Environmental Benefits of Plug-In Hybrid Electric Vehicles

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Environmental Analysis Overview

• **What are we doing here in plain english?**
  • Study has two major components
    – Nationwide CO$_2$ impacts of plug-in hybrids from 2010 to 2050
    – Air quality impacts of plug-in hybrids in 2030

• **EPRI Cross Sector Effort**
  – Power Delivery & Markets: Electric Transportation, Electric System Modeling
  – Environment: Air Quality & Climate Change
Today’s Presentation – CO2

• Covers analysis results for CO2 in the electric and transport sectors
• Represents current analysis done for EPRI
Scope and Methodology Climate Task

- Nationwide CO₂ analysis
  - Based on EPRI electric system model (NESSIE)
  - Expanded scenario matrix
    - High, medium and low carbon intensity electric generation portfolios
      - Additional scenario consistent with air quality task
    - Different transportation sector & PHEV technology/adoption scenarios
  - 2010 to 2050 timeframe
- Primary outputs:
  - CO₂ emissions
  - Generation mix
  - Fuel usage
Potential PHEV 20 CO₂ Offsets Based on Different Electricity Generation Portfolios

- Vehicle Tailpipe
- Upstream Gasoline
- Upstream Electricity

Electricity CO₂ emissions in gCO₂ kWh⁻¹

Total vehicle CO₂ emissions in g CO₂ mi⁻¹

- Conventional Midsize Sedan
- Hybrid (HEV 0) Midsize Sedan

- New Coal
- National Average Mid-Year'05
- Southern Illinois & Nearby States Today
- CCNG
- California Off-Peak Today & US in 2050
- California in 2050
- 100% Wind, Solar, Hydro
- Nuclear, Geothermal

Source: EPRI
**CO₂ Analysis Background & Objectives**

- Understand the value of the PHEV technology
  - CO₂ emissions
  - Gasoline consumption

- Understand the impact of the PHEV on the electric system
CO₂ Methodology – Charging Energy

• National model with 13 regions
• Carefully models loads and how units serve this load (Production simulation)
• Add a PHEV charging profile to the base load shape
• Charging CO₂ calculated by differences

RFC - ReliabilityFirst Corporation
SERC - Southeastern Electric Reliability Council
SPP - Southwest Power Pool
WECC - Western Electricity Coordinating Council
ERCOT - Electric Reliability Council of Texas
FRCC - Florida Reliability Coordinating Council
MRO - Midwest Reliability Organization
NPCC - Northeast Power Coordinating Council
Example Impact on the Electric System - Simulated Cal ISO System Load

Source: California ISO (Sept. 1-2, 2005) and EPRI data
Methodology – Evolution of the Electric System Over Time

• Capacity is added to serve new load plus retirements
• Technology economics reflect all costs, including the monetized value of the right to emit CO2
• California tracked carefully
  – 20% renewable energy by 2010
  – No coal except IGCC with CO2 capture and sequestration
  – No nuclear until 2020
Assumptions on the PHEV

• 2,000 KWh per year of charging energy

• Charging timing
  – 70% off-peak
  – 30% on-peak

• National PHEV fleet
  – 25 million in 2030
  – 70 million in 2050

• California PHEV fleet
  – 2.3 million in 2030
  – 6.2 million in 2050
National CO2 Results Versus HEV and ICE Breakeven

Hybrid vehicle CO2 intensity equivalent
Gasoline vehicle CO2 intensity equivalent
Adding California to the National Results

Hybrid vehicle CO2 intensity equivalent

Gasoline vehicle CO2 intensity equivalent

CO2 (grams/kWh)

2010 2015 2020 2025 2030 2035 2040 2045 2050

Calif. Powerplant Mix  U.S. Powerplant Mix

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Results for a Number of Regions

- Hybrid vehicle CO2 intensity equivalent
- Gasoline vehicle CO2 intensity equivalent

CO2 (grams/kWh)

- ECAR
- ERCOT
- MAAC
- MAIN
- MAPP
- NPCC/NY
- NPCC/NE
- NPCC/NE
- SERC/TVS
- SPP
- WSCC/NPP
- WSCC/RA
- WSCC/CNV

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Results for a More CO2 Intensive System

Hybrid vehicle CO2 intensity equivalent

Gasoline vehicle CO2 intensity equivalent

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Results for a Less CO2 Intensive System

Hybrid vehicle CO2 intensity equivalent
Gasoline vehicle CO2 intensity equivalent

CO2 (grams/kWh)

U.S. Powerplant Mix
Calif. Powerplant Mix
Peak demand increases 0.75% in 2050.

Energy increases 1.7% in 2050.
Summary – CO2

- Detailed modeling of the electric system shows a true picture of the CO2 impacts of PHEV’s.
- The electric system is getting less CO2 intensive over time.
- On a national basis PHEV’s save a large fraction of the CO2 emissions on the all electric range of the vehicle.
- The California grid is marginally cleaner that the national average, and also offers the potential for saving CO2.
- The impacts on the grid are not significant.
Future Work

• Perform CO2 analysis
  – Look at three different levels of electric system CO2 intensity
  – Analyze three PHEV penetration scenarios
  – Perform extensive sensitivity analysis
• Perform air quality analysis
  – Run air quality model for the US in 2030
  – Develop detailed analysis for California and Ohio
Impacts of Electricity as an Alternative Transportation Fuel

• Many drivers in the utility industry
  – Regulation
  – Fuel cost
  – Infrastructure
  – Capital costs
• Generating portfolio varies widely by region
• There is no simple answer
• Must examine the details very closely
Scope and Methodology Air Quality Task

• National and California/Ohio Analysis
• Two Scenarios in 2030:
  – 0% and ~30% PHEV market penetration
  – Includes all current EPA regulations:
    • Clean Air Interstate Rule, Clean Air Mercury Rule,
      Clean Air Non-Road Diesel Rule, Clean Highway
      (Heavy Duty) Diesel Rule, etc.
  – Model power-plant emissions using North American
    Electricity and Environment Model (NEEM)
  – Full-year air quality analysis using EPA CMAQ model
    • Outputs:
      – O₃, PM_{2.5}, PM_{10-2.5}, Hg, VOC, NOx, SO₂
      – Deposition: Hg, NH₄⁺, NO₃⁻, SO₄²⁻
      – Visibility in Class I Areas (e.g. National Parks)
U.S. Power Plant Emissions Trends

Source: U.S. Environmental Protection Agency
Scope and Methodology Air Quality Task

• National and Focused California/Ohio Analysis
  – Phase I:
    • Reflects a generation mix in the absence of any national or state greenhouse gas policies
  – Phase II:
    • Second phase will look at a scenario that is consistent with a generation portfolio that includes greenhouse gas abatement policies.
    • Expand focused air quality analysis to other regions
Scope and Methodology Air Quality Task (Phase I)

- **Principal Assumptions Beyond AEO 2006 and 2005 IEPR**
  - Project Clean Air Visibility Rule emissions developed by Regional Planning Organizations for 2018 to 2030
    - Develop mobile source emissions for Base Case (no-PHEV) Scenario and PHEV Scenario
      - Includes all EPA and CARB regulations
    - Develop EGU emissions from NEEM modeling
      - Includes all EPA regulations
    - Assume that for all other emissions, technology improvements offset emissions growth, i.e. emissions remain at 2018 levels
  - Special consideration for non-EGU point sources in Southern California
Scope and Methodology Air Quality Task (Phase I)

Additional Consideration in NEEM Modeling

• New Source Review
• Regional Clean Air Incentives Market (RECLAIM)
• New Transmission Intertie Capacity
• Renewable Portfolio Standards (RPS)
• California Million Solar Roofs Initiative
Scope and Methodology Air Quality Task (Phase I)

• **Key Transportation Assumptions**

• 2030 Base Case (no-PHEV) scenario
  – EIA-consistent assumptions
  – Vehicle growth in vehicles miles traveled (VMT)
  – Fleet turnover

• 2030 PHEV scenario
  – ~30% Vehicle Penetration by 2030
    • ~14% of VMT provided in all-electric mode

• Additional benefits from lower upstream (refinery, transport, storage, refueling evaporative, spillage) emissions per VMT