



**Fuels Institute**

**EVC** ELECTRIC VEHICLE  
COUNCIL

# EV Consumer Behavior

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# EXECUTIVE SUMMARY

## Electric Vehicle Consumer Behavior

Ricardo Strategic Consulting (“Ricardo”) conducted a literature review to better understand how and where consumers drive and recharge their electric vehicles (EVs) and what they would like to experience while recharging in terms of site design, amenities, capabilities, and services.

Ricardo has also analyzed existing literature to both understand current consumer behavior and anticipate how it could evolve over the next 10 years as more consumers purchase EVs. This exercise has been focused on answering five questions:

1. Who is the customer?
2. When and where does the customer recharge?
3. Why does a customer choose a particular recharging facility?
4. How do customers interact with charging equipment?
5. What do customers do at facilities while charging?

This literature review included various publicly available sources such as existing Ricardo research on consumer preferences; published surveys; federal, state, and local government publications;



cross-functional organization publications; scholarly articles; university/institute publications; national lab publications; public policies; and press reports. This was supplemented with persona interviews to exemplify findings.

Key findings that emerged from the literature review are below:

### ***Who is the customer?***

- The top demographic of 2019 EV owners are middle-aged white men earning more than \$100,000 annually with a college degree or higher and at least one other vehicle in their household.
- 37% of Democrats and 34% of Republicans appear to view EVs positively, and a guaranteed \$7,500 tax rebate could make 78% of Democrats and 71% of Republicans more likely to consider an EV during their next purchase or lease (2019).

- EV sales have grown exponentially over the past 10 years; however, the ownership demographic has remained relatively the same. The average EV owner continues to be male, aged 40-55 years old, with an annual household income of more than \$100,000 (2019). Mileage driven, however, has increased from 100 miles to 250 miles a week over the years.
- In the next 10 years, EV sales are expected to constitute between 12% and 40% of all light-duty vehicle sales, implying that:
  - EV buyer age could normalize with the broader new vehicle buying trend
  - EVs could become more affordable
  - Number of EV buyers with no provision to charge at home could increase
  - Driving pattern is expected to be similar to the way internal combustion engine (ICE) vehicles are driven
  - Gender distribution could become more balanced
- EV fleet sales are expected to grow in the upcoming years, driven by state mandates.
- Household income, family size, age, driving distance, geographical location, and type of residence tend to influence EV ownership.

- Total cost of ownership (TCO) and payback period are the key drivers in a business' decision involving adoption of EVs in their commercial fleet.
- Affordability, availability, and familiarity appear to be amongst the key factors influencing likelihood of EV purchases.
- EV trips are mostly planned with charging locations in mind, unlike conventional vehicles; however, more daily miles are driven on average in an EV (2020) than in an ICE-powered vehicle.

***When and where does the customer recharge?***

- EV drivers tend to recharge daily or once every two days, typically overnight at home, and overall, about 70-80% of charging occurs at home or at a workplace parking lot.
- Most EV fleet customers today (2020) operate in a hub-and-spoke network and exclusively recharge their vehicles overnight at their home base.
- The most used public chargers are those where vehicles are typically parked for long periods (e.g., airport parking lots, grocery store, etc.) (2012-2014).
- Most customers drive within their battery range only, using a public charger when making trips longer than their range would permit.
- Drivers of ICE vehicles fill up based on the cost, necessity, and time of the day; 32% only fill up when they see the fuel warning light in the dashboard (2019).
- Nonavailability of chargers at home and making trips longer than the battery range are two of the various reasons why drivers use public charging stations.
- EV charging stations spaced 70 miles from each other on average could provide convenient access to battery electric vehicle (BEV) drivers across the interstate system (2017).





**Why does the customer choose a particular public recharging facility?**

- EV drivers tend to base their choice of public chargers on various factors, including: speed of charging, need for charging, brand of the charger, compatibility with the electric vehicle supply equipment (EVSE), dependability, availability, identity of charging host/facilities available (e.g., grocery store, gym, etc.), payment options available, and app/in-car interface suggestions.
- Dependability, convenience, cost of use, and the need to travel beyond the EV’s battery range appear to have the greatest influence in the choice of charging location (2011-2019).
- Approximately 75% of today’s non-Tesla drivers feel the current charging network is “somewhat” or “very adequate” (2017).
- Approximately 46% of BEV drivers (2016) feel availability of direct current fast charging (DCFC) as a feature is not a very big influencer in their EV buying decision.
- More than 80% of EV drivers use three charging locations or fewer away from their home, where they do most of their charging (2011-2014).
- The drivers’ decision in picking a brand of charger is influenced by factors such as favoring the provider of the default EV charge card (e.g., Hyundai Ioniq has a ChargePoint card in the glovebox). Other factors include being of the same brand as their home charger, dependability of the network, availability in their primary area of operation of the vehicle, and availability at the places they visit often.
- Fewer than 5% of EV owners rely on smartphone applications (“apps”) to find charging stations for daily use, although many EV owners likely have a charging app on their smartphone. Tesla models have point-to-point trip planning with charging integrated in the vehicle, and it is likely other original equipment manufacturers (OEM) will follow (2020).

