Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Sequestration Policy and Feasibility Studies (2)

Alternative Approaches to Reducing Petroleum Use and CO2 Emissions By Means of a Hydrogen Economy: Technology and Economic Modeling and Scenario Analysis

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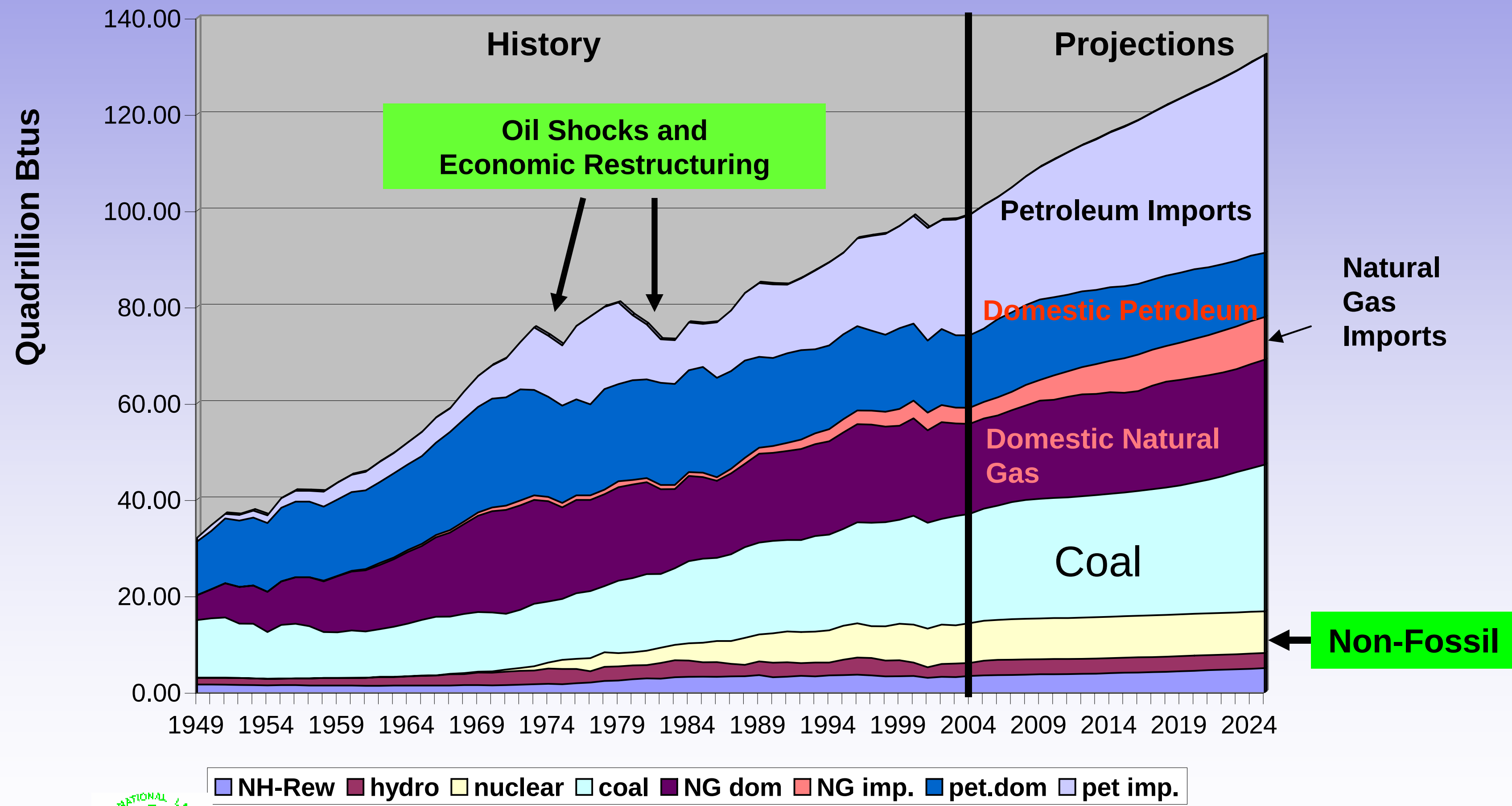
Primary Drivers: Oil and Carbon

Presidential Goals

- Reduction of Petroleum Consumption
  - 11 million barrels per day, by 2040

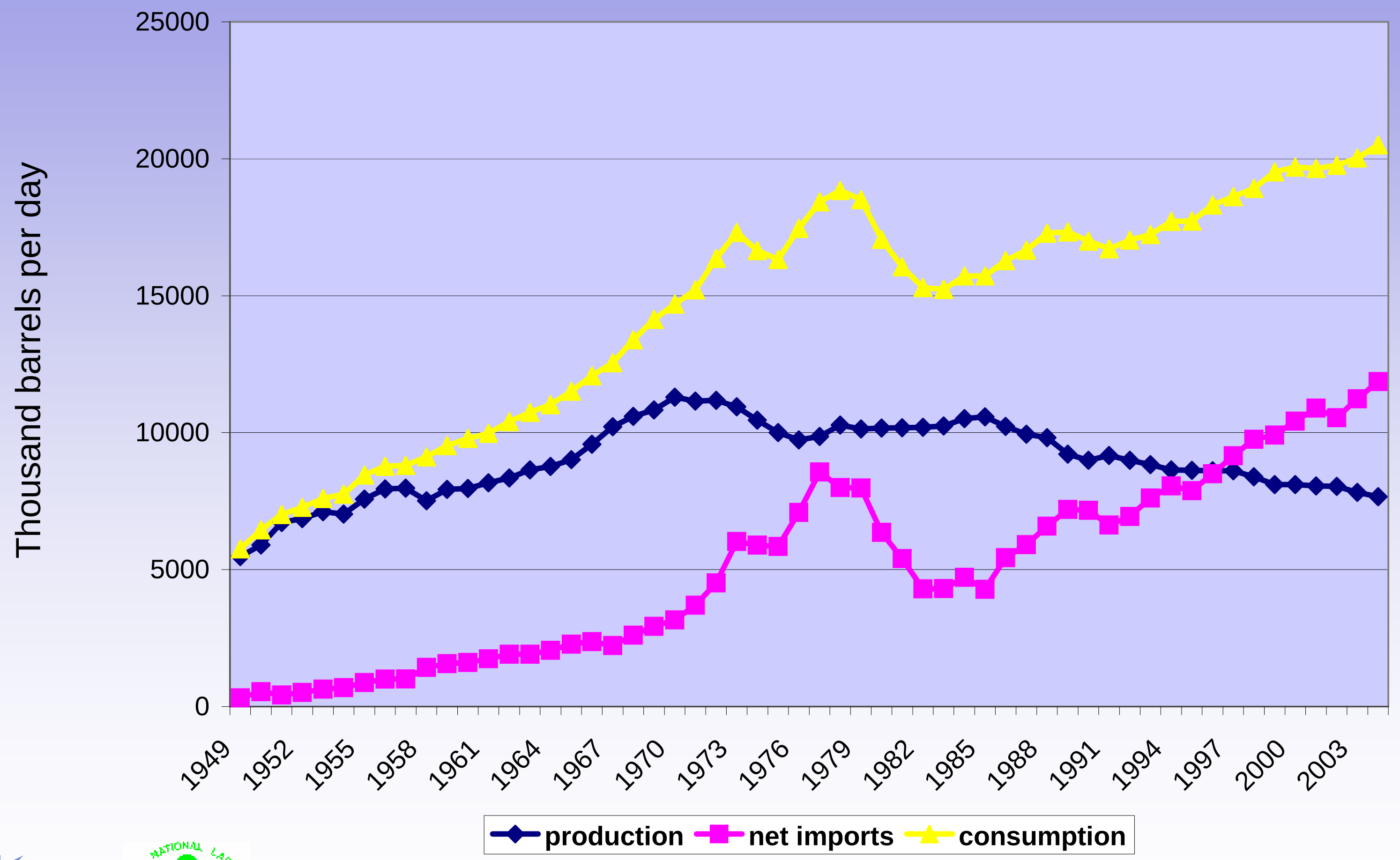
- Reduction of Carbon Equivalent
  - 500 million metric tons per year, by 2040

