2018 ANNUAL EVALUATION OF FUEL CELL ELECTRIC VEHICLE DEPLOYMENT & HYDROGEN FUEL STATION NETWORK DEVELOPMENT

Findings and Special Topics

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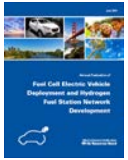
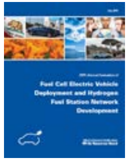
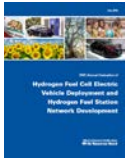
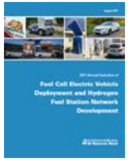
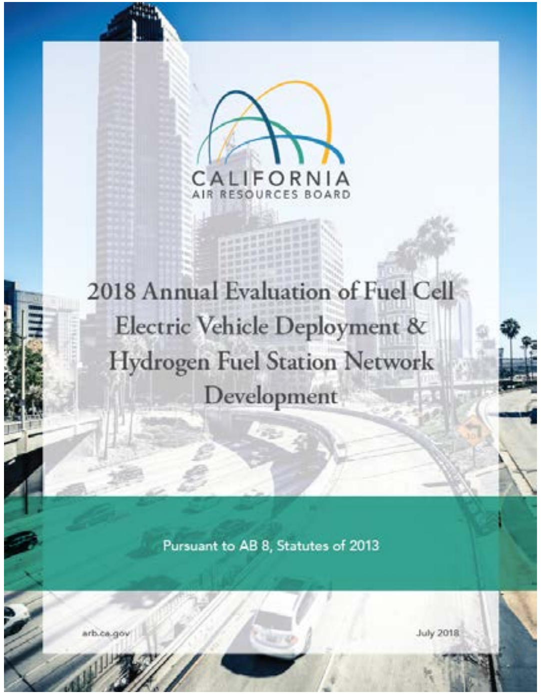
CALIFORNIA
AIR RESOURCES BOARD

Overview of AB 8

- Signed by Governor Brown in 2013
- Allocates up to $20M annually for hydrogen infrastructure investment

- CARB annually reports to Energy Commission
  - Current and projected FCEV fleet and station progress
  - Assessment of coverage and capacity
  - Recommended station placement
  - Recommended funding level
  - Recommended station technical specifications

Background

- Zero Emission Vehicles vital to addressing air quality & climate change
- Goal to enable industry to scale up to a self-sustained market
- Hydrogen fueling stations are needed ahead of FCEVs to enable market launch

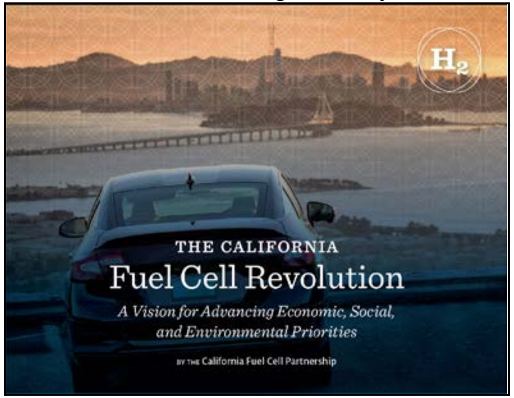
Major Influences

- EO B-48-18:
  - 200 stations by 2025 (only 2 years after AB 8)
  - 250,000 chargers (10,000 DC) by 2025
  - 5,000,000 ZEVs in California by 2030
  - Expand infrastructure through the Low Carbon Fuel Standard

Image courtesy of Governors Office

- The California Fuel Cell Revolution:
  - Public-private cooperation
  - Shared vision for 2030
  - 1,000,000 FCEVs and 1,000 stations as early as 2030
  - Market support and expansion strategies

Image courtesy of CaFCP

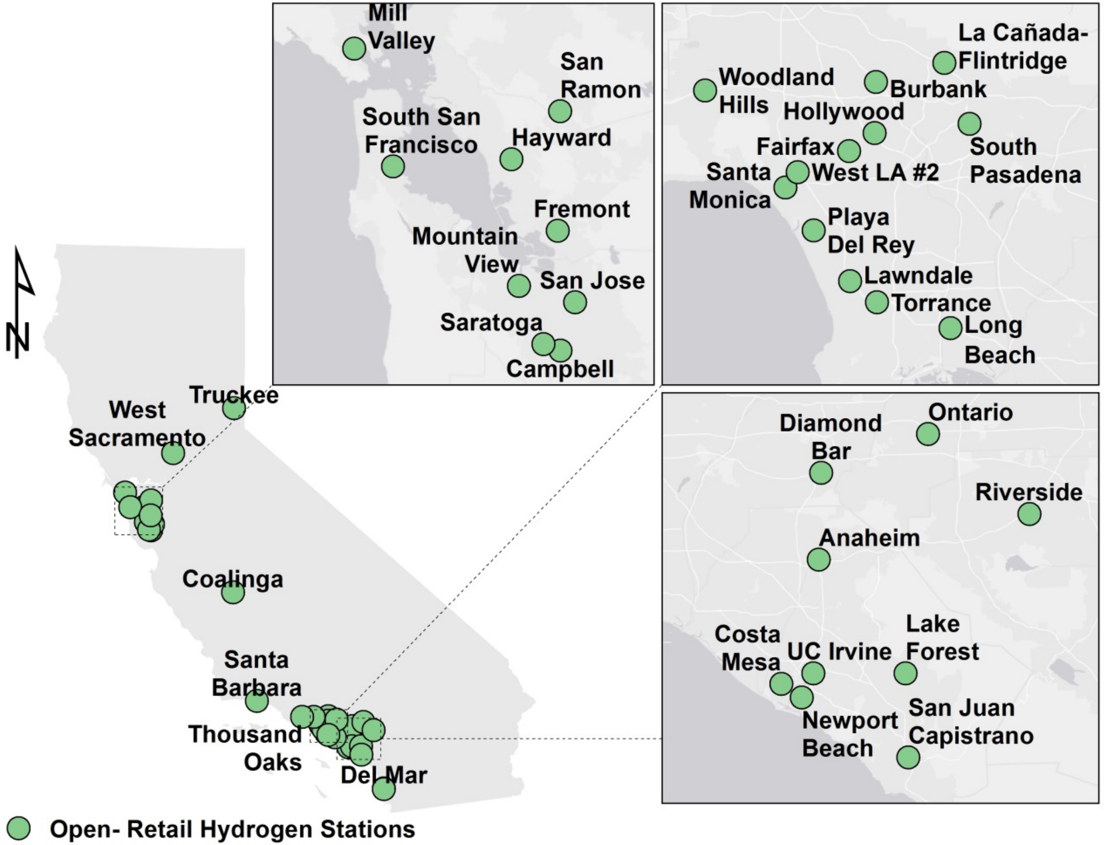


FINDINGS

Image courtesy of CaFCP

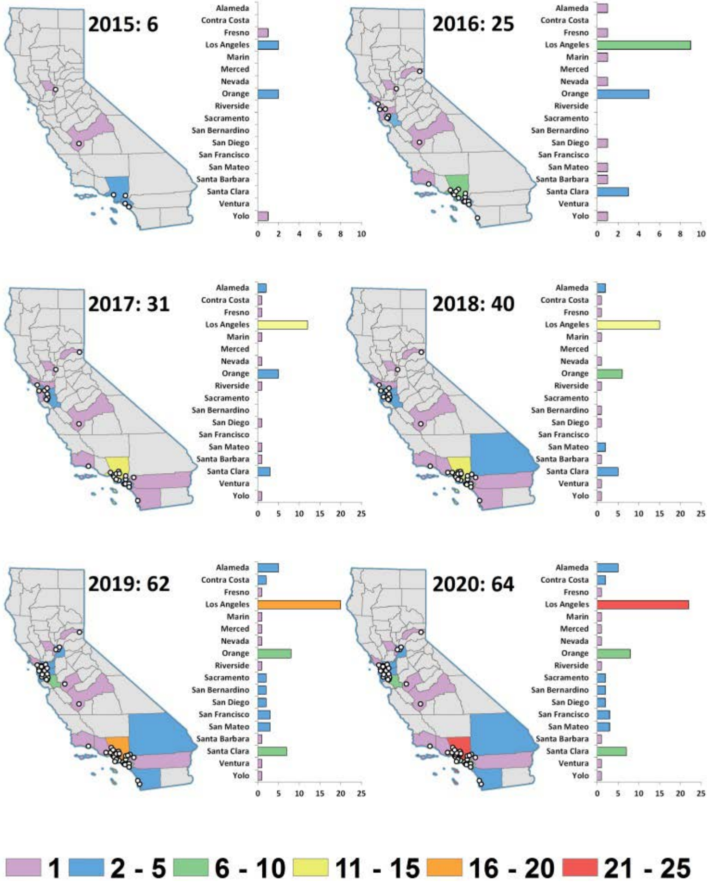
Finding 1

California's fueling network continues to mature



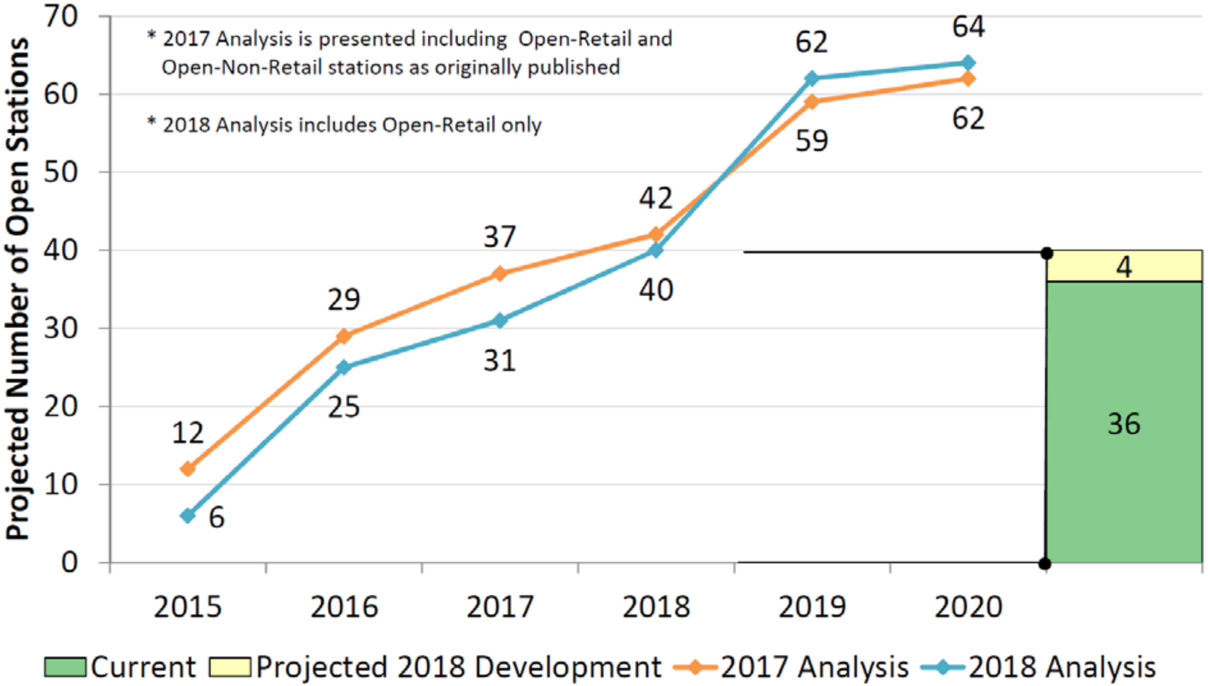
Finding 1

- All station tracking on Open-Retail basis
- Upgrade of Newport Beach to Retail fully self-funded



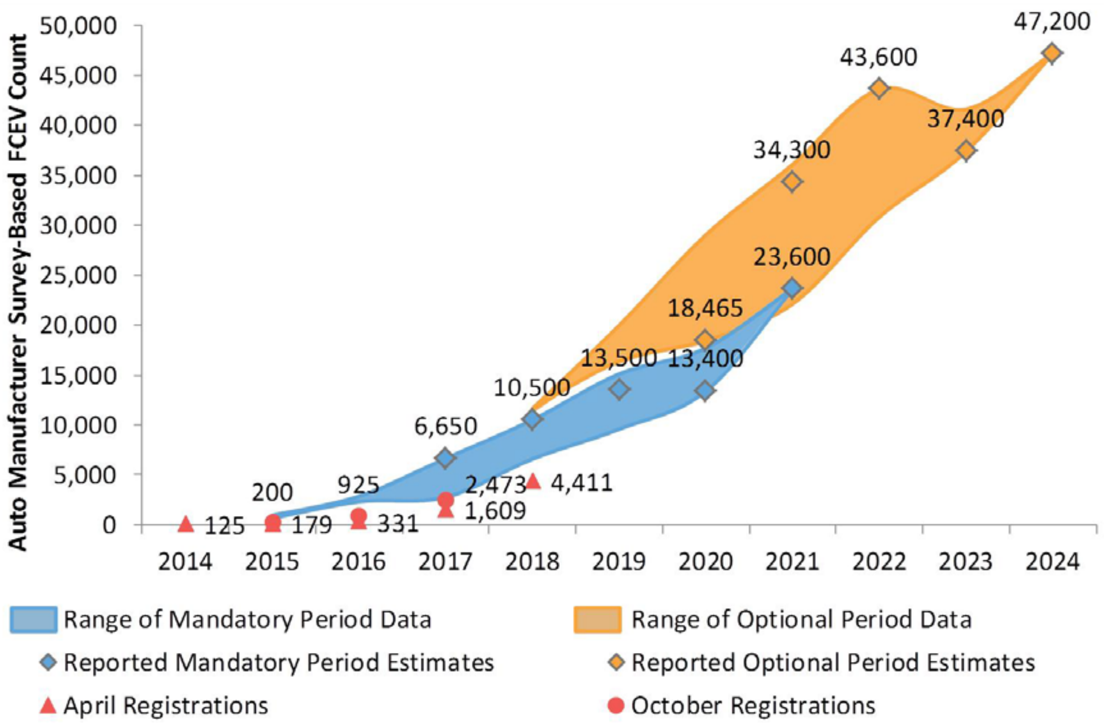
Finding 2

Station deployment in the past year has remained almost completely on schedule

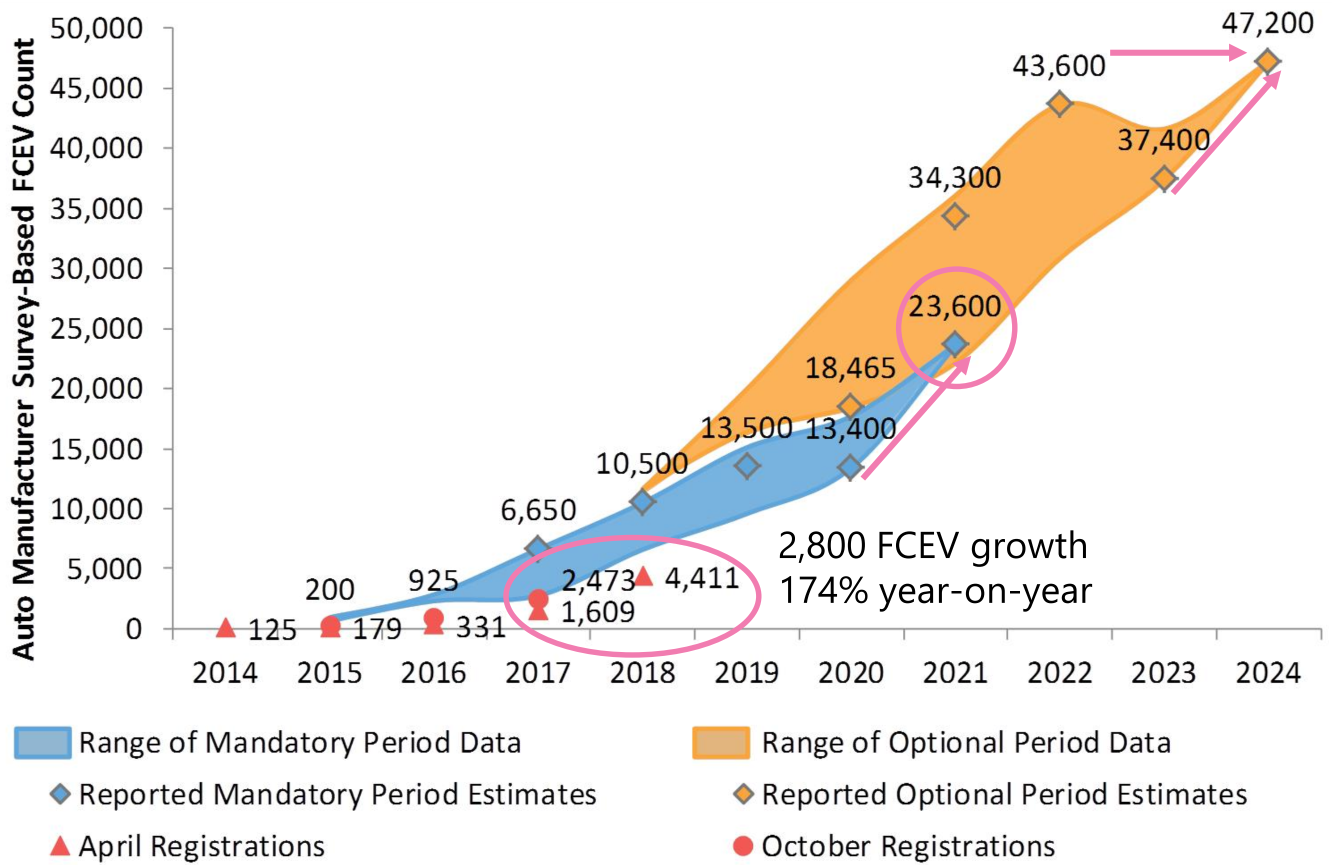


Finding 3

Auto manufacturer projections for future FCEV releases have recovered substantially



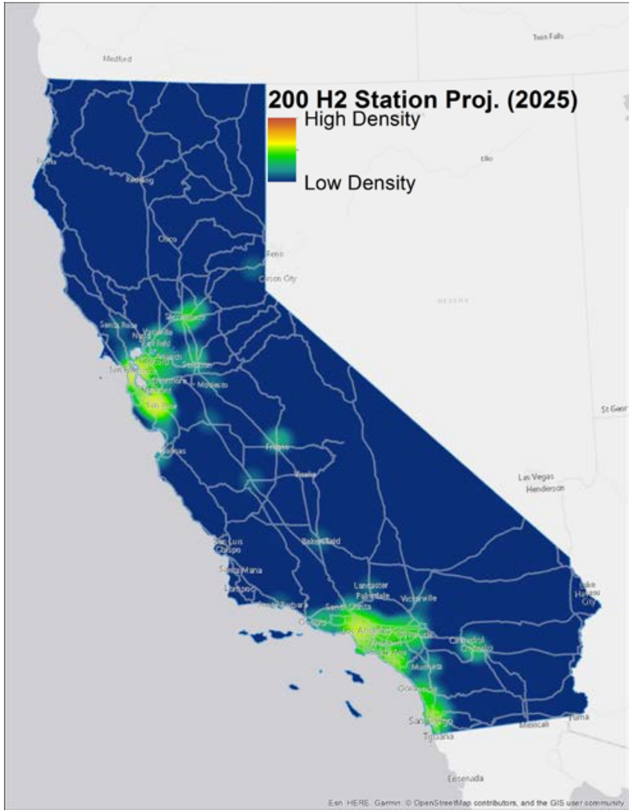
Finding 3

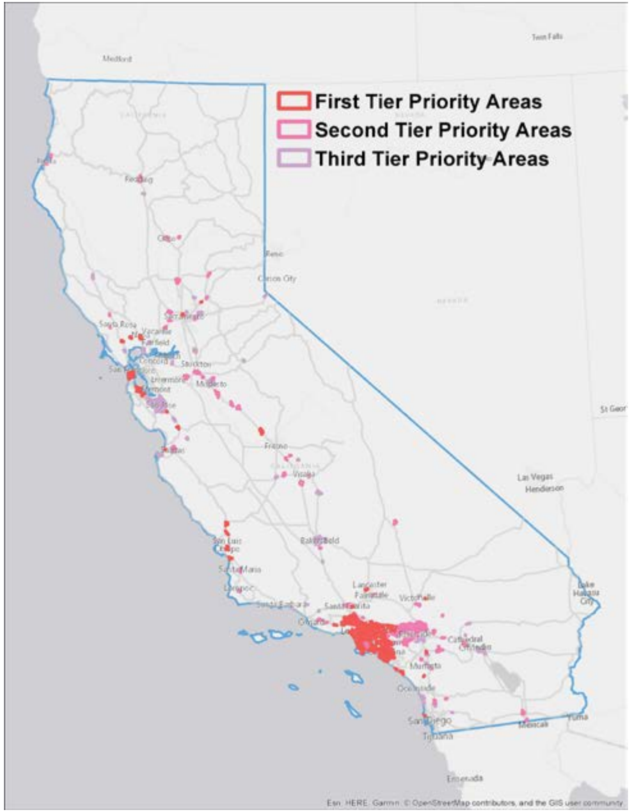


Auto Manufacturer Survey-Based FCEV Count
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
125
200
179
925
331
6,650
2,473
1,609
4,411
10,500
13,500
13,400
18,465
23,600
34,300
43,600
37,400
47,200
2,800 FCEV growth
174% year-on-year
Range of Mandatory Period Data
Range of Optional Period Data
Reported Mandatory Period Estimates
Reported Optional Period Estimates
April Registrations
October Registrations

Finding 4

New station priorities can be informed by work completed to support EO B-48-18 and CaFCP 2030 vision





Finding 5

CHIT analyses demonstrate a path to 2025 and 2030 goals that satisfies market needs and ensures equitable benefits

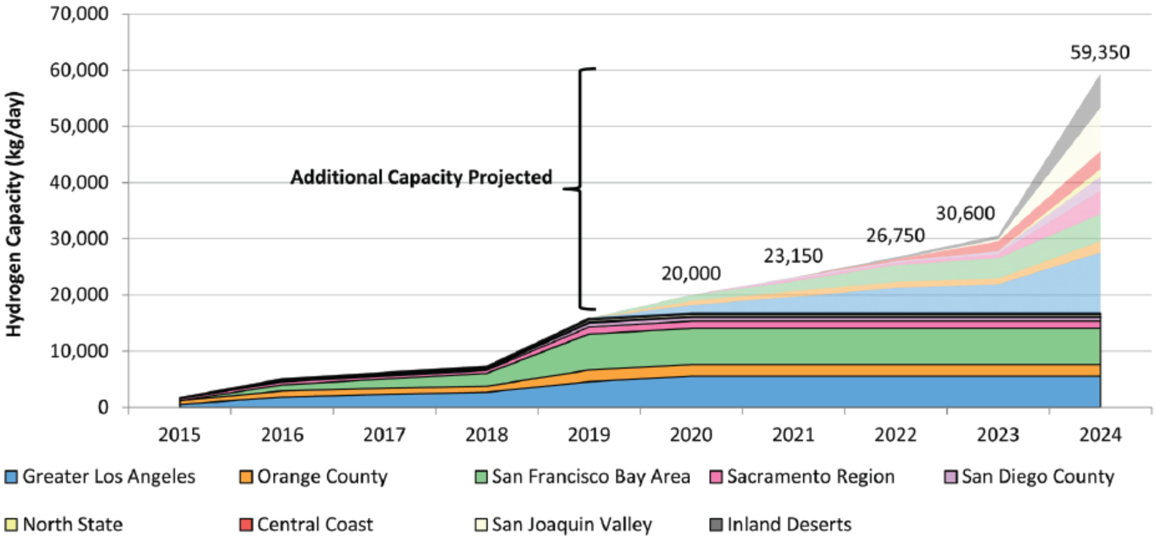
64 Stations CalEnviroScreen Score	Count of Stations	Population in Station Home Tract	Population in 15-Minute Coverage	Percent of CA Population in 15-Minute Coverage	Percent of Covered Population
Non-DAC Subtotals:	52	262,415	12,118,311	32.5%	79%
DAC Subtotals:	12	46,604 (~1% of all DAC)	3,238,482 (~35% of all DAC)	8.7%	21%
Totals	**64**	**309,019**	**15,356,793**	**41.2%**	**100%**
For Reference: CalEnviroScreen Indicates 9,152,024 Residents Living in Disadvantaged Communities					

1,000 Stations CalEnviroScreen Score	Count of Stations in Future Priority Areas*	Population in Priority Areas	Population in 15-Minute Coverage	Percent of CA Population in 15-Minute Coverage	Percent of Covered Population
Non-DAC Subtotals:	403	17,704,848	26,199,288	70.3%	75%
DAC Subtotals:	597	7,663,418 (~84% of all DAC)	8,883,966 (~97% of all DAC)	23.8%	25%
Totals	**1,000**	**25,368,266**	**35,083,254**	**94.1%**	**100%**
For Reference: CalEnviroScreen Indicates 9,152,024 Residents Living in Disadvantaged Communities					

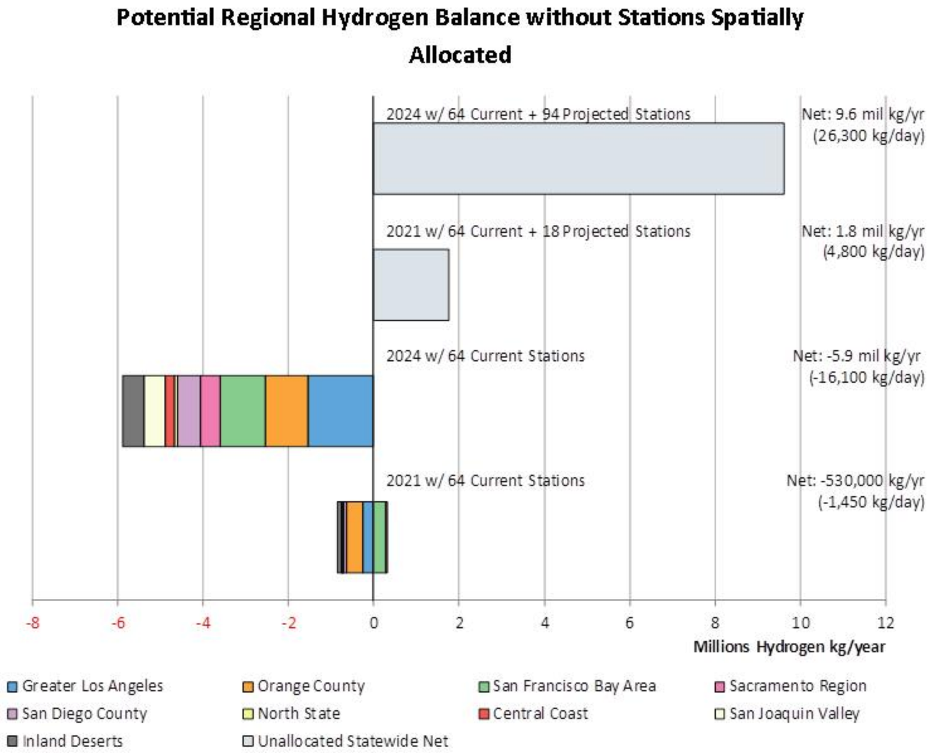
* Counts for Priority Areas include all Priority Areas that partially or wholly overlap a DAC. Data for populations in Priority Areas and 15-Minute Coverage are exact and only include population wholly contained within both the DACs and either Priority Areas or 15-Minute Coverage.

Finding 6

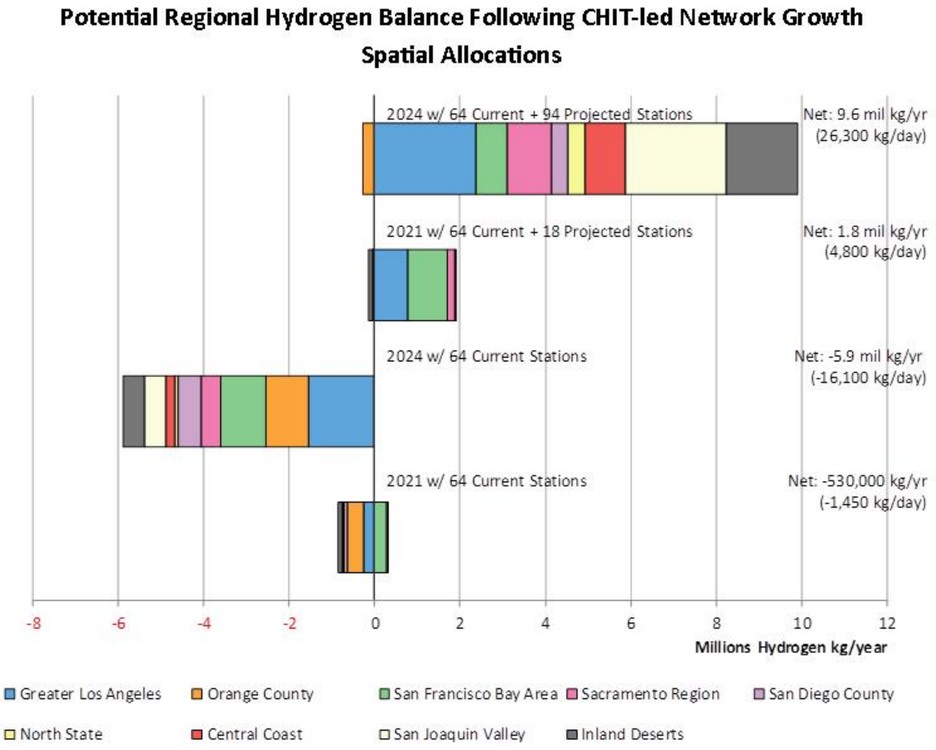
It is possible to meet projected FCEV fueling capacity needs through 2025 by meeting the goals of EO B-48-18



Finding 6



Potential Regional Hydrogen Balance without Stations Spatially Allocated
2024 w/ 64 Current + 94 Projected Stations
Net: 9.6 mil kg/yr (26,300 kg/day)
2021 w/ 64 Current + 18 Projected Stations
Net: 1.8 mil kg/yr (4,800 kg/day)
2024 w/ 64 Current Stations
Net: -5.9 mil kg/yr (-16,100 kg/day)
2021 w/ 64 Current Stations
Net: -530,000 kg/yr (-1,450 kg/day)
-8
-6
-4
-2
0
2
4
6
8
10
12
Millions Hydrogen kg/year
Greater Los Angeles
Orange County
San Francisco Bay Area
Sacramento Region
San Diego County
North State
Central Coast
San Joaquin Valley
Inland Deserts
Unallocated Statewide Net



Potential Regional Hydrogen Balance Following CHIT-led Network Growth Spatial Allocations
2024 w/ 64 Current + 94 Projected Stations
Net: 9.6 mil kg/yr (26,300 kg/day)
2021 w/ 64 Current + 18 Projected Stations
Net: 1.8 mil kg/yr (4,800 kg/day)
2024 w/ 64 Current Stations
Net: -5.9 mil kg/yr (-16,100 kg/day)
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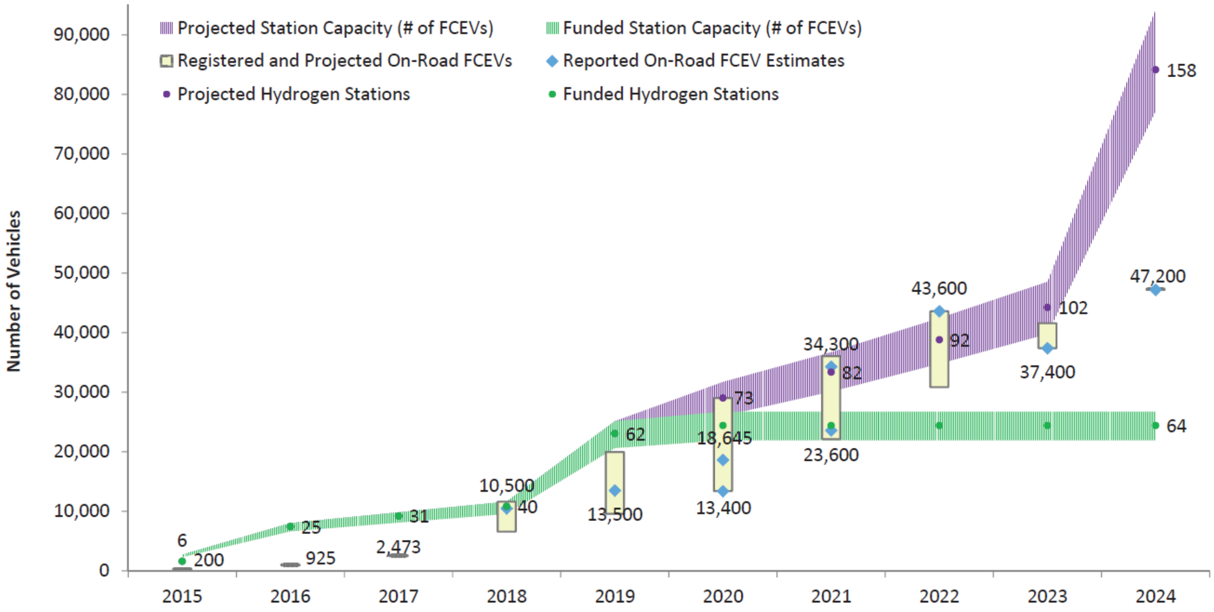
-8
-6
-4
-2
0
2
4
6
8
10
12
Millions Hydrogen kg/year
Greater Los Angeles
Orange County
San Francisco Bay Area
Sacramento Region
San Diego County
North State
Central Coast
San Joaquin Valley
Inland Deserts

Finding 7

Achieving the goals of EO B-48-18 enables two to three times greater FCEV deployment than currently planned



Finding 8

Analysis of FCEV drivers' self-reported fueling habits through the CVRP survey provide valuable insights into network planning approaches

FIGURE 25: IMPORTANCE OF HYDROGEN STATIONS IN CATEGORIZED LOCATIONS TO PURCHASE DECISION

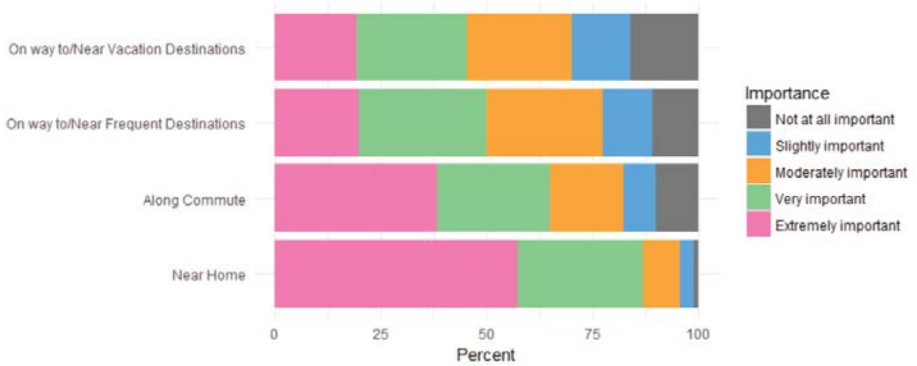
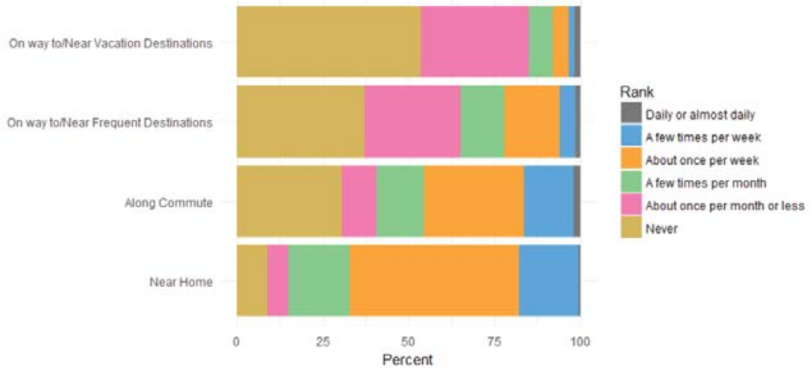
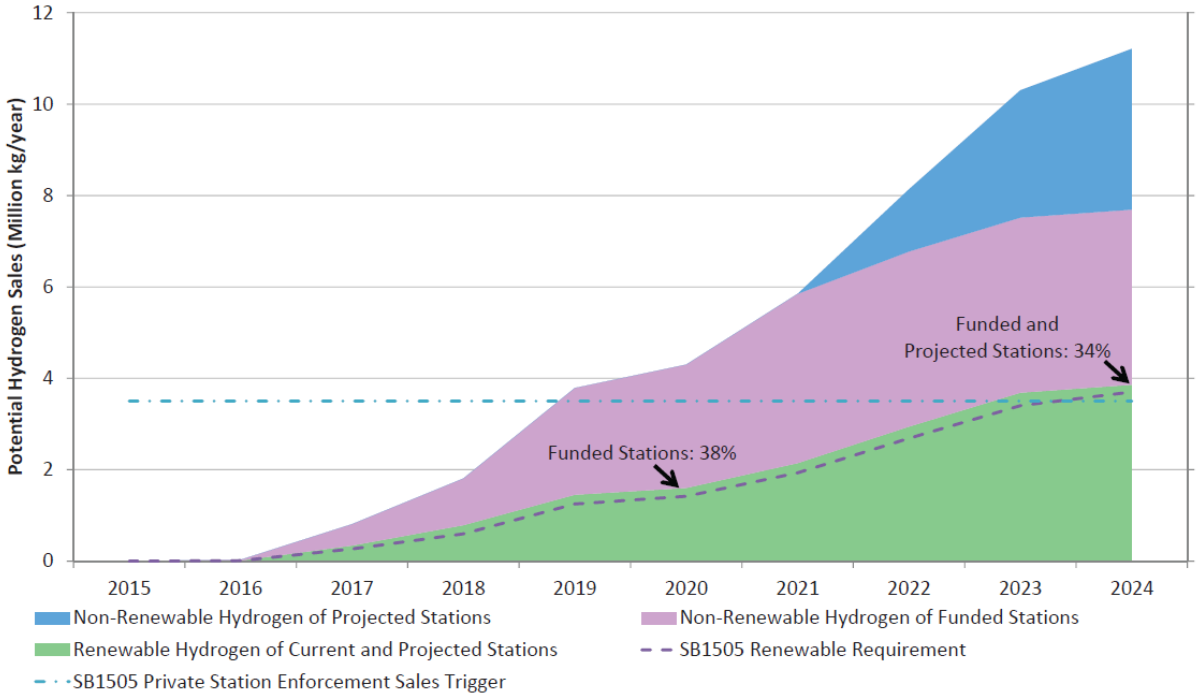


FIGURE 29: FREQUENCY OF HYDROGEN FUELING GROUPED BY CATEGORIZED STATION LOCATION



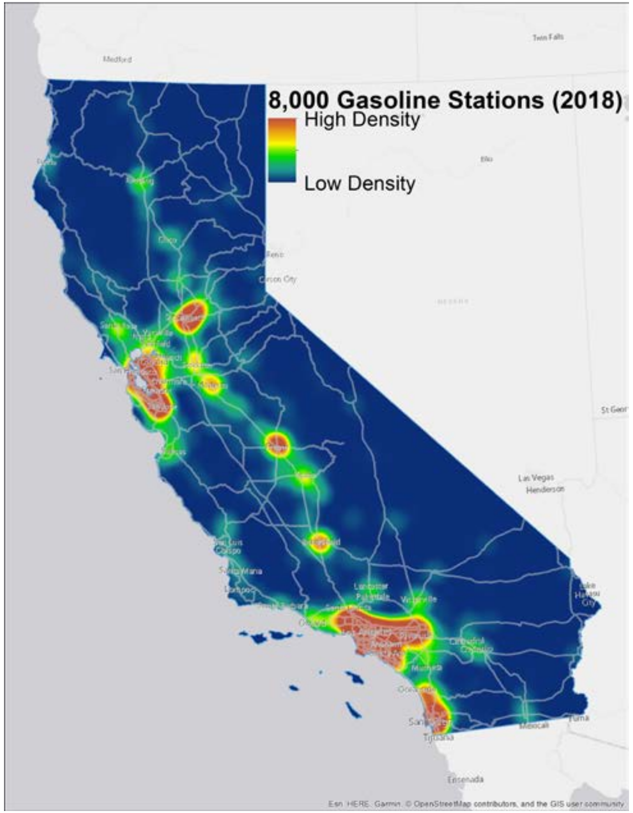
Finding 9

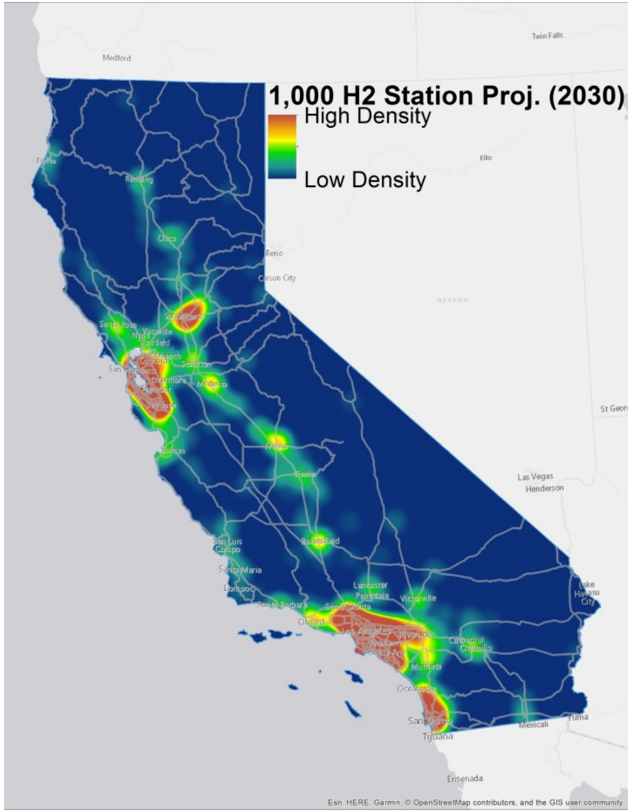
California's hydrogen fueling network is on track to satisfy the 33% renewable requirement of SB 1505



Finding 10

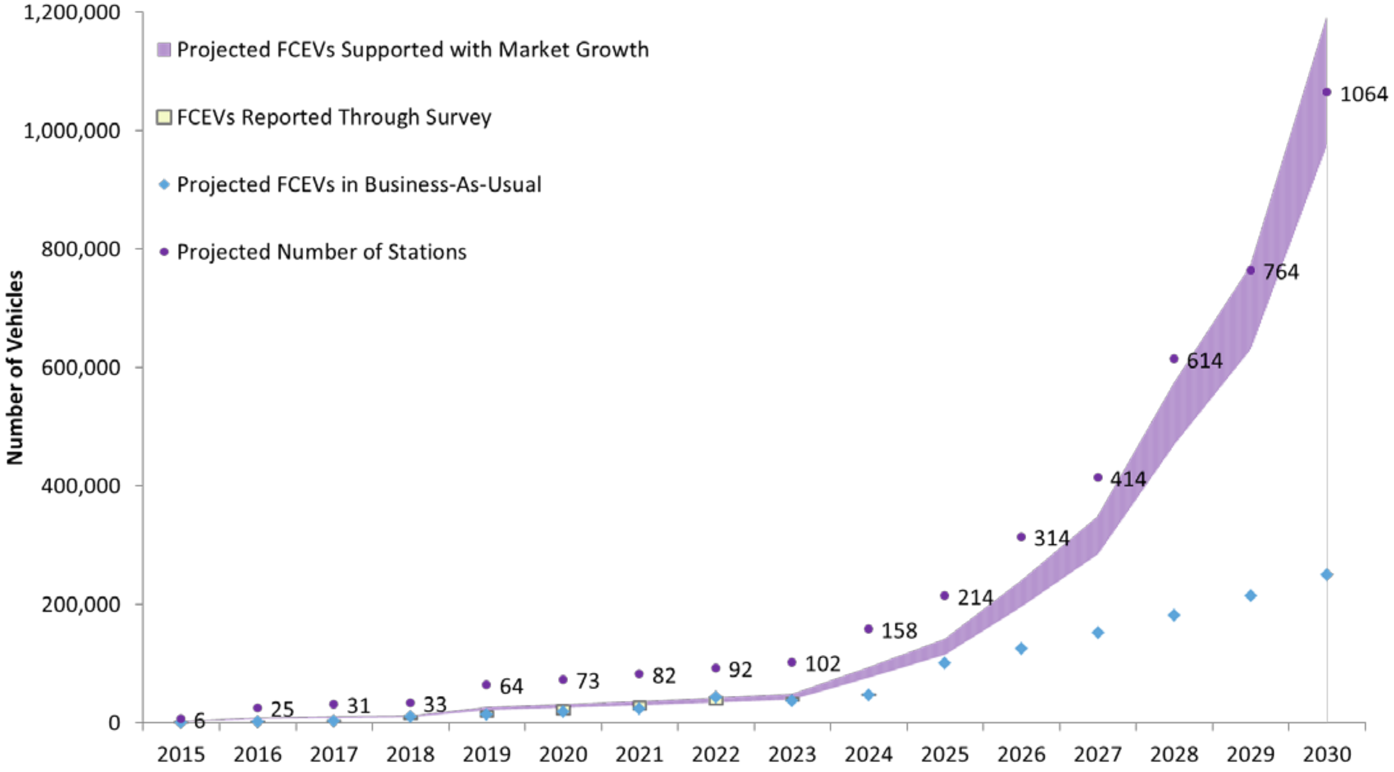
Achieving the 2025 goals of EO B-48-18 enables California to achieve the CaFCP 2030 goals and requires accelerated investment





Finding 10

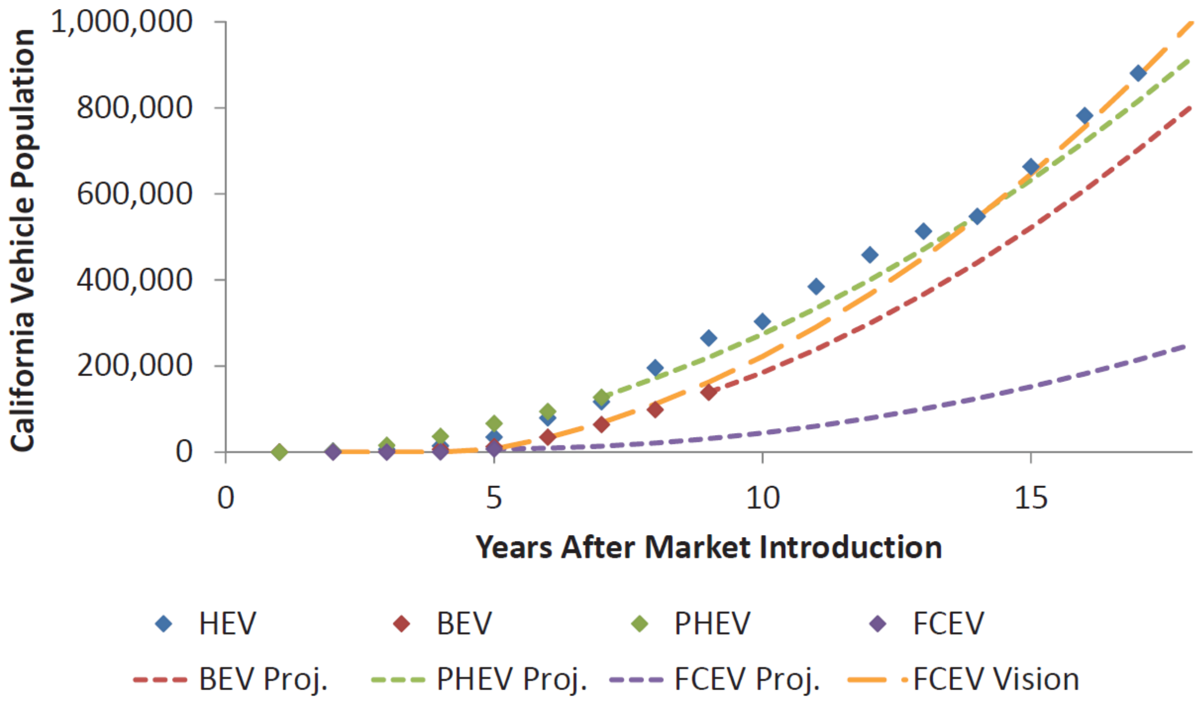
NOTE: Figure does not appear in report, but generated from same data



2030 SCENARIO ANALYSIS

Why 1M FCEVs by 2030?

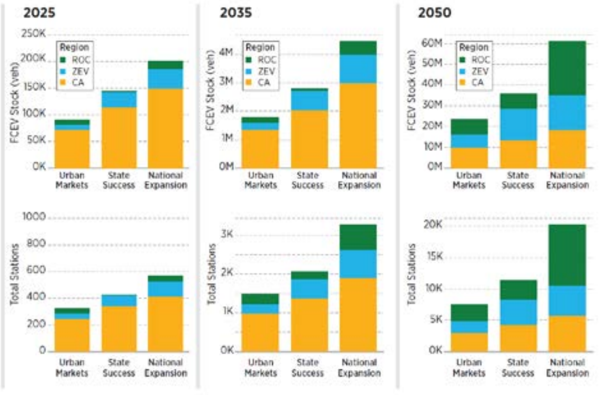
Business-as-Usual projections do not indicate mass-market FCEV entry



Why 1M FCEVs by 2030?

Independent studies confirm 1M FCEVs and 1k stations by 2030 is a reasonable expectation

*From H2USA Locations Roadmap Working Group Publication *National Hydrogen Scenarios (2017)*



*From Hydrogen Council Publication *Hydrogen Scaling Up (2017)*

2030 milestones

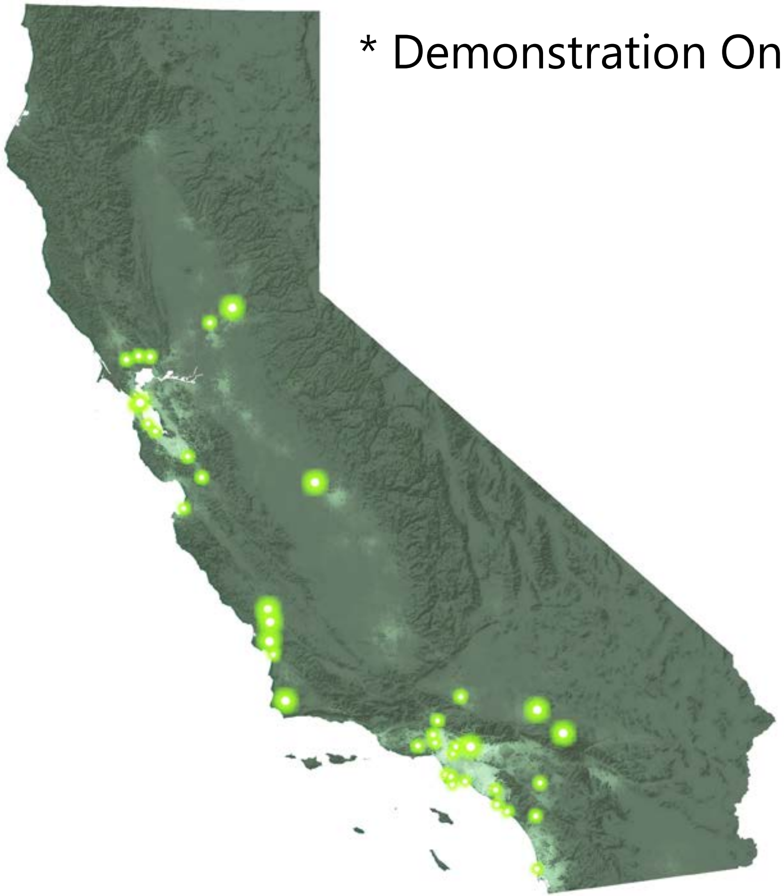
- 1 in 12 cars in Germany, Japan, South Korea, and California powered by hydrogen
- Globally 10 to 15 million cars and 500,000 trucks powered by hydrogen
- Deployment of hydrogen-powered trains and passenger ships

2050 target picture

- Up to 400 million passenger vehicles (~25%), 5 million trucks (~30%), and more than 15 million buses (~25%) running on hydrogen
- 20% of today's diesel trains replaced with hydrogen- powered trains
- 20 million barrels of oil replaced per day, 3.2 Gt CO_2 abated per year

Method

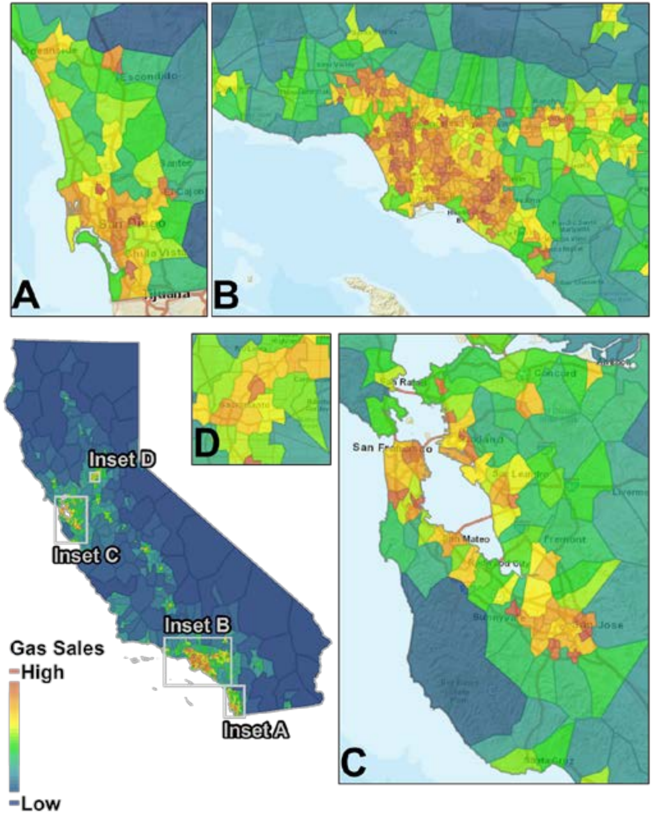
Iterative placement of stations using CHIT based on combined capacity and coverage evaluation



* Demonstration Only

Method

Key input became gas station density template to tune hydrogen station density



Source: Air Resources Board analysis of Energy Commission PIIRA form CEC-A15 results

- Limited to two hydrogen stations per polygon
- Polygons semi-optimized to contain *at least* 10 gas stations

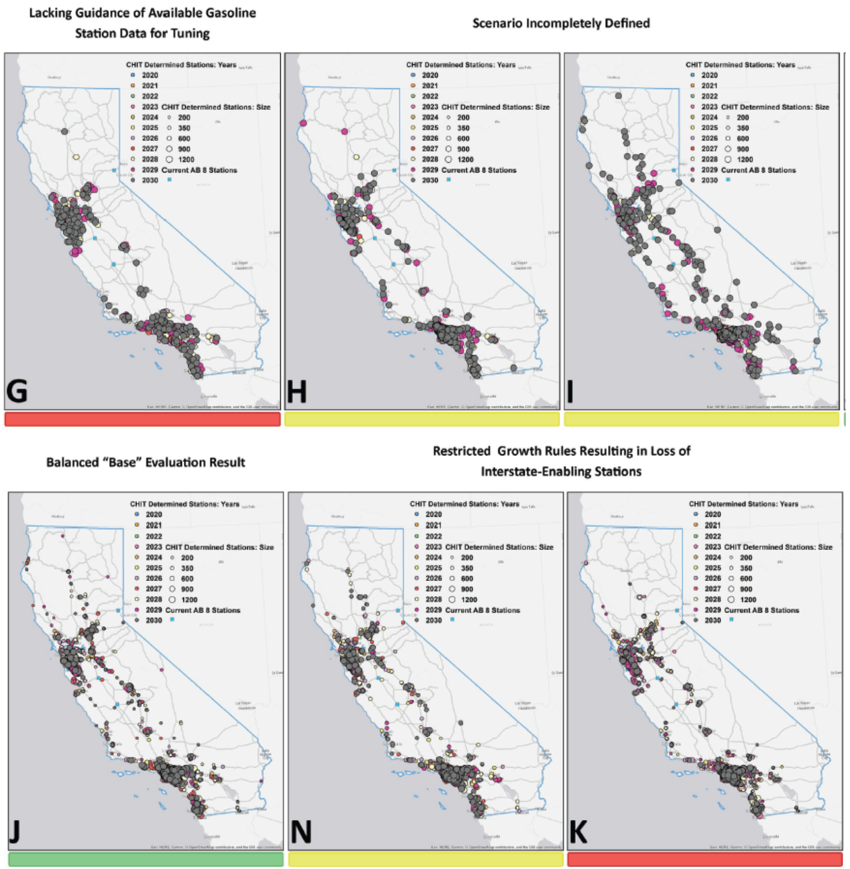
Method

Iterative review of scenario analysis with CaFCP members to define assumptions and parameters

Evaluation	Method	Ratio Coverage: Capacity	Capacity Basis	Lock Out	Priority Areas: Recalculation Frequency	Priority Areas: Minimum Threshold	Available Station Locations	Gas Station Density Following	Evolving Station Size Distribution	Low Through-put Lockout	Early Adopter % Defined	Simulation Guiding Principle
A	1 (Highest Point Basis)	2:1	2030	Station Cell	N/A	N/A	Full State	No	No	No	No	"Where would we put hydrogen stations if we could put them anywhere in the state such that we optimize local capacity and coverage needs? What can we also learn about the order of these stations?"
B	1 (Highest Point Basis)	4:1	2030	Station and Adjacent Cells	N/A	N/A	Full State	No	No	No	No	
C	1 (Highest Point Basis)	4:1	Annually Variable	Station and Adjacent Cells	N/A	N/A	Full State	No	No	No	No	
D	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	Annual	Constant	Full State	No	No	No	No	
E	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	Every 30 stations	Constant	Full State	No	No	No	No	
F	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 3 stations in each	Constant	Full State	No	No	No	No	
G	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time	Full State	No	No	No	No	
H	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time	Restricted Around Gas Stations	Yes	No	No	No	"We have candidates for the optimal locations, but can only choose a subset. Which ones do we choose to optimize coverage and capacity, and in what order ?"
I	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time and starts broader	Restricted Around Gas Stations	Yes	No	No	No	
J	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time and starts broader	Restricted Around Gas Stations	Yes	Yes	No	No	
K	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time and starts broader	Restricted Around Gas Stations	Yes	Yes	Yes	No	
L	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time and starts broader	Restricted Around Gas Stations	Yes	Yes	Yes	Yes	
M	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time	Restricted Around Gas Stations	Yes	Yes	No	Yes	
N	2 (Highest Points within Priority Areas)	2:1	Annually Variable	Station and Adjacent Cells	After 1 station in each	Decreases over time	Restricted Around Gas Stations	Yes	Yes	Reduced	Yes	

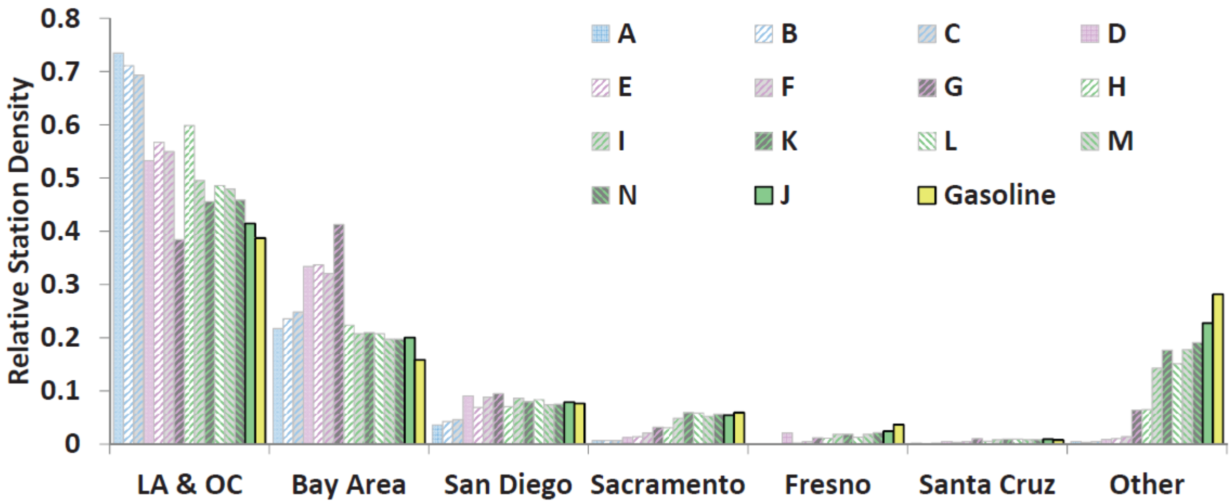
Scenario Selection

Investigated results of several combinations of parameter settings



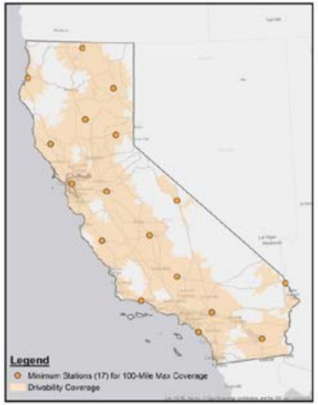
Scenario Evaluation

Finalized scenario most balanced and similar to gasoline

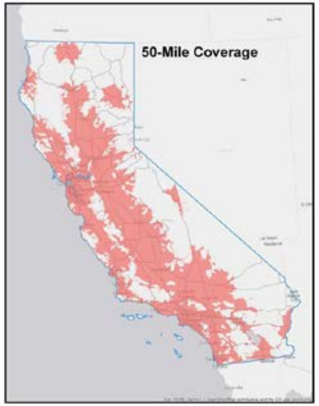


Scenario Evaluation

Finalized scenario balances geographic optimization and market needs, provides equitable baseline coverage, ensures convenience in core markets, and enables long-distance travel



Optima (for Covering Demand Points)	Drive Distance		
	25	50	100
Minimum # of Stations	90	40	17
% of ZIP Codes Crossed	85.2%	90.5%	96.3%
% of Census Blockgroups Contained	89.8%	94.0%	96.3%
% of Population Covered	95.6%	98.1%	99.4%
% of Households Covered	95.5%	97.9%	99.3%
% of Mileage Contained	55.6%	69.1%	86.9%



Roadmap 2030 Coverage Metrics	6-Minute Drive	15-Minute Drive	50-Mile Drive
% of ZIP Codes Crossed	62.6%	73.9%	93.1%
% of Census Blockgroups Contained	49.6%	86.3%	94.5%
% of Population Covered	62.8%	94.1%	99.1%
% of Households Covered	64.2%	93.9%	99.0%
% of Mileage Contained	19.4%	41.4%	77.6%

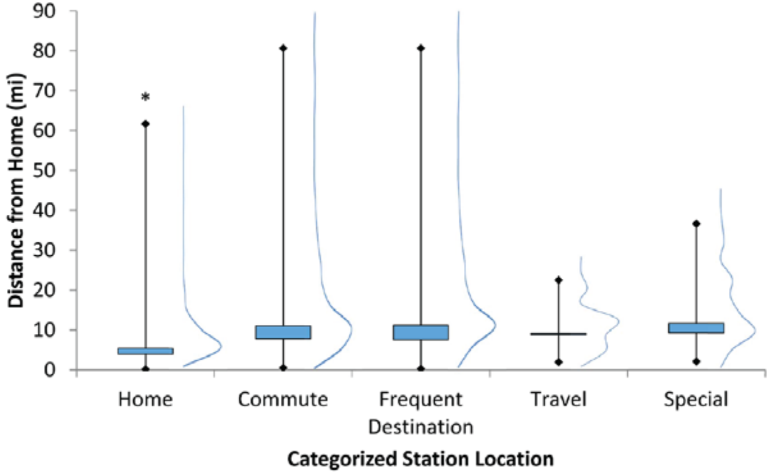
GEOSPATIAL CVRP ANALYSIS

Image courtesy of FirstElement Fuel

Geospatial Analyses

- Drivers who identify as fueling near home drive shorter distances to fuel

- Non-trivial portion of drivers may be fueling further than they need to



	Reported Generalized Location of Most-Used Station				
	Home	Commute	Frequent Destination	Travel	Special
Respondents whose most-used station is the closest to home	244	102	54	5	26
Respondents whose most-used station is NOT the closest to home	118	109	43	10	31
Percentage of respondents whose most-used station is the closest to home	67%	48%	56%	33%	46%
	Aggregated percentage of respondents whose most-used station is the closest to home.				58%

Geospatial Analyses

- Longer daily driving may lead drivers to be less likely to report needing a station near home than at other locations

Table 4: Incremental Changes in Odds Ratio for Choosing the "Comparison" Location over the "Baseline" Location as the Most Necessary to Enable Exclusive Use of FCEV per Incremental Increase of 10 Miles in Daily Drive[11]

		Comparison Location					Descriptive Daily Drive Stats			
		H	C	D	T	All Others	Mean	Median	Min	Max
Baseline Location	H		4.7%	2.6%	-9.7%	2.5%	77.2	45.0	5	500
	C	-4.6%		-2.1%	-5.6%	-4.5%	129.5	77.5	9	450
	D	-2.6%	2.1%		-3.5%	-1.4%	100.8	50.0	14	500
	T	0.9%	5.6%	3.5%		2.4%	71.0	45.0	5	300

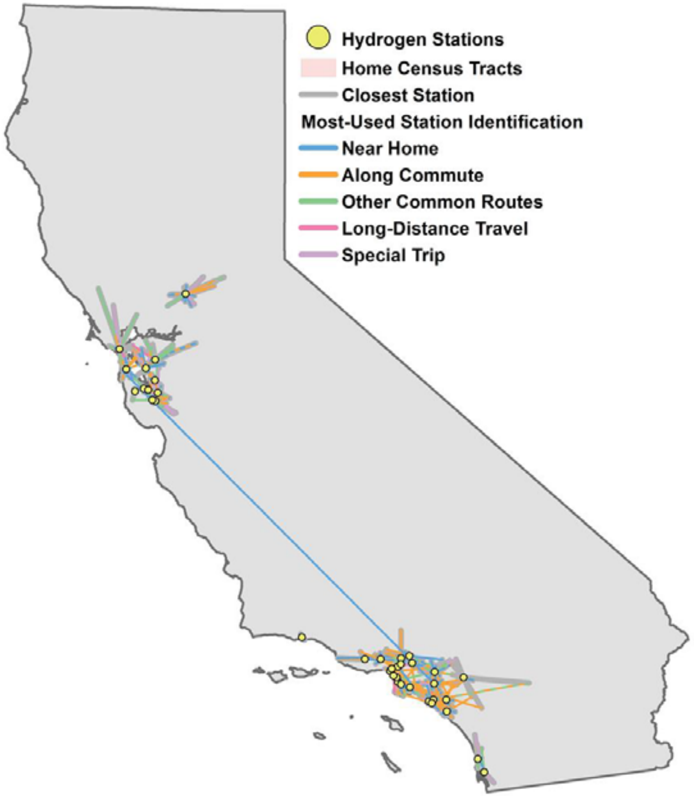
Geospatial Analyses

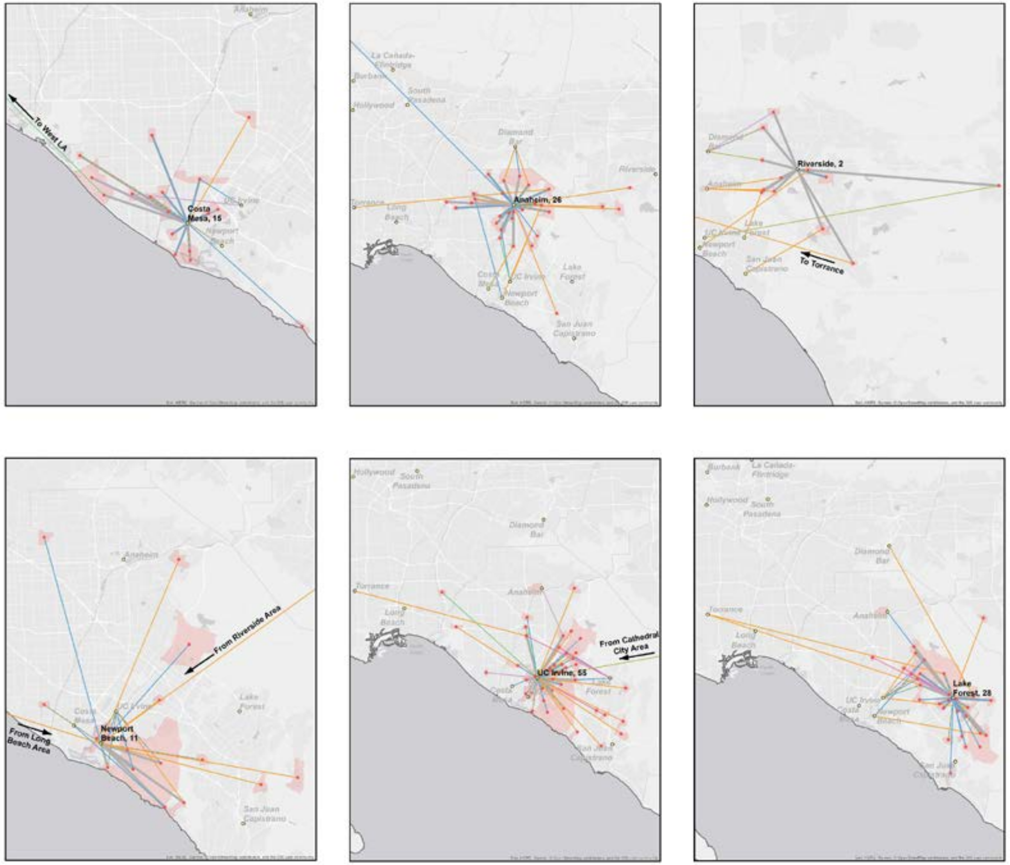
- Daily driving distance does not appear to be associated with differences in the influence of station locations on purchase decision

Table 5: Incremental Changes in Odds Ratio and p-Value for Choosing the "Comparison" Location over the "Baseline" Location as the Most Influential in the Purchase Decision per Incremental Increase of 10 Miles in Daily Drive[11]

		Odds Ratio					p-Value				
		Comparison Location					Comparison Location				
		H	C	D	T	All Others	H	C	D	T	All Others
Baseline Location	H		1.6%	0.9%	-0.5%	9.8%		0.067	0.448	0.698	0.212
	C	-1.6%		-0.8%	-2.1%	-1.5%	0.067		0.510	0.100	0.055
	D	-0.9%	0.8%		-1.4%	-0.3%	0.448	0.510		0.356	0.752
	T	0.5%	2.1%	35.6%		1.2%	0.700	0.099	0.356		0.297

Geospatial Usage Patterns





QUESTIONS