Transportation Electrification Assessment

Prepared for:

California Electric Transportation Coalition

December 19, 2014

Overview

- Introductions – Organizations & Key Staff
- Introduction to the Transportation Electrification Assessment
- Cost and Benefits of Electrification Technologies
- PEV Forecasts for Grid Impacts Modeling
- Market Gaps and Barriers and Potential Solutions
- Grid Impacts Modeling

Introduction

Overview of Project

Project Objectives

ICF and E3 are providing analytical support to CalETC and its members to characterize the benefits of electrification technologies. Two key aspects of the study:

- **Utility Coordination**: This project includes active coordination and collaboration from utilities – PG&E, SCE, SDG&E, SMUD, City of Palo Alto, LADWP, and CMUA members. Engagement of so many utilities demonstrates the collective commitment of the industry to develop a coordinated plan related to electrification.

- **Changing landscape**: With the new OIR from the CPUC, there is a change in the landscape for electrification. Generally speaking, the current trajectory in California, as it pertains to electrification, will achieve one class of benefits. This study seeks to determine: What *could* the trajectory be and what benefits are we leaving on the table? And what is the course of intervention to change the current trajectory?

Work Flow (1 of 2)

Phase 1 of Transportation Electrification Assessment

- **Assess existing studies**: Literature review of transportation electrification opportunities. Dozens of reports reviewed. Focusing on 18 segments.
- **Market sizing**: Segment-by-segment forecasting for 2020 and 2030.
- **Cost and benefits of selected segments**: Reviewing the costs and benefits of selected TE segments. Considering incremental up-front costs, the incremental infrastructure costs, incremental benefits including lower operational costs for TE vehicles and equipment, and cost savings from lower electricity fuel costs.
- **Identify market gaps/barriers and potential solutions to address gaps/barriers:** Focusing on mitigation recommendations that could be implemented for whole or partial gaps and barriers. Identifying the party or parties that would be responsible for implementing the solution or corrective action necessary to address the gap or barrier. Keeping in mind that there may be some market gaps barriers for which there is no immediate mitigating solution.

Work Flow (2 of 2)

Phase 2 of Transportation Electrification Assessment

- **Grid impacts of light duty plug-in electric vehicles:** Considering a variety of impacts including generation, energy, transmission/distribution, ancillary services, losses, increased RPS procurement.

Potential Future Work (Phase 3)

- CalETC considering targeting future analysis of the grid impacts of off-road technologies with the largest potential impact (e.g., forklifts)

Costs and Benefits of Electrification Technologies

Electrification Technologies

Detailed Forecasting Update and Cost Analysis	Detailed Forecasting Update	Projection to 2030 from Previous Forecast
• *PEVs (PHEVs and BEVs)* • Forklifts • Truck Stop Electrification • Transportation Refrigeration Units	• Shore Power • Port Cargo Handling Equipment • Airport Ground Support Equipment • High Speed Rail • Light (including trolley buses) and Heavy Passenger Rail (BART, LA Metro, SDMTS) • Commuter Rail (Caltrain) • Dual Mode Catenary Trucks on I-710/SR60 • Medium- and Heavy-Duty Vehicles	• Lawn & Garden • Sweepers/Scrubbers • Burnishers • Tow Tractors/Industrial Tugs • Personnel/Burden Carriers • Turf Trucks • Golf carts

Detailed Forecasting

- **Detailed forecasting includes the following:**
  - Literature review to reassess the current market and future market conditions
  - Contacting industry and government experts (including ARB, CEC and EPA) to characterize the future market conditions and regulatory drivers
  - Forecasting future populations and GWh of electricity consumption for three cases:
    - "In Line with Current Adoption" is a low case based on anticipated market growth, expected incentive programs, and compliance with existing regulations; for build/no-build projects like HSR and I-710 catenary could be zero
    - "Aggressive Adoption" is a high case based on aggressive new incentive programs and/or regulations and make sure the high cases are tangibly aggressive and not simply hypothetical maximum
    - "In Between" is a medium case that will fall somewhere in the middle and will vary by technology
  - A working group consisting of utility representatives helped review the electrification forecasts prior to calculation of benefits and costs

Costs and Benefits of Electrification Technologies

- **Based on the projected GWh and populations for each technology and their comparison conventional fuel technologies, the following societal benefits were calculated for all technologies:**
  - GHG emission reductions
  - Criteria pollutant emission reductions
  - Petroleum displacement
- **The lifecycle cost or savings of electric technologies were analyzed by including the following aspects of lifecycle cost:**
  - Equipment costs
  - Infrastructure costs
  - Operations and maintenance
  - Fuel costs
  - Equipment lifetime

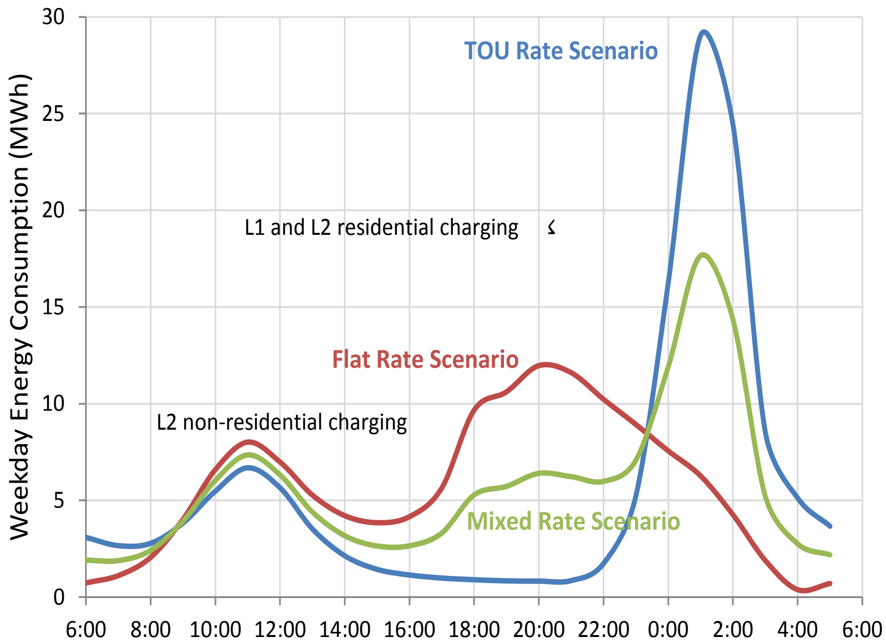
Light-duty PEV Forecasts

Background and Assumptions for
a) Cost-Benefit Analysis and b) Grid Impacts Modeling

Developing scenarios

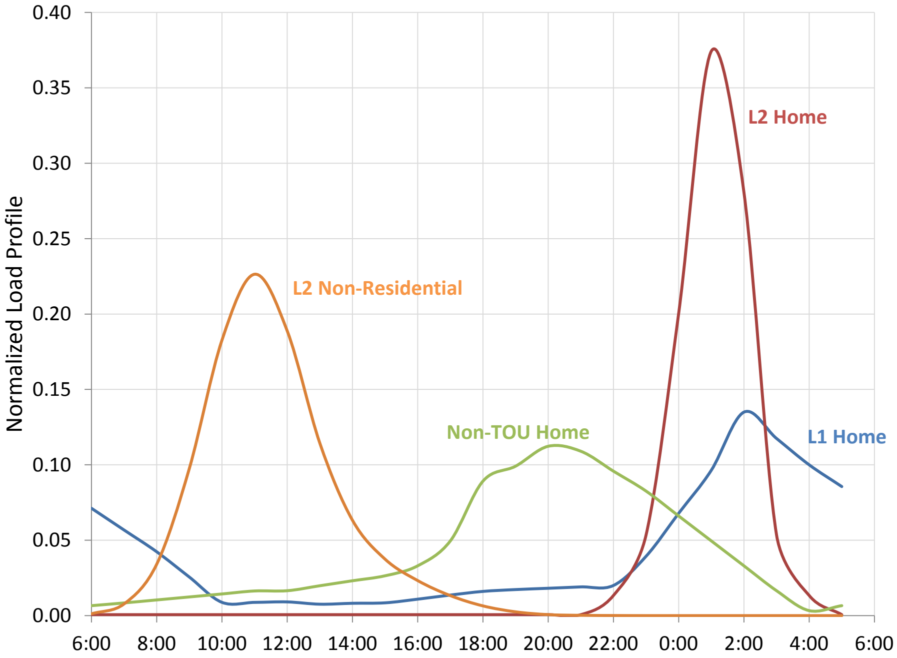
- **Multiple Scenarios**
  - TOU Rate Scenario
  - Domestic Rate Scenario
  - Mixed Rate Scenario
- **Each scenario is developed considering**
  - Load shapes
  - Level of charging: L2 and L1
  - Location: residential and non-residential
  - Vehicle Forecasts: Number and Type (PHEV vs BEV)
  - Energy Consumption

Illustrative Scenario for 15,000 PEVs



Load shapes

- **L2 residential charging, TOU rate:** Level 2 charging at home is a proxy for BEV or PHEV40 charging.
- **L1 residential charging, TOU rate:** Level 1 charging at home is a proxy for charging of PHEVs with smaller batteries, like the PHEV10 or PHEV20. The normalized profile is based on a similar start time as L2 charging; however, it is stretched out over a longer period.
- **Residential charging, Domestic rate:** Residential charging in the non-TOU case is a modified version of what is reported in the EV Project for Nashville, Tennessee – a region without a TOU rate. The modifications were made based on the at-home arrival times (at home) reported in the National Household Transportation Survey (NTHS).
- **L2 non-residential charging:** The non-residential charging is a proxy for workplace charging (weekdays) and public charging (weekends) and is used in the TOU scenario and the Flat Rate Scenario (described in more detail below) and scaled incrementally in a modification to each scenario.

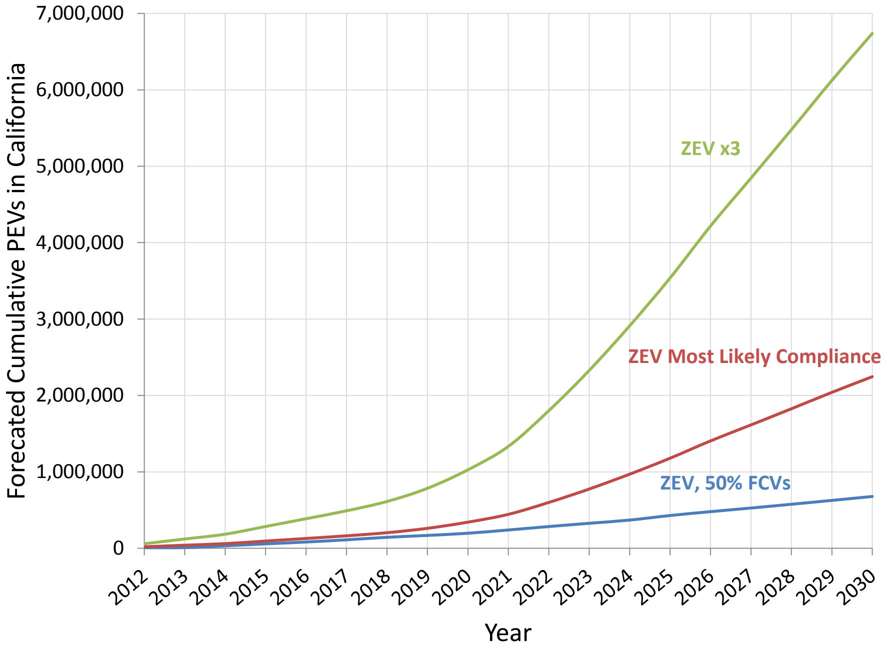


PEV Forecasts – Three Scenarios representing range of adoption

- **ZEV Program with 50% Compliance from FCVs:** Compliance with the Zero Emission Vehicle Program and modifying the most likely compliance scenario to achieve 50% compliance from FCVs.

- **ZEV Program "Most Likely Compliance Scenario" from CARB:** In the development of the Zero Emission Vehicle Program, CARB staff developed a most likely compliance scenario. There were some modifications to this scenario to reflect recent PEV sales data.

- **ZEV Program Scenario x 3:** This scenario is a factor of three larger than the ZEV program's most likely compliance scenario.



Energy Consumption

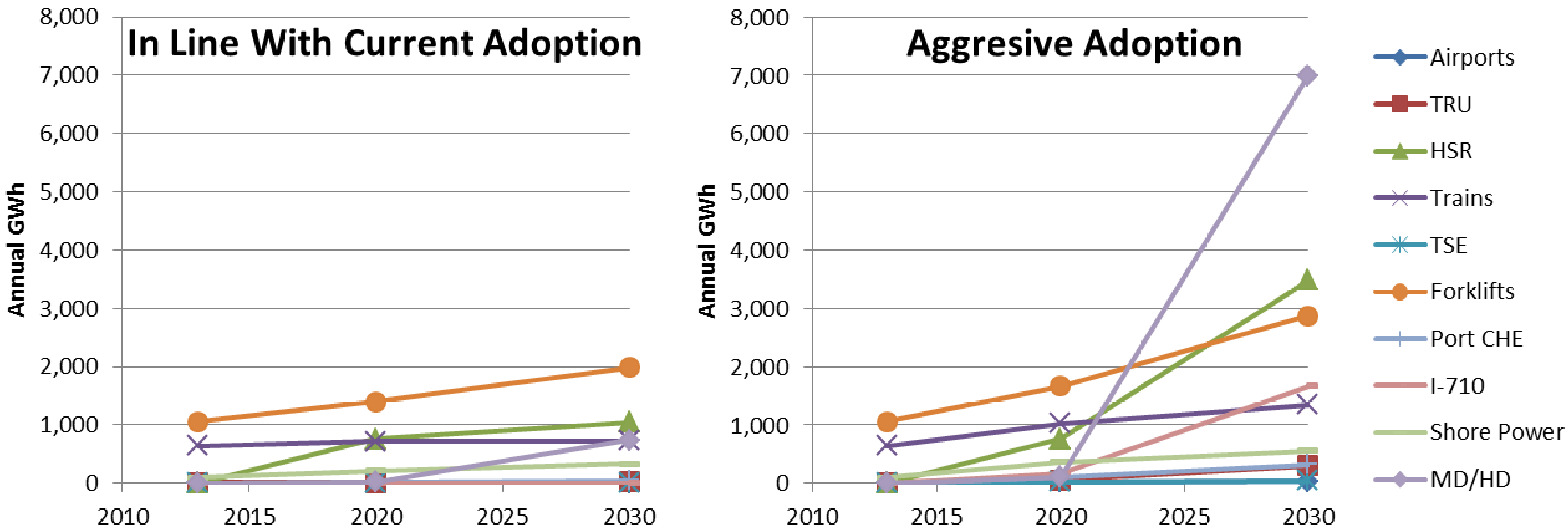
Vehicle Type	VMT		eVMT		Energy Consumption (kWh)					
					Daily			Annual		
	Daily	Annual	Daily	Annual	Res	NonRes	Total	Res	NonRes	Total
PHEV10	41.0	14,965	10.0	3,650	2.8	0.7	3.5	1,022	256	1,278
PHEV20			20.0	7,300	5.6	1.4	7.0	2,044	511	2,555
PHEV40			30.6	11,169	8.6	2.1	10.7	3,127	782	3,909
BEV	29.5	10,768	29.5	10,768	8.3	2.1	10.3	3,016	754	3,770

Developed modification for each scenario whereby the eVMT for each PEV-type is increase by one mile per day per year, not to exceed 39 daily VMT. Additional charging is assumed to happen on commercial circuits.

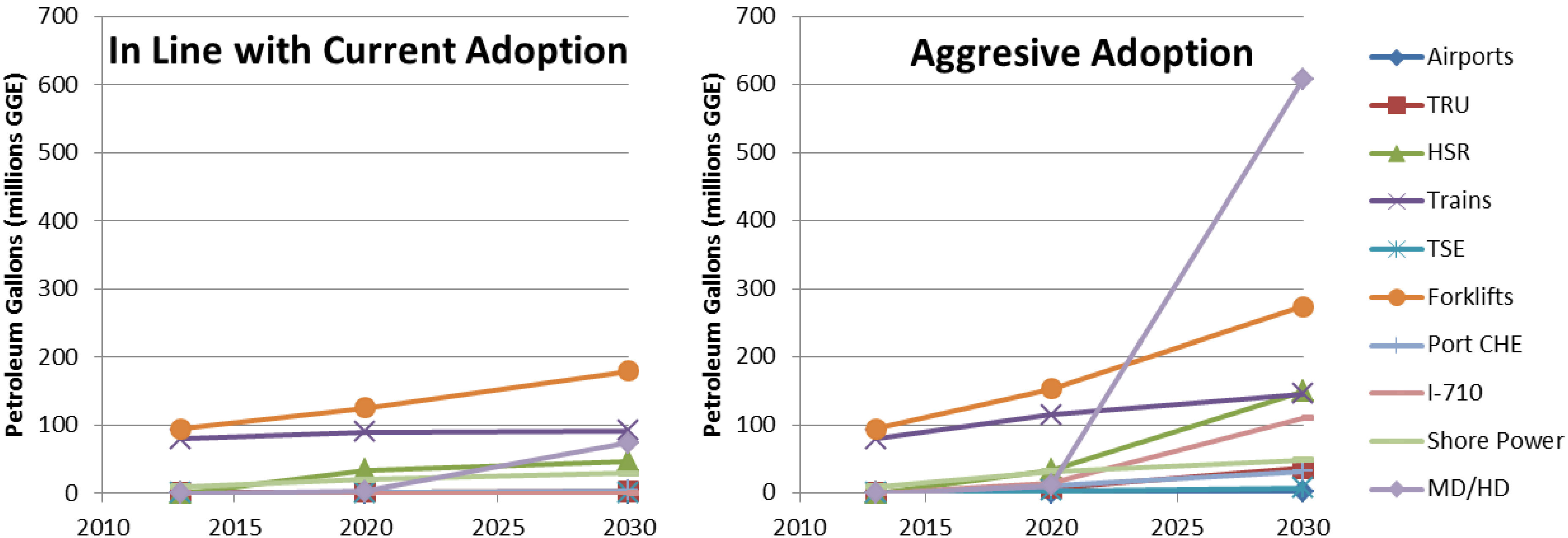
Overview of Results

Electricity Consumption, Petroleum Displacement, GHG Emission Reductions

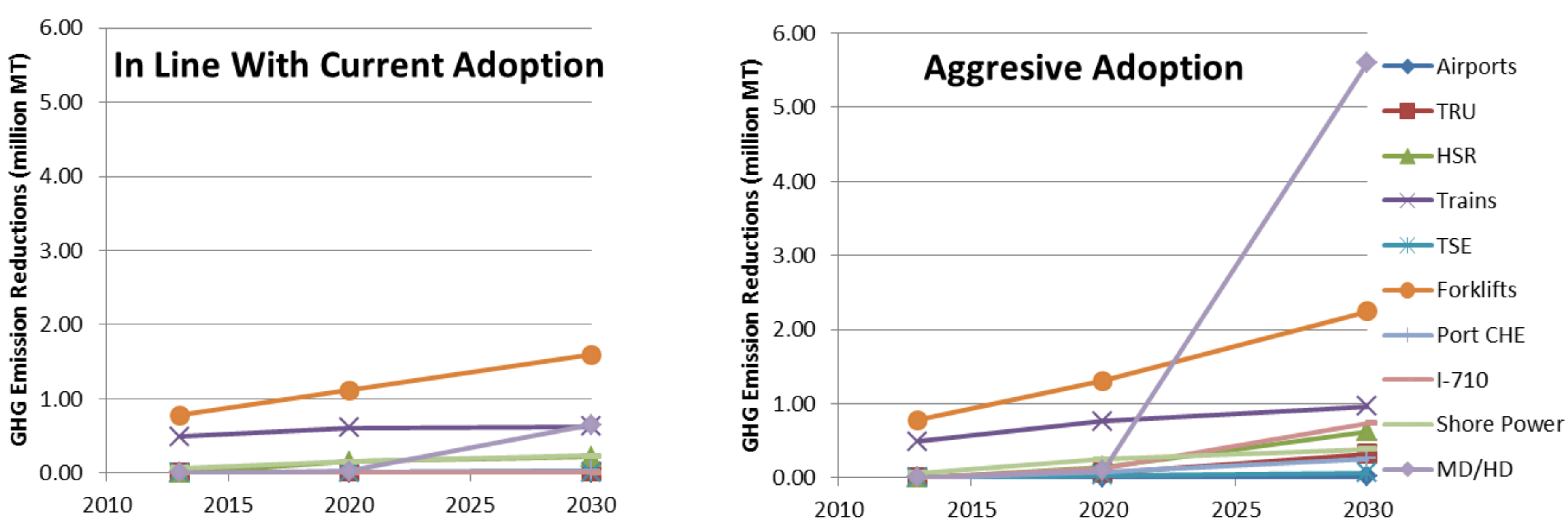
Electricity Consumption



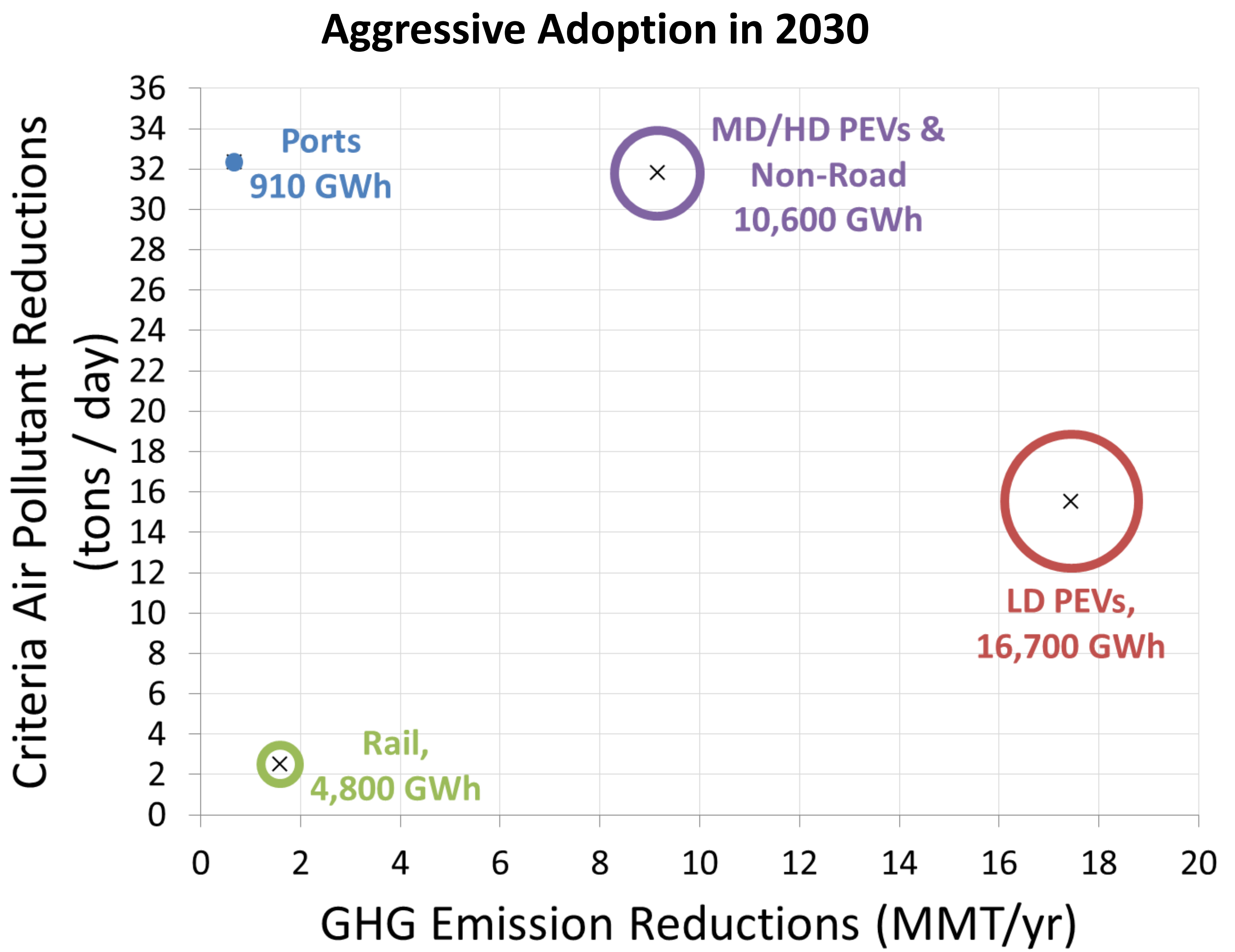
Petroleum Gallons Displaced



Greenhouse Gas Emission Reductions



Comparison of Transportation Electrification Segments in 2030



Market Gaps and Barriers and Potential Solutions

Potential Solutions to Maximize PEV Adoption

Main Areas of Focus (1 of 2)

Market Gaps and Barriers		Potential Solutions
Consumer Costs	• Upfront vehicle costs • Upfront charging infrastructure (EVSE) costs • Vehicle operating costs; need for competitive charging rates for PEVs and shift in traditional billing paradigm	• Increased publicity and continued availability of existing incentives • Creative use of utility LCFS credits or utility developed programs (e.g. battery second life) to reduce the upfront vehicle or EVSE costs • Improved PEV charging rate structures to increase the reduced fuel cost benefits for drivers
Charging Infrastructure	• Lack of information available to single family homeowners seeking to decide between Level 1 and Level 2 charging installation • Little to no progress made in deploying charging at multi-dwelling units; MDU installations are particularly challenging due to technical and logistical issues • Lack of investment in workplace charging infrastructure to date	• Engage MDUs/HOAs, employers and workplace parking providers as a trusted advisor regarding optimal and cost-effective EVSE solutions

Main Areas of Focus (2 of 2)

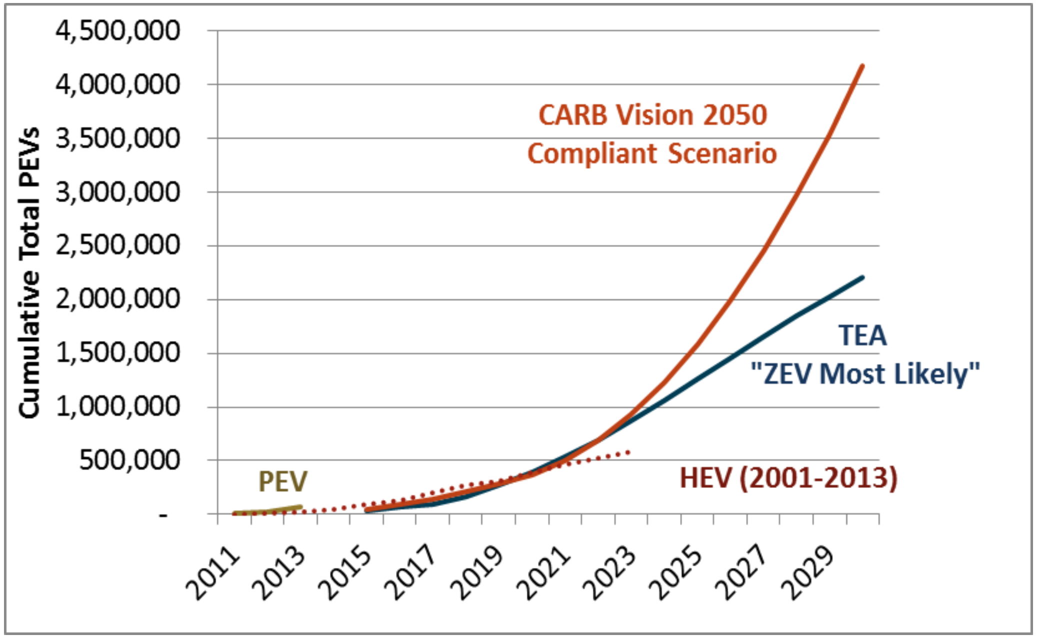
Market Gaps and Barriers		Potential Solutions
Sustainability of Third-Party Ownership of EVSE Networks	• Sustainability of revenue model is frequently challenged and has not been convincingly demonstrated • Demand for non-home charging is unclear due to several factors: vehicle purchasing behavior, consumer willingness to pay for charging, and charging needs/behaviors	• Alternatives to additional public investment in charging infrastructure • Revisiting the CPUC ruling regarding utility investment in charging infrastructure • Improved evaluation of charging infrastructure deployment
Consumer Education and Outreach	• General lack of PEV awareness and knowledge • Total cost of vehicle ownership is poorly understood • Disparate efforts to improve PEV education	• The utility acting as a trusted advisor in the PEV market • Engage with PEV ecosystem partners
Vehicle Features	• Limited vehicle offerings in marketplace	• Modifications to the ZEV program to incentivize the development of PEVs outside of traditional market segments (e.g. subcompacts or midsize sedans)

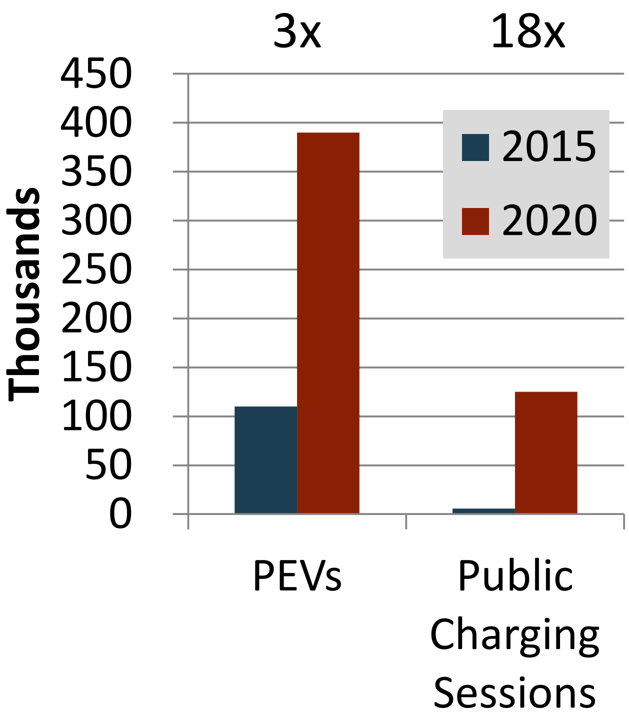
Appendix | Phase 2: Grid Impacts Modeling

Distributed Energy Resource Modeling

Energy+Environmental Economics

Infrastructure Investment Required





- ~90% of car buyers are not familiar with electric vehicles (nationally)
- Will saturate early adopter market segment soon
- Need to reach beyond single-family home owners

Utility Role in Transportation Electrification

- **Customer, EVSE and utility investment in infrastructure is needed to provide readily accessible charging for higher penetrations of PEVs**

Hearing Room	Board Room
✓ PEVs provide environmental and societal benefits	✓ PEVs increase revenues with "good" load
✓ PEVs will reduce rates for all customers	✓ PEV load creates headroom for capital investment without rate increases
✓ PEVs pass cost-effectiveness tests	✓ PEVs can increase shareholder earnings
✓ Utility investment accelerates PEV adoption	✓ Utility investment provides positive customer engagement

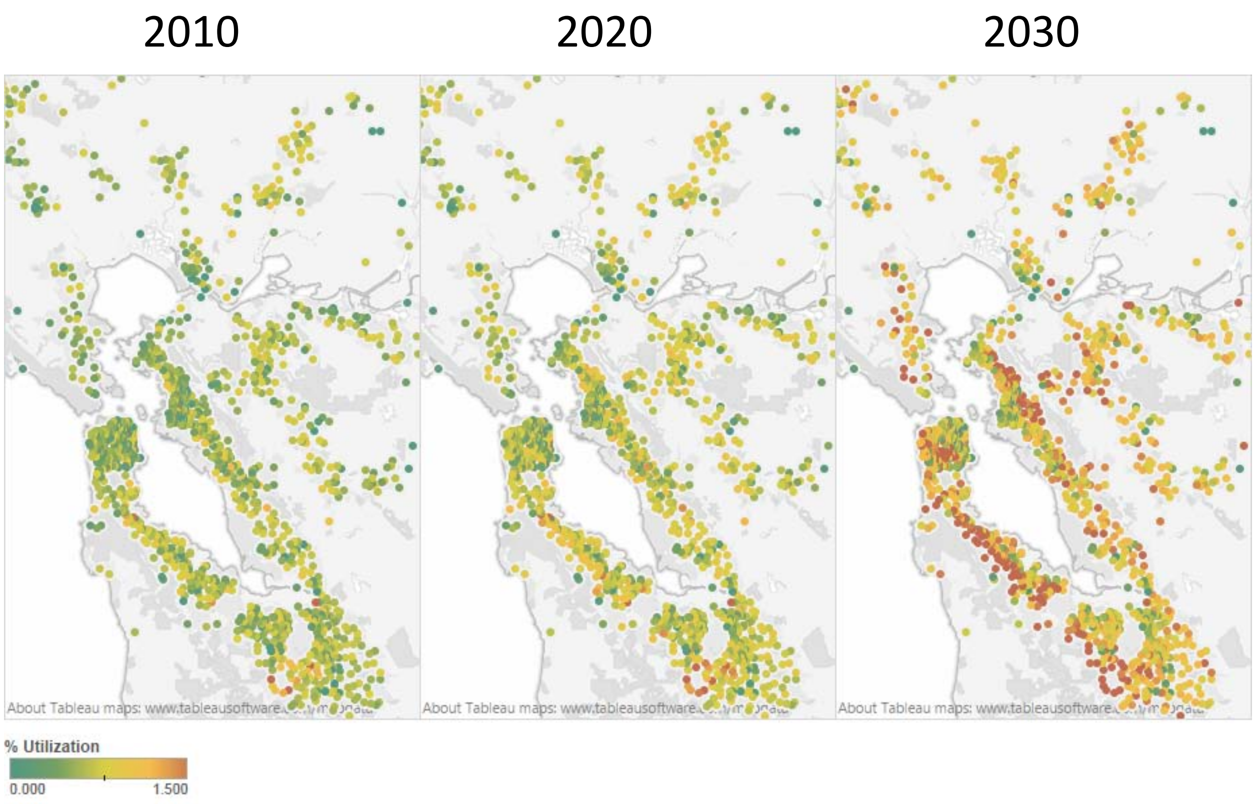
Utility Role in Transforming Transportation

- **Utility planning (Yesterday)**
  - **meet forecasted load with lowest utility costs and emissions**
  - Pass "standard" cost-effectiveness tests

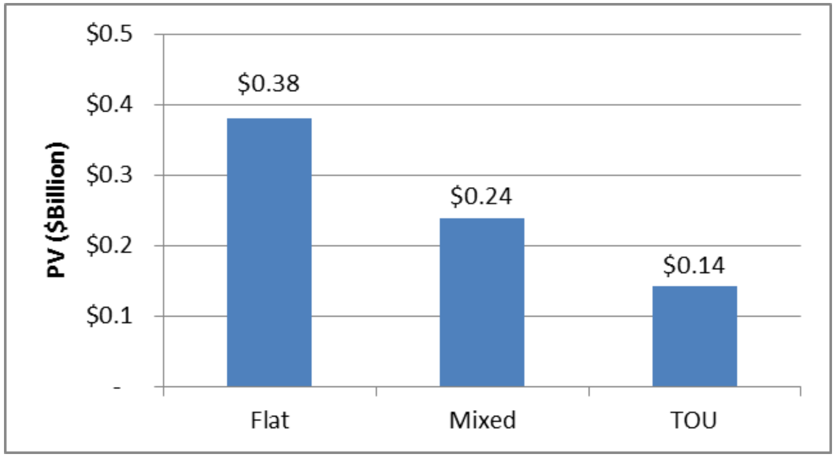
- **Electrifying transportation (Tomorrow)**
  - **meet GHG and criteria pollutant targets at lowest regional cost**
  - Requires rapid adoption of new technologies with cross-sector coordination
  - Requires expanded cost-effectiveness framework with new metrics

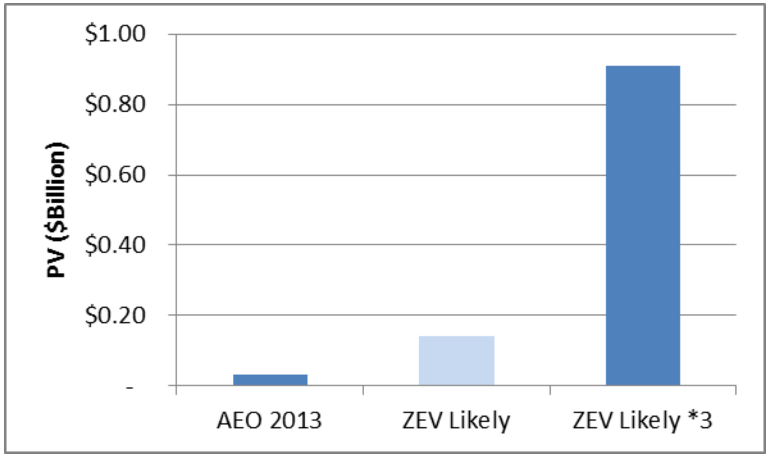
Grid Impact Overview

- **Emphasis on quantifying distribution impacts**
- **Map PEV Clusters and load shapes to individual feeders and substations**
- **Utilities provided**
  - equipment rating
  - peak day load shape
  - forecasted load growth
- **Calculate upgrades required at each location**
- **Found minimal upgrade costs even at higher penetration scenarios**



Distribution Upgrade Costs





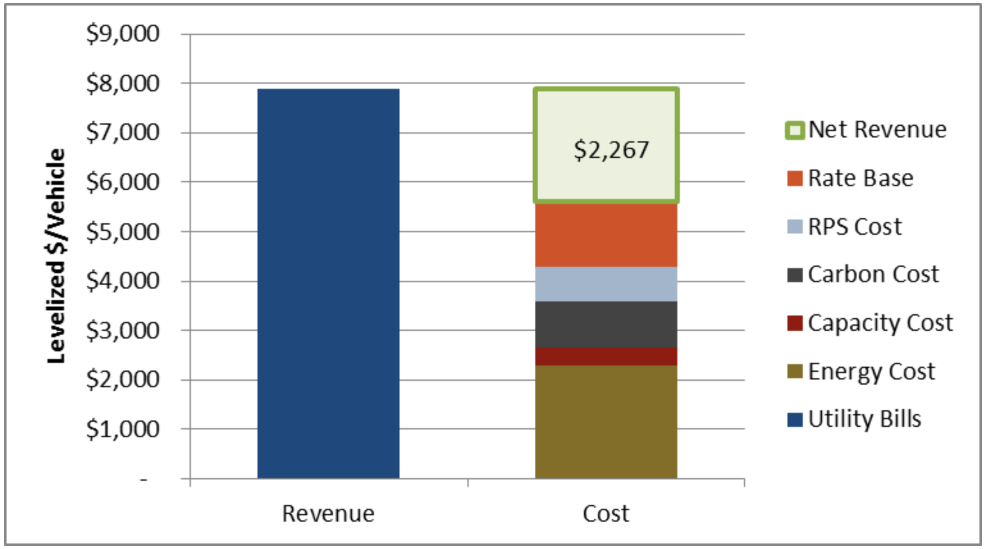
- **Managed charging reduces distribution upgrade costs by 60%**
- **Distribution costs are manageable under current trajectory**

- **Bigger cost challenge: "make-ready" and circuit upgrades for higher concentrations of multi-family, workplace and fast DC charging**

Standard Cost-tests (for EE, DR, DG)

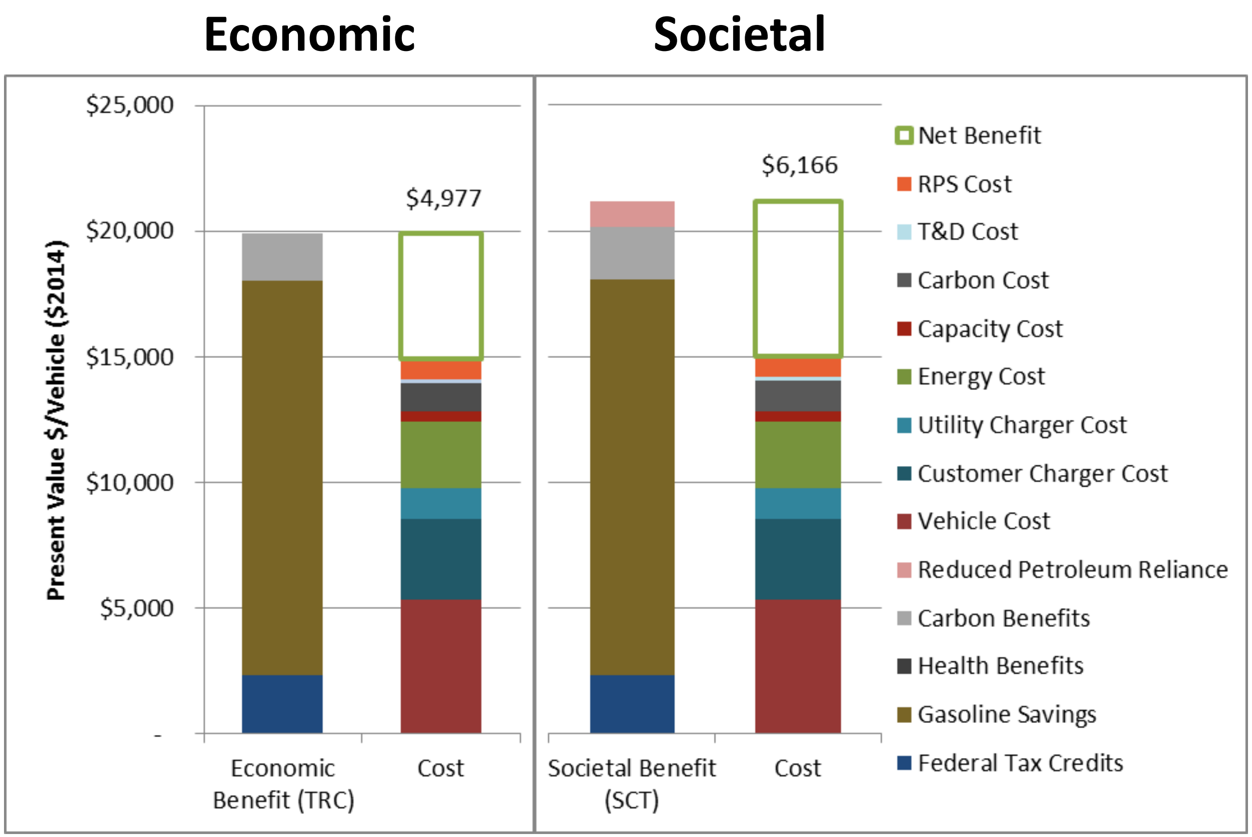
Cost Test		Key Question Answered	Summary Approach
Ratepayer Impact Measure	RIM	**Will utility rates for non PEV owners increase?**	**Comparison of utility infrastructure and supply costs to retail bill revenues**
Total Resource Cost	TRC	**Are there net economic benefits to the region as a whole?**	**Comparison of vehicle, infrastructure and energy costs to reduced gasoline (and GHG) costs and federal tax credit**

PEV Load Benefits to Utility Ratepayers



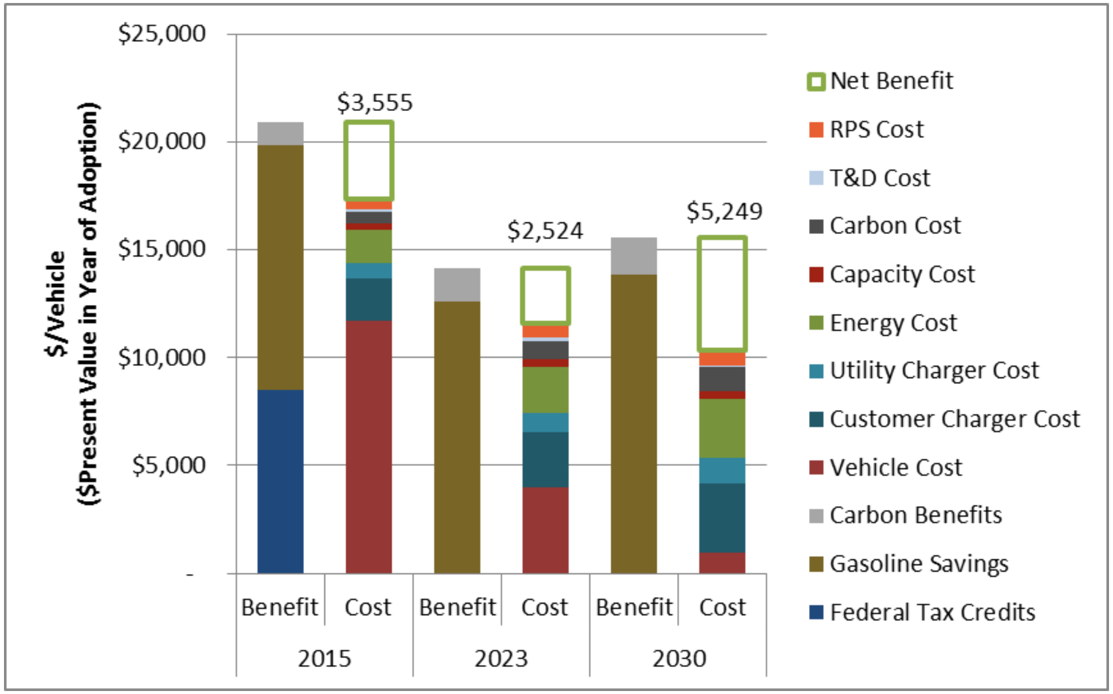
- **Utility rates represent average fixed and variable costs and are higher than the marginal cost of delivered energy in most hours**
- **Typically distributed energy resource programs (EE, DR, DG) reduce customer bills and utility revenues, but increase rates**
- **PEVs are unique in providing environmental benefits while reducing rates**
- **Northwest: true for the region as a whole, but will differ by utility based on BPA Tiered Rate allocation**

TRC and "740.8" SCT Results



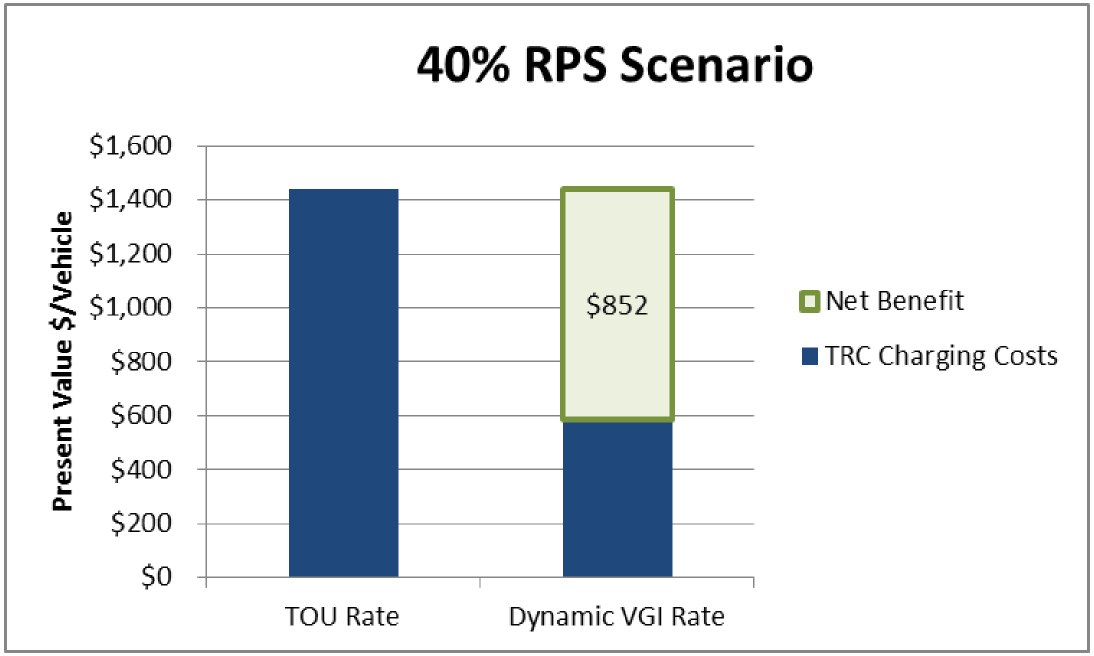
- **"740.8" SCT represents a combination of CARB and CPUC cost-effectiveness methods**
- **Present value net benefits for TRC and "740.8" SCT of $4.7 Billion and $5.8 Billion with ZEV Most Likely vehicle adoption**

How TRC Changes Over Time



- **TRC is positive in 2015 due to federal tax credit**
- **TRC net benefit is lower in 2023 after tax credits presumed to expire**
- **TRC is higher in 2030 with declining incremental PEV costs and higher gasoline prices**

Dynamic Vehicle Grid Integration (VGI) Charging



- **Dynamic VGI charging provides additional benefits, reducing charging costs**
- **TOU Rates discourage charging on-peak**
- **VGI rates encouraging day-time charging during periods of excess renewable generation in Spring and Fall.**

California Utility PEV Applications

SDG&E Vehicle Grid Integration (VGI)	SCE – Charge Ready
$103 Million over 10 years	$355 Million over 5 years
Install up to 5,500 charging stations	Supporting infrastructure for up to 30,000 charging stations
Focus on workplace and multifamily	Focus on expanding availability of long dwell-time infrastructure especially at work places and multifamily dwellings
Day-ahead dynamic hourly VGI rate provides economic incentives to charge when most beneficial for the grid	EV specific TOU rates
Focus on vertically integrated billing and charging solution for customer	Focus on service upgrades needed to install and operate charging infrastructure
Competitively bid, but charging equipment is SDG&E owned.	Host can choose to own and operate charging station

Expanded Cost-tests

- Societal Cost Test (SCT)
  - TRC test plus environmental and societal benefits
  - Benefits include
    - Health and environmental impacts
    - Reduced reliance on petroleum
    - “Social” cost of carbon
  - Included in California Public Utility Code 740.3 and 740.8
  - Combination of public utility and air resources board cost-benefit evaluation
- Cost of meeting GHG and criteria pollutant emission targets
  - Compare costs of alternative strategies (renewables, efficiency, transportation) to reduce emissions

Conclusions

- Distribution system upgrade costs related specifically to PEV charging are manageable in near-term, even under the most aggressive PEV adoption scenario
- **"Make ready" costs for multi-family, public and workplace charging** are larger than distribution upgrade costs and may pose a more significant barrier to PEV adoption
- **Utility investment in enabling technology and infrastructure is needed to accelerate PEV adoption and market transformation**.
- **Such investment may not pass current cost-effectiveness tests in the short-term, but still provide net ratepayer and societal benefits in the long-term**
- Over time, with reduced incremental vehicle costs and increasing gasoline prices, PEVs provide net TRC benefits even without the federal tax credit
- "740.8" SCT as presented here produces net benefits that are 22% higher than the SPM TRC test using health and reduced reliance on imported petroleum benefits

Conclusions

- Current CARB and CPUC cost-effectiveness tests evaluate resource measures largely against “traditional” investments. More comprehensive methods are need to evaluate alternative strategies towards meeting California’s ambitious GHG reduction goals

- Over the long-term, PEV rates can be designed to provide sufficient net revenues to more than cover short-term and long-term marginal costs, providing additional fixed cost recovery and lowering average rates for non-PEV owners in the rate class

- The increased benefits provided by TOU rates and VGI charging show that **utility or government programs funding PEV charging infrastructure should also include strong incentives for PEV owners and electric vehicle service entities to engage in managed charging that is responsive to grid needs**

CalETC	ICF	E3
Eileen Wenger Tutt Executive Director California Electric Transportation Coalition (916) 551-1943 eileen@caletc.com	Jeffrey Rosenfeld Manager ICF International (408) 216-2818 jeffrey.rosenfeld@icfi.com	Eric Cutter Senior Consultant Energy and Environmental Economics (415) 391-5100 eric@ethree.com

Standard Practice Manual Cost Tests for PEVs

Component	PCT	RIM	TRC	SCT (740.8)
EV Customer costs and benefits				
Incremental Vehicle Costs	-		-	-
Gasoline Savings	+		+	+
Utility Bills	-	+		
Federal Tax Credits	+		+	+
State Tax credits	+			
EV Charger Cost				
Utility Asset		-	-	-
Customer Assets	-		-	-
Admin Costs				
Utility Program Administration		-	-	-
Electricity Supply Costs				
Energy Costs		-	-	-
Losses Cost		-	-	-
A/S Cost		-	-	-
Capacity Cost		-	-	-
T&D Cost		-	-	-
RPS Cost		-	-	-
Utility GHG Allowance Costs		-	-	-
Societal Benefits				
Transportation GHG Allowance Costs			+	+
"Societal" value for CO2				+
Health benefits				+
Decreased Petroleum Use				+