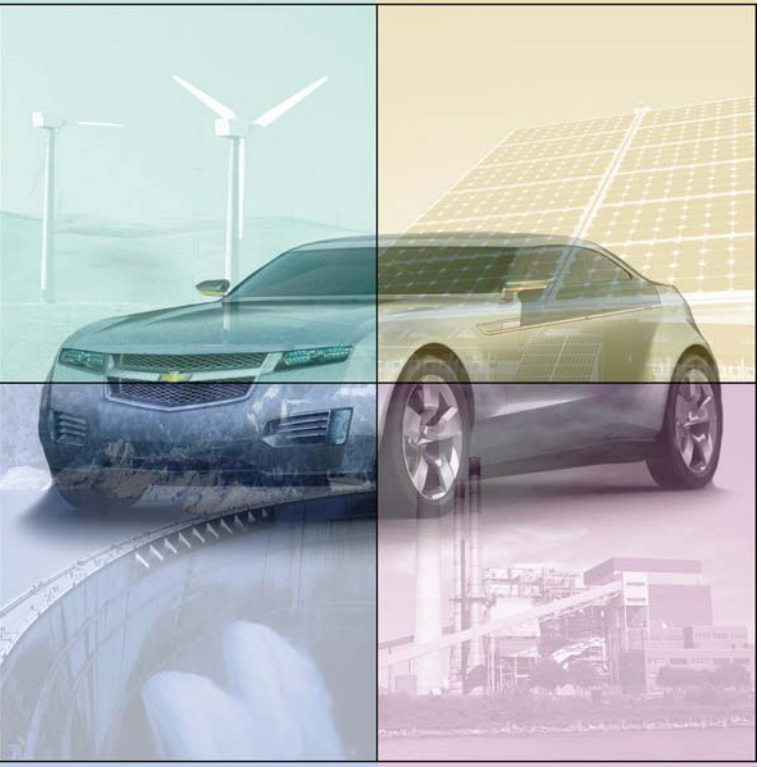

ELECTRIC POWER RESEARCH INSTITUTE

NRDC
THE EARTH'S BEST DEFENSE

Environmental Assessment of Plug-In Hybrid Electric Vehicles (PHEVs)

Greenhouse Gas Emissions and Air Quality Impacts of PHEVs

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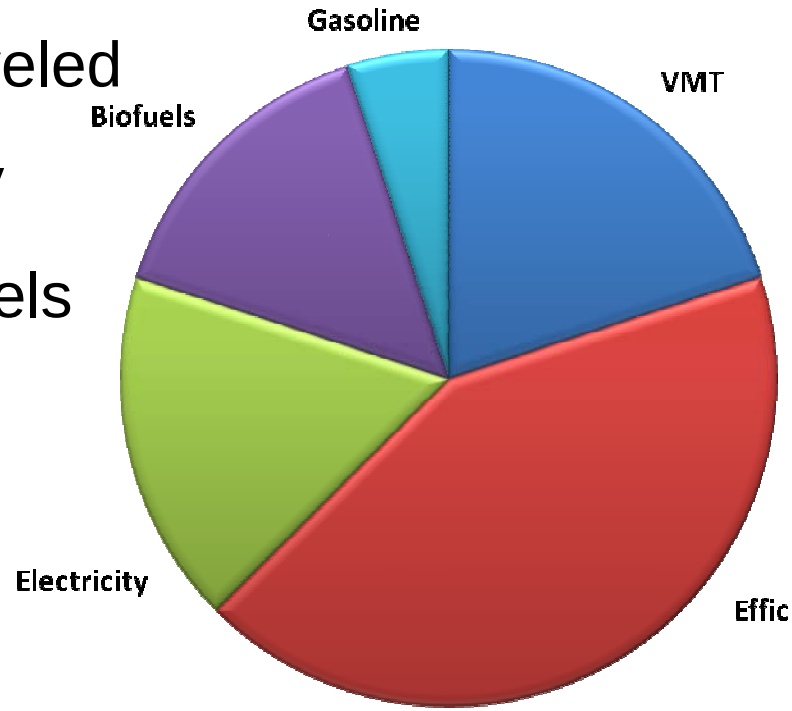
Eladio M. Knipping, Ph.D. *EPRI Environment*

Luke Tonachel, *National Resources Defense Council*

Reduce Gasoline Use and Greenhouse Gas Emissions

NRDC Scenario for Light Duty Vehicles in 2050

- **Reduce gasoline demand up to 90% in 2050**
- **Combination of approaches**
  - Reduce vehicle miles traveled
  - Improve vehicle efficiency
  - Sustainable alternative fuels
    - Electricity
    - Biofuels



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Collaborative Study

Environmental Assessment of Plug-in Hybrid Vehicles

Volume 1: Nationwide Greenhouse Gas Emissions

Volume 2: United States Air Quality Analysis Based on AEO-2006 Assumptions for 2030

Joint report available at: www.epri-reports.org

NRDC plug-in policy sheet: www.nrdc.org/energy/plugin.pdf

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Understanding Environmental Impacts of Plug-In Hybrid Electric Vehicles

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- Environmental impacts of shifting vehicle energy supply from petroleum to electricity not well understood
- Location and characteristics of vehicle and power plant emissions are different
  - Temporal and geographic locations
- Electricity supplied by diverse mix of fuels, plant technologies
- New technologies take time to penetrate nationwide vehicle fleet
- Generation capacity and economics evolve over time
  - Energy pathway analyses are insufficient to appropriately model these changes

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Analysis Methodology for Electricity Impacts

- Least-cost economics for power plant construction, operation, maintenance
- Plant capacity expansion/retirement model
- Adherence to national, regional, local constraints on capacity (regulatory)
- Monetization of the right to emit (criteria pollutants, GHGs)
- Electricity production simulation
  - Least-cost dispatch order
  - Availability model
- Electric sector evolution over time

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The Future of the Electric Sector
Three Possible Scenarios

Key Parameters

- Value of CO_2 emissions allowances
- Plant capacity retirement and expansion
- Technology availability, cost and performance
- Electricity demand
- PHEV bounding scenarios of 20%, 62%, and 80% new vehicle market share by 2050

Scenario Definition	High CO_2	Medium CO_2	Low CO_2
Cost of CO_2 Emissions Allowances	Low	Moderate	High
Power Plant Retirements	Slower	Normal	Faster
New Generation Technologies	Unavailable: Coal with CCS New Nuclear New Biomass	Normal Technology Availability and Performance	Available: Retrofit of CCS to existing IGCC and PC plants
	Lower Performance: SCPC, CCNG, GT, Wind, and Solar		Higher Performance: Solar
Annual Electricity Demand Growth	1.56% per year on average	1.56% per year on average	2010 - 2025: 0.45% 2025 - 2050: None

SCPC – Supercritical Pulverized Coal CCNG – Combined Cycle Natural Gas

GT – Gas Turbine (natural gas) CCS – Carbon Capture and Storage

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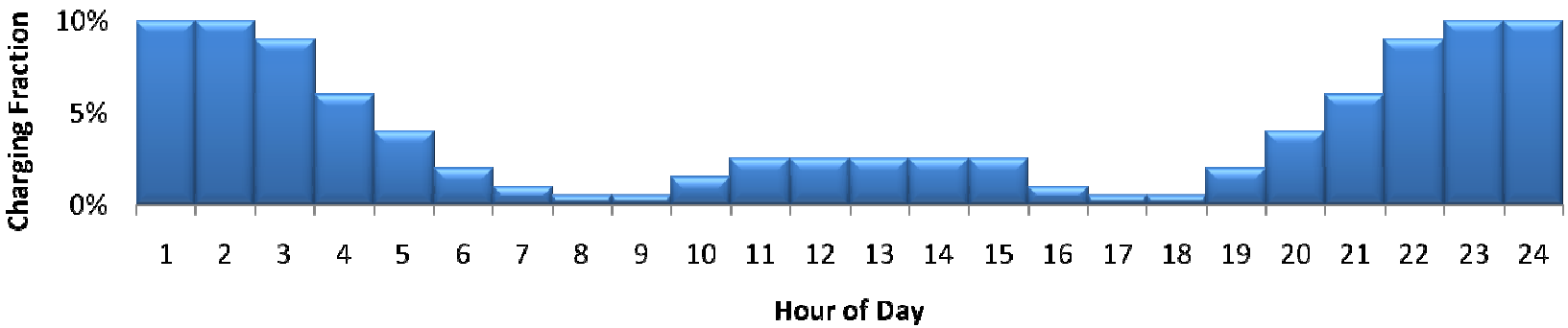
PHEV Charging Profile Assumptions

- Base Case represents 74% of energy delivered from 10:00 pm to 6:00 am, 26% between 6:00am and 10:00 pm
- Vehicle charged primarily, but not exclusively, at each vehicle's "home base"
- Owners incentivized or otherwise encouraged to use less expensive off-peak electricity
- Charge onset delays built into near-term vehicles—allow battery system rest and cooling before recharge
- Long-term with large PHEV fleets, utilities will likely use demand response or other programs to actively manage the charging load



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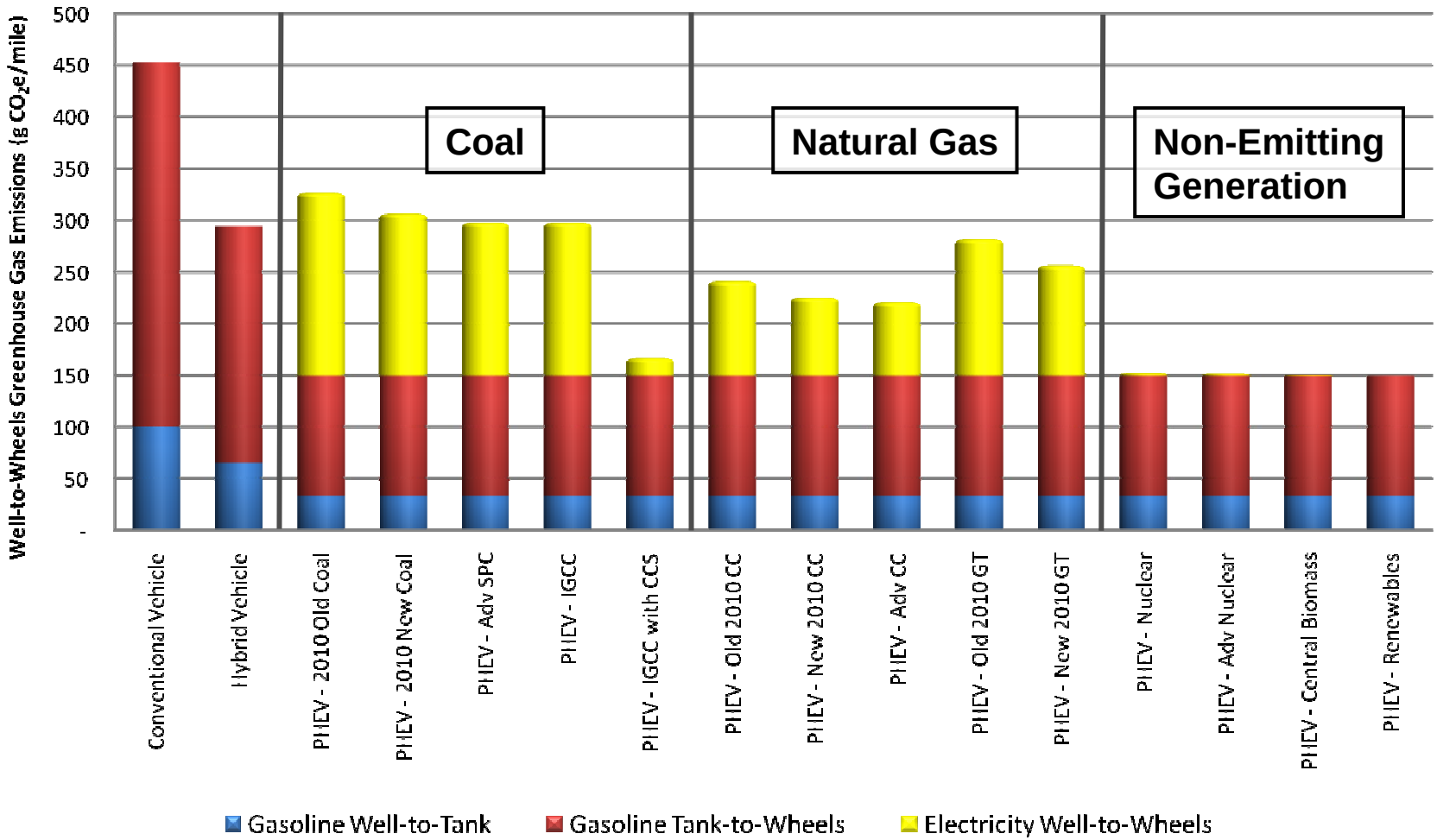
Power Plant-Specific PHEV Emissions in 2010
PHEV 20 – 12,000 Annual Miles



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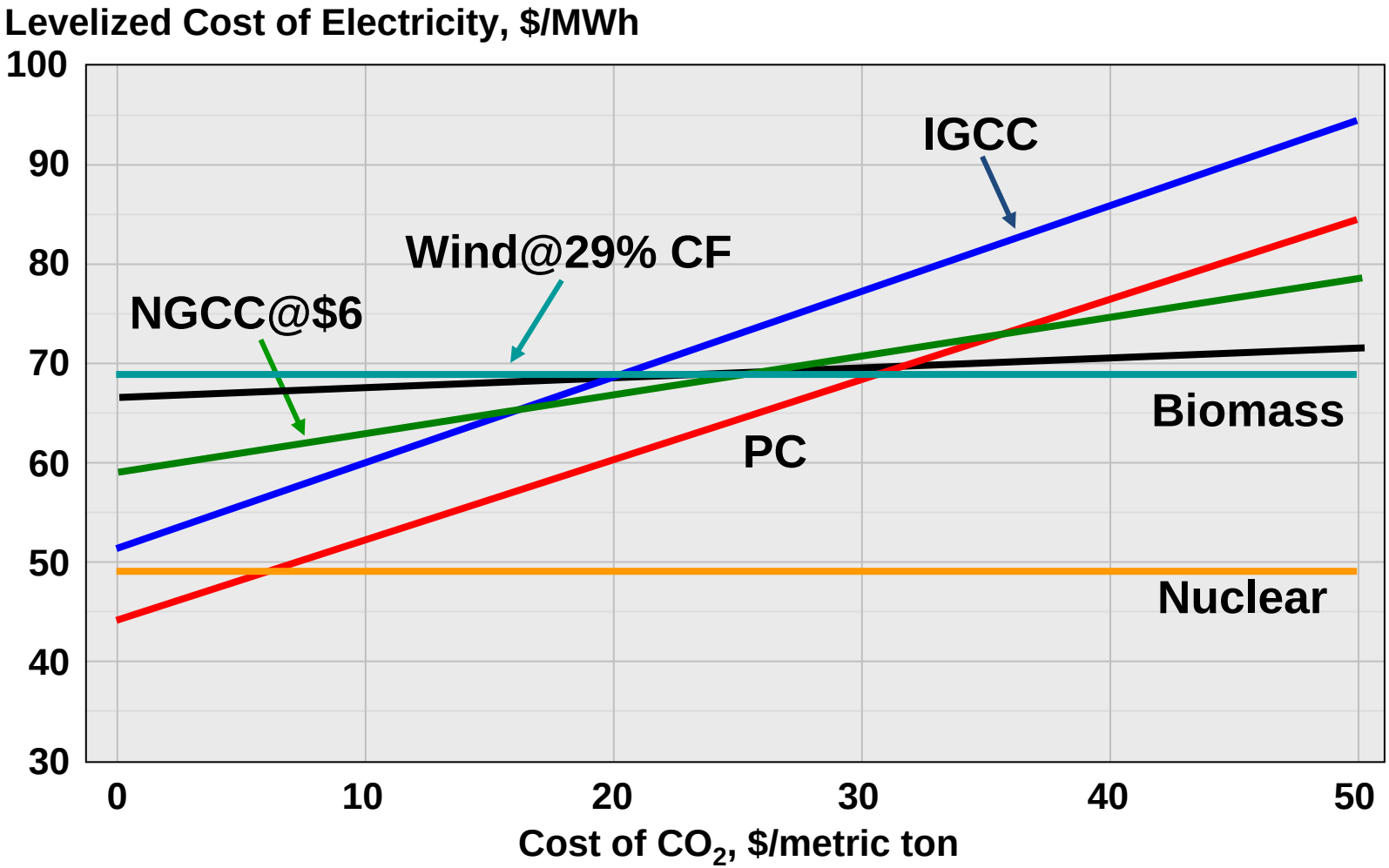
Technologies for New Generation in 2010-2015



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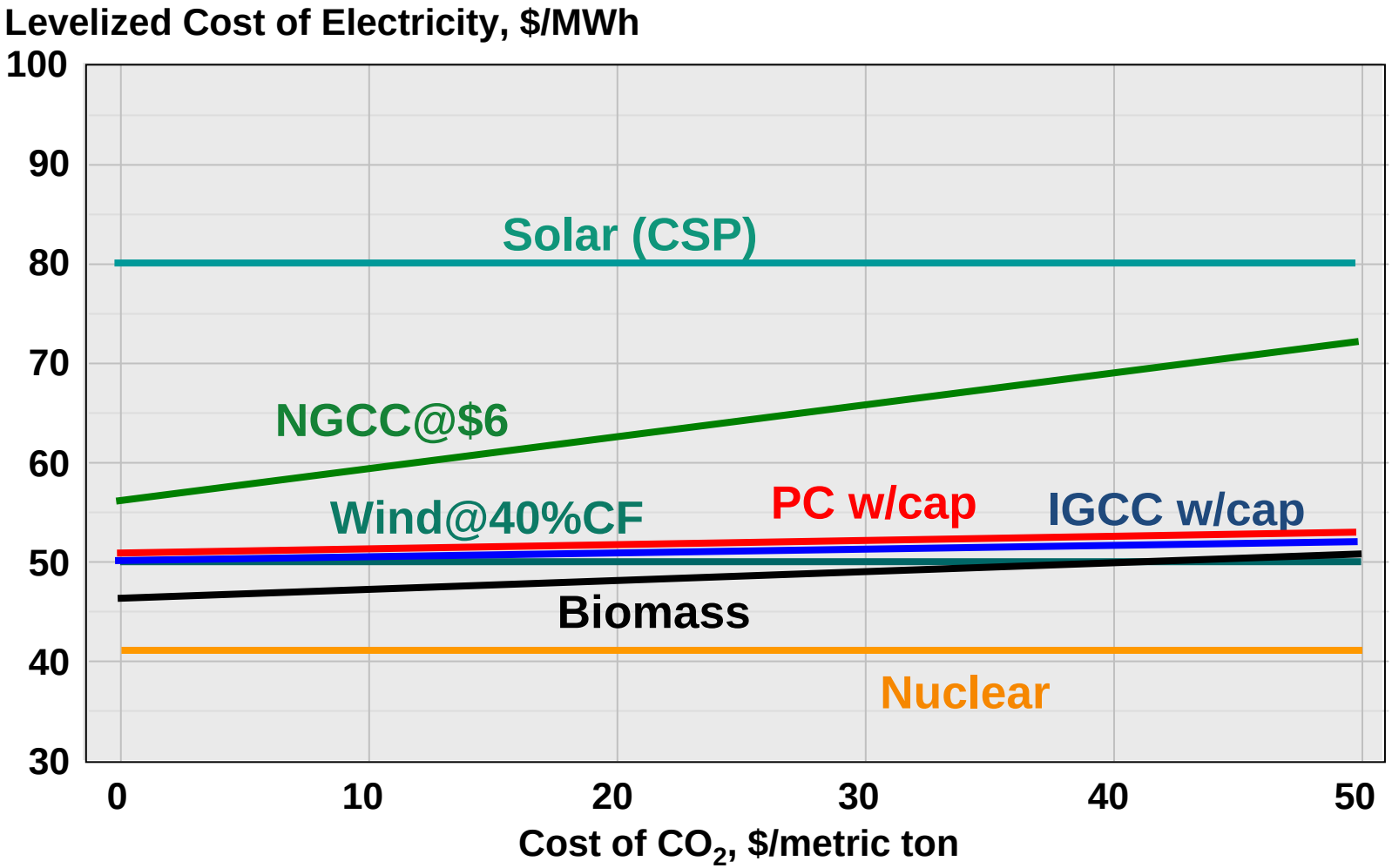
Technologies for New Generation in 2020-2025



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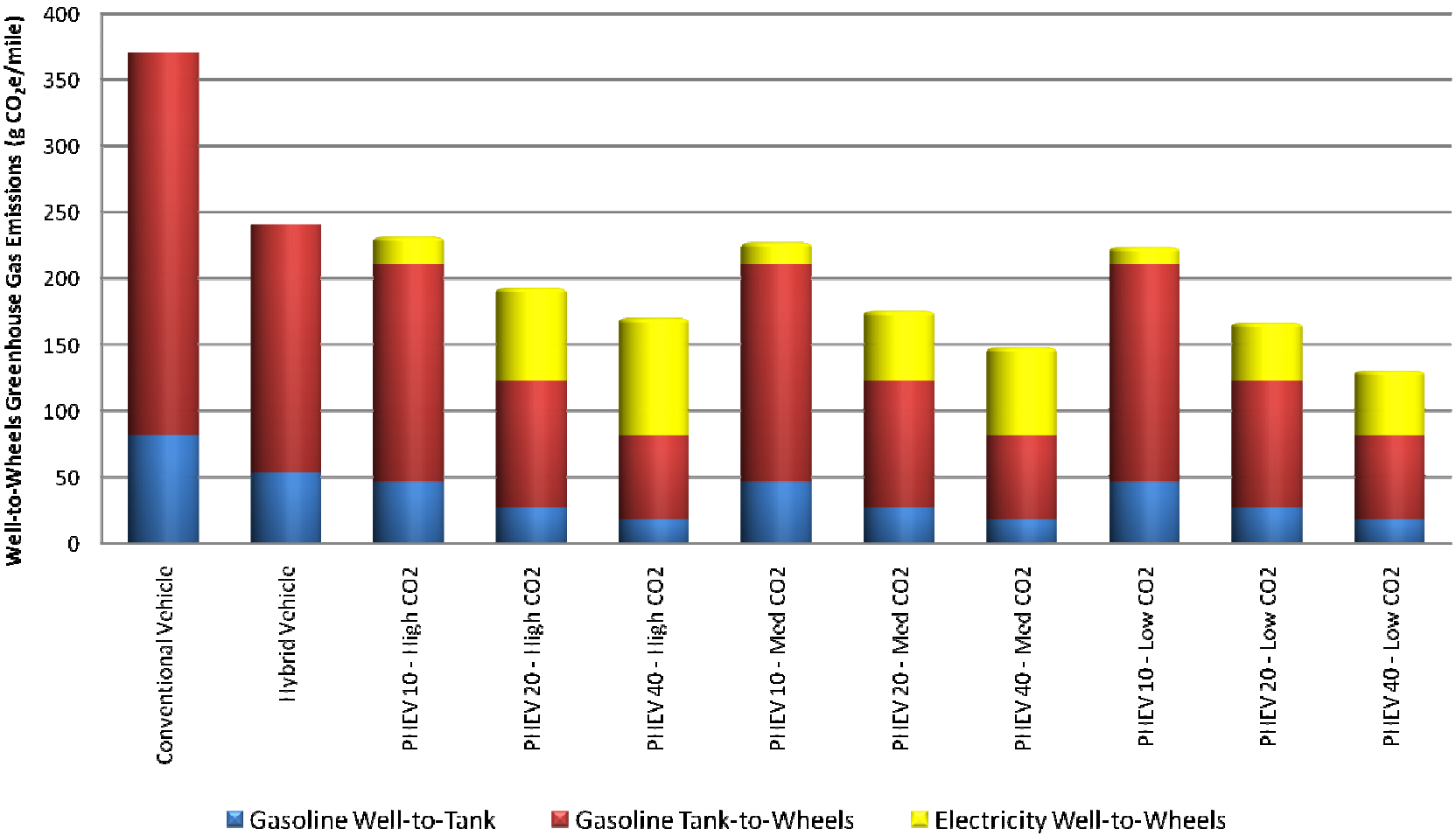
Electric Sector Simulation Results (2050)
PHEV 10, 20, & 40 – 12,000 Annual Miles



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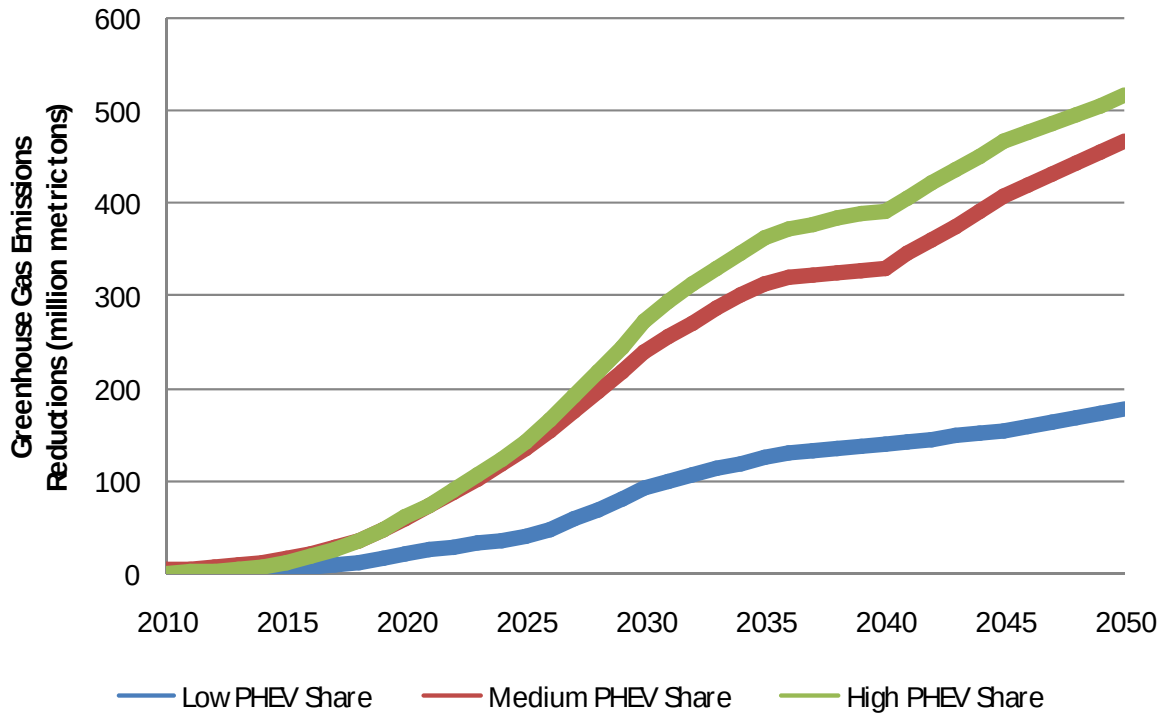
Greenhouse Gas Emissions

- Electricity grid evolves over time
- Nationwide fleet takes time to renew itself or “turn over”
- Impact would be low in early years, but could be very high in future
- A potential 400-500 million metric ton annual reduction in GHG emissions



Annual Reduction in Greenhouse Gas Emissions From PHEV Adoption

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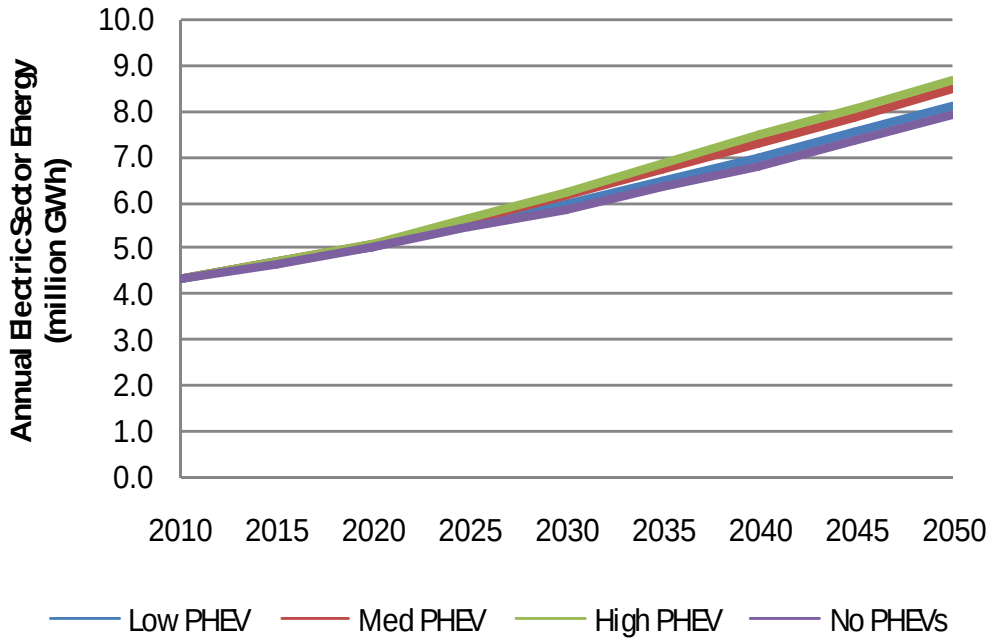
Impacts to Energy
Electricity and Petroleum

- Moderate electricity demand growth
- Capacity expansion 19 to 72 GW by 2050 nationwide (1.2 – 4.6%)
- 3-4 million barrels per day in oil savings (Medium PHEV Case, 2050)



Electricity Demand: Medium CO_2 Case

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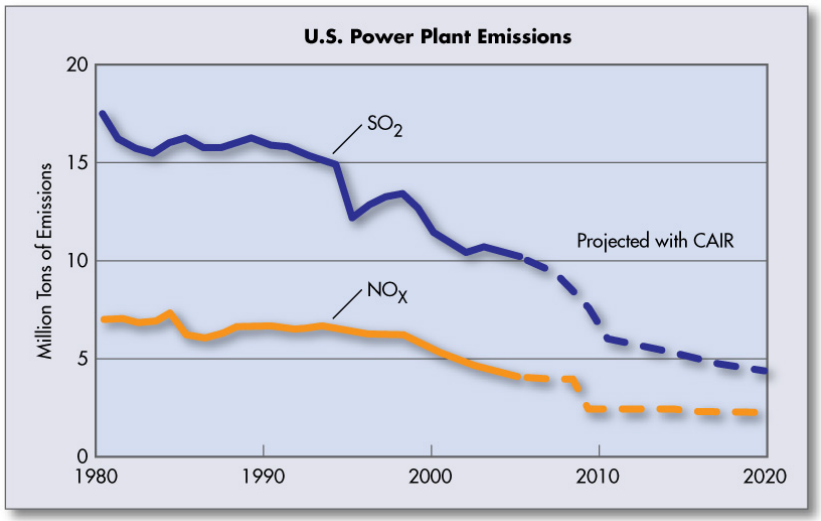
U.S. Power Plant Emissions Trends



Source: U.S. Environmental Protection Agency

- Power plant emissions of SO_2 and NOx will continue to decrease due to tighter federal regulatory limits (caps) on emissions
- Other local and national regulations further constrain power plant emissions
- Air quality is determined by emissions from all sources undergoing chemical reactions within the atmosphere

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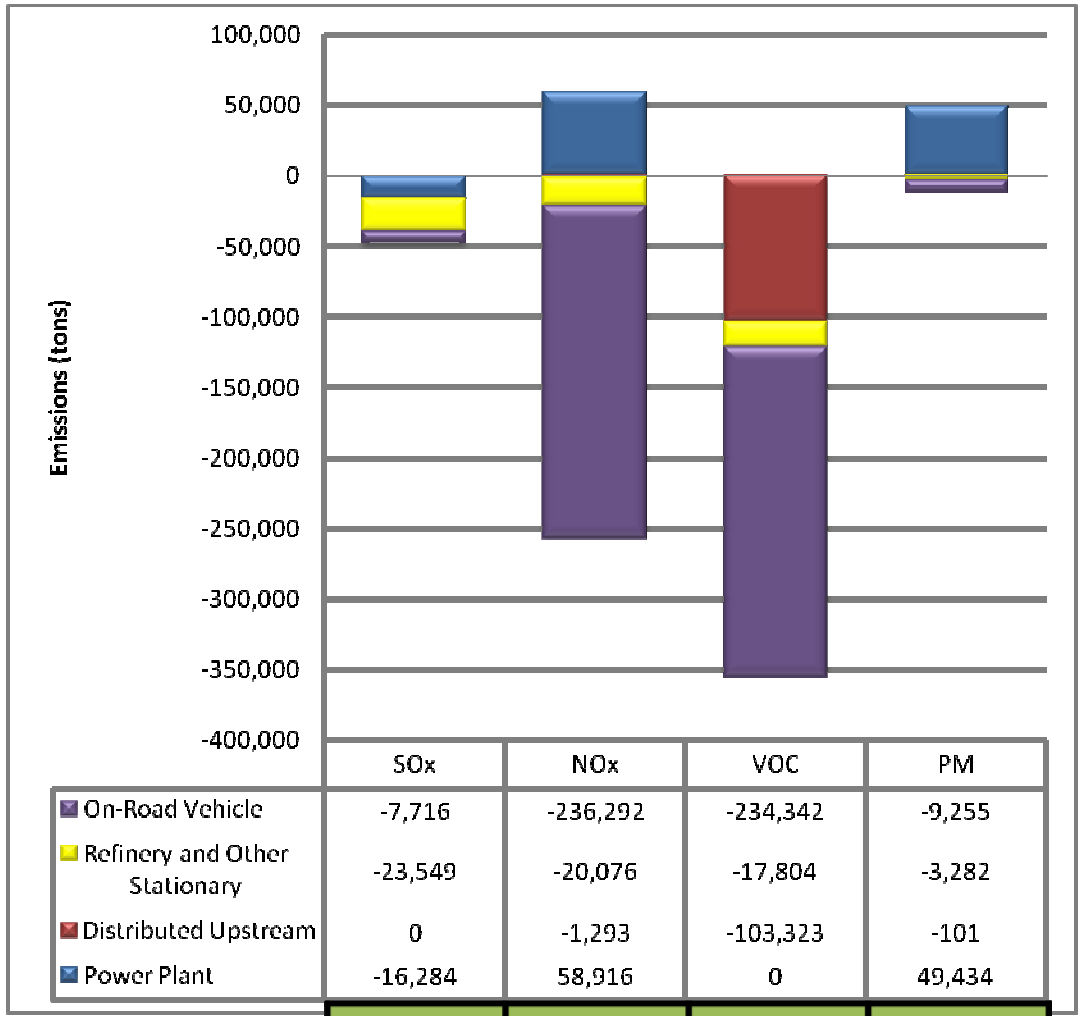
Net Changes in Criteria Emissions Due to PHEVs

Power Plant Emissions

- Emissions capped under law (SO_2, NOx, Hg) are essentially unchanged
- Primary PM emissions increase (defined by a performance standard)

Vehicle Emissions

- NOx, VOC, SO_2, PM all decrease
- Significant NOx, VOC reductions at vehicle tailpipe
- Reduction in refinery and related emissions



	SOx	NOx	VOC	PM
On-Road Vehicle	-7,716	-236,292	-234,342	-9,255
Refinery and Other Stationary	-23,549	-20,076	-17,804	-3,282
Distributed Upstream	0	-1,293	-103,323	-101
Power Plant	-16,284	58,916	0	49,434
	-47,549	-198,745	-355,469	36,796

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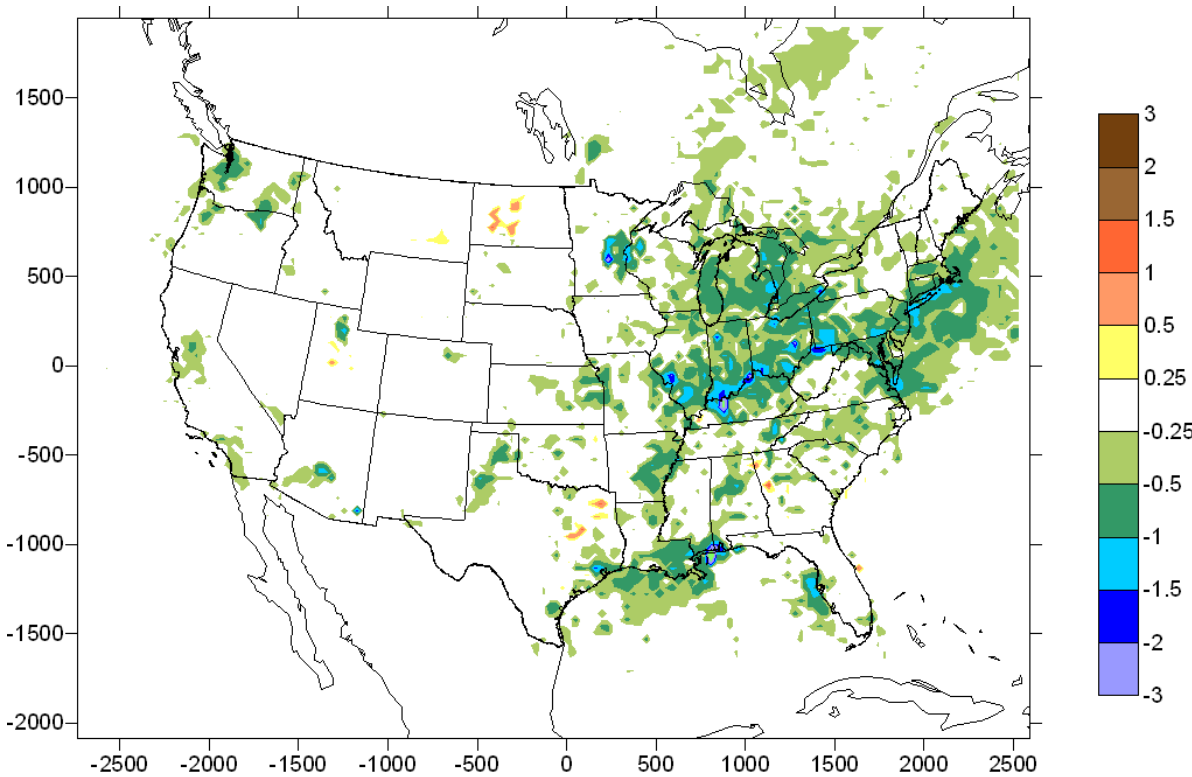
PHEVs Improve Overall Air Quality
Reduced Formation of Ozone

- Air quality model simulates atmospheric chemistry and transport
- Lower NOx and VOC emissions results in less ozone formation particularly in urban areas



Change in 8-Hour Ozone Design Value (ppb)
PHEV Case – Base Case

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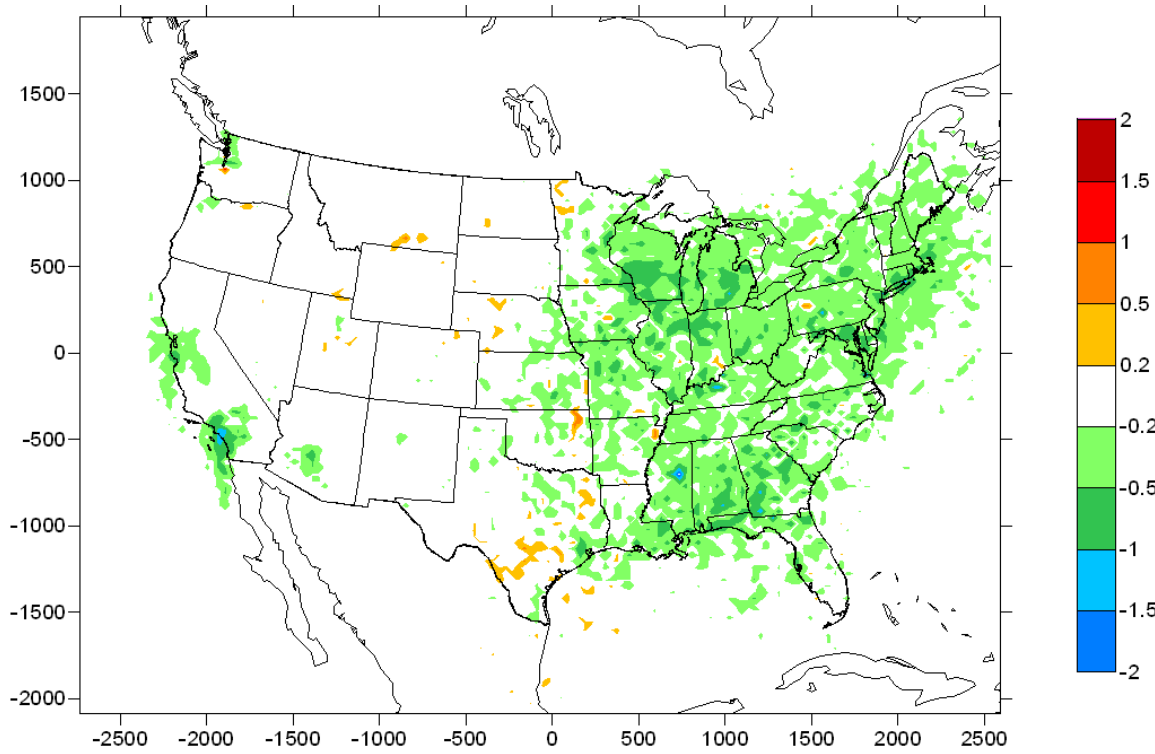
PHEVs Improve Overall Air Quality
Reduced Formation of Secondary $PM_{2.5}$

- $PM_{2.5}$ includes both direct emissions and secondary PM formed in the atmosphere
- PHEVs reduce motor vehicle emissions of VOC and NOx.
- VOCs emissions from power plants are not significant
- Total annual SO_2 and NOx from power plants capped by federal law
- The net result of PHEVs is a notable decrease in the formation of secondary $PM_{2.5}$



Change in Daily $PM_{2.5}$ Design Value ($\mu g\ m^{-3}$)
PHEV Case – Base Case

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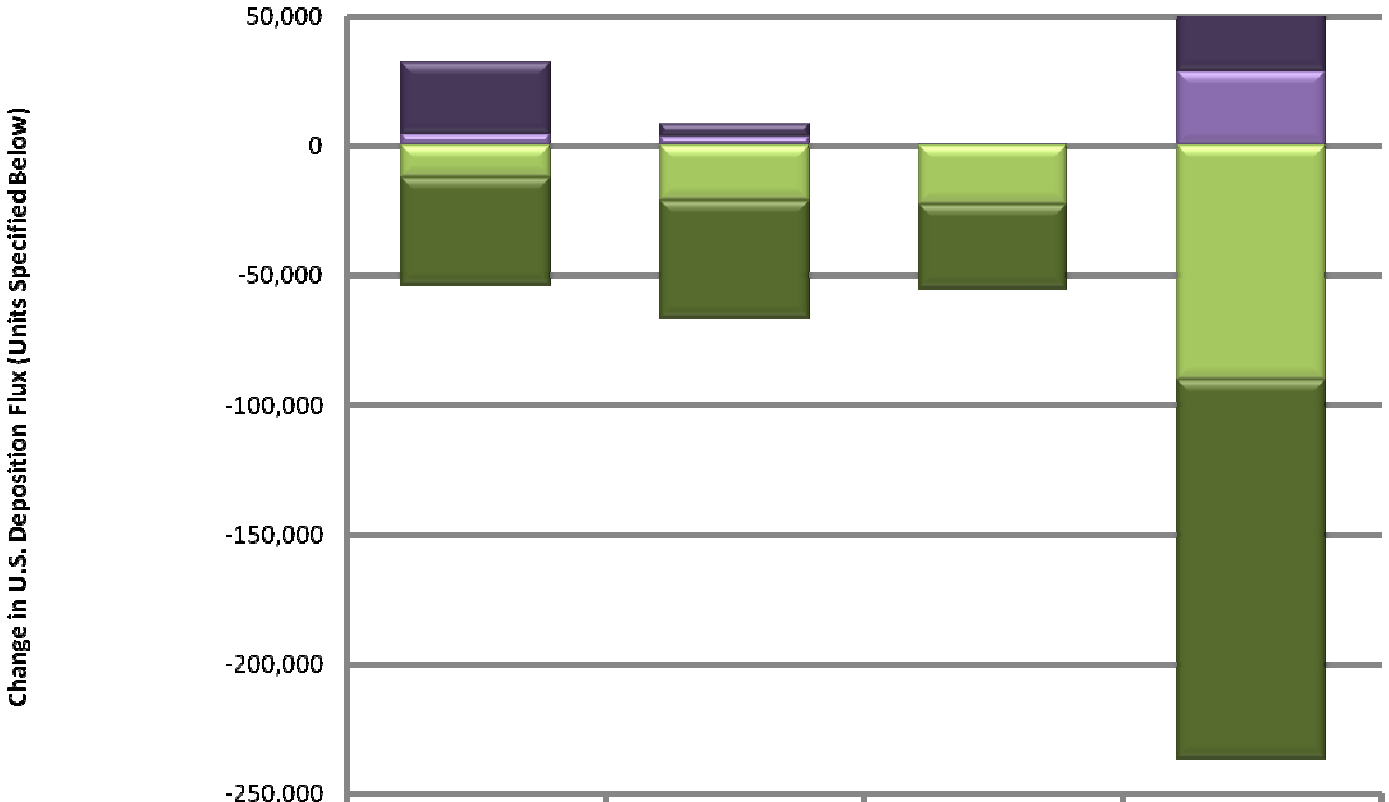
PHEVs Improve Overall Air Quality

Reduced Deposition of Sulfates, Nitrates, Nitrogen, Mercury



	Sulfate (ton)	Nitrate (ton)	Nitrogen (ton N)	Mercury (g)
Benefit above Threshold	-41,472	-45,490	-32,413	-146,370
Benefit below Threshold	-12,416	-20,995	-22,784	-90,202
Disbenefit above Threshold	27,769	4,973	233	48,377
Disbenefit below Threshold	4,562	3,396	233	28,693
	-26,114	-61,508	-54,963	-188,166

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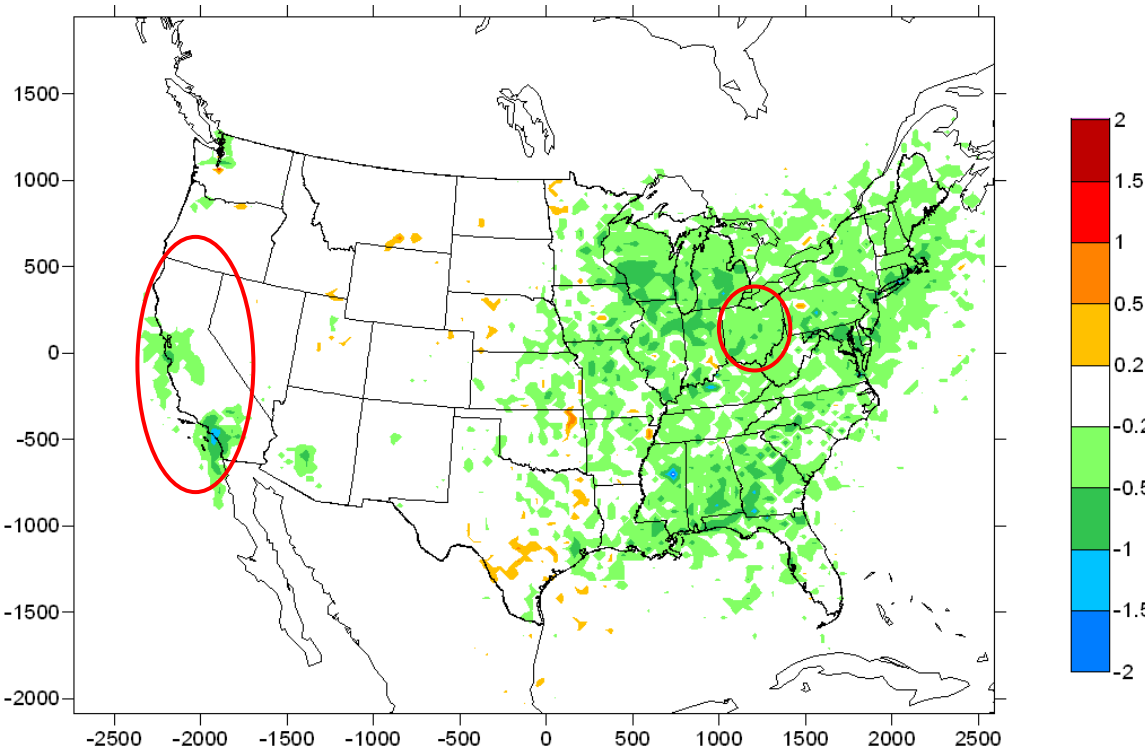
Summary – Next Steps

- State-specific results for CA, OH, due in Q1-08
- Expand air quality analysis to include carbon constraints
- Continue GHG analysis as industry economics and technology changes
- Adopt market penetration forecasts in place of bounding scenarios
- Modify vehicle assumptions as PHEV technology evolves
- Expand analysis to other regions of interest



Change in Daily $PM_{2.5}$ Design Value ($\mu g\ m^{-3}$)
PHEV Case – Base Case

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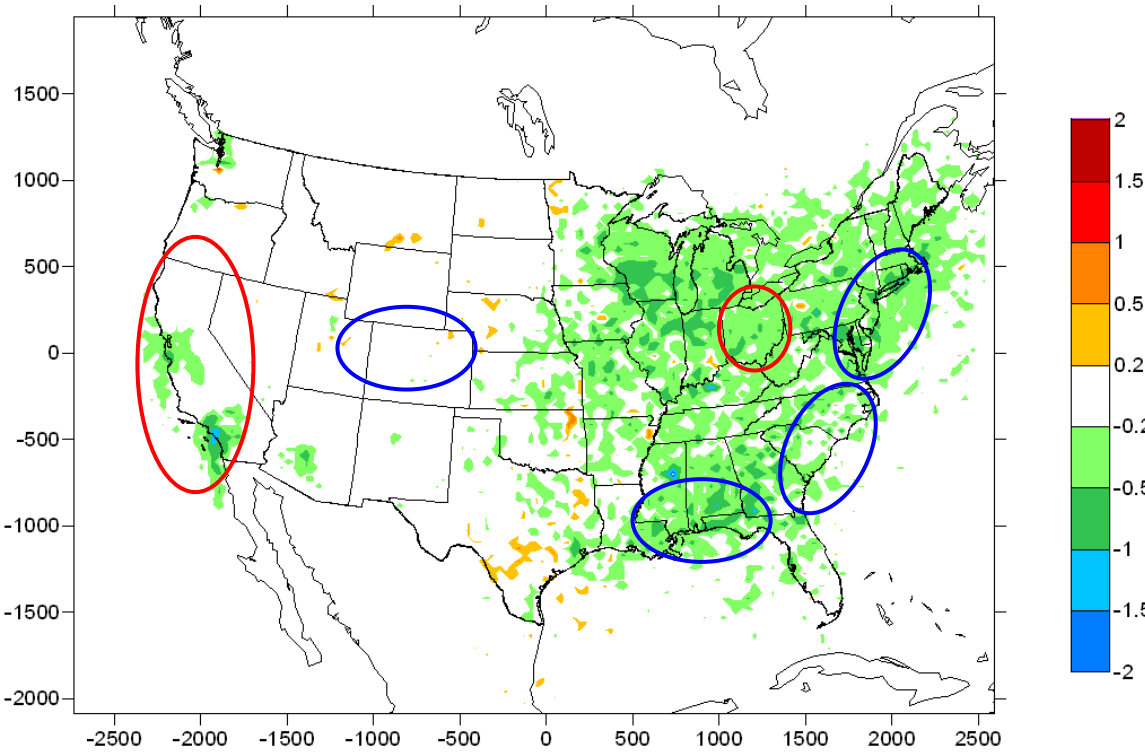

Change in Daily $PM_{2.5}$ Design Value ($\mu g\ m^{-3}$)
PHEV Case – Base Case

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Full Presentation – Session 3A
Tuesday 8:00am to 9:30am

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