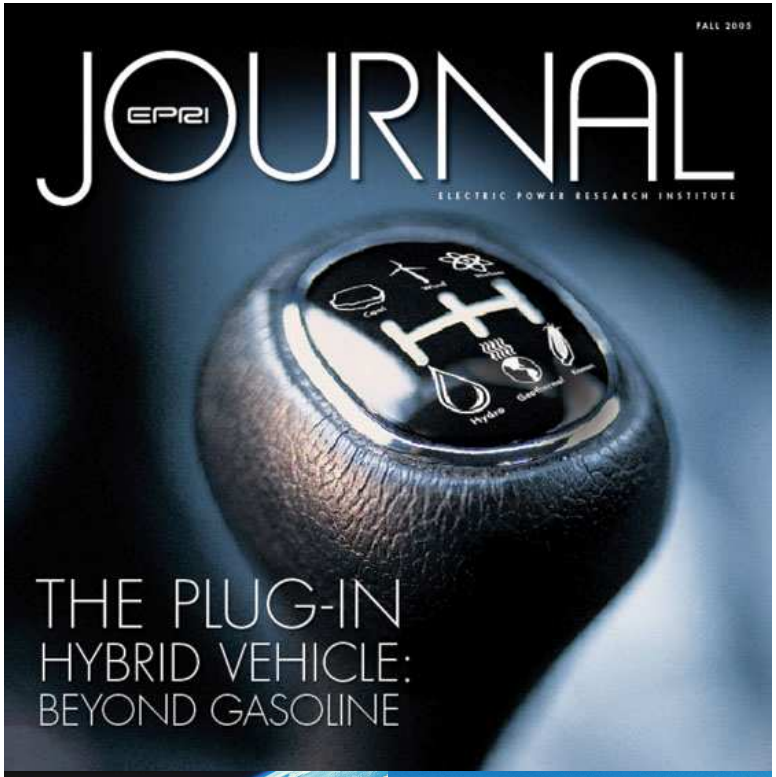
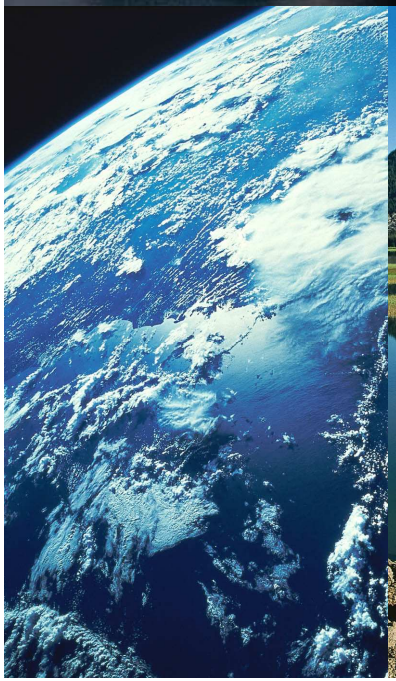
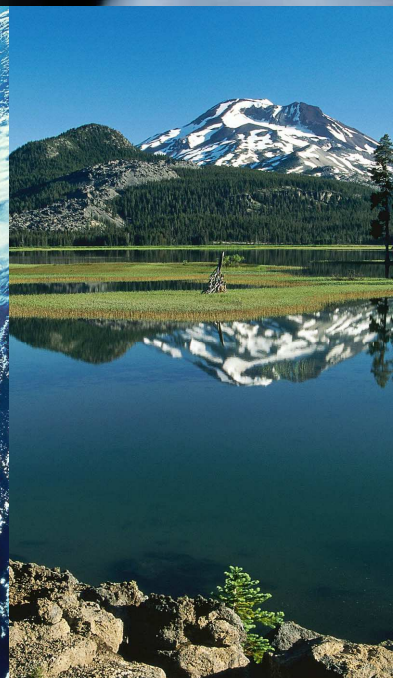






EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Environmental Benefits of Plug-In Hybrid Electric Vehicles