US Energy Consumption by Fuel 1949-2025



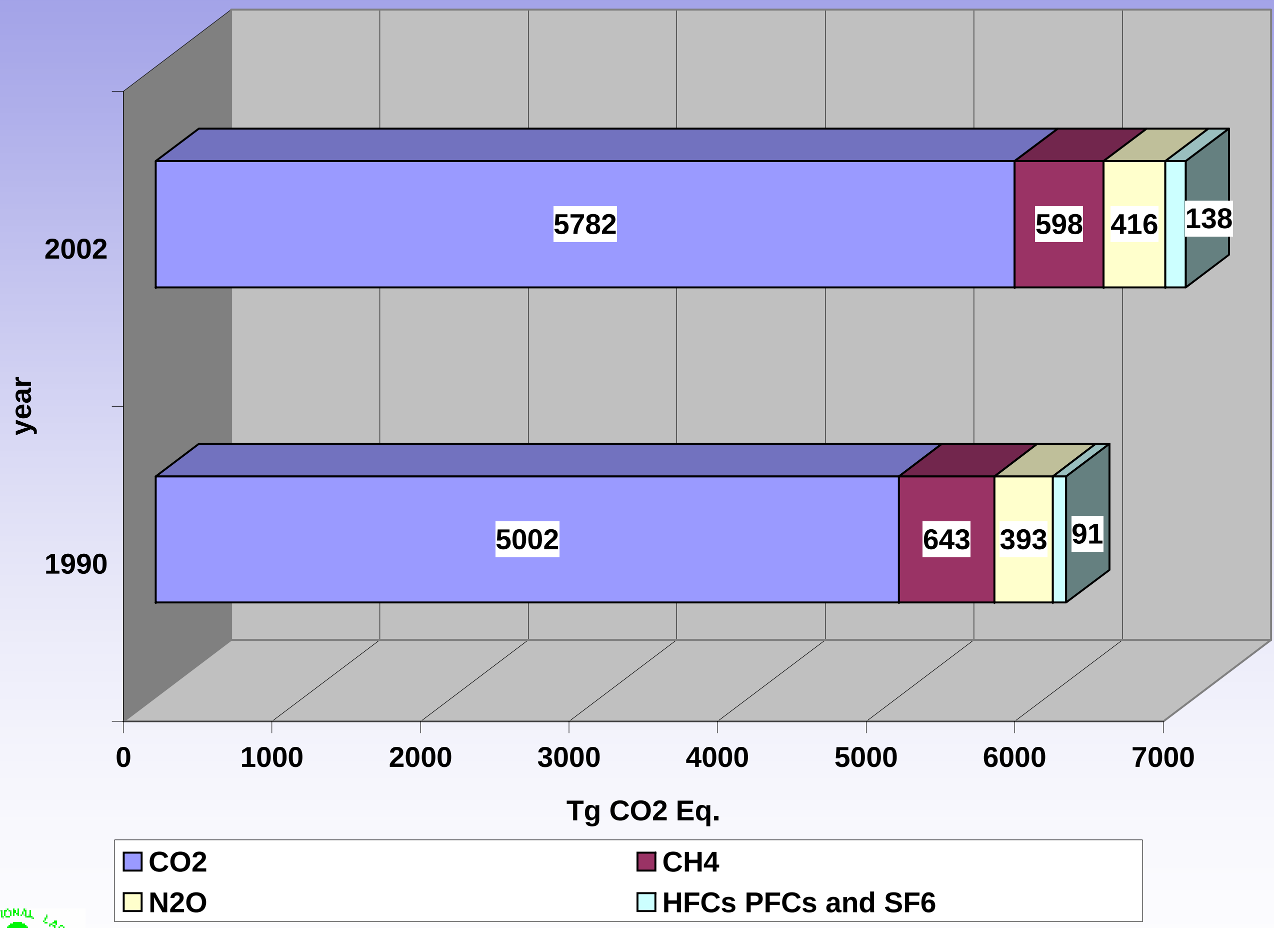
Source: **EIA**; 1948-2003: ***Annual Energy Review 2003***, Table 1.3; 2004-2025: ***Annual Energy Outlook 2005***, Tables 1,2, and 17

US Petroleum Trends, 1949-2004



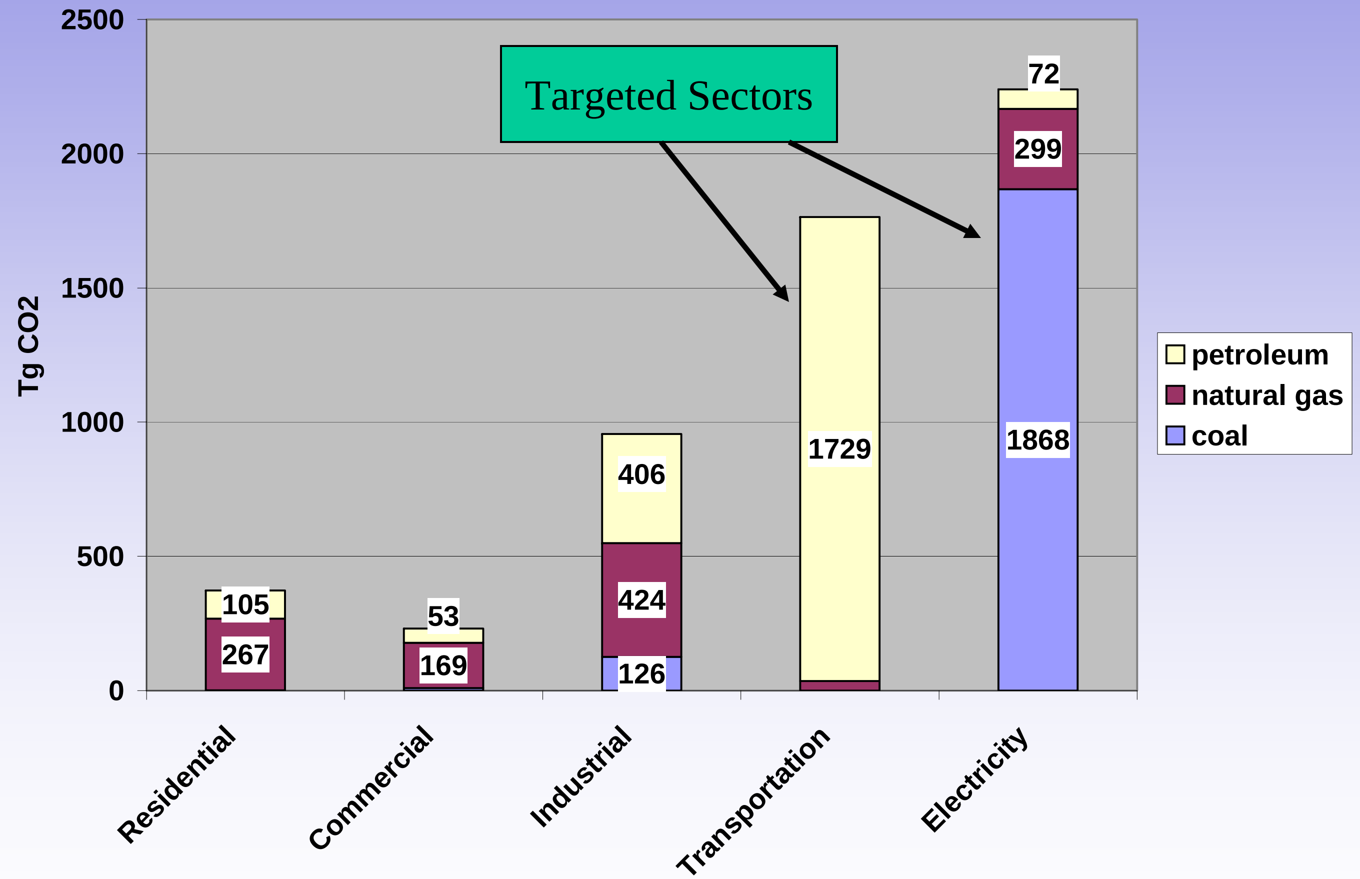
Note: Figures include crude oil, natural gas liquids, merchant oxygenates, and imported petroleum products. Source: EIA, *AER 2003*, Table 5.1 Petroleum Overview, 1949-2003; Petroleum Supply Monthly, January 2005, Table S1

US GHG Emissions, 1990-2002



Source: EPA, *2004 Greenhouse Gas Inventory*, National Inventory Tables, Table ES-2

2002 US CO_2 Emissions from Fossil Fuel Combustion, by Sector

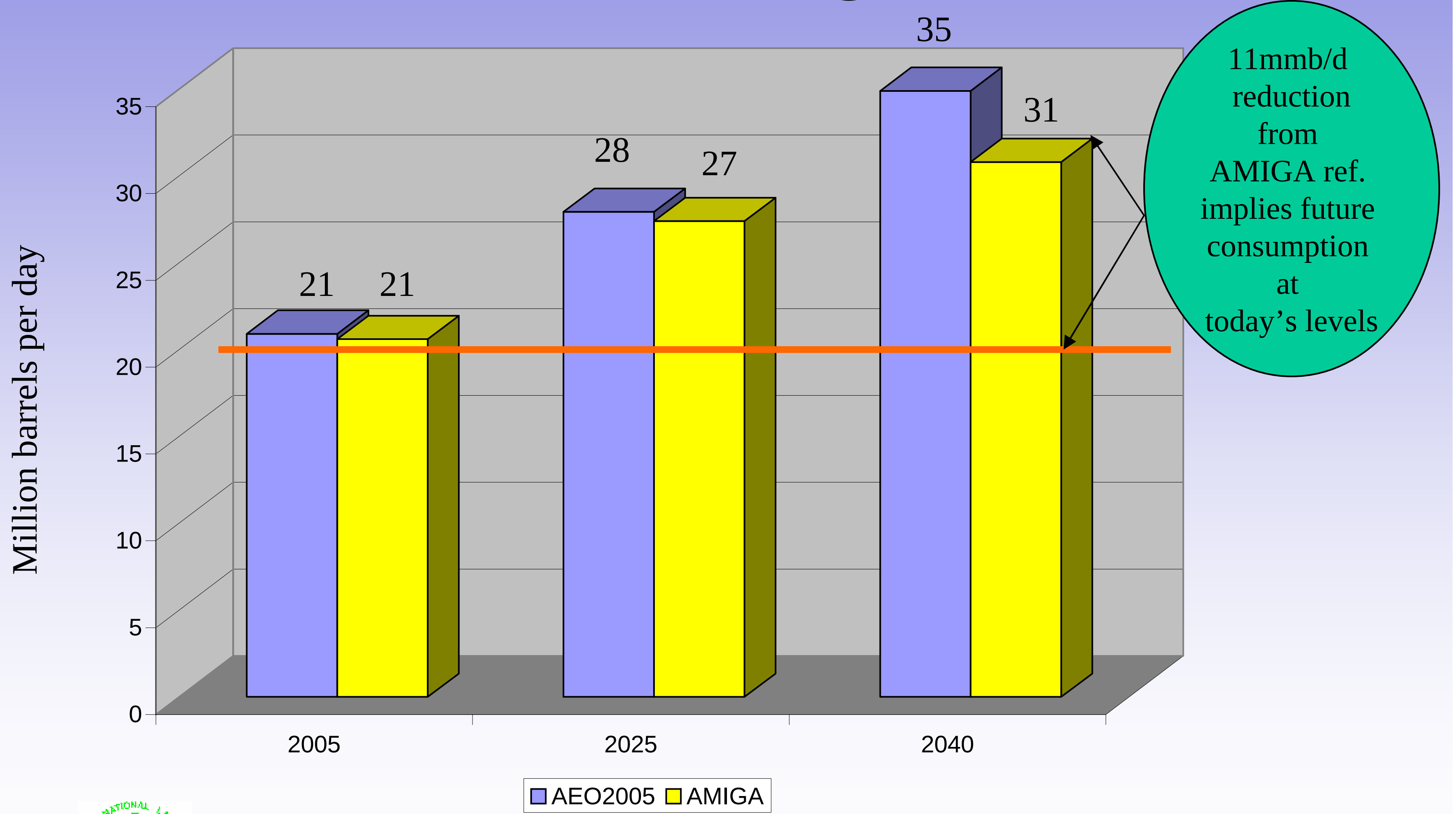


Source: EPA, 2004 Greenhouse Gas Inventory, National Inventory Tables, Table 3.3

How to Achieve Cuts

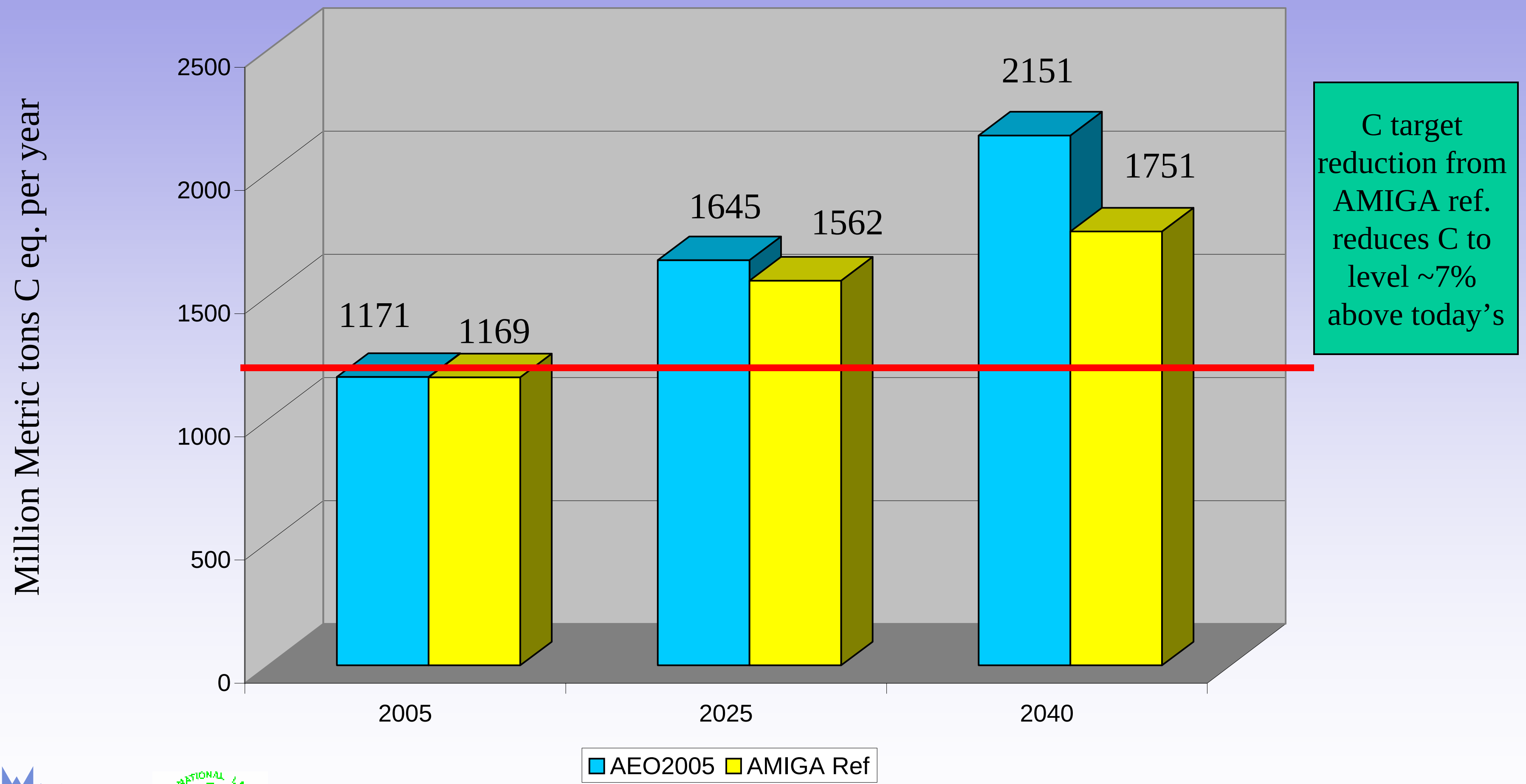
Reference Case: "Business as usual"	**"Chemical H_2"** Hybrid-electric vehicles and Clean Hydrocarbons	**Gaseous H_2 (preliminary)** Hydrogen Production for Fuel Cell Vehicles
Oil Prices From $37/b in 2010; Gas Prices from $6/mmBtu	Coal Power/Fischer-Tropsch Co-Production Plants	DOE H_2 Posture Plan guidelines
"Clear Skies"-Like Emissions Targets	Energy Security Charges on premium fuels from 2010	H_2A program (DOE EE) H_2 cost data
Gasification, Hydrotreating and Clean fuels Refinery Modeling	Carbon Charges on Electricity generation from 2015	More stringent clean air regulations begin in California
Nuclear Generating Capacity Constant	Four size categories of Hybrids; eventual Plug-Ins	Technological "breakthroughs" assumed

Petroleum Target



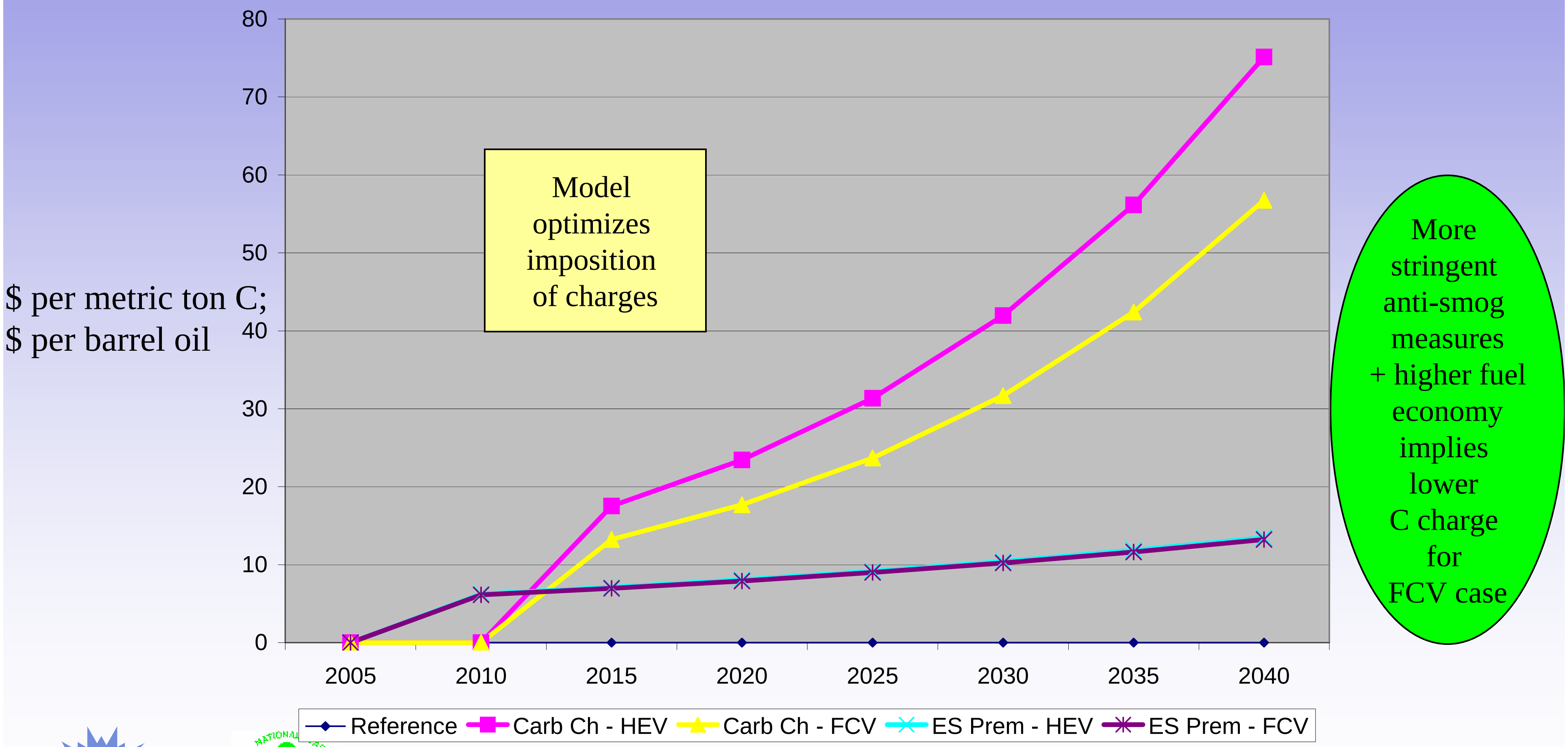
Source: EIA *AEO2005* Yearly Table 11; author extrapolation;
AMIGA reference run

Carbon Emissions Target



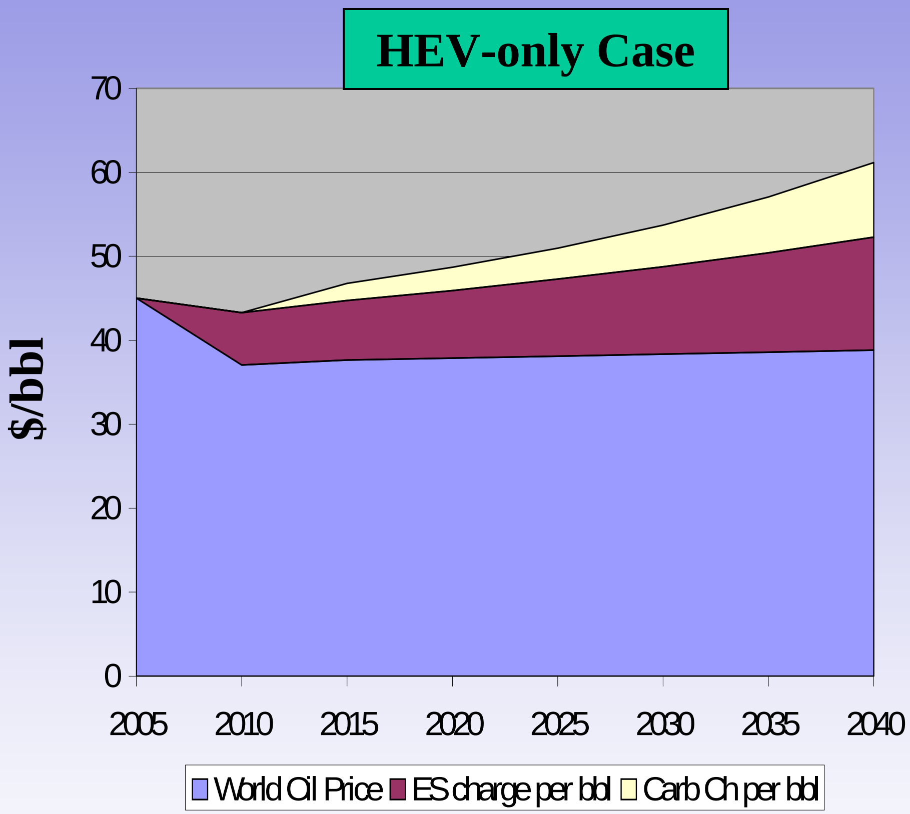
Source: EIA *AEO2005* Yearly Table 18 (transport petroleum; electric power); author extrapolation; AMIGA reference run

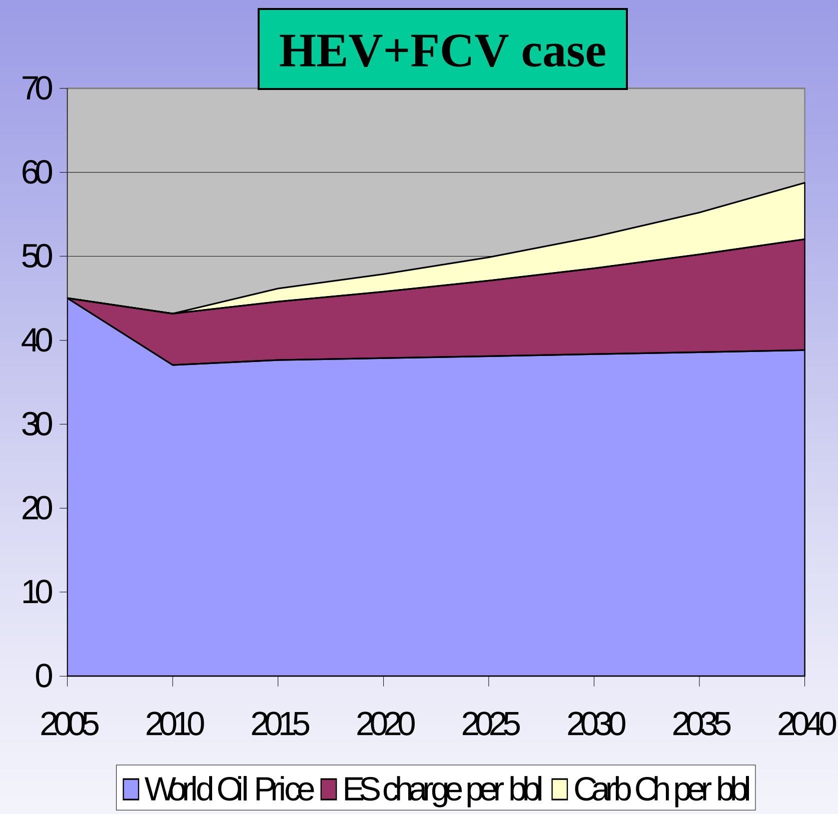
Externality Charges



Source: AMIGA Presidential Goals Scenario Runs

Effective Oil Prices





Externality charges result in higher effective than nominal oil prices;
Slightly higher imputed carbon and energy security charges in HEV-only case

Source: AMIGA Presidential Goals Scenario Runs

Coal Power/Fischer-Tropsch Fuels Co-Production

- Plants Optimized for Fuels Production
- Plant products: 33 kWe/ton per day of dry coal feed and 1.63 bpd of F-T liquid fuel precursors/ton per day of dry coal feed
- Capital cost: $135,000 per ton per day of dry coal feed including carbon capture; this cost includes carbon capture but not carbon transport and sequestration.
- The carbon sequestered in the CO_2 stream is 53% of the carbon in the coal feed.
- Return on investment projections show > 15% ROI when the power selling price is > $40/MW-hr and the selling price of the F-T liquids is > $60/bbl

Source: Dale Keairns and Richard Newby, 2005, "Fuels and Electric Co-Production Plant Cost and Performance Projections," NETL working paper

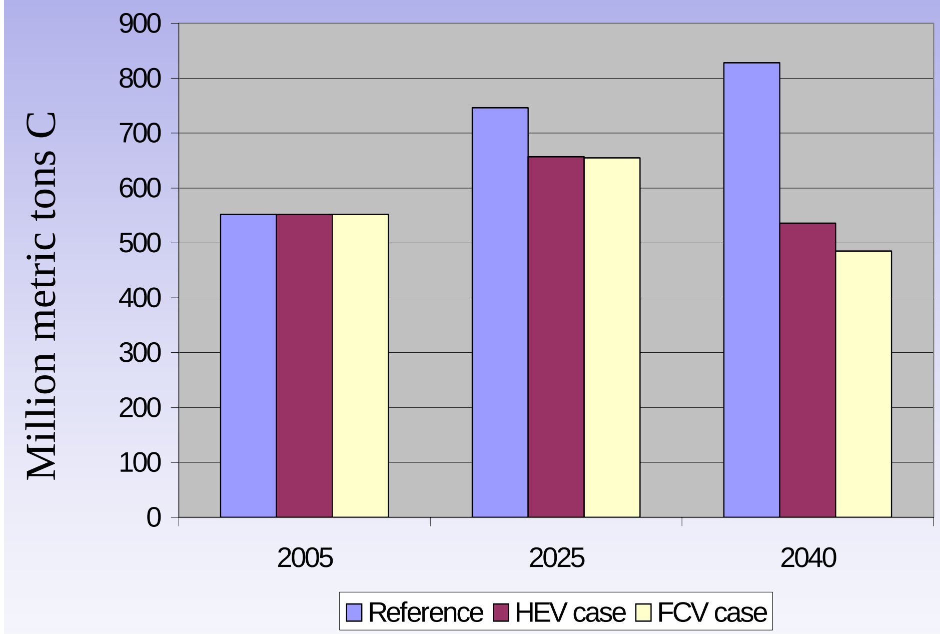
Coal Power/FT Fuels II

- **Capture of CO2 from the F-T liquids co-production plant will be lower cost than capture from a power-only plant**
  - CO2 capture requirements should be achieved first from Power/FT liquids plants with additional capture from power-only plants
    - The off-gas from the F-T reactor has a very high CO_2 content (>60 vol%) and relatively low CO content (< 10 vol%). Thus, little shift is needed to maximize the CO_2 content in the gas.
- Accounting:
  - FT fuel counts against petroleum consumption
  - 95% of C from co-production plants is captured.

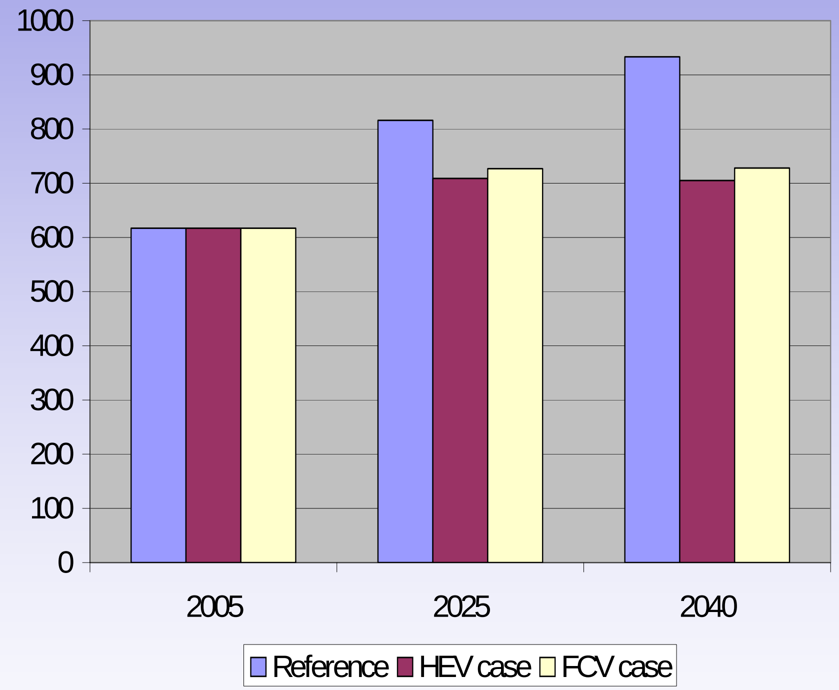
Source: Dale Keairns and Richard Newby, 2005, "Fuels and Electric Co Production Plant Cost and Performance Projections," NETL working paper

Sectoral Carbon Reductions

Transport Sector Emissions



Electricity Generation Sector Emissions



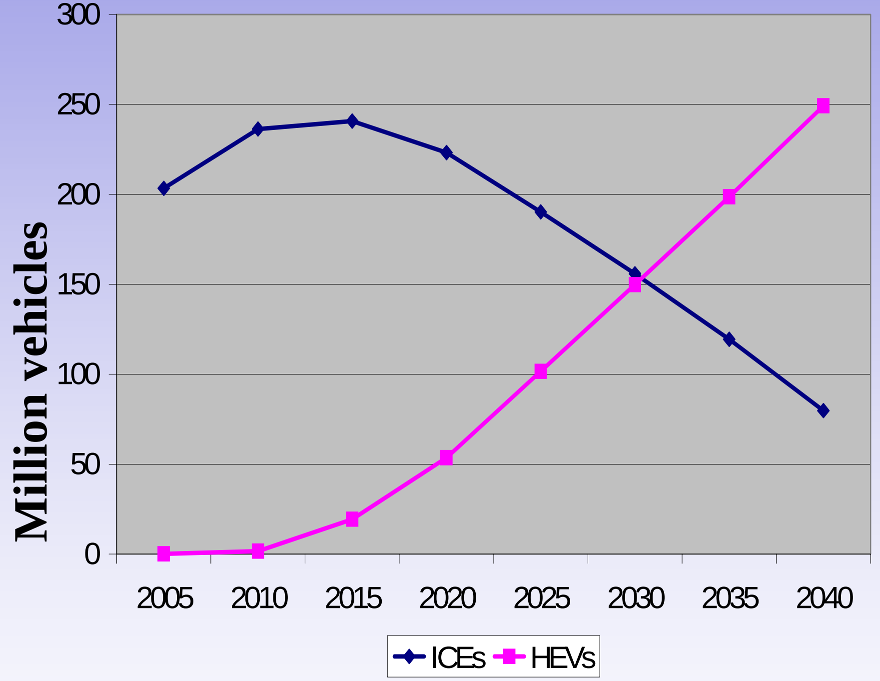
Greater C reductions from FCV+HEV case

More FT C capture in HEV-only case

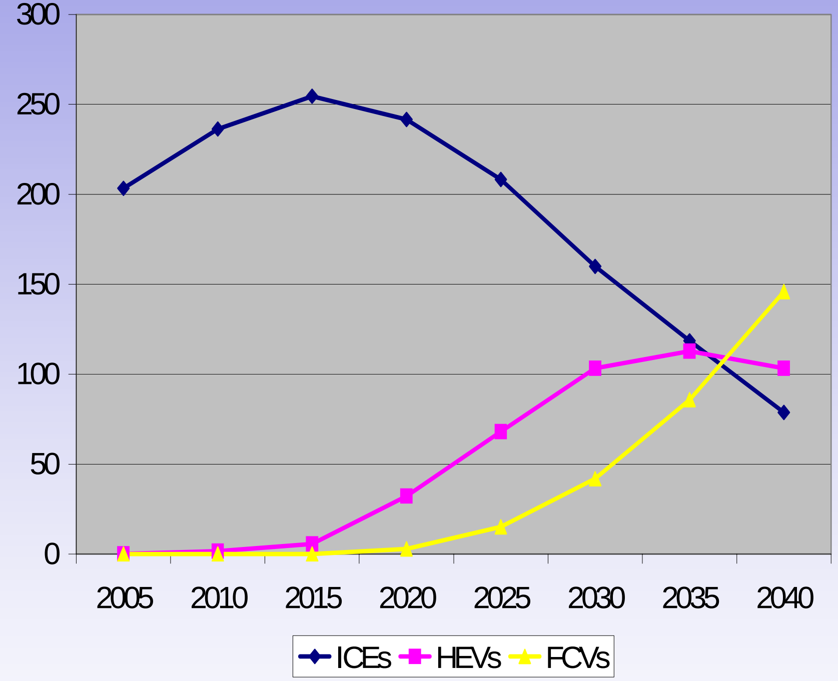
Source: AMIGA Presidential Goals Scenario Runs

Vehicle Stocks

HEV –only case



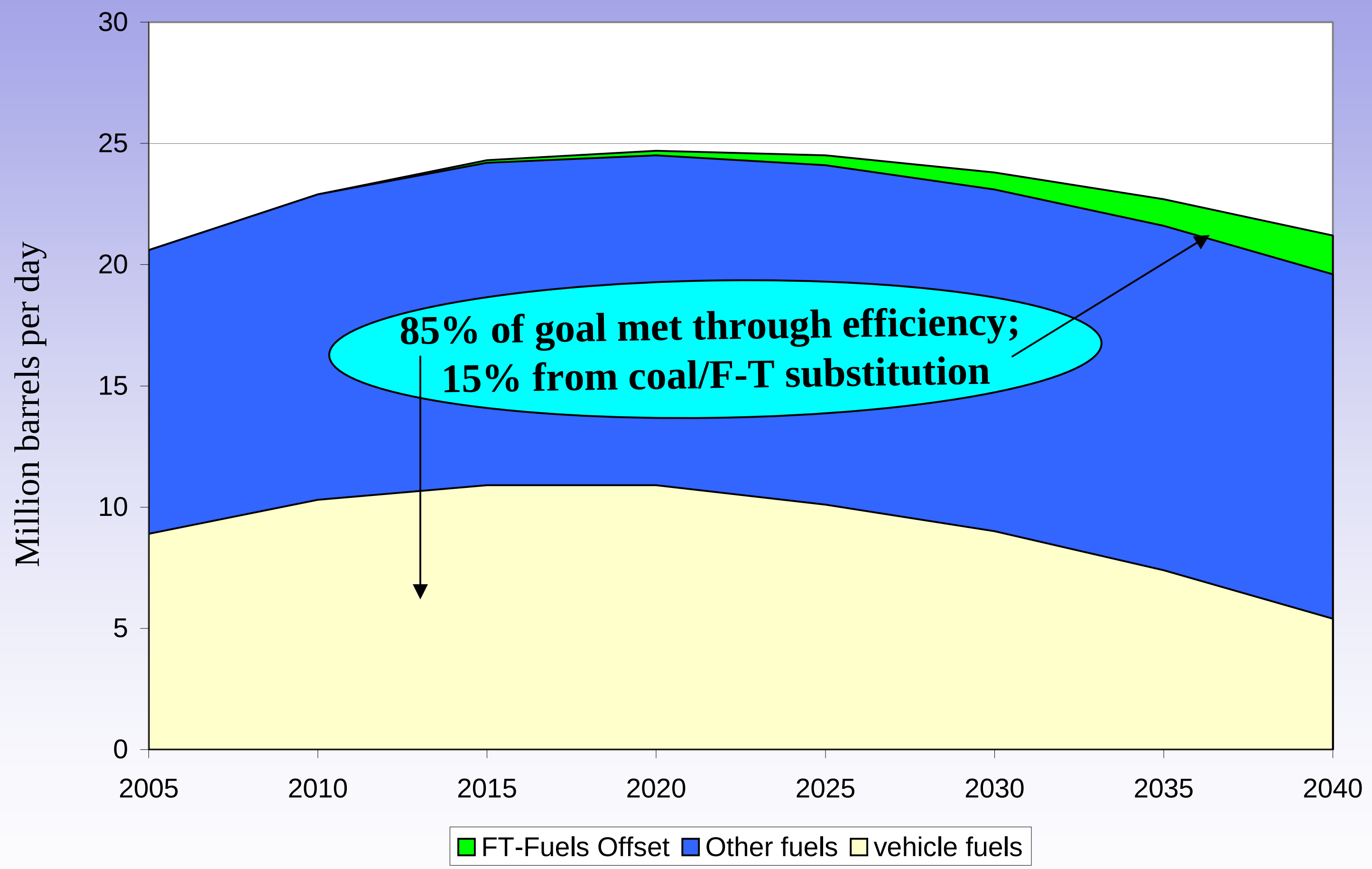
HEV+FCV case



Internal Combustion Engines
decline but remain;
externality charges drive
adoption of alternative vehicles

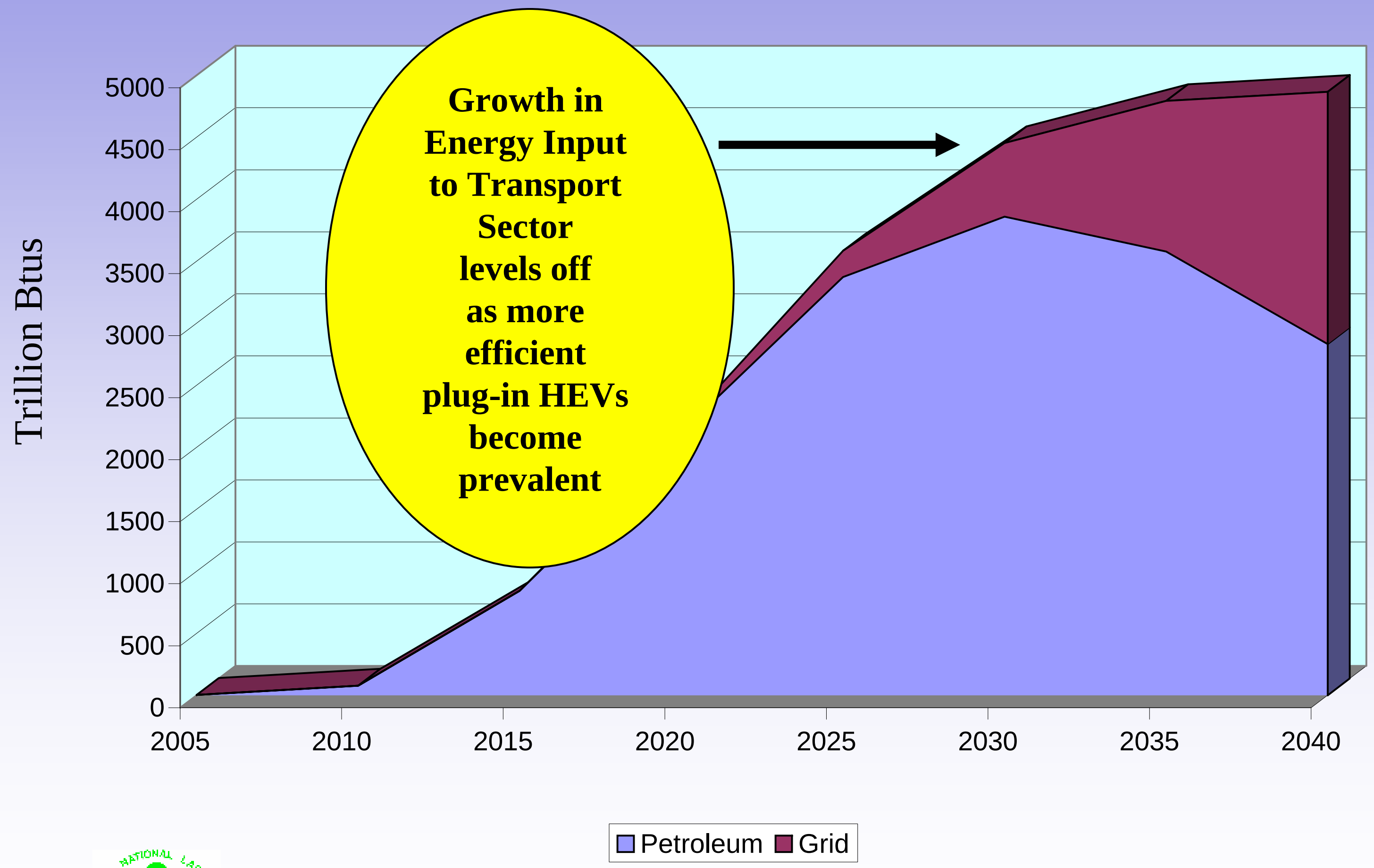
Source: AMIGA Presidential Goals Scenario Runs

Reduced Petroleum Consumption



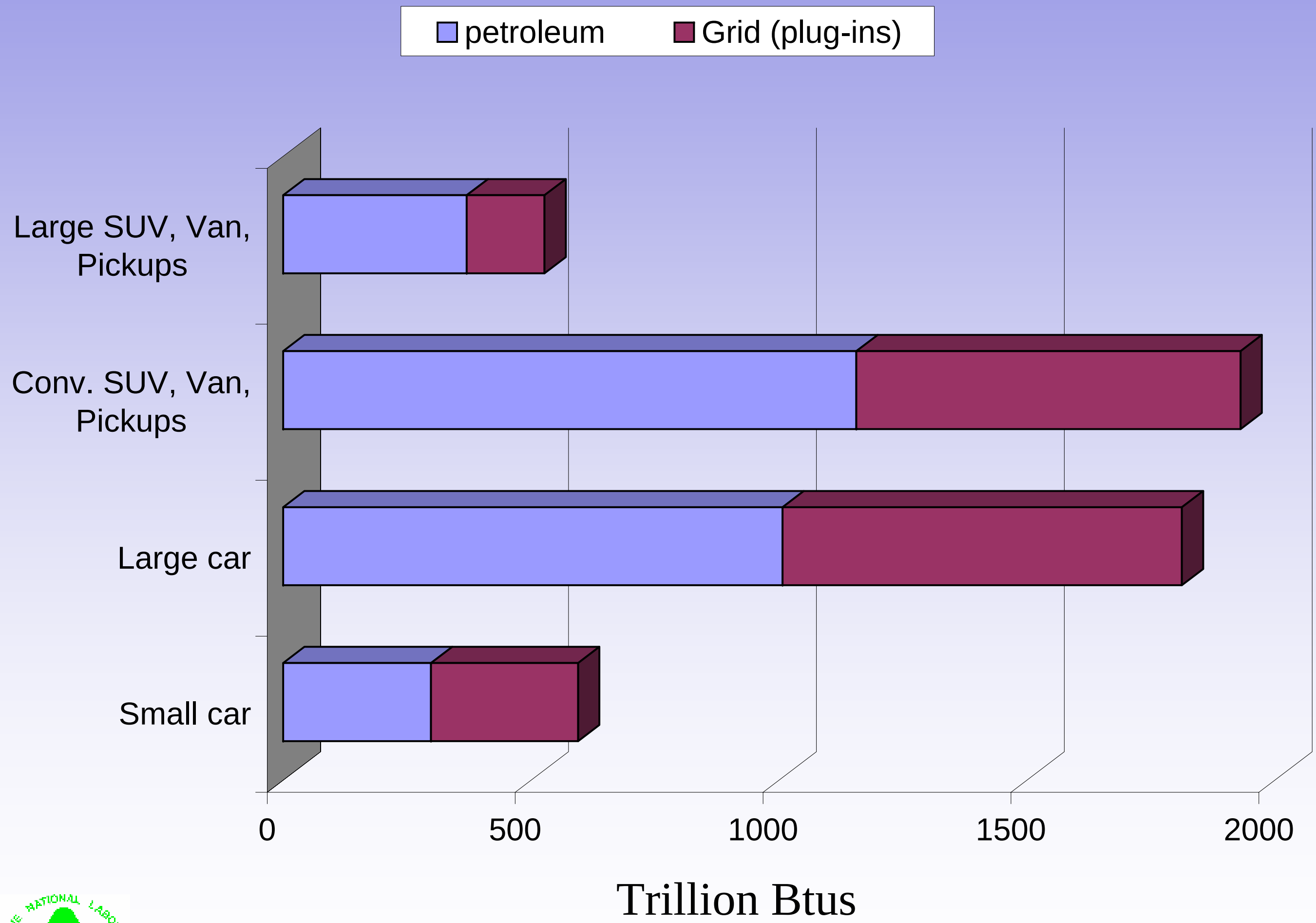
Source: AMIGA Presidential Goals Scenario Runs- HEV case

Energy Supply to Vehicles, HEV Case



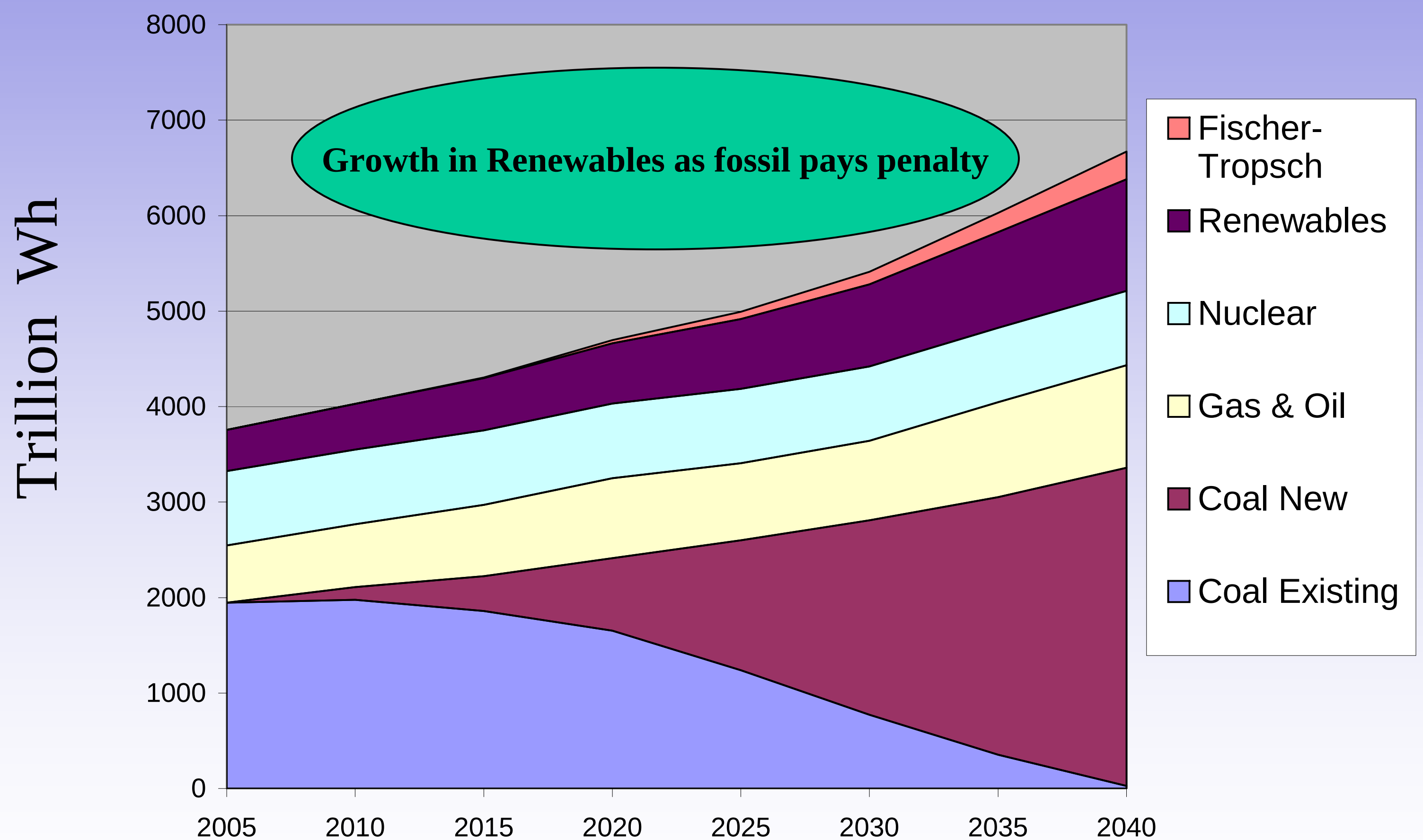
Source: AMIGA Presidential Goals Scenario Runs- HEV case

Energy Supply by HEV Size Type, 2040



Source: AMIGA Presidential Goals Scenario Runs- HEV case

Electricity Generation by Fuel Type, HEV Case



Source: AMIGA Presidential Goals Scenario Runs- HEV case

Concluding Remarks

- **Both Scenarios Meet Goals**
  - Advent of plug-In HEVs ties Electricity and Transport Sectors
  - To meet goals, significant amount of CO2 capture and sequestration needed
    - HEV case C reduction: 56% from Transport, 46% from Power
    - FCV case C reduction: 62% from Transport, 37% from Power
    - ~95% of Power/FT plants' CO2 captured
    - 10 % of new IGCC coal fleet captures ~20% of target reduction.
  - Higher C goal with constant petroleum goal will increase level of required power sector sequestration
- **Modeling Challenges**
  - At early stage of implementing DOE EE's H2A efforts