- Today’s EV owners are not deterred by the deficits of the current EV infrastructure and have found ways around the limitations, but for mass adoption, it is critical to understand views of buyers who are not considering buying an EV today (2020).
- **How do customers interact with charging equipment?**
- Approximately 57% of surveyed EV drivers are willing to pay a premium over at-home charging rates to use a public Level 2 charger, and more than half of EV drivers are willing to pay more for DCFC compared to Level 2 charging when convenient (2020).
- EV drivers preferred optimized charging and to be billed by the kilowatt-hour (kWh) to attain a good balance of cost and time (2016).
- Approximately 77% of people used mobile payments last year, including 80% of 35- to 50-year-old U.S. residents; all top charging network appear to support mobile payments (2019).

**What do customers do at facilities while charging?**

- Plug-in electric vehicle (PEV) consumers expect to spend 30 minutes to one hour at the charger (2019-2020). Some other studies/surveys suggest that this consumer would prefer an event (15 minutes or less) to minimize downtime in their daily routine. Grocery store visits, dining, and shopping are the most preferred activities while waiting for their EVs to be charged.
- Broadly, free charging while shopping tends to increase dwell time. Kohls found that when provided with free charging, EV owners spend about \$1 per minute within an hour window (2015).
- PEV drivers appear to prefer to run errands or to be entertained while charging their vehicle at a public charger (2019).

# Contents

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<b>EXECUTIVE SUMMARY</b> .....	<b>01</b>
<b>INTRODUCTION</b> .....	<b>06</b>
Literature Study Context .....	06
Objective of the Study .....	07
Personas .....	08
<b>METHODOLOGY</b> .....	<b>09</b>
<b>PROJECT REPORT</b> .....	<b>10</b>
Who Is the Customer? .....	10
Demographics .....	10
Evolution of EV Buyer Demographics and Behavior Over the Past 10 Years .....	16
Anticipated Evolution of EV Buyer Demographics and Behavior Over the Next 10 Years .....	18
Demographic Characteristics and Their Relationship With EV Ownership and Behavior .....	20
Difference in Trips Taken in EVs Versus Liquid-fuel Vehicles .....	21
When and Where Does the Customer Recharge? .....	22
EV Drivers’ Charging Frequency .....	22
EV Drivers’ Preferred Recharge Location .....	24
Factors That Influence a Recharge Occasion .....	26
Charging Infrastructure Requirement .....	27
Why Does the Customer Choose a Particular Public Recharging Facility? .....	28
Level 2 Charging Availability’s Influence on Consumer Perception of Availability, Capacity, and Convenience Compared to DCFC Equipment .....	28
Influence of Charging Equipment Brand .....	30
How Do Customers Interact With Charging Equipment? .....	32
EV Consumers’ Willingness to Pay for Charging Services and the Influence of Price in This Perception .....	32
EV Consumers’ Perception of Various Billing Methods .....	34
EV Consumers’ Comfort With the Various Payment Options .....	36
What Do Customers Do at Facilities While Charging? .....	38
Dwell Time at Public Chargers and the Features That Could Influence That Dwell Time .....	38
Features and Amenities That Are Most Desired by EV Drivers, Used During a Charging Session, and That Could Influence Drivers to Use Charging Stations Frequently .....	41
Features and Amenities That Yield the Greatest Influence Over an EV Driver’s Decision Regarding Where to Charge .....	42

<b>PERSONA FINDINGS</b> .....	<b>45</b>
<b>Michael:</b> Affluent Middle-aged White Male With BEV As Secondary Vehicle Living in the California Bay Area With Access to At-home Charging.....	44
<b>Shou:</b> Affluent, Middle-aged Asian American Male With BEV As Secondary Vehicle Living With At-home Charger Who Frequents a Metropolitan City.....	46
<b>Raj:</b> Middle-class Young Male of Indian Heritage With BEV As Primary Vehicle for a 20-mile Commute Who Lives in an Apartment Building With Shared Chargers.....	48
<b>Millicent:</b> Elderly Environmentally Conscious Female on a Fixed Income With a BEV As a Primary Vehicle With an At-home Charger.....	50
<b>Amy:</b> Businesswoman Who Drives a Work Truck and Could Potentially Buy an Electric Truck.....	52
<b>CONCLUSIONS</b> .....	<b>54</b>
<b>APPENDIX</b> .....	<b>55</b>
Acronyms and Abbreviations.....	56
Bibliography.....	57



# INTRODUCTION

The Fuels Institute commissioned Ricardo Strategic Consulting (“Ricardo”) to review existing literature to better understand how consumers drive, where they recharge their EVs, and what they would like to experience during a recharging occasion in terms of site design, amenities, capabilities, and services. In addition to this, the study seeks to understand consumer behavior today and anticipate how it might evolve over the next 10 years as more consumers purchase EVs.

