Plug-In Hybrids: A Scenario Analysis

State Clean Energy-Environment Technical Forum

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What is a Plug-In Hybrid?

A Plug-In Hybrid Electric Vehicle (PHEV) is a Hybrid Electric Vehicle (HEV) with additional battery energy that can be charged from the electric grid and used to propel the vehicle for some portion of a trip

- Compared to a HEV, the PHEV can drive under an "all electric" mode for a larger fraction of driving time
- If a current HEV were getting 50 mpg, a PHEV might achieve 90+ mpg (gasoline) because some of the miles are powered with electricity from the grid, not gasoline.
- An owner could "fill-up" with gasoline during the day and charge the vehicle at night

Image: J. Romm, A. Frank, *Scientific American*, April 2006

Why the Interest?

- Possibility of significant GHG reductions over 20 – 30 years with complementary electric sector GHG reduction technologies
- Large potential petroleum reductions/reduced oil import reductions
- Potentially a “game changing” or “disruptive innovation” that allows transportation energy to be shifted from conventional fuels to electricity.
- Electric mode fuel costs are equivalent to about $0.60 - 0.95/gallon* gasoline
- No need for large new energy supply infrastructure investments since PHEVs use the existing infrastructure for gasoline and electricity

• Breakeven price estimate based on 6 - 10 cents/kWh range, 90 mpg-equiv. (electric) compared to 25 mpg conventional vehicle

PHEV Challenges

- High up-front costs for PHEVs
  - Currently, after-market conversion kits cost $10,000 - $12,000 or more (retail)
  - Lithium ion battery would likely cost at least $3000- $5000 in near to mid-term
  - Additional costs of electric powertrain
- Battery durability and performance
- Consumers acceptance
  - Fuel/energy efficient products tend to have larger up-front costs
  - Access to garages, some may need to add a charging circuit
  - Availability of off-peak pricing
  - Resale value

PHEV & Electricity Sector Scenario

- Desire for approaches that can simultaneously reduce petroleum consumption and reduce GHGs emissions from the U.S. transportation sector

Key Questions:
- What are the environmental, technical, and economic merits of PHEVs?
- What are the interactions between PHEVs and the electricity sector?
- What are the overall GHG emission reductions and costs of the approach?

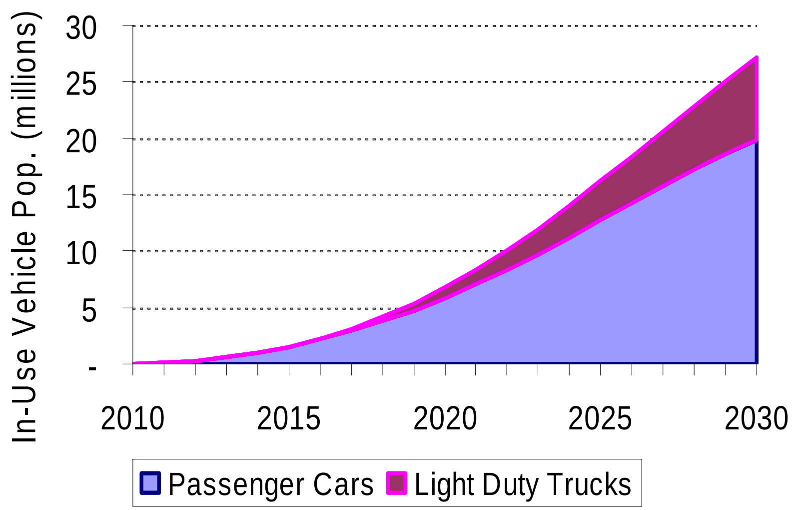
Modeling of “What If” Scenario

- Integrated Planning Model (IPM)* is a dynamic linear programming model of the U.S. electricity sector

- In-house vehicle stock, fuels and greenhouse gas emissions accounting model based on parameters in MOVES

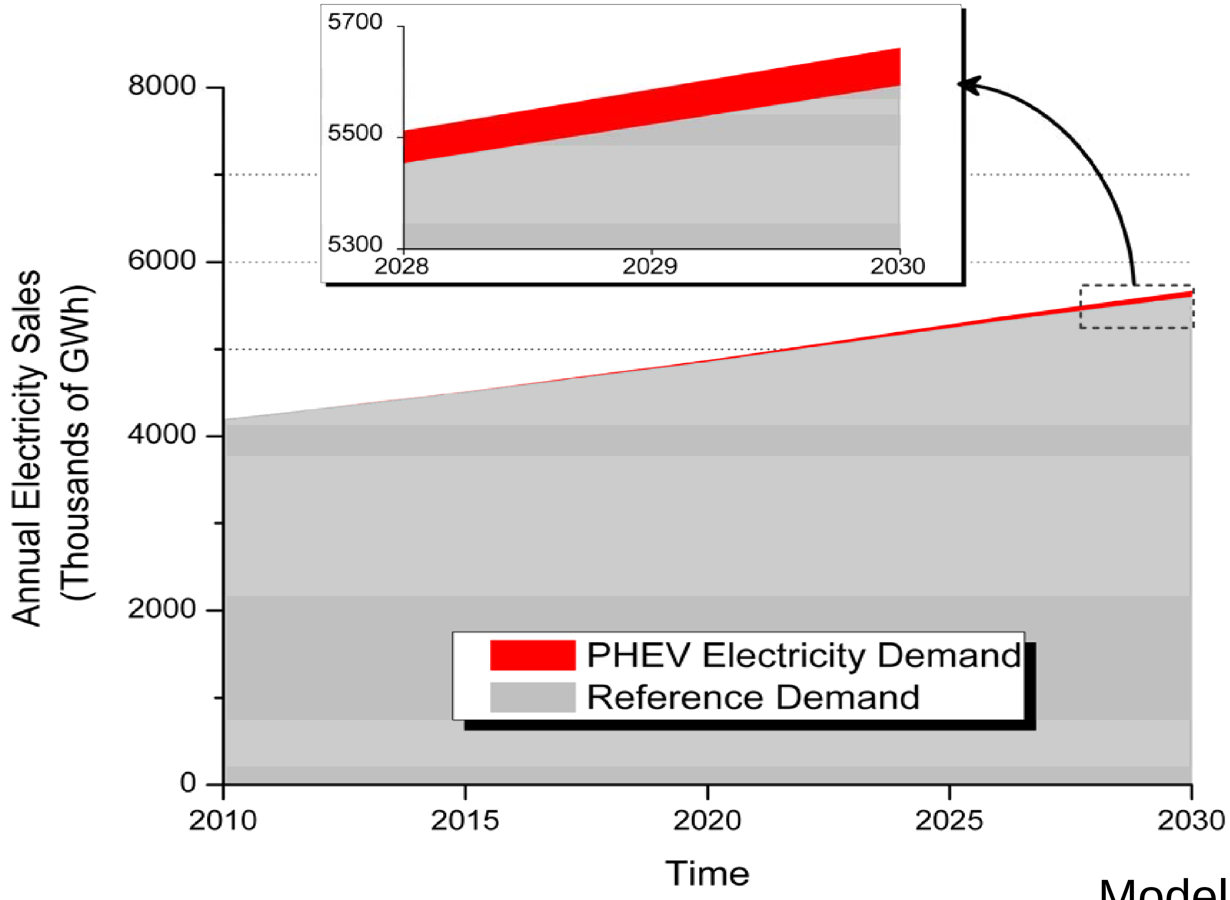
- “What-If Scenario” – PHEVs sales begin in 2011 and grow to 15% of all passenger vehicle sales by 2030.

- In terms of vehicles on the road, this sales trajectory means almost 10% of passenger vehicles would by PHEVs by 2030 (~ 27 million)



* "Modeling Framework," Introduction to EPA Modeling Applications Using IPM, EPA's Clean Air Markets Division, 2004

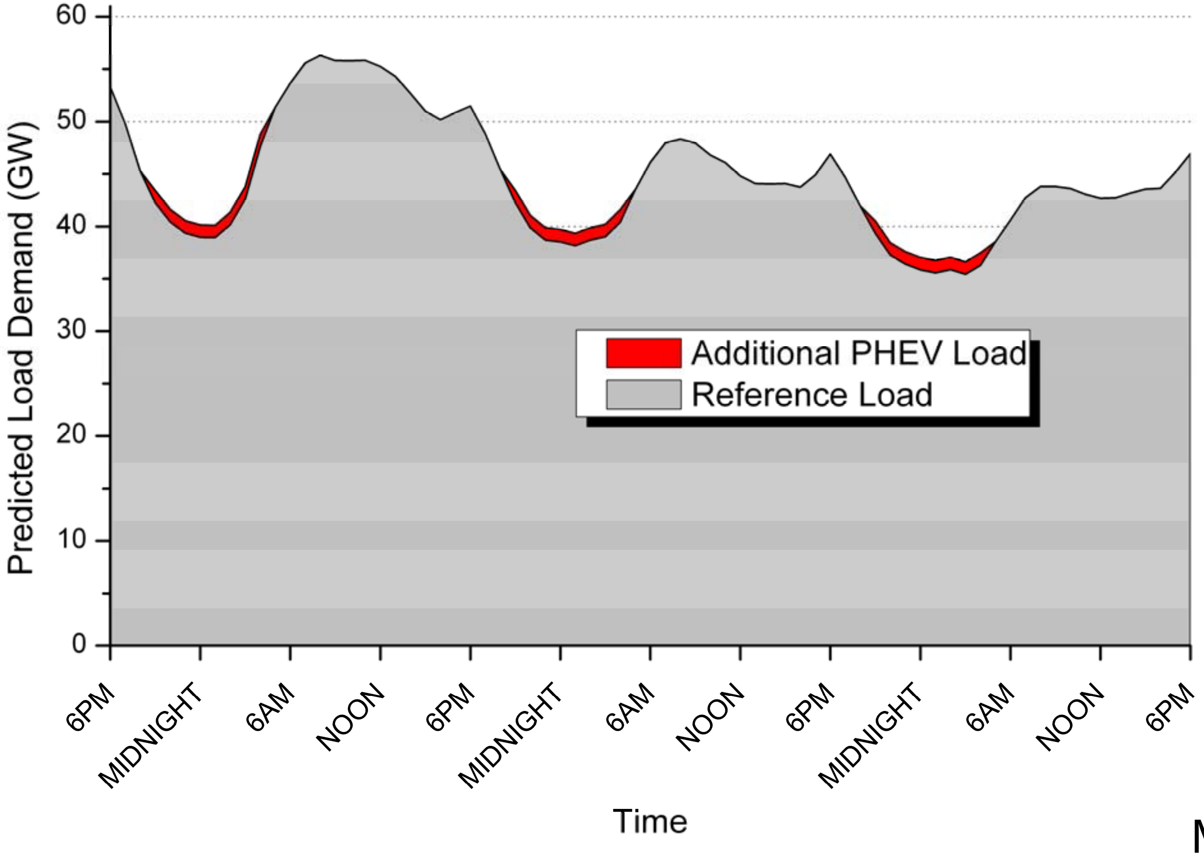
U.S. Electricity Sales for PHEVs



Model: IPM

- Electricity sales from PHEVs represent a small fraction of total U.S. electricity demand (In 2030, 1.2% of demand is from PHEVs)

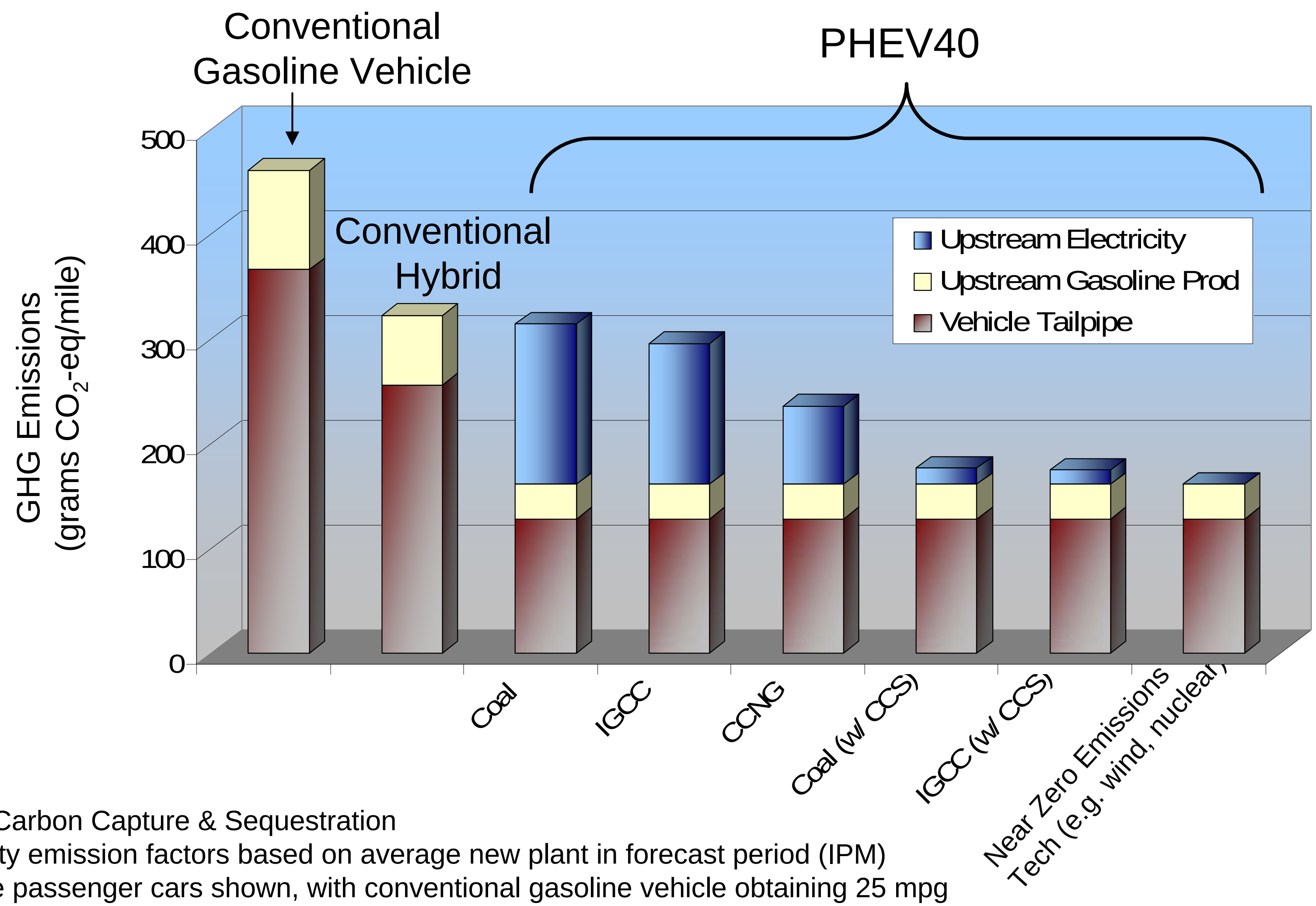
PHEV Electricity Demand Likely in Off-Peak



Model: IPM

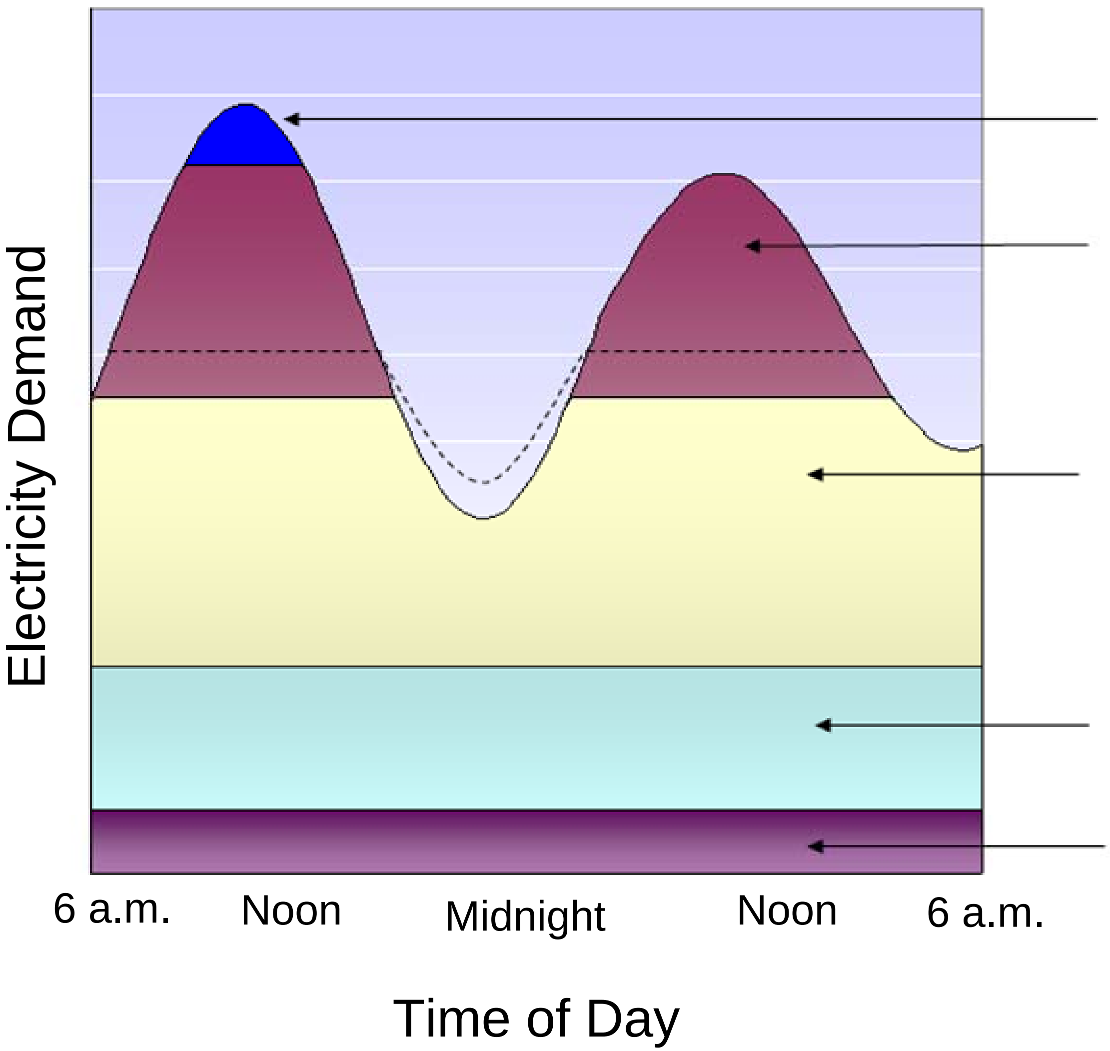
- Additional load from PHEVs is small
- PHEVs could be charged mostly via base-load filling during evenings and nights, when electricity costs are low

Choice of Electricity Generation Influences PHEV GHG Emissions



CCS = Carbon Capture & Sequestration
Electricity emission factors based on average new plant in forecast period (IPM)
Mid-size passenger cars shown, with conventional gasoline vehicle obtaining 25 mpg

Typical Dispatch Schematic



Peaking Generation, typically simple cycle oil and gas fired turbines. Capacity factors for peaking generation are less than 3 - 5%.

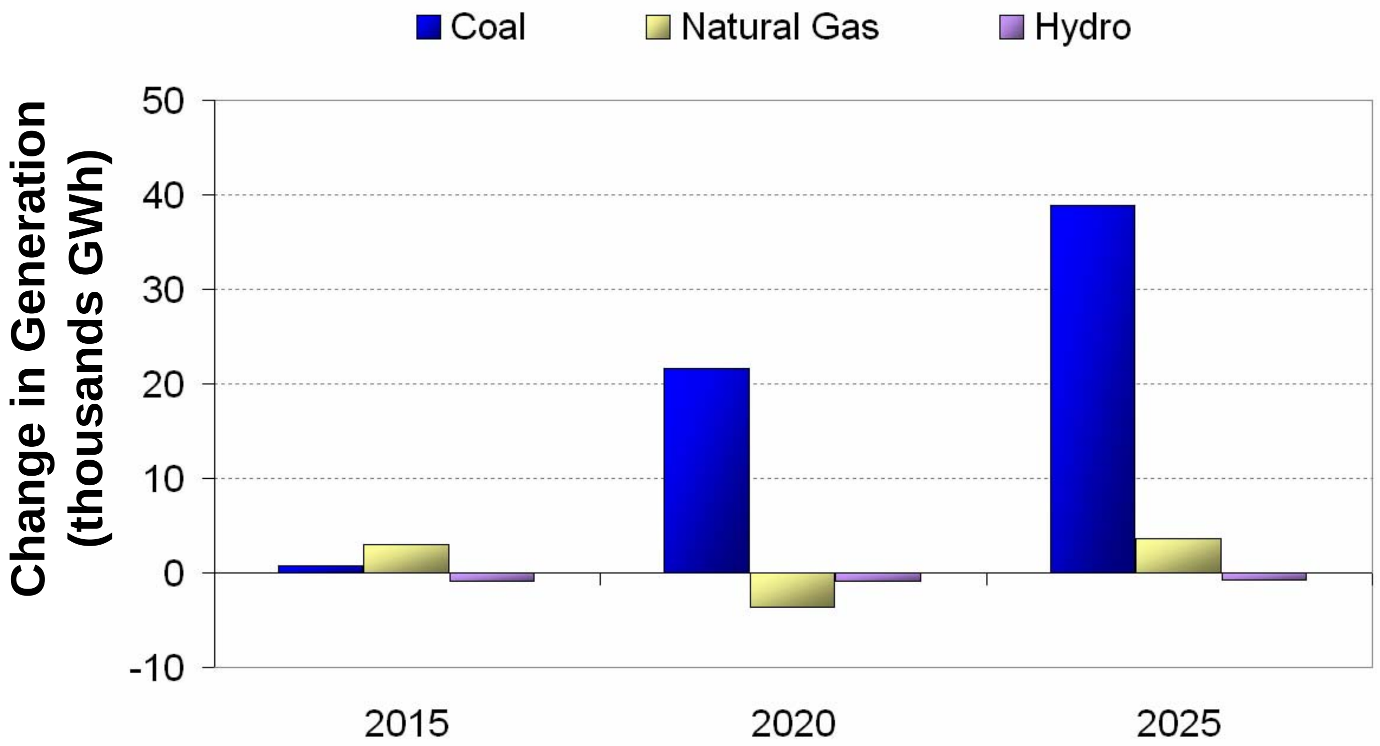
Intermediate Load Generation, typically gas-fired combined cycle systems. Units in this range offer fast ramp rates and short start-up times.

Base Load Generation, typically coal fired. Base load generation has some ability to follow loads, though ramp rate and minimum nighttime load constraints exist.

Nuclear

Hydro

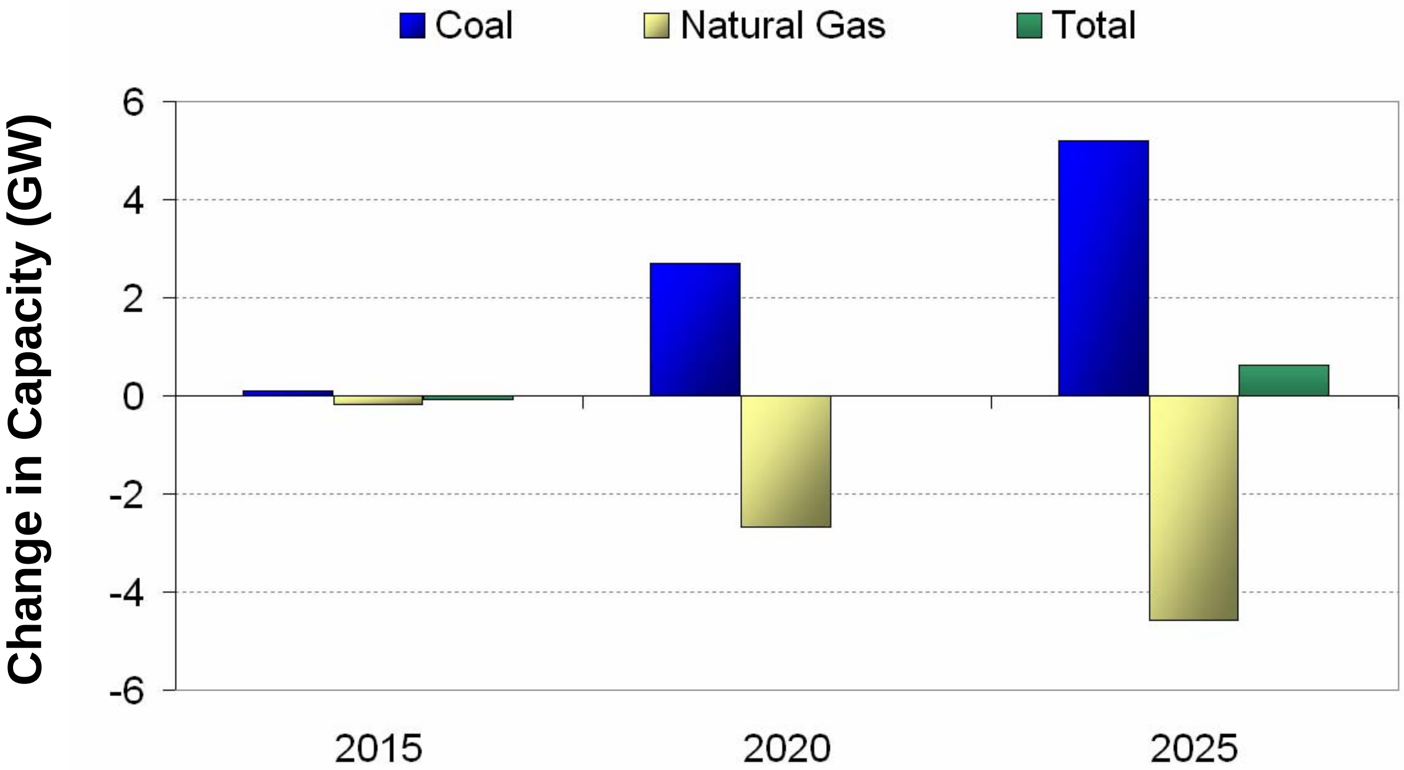
Additional Electricity Generation for PHEVs (Night-Time Case)



- Additional generation is initially natural gas fired plants
- After 2020, increased generation is almost all from coal

Model: IPM

Capacity Changes for PHEVs (Night-time Case)

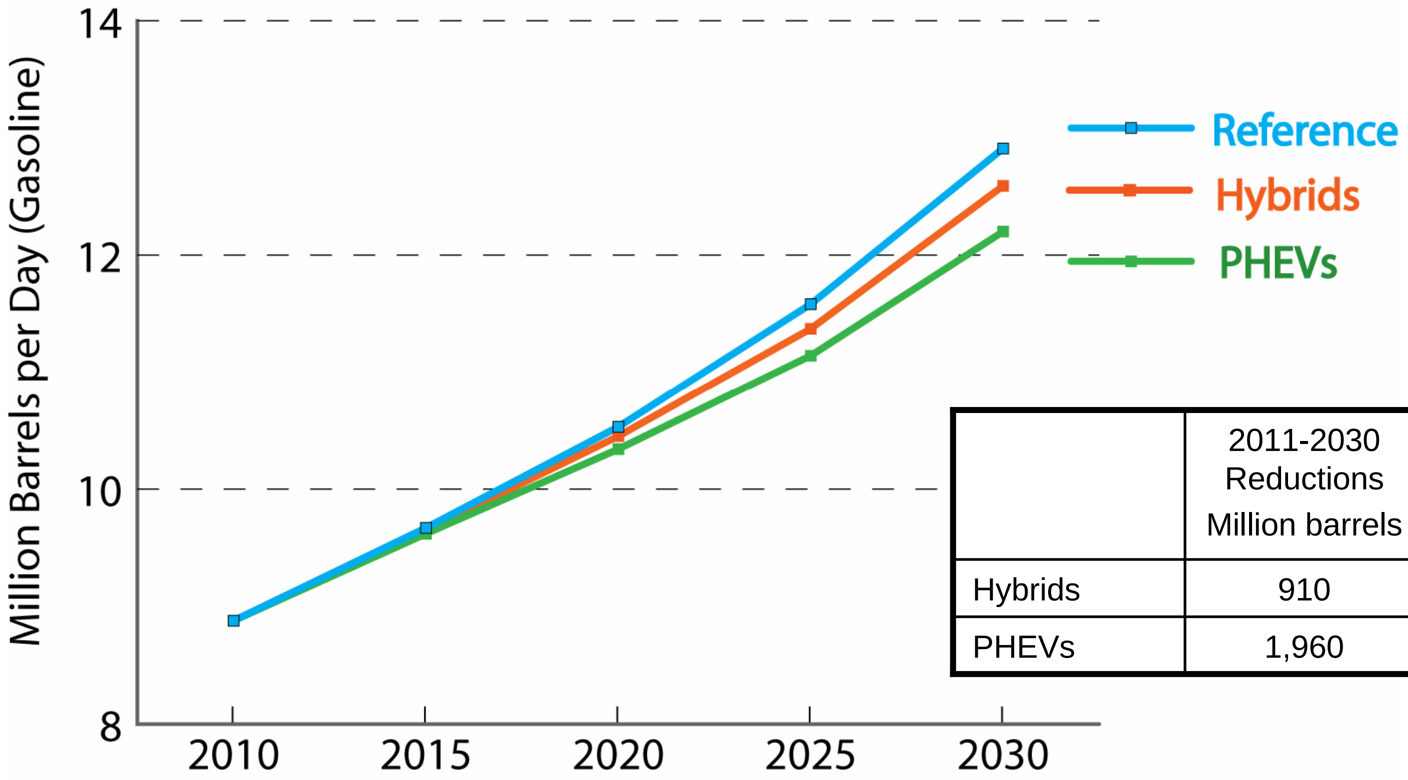


Model: IPM

- Electric utilities build more coal, less natural gas
- Net increase in capacity is only 620 MWs by 2025

* 2025 change in coal capacity includes a 0.1 GW decrease in expected retirements;
2025 change in natural gas capacity includes a 0.64 increase in expected retirements

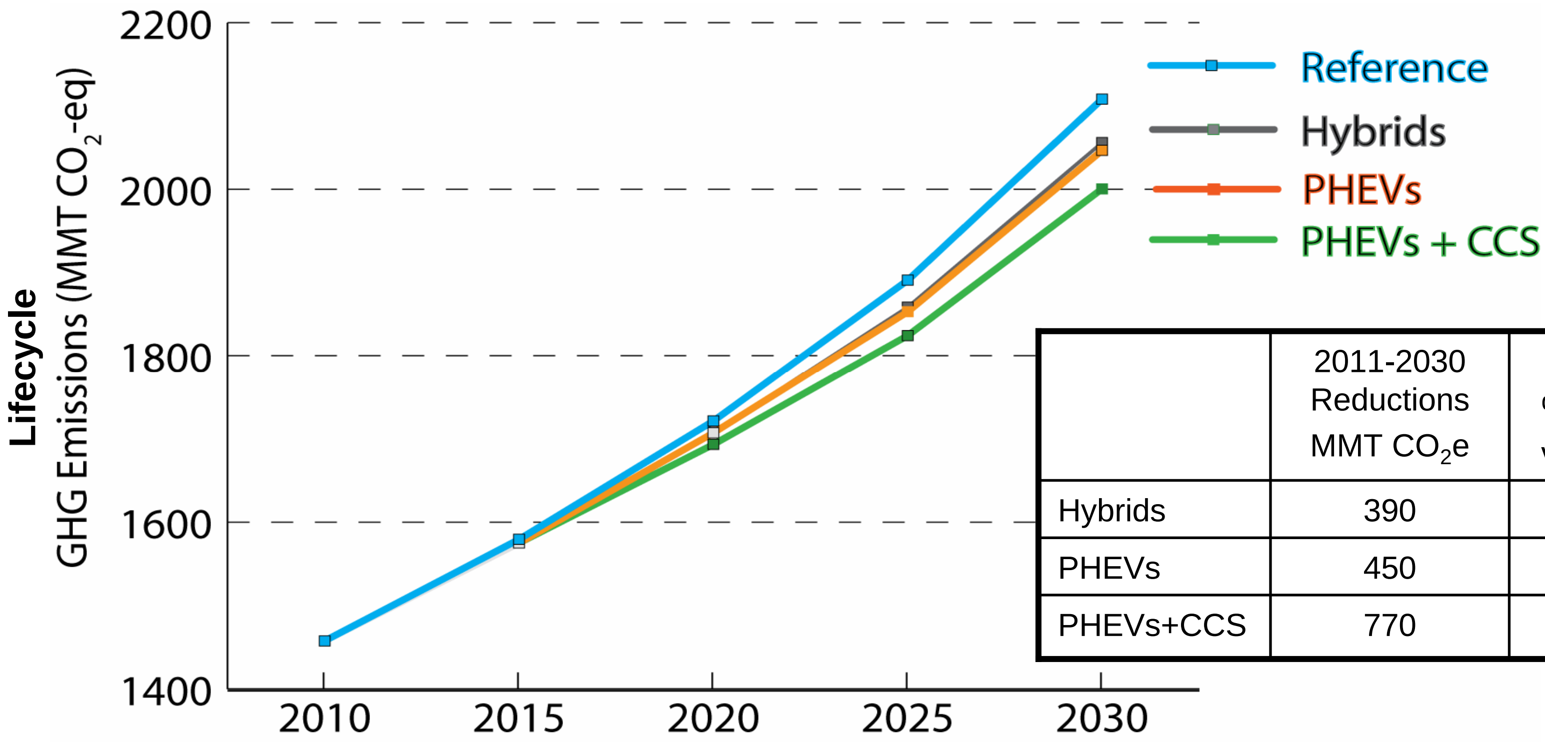
Impact on Passenger Vehicle Gasoline Consumption



	2011-2030 Reductions Million barrels	In 2030: % Reductions vs. Reference
Hybrids	910	2.6%
PHEVs	1,960	5.5%

- In 2030, annual gasoline savings of 710,000 barrels per day (versus 330,000 barrels per day for the “Hybrids” Scenario)
- Purchasers of PHEV40s reduce gasoline fuel purchases by 65%

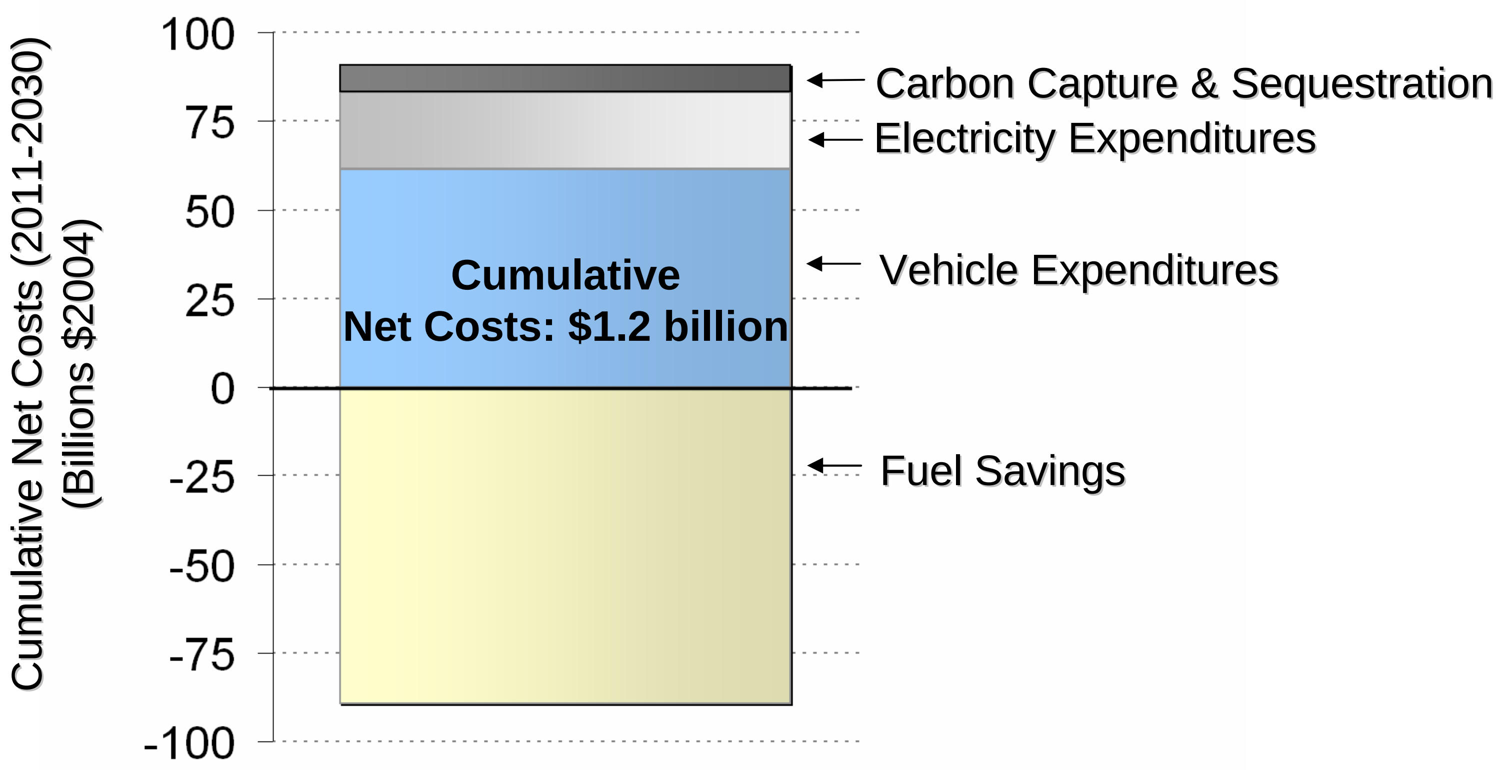
Impact on Passenger Vehicle GHG Emissions



	2011-2030 Reductions MMT CO_2e	In 2030: % Reductions vs. Reference
Hybrids	390	2.5%
PHEVs	450	2.9%
PHEVs+CCS	770	5.1%

- PHEVs lower GHGs compared to conventional gasoline-powered vehicles
- Marginal GHG benefits for PHEVs compared to “Hybrids” Scenario
- GHG emission savings nearly double with low emitting electricity source (e.g., coal with Carbon Capture and Storage (CCS))

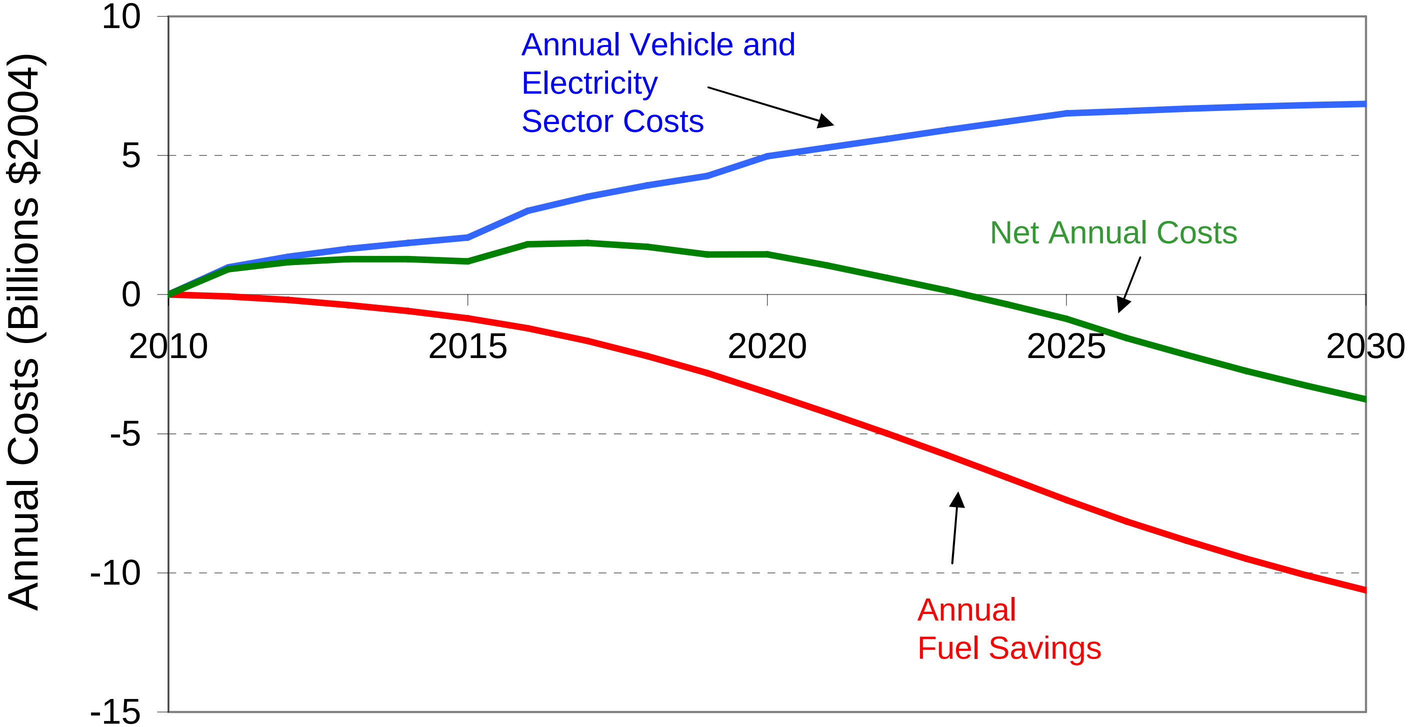
Costs of PHEV Scenario



- Using a 3% discount rate, AEO reference world crude oil price forecast ($50/barrel in 2030), and 6¢/kWh electricity, CCS cost: $35/ton of CO_2 reduced*

*IPCC Special Report on Carbon Dioxide Capture and Storage (2005)

Annual Costs of PHEV Scenario



- In near-term, vehicle costs exceed fuel savings
- PHEVs begin to payback in 2024 (annual fuel savings exceed other annual costs)
- In 2024, incremental vehicle costs are $1500 for PHEV automobiles and $3100 for PHEV trucks

Conclusions

- As part of a suite of vehicle technological possibilities, PHEVs have considerable potential
- PHEVs are a promising option for reducing U.S. petroleum consumption/oil imports
- GHG impacts depend on amount of electric operation/grid fuel source
  - If coal is primary fuel source for electricity, GHG emissions benefits from PHEVs are likely to be more modest than if no/low GHG electricity sources power the PHEVs (*compared to conventional hybrids)*
- No need for large new energy supply infrastructure investments
- Cost is the largest single barrier – high capital costs precede large fuel savings

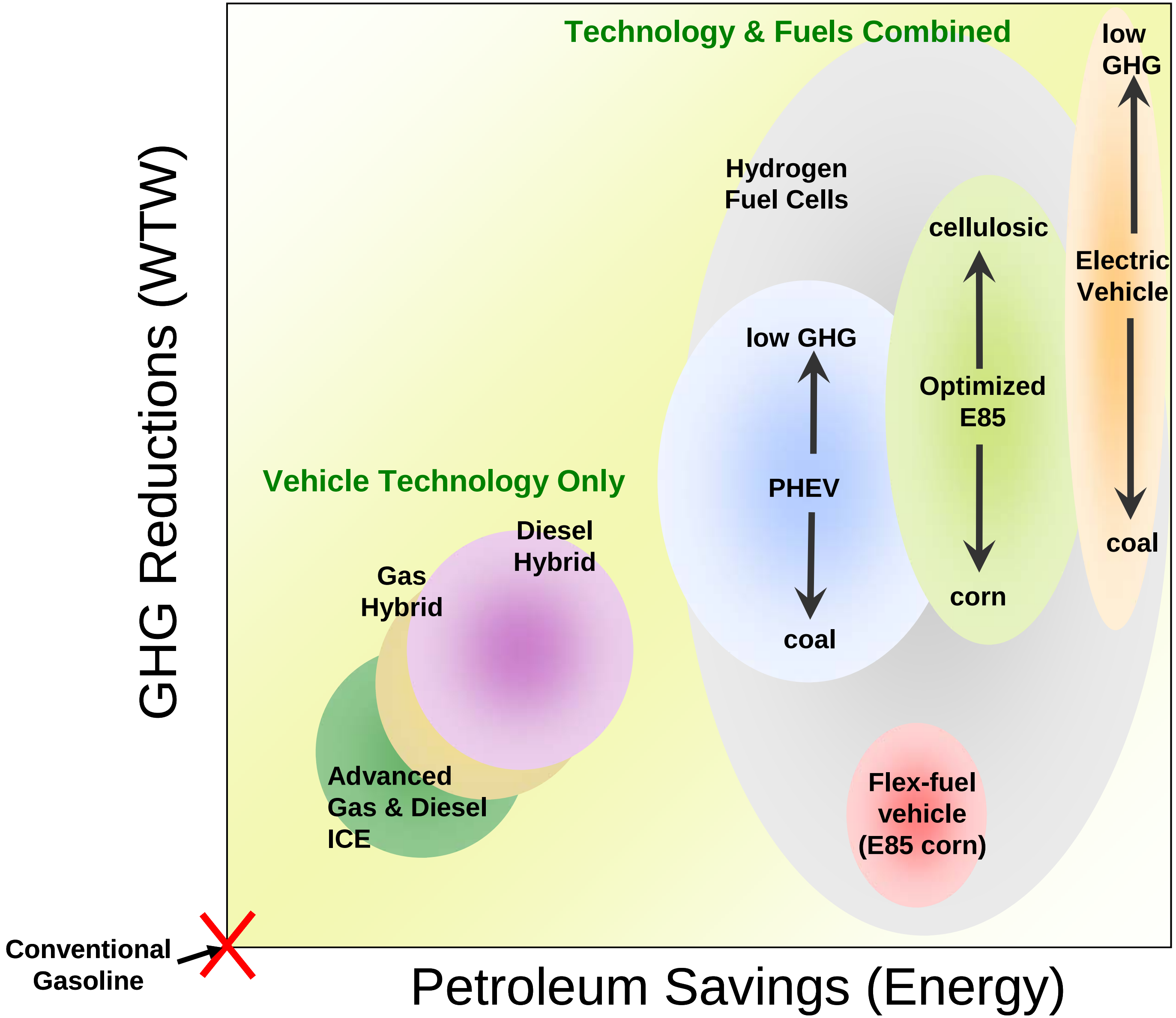
Appendix Slides

- PHEV Background History
- PHEV relative GHG and petroleum reductions
- Partial Day Time Charging Case Slides
- Vehicle Rollout Scenario
- Experience Curve Assumptions
- Sensitivity Analysis

PHEV Background History

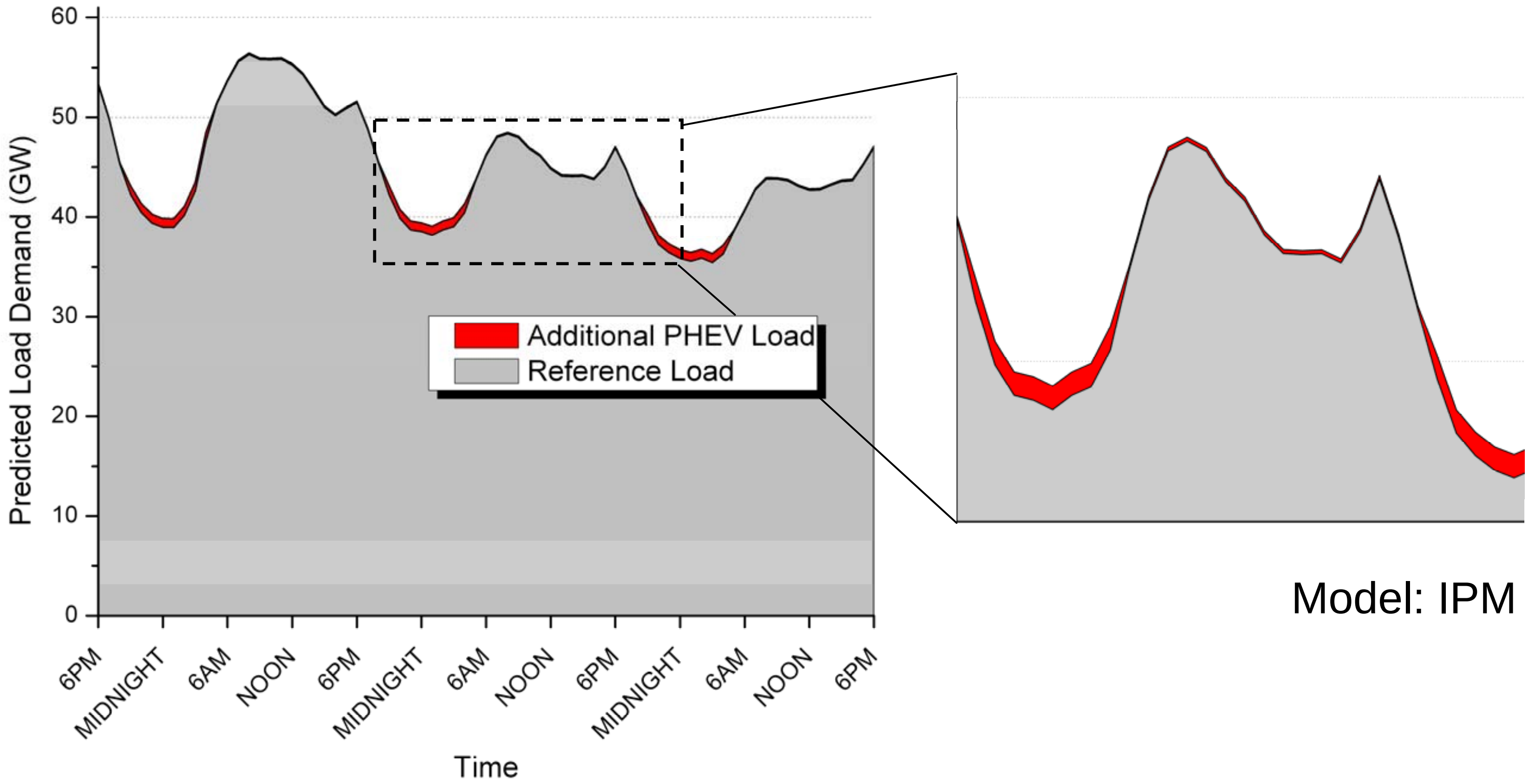
- Prof. Andy Frank of UC Davis began modern PHEV research in 1990
- The first major study of PHEVs was conducted by EPRI (Electric Power Research Institute) between 1999 and 2002
- CalCars began modifying the Toyota Prius in April, 2004
- Numerous individuals have “hot-rodded” their Prius HEVs in home garages
- At first, there was much criticism and resistance from Toyota and some media
  - Safety and Warranty issues (media, Toyota)
- GM announced in 2007 its plans to produce PHEVs (Saturn Vue and Chevy Volt). Toyota and Ford announced research efforts.
- Several companies are offering retail conversion kits for the Toyota Prius, Ford Escape
- DaimlerChrysler and EPRI are currently developing a demonstration PHEV delivery van (Sprinter).

PHEVs among a suite of approaches…



Caveat: The size of the bubbles and their positions are relative and assumptions driven

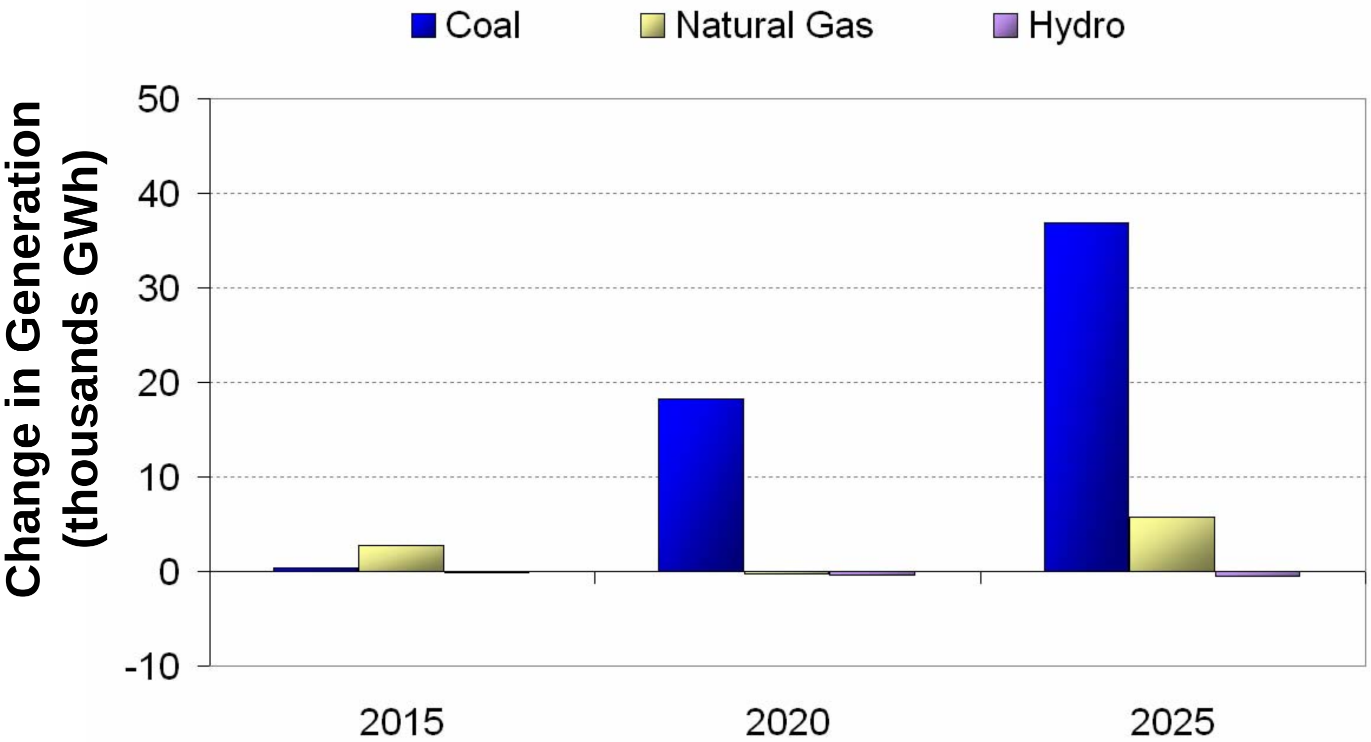
PHEV Electricity Demand with Partial Day-Time Charging



Model: IPM

- Also considered scenario where 25% of the charging occurs during the day time, and 75% during the evening and nights

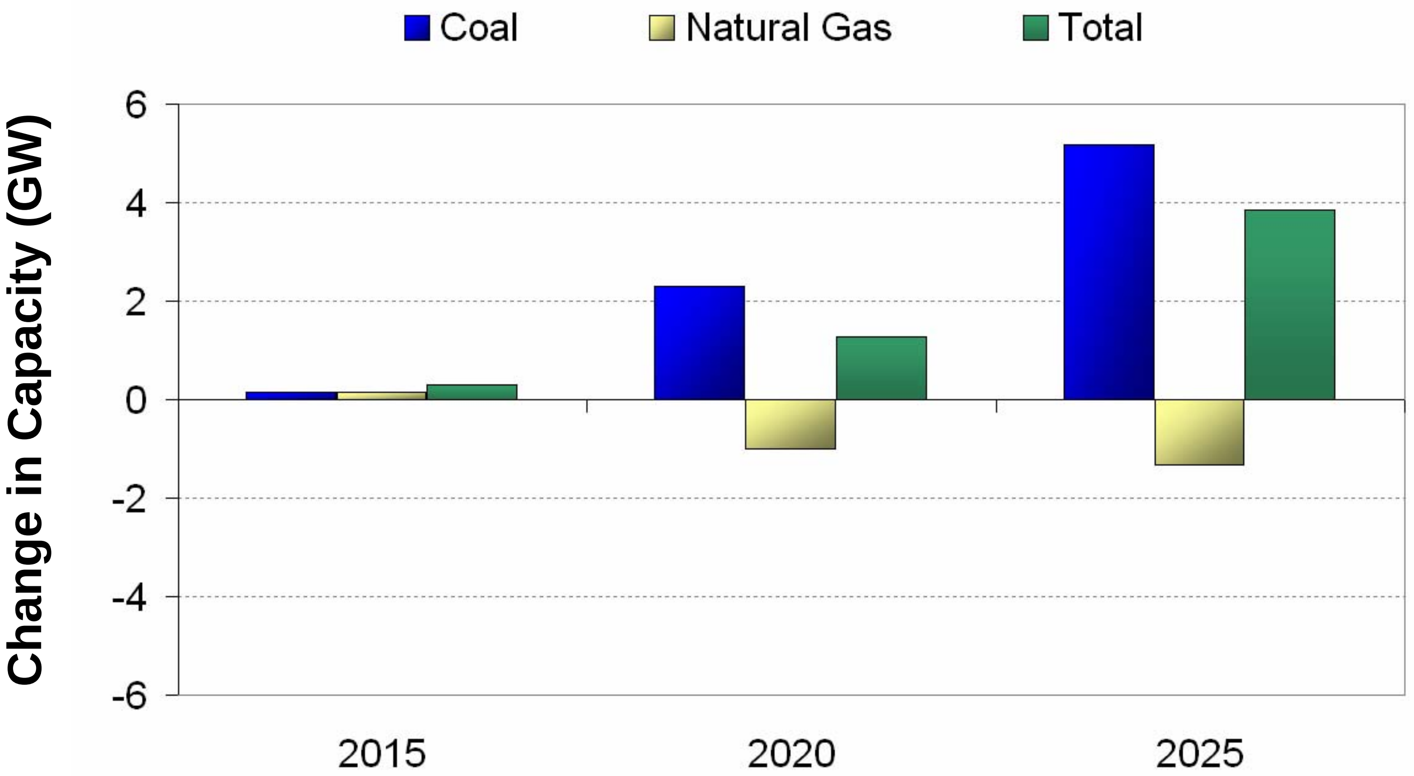
Additional Electricity Generation for PHEVs (25% Day-Time Case)



- Day-time case results in slightly more natural gas, but coal is still dominant

Model: IPM

Capacity Changes for PHEVs (25% Day-time Case)

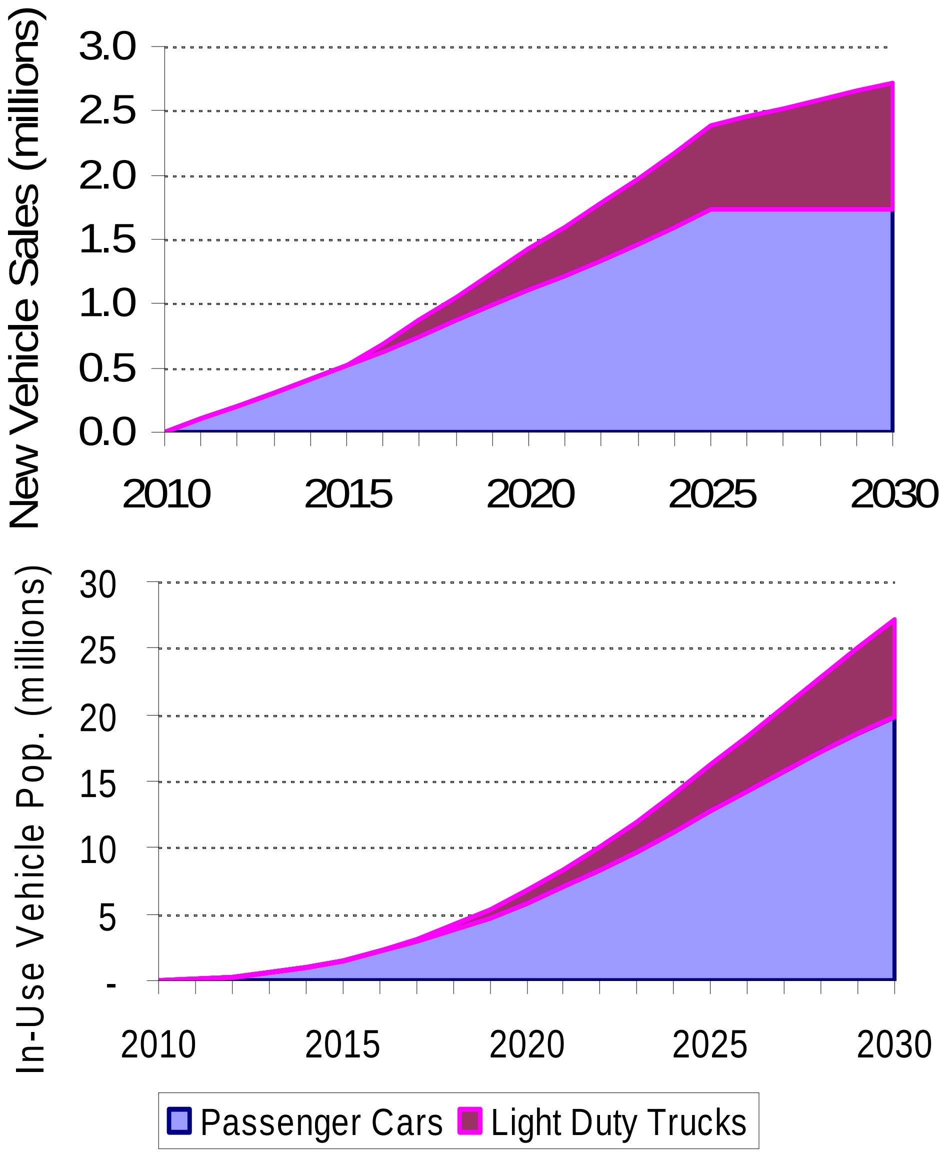


Model: IPM

- Electric utilities still build more coal, but less natural gas capacity is retired
- Net increase in capacity rises to 3840 MW by 2025

* 2025 change in coal capacity includes a 0.15 GW decrease in expected retirements;
2025 change in natural gas capacity includes a 0.19 GW increase in expected retirements

“What-If” PHEV Rollout Scenario



- Passenger vehicle fleet: PHEVs start penetrating in 2011 and grow to 15% of passenger vehicle sales by 2030

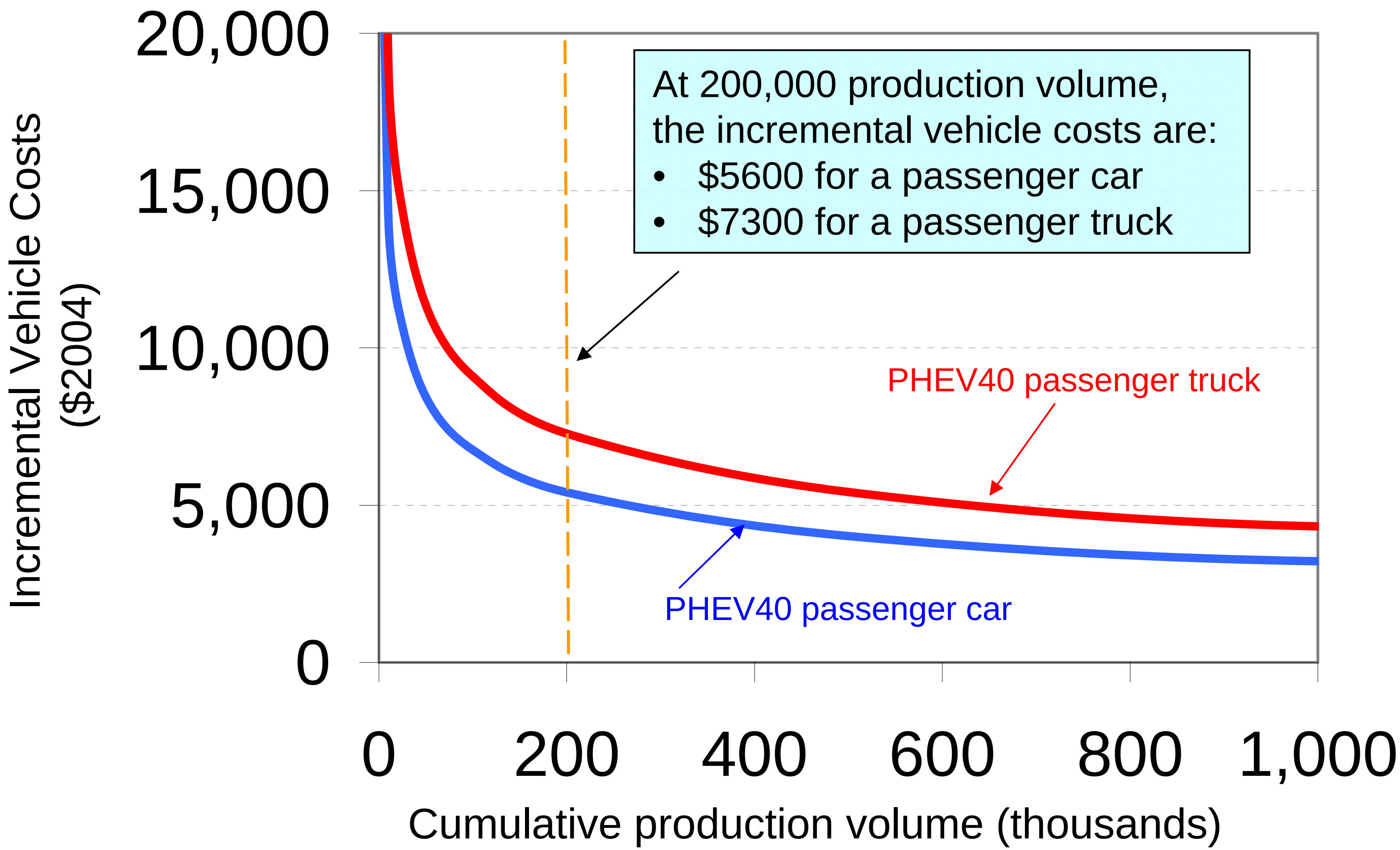
In 2030:

- Annual sales reach 2.7 million PHEVs
- 27 million PHEVs on the road (9% of the nearly 300 million vehicles)

By comparison:

- Conventional hybrids represented 1.5% of all U.S. sales in 2006 (3 - 5% by 2010?)

PHEV Experience Curves



- Key assumption: Each doubling in PHEV volume reduces costs by 20%

Cost Sensitivity Analysis