Charles Clark

Charles Clark Group

ZEVTECHnology Seminar

September 27, 2006

Sacramento, California

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

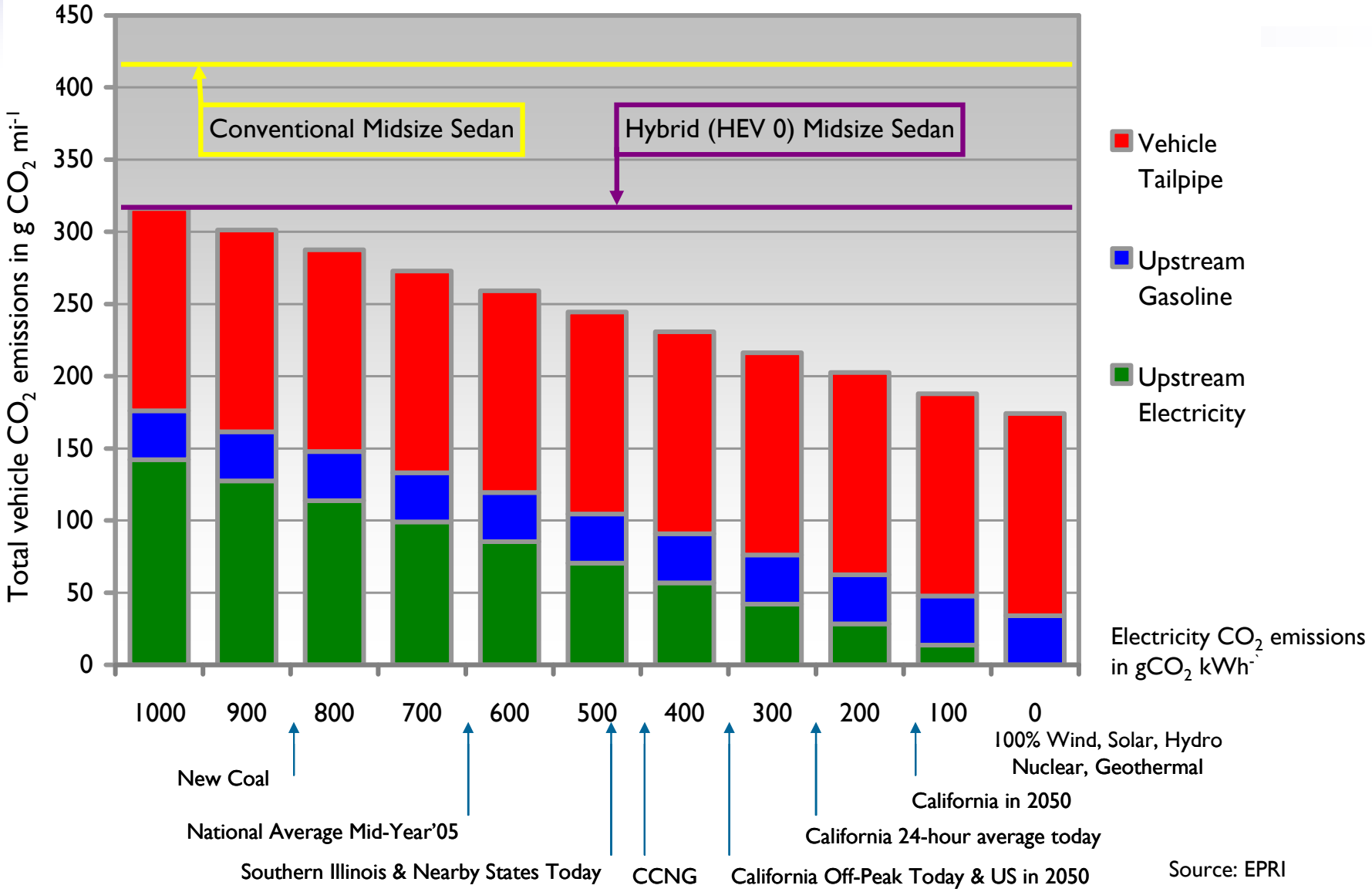
Today's Presentation – CO2

- Covers analysis results for CO2 in the electric and transport sectors
- Represents current analysis done for EPRI

Scope and Methodology Climate Task

- Nationwide CO_2 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:
    - CO_2 emissions
    - Generation mix
    - Fuel usage

Potential PHEV 20 CO_2 Offsets Based on Different Electricity Generation Portfolios

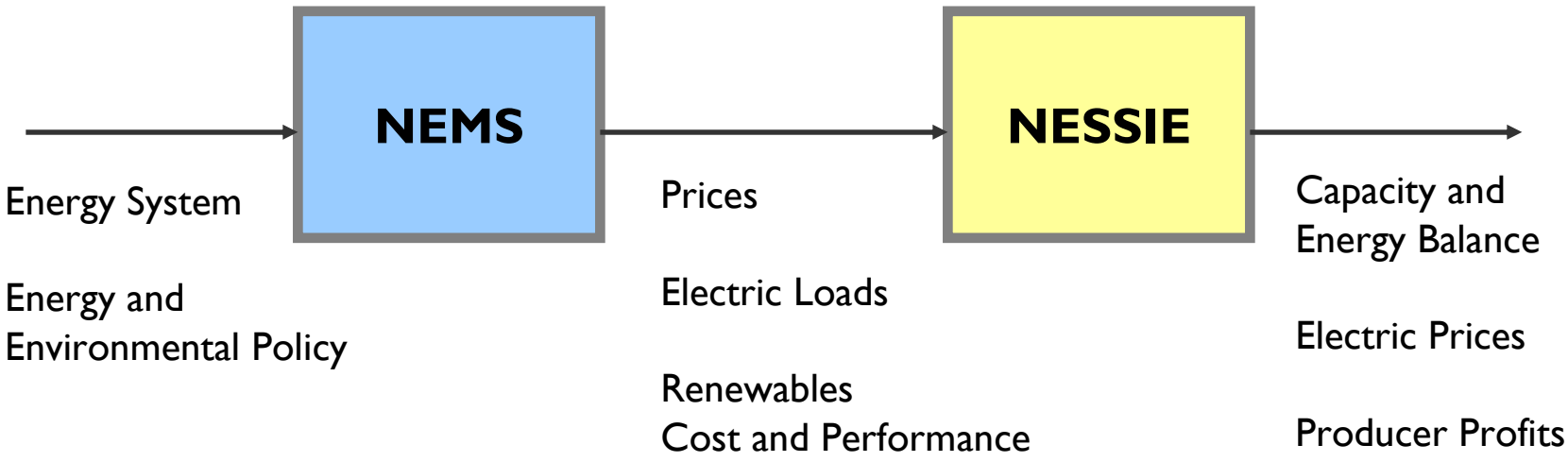


Source: EPRI

CO_2 Analysis Background & Objectives

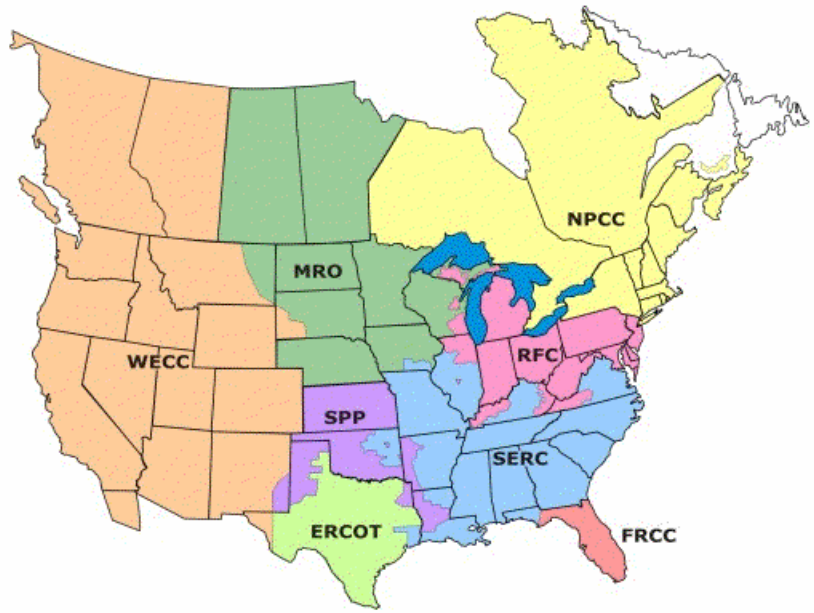
- Understand the value of the PHEV technology
  - CO_2 emissions
  - Gasoline consumption

- Understand the impact of the PHEV on the electric system



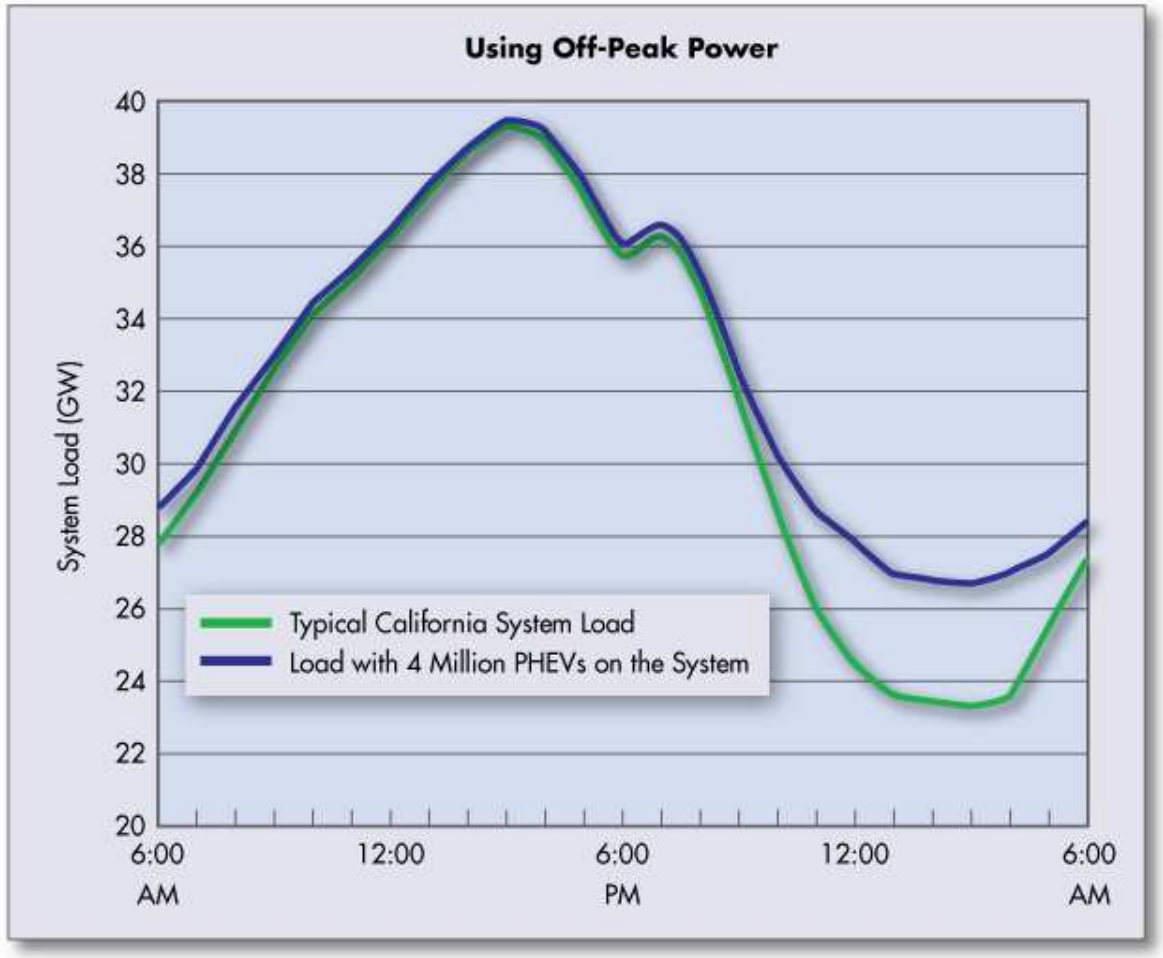
CO_2 Methodology – Charging Energy

- 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 - Reliability*First* 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

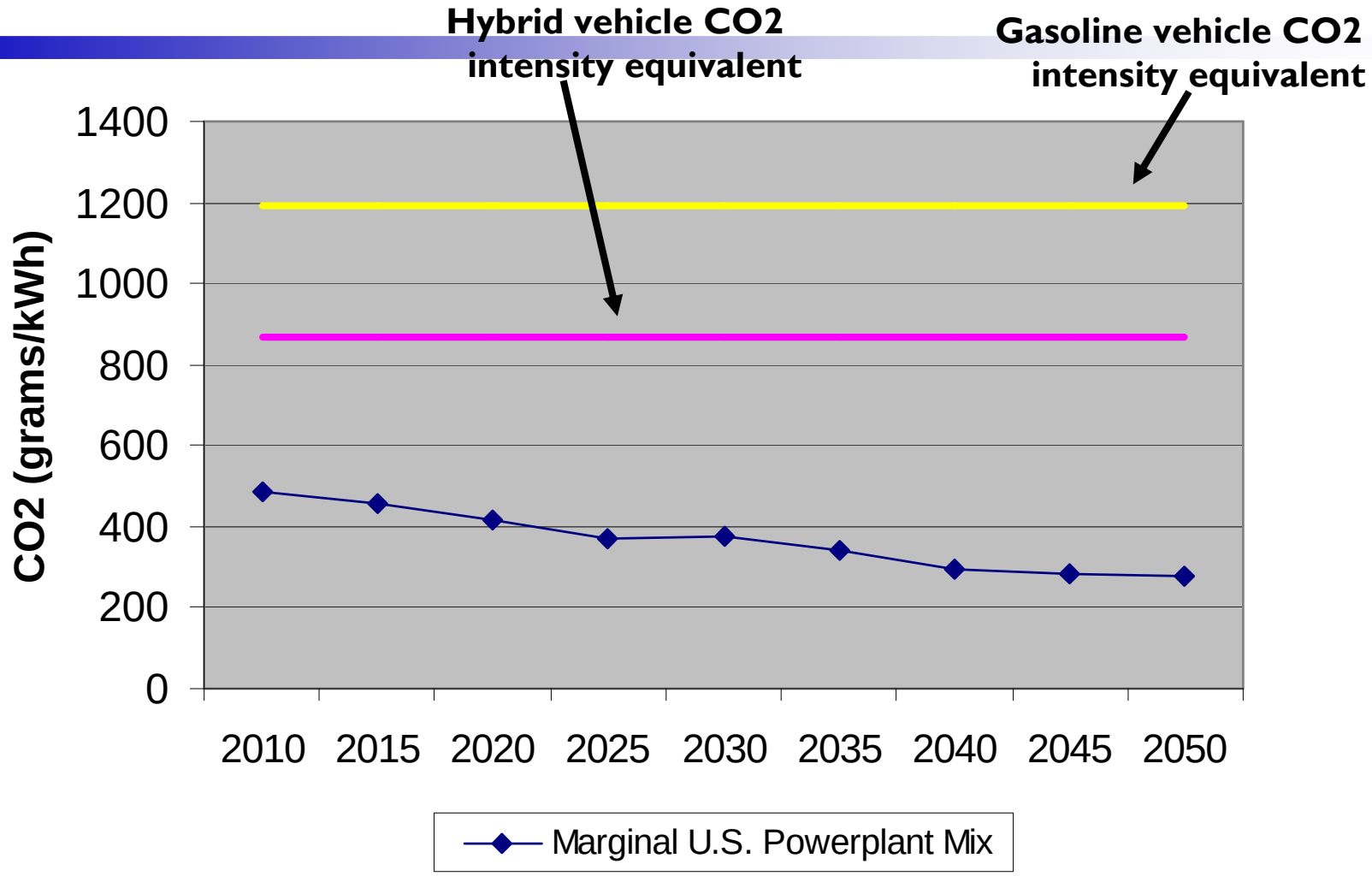
Methodology – Evolution of the Electric System Over Time