Fuels Institute is a not-for-profit organization led by a collaborative group of fuel retailers, fuel producers and refiners, alternative and renewable fuels producers, automobile manufacturers, and others with expertise in the fuels and automotive industries. The Institute delivers comprehensive and balanced research and analysis concerning fuels, vehicles, and related policy issues. The Electric Vehicle Council is a project of the Fuels Institute comprised of organizations seeking to eliminate confusion and provide guidance for success relative to the installation and operation of retail EV charging stations through stakeholder collaboration, objective research, and market education. Ricardo has aligned its research and opinions in this report to a similar unbiased philosophy.

## LITERATURE STUDY CONTEXT

The market for EVs is expanding, and there is significant need for charging infrastructure. To ensure that the infrastructure satisfies the needs and interests of EV drivers and site hosts alike, it is important to understand what those drivers want and how they would use the infrastructure. This information would be particularly useful to charger operators to help design appropriate facilities. Furthermore, as the EV market grows, the



demographic profile of the EV driver is likely to change and become more diverse. The diversity of future EV drivers could require different designs and amenities to support the various demands of the consumers. Given that charging systems will be long-lived assets that could be in use 10 years or longer following installation, it is essential to better anticipate how drivers will use these systems to ensure the designs remain relevant to driver needs throughout their expected useful life. This literature review is intended to identify trends in EV consumer behavior today, how it has evolved over the past 10 years, and how it could evolve in the next few years to align with the goal of anticipating how drivers will use these systems over the life of the systems.

Ricardo has found that most of the existing research on EV charging preferences is conducted with current EV owners and potential buyers. These owners are likely to use, or work around, the existing infrastructure even with sub-optimal charging speed, density, or site design. Identifying charging preferences of the buyer who is not yet considering EV purchase will be equally important to future infrastructure. This report cites existing literature.



## OBJECTIVE OF THE STUDY

In order to understand consumer behavior today, in the past 10 years, and expected trends over the next 10 years, this report has been structured to answer the following broad questions and their sub-questions:

### ***Who is the customer?***

- What is the demographic profile of today's EV drivers? How does this compare to the population at large, how has it evolved over the past 10 years, and how might it evolve over the next 10 years?
- Which demographic characteristics most influence EV ownership and behavior?
- How do trips taken in an EV differ, if at all, from those taken in a liquid-fueled vehicle?

### ***When and where does the customer recharge?***

- With what frequency do EV drivers recharge their vehicles? Where do consumers recharge their vehicles? What are the factors that influence drivers to initiate a recharging occasion? How does this behavior compare with drivers of liquid-fueled vehicles?
- How often do EV drivers charge at public stations? Why do they choose to charge at a public station versus at home, work, or other locations? What would encourage them to use public charging stations more frequently?
- How much charging infrastructure will be required to service demand compared to the amount of charging infrastructure required to provide consumers with sufficient comfort regarding convenient accessibility of chargers?

### ***Why does the customer choose a particular public recharging facility?***

- To what extent does the availability of Level 2 charging influence consumer perception about charging availability, capacity, and convenience compared with DCFC equipment? How would the price of the service influence this perception?

- Is there a difference in consumer perception relative to the identity type of the charging station host, e.g., a restaurant, convenience store, shopping center, grocery store, parking garage, public versus private entity?
- To what extent does the brand of the charger equipment influence selection?
- How often do consumers use apps to find appropriate public charging, and will the use of these apps grow or diminish as EVSE becomes more available?

### ***How do customers interact with charging equipment?***

- How willing are consumers to pay for charging services?
- How do they perceive various billing methods?
- How comfortable are they with various payment options?
- Do their perceptions change depending on the identity of the company initiating the transaction?

### ***What do customers do at facilities while charging?***

- How much time do drivers expect to spend at a charging station, and what facility features would influence that expected dwell time?
- Which facility features and amenities are most desired by EV drivers and used during a charging occasion? How does this change with variations in dwell time? Which features or amenities yield the greatest influence over an EV driver's decision regarding where to charge?
- Do EV drivers use facility amenities more or less frequently than other customers at the facility?
- How much money do EV drivers spend at these facilities compared with other drivers?

## PERSONAS

Personas are created to exemplify predicted individual preferences by conducting internal interviews. Five personas and their daily habