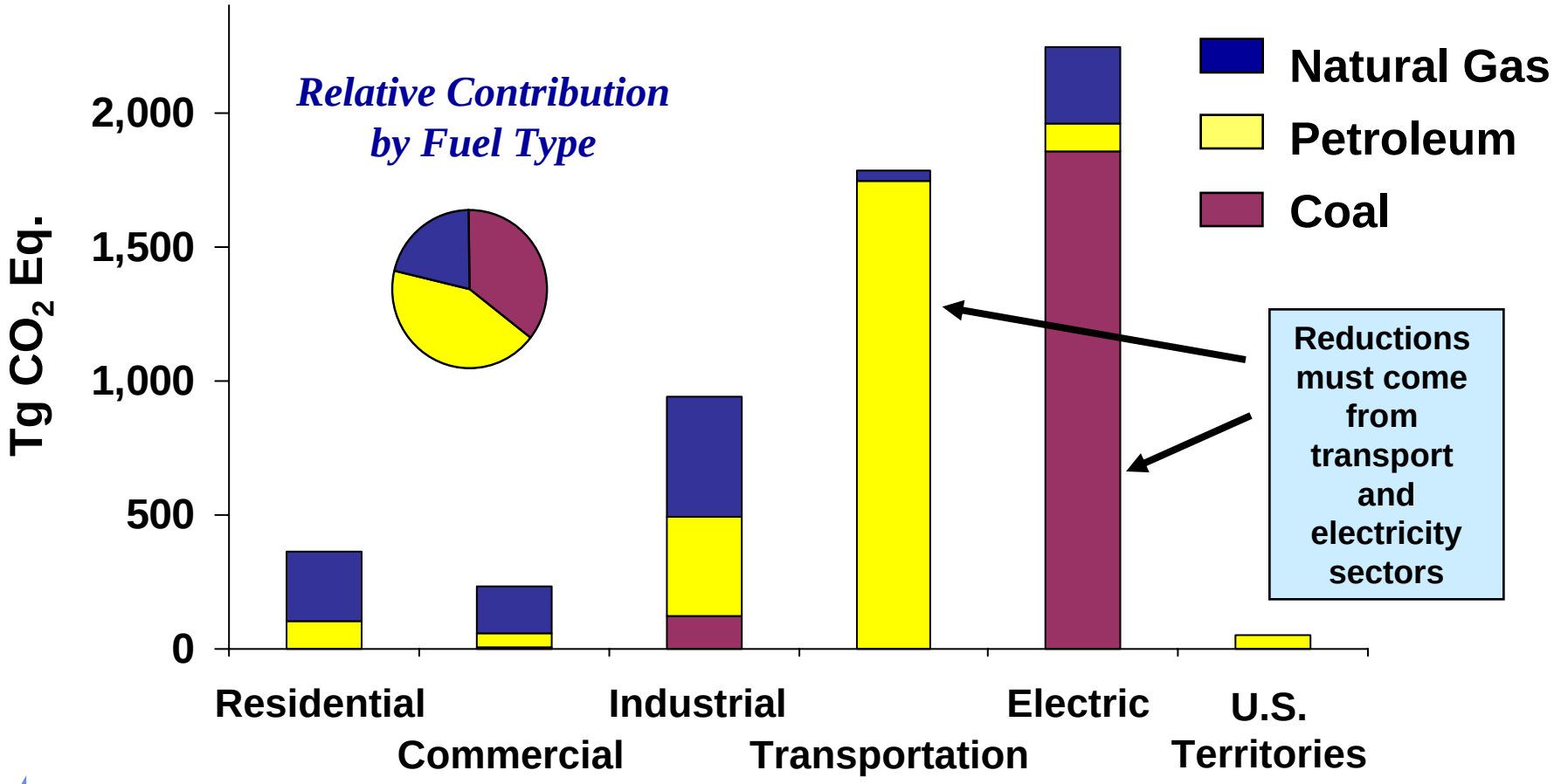
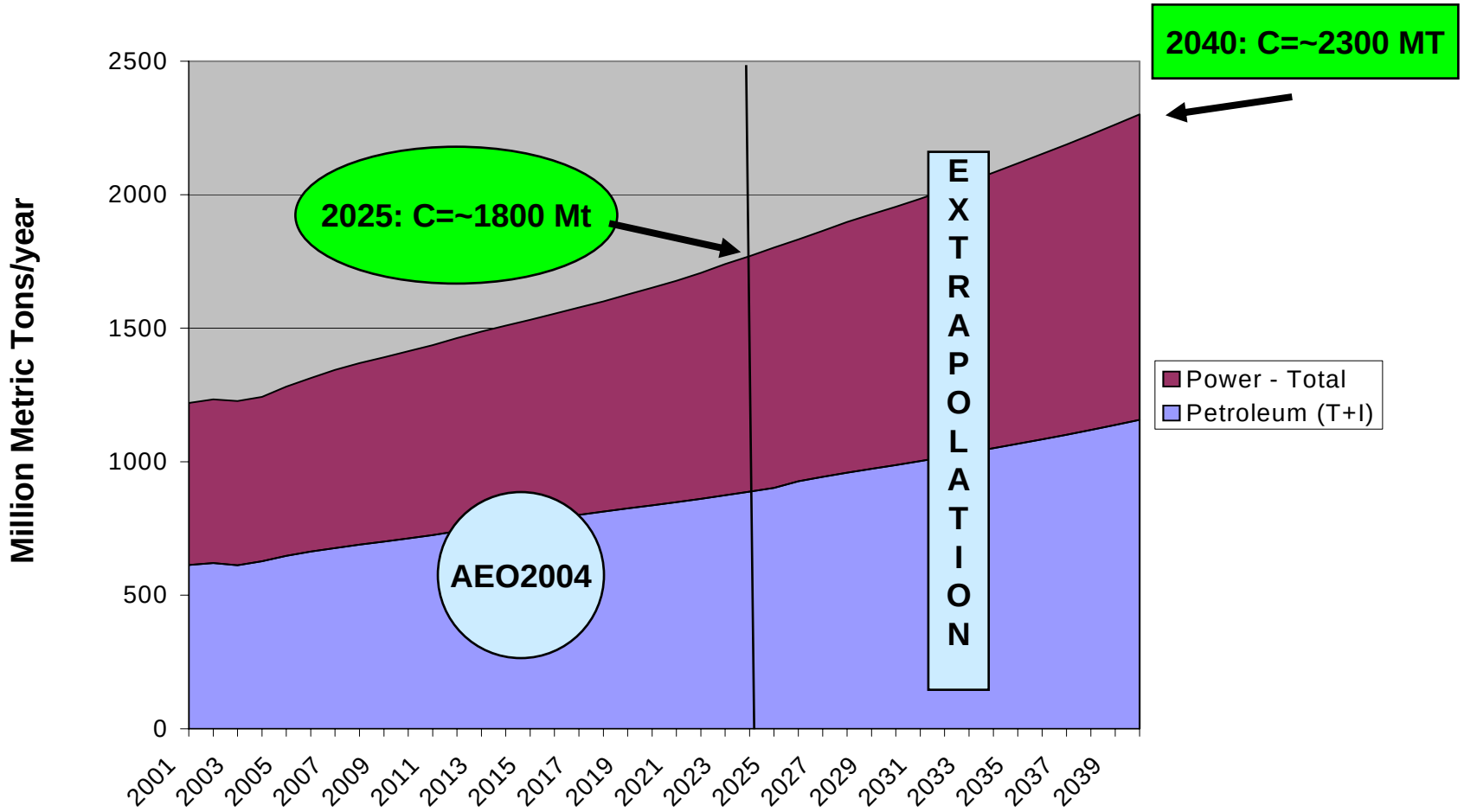


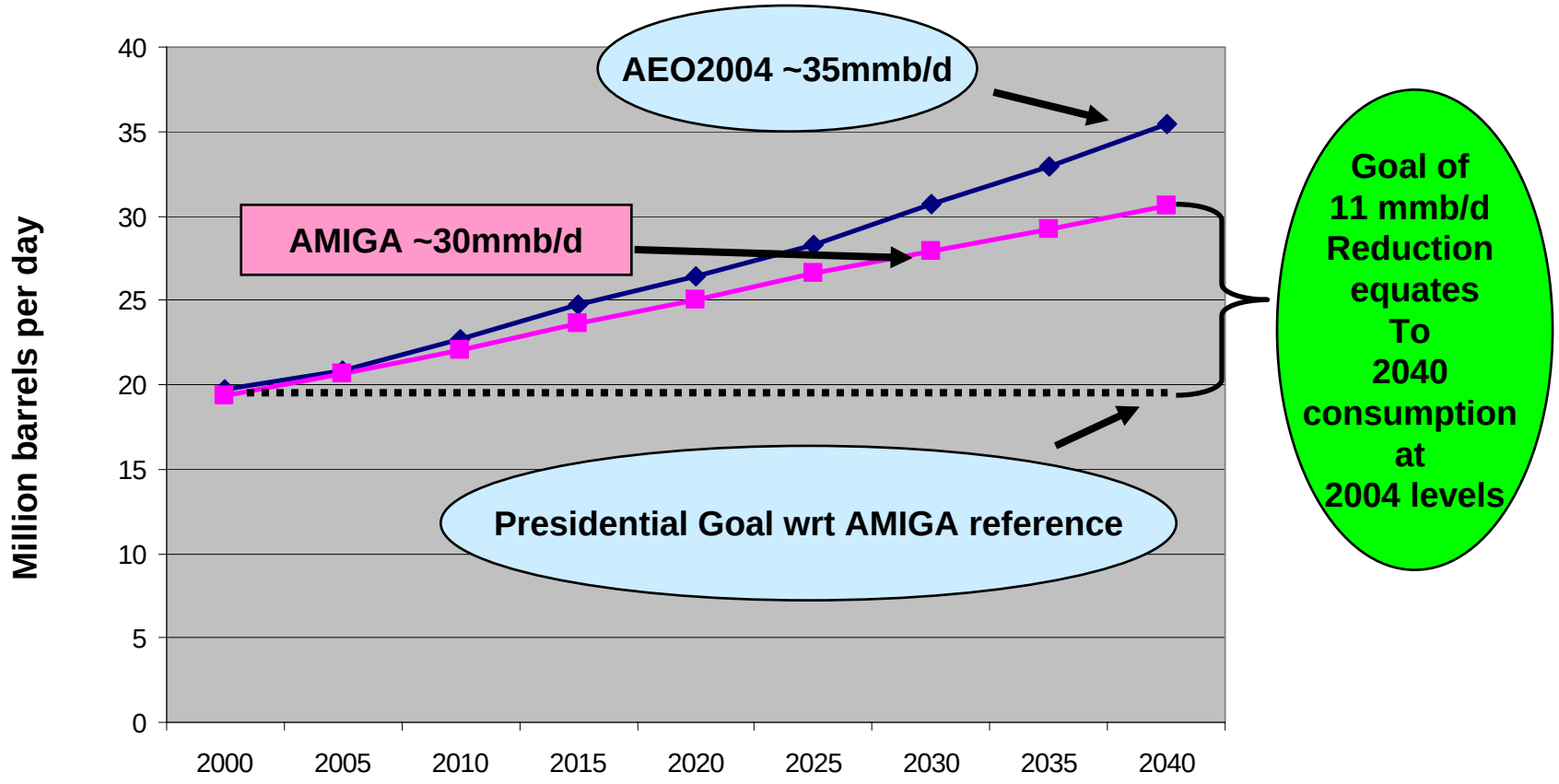
Table 2-3, EPA 430-R-03-004, April 2003
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001

NEMS Carbon equivalent emissions, AEO2004 and extrapolation



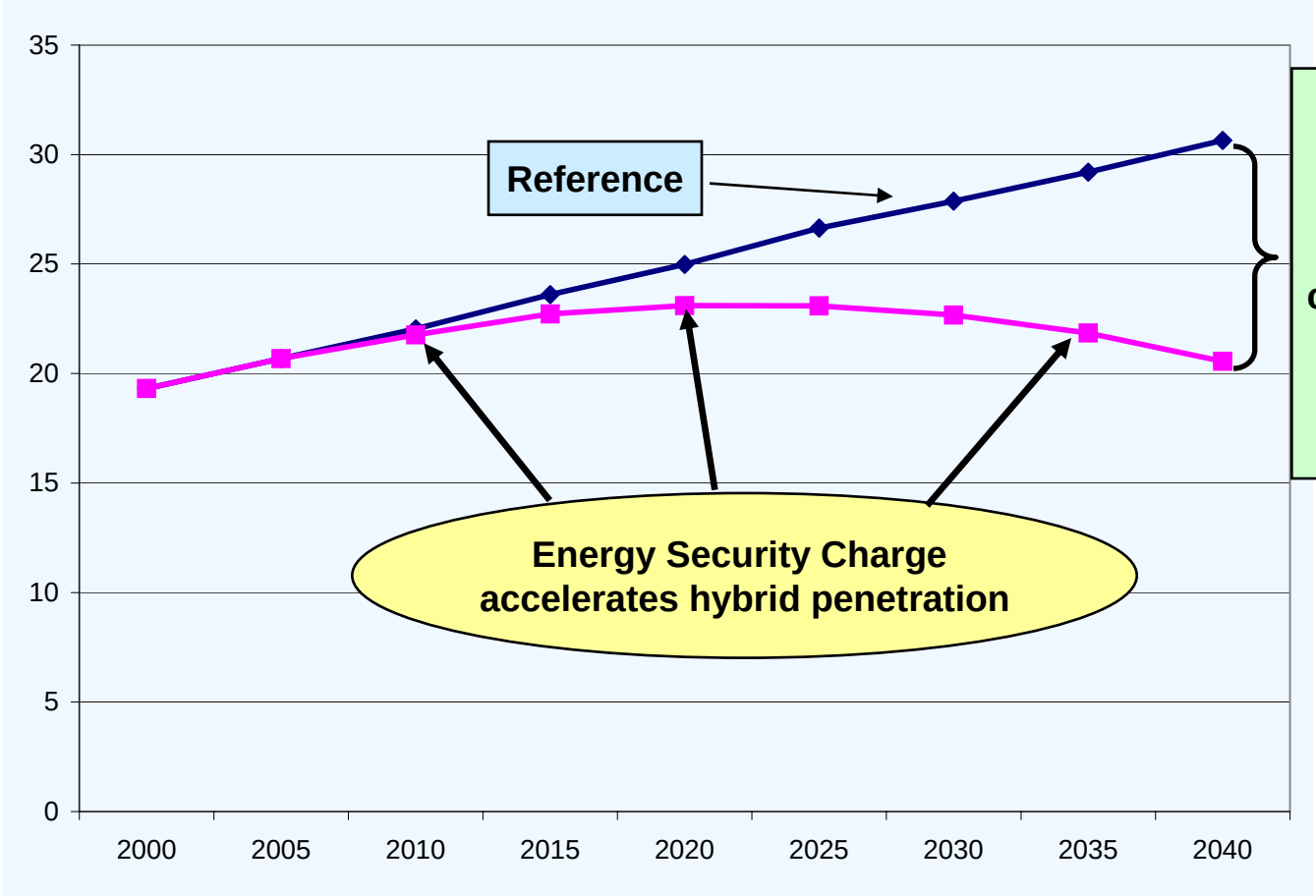
Source: 1970-2025; *AEO2004*
2025-2040, author calculation

2040 Comparison: AMIGA Reference v AEO2004 Extrapolation



Source: 2000-2025; *AEO2004;* 2025-2040, author calculation; AMIGA reference run

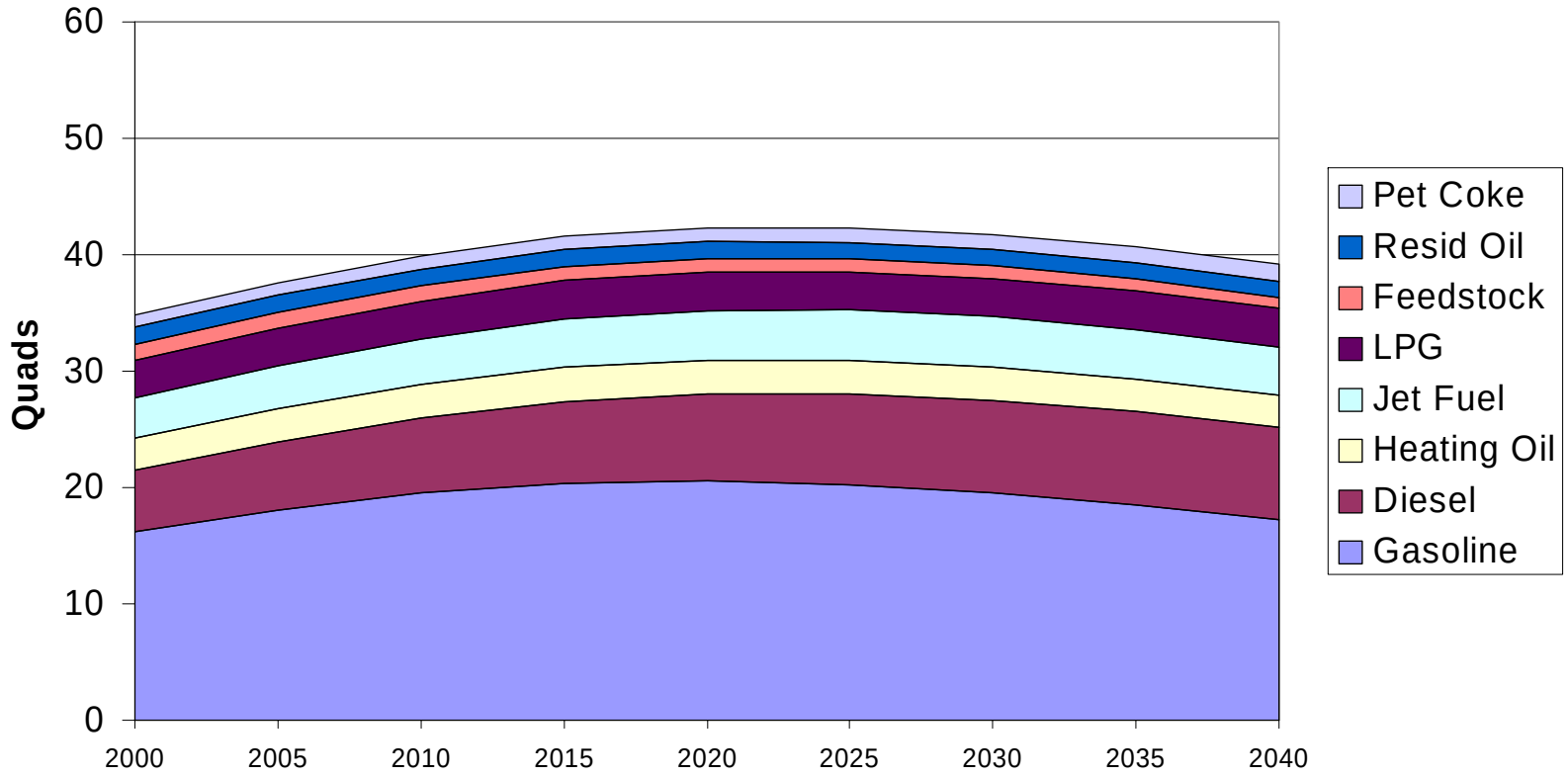
Reduced Petroleum Consumption



Source: AMIGA reference and Pres. Goals runs

More Efficient Transportation Reduces Petroleum

Petroleum Products Consumption: President's Goals Scenario



Source: AMIGA Pres. Goals run

Main Features of Two Compliance Scenarios

- **Features Common to Both Scenarios**
  - Economic driver for carbon emission reduction provided by carbon emission charge on electricity generators beginning at $18/tonne C in 2015, increasing with time.
  - Economic driver for reduced petroleum consumption provided by energy security premium beginning at $6.50/bbl in 2010, increasing with time.
  - Carbon emission reduction achieved by increased efficiency of light duty transportation fleet and carbon capture/sequestration at coal-based electricity generators.

Main Features of Two Compliance Scenarios

- **Hydrogen Transformation Achievement Scenario**
  - H_2 fuel cell vehicles dominate light duty fleet by 2040.
  - H_2 supplied by distributed fueling stations using SMR initially, possible coal-based central H_2 generation in urban areas later.

- **Extended Transition to Future Energy Scenario**
  - H_2 fuel cell vehicles achieve only small market penetration by 2040.

- **Extended Transition to Future Energy Scenario – cont.**
  - ICE/battery hybrids, including plug-in hybrids, and diesel vehicles dominate light duty fleet by 2040.
  - Supplemental liquid fuels supplied by coal-based coproduction of electricity and FT liquids, optionally employing carbon capture/sequestration.

Enabling Technologies

- **Model optimizes path with end goals in mind.**
- **Still, technologies must be available for path to unfold**
  - Coal-to-FT-Liquids
  - Vehicle concepts
  - Other electricity options, including IGCC with carbon capture and sequestration

Coal-Based Coproduction of Power and FT Liquids-I

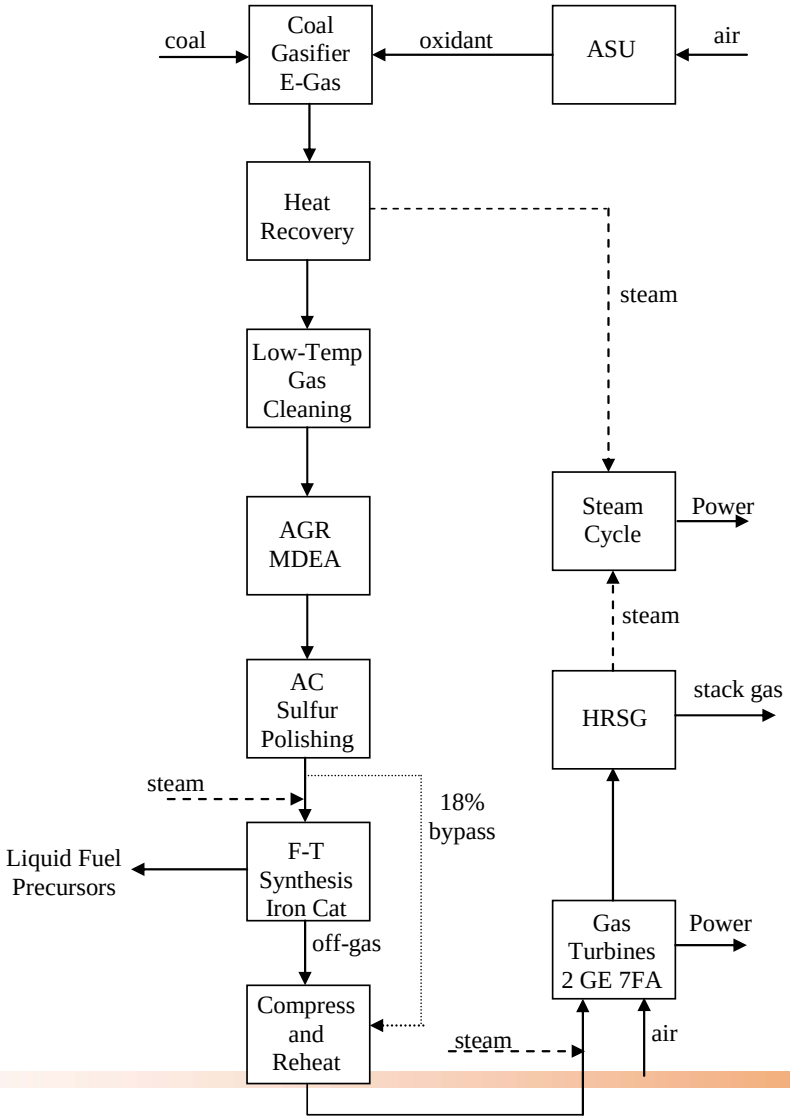
- **Background**
  - Once-through operation with syngas feed is advantageous in capital cost and energy efficiency compared to liquid-only FT plant.
  - Bechtel, Global Energy/Nexant, and Mitretek have prepared case studies of coal-based coproduction plants for NETL, but none matched needs of this project:
    - With/without carbon capture
    - Product slate with high (liquid fuel/electricity)
    - Gas turbine capable of running on low BTU gas

Coal-Based Coproduction of Power and FT Liquids-II

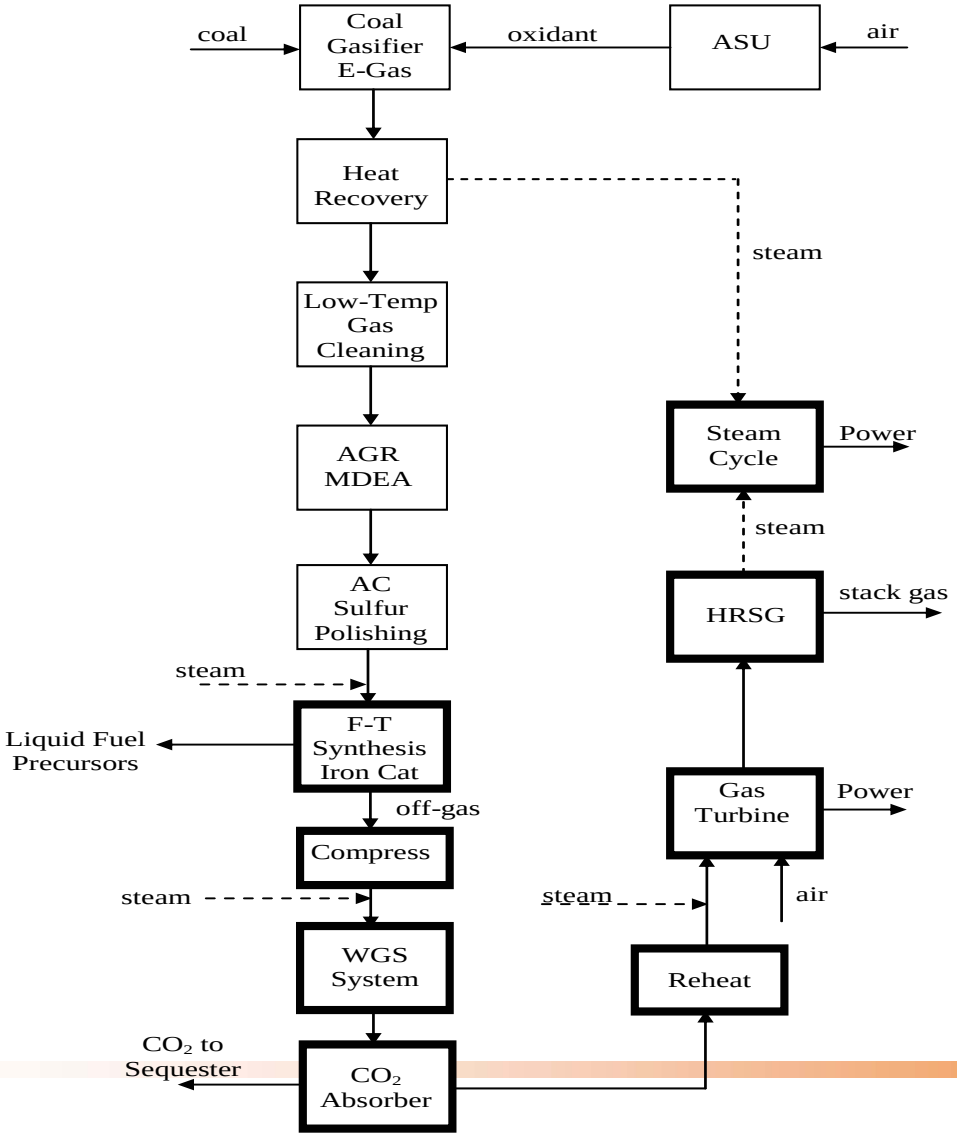
- **Three plants analyzed in this study-**
  - Base Plant: 10, 837 TPD feed, IL #6 bit. coal, four E-gas® gasifier trains.[1]
  - Case 2: Base Plant with elimination of 18% syngas bypass of FT reactors.
  - Case 3: Case 2 with CO_2 capture from effluent of FT reactors.

1. Bechtel, Global Energy, Nexant: "Gasification Plant Cost and Performance Optimization" Task 2 Topical Report Coke/Coal Gasification with Liquids Coproduction, Sept. 2003.

Nexant Base Case and Case 2 Plants



Modified Nexant Plant with CO_2 Capture



Snapshot Comparison of Cases

	Base Plant	Case 2: frac. base	Case 3: frac. base
Coal feed, TPD (mf)	9264	1.00	1.00
Clean syngas, lb/hr.	1,468,000	1.00	1.00
Liquid product, lb/hr	146,018	1.22	1.22
Gross power gen., MW	819.6	0.84	0.61
Net power gen., MW	675.9	0.80	0.46
Cap. Cost, MM 2003 $	1,239	0.98	1.01

Plant Performance Comparison

	Base Plant	Case 2:	Case 3:
First Law Eff., (Elec.+Liquids)/coal	0.57	0.58	0.49
Turbine fuel gas LHV, BTU/scf	210	184	388
CO_2 capture, ton/hr	0	0	524
Carbon disposition, fraction of feed			
-In liquid fuel	0.23	0.28	0.28
-In captured CO_2	0	0	0.53
-In stack gas	0.77	0.72	0.19

Summary

- A technoeconomic study in progress will show that by increasing fuel economy in the light duty fleet, the President's twin goals of reducing petroleum consumption and carbon emissions can be met by 2040 without disrupting the economy.
- Coal-based coproduction of power and liquid fuels can supply supplemental fuel needed to reach the goal of 11 MM bpd reduction in petroleum consumption if hybrids and diesel vehicles dominate the light duty fleet.

Summary, cont.

- By employing carbon capture and sequestration, coal-based coproduction can also contribute to reaching the goal of 500 MM tonne per year carbon emission reduction.
- Relative to a previously published engineering study of liquid fuel/electricity coproduction, this study shows that a higher ratio of liquid fuel/power is feasible.