UNIVERSITY OF CALIFORNIA Berkeley
Transportation Sustainability
RESEARCH CENTER

PLUG-IN ELECTRIC VEHICLES IN CALIFORNIA

Review of Current Policies, PEV-Related Emissions Reductions for 2020, and Policy Outlook

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Presentation Outline

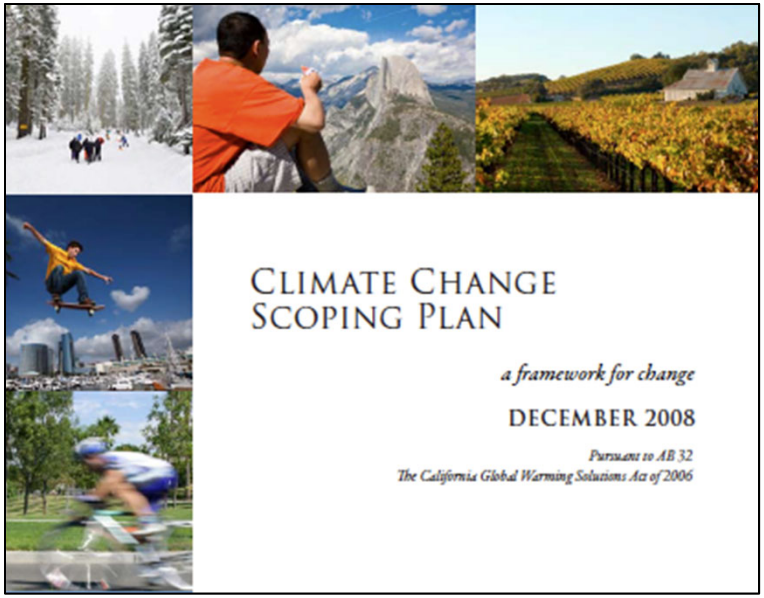
- **California's PEV policy landscape**
  - Existing and forthcoming policies
- **Emissions reductions for 2020 air quality modeling**
  - Motivations and objectives
  - Methodology and assumptions
  - Grid dispatch and impact assessment results

CALIFORNIA'S PEV POLICY LANDSCAPE

Existing Policies

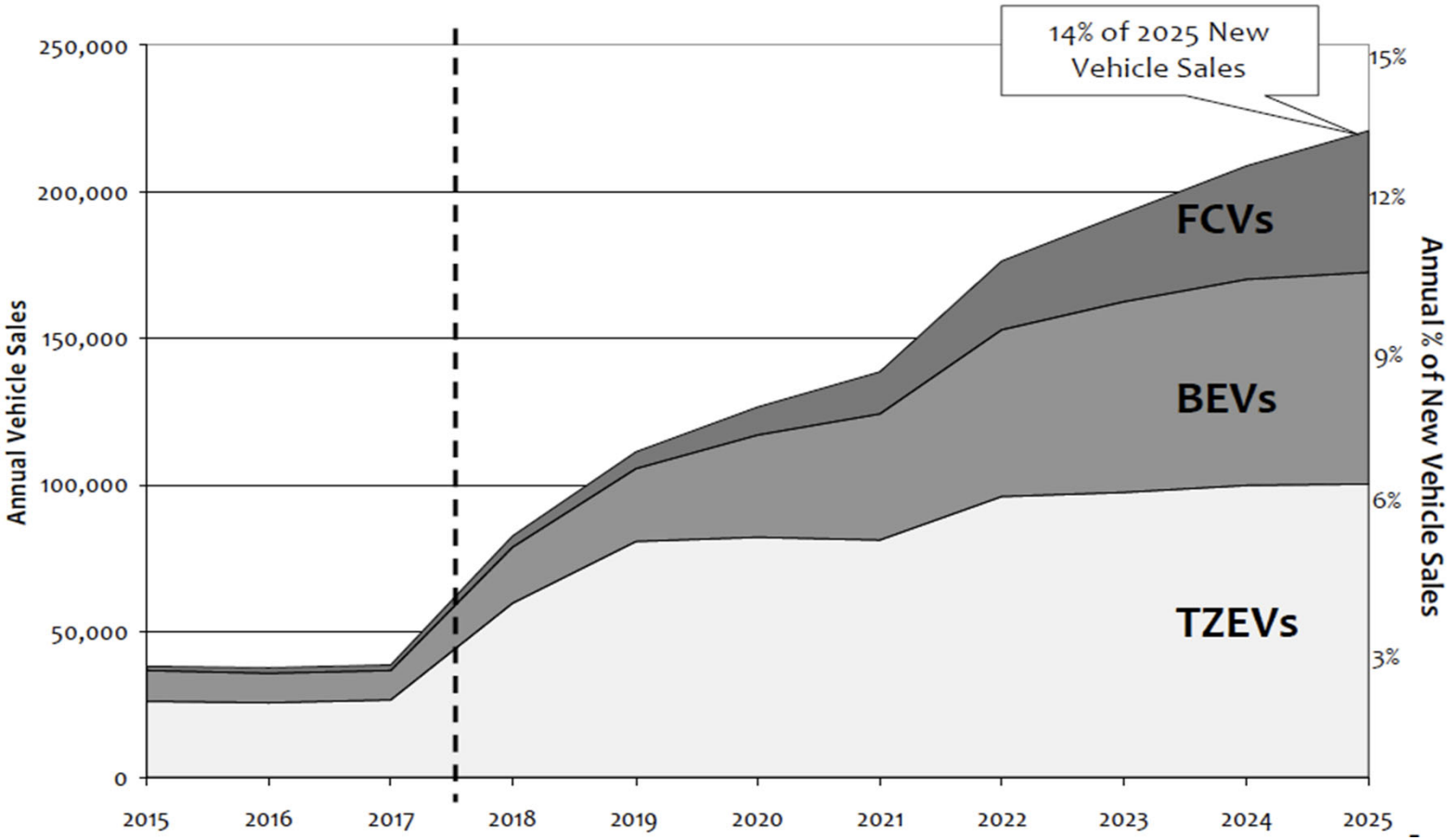
- Global Warming Solutions Act of 2007 (Assembly Bill 32)
- Zero Emissions Vehicle (ZEV) Program
- Low Carbon Fuel Standard (LCFS)

California Environmental Protection Agency
Air Resources Board



ZEV Regulation & GHG Goals

Likely ZEV Regulation compliance scenarios for 2015-2025 necessary to reduce GHG emissions to 80% below 1990 Levels by 2050.



Source: CARB (2010).

ZEV Regulation

- 2009 ZEV Review
  - Incorporate GHG emissions reductions goals.
  - Phase out credits for partial ZEVs, etc. in order to encourage the rollout of PEVs and facilitate the development of new ZEV technology.

Low Carbon Fuel Standard

- Issues related to electric fuel and the LCFS
  - Role of electric-fuel (e-fuel) in meeting state goals
  - Tracking and reporting e-fuel

California Environmental Protection Agency

Air Resources Board

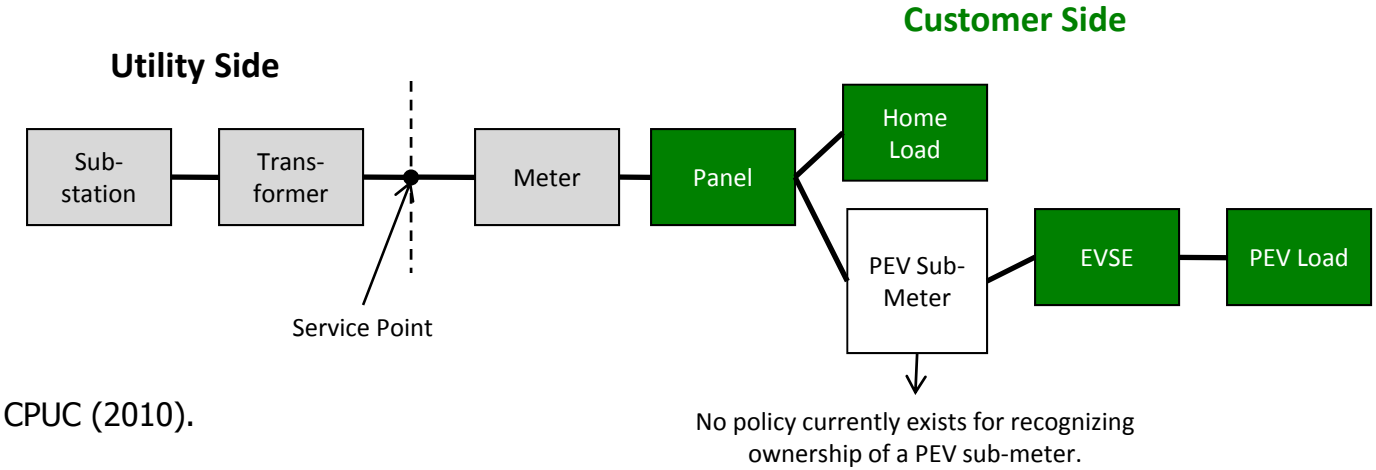
http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf

Recent and Forthcoming Policies

- CPUC's Alternative-Fueled Vehicle Rulemaking
  - Phase 1 (May 2011): Charging facility operators are not utilities and thus should be treated like retail customers.
  - Phase 2 (July 2012): Rates designs, utility costs/revenues, metering, data and information collection, and public education/outreach.

Phase 2 AFV Rulemaking: Key Aspects

- Rate designs
  - TOU or electricity for PEV-specific rates discussed
  - Current PEV rates sufficient for early market
- Electricity Metering
  - i.e. separate metering or submetering (figure below).



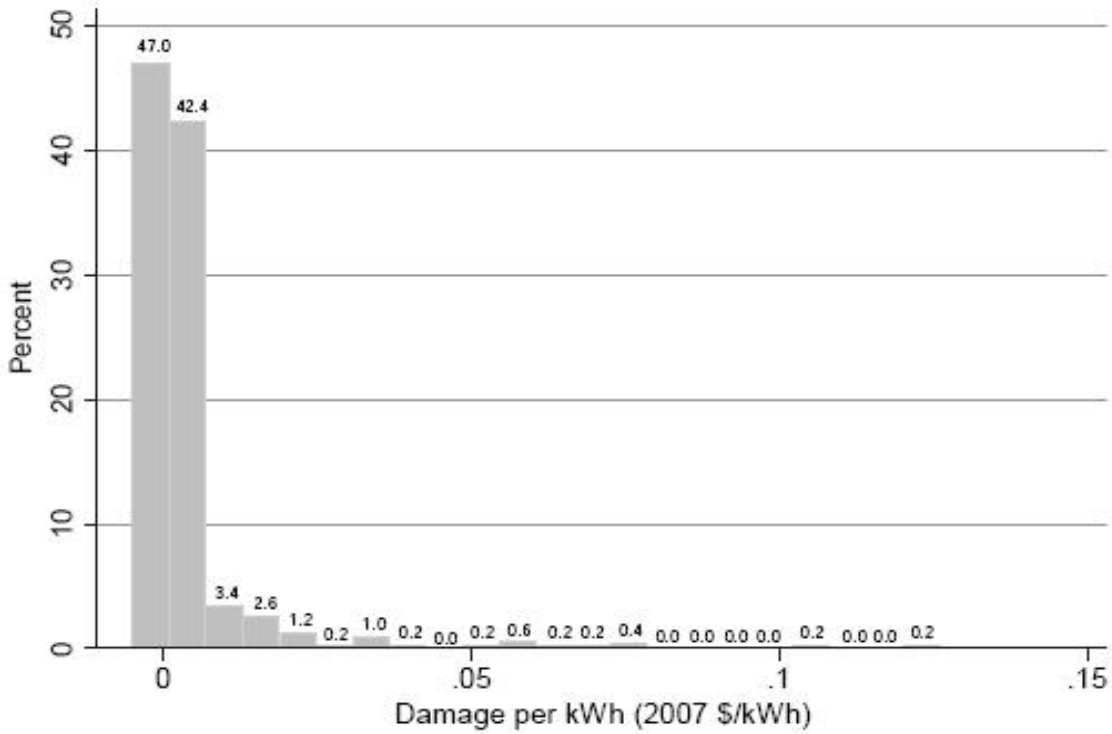
Source: CPUC (2010).

AIR QUALITY MODELING: MOTIVATIONS & OBJECTIVES

Research Objectives

- Assess air quality **costs and benefits** of shifting emissions from tailpipes to smokestacks
- Account for **spatial variation** in impacts
- Consider **uncertainty** in PEV adoption and charging behavior
- Bay Area case study

The tail of natural gas plant damages distribution is long: how bad is the marginal plant?

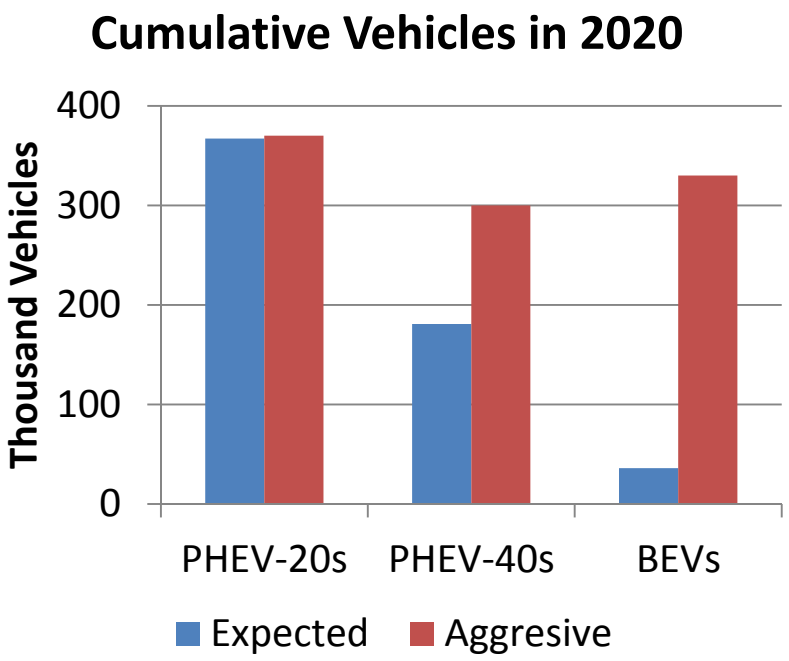


Source: NAS (2010)

AIR QUALITY MODELING: METHODOLOGY & ASSUMPTIONS

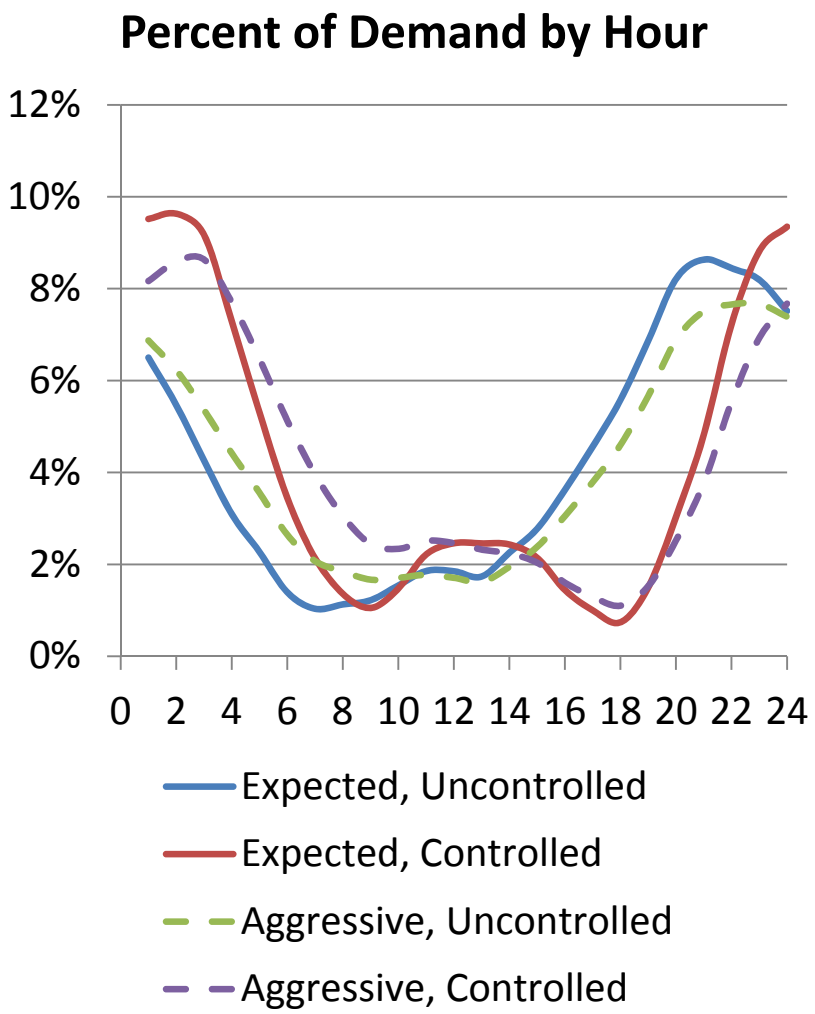
Vehicle Adoption Scenarios

- Expected Scenario:
  - Based on TIAX "Expected Population" (TIAX LLC 2009)
- Aggressive Scenario
  - Ramped up BEV consumption
  - Achieve 1 million PEVs in California
  - "Beyond Oil"



Charging Profiles

- Controlled Charging
  - "Valley filling"
  - Marginal cost minimizing demand allocation
- Uncontrolled Charging
  - "Plug and Play"
  - Based on travel diaries (Axsen et al. 2011)

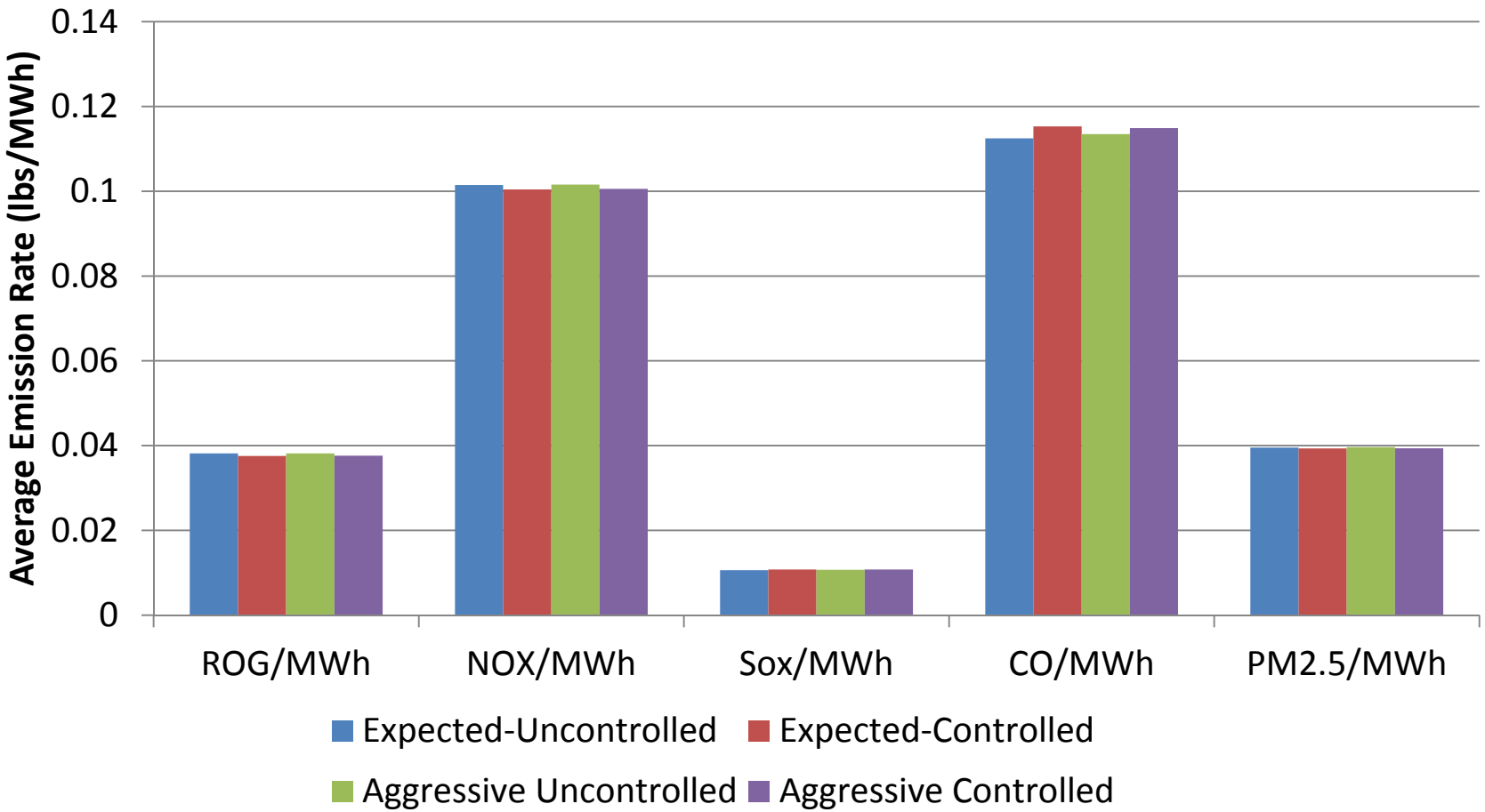


Data sources and caveats

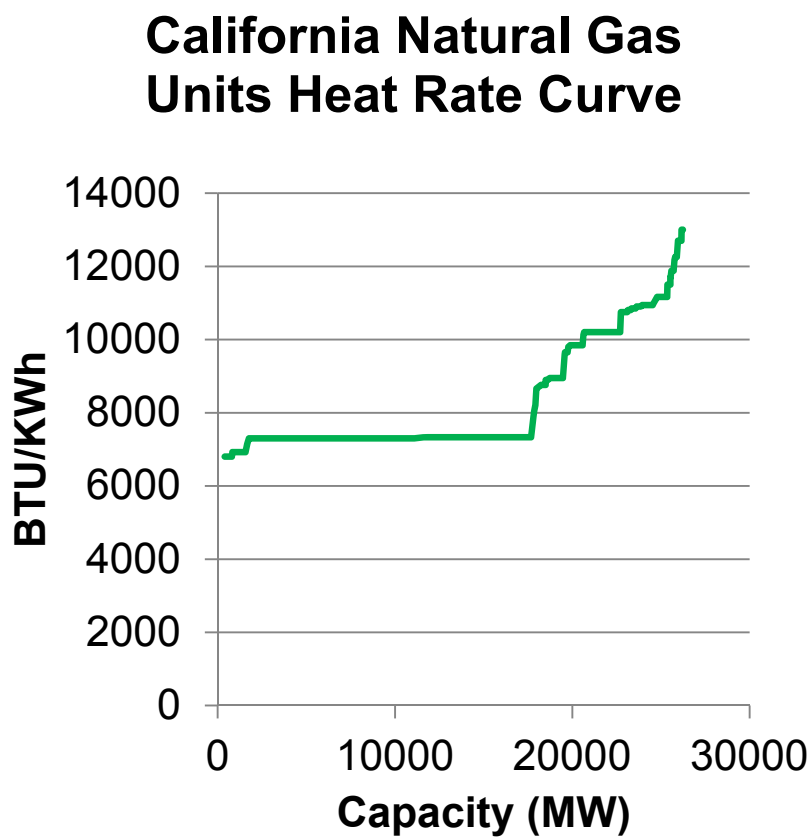
Data Need	Source	Notes
Powerplant EFs	CARB averages	• 2010 grid mix
Tailpipe EFs	EMFAC 2020 model	• Baseline fleet turnover assumptions
Grid dispatch	E3's PLEXOS Production Simulation Model	• Least cost dispatch • Policy compliant (low load) baseline • Results at county level
Impact assessment	EPA's COBRA Model	• Damages from PM2.5 • No ozone • Only human health

AIR QUALITY MODELING: GRID DISPATCH RESULTS

All natural gas generation; emissions rates vary little across scenarios



All scenarios within same flat region of heat rate curve

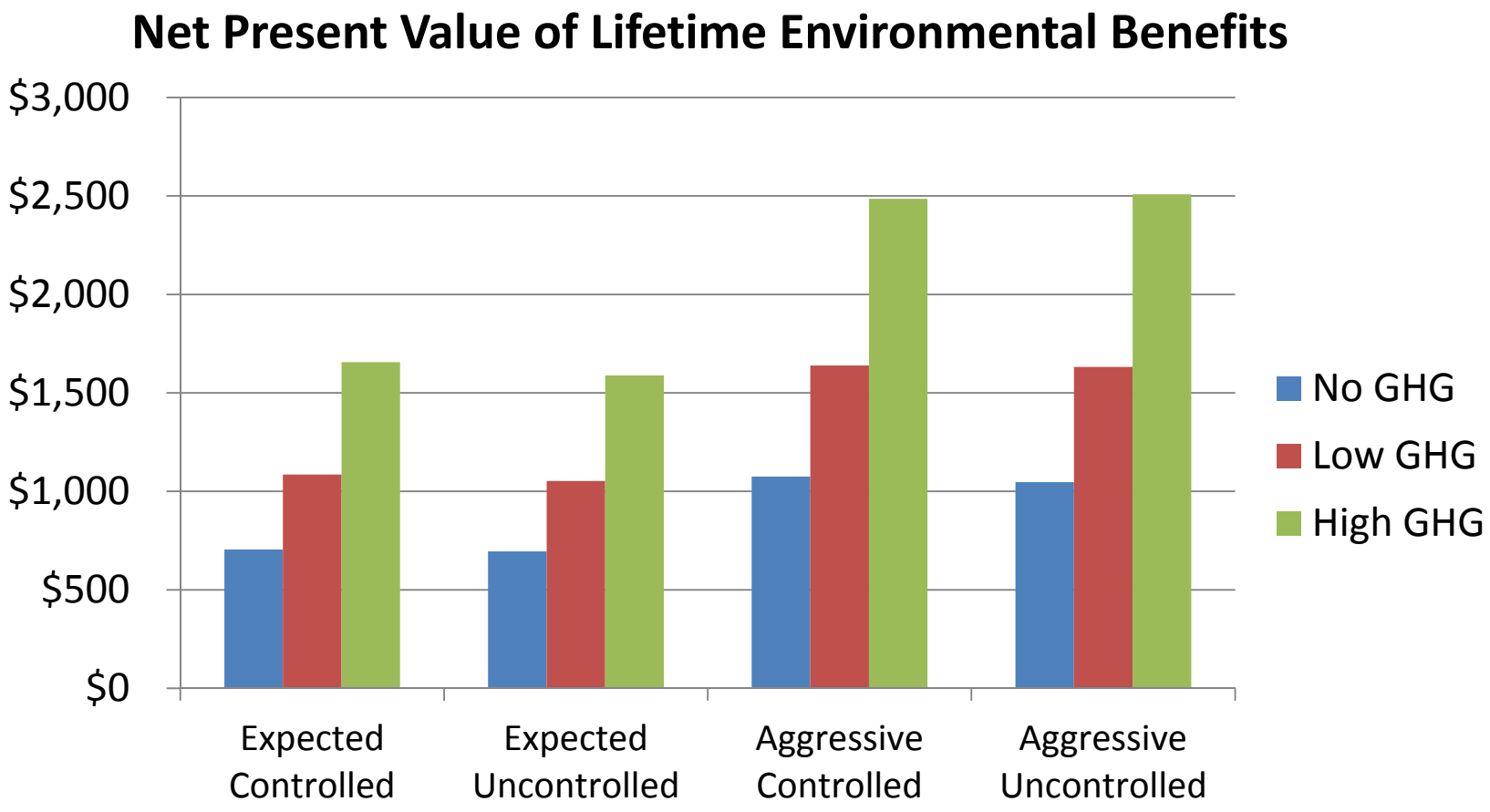


- **Similar plants** coming online in all scenarios
- Load **increment too small** to push into new regime of plants
- Emissions will **scale linearly** with e-fuel demand
  - BUT Impacts may NOT – differences in exposure

Figure from E3

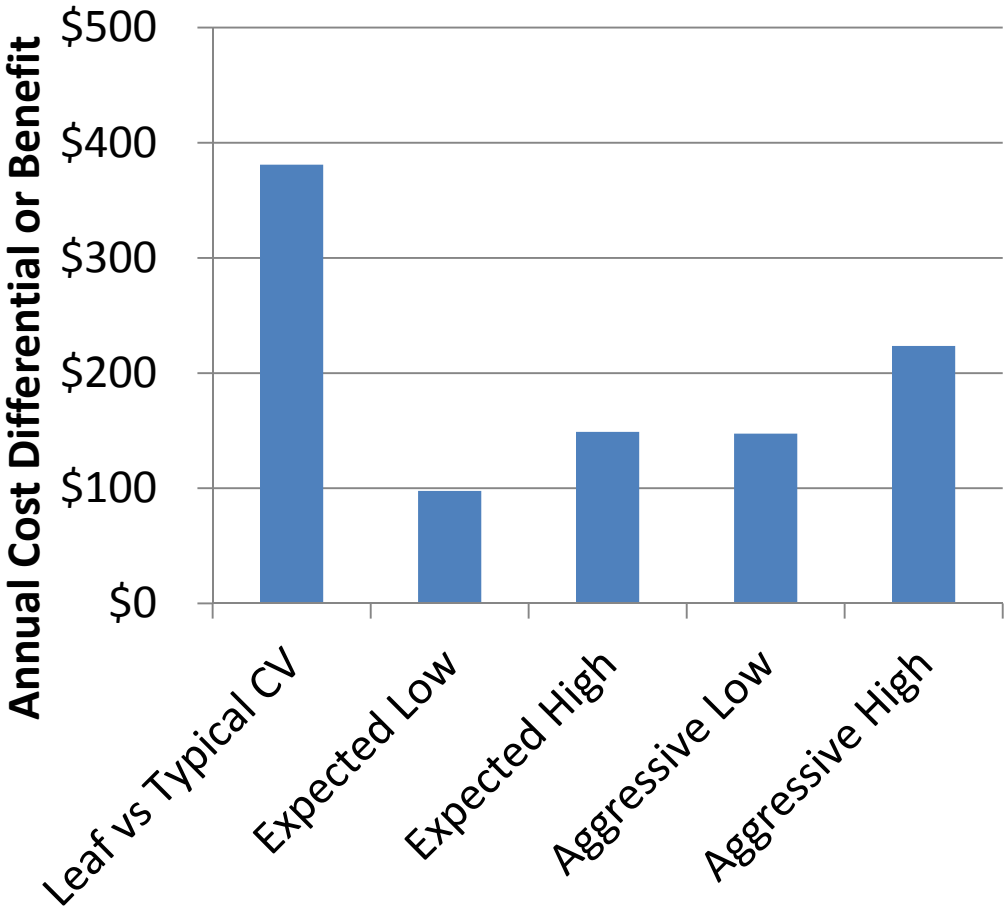
AIR QUALITY MODELING: IMPACT ASSESSMENT RESULTS

Air quality benefits are within an order of magnitude of available EV subsidies



Notes: annual benefit discounted at 4% assuming 15 year vehicle lifetime

Air quality benefit covers substantial part of private cost gap



Assumes:

-Vehicles amortized at 4% for 15 yrs

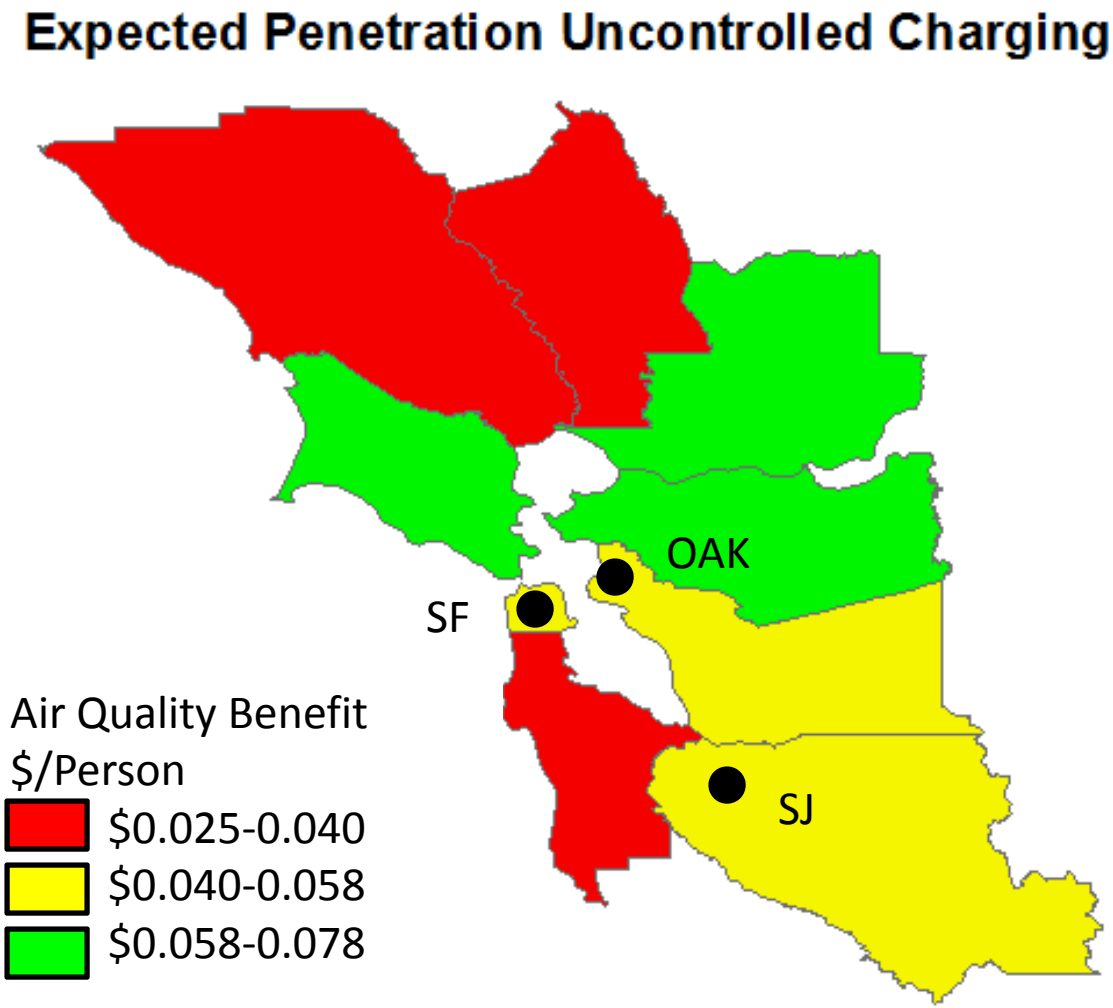
-$3.50/gal, 12¢/kWh

-30 mpg, $18,000 CV

-Low: $20/ton GHGs

-High: $50/ton GHGs

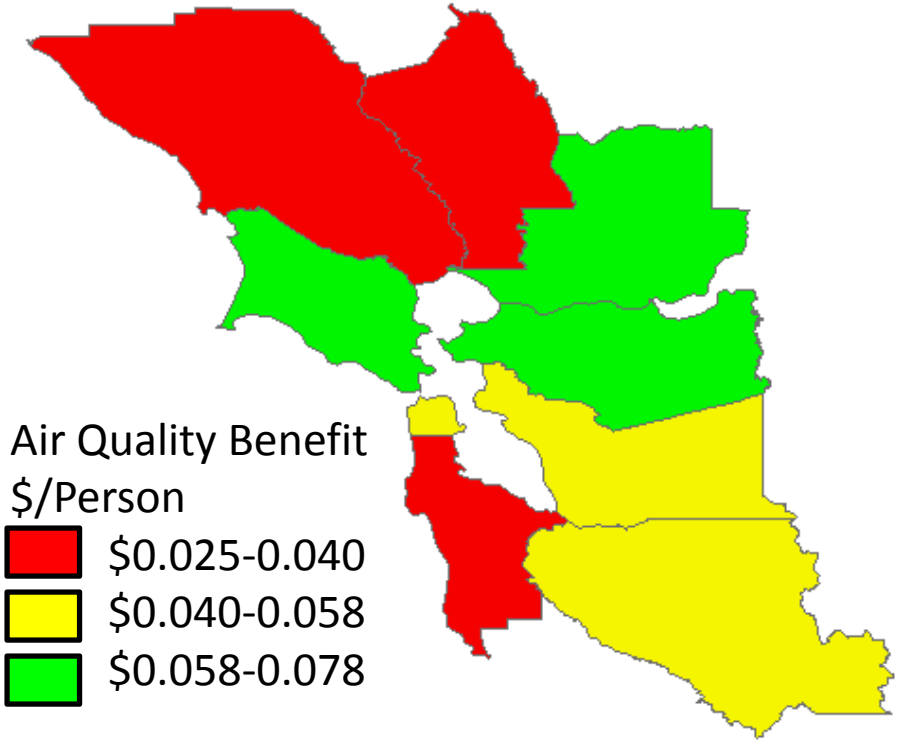
All Bay Area counties are net air quality beneficiaries, though size of benefit differs



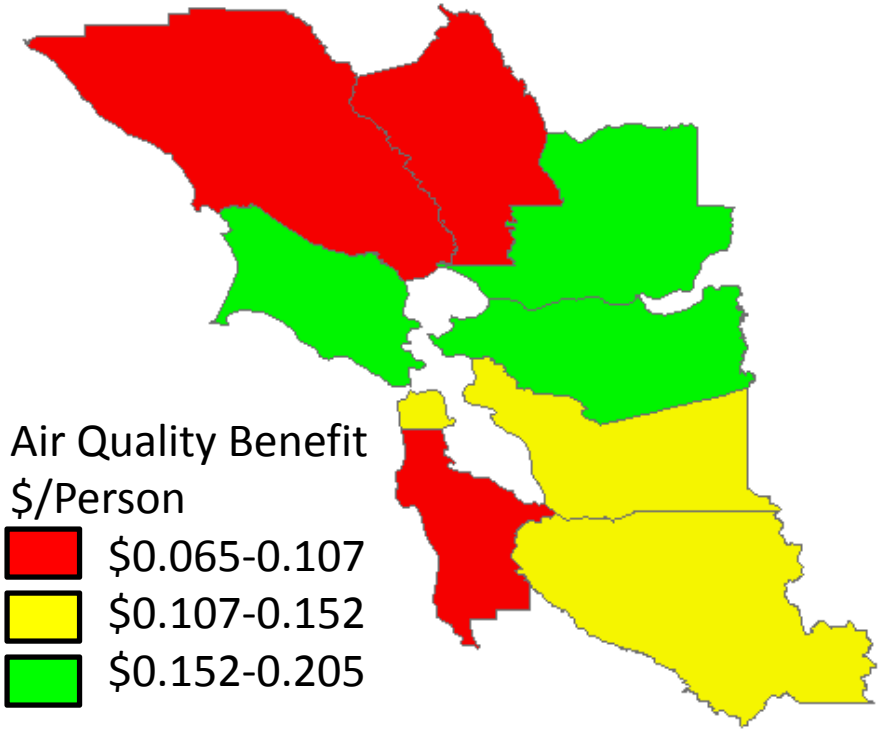
Map shows **per capita** benefits from reduced emissions of criteria air pollutants (No GHGs)

Location of air quality benefits
independent of PEV penetration

Expected Penetration Controlled Charging



Aggressive Penetration Controlled Charging



Maps show per capita benefits from reduced emissions of criteria air pollutants (GHGs excluded)

AIR QUALITY MODELING: CONCLUSIONS & POLICY IMPLICATIONS

Takeaways and policy implications

- AQ benefits
  - Cover up to 50% of private cost gap
  - Within order of magnitude of EV subsidies
- Emissions and AQ impacts insensitive to level of PEV penetration

Closing thoughts on EV subsidies

- Why subsidize EVs?
  - Economist: internalize a positive externality
- Blunt instrument
- Advantages
  - Dispersed costs
  - Prime demand to move to lower cost part of supply curve

Thank you! Questions of comments?

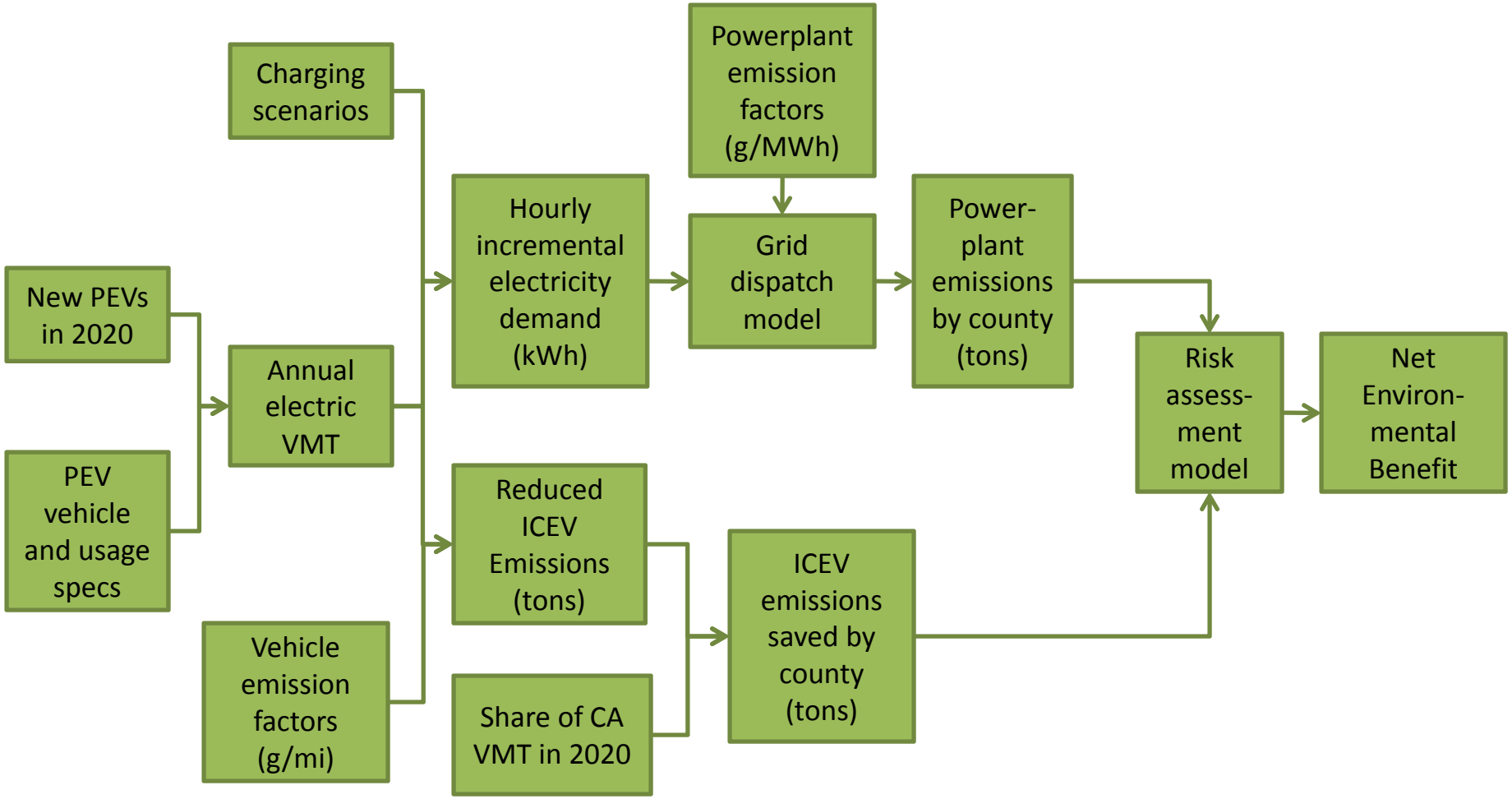
Acknowledgments: Jim Williams, Eric Cutter, Snuller Price, Priya Sreedharan, and Ben Haley of E3, Tim Lipman, Brett Williams, and Maggie Witt of TSRC

References

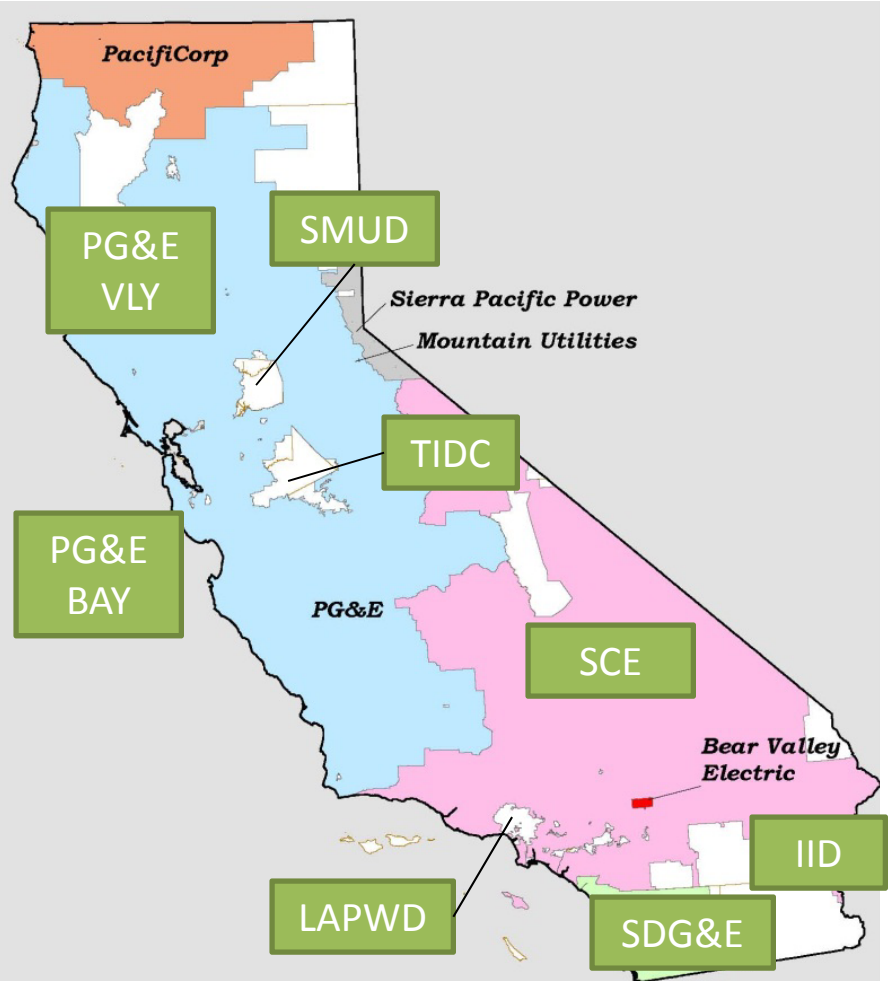
1. California Air Resources Board (CARB), 2010. "ZEV Regulation 2010 Staff Proposal. http://www.arb.ca.gov/msprog/levprog/leviii/meetings/111610/zev_workshop_presentation_final.pdf
2. California Public Utilities Commission (CPUC), 2010. "The Utility Role in Supporting Plug-In Electric Vehicle Charging." http://docs.cpuc.ca.gov/EFILE/RULINGS/122657.PDF

RESERVE SLIDES

Modeling Framework



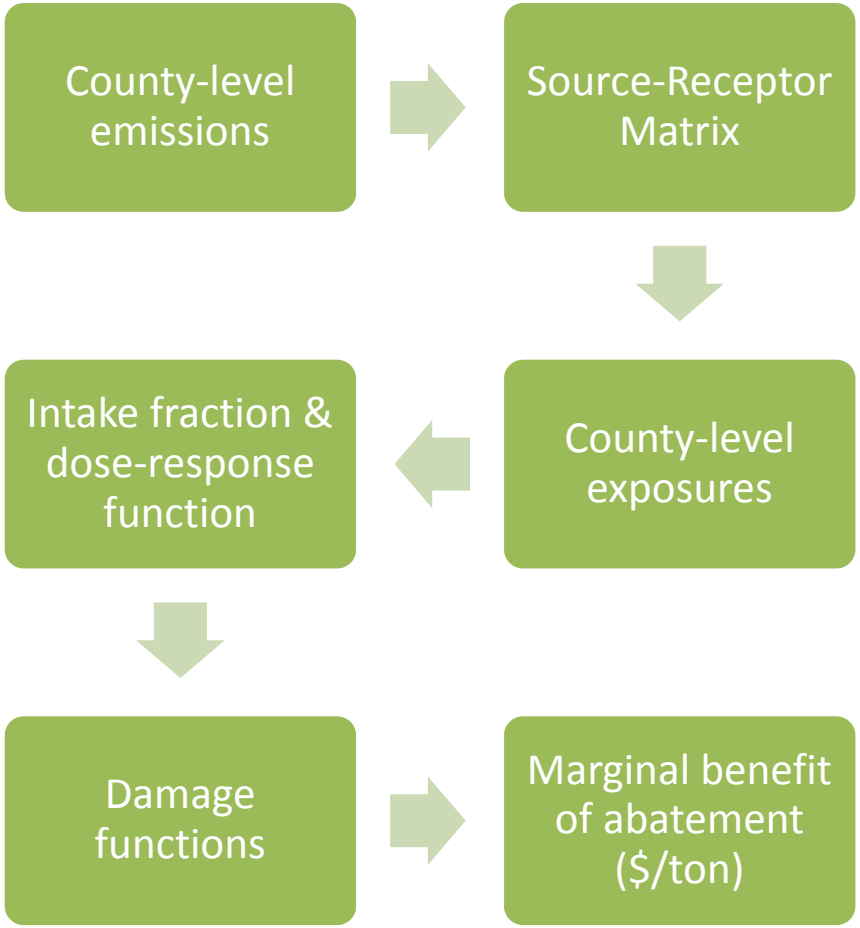
PLEXOS Production Simulation Model



- Models **least-cost grid dispatch** subject to transmission constraints
- Dispatch results given at individual plant level, but **higher confidence in zonal results**
- Base load from 2020 IEPR policy compliant scenario

Slide courtesy of E3

EPA's Cost-Benefit Risk Assessment (COBRA) Tool



- Risk/impact assessment model
- Dispersion based on source type
- Damages based on economics literature

Modeling Caveats

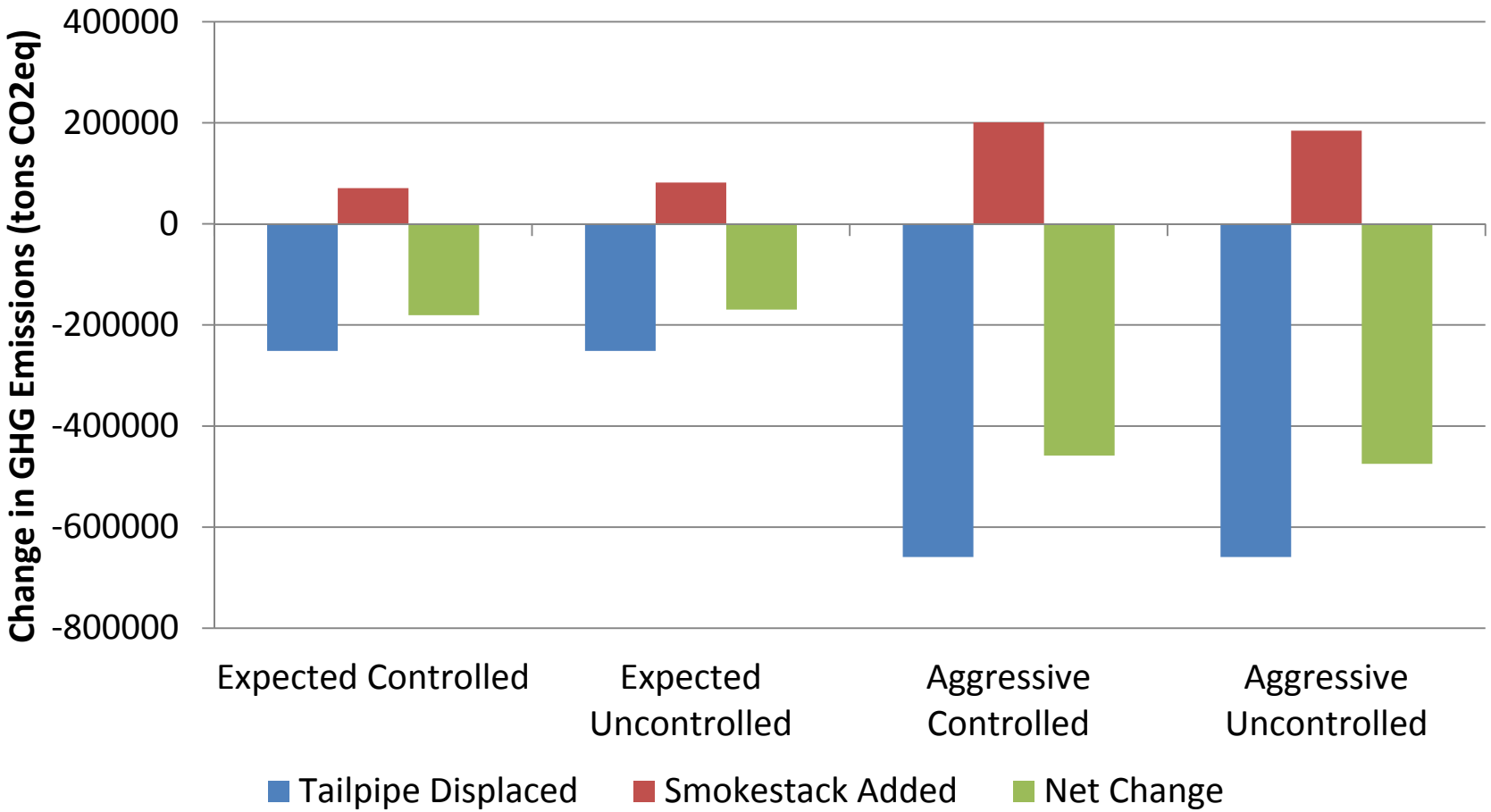
Grid Dispatch Model

- No model will accurately represent individual plants
  - Small heat rate differences
  - Poor representation of transmission constraints
- ARB average emission factors for existing power plants used
- Generation mix will change over time

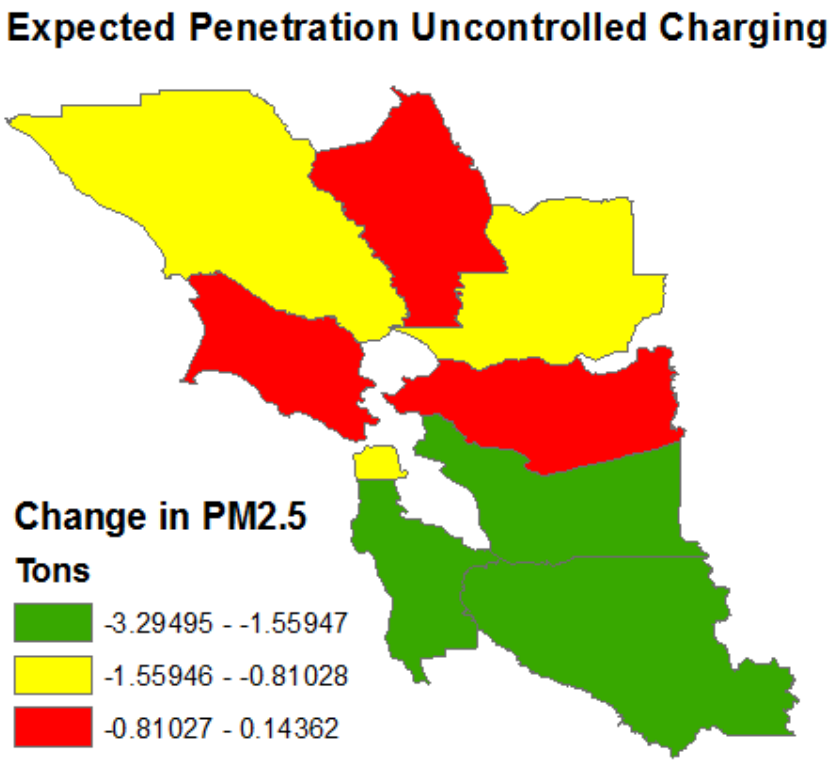
Risk Assessment Model

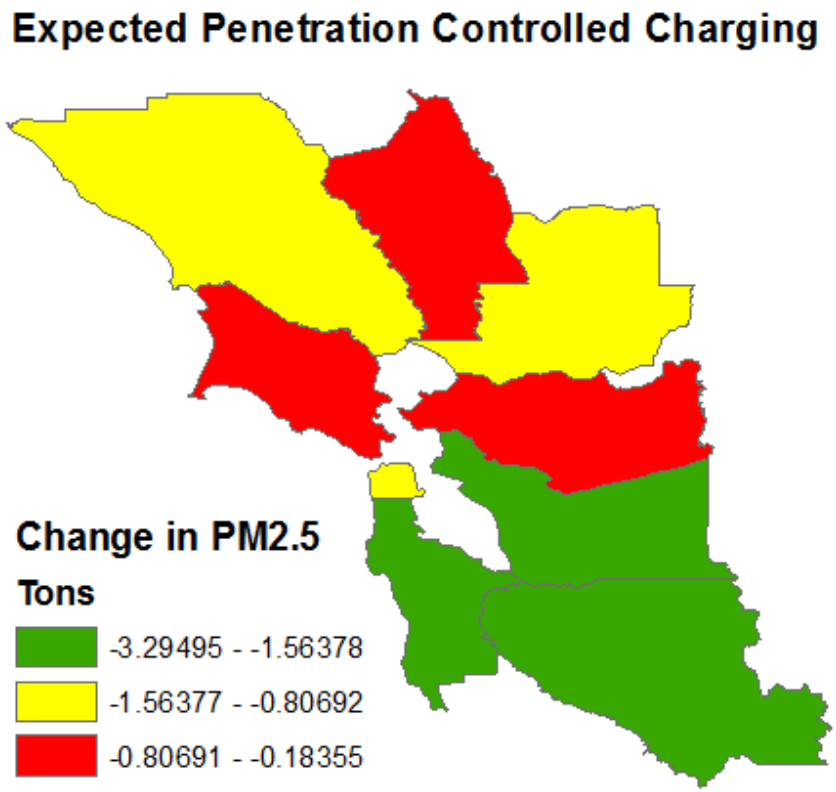
- APEEP differentiates source types into low point, tall point, and ground level
- Use of generic ground level damage costs makes results conservative
  - Tailpipe emissions very high exposure
- No accounting for time dependence of **exposure**
  - People in homes overnight

Absolute GHG Change for Different Scenarios

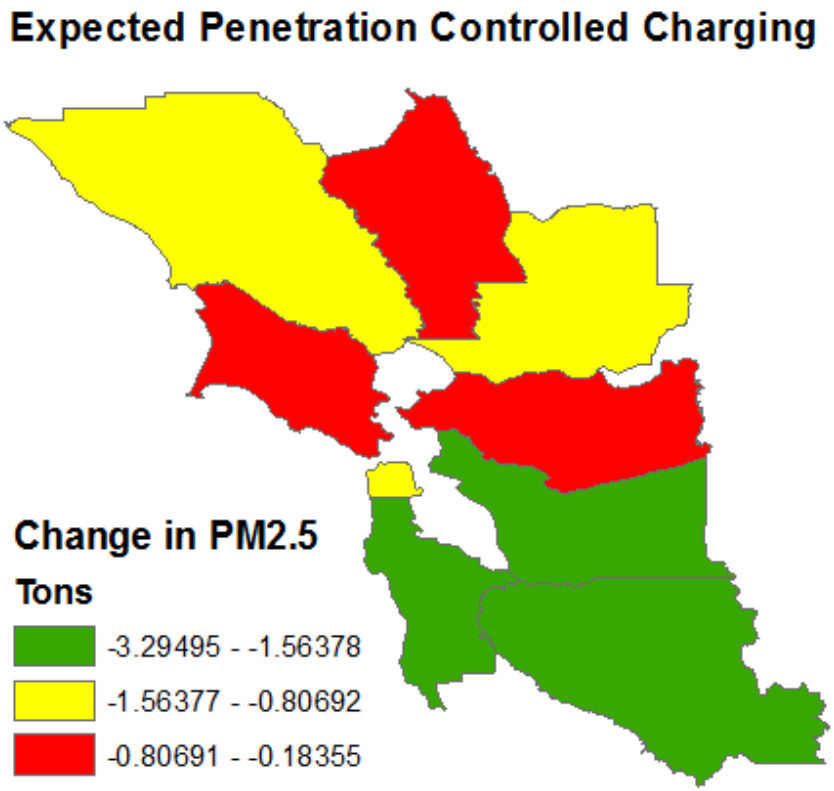


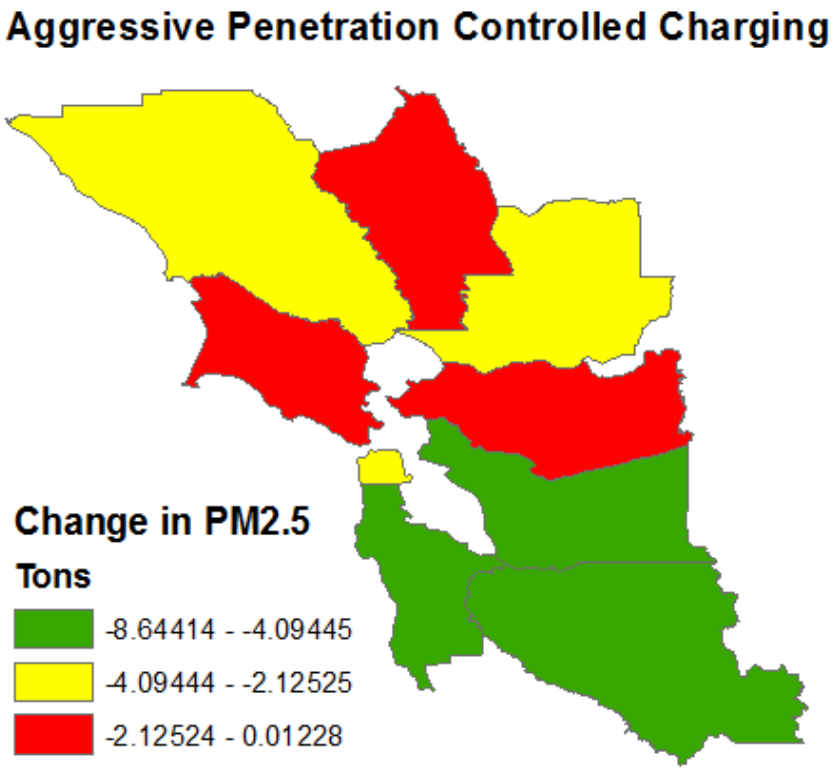
Controlled charge profile offers slight Criteria Air Pollutant reduction





Aggressive penetration more than doubles CAP reductions in Bay Area

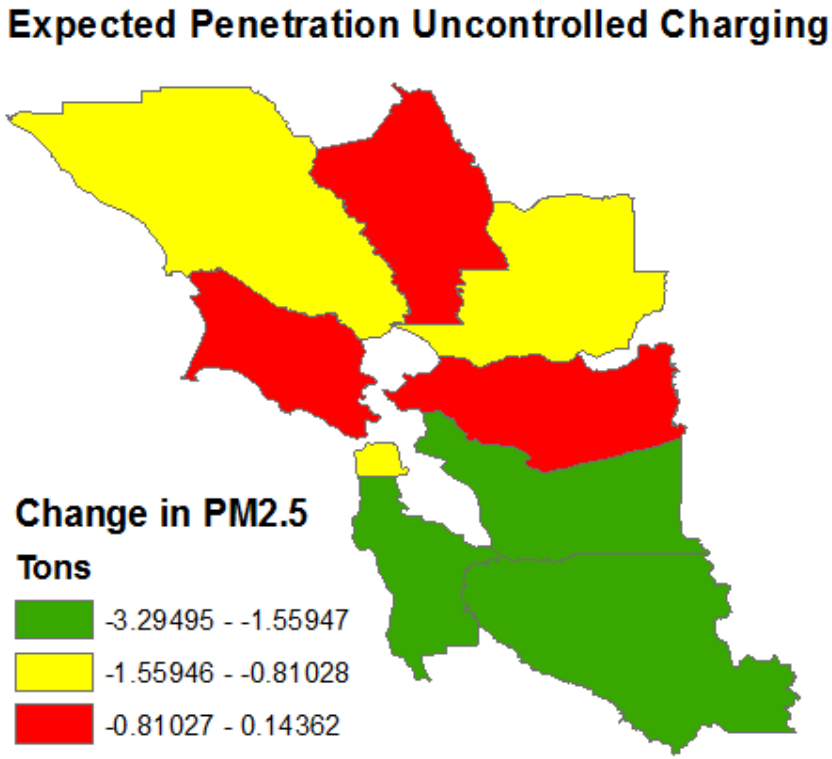


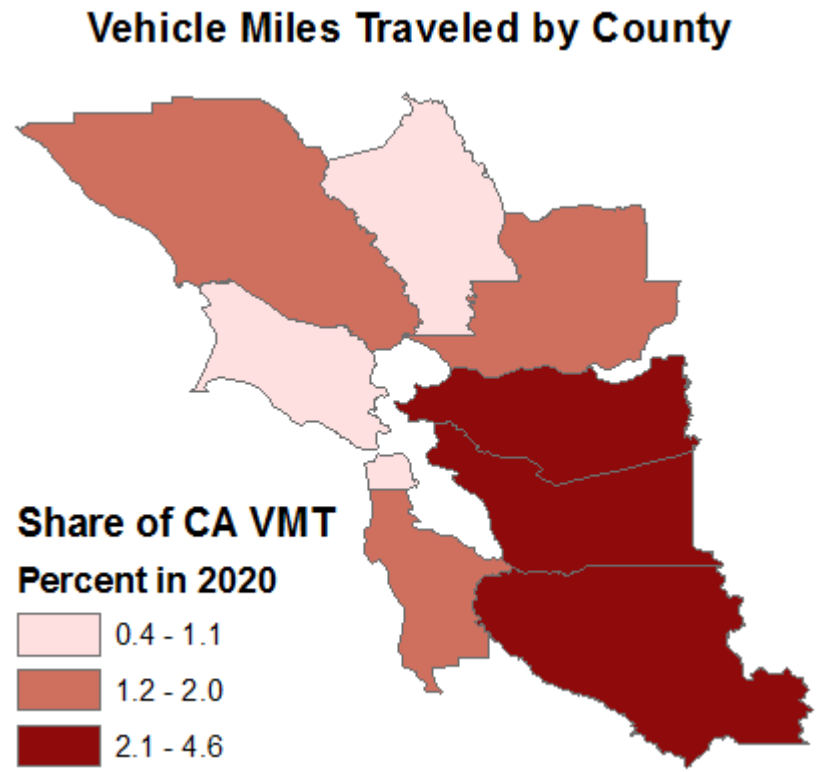


Expected Penetration: 1,200 GWh

Aggressive Penetration: 3,000 GWh

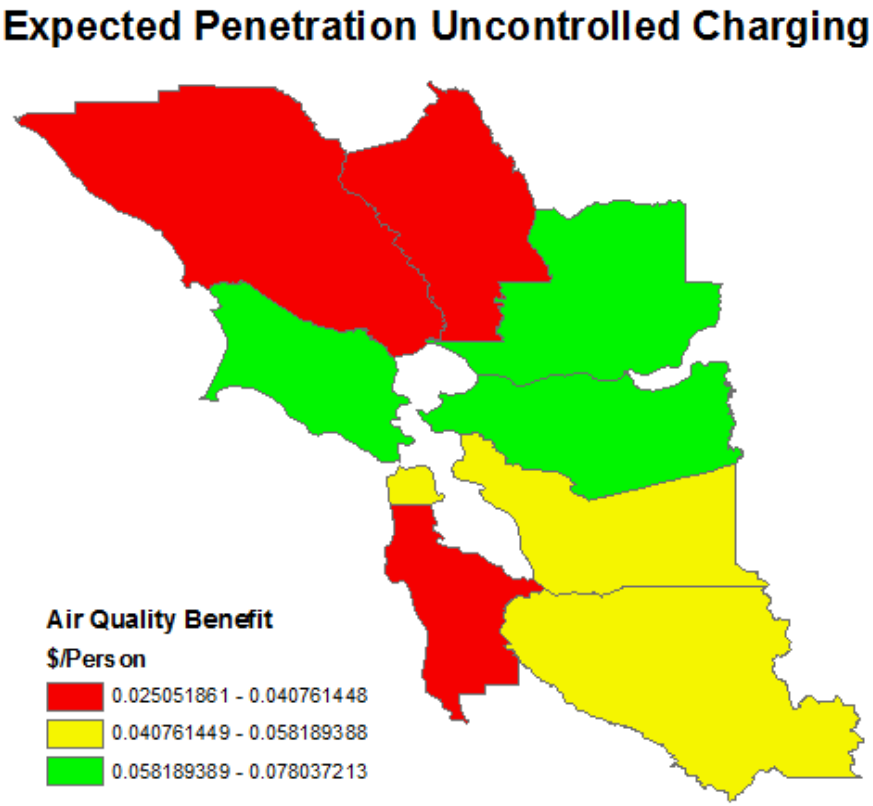
CAP reduction tracks electrified miles closely but NOT completely

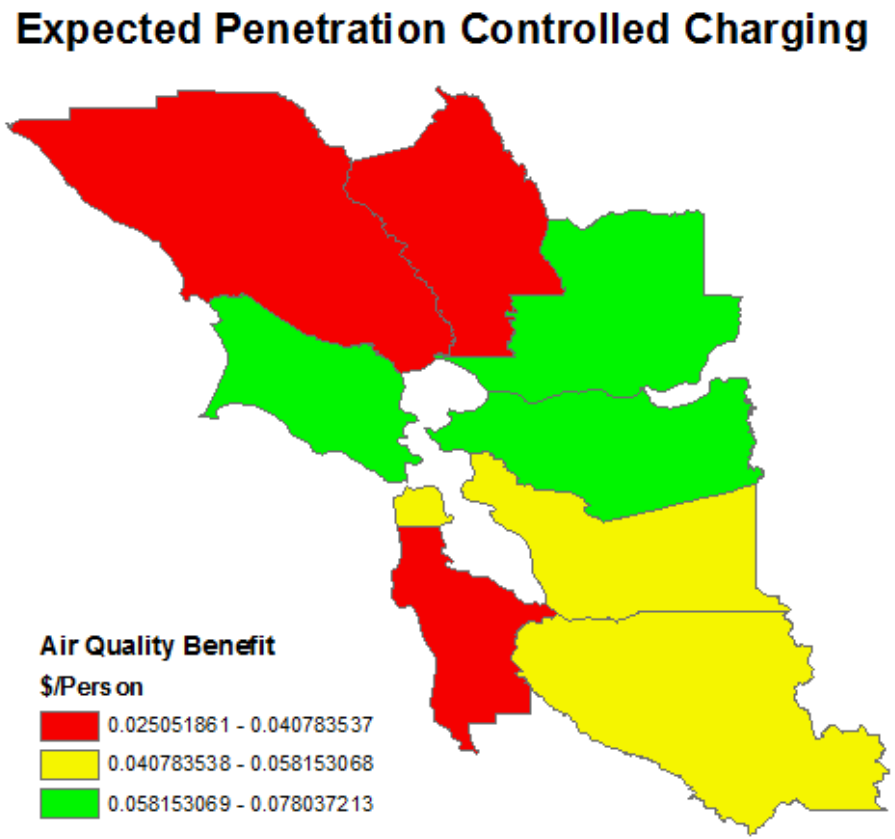




Implies CAP reduction not just function of displacing gasoline miles; location of powerplant emissions also important!

Location and size of air quality benefits insensitive to charge profile

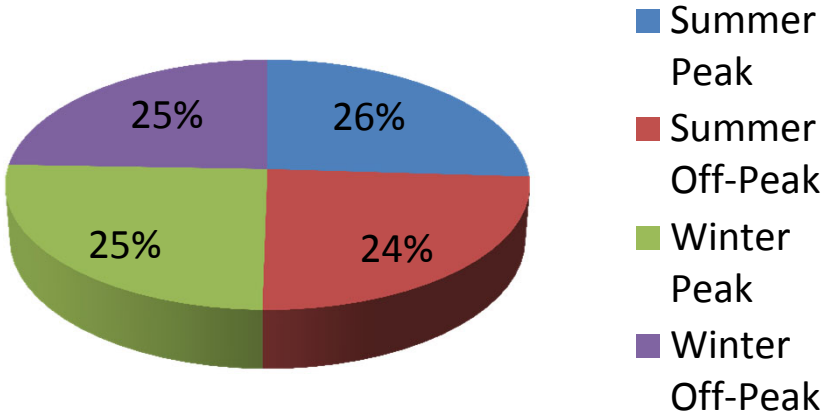




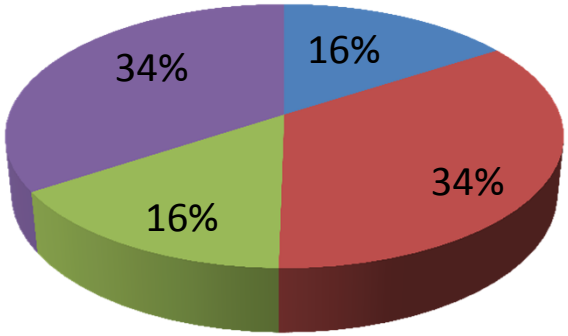
Maps show per capita benefits from reduced emissions of criteria air pollutants (GHGs excluded)

Controlled charging shifts emissions to off-peak

Expected Adoption, Uncontrolled Charging

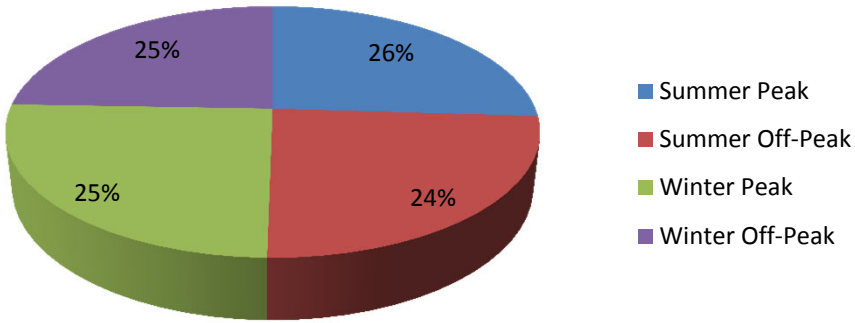


Expected Adoption, Controlled Charging

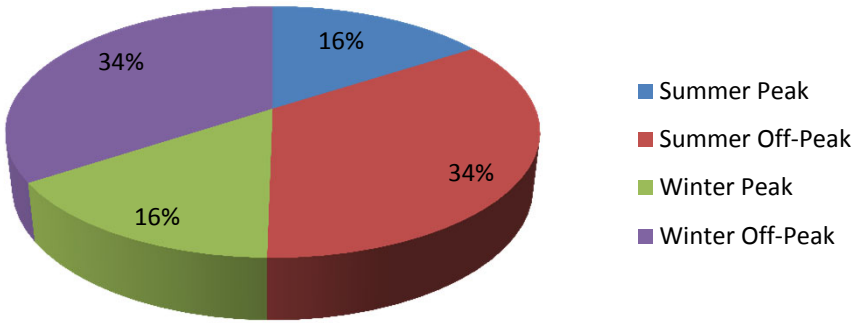


Benefits from controlling charging less at higher levels of PEV adoption

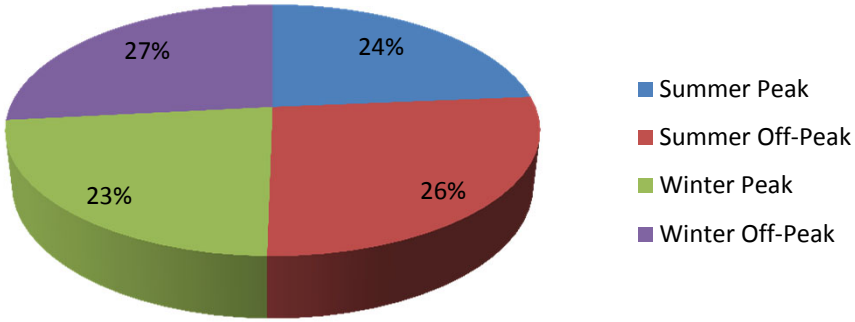
Expected Adoption, Uncontrolled Charging



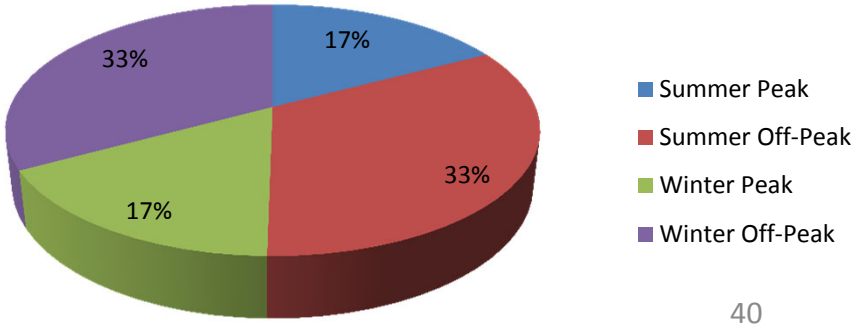
Expected Adoption, Controlled Charging



Aggressive Adoption, Uncontrolled Charging



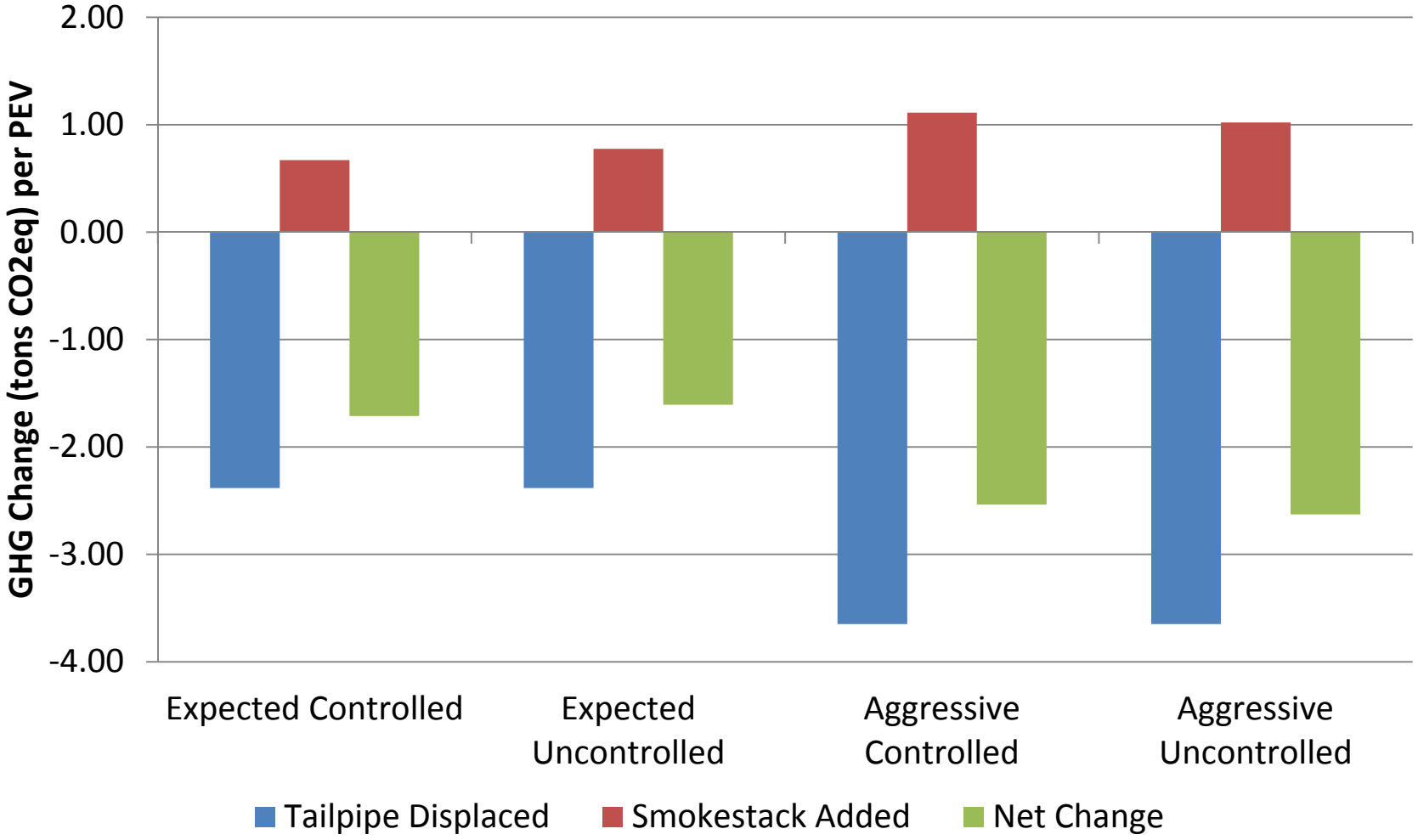
Aggressive Adoption, Controlled Charging



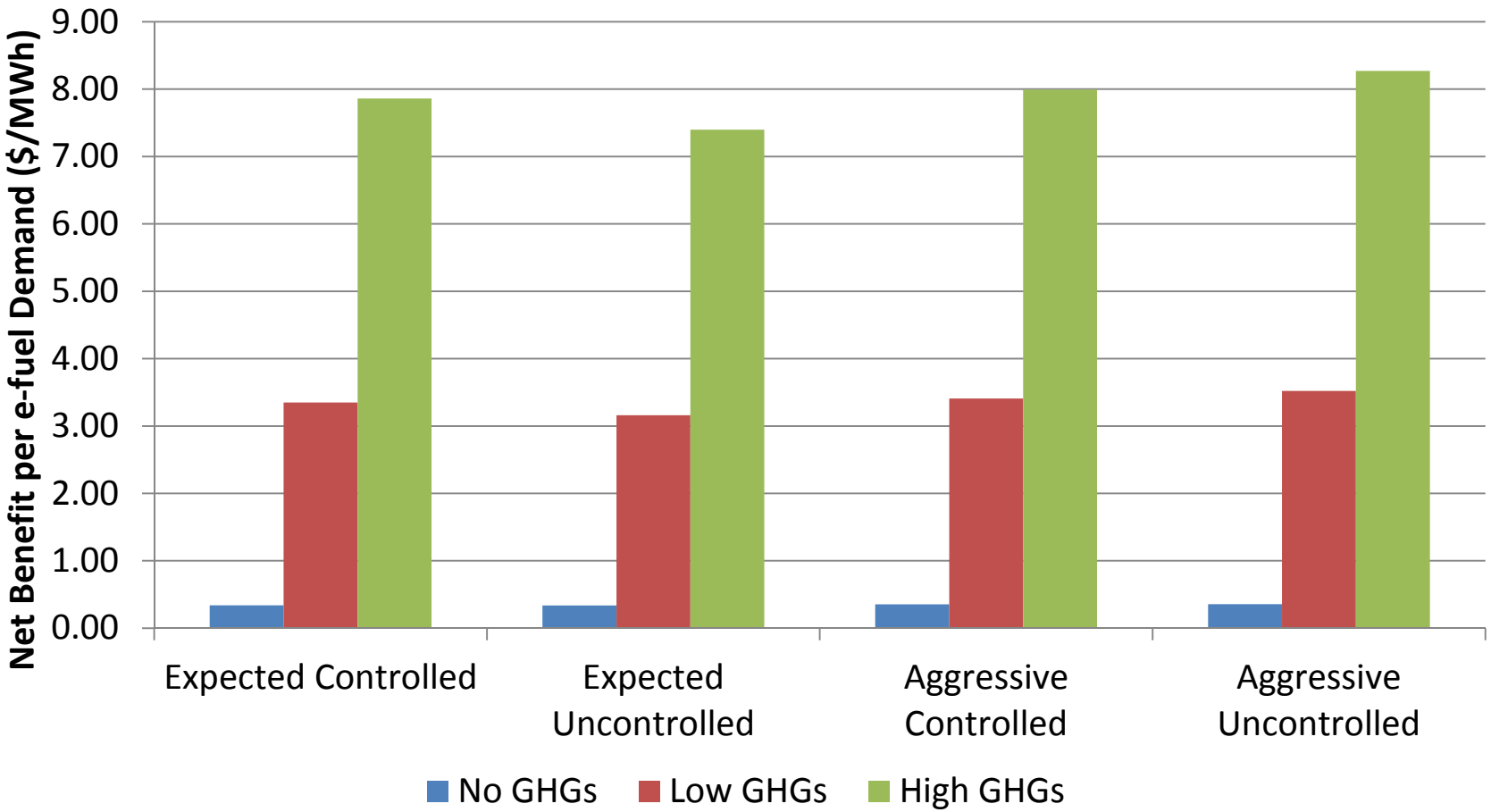
Air quality benefit covers up to 33% of first life cost gap

Generic Conventional Vehicle			Nissan Leaf	
Price	$18,000		Price	$32,780
Annualized (15 yrs, 4%)	($1,619)		Annualized (15 yrs, 4%)	($2,948)
Engine MPG	30		Motor kWh/mi	0.34
Gas Price	$3.50/gal		Electric Price	$0.12/kWh
Annual Gas Cost	($1458)		Annual e-fuel Cost	($510)
Total Annual Cost	($3,077)		Total Annual Cost	($3,458)
First Life Cost Gap			$388	
Per Vehicle AQ Annual Benefit			$40 to $80 (Expected) $60 to $130 (Aggressive)	

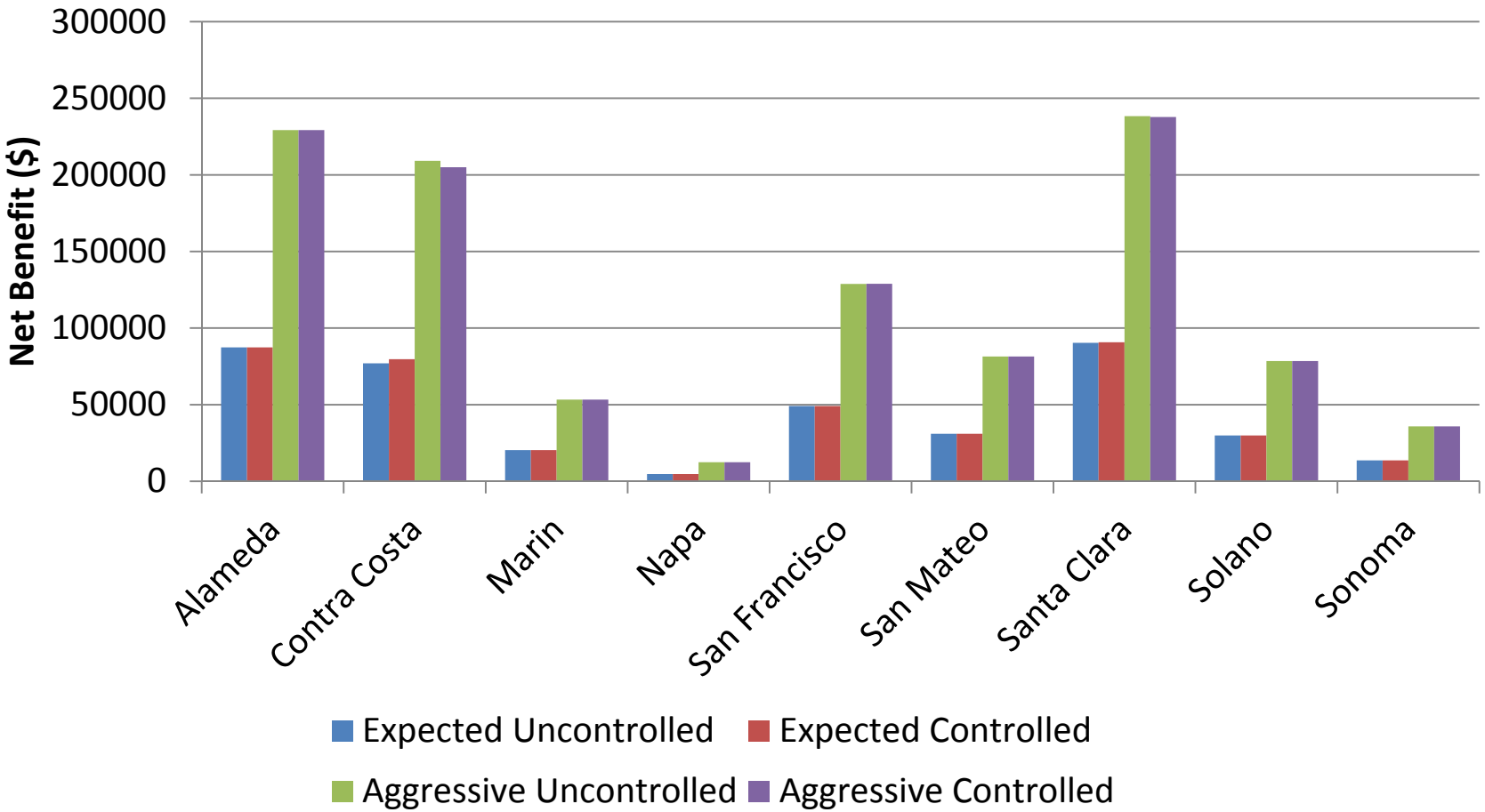
GHG Change Normalized by Vehicle Adoption



Net benefits normalized by e-fuel demand

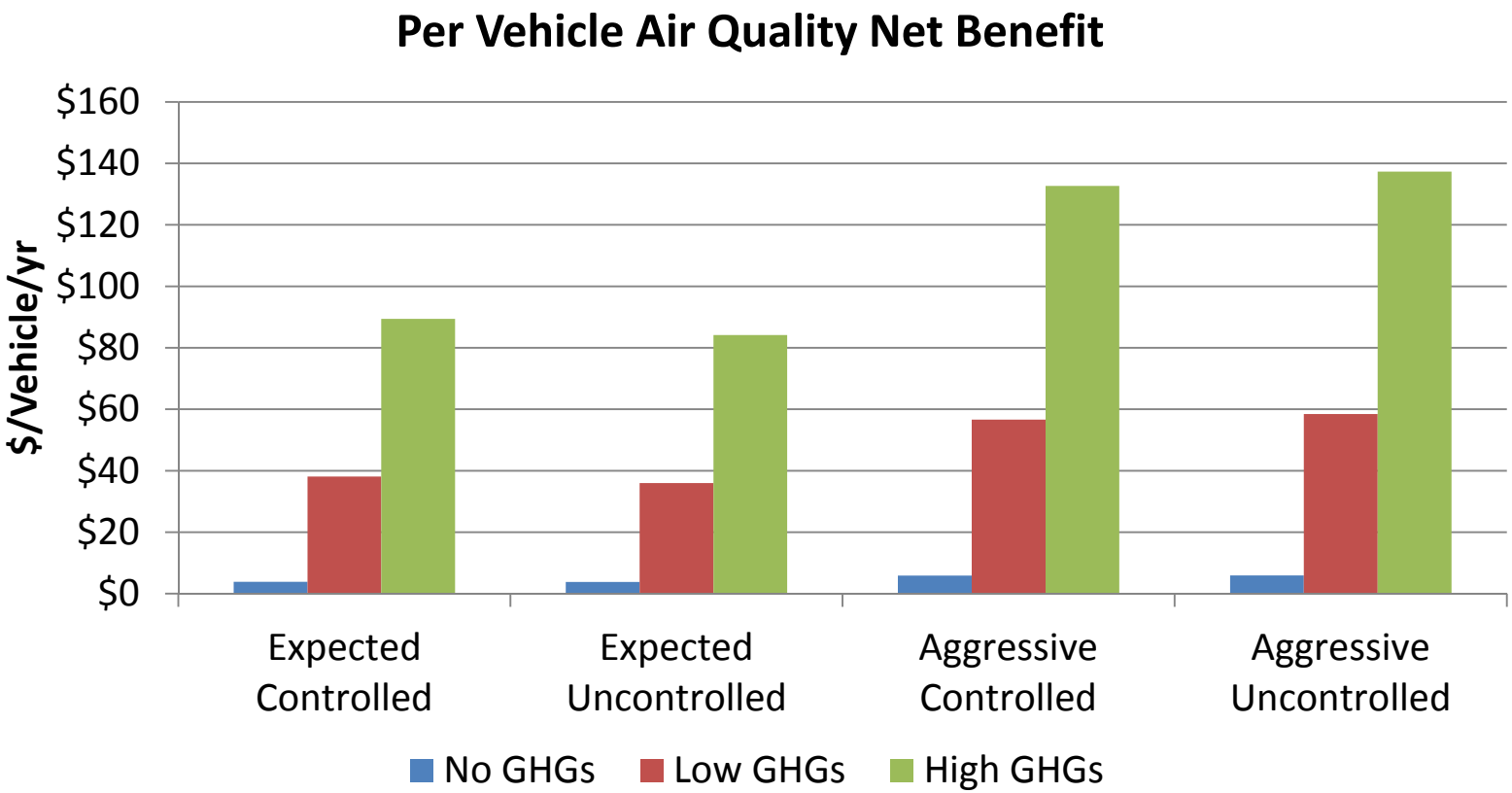


Absolute monetized air quality benefits by county



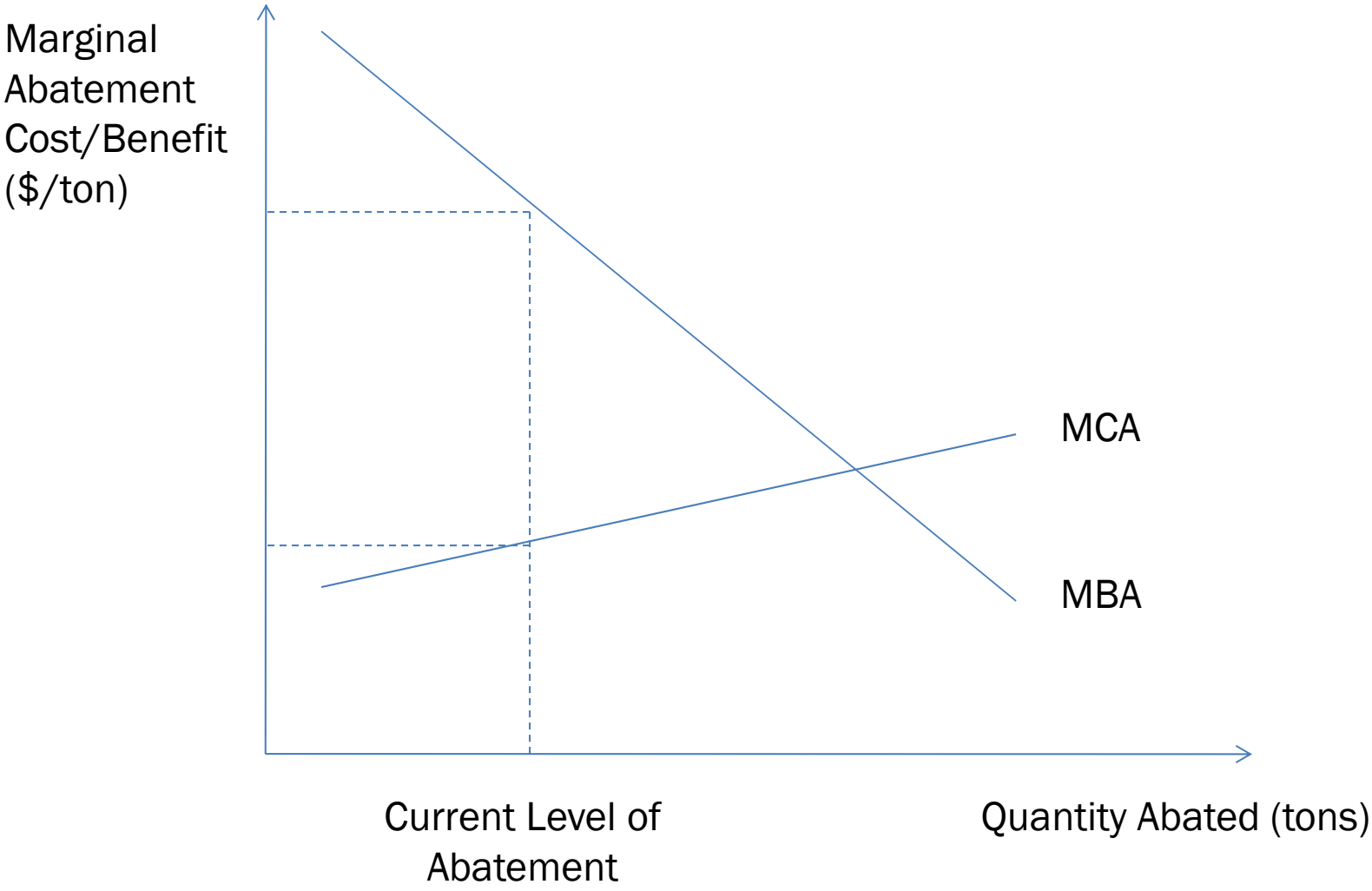
Benefits due to reduced CAPs only (GHGs excluded)

Monetized air quality benefit grows faster than PEV penetration



Recall: CAP impacts likely undervalued because generic ground level MBA ($/ton) values used – LDVs = very direct exposure

The economics of an externality



Caveats with subsidies

- Disadvantage - blunt instrument
  - Trying to influence fuel consumption behavior by pricing the vehicle
  - GHGs – pricing carbon would accomplish same objective and more
  - CAPs – difficult to establish market for individual drivers; problematic to assess upstream since impacts depend on use
- Advantages
  - Politically easy – no organized constituency bears cost
  - Can help prime demand – EV industry growth