Overview: California Statewide Plug-in Electric Vehicle Infrastructure Assessment

Dr. Marc Melaina
Senior Engineer, NREL

Sacramento, California – June 5, 2014

Presentation Overview

- Introduction to NREL
- Purpose of Statewide Assessment and Key Results
- Methodology: How were the quantitative results determined?
- How can the Energy Commission use the Assessment Framework into the future?

National Renewable Energy Laboratory

Only National Laboratory Dedicated Solely to Energy Efficiency and Renewable Energy

- Leading clean-energy innovation for 34 years
- 1740 employees with world-class facilities
- Campus is a living model of sustainable energy
- Owned by the Department of Energy
- Operated by the Alliance for Sustainable Energy

Scope of NREL's Mission

Energy Efficiency

- Residential Buildings
- Commercial Buildings
- Personal and Commercial Vehicles

Renewable Energy

- Solar
- Wind and Water
- Biomass
- Hydrogen
- Geothermal

Systems Integration

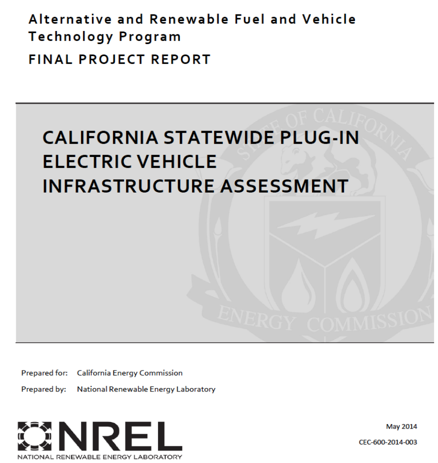
- Grid Infrastructure
- Distributed Energy Interconnection
- Battery and Thermal Storage
- Transportation

Market Focus

- Private Industry
- Federal Agencies
- Defense Dept.
- State/Local Govt.
- International

Purpose of the Assessment

- ***This is the first statewide analytical framework for EVSE infrastructure***
- ***The Assessment establishes a framework for how to achieve the ZEV Action Plan Goal of EVSE Deployment Sufficient to support 1.0 Million ZEVs by 2020***


Alternative and Renewable Fuel and Vehicle Technology Program
FINAL PROJECT REPORT

CALIFORNIA STATEWIDE PLUG-IN ELECTRIC VEHICLE INFRASTRUCTURE ASSESSMENT

Prepared for: California Energy Commission
Prepared by: National Renewable Energy Laboratory

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

May 2014
CEC-600-2014-003

The assessment achieves the following:

- Articulates the Energy Commission's conclusions and recommendations regarding PEV infrastructure planning
- Conveys stakeholder feedback collected from the PEV Infrastructure Plan Stakeholder Workshop, review comments on earlier draft versions, and results from discussions with key stakeholders

Summary of Quantitative Results

The EVSE charge point results below summarize key quantitative results from the statewide assessment

	Total Statewide EVSE Charge Points by Location and Type (2020)						
Scenario	***L1 Home***	***L2 Home***	***L1 Work***	***L2 Work***	***L1 Public***	***L2 Public***	***DCFC***
Home Dominant	511,000	365,000	20,100	82,000	1,620	20,100	551
High Public Access	517,000	289,000	22,900	144,000	2,100	46,500	1,550

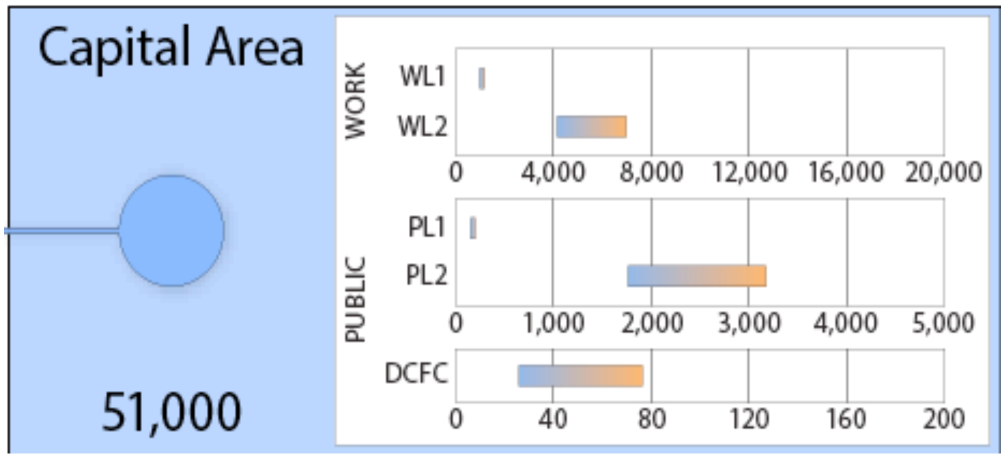
Resulting EVSE Stations by Type and Region

Region & Scenario	Home			Work			Public			
	L1	L2	Total	L1	L2	Total	L1	L2	FC	FC Stns
Home Dominant										
Southern California	235,000	168,000	403,000	9,200	37,700	47,000	750	9,300	247	124
Bay Area	126,000	90,000	216,000	5,000	20,200	25,200	400	5,000	133	66
San Joaquin Valley	21,000	15,000	36,000	800	3,400	4,200	70	800	22	11
San Diego	46,000	33,000	79,000	1,800	7,400	9,200	150	1,800	49	24
Capital Area	26,000	19,000	45,000	1,000	4,200	5,200	80	1,000	27	14
Coachella Valley	22,000	16,000	38,000	900	3,600	4,500	70	900	23	12
Central Coast (S.)	15,000	11,000	26,000	600	2,400	3,000	50	600	16	8
Monterey Bay	7,600	5,500	13,100	300	1,200	1,500	20	300	12	6
Central Coast	7,800	5,600	13,300	300	1,200	1,600	20	310	12	6
Upstate	1,800	1,300	3,100	70	290	360	6	70	4	2
North Coast	1,100	800	1,900	40	180	220	4	40	5	2
Total	511,000	365,000	876,000	20,100	82,000	102,000	1,620	20,100	551	275
High Public Access										
Southern California	239,000	133,000	372,000	10,600	67,000	77,000	970	21,500	702	351
Bay Area	128,000	72,000	200,000	5,700	36,000	41,000	520	11,500	377	189
San Joaquin Valley	22,000	12,000	34,000	1,000	6,000	7,000	90	1,900	63	32
San Diego	47,000	26,000	73,000	2,100	13,000	15,000	190	4,200	138	69
Capital Area	26,000	15,000	41,000	1,200	7,000	9,000	110	2,400	78	39
Coachella Valley	23,000	13,000	35,000	1,000	6,000	7,000	90	2,000	67	33
Central Coast (S.)	15,000	9,000	24,000	700	4,000	5,000	60	1,400	45	23
Monterey Bay	7,700	4,300	12,100	300	2,000	3,000	30	700	34	17
Central Coast	7,900	4,400	12,300	300	2,200	2,500	30	710	35	17
Upstate	1,800	1,000	2,900	80	510	590	7	160	11	5
North Coast	1,100	600	1,800	50	310	360	5	100	13	7
Total	517,000	289,000	806,200	22,900	144,000	167,000	2,100	46,500	1,550	775

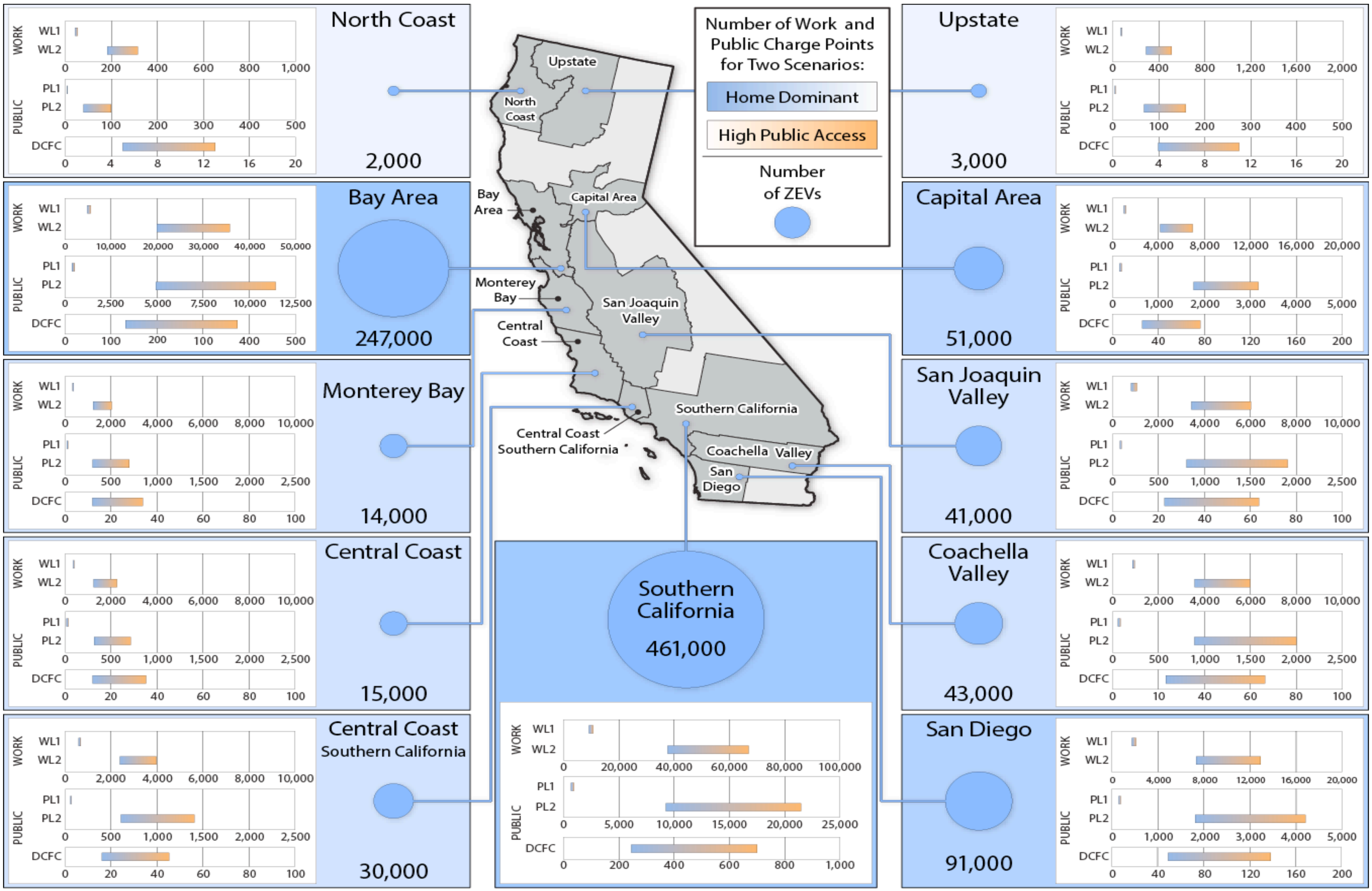
Note: L1: Level 1 charger; L2: Level 2 charger; FC: fast charger

How to read the main summary graphic

Explanation example.



Comparisons across Planning Regions



Scenario Methodology

- **We do not yet have sufficient empirical market and consumer behavior data to develop a predictive model of EVSE expansion**
- **Therefore, a scenario approach is warranted**

Some high-level numbers…..

- Electricity demand = total miles * Wh/mile = 2,759 million kWh
- This is 900,000 PEVs driving on average ~ 20 e-miles per day

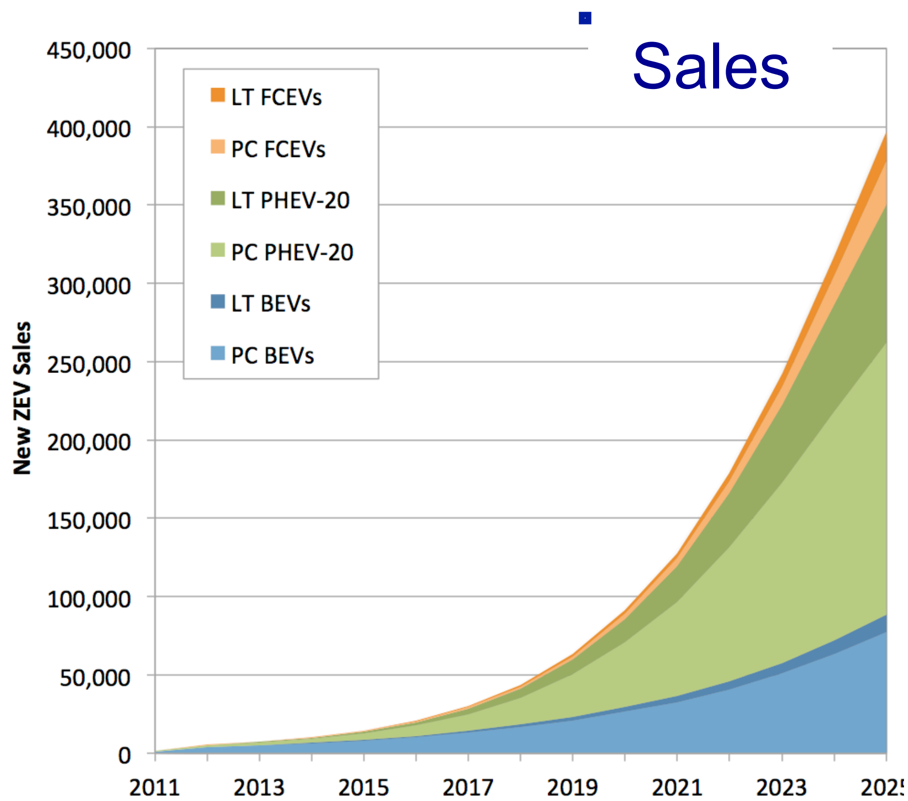
General approach: Allocate kWh by EVSE location and type

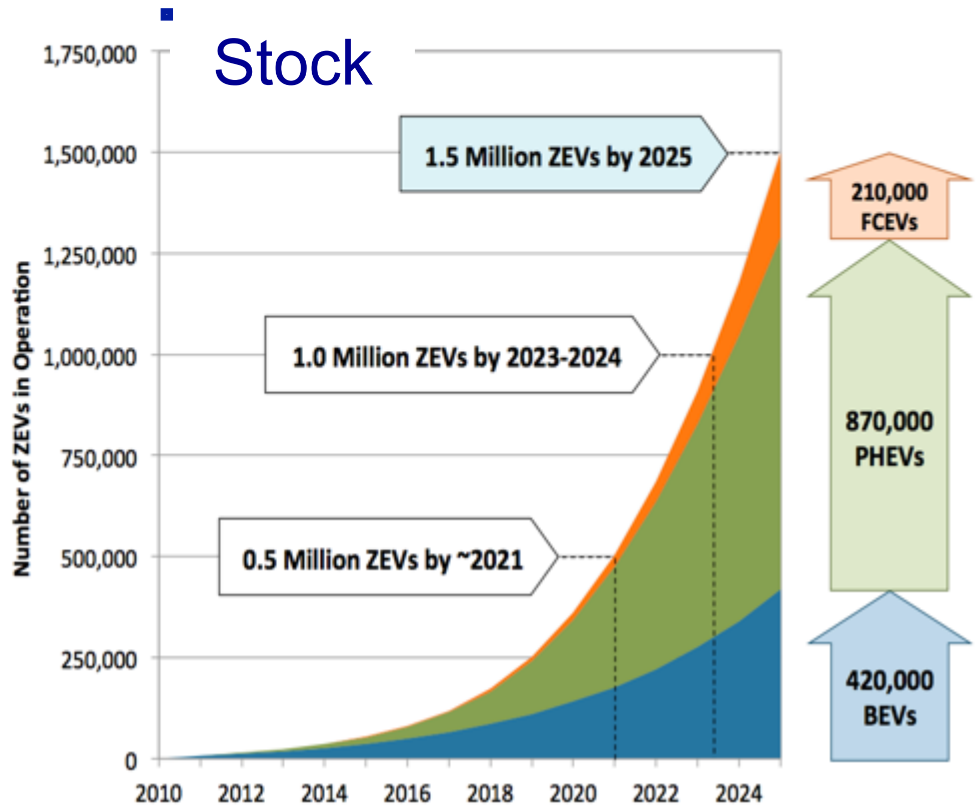
- Home, Public, and Workplace EVSE stations
- Three types EVSE: Level 1, Level 2, Fast Charge

The 2020 goal is a snapshot of a rapidly expanding market
This demand would increase rapidly with exponential PEVs sales, reaching 4.0 billion kWh in 2025, and nearly 10 billion kWh by 2030.

ZEV Rollout Scenario and Electricity Demand

- ZEV Action Plan Identifies 2020 and 2025 Goals
  - Sufficient EVSE to support 1.0 million ZEVs by 2020
- ZEV likely compliance scenario proposes vehicle market share trends
- ARB-VISION model used to account for ZEV fleet adoption dynamics
- New vehicles introduced to the fleet over time (stock turnover model)

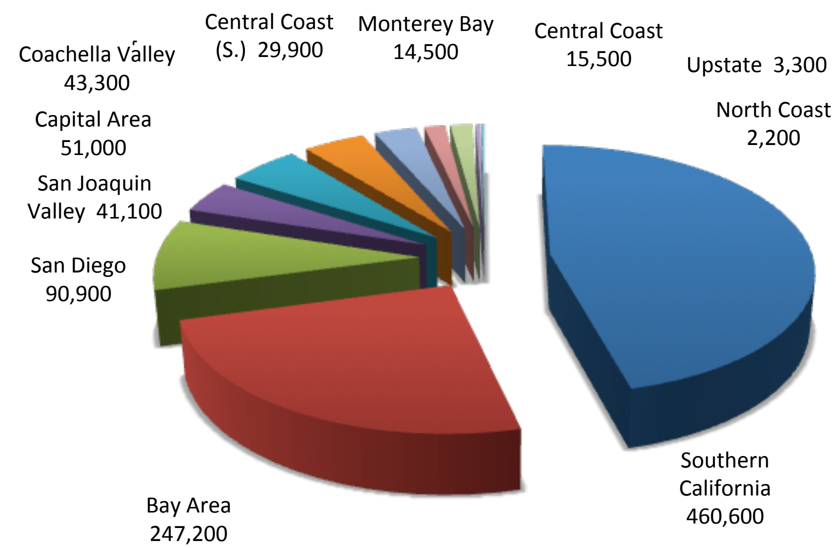




Early Adopter Metric (EAM) applies for all ZEVs

Based on household income and historical sales of HEVs and luxury vehicles

Number of ZEVs by Region ➔



EAM is a proxy for future market analysis results

Planning Region	Nominal Number of ZEVs Deployed by 2023-2024			
	PHEVs	**BEVs**	**FCEVs**	**Total ZEVs**
Southern California	279,000	137,000	45,100	461,000
Bay Area	149,000	74,000	24,200	247,000
San Joaquin Valley	25,000	12,000	4,100	41,000
San Diego	55,000	27,000	8,900	91,000
Capital Area	31,000	15,000	5,000	51,000
Coachella Valley	26,000	13,000	4,300	43,000
Central Coast (S.)	18,000	9,000	2,900	30,000
Monterey Bay	9,000	4,000	1,500	14,000
Central Coast	9,000	5,000	1,500	15,000
Upstate	2,000	1,000	300	3,000
North Coast	1,000	1,000	200	2,000
TOTAL	**605,000**	**297,000**	**98,000**	**1,000,000**

Two EVSE Scenarios

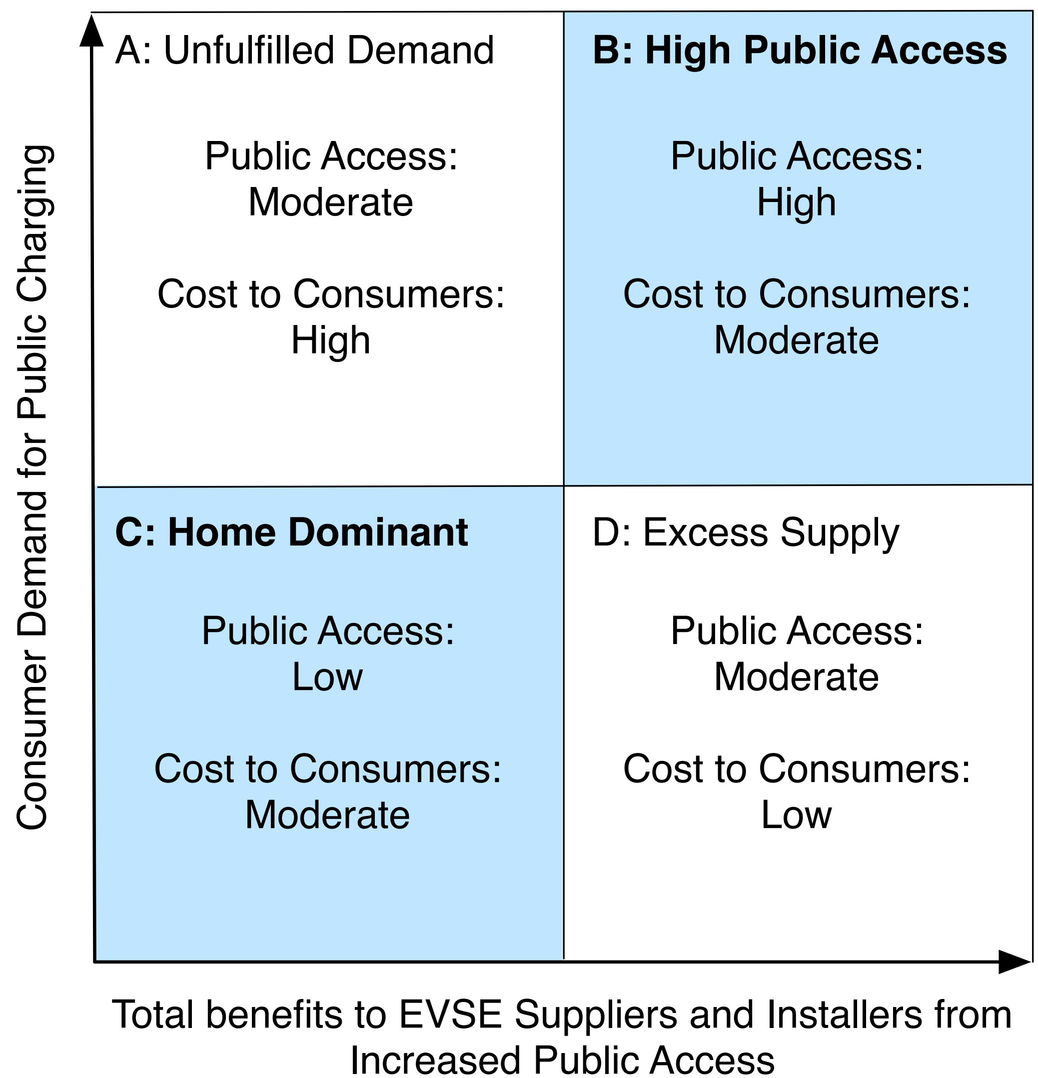
<u>**Focus on Two Key Trends**</u>

Consumer Demand

- **Overall consumer demand for workplace and public charging**

EVSE Supply

- **Total benefits to EVSE suppliers from increased workplace and public access**



General Analytic Approach

- The number of EVSE stations is determined by adjusting multiple input parameters and assumptions such that the two scenarios represent distinct trends in both EVSE expansion and the use of EVSE stations by PEVs.

Capacity (kW) by EVSE type?

Chargepoints per EVSE?

Charges per chargepoint per day?

How many miles per charge?

How many stations?

Type
L1, L2, DCFC

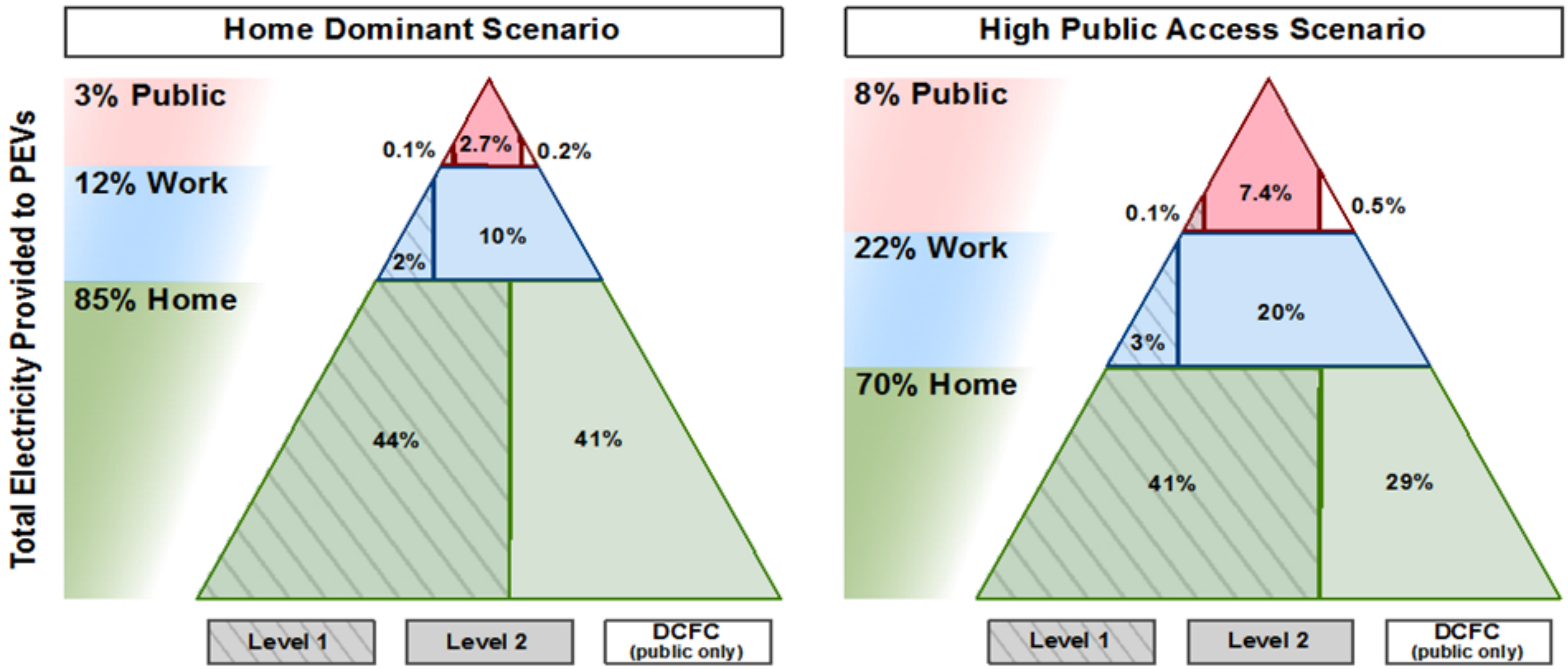
Location
Home, Work, Public

Where?

- Early adopters
- Urban density
- Interstate mile basis for DCFCs

Distribution of kWh by EVSE Type

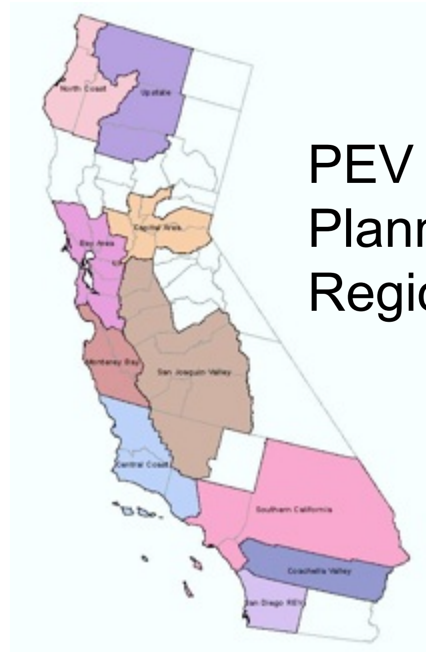
- These high-level input assumptions are balanced against a variety of EVSE supply metrics
- Most charging is still done at home in both scenarios



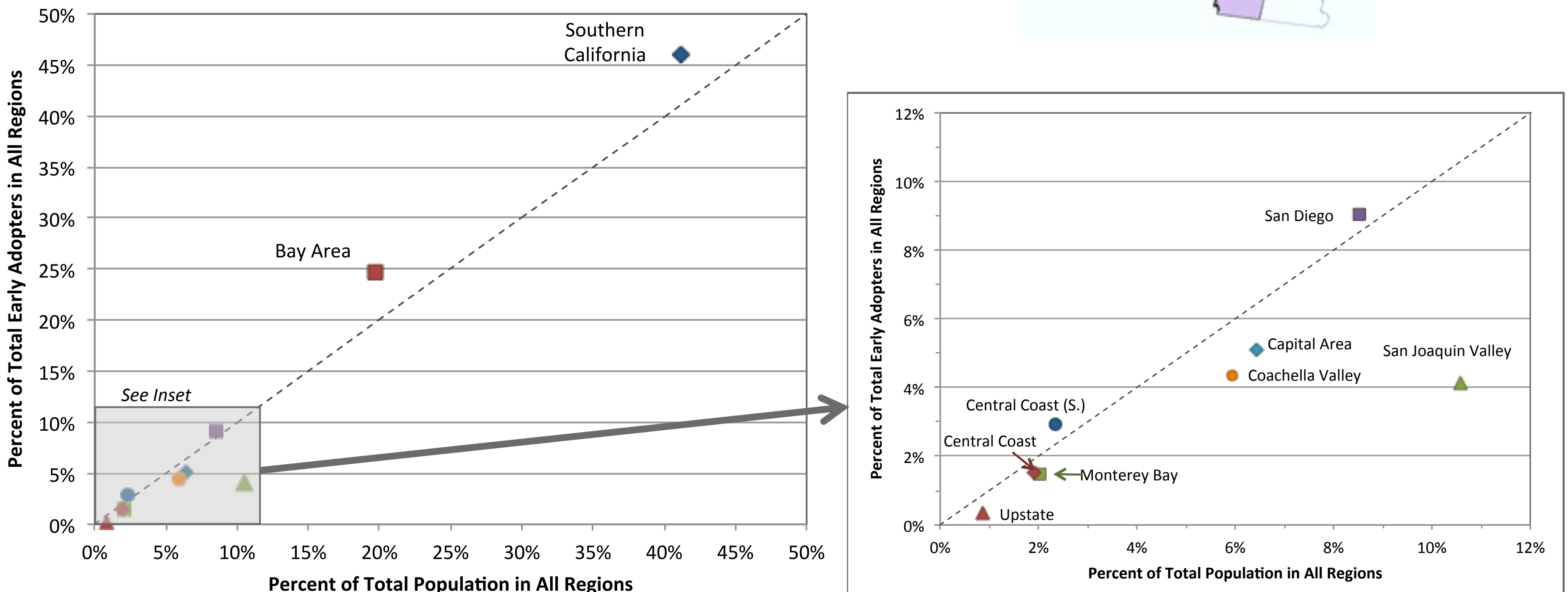
EAM Distribution differs from general population distribution

Some regions have more early adopters than others.

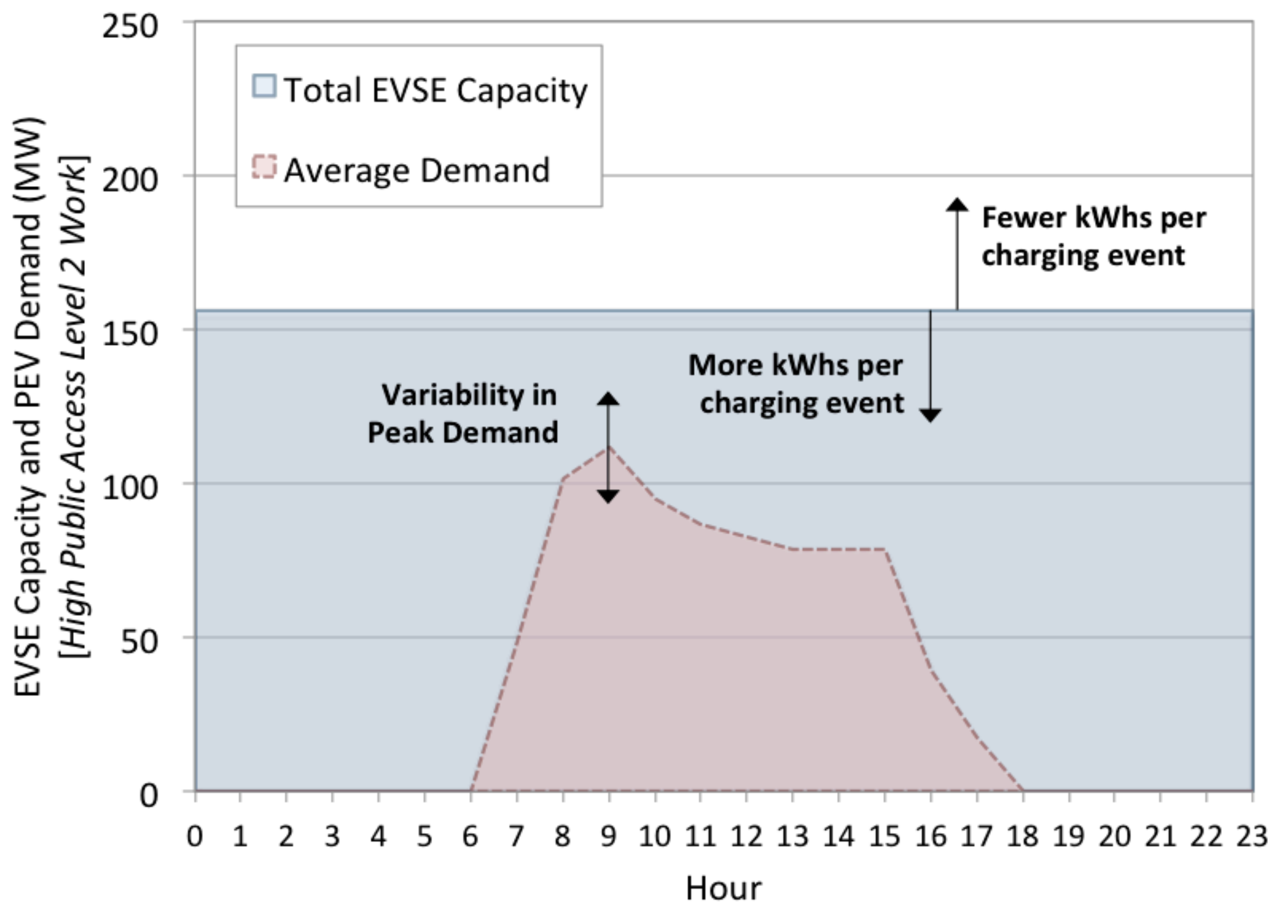
The percent of Early Adopters (Y axis) in each region is compare to the percent of total population (X axis) in the figures below:



PEV Planning Regions



Demand Profiles and EVSE Capacity



Number of Stations as a Function of Peak Hourly Demand and EVSE Capacity

This equation is used to determine the number of EVSE stations *(N)* by type and location *(i)* providing electricity to a particular PEV type *(j)* :

$$N_{i,j} = \frac{Q_{total} \cdot f_{i,j} \cdot d_{hr,peak,i,j} \cdot (1 + \beta_{i,j})}{C_i}$$

where,

$N_{i,j}$ = Number of EVSE stations of type and location type *i* providing electricity to PEV type *j*
Q_{total} = Total electricity provided to all PEVs (kWh/day)
$f_{i,j}$ = Percent of total electricity provided by EVSE type *i* to PEV type *j* (percent)
$d_{hr,peak,i}$ = Percent of electricity provided during the peak hour of a typical day (% per hour)
$\beta_{i,j}$ = Capacity buffer for EVSE of type *i* providing electricity to PEV type *j* (percent)
C_i = Nominal installed capacity of EVSE type and location *i* (kW)

Number of stations as a function of total electricity needed and electricity provided per EVSE station

This equation is used to determine the number of EVSE stations *(N)* by type and location *(i)* providing electricity to a particular PEV type *(j)* :

$$N_{i,j} = \frac{Q_{total} \cdot f_{i,j}}{m_{event,i,j} \cdot \eta_j \cdot N_{Chgpts/Stn} \cdot N_{Chgs/Chgpt}}$$

where,

$N_{i,j}$ = Number of EVSE stations of type and location *i* providing electricity to PEV type *j*
Q_{total} = Total kWh of electricity required for all PEVs (kWh/day)
$f_{i,j}$ = Percent of total electricity provided by EVSE type *i* to PEV type *j* (percent)
$m_{event,i,j}$ = Average daily e-miles provided per charging event by EVSE type *i* to PEV type *j*
η_j = Electricity consumption rate by PEV type *j* (Wh per mile)
$N_{Chgpts/Stn}$ = Average number of charge points per EVSE station
$N_{Chgs/Chgpt}$ = Average number of charging events per charge point per day

Goal Seek used to set e-miles per charge to specified values (input assumptions)

- The two "open" variables in these equations are: $\beta_{i,j}$ and n_j
- The other variables have been determined using consistent assumptions about average technology attributes (stations and vehicles) and behavior (VMT and hourly charging profiles)
- Goal seek solves the capacity and electricity equations simultaneously

$$N_{i,j} = \frac{Q_{total} \cdot f_{i,j} \cdot d_{hr,peak,i,j} \cdot (1 + \beta_{i,j})}{C_i}$$

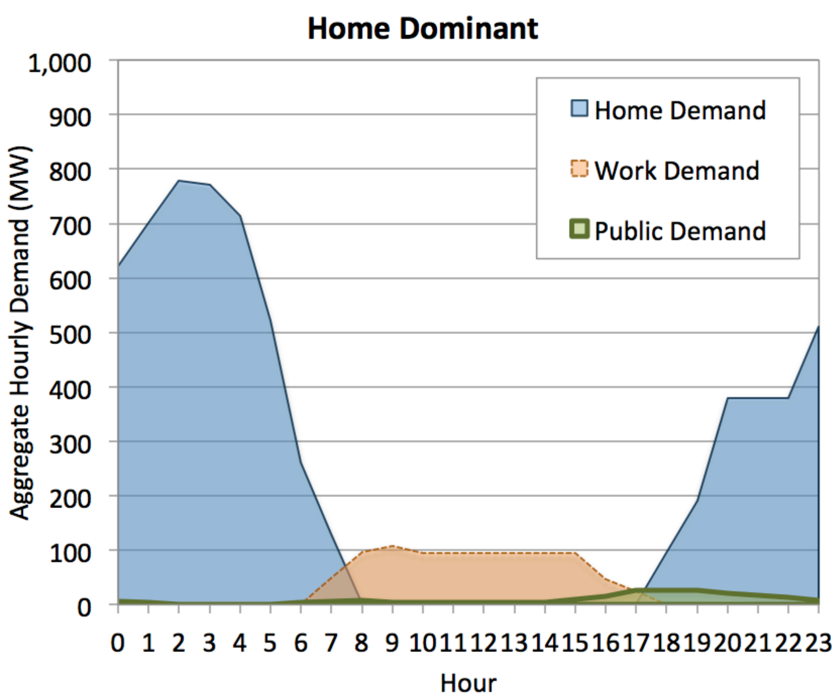
$$N_{i,j} = \frac{Q_{total} \cdot f_{i,j}}{m_{event,i,j} \cdot \eta_j \cdot N_{Chgpts/Stn} \cdot N_{Chgs/Chgpt}}$$

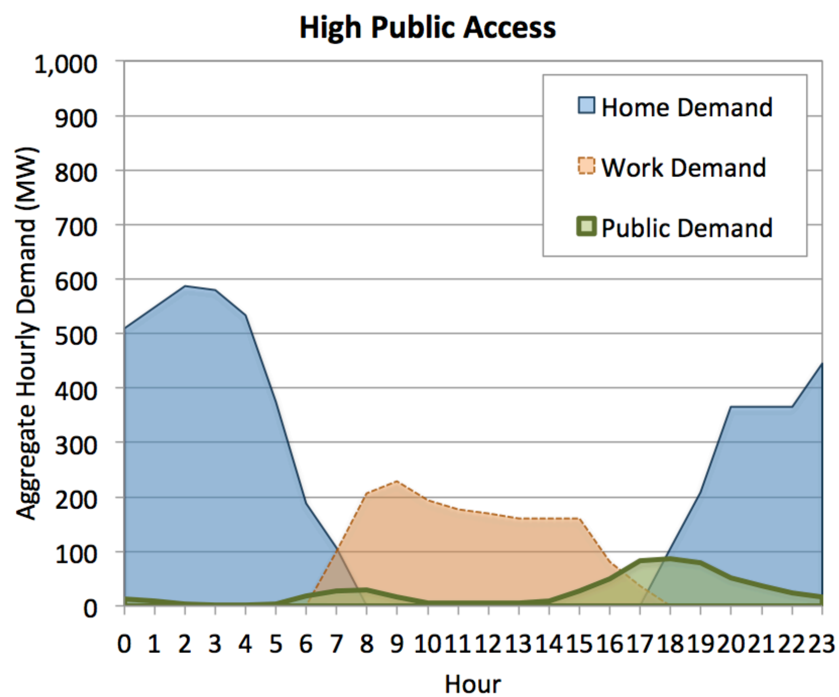
$\beta_{i,j}$ = Capacity buffer for EVSE of type *i* providing electricity to PEV type *j*

η_j = Electricity consumption rate by PEV type j (Wh per mile)

Demand Profiles Results

Broken out by EVSE location and type.





Adjustments to Meet Expected Metrics

- Adjust assumptions above to satisfy acceptable values for the following metrics:

DEMAND METRIC

Modeling Constraint

- Some fraction of PEV do not need home charging. The calculations balance the non-home kWhs across the workplace and public EVSE station types
    - More MUDs in High Public Access Scenario

SUPPLY METRICS

"Rule of Thumb" Metric

- EVSE units per square mile in urban areas
- Interstate miles (nominal) between FC stations
- Approximately 200 FC stations total (based on other studies)

How will CEC use these scenarios?

Adaptive management strategy. Need more data on market trends.

Two of the investment strategy responses the Energy Commission may consider as additional data are collected and trends are characterized include the following:

Apparent deficiency in EVSE Availability. If PEV sales or e-miles driven in a given locality or region appear to be dampened due to a lack of EVSE availability, the Energy Commission may consider increasing efforts to support focused EVSE deployment.

Apparent lack of PEV market support. If conditions for PEV adoption appear to be favorable in a given locality or region, including sufficient EVSE availability and favorable early adopter demographics, the Energy Commission may consider increasing efforts to support focused PEV market adoption.

Questions?

Backup Slides

Additional Assumptions and Metrics

Scenario Assumption or Metric	Home Dominant	High Public Access
Percent of PEVs without home charging (assumption)		
BEVs	0.9%	6.5%
PHEVs	3.9%	12.4%
Public Commercial EVSE: Average miles traveled (and percent of average daily e-miles) provided per charging event (assumption)		
BEVs		
DC Fast Charging Stations	20.9 mi (60%)	22.6 mi (65%)
Level 2 Public	15.6 mi (45%)	19.2 mi (55%)
Level 1 Public	7.0 mi (20%)	8.7 (25%)
PHEVs		
Level 2 Public	11.7 mi (75%)	12.5 mi (80%)
Level 1 Public	8.6 mi (55%)	9.4 mi (60%)
Workplace EVSE: Average miles traveled (and percent of average daily e-miles) provided per charging event (assumption)		
BEVs		
Level 2 Work	12.2 mi (35%)	14.0 mi (40%)
Level 1 Work	10.5 mi (30%)	12.2 mi (35%)
PHEVs		
Level 2 Work	11.7 mi (75%)	13.3 mi (85%)
Level 1 Work	9.4 mi (60%)	10.2 mi (65%)
Average number of EVSE stations per 100 square miles in urban areas (metric)		
Level 2 Public	127	294
Level 1 Public	20	26
FC Stations	3.5	9.8
FC stations in reference to urban interstate miles (metric)		
Average nominal distance between FCs along urban interstates[a]	8.2 miles	2.9 miles

a Length of interstate miles within each planning region is used as a proxy for the density of high-volume travel. It is not assumed that all FC stations would actually be located along interstates.