Sacramento Metro AQMD
2019

ZEV Regional Readiness & Planning

Deployment & Travel
2019-2030

Contents

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Regional Deployment Plan

The Sacramento region lags other California cities in adopting and using zero-emission vehicles. A 2017 study by the International Council on Clean Technology (The ICCT) states that areas with promotional activities that combined city and regional governments, utilities, businesses, nonprofit advocacy groups, and media had higher EV use.[1]

The goals of this task in the CEC-funded ZEV Readiness project[2] are to identify regional messaging about zero emission vehicles (ZEVs) and to develop a plan for providing education and training that will encourage business and fleet ZEV adoption through the following activities:

- Project ZEV deployment over a 10-year period and needed investment, including transit and freight vehicles
- Identify current and forecasted regional driving patterns
- Identify existing and planned hydrogen stations and DC fast chargers, existing and planned Level 2 public charging, conventional fuel stations that fleets use, and existing gasoline demand patterns
- Identify environmental data based on SMAQMD's air pollution index, Environmental Justice Plan and CalEnviroScreen scores.
- Assess municipal and public properties as future infrastructure locations
- Assess fleet fueling models, including fleet credit cards and third-party operators, to determine opportunities to leverage fleet and public fueling/charging

This project's focus is on infrastructure to support high-mileage drivers, defined as people who drive at least 50 miles or 90 minutes one way to commute to work or drive at least 100 miles during work. This report focuses on the ZEV deployment, regional driving patterns, and the projected infrastructure needs to inform the interactive map developed during this project.

Projected ZEV Deployment

In late 2018, the California Department of Motor Vehicles began posting vehicle registration data by county and zip code.[3] The DMV reports aggregate all vehicles, including heavy-duty, fleet, and exempt vehicles (e.g. registered to a government agency) without a way to distinguish a passenger car from a transit bus from a police car. It does, however, provide a starting point for estimating ZEV growth.

Table 1 and Table 2 show the total number of registered vehicles by fuel type in January 2018 and October 2018, respectively. The Natural Gas column combines liquid and compressed natural gas vehicles. The Other column combines diesel hybrids, propane, butane, methanol, and methane vehicles. Table 3 shows the difference in registered vehicles between January and October. A negative number indicates vehicles removed from registration in that county.

In October 2018, zero-emission vehicles (including plug-in hybrids) were slightly less than one percent of all vehicles on the road in the six counties that are part of this project.

[1] https://www.theicct.org/sites/default/files/publications/EV-charging-best-practices_ICCT-white-paper_04102017_vF.pdf
[2] CEC-ARV-16-023
[3] https://www.dmv.ca.gov/portal/dmv/detail/pubs/media_center/statistics

Table 1: Registered vehicles by county on January 1, 2018

County	Battery Electric	Fuel Cell	Plug-in Hybrid	Diesel	Ethanol	Gasoline	Hybrid Gas	Natural Gas	Other	Grand Total
El Dorado	622	8	770	13,756	9,975	152,103	4,615	32	41	181,922
Placer	1,948	23	1,463	19,921	21,585	287,476	10,772	76	57	343,321
Sacramento	3,803	106	3,785	53,033	71,564	1,010,251	37,248	1,052	409	1,181,251
Solano	967	7	1,595	15,600	22,361	314,039	11,043	352	82	366,046
Sutter	67	1	74	8,030	5,970	65,595	1,258	24	26	81,045
Yolo	782	30	754	10,671	12,804	130,976	6,413	208	56	162,694
Total	8,189	175	8,441	121,011	144,259	1,960,440	71,349	1,744	671	**2,316,279**

Table 2: Registered vehicles by county on October 1, 2018

County	Battery Electric	Fuel Cell	Plug-in Hybrid	Diesel	Ethanol	Gasoline	Hybrid Gas	Natural Gas	Other	Grand Total
El Dorado	800	11	953	14,215	7,288	154,835	4,749	32	33	182,916
Placer	2,297	35	1,825	20,594	16,644	294,552	11,237	82	58	347,324
Sacramento	4,814	130	5,045	53,902	55,399	1,029,992	40,029	1,041	360	1,190,712
Solano	1,224	6	2,027	16,138	16,752	320,613	11,464	324	63	368,611
Sutter	92	1	88	8,515	4,866	66,706	1,327	22	26	81,643
Yolo	973	36	997	10,808	9,251	134,568	6,707	219	49	163,608
Total	10,200	219	10,935	124,172	110,200	2,001,266	75,513	1,720	589	**2,334,814**

Table 3: Change in registrations January to October 2018

County	Battery Electric	Fuel Cell	Plug-in Hybrid	Diesel	Ethanol[4]	Gasoline	Hybrid Gas	Natural Gas	Other	Grand Total
El Dorado	178	3	183	459	-2,687	2,732	134	0	-8	994
Placer	349	12	362	673	-4,941	7,076	465	6	1	4003
Sacramento	1,011	24	1,260	869	-16,165	19,741	2,781	-11	-49	9461
Solano	257	-1	432	538	-5,609	6,574	421	-28	-19	2565
Sutter	25	0	14	485	-1,104	1,111	69	-2	0	598
Yolo	191	6	243	137	-3,553	3,592	294	11	-7	914
Total	2,011	44	2,494	3,161	-34,059	40,826	4,164	-24	-82	**18,535**

[4] Some E-85 vehicles may have been reclassified as Gasoline between January and October

California's Clean Vehicle Rebate Program (CVRP) publishes data by county, census tract, and zip code about the vehicles that were approved for a rebate.[5] Table 4 shows the difference in ZEV registrations between January and October 2018 and the rebate applications during the same period. Some vehicles may have been registered with DMV and/or applied for a rebate in December 2017 and November 2018. Data from the California Hybrid Voucher Incentive Program (HVIP)[6] and School Bus Replacement Project indicates that none of the ZEVs added during this period were heavy-duty vehicles.

Table 4: New ZEV registrations and rebate applications January through October 2018

County	Battery Electric	Fuel Cell	Plug-in Hybrid
El Dorado	178	3	183
Placer	349	12	362
Sacramento	1011	24	1,260
Solano	257	-1	432
Sutter	25	0	14
Yolo	191	6	243
Total Registered Vehicles	**2,011**	**44**	**2,494**
Total Rebate Applications	1,843	56	1,197
Percent of ZEVs Rebated	92%	100%	48%

Between November 2018 to January 2019, CVRP issued rebates for 1,138 vehicles. Table 5 shows the number of rebates (pending and issued) by county during this period.

Table 5: CVRP rebates November 2018 through January 2019

County	Battery Electric	Fuel Cell	Plug-in Hybrid
El Dorado	65	0	43
Placer	141	1	59
Sacramento	387	3	171
Solano	105	0	57
Sutter	10	0	6
Yolo	65	1	24
Total	**773**	**5**	**360**

The number of ZEVs registered in the Sacramento region in January 2019 was determined by adding:

- The number of registered ZEVs in October 2018 (from Table 2)
- The number of rebates November through January (from Table 5)
- The "multiplier" from Table 4 for ZEVs that did not apply for a rebate

Using this formula, about 29,000 ZEVs were registered in the six-county Sacramento region in January 2019, as shown in Table 6.

Table 6: Estimate of ZEVs in the Sacramento region in January 2019

County	Battery Electric	Fuel Cell	Plug-in Hybrid	County Total
El Dorado	865	11	996	1,872
Placer	2,438	36	1,884	4,358
Sacramento	5,201	133	5,216	10,550
Solano	1,329	6	2,084	3,419

[5] https://cleanvehiclerebate.org/eng/rebate-statistics
[6] https://www.californiahvip.org/tools-results/#program-numbers

County	Battery Electric	Fuel Cell	Plug-in Hybrid	County Total
Sutter	102	1	94	197
Yolo	1,038	37	1,021	2,096
Total	**10,973**	**224**	**11,295**	22,492
Multiplier	.08	0	.52	
Region Total	**11,851**	**224**	**17,168**	**29,243**

Data indicates that plug-in hybrids drivers do not use DC fast chargers, therefore forecasts are focused on battery (BEV) and fuel cell (FCEV) electric vehicles that will need fueling/charging infrastructure to enable high-mileage driving.

Light-Duty ZEVs

Between January 2018 and January 2019, registrations of battery electric vehicles grew by 2,895 vehicles—45 percent—in the six-county region. From available data, characteristics of the vehicles are:

- 2,649 ZEVs were approved for "individual" rebates from CVRP; 70% were for Tesla cars
- 28 ZEVs were approved for "business" rebates from CVRP; all were for Tesla cars
- The City of Sacramento Fleet Services registered 35 new ZEVs in March 2018; they were the only fleet that reported purchasing BEVs and FCEVs in 2018.

CVRP data indicates that ZEV consumers are largely college-educated males that own detached homes and have a household income of $100,000 or more.[7] This is generally the demographic of new car buyers, however, women account for almost 50% of new conventional vehicle purchases. Although people from all walks of life buy and lease new cars, using the demographic of the group that is most likely to buy or lease a new car is a good weather balloon to estimate future market capacity for new ZEVs.

Table 7 shows the 2017 American Community Survey five-year average of selected economic characteristics by county. The table also includes the number of all new vehicle registrations and the number of new BEV/FCEV registrations from the DMV data between January and October 2018. Table 8 extrapolates the numbers to arrive at the percentage of households that may have registered a new vehicle during the 10-month period.

Table 7: Demographics of typical new car buyer and new DMV registrations January to October 2018

County	Total Owner-Occupied Housing Units[8]	Number of Households with Income over $100k	Number of Owner-Occupied Housing Units Bachelor's Degree or Higher[9]	New Vehicle Registrations (1/1-10/30/2018)	New ZEV Registrations (1/1-10/30/2018)
El Dorado	37,803	19,611	21,848	994	181
Placer	71,620	39,889	44,898	4,003	361
Sacramento	214,839	96,458	122,627	9,461	1,035
Solano	66,821	34,052	30,030	2,565	256
Sutter	12,048	4,632	4,695	598	25
Yolo	26,361	14,521	19,210	914	197

[7] https://cleanvehiclerebate.org/sites/default/files/attachments/CVRP_Analysis_Update-2018-12-04.pdf
[8] Table S2506 Financial Characteristics for Housing Units with a Mortgage
[9] Table B25013 Tenure by Educational Attainment of Householder

Table 8: Extrapolated percentage of households that potentially registered a new car January to October 2018

County	Percentage of Households that Registered a New Car	Percentage of Households that Registered a New BEV or FCEV
El Dorado	5.1%	0.9%
Placer	10.0%	0.9%
Sacramento	9.8%	1.1%
Solano	7.5%	0.8%
Sutter	12.9%	0.5%
Yolo	6.3%	1.4%

The California New Car Dealers Association expects that statewide new vehicle registrations will remain at about 2 million a year, a number that has been consistent for the last three years. Household income in the Sacramento region has changed very little over the last decade and, therefore, is assumed to remain stable in the next decade.

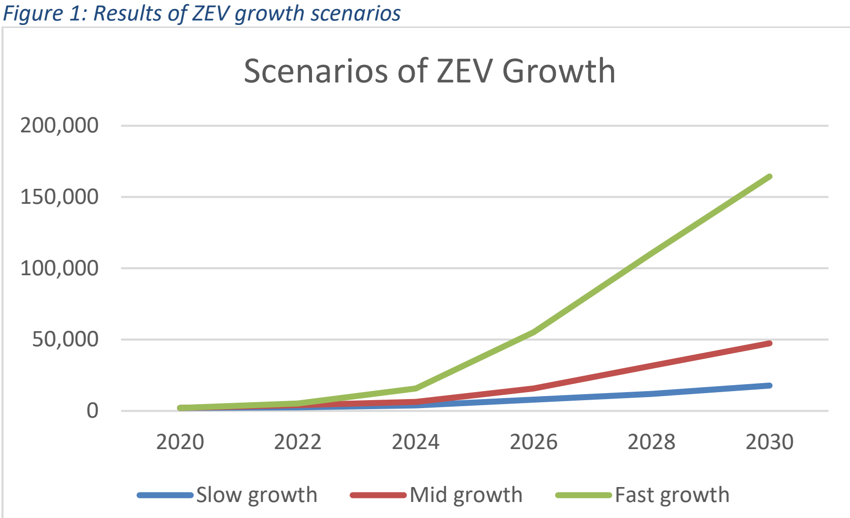
To estimate the potential for light-duty ZEVs, the team created three scenarios that assume the number the percentage of ZEV buyers will increase each year. To estimate the number of households in each county, the team multiplied number of households in 2017 by each county's estimate of population growth through 2030. It was assumed that the number of households that meet the new-car-buyer demographic will increase proportionality to household growth. The findings in Table 9 are consistent with global market forecasts by the International Energy Agency.[10]

Table 9: ZEV growth scenarios

	Percentage of New Car Sales that are ZEVs					
Growth Scenario	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**
Slow growth	0.9%	1.1%	1.7%	3.4%	5.1%	7.6%
Mid growth	0.9%	1.8%	2.7%	6.8%	13.5%	20.3%
Fast growth	0.9%	2.3%	6.8%	23.6%	47.3%	70.9%

If the 12,000 currently registered ZEVs and all new ZEV registrations stay in operation (e.g., in the used car market), the number of ZEVs in the Sacramento region ranges from a conservative 58,230 to an aggressive 365,279. Figure 1 illustrates the growth curve for all three scenarios.

Figure 1: Results of ZEV growth scenarios



[10] https://www.iea.org/publications/reports/globalevoutlook2019/

From the forecast, it appears that ZEV registrations climb from thousand to tens of thousands between 2024 and 2026. Infrastructure needs to be placed to encourage adoption before 2024 and then support a growing number of vehicles through the end of the 2030.

The Tipping Point

A tipping point is an accumulation of forces that move for change in one direction or another. At some point, the accumulation made enough change that things seem to be different. “A tipping point is something that has broad societal implications,” said Oxford professor Margaret MacMillan, “and we usually don’t see a tipping point until we are years past it.”

Reports and forecasts about the potential of the EV market all mention the number of factors that need to move to influence the market. For example, the IEA report previously referenced noted that to reach the fast-growth scenario:

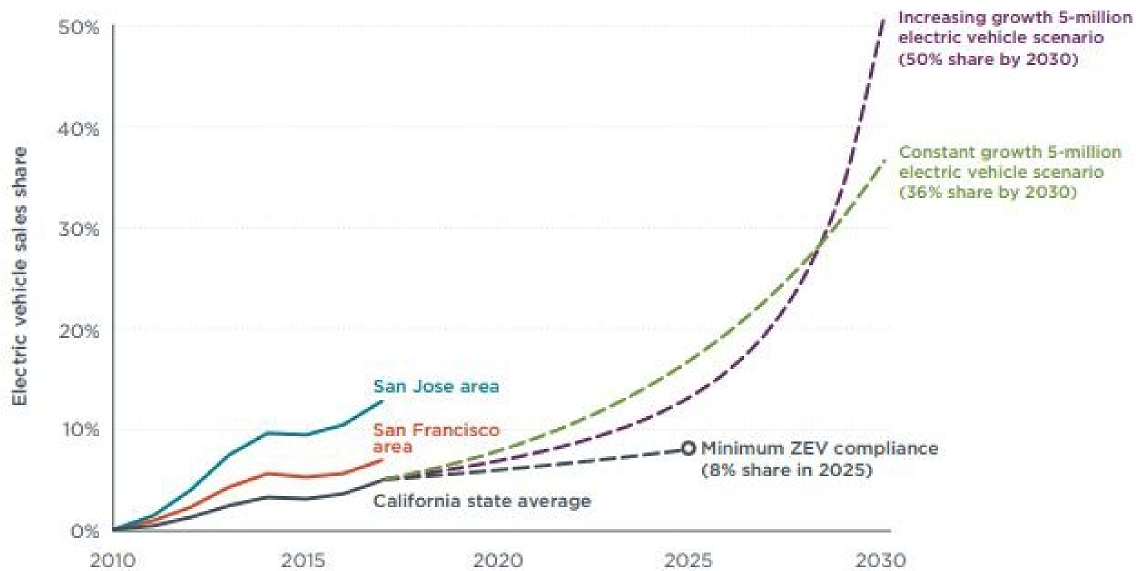
- Automakers need to produce a wider range of EV models and at a variety of prices, potentially even redesigning the way vehicles are manufactured.
- Policies and incentives must help bridge the cost gap between conventional and electric vehicles.
- Technical advances in batteries (and fuel cells) must help deliver substantial cost cuts and manufacturing capacity must increase.
- The supply of cobalt, lithium, and other raw materials will need to scale up in a way that is mindful of environmental impacts and social issues. End-of-life management of batteries (and fuel cells) may play a role availability of materials.
- The tax revenue base derived from vehicle and fuel taxes must be replaced, potentially by gradually increasing taxes on carbon-intensive fuels combined with the use of location-specific distance-based charges.
- Electricity demand will increase, and the demand will change as more cars fuel with electricity (or hydrogen). Electric mobility will need to play a role in increasing the flexibility of power systems.

Other factors simply influence the number of new cars sold: the economy, the age of the population, the distance between home and work, and the overall cost of owning a personal vehicle. Factors are outside the control this report’s stakeholders include:

Vehicle Availability: In May 2018, the International Council on Clean Transportation (The ICCT) published a briefing[11] about California’s electric vehicles market development that shows the distinct difference between the State’s 5 million ZEV goal and the minimum number of vehicles required for automakers to comply with the Zero Emission Vehicle Regulation.[12] As shown in Figure 2, ZEV sales need to be 15 percent of new car sales by 2025 and then steeply ramp up to meet the State’s target, but automakers do not need to produce that many cars to comply with the regulation. It could result in fewer EVs being produced and sold than needed to achieve ZEV goals.

[11] https://www.theicct.org/sites/default/files/publications/CA-cityEV-Briefing-20180507.pdf
[12] https://www.arb.ca.gov/msprog/zevprog/factsheets/zev_regulation_factsheet_082418.pdf

Figure 2: Number of ZEVs required to meet regulations and State of California goals



Vehicle Models: According to the California New Car Dealers Association, about half of new vehicles sales statewide are light trucks, pick-ups, SUVs, and vans;[13] EVs are currently not available in this class of vehicle.[14] Volvo, Audi, Mercedes, and Hyundai are introducing ZEV SUVs in 2019 and 2020 and start-up companies Rivian and Atlis plan to introduce EV pick-up trucks in 2020 and 2021. Volkswagen announced an all-electric version of its minibus to be available in 2022. All these vehicles are aimed at the luxury car buyer, but they will pave the way for non-luxury versions. Until EV light trucks are available and have similar utility as conventional pick-ups and SUVs, it will limit EV adoption for a large group of buyers.

Used Car Sales: When cars are traded into a dealership, the car often heads to a wholesale auction. At international conferences about clean transportation, Frontier Energy learned that wholesalers buy EVs at U.S. auctions and then export them to countries where new EVs are not sold. The EVs are late-model cars with low miles that wholesalers can buy relatively cheaply and sell at premium prices outside the county. If this trend continues, most EVs traded in will not enter Sacramento's used car market.

Pay-per-Charge: Many workplace and parking lot chargers are free to use or free to use with paid parking. As property owners and facility managers have noted, this doesn't cover operating and maintenance costs. A fee for charging could reduce interest in EVs or encourage more people to charge at home instead of using public charging.

VMT Reduction: The Sacramento region has many initiatives aimed at reducing vehicle miles traveled (VMT) that include expanded access to transit and active modes of travel and changes in land-use planning. SACOG's Green Means Go pilot is a first step at intensifying infill development to increasing housing options in center and corridor communities. It may reduce the number of EVs because people will sell personal vehicles and not replace them at all.

[13] CNCDA states that 51.3% of new vehicle registrations statewide are light trucks (pick-ups, SUVs, vans). www.cncda.org

[14] Tesla's Model X is a cross-over (CUV) and registered as a car, not a light truck

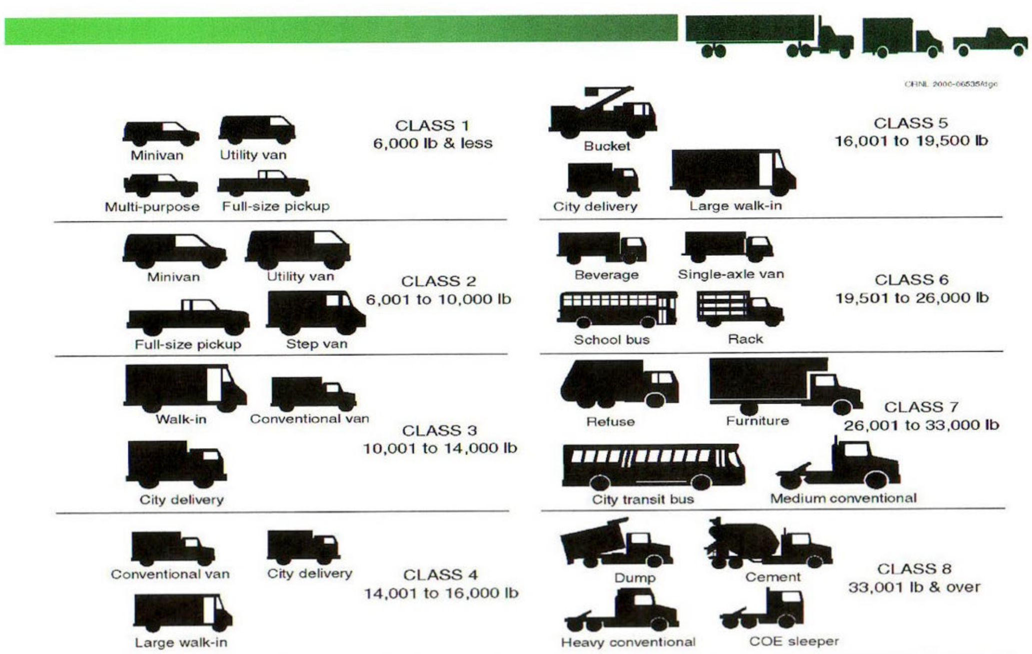
Trucks

Truck electrification has more challenges than cars, particularly related to range for long-haul trucks. Current battery and fuel cell prototype trucks have a range of about 300 miles, although Telsa and Nikola promise 500- and 700-mile range respectively. Both these trucks require large-capacity infrastructure for charging the battery or filling with hydrogen at truck stops on the nation's highways.

The California Air Resources Board's proposed Advanced Clean Truck Regulation is expected to be finalized in 2019 or 2020. If passed as written, the regulation will require:

- Manufacturers of Class 2B and Class 3 vehicles (see Figure 2) must have 3 percent of sales be ZEVs by the 2024 model year, increasing by 2 percent each year through 2030, when 15 percent of sales would need to be zero-emission vehicles.
- Manufacturers of Class 4 through Class 8 vocational trucks must have 7 percent of sales be ZEV by the 2024 model year. By 2030, it would increase to 50 percent.
- Manufacturers and integrators of Class 7 and Class 8 tractors (long-haul trucks) must have 9 percent of sales be ZEVs by the 2027 model year and increase to 15 percent by 2030.
- Large employers, including retailers, manufacturers, and freight brokers, and fleets that operate 100 or more trucks must report about their deliveries and shipments to help identify future strategies for purchasing and placing zero-emission trucks.

Figure 3: Truck Classifications (source: Freightliner)



The Sacramento region is a distribution hub for agriculture, finished food products, chemicals and pharmaceuticals, technology products. Yolo County has regional distribution centers for Walmart, Target, Rite Aid, Raley's, UPS, and the U.S. Post Office. Sacramento County is home to an Amazon distribution center. It's estimated that at least 44,000 trucks are registered in the Sacramento/West Sacramento area.

Experian Automotive research showed that the average age of medium-duty vehicles was 11 years and heavy-duty vehicles averaged 12.3 years. Experian also showed that Ford vehicles were nearly 21 percent of the trucks on the road, followed by International at 17.5 percent and Freightliner at 15.6 percent. Experian considered the following vehicles in its research:

- Semis
- Cement trucks
- Buses
- Delivery vans
- Utility vehicles
- Fire trucks
- Ambulances
- Large pickups
- Motorhomes

The Advanced Clean Truck Regulation will require ZEV sales beginning in 2024 and will not apply to all the trucks listed above. It is likely that uptake of ZEV trucks by fleets and freight operators will be in the dozens through 2024 and hundreds through 2030. Thoughtfully planned infrastructure can spur adoption of ZEV trucks through 2024, particularly local delivery vehicles.

Transit Buses

The California Air Resources Board's Innovative Clean Transit regulation was adopted in late 2019. It is the first regulation to require an entire class of vehicles transition to ZEVs on a timeline.[15] The regulation requires that:

- Large transit agencies (those operating more than 65 buses) purchase 25% zero emission buses (ZEBs) starting in 2023, 50% in 2026, and 100% in 2029
- Small transit agencies purchase 25% ZEV buses starting in 2026 and 100% in 2029

The Sacramento region has 14 transit agencies. Only Sacramento RT and Paratransit are large agencies. Table 10 lists the agencies and the buses each operates.

Table 10: Transit agency rolling stock

Transit Agency	Buses CNG	Buses Gasoline (g) or Diesel (d)	Cutaways Gasoline	Notes
Yuba/Sutter Transit		35[d]	16	13 of 35 are commuter coaches, cutaways diesel
Roseville Transit		27[d]	11	11 of 27 are commuter coaches
Paratransit Inc.			170	Paratransit is shifting to CNG
Unitrans	42	5[d]	1	Includes 5 double-deckers
Davis Community Transit			4	
Folsom Stageline		5	6	
Elk Grove e-tran*	52		10	Cutaways: 8 gasoline, 2 diesel

[15] https://ww3.arb.ca.gov/regact/2018/ict2018/ictfro.pdf?_ga=2.248038407.1483376234.1563302919-368227744.1484264568

Transit Agency	Buses CNG	Buses Gasoline (g) or Diesel (d)	Cutaways Gasoline	Notes
Yolobus	43	17^d	11	Cutaways: diesel
Sacramento Regional Transit	192		21	Cutaways: 17 CNG, 4 gasoline
Auburn Transit	1	1^d	3	
South County Transit-SCT Link		$16^g + 2^d$	16	2 diesel commuter coaches
East County		2	2	Purchased by Sac County for Amador Transit
Placer County Transit	12	$2^g + 5^d$	2	5 diesel commuter coaches
El Dorado Transit		27^d	12	16 commuter coaches
Total	**342**	**144**	**285**	

**In April 2019, Sacramento RT started negotiations with the City of Elk Grove to assume the city's transit operations from e-tran.*

Figure 4 shows three styles of buses the transit agencies operate: commuter coaches that make few local stops, cutaways that are typically used for low-demand routes or for disabled passengers, and traditional transit buses that operate on a fixed route. The ICT requires that tradition fixed-route buses be electrified first. ZEV cutaways or over-the-road commuter coaches don't toward the minimum ZEB requirement until January 1, 2026 or until the transit agency has met the minimum ZEB requirements with traditional fixed-route buses.

Figure 4: Types of buses (Source: El Dorado Transit)

Sacramento Regional Transit (SacRT) purchased six EV minibuses to use in its on-demand transit program. In September 2018, SacRT and Yolo Transportation District (YCTD) entered into a cooperative agreement with Electrify America for each agency to acquire six battery-electric buses with Electrify America paying the $12 million acquisition cost. SacRT and YCTD will operate 12 BEV buses as a shuttle between the UC Davis campus and the UC Davis Medical Center. The Sacramento Area Council of Governments (SACOG) awarded $3 million in 2018 Regional Program grant funds to help subsidize the costs of the service, and both agencies received additional support from SMUD and PG&E to deploy charging infrastructure. After the SACOG grant is exhausted, operating costs are estimated to be $700,000 annually for each agency ($140,000 total). SacRT and YCTD also submitted funding applications for electric buses for to/from the Sacramento International Airport.

Only three of the agencies publicly indicated that they are starting their transition planning:

- SacRT has a 2019 goal to "work with various internal departments and partners to develop a ZEV fleet conversion plan to replace CNG and gasoline revenue vehicles to electric battery."[16]

- A short-range plan for the Placer County Transportation Planning Agency recommended that Roseville Transit should purchase four zero emission buses in 2026 to replace four fixed-route buses that are scheduled to retire.[17]
- YCTD is seeking funding to conduct an electrification study.

As a frame of reference for bus purchases, SacRT's 2018-2019 budget included replacing 31 2008 model year CNG buses with new CNG buses. Another 60 2008 model year buses will be budgeted for replacement in FY21 and FY22. If the agency buys 30 new buses a year and follows the ZEB percentages in ICT, they will buy:

- 8 ZEBs each year 2023 through 2025
- 15 each year in 2026 through 2029
- 30 ZEVs each year starting in 2029.

With 192 buses in the fleet, all buses would be replaced with ZEBs by 2033. (In meetings, Sacramento RT representatives stated they plan to adopt ZEBs earlier than the regulation requires.)

If we assume that by 2030, half of the existing fixed-route transit buses will have been replaced by ZEBs, the Sacramento region could have 240 zero-emission buses on the road. Factors like extending light rail and a greater shift to on-demand transit could reduce the overall number of buses. Or an emphasis on transit-oriented, mixed-use, and in-fill development could increase the number of buses.

Driving Patterns

This project focuses on long-distance drivers, which fit into three categories:

1. Super-commuters: A U.S. Census designation for people who drive at least 50 miles or 90 minutes one way between home and work.
2. Livery driver: People who drive taxies, limos, or ride share vehicles, typically 5-to-10 miles at a time.
3. Service drivers: People who drive a car or truck for work-related purposes like a realtor, a repair person, and a delivery driver, typically 10-to-15 miles at a time

Transit buses can be considered high-mileage vehicles but operate on fixed routes in a city or between cities. Vanpools and shuttle buses have a driving pattern like super commuters and a fueling pattern more like service drivers.

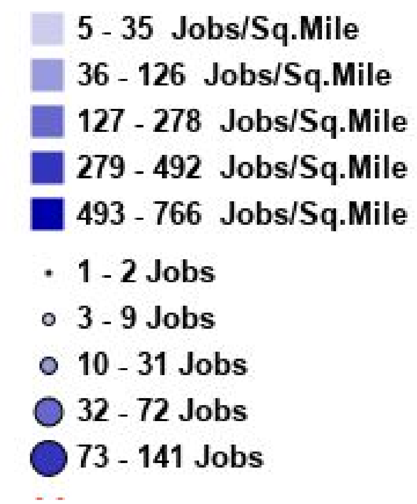
Commuters

OnTheMap, an online tool from the U.S. Census agency, is a data portal for visualizing travel data.[18] The current iteration uses data from the 2017 American Community Survey to estimate the number of miles that people between their home census blocks to their work census blocks. This data indicates the travel patterns of the super commuter group. Figure 5 is the key to interpreting the destination data of the GIS

[16] https://www.sacrt.com/documents/financialdocs/FY18-19_Final_Budget.pdf
[17] http://pctpa.net/library/srtp/2018/Roseville/Complete.pdf
[18] https://onthemap.ces.census.gov/

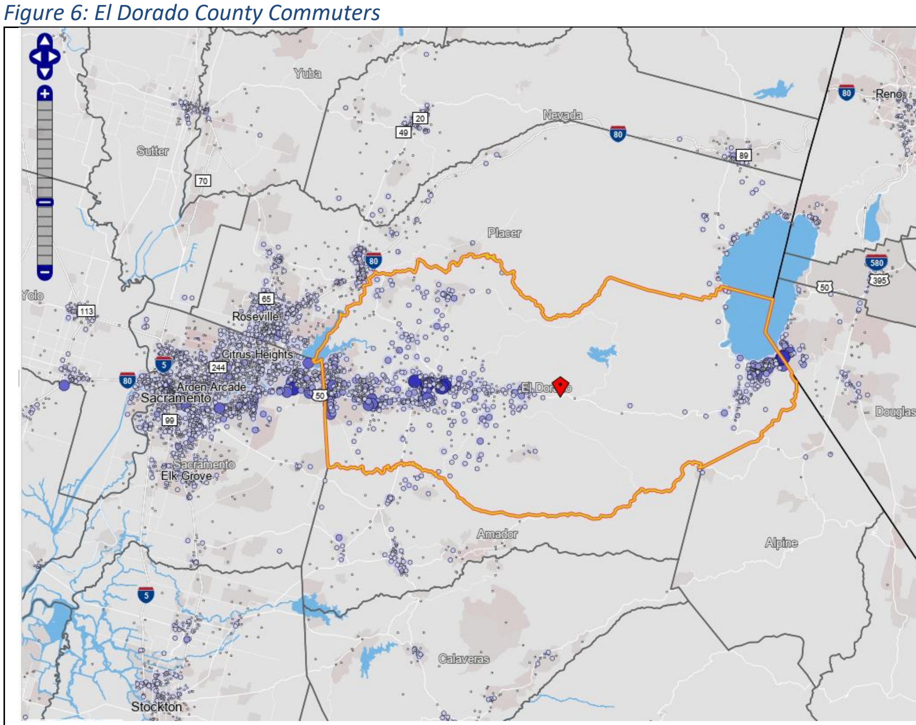
maps that show the number of jobs per square mile in each census tract by color and the number of commuters by the size of the circle.

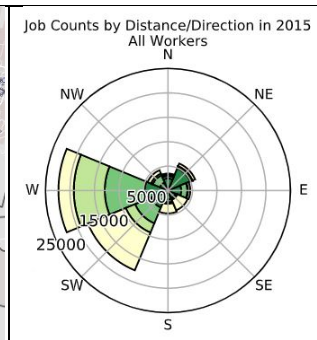
Figure 5: OnTheMap key



El Dorado County data shows 45,642 total commuters. Nearly half commute less than 10 miles and about 8,200 people drive 50 or more miles one way from home tract to work tract, mostly driving west. Figure 6 shows El Dorado County commute patterns.

Figure 6: El Dorado County Commuters



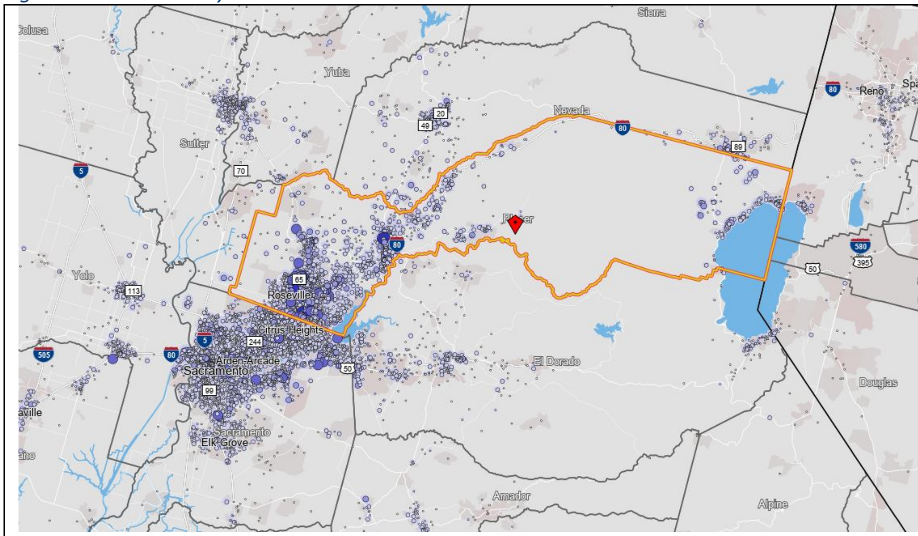


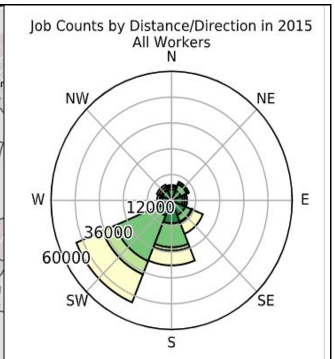
<50 miles N: 201
<50 miles NE: 489
<50 miles E: 292
<50 miles SE: 1,288
<50 miles S: 1,447
<50 miles SW: 2,691
<50 miles W: 1,088
<50 miles NW: 718

Placer County data shows 133,360 total commuters. Nearly half commute less than 10 miles and about 25,000 people drive 50 or more miles one way from home tract to work tract, mostly driving south.

Figure 7 shows Placer County commute patterns.

Figure 7: Placer County Commuters





<50 miles N: 833
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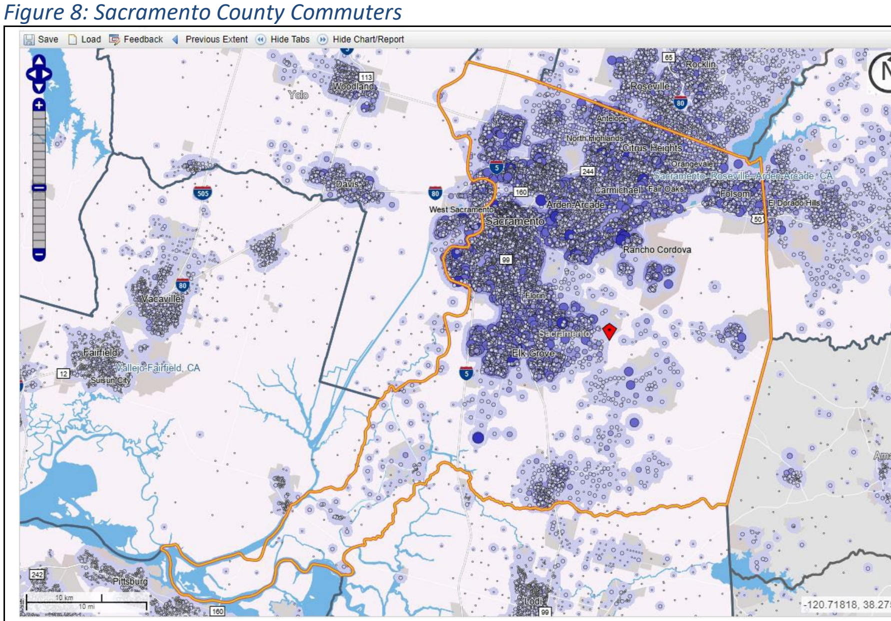
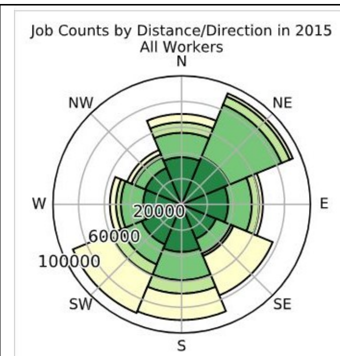
<50 miles E: 888
<50 miles SE: 4,882
<50 miles S: 5,622
<50 miles SW: 8,901
<50 miles W: 1,274
<50 miles NW: 1,856

Sacramento County data shows 586,125 total commuters. Nearly half commute less than 10 miles and about 106,000 people drive 50 or more miles one way from home tract to work tract, driving in all directions. Figure 8 shows Sacramento County commute patterns.

Figure 8: Sacramento County Commuters





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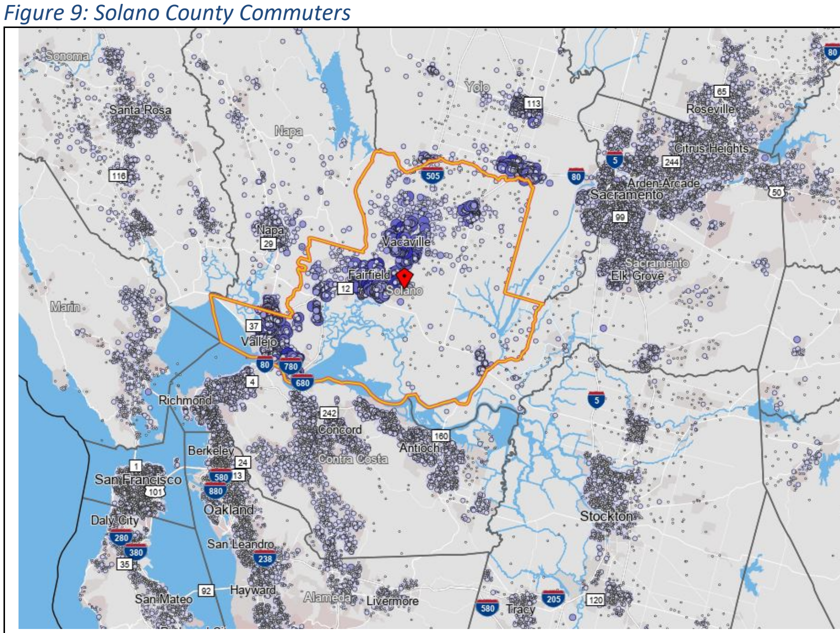
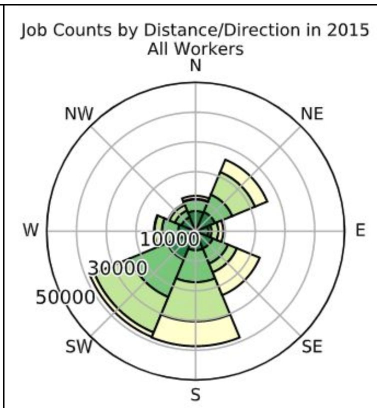
<50 miles E: 2,879
<50 miles SE: 32,971
<50 miles S: 20,571
<50 miles SW: 31,987
<50 miles W: 4,706
<50 miles NW: 3,541

Solano County data shows 133,455 total commuters. About 40% commute less than 10 miles and about 22,000 people drive 50 or more miles one way from home tract to work tract, mostly driving. Figure 9 shows Solano County commute patterns. The fewest number of commuters head west and northwest toward the Sacramento region.

Figure 9: Solano County Commuters





<50 miles N: 1,680
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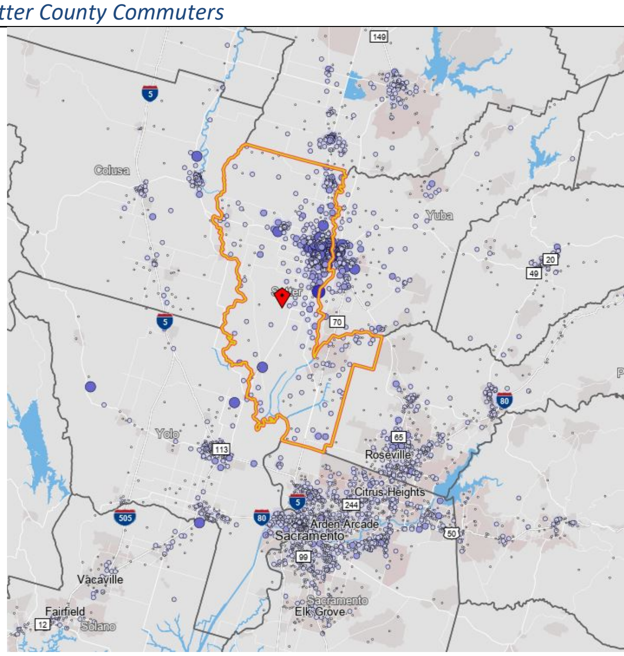
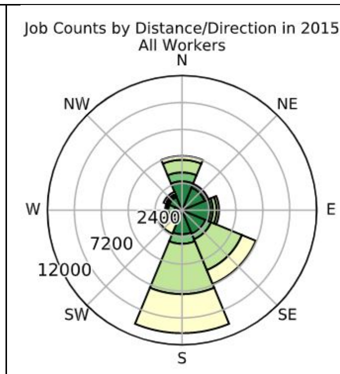
<50 miles E: 2,303
<50 miles SE: 7,374
<50 miles S: 4,709
<50 miles SW: 1,339
<50 miles W: 160
<50 miles NW: 720

Sutter County data shows 25,740 total commuters. More than half commute less than 10 miles and about 4,000 people drive 50 or more miles one way from home tract to work tract, mostly driving south. Figure 10 shows Sutter County commute patterns.

Figure 10: Sutter County Commuters

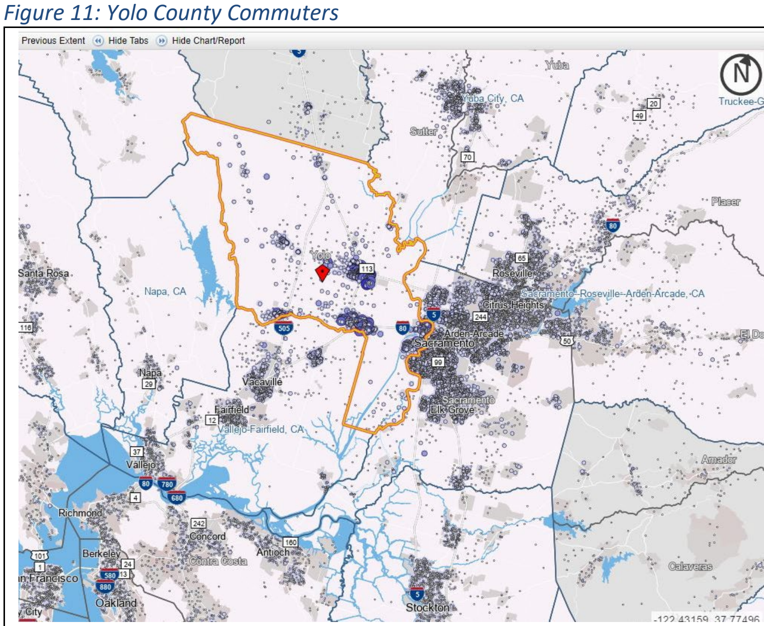


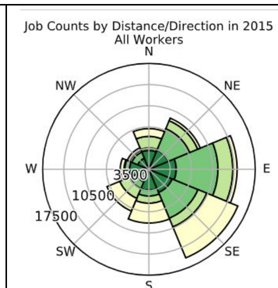


<50 miles N: 401
<50 miles NE: 62
<50 miles E: 236
<50 miles SE: 849
<50 miles S: 1,385
<50 miles SW: 415
<50 miles W: 89
<50 miles NW: 375

Yolo County data shows 71,119 total commuters. About 36% commute less than 10 miles and about 14,565 people drive 50 or more miles one way from home tract to work tract, mostly driving southeast. Figure 11 shows Yolo County commute patterns.

Figure 11: Yolo County Commuters





<50 miles N: 1,284
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<50 miles E: 702
<50 miles SE: 5,532
<50 miles S: 3,271
<50 miles SW: 2,280
<50 miles W: 619
<50 miles NW: 414

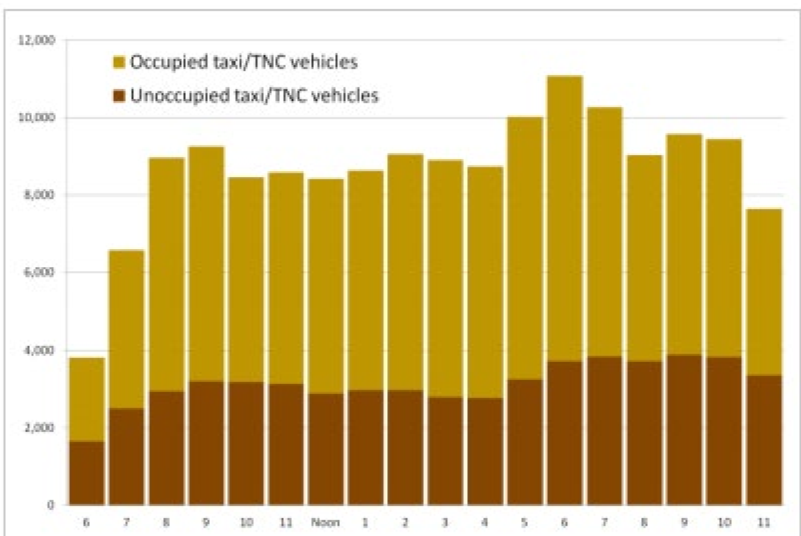
Data shows fewer-than-expected commuters traveling west from Sacramento to the Bay Area. News and anecdotical evidence indicated that people moved to the Sacramento region for affordable housing and commuted every day. Performance data from Amtrak's Capitol Corridor train service[19] and the Sacramento Transportation Management Association[20] show the number of riders steadily increasing between Sacramento and the Bay Area. Corresponding data by the Metropolitan Transportation Commission[21] also indicates that Bay Area commuters may not be driving personal vehicles.

The team was surprised by the number of drivers that commute to Stockton and Lodi from Sacramento, Solano, Sutter, and Yolo Counties, and the number of people from all counties commuting to Roseville and Folsom.

Livery Drivers

According to California Employment Development Department (EDD), about 1,500 people are full-time drivers for taxi cabs, limousine, or ride-hailing services. This likely far short of the number of people who drive for ride-hailing and other gig services like Door Dash because these drivers are independent contractors. During interviews with drivers for other research projects, Uber and Lyft drivers reported that the average trip in Sacramento is about five miles and drivers typically have 20 trips per 10-hour shift. A report by Schaller Consulting for the City of Manhattan found that taxi/TNC vehicles were unoccupied and driving around the city about 35% of the time, as shown in Figure 12 from the report.[22] Several drivers interviewed for this report stated they and are unoccupied at least half the time.

Figure 12: Number of taxi/TNC vehicles in Manhattan by hour June 2017 (Source: Schaller Consulting)



Drivers report that most trips start or end in downtown and midtown Sacramento, at the Sacramento airport, or at entertainment destinations including Golden 1 Center, Raley Field, and Cal Expo. Driver also reported an increase of people taking Uber and Lyft to UC Davis and Sac State.

[19] https://www.capitolcorridor.org/ccjpa-performance/
[20] http://www.sacramento-tma.org/Vanpooling.html
[21] http://www.vitalsigns.mtc.ca.gov/traffic-volumes-regional-gateways
[22] http://schallerconsult.com/rideservices/emptyseatsfullstreets.pdf

Service Vehicles

DMV registrations don't differentiate business and personal vehicles. EDD has limited information about employers in each county by industry (NAICS) code. Table 11 is a summary of data from OnTheMap for the number of jobs in service-related businesses (real estate, repair, wholesale sales, personal service) and industrial-related jobs (warehousing, transportation, manufacturing, delivery.)[23] Jobs and vehicles are not a one-to-one correlation but is a good indicator of the number of people who may drive 100 miles or more during their work day. During two years of casual interviews with hundreds of people employed in a variety of service businesses, they stated that the average trip between clients is 15 miles and they average 15 trips a day. Unlike livery drivers, service drivers have little time between clients.

Table 11: Number of service- and industrial-related jobs per county

	Service Jobs	**Industrial Jobs**
El Dorado	7,290	3,683
Placer	21,320	15,252
Sacramento	69,701	96,058
Solano	7,858	9,476
Sutter	3,229	5,400
Yolo	15,119	15,442

[23] This project excluded the Lake Tahoe area and census tracts east of Vacaville in Solano County. Jobs from excluded census tracts are not in this table.

Investment Need

This project identified a need for investment in transit planning. None of the transit agencies have a plan for transitioning to electric buses—battery or fuel cell—and information from transit consultants is to wait until costs come down. Transit agencies identified Caltrans Strategic Partnership Grants as a funding source for electrification studies. No Sacramento-area agencies won a grant in the 2019 cycle but are reapplying for 2020 funding.

During interviews with Roseville Electric Company, representatives stated that they didn't have the grid availability to support charging buses. PG&E, which filed for bankruptcy protection in 2019,[24] is seen as an uncertain partner. With a projected $30 billion in liabilities for the 2017 and 2018 wildfires, investment in charging infrastructure may be curtailed.

The team also recognized that transit agencies and transit consultants are missing information about operational costs for battery and fuel cell electric buses and infrastructure, and that some transit consultants have dismissed hydrogen and fuel cells altogether.

Electrification planning should also include other transit operators in the region, including Amtrak's Thruway buses, charter bus operators, and companies that operate on-demand transit, vanpools, and shuttle operators.

A regional approach to funders that include Sacramento Area Council of Governments (SACOG), FTA, ARB, and Caltrans could result in a single grant that funds a regional planning effort to transition more buses to ZEVs on a faster time frame and potentially fund shared infrastructure, particularly for buses that operate in multiple cities and/or are not covered by the Innovative Clean Transit regulation.

A second investment need was identified near the end of this project. The mayors of Sacramento and West Sacramento formed the Mayors' Commission on Climate Change[25] with the intent of identifying actions that both cities could include in their upcoming Climate Action Plans. As the commission and its technical advisory committees met, the topic of equity became a priority. It was clear that the 100-plus participants in this exercise had different definitions of equity.

In September 2019, Tim Litman from the Victoria Transport Policy Institute spoke at a special commission meeting. He said, "Equity is the fairness with which benefits and costs are distributed. Equity analysis can be difficult because of the several types of equity, many potential impacts to consider, various ways to measure impacts, and may possible ways to categorize people." His report, *Evaluating Transportation Equity*,[26] includes a list of equity variables. Table ES-1 from the report is shown in Figure 13.

As the Sacramento region moves forward with this and other clean transportation plans, it is worth ensuring that all market actors evaluate equity with the same set of variables to ensure the vehicles and infrastructure deployed meets all needs.

[24] https://www.pge.com/en_US/about-pge/company-information/reorganization.page?WT.pgeac=Reorganization_Footer
[25] https://www.lgc.org/climatecommission/
[26] https://www.vtpi.org/equity.pdf

Figure 13: Various types, impacts, measurement units and categories to consider in equity analysis

Table ES-1 **Equity Evaluation Variables**

Types of Equity	Impacts	Measurement	Categorization
Horizontal Equal treatment of equals **Vertical With-Respect-To Income And Social Class** Transport affordability Housing affordability Impacts on low-income communities Fare structures and discounts Industry employment Service quality in lower-income communities **Vertical With-Respect-To Need And Ability** Universal design Special mobility services Disabled parking Service quality for non-drivers	**Public Facilities and Services** Facility planning and design Public funding and subsidies Road space allocation Public involvement **User Costs and Benefits** Mobility and accessibility Taxes, fees and fares **Service Quality** Quality of various modes Congestion Universal design **External Impacts** Congestion Crash risk Pollution Barrier effect Hazardous material and waste Aesthetic impacts Community cohesion **Economic Impacts** Economic opportunities Employment and business activity **Regulation and Enforcement** Traffic regulation Regulations and enforcement Regulation of special risks	**Per capita** Per adult Per commuter or peak-period travel Per household **Per Unit of Travel** Per vehicle-mile/km Per passenger-mile/km Per trip Per commute or peak-period trip **Per dollar** Per dollar user fees Per dollar of subsidy Cost recovery	**Demographics** Age and lifecycle stage Household type Race and ethnic group **Income class** Quintiles Poverty line Lower-income areas **Ability** People with disabilities Licensed drivers **Location** Jurisdictions Neighborhood and street Urban/suburban/rural **Mode** Pedestrians Cyclists Motorcyclists Motorists Public transit **Industry** Freight Public transport Auto and fuel industries **Trip Type** Emergency Commutes Commercial/freight Recreational/tourist

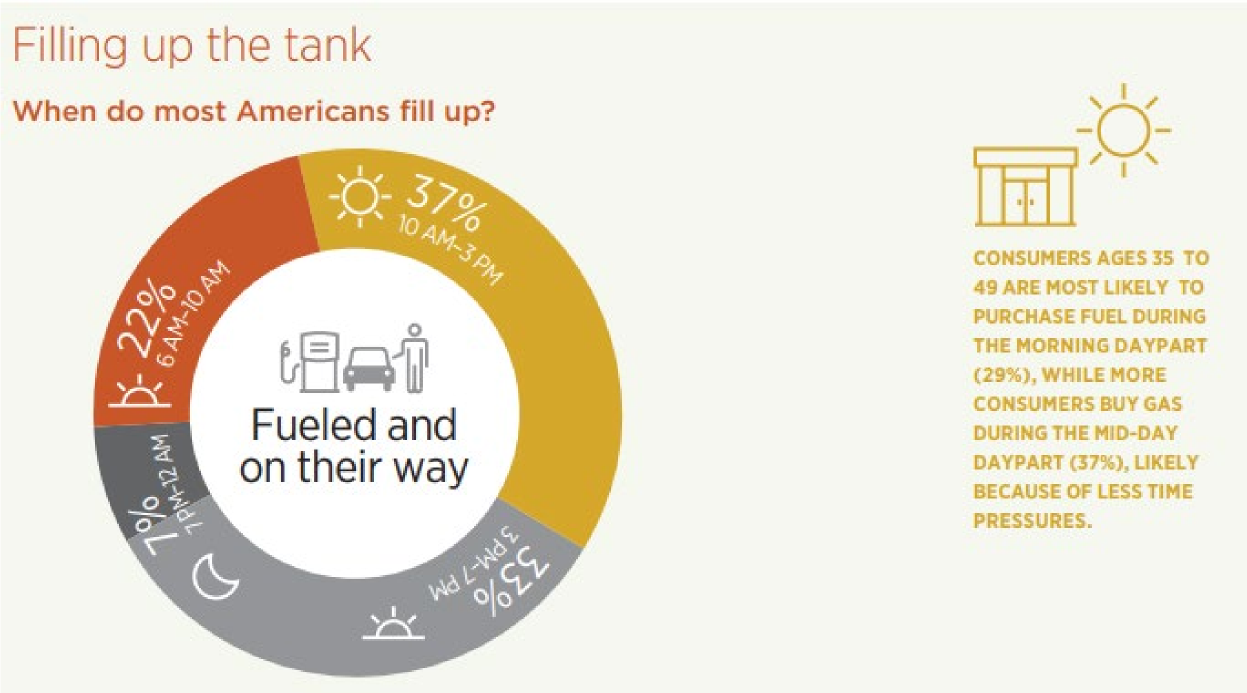
Infrastructure Projections

Infrastructure must provide coverage and capacity for daily use in work and leisure travel.[27,28] This particularly applies to FCEV and BEV users that travel more than 50 miles a day and have limited time for fueling stops. The question that everyone grapples with is how many stations and where to put them. All research is based on early models of vehicles that had more-limited range and early adopters who are willing to be inconvenienced for the sake of progress.

To understand the number and location of fuel stations for future ZEVs, it's important to understand each driver type's current fueling pattern and how charging or filling with hydrogen might be different.

Commuters: Between 2010 and 2012, California Fuel Cell Partnership (CaFCP) members researched driving and fueling habits to understand where to locate the first fueling stations. Research from CaFCP and the National Association of Convenience Stores (NACS) found that drivers fuel at one of three places: near home, near work, and near an entertainment center (e.g., the gym, shopping center, restaurant.) Drivers often where to fill based on first on the fuel price and second on perceived quality of the station. (Quality includes brand name, curb appeal, lighting, and presence of a convenience store or food.) People fuel nearly equally throughout the day, as shown in Figure 14.

Figure 14: Times of day that Americans fill their cars with conventional fuels[29]



[27] "Charging ahead: Electric-vehicle infrastructure demand" McKinsey, 2018: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand

[28] "A California Road Map - Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State" (2012): https://cafcp.org/sites/default/files/20120814_Roadmapv%28Overview%29.pdf

[29] https://www.convenience.org/Topics/Fuels/Documents/How-Consumers-React-to-Gas-Prices.pdf

Potential differences with ZEV fuels:

- Hydrogen—same as gasoline model, but limited number of stations will require people to drive slightly out of the way.
- DCFC—20-to-40 minutes to charge makes it more likely for commuters to charge at lunch or on their way home from work. DCFC plazas need to be located where people can be productive. Drivers are unlikely to drive from place to place if the charger is occupied.

Livery drivers: TNCs (Uber, Lyft, etc.), taxis, and hired cars look for stations at the gateways to Sacramento's core. They report most trips originate in downtown and midtown Sacramento, and stations that are easily accessible along the major highways are preferable. In interviews for other ZEV projects, drivers stressed that time was most important; every minute not driving is a minute not making money.

Potential differences with ZEV fuels:

- Hydrogen—same as gasoline model. Stations must be strategically located so that drivers do not lose time driving out of their way or at conjected intersections and freeway ramps.
- DCFC—Chargers must be strategically located; drivers cannot wait in line or drive from location to location. Ideally, DCFCs can be located at car washes, near mobility hubs, and at top destinations (e.g., Cal Expo, Raley Field, Old Sacramento, UC Davis).

Service vehicles: Independent workers that drive light-duty vehicles (e.g., home healthcare workers, personal trainers, real estate agents) buy gasoline similarly to commuters. Company drivers have two different models: some fuel vehicles during the workday and others rely on support staff to fuel vehicles at private or public stations. Large trucks and buses fill at truck-only stations that have higher canopies, more room for maneuvering, and are designed for a longer fueling time.

Fueling is "on-the-clock" time. Wage and hour laws do not address time spent charging a car as work or non-work time,[30] but the meal break regulation[31] states that an employee cannot work during the break. Based results of recent class action suits, it's likely that the State of California would deem charging a vehicle as work time even if the vehicle was charging while the driver ate lunch.

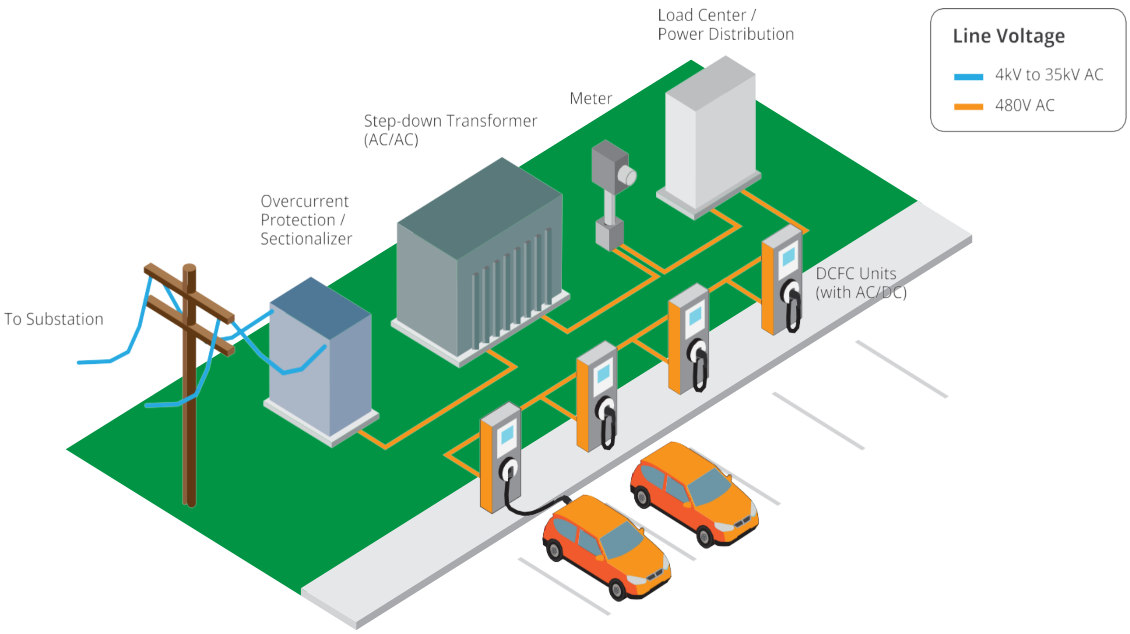
- Hydrogen—Trucks use a different fueling protocol that passenger vehicles use. Ideally, at least one station will have a fueling island specific to trucks. It is unlikely that a fleet operator would have a private hydrogen station and, therefore, time spent driving to a from a station needs to be calculated in operational costs.
- DCFC—Charges must be strategically located; drivers cannot wait in line or drive from location to location. Because charging is likely to be considered work hours, delivery vehicles and local trucks that need midday charging will likely need to return to base or charge at a load/unload zone.

[30] https://www.dol.gov/whd/FOH/FOH_Ch31.pdf
[31] https://www.dol.gov/whd/state/meal.htm

Number of Fueling Points to Support High-Mileage Drivers

Research from NREL, the Transportation Research Board, EPRI, and others summarized in an ICCT white paper[32] estimate the average time to reach 85% state of charge is 25 minutes. Actual time depends on the size of the car's battery and the power of the fast charger. Assuming 25 minutes to charge and five minutes between cars, one DCFC plug can fuel two cars an hour. Figure 15 is an illustration of a DC fast charging plaza in a parking lot.

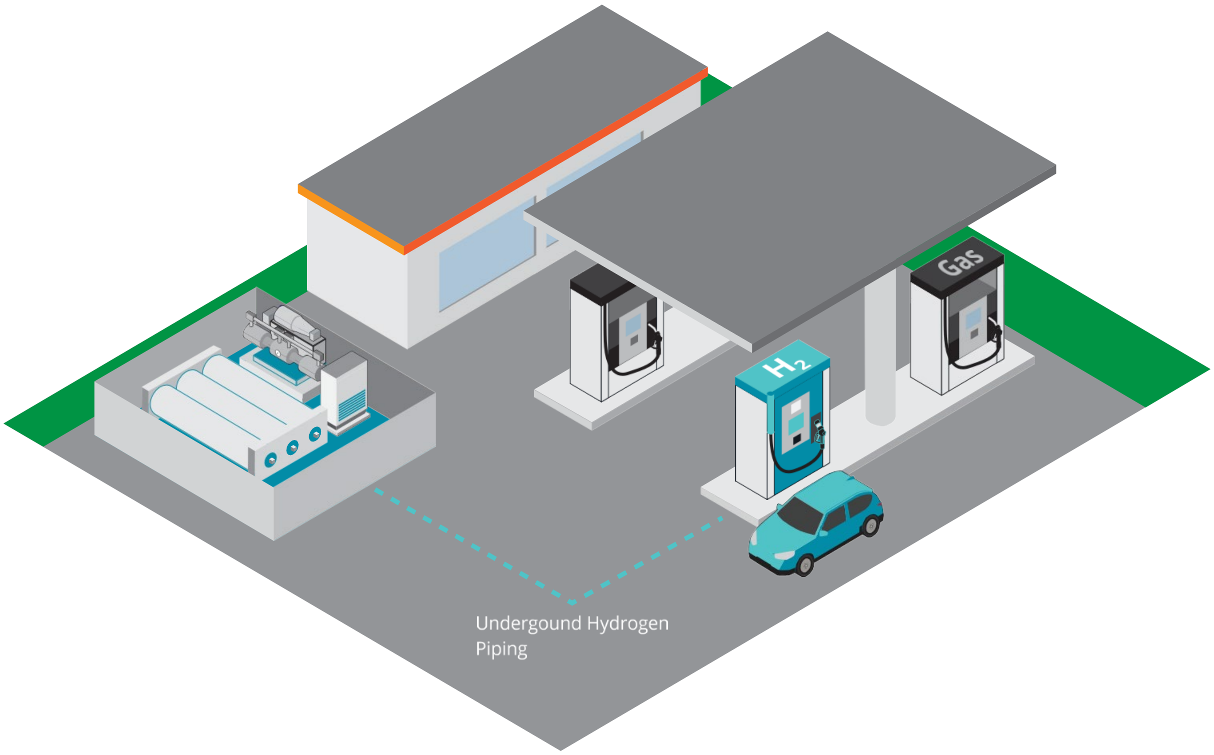
Figure 15: Illustration of a DCFC plaza



[32] https://theicct.org/sites/default/files/publications/ZEV_fast_charging_white_paper_final.pdf

Similarly, the time needed to fill with hydrogen depends on the size of the storage tank on the car and the pressure of the fuel at the station. Filling with hydrogen takes about five minutes per car, with five minutes between cars. A hydrogen dispenser with one nozzle can fill six cars an hour. Figure 16 is an illustration of a hydrogen station.

Figure 16: Illustration of a hydrogen station



Organizations and stakeholders that develop station deployment plans for hydrogen and DCFC consider coverage or capacity. “Coverage” is defined as more fueling points in a region so that drivers have multiple options or that more people are close to fuel. “Capacity” is defined as more plugs/additional hydrogen storage to provide fuel to many drivers at one location.[33]

To meet coverage and capacity, a California Energy Commission staff report[34] recommended a BEV-to-DFCF ratio ranging from 29-to-80 cars for each DCFC plug to meet the needs of mainstream drivers. NREL, however, suggests the number is closer to 275 cars for each DCFC plug.[35] The California Air Resources Board designed the California Hydrogen Infrastructure Tool (CHIT) as a GIS model that displays anticipated hydrogen need by capacity through 2025. Figure 17 from CHIT shows Sacramento needing about 200 kilograms a day (kg/d) and through surrounding areas (in bright green) at about 100 kg/d.

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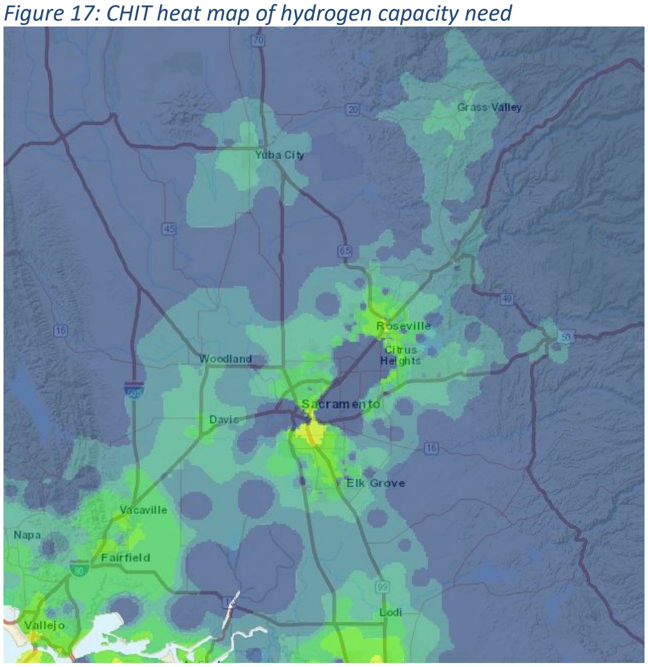
33 https://ww3.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2018_print.pdf?_ga=2.178019685.1390958982.1563828005-368227744.1484264568 and https://www.nrel.gov/docs/fy17osti/69031.pdf

34 http://docketpublic.energy.ca.gov/ PublicDocuments/17-ALT-01/TN222986_20180316T143039_Staff_Report__California_ PlugIn_Electric_Vehicle_Infrastructure.pdf

35 https://www.nrel.gov/docs/fy17osti/69031.pdf

Figure 17: CHIT heat map of hydrogen capacity need



To meet the needs of the three types of high-mileage drivers addressed in this report, including trucks, the recommendation is to design a network that prioritizes capacity. It is likely that multiple drivers will fuel/charge at the same time in the middle of the day and on the commute home. Placing DCFC plazas and hydrogen stations within ½ mile of major freeways and arterials will support local and distance travel.

To be successful in luring high-mileage drivers from their conventual cars and trucks, the initial ZEV infrastructure must be overbuilt in the early years, which carries two risks:

- Technology and regulations are likely to change. For example, charging equipment is, for the most part, installed in parking spaces. Safety regulations for fuel stations may be applied to charging when electricity is regulated as a fuel in 2021. That requires a pull-through design to allow two paths of egress. For hydrogen, studies are underway to enable hydrogen to be stored below ground, like today's gas stations, instead of in above-ground storage tanks.
- The business case for ZEV fuels might change. Currently, operators of DCFCs and hydrogen stations can earn Low Carbon Fuel Credits (LCFS) for the ZEV fuel that is available but isn't dispensed. If LCFS credits remain valuable, it creates an initial business case for fuel providers. If LCFS credits become less valuable, the operators need to sell fuel at volume to cover station operating costs.

If 64,000 personal vehicles, plus hundreds of trucks are ZEVs in 2030, and one-fifth of the ZEVs are FCEVs,[36] infrastructure will need to support 12,800 FCEVs and 51,200 BEVs. Assuming most vehicles on the road will have the range of today's vehicles,[37] the Sacramento region will need about 15 hydrogen stations with multiple dispensers and 320 DCFC plazas with an average of four plugs each.

[36] Based on Governor Brown's goal of 5 million ZEVs by 2030 and CaFCP's vision of 1 million FCEVs by 2030 statewide.
[37] Assumes that lower-prized ZEVs will have improved, but smaller, batteries and fuel cells.

The Heat Island Effect

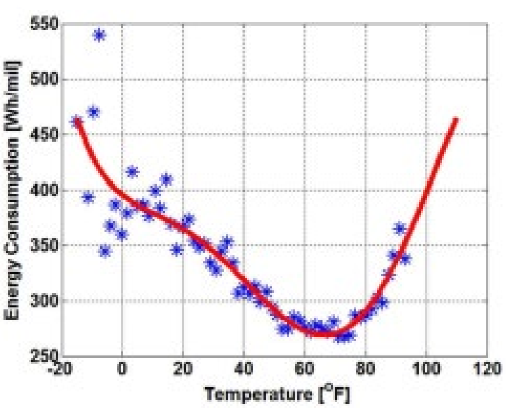
In a Caltrans-funded project, The Sacramento Metropolitan Air Quality Management modeling the urban heat island effect for the Sacramento region. The project is identifying areas that an increased temperate due to absorbed heat when compared to nearby areas that reflect heat. The project is also assessing effectiveness of different cooling strategies.

Summers in the Sacramento region are predicted to become more like those of Phoenix, Arizona, in 30 years, with 40 to 68 days above 100 °F projected each year by 2050 based on the present-day GHG emissions trajectory.[38] The study was still underway in late 2019, but modeled results had shown the necessity of taking actions now to reducing extreme heat.

Cars and Heat Islands

Internal combustion engine vehicles lose 58 to 62 percent of the energy contained in gasoline as waste heat, which is then radiated as exhaust heat into the surrounding environment.[39] This waste heat then contributes to the urban heat island effect. ZEVs have very little waste heat.[40] One study predicted that if Beijing converted to all ZEVs it would lower urban temperatures by 1.7 F in the summer and save 14.4 million kWh from air-conditioning use.[41] In Sacramento, the temperature cooling benefit could be even greater because the electricity is cleaner and drivers spend more time in their cars. For example, models show that if 30 percent of vehicles in central Sacramento were ZEVs, the air temperature could be 3 degrees Fahrenheit cooler at 5pm.[42]

Figure 18: Nissan Leaf per-mile energy consumption versus air temperature



Until large numbers of ZEVs are deployed, however, the heat islands may have a negative effect on batteries. Higher ambient temperatures degrade battery performance forces the battery's thermal management system works harder to prevent overheating. This consumes energy and thus depletes range, even when the vehicle is parked.

When cabin cooling requirements are factored in, warmer temperatures can lead to a 29 percent average decrease in driving range for EVs.[43] Figure 18 shows data from FleetCarma shows that energy consumption per mile climbs steeply when outside temperatures are 80°F or higher.

The National Renewable Energy Lab's Battery Lifetime Analysis and Simulation Tool Suite (BLAST) also models a greater battery degradation and 10-year resistance growth and capacity-fade for an EV in

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[38] Cal-Adapt, RCP 8.5 scenario analysis for City of Sacramento, Auburn, Yuba City, and El Dorado Hills: https://cal-adapt.org/tools/extreme-heat/

[39] Department of Energy: https://www.fueleconomy.gov/feg/atv.shtml

[40] Department of Energy: https://www.fueleconomy.gov/feg/atv-ev.shtml

[41] Li C., Cao Y., et al. https://www.nature.com/articles/srep09213

[42] Presentation from Dr. Haider Taha, 26 June 2019, for SMAQMD's urban heat island project technical advisory committee.

[43] Yuksel and Michalek. https://www.cmu.edu/me/ddl/publications/2015-EST-Yuksel-Michalek-EV-Weather.pdf

Phoenix compared to Sacramento today.[44] In some instances, EV drivers in Arizona and Texas reported at least a 15 percent loss in battery capacity after one year of car ownership.[45]

Batteries also charge more slowly in the heat. FleetCarma and Clipper Creek recommend that EV chargers be placed in the shade and to charge at slower speeds in high temperatures.[46]

Station Design for Heat Islands

Designing charging stations (and hydrogen stations) to provide passive cooling can help protect battery health and maintain charging time, even in hot temperatures. Suggested solutions are:

- Add shade: Canopies are common at hydrogen stations, which are usually added to existing gas stations, but not common for DC fast charging. Incorporating light-colored shade structures, solar canopies, or trees and other native vegetation can cool the vehicle during charging and reduce reflective heat.
- Use higher-albedo pavement: “Albedo” is a measurement of thermal reflection. Asphalt and chip seal absorb up to 95% of incoming solar energy and then radiate the heat, which makes the air hotter. Newer concrete pavements reflect up to 50% of the sun’s rays and reduce heat absorption.
- Use the shadows: Position chargers and hydrogen dispensers to take advantage of afternoon shadows, even if that means they absorb the morning sun. Using the shade from neighboring structures could minimize the effects of mid-day temperature rise.

The heat map in Figure 19 shows the locations of potential stations identified in this project[47] overlaid with the urban heat island study area. The darkest red areas are the most extreme temperature differences--10-to-12 degrees hotter than the surrounding area.

By combining results of the heat island and ZEV readiness studies, Sac Metro AQMD can show specific locations that can most benefit from the combination of ZEV deployment and “cool” station design.

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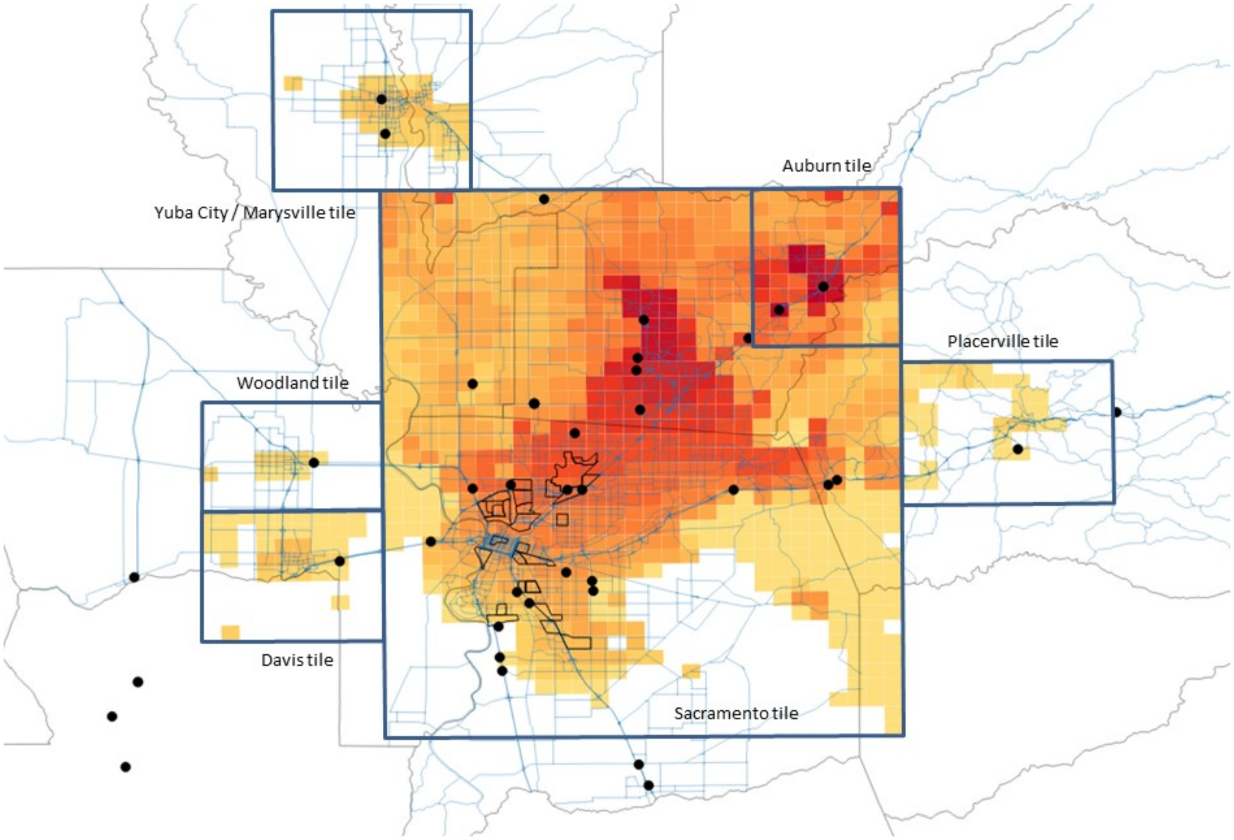
[44] https://www.nrel.gov/transportation/blast.html
[45] Green Car Reports: https://www.greencarreports.com/news/1077107_more-nissan-leaf-battery-loss-nissan-doesnt-blink
[46] Green Car Reports: https://www.greencarreports.com/news/1077731_how-to-keep-your-nissan-leafs-battery-pack-happy-in-hot-weather
[47] www.zevreadiness.frontierenergy.com

Figure 19: Sacramento heat map and potential station locations



References and Resources

EV and Hydrogen Planning Documents

- Sacramento PEV Collaborative *EV Readiness and Infrastructure Plan* www.cleancitiessacramento.org/uploads/2/7/8/6/27862343/sac_county_ev_inf_planfinal_6-20-17.pdf
- SACOG *Take Charge II* www.sacog.org/sites/main/files/file-attachments/master_takecharge_ii_12-21-16.pdf
- SMUD EV Innovator's Pilot - Load Impact Evaluation www.smud.org/-/media/Documents/Corporate/About-Us/Energy-Research-and-Development/research-EV-innovators.ashx?la=en&hash=F96D5C4B1826938B1A82A55C125725CAF9A4FC4D
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