What Color are your Electrons?
Implications of Mass Adoption of PHEVs and EVs on Greenhouse Gas Emissions Due to Charging

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December 6, 2010
Introduction and Motivation

- Electrification of Transportation to address environmental externalities

- California is leading the way in environmental initiatives

- The state also has a unique electricity generation mix in the U.S.

- A ruling by the EPA / NHTSA declared EVs as being zero-emission vehicles (models produced 2012 – 2016)
  - Electric cars will initially be given a "zero" emissions rating in new U.S. auto fuel efficiency regulations as an incentive for the industry to mass produce them
Key Question

“What will the implications of the incremental load from EVs be on carbon emissions from electricity-use for charging PHEVs and EVs?”
Approach and Methodology
Impacts of Mass Adoption of EVs on the Grid

- **Short Term / Low Adoption Rates**
  - Small Incremental Load from Electric Vehicles
  - **Limited Impact on the Generation Mix**

- **Long Term / High Adoption Rates**
  - High Incremental Load on the Grid
  - Charging Profile will directly influence peak, intermediate and baseload demands
  - **High Impact on Generation Mix**

- **Demand-Side & Supply-Side Characteristics**
  - Carbon Accounting Approach - Consider **Marginal** electricity emissions from last plant to come online (dispatch orders)

- **Emissions from Electric Vehicles**
  - Carbon Accounting Approach
    - Calculate Generation Mix for BAU and Mass EV Scenarios
    - Compute total Emissions from EVs and non-transportation

Focus of this study
Model Structure
Overview of Core Modules

Model Inputs

- Vehicle and Market Assumptions
  - EV Adoption Rate
  - Vehicle Technology
  - Commercial Availability

- Driver Assumptions
  - Driving Patterns
  - Charging Behavior

- On-Road Fuel Economy
  - Available Electricity Production technologies

Key Outputs

- Load Curves
- Generation Mix
- Total Electric Miles Driven
- Aggregate Emissions from EVs
- Emissions Saved from ICEs

Time Horizon: 2010 – 2050
Three Levels of Adoption Rates
Two Charging Profiles
Results
Impact on 2050 Load Curve

The graph illustrates the impact on the 2050 load curve with different adoption scenarios.

- **BASE 2050**: The baseline scenario without significant changes.
- **BASE 2010**: The base load of 2010 for comparison.
- **PEAK**: Peak load scenarios.
- **INTERMEDIATE**: Intermediate load scenarios.
- **BASELOAD**: Base load of 2050.
- **High Adoption Off-Peak Charging 2050**: A scenario indicating high adoption of off-peak charging in 2050.

The y-axis represents electricity consumption (GWh), and the x-axis represents capacity factor (%). Different lines indicate various adoption levels and time periods.
Results
Impact of EV Mass Adoption on Electricity Mix (1)

Key Parameter
Non-transportation electricity (BASE) growing at CAGR 0.8%

Note: Electricity Consumptions shown are 2050 or 2010 annual levels
Results

Impact of EV Mass Adoption on Electricity Mix (2)
Results
Impact of EV Mass Adoption on Electricity Mix (3)
Results

Net CO₂ Emissions Savings from EV fleet

Key Parameters
31.85 MPG (on road) = 7.5 L/100km
Emissions from Coal: SB1368 Standard
(1,100 lbs / MWh = 500 g / kWh)

Note: Emissions shown are total over 2010 - 2050
Sensitivity Analysis

Sensitivity Analysis - "Net" Emissions from EVs for different Coal Pathways

Note: Emissions shown are total over 2010 - 2050
EV Emissions from Electricity-use

Key Insights

- **It’s LOCAL**: Emissions from electricity-use of EVs depend on the generation mix of the grid to which they are connected.

- **CARBON ACCOUNTING**
  - Long-term/high adoption rates: the mix can be strongly influenced by an incremental load from EV charging.

- **CHARGING PROFILE**
  - In medium to high-level penetration rates of EVs, the *baseload component* of electricity is critical.
  - Uncontrolled Charging vs. Off-Peak charging: the answer is not trivial!
  - California: policy implications on capacity planning and electricity imports.
THANK YOU

- Questions?
Note: Emissions shown are total over 2010 - 2050