- 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

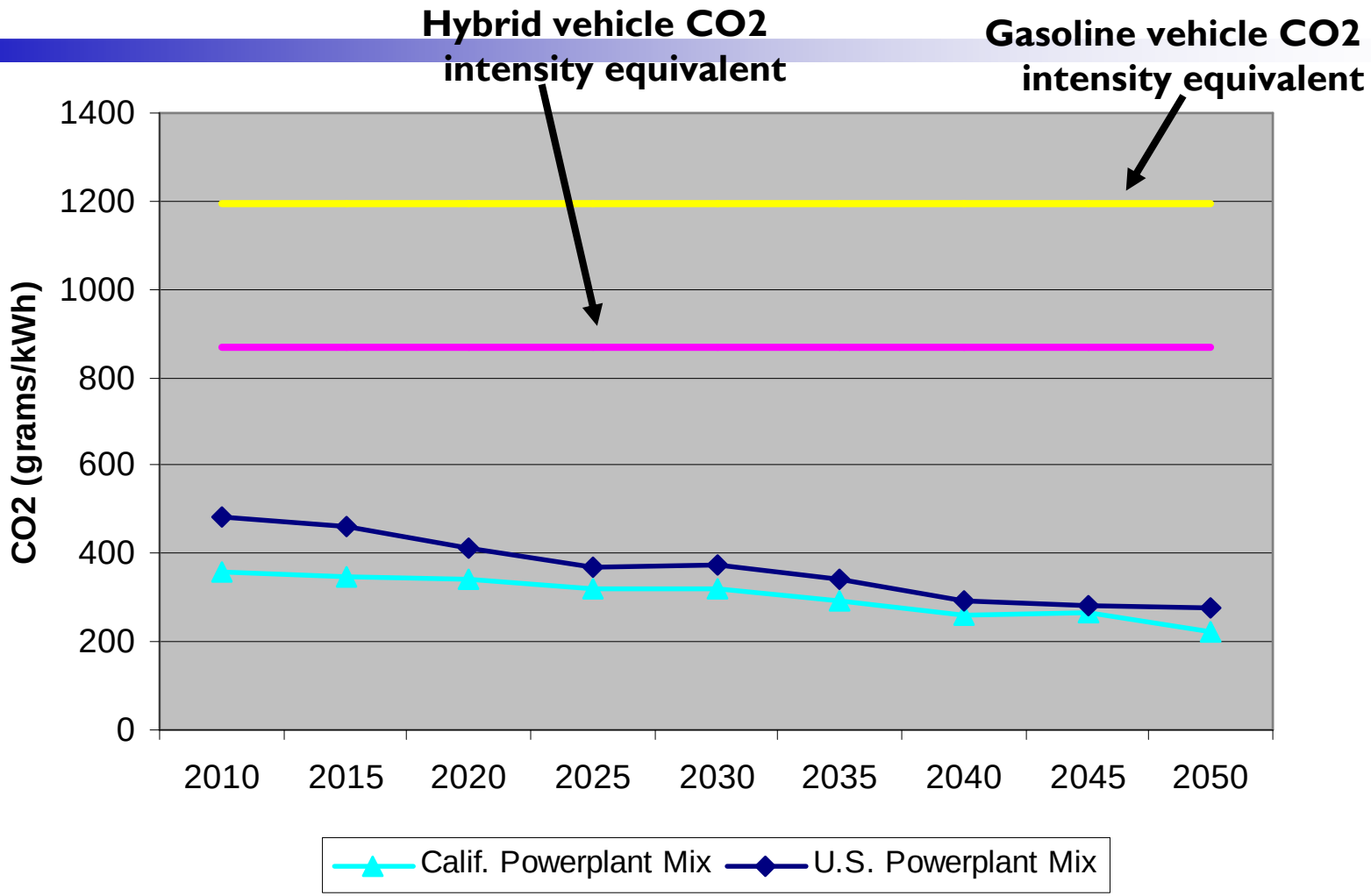
Assumptions on the PHEV

- 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

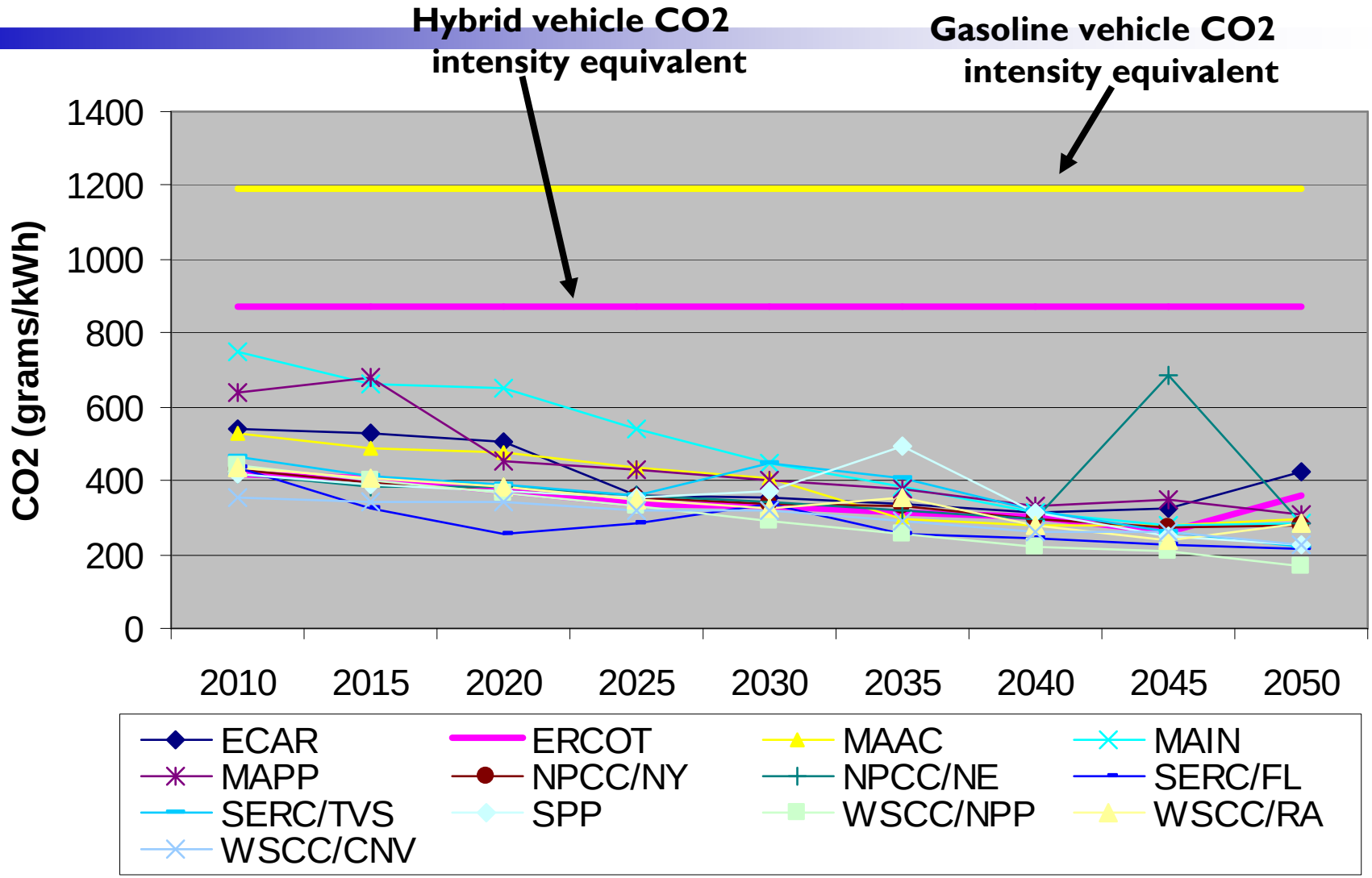
National CO2 Results Versus HEV and ICE Breakeven



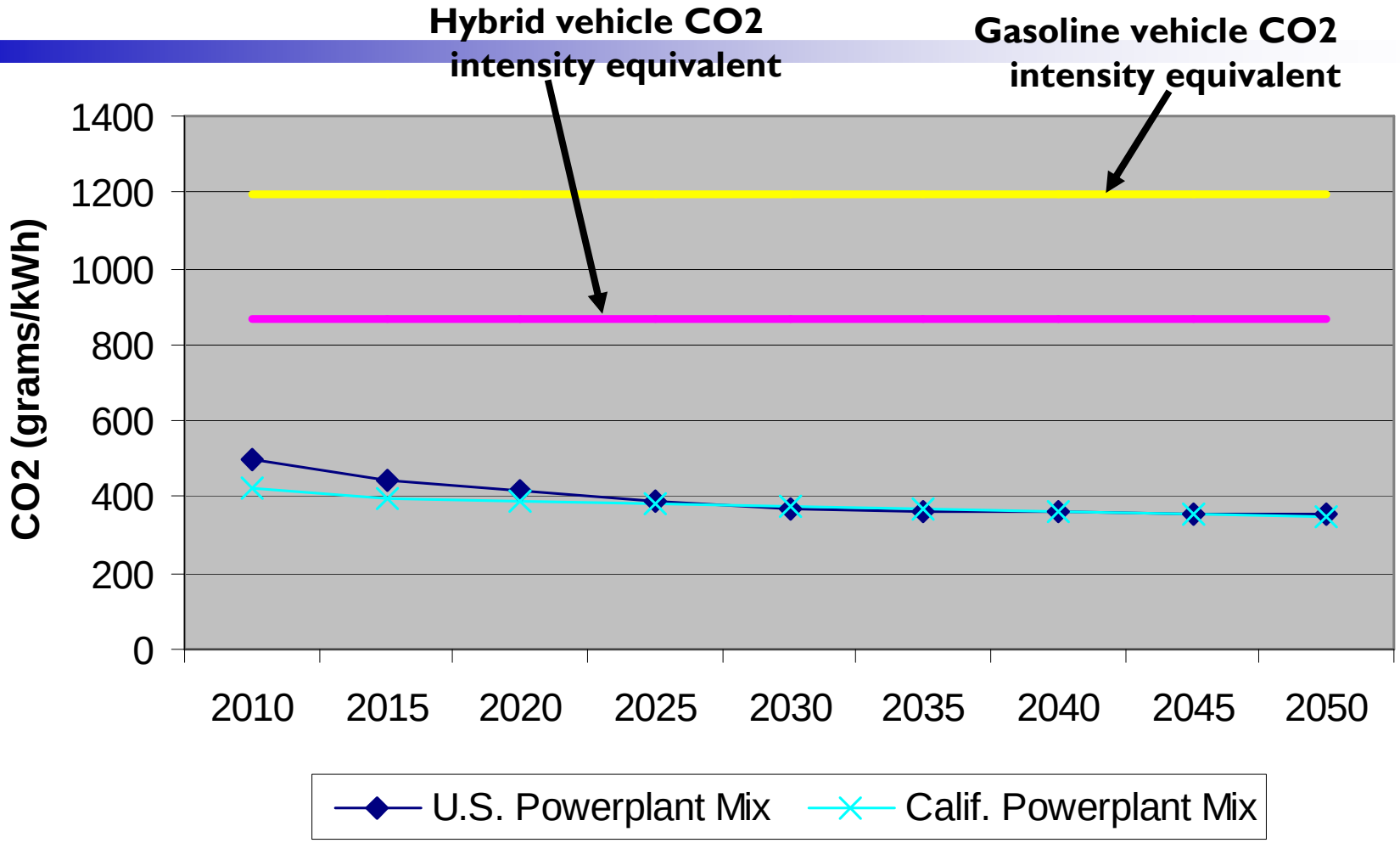
Adding California to the National Results



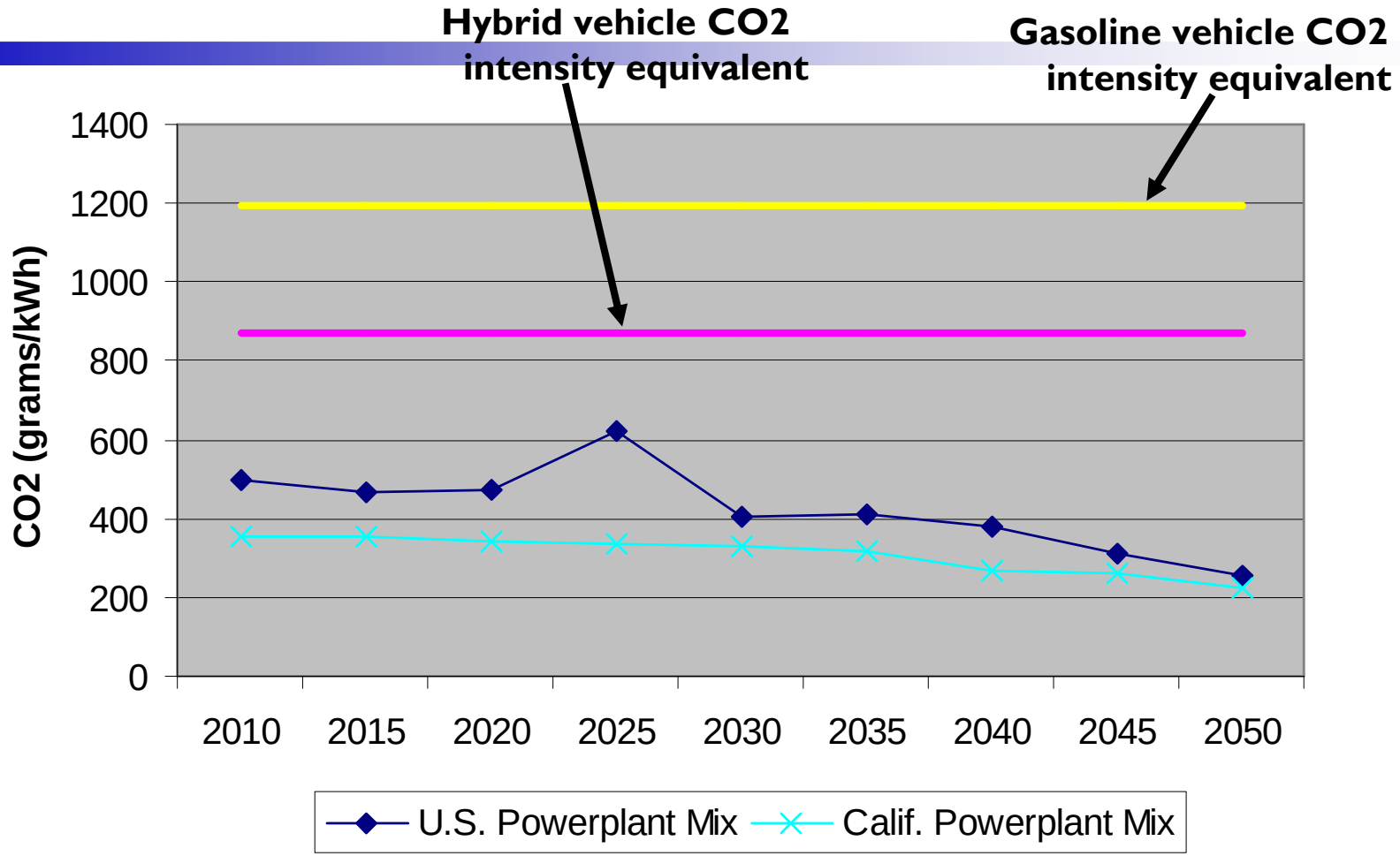
Results for a Number of Regions



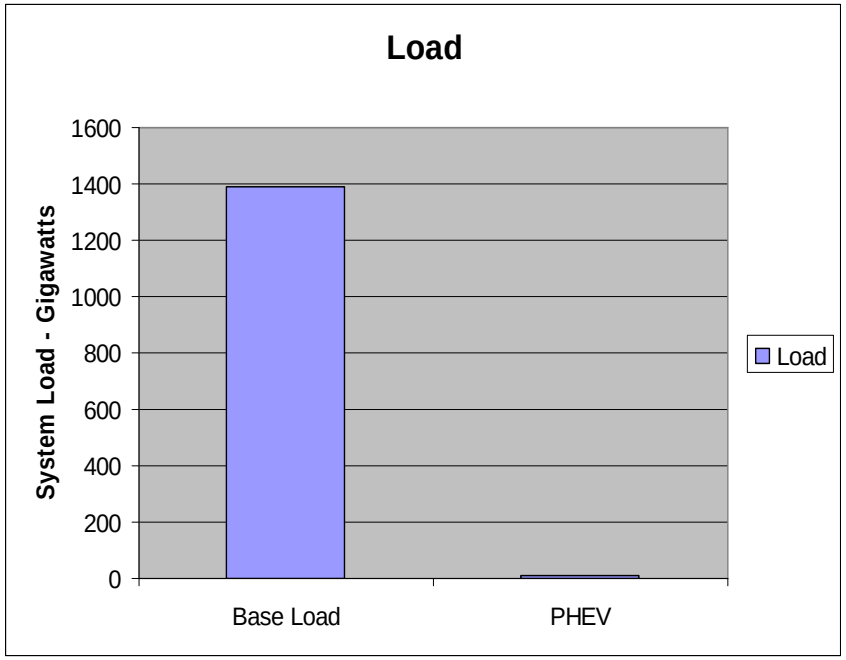
Results for a More CO2 Intensive System

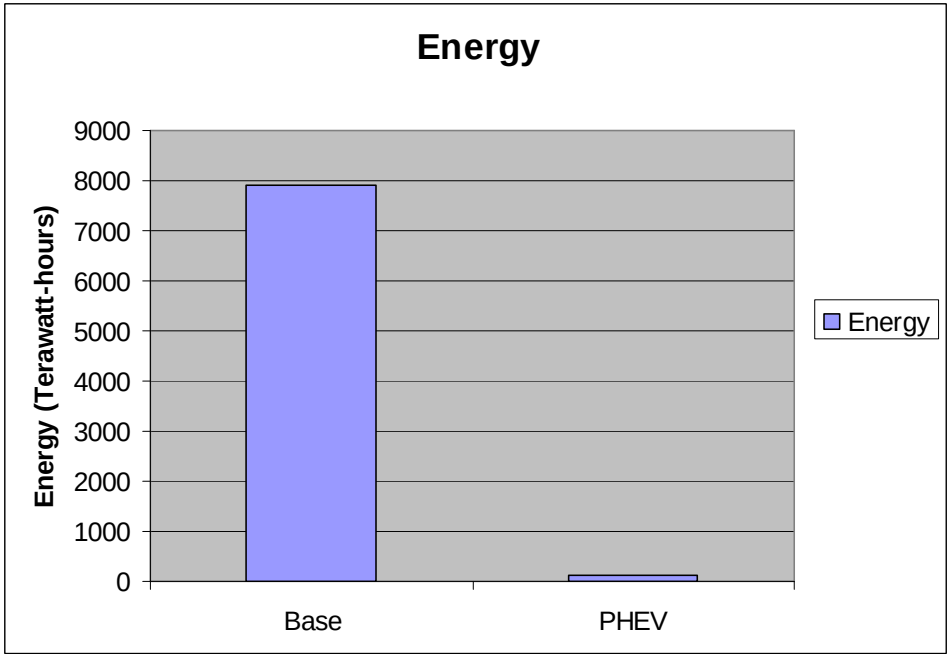


Results for a Less CO2 Intensive System



Impact of PHEVs on the Electric System





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.

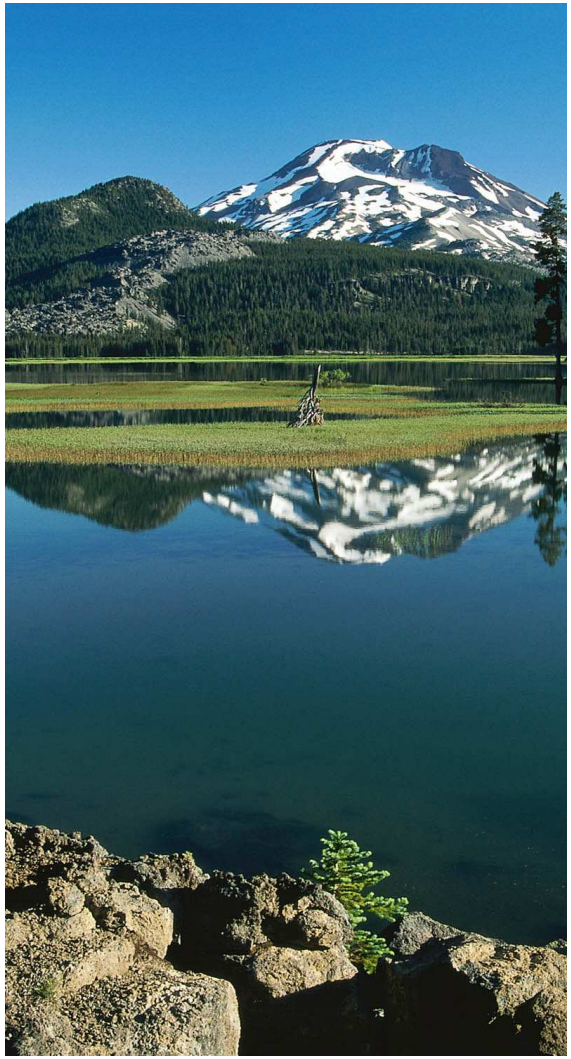
Future Work

- Perform CO2 analysis
  - Look a 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

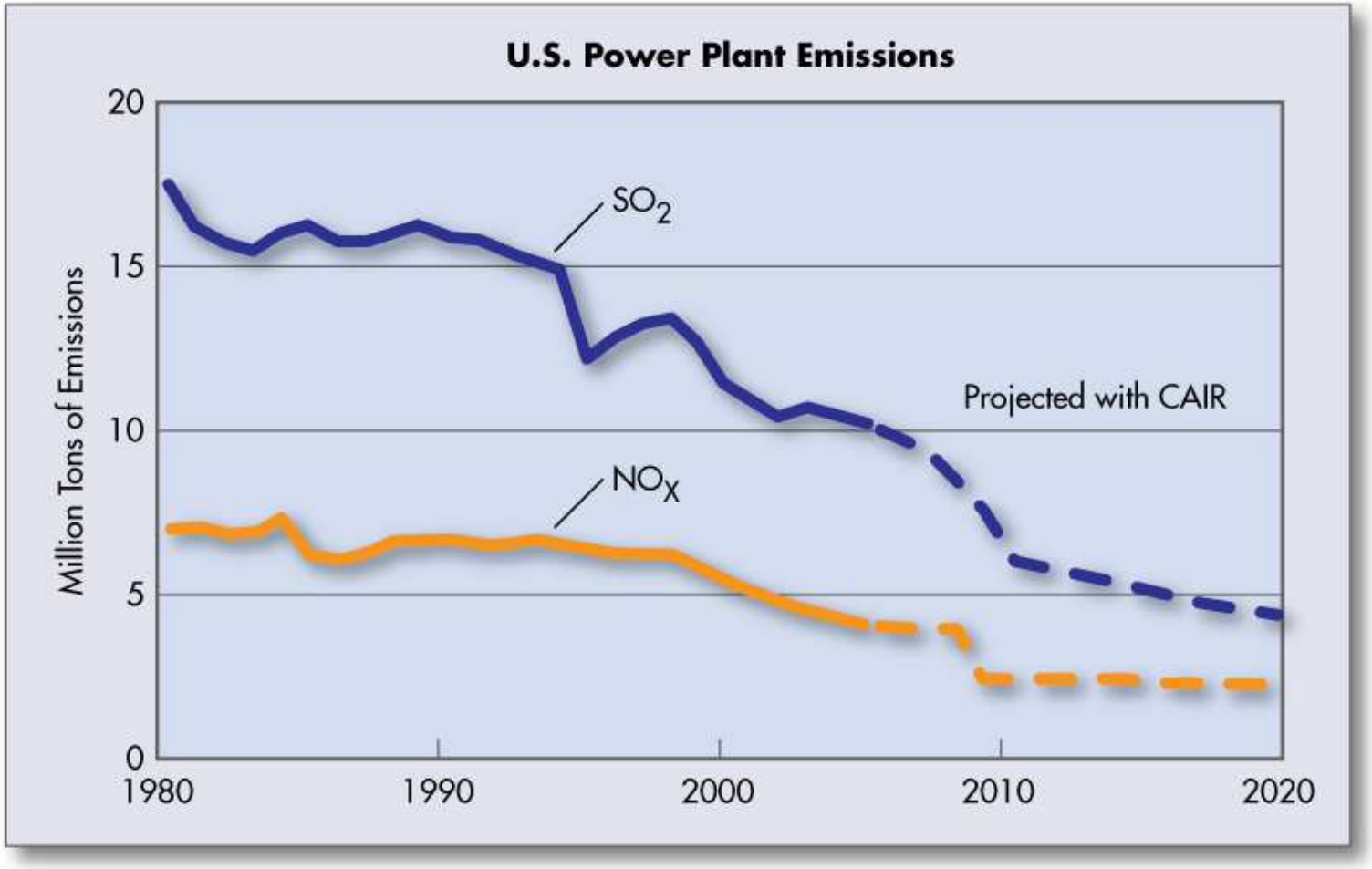
- Many drivers in the utility industry
  - Regulation
  - Fuel cost
  - Infrastructure
  - Capital costs
- Generating portfolio varies widely by region
- There is no simple answer
- Must examine the details very closely

Scope and Methodology Air Quality Task



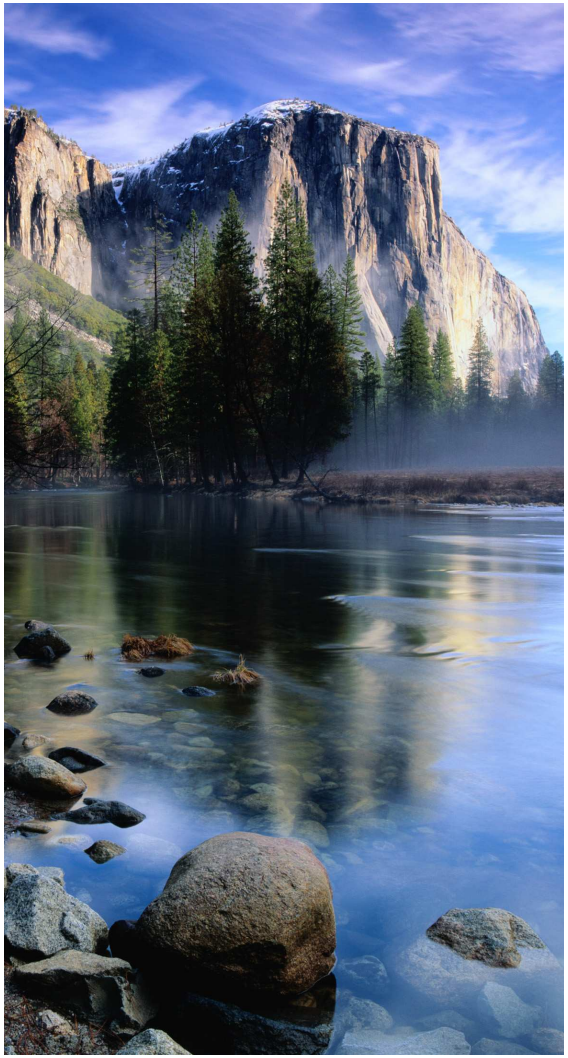
- **National and California/Ohio Analysis**
- **Two Scenarios in 2030:**
  - 0% and ~30 % PHEV market penetration
  - Includes all current EPA regulations:
    - Clean Air Interstate Rule, Clean Air Mercury Rule, Clean Air Non-Road Diesel Rule, Clean Highway (Heavy Duty) Diesel Rule, etc.
  - Model power-plant emissions using North American Electricity and Environment Model (NEEM)
  - Full-year air quality analysis using EPA CMAQ model
    - Outputs:
      - O_3, $PM_{2.5}$, $PM_{10\text{-}2.5}$, Hg, VOC, NOx, SO_2
      - Deposition: Hg, NH_4^+, NO_3^-, SO_4^{2-}
      - 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

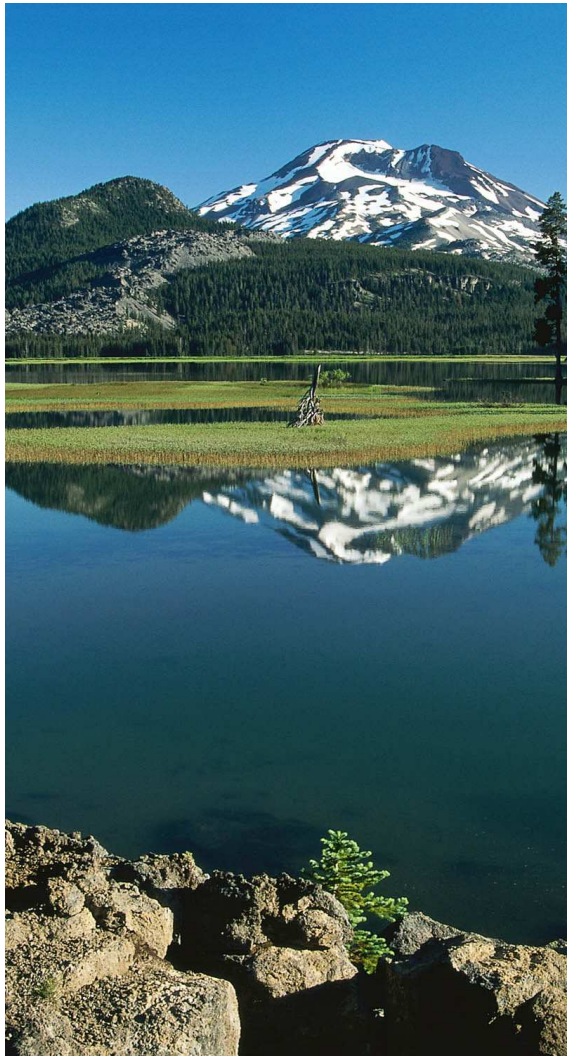


- **National and Focused California/Ohio Analysis**
  - **Phase I:**
    - Consistent with U.S. Department of Energy's 2006 Annual Energy Outlook (AEO) and California Electricity Commission's 2005 Integrated Energy Policy Report (IEPR)
    - Reflects a generation mix in the absence of any national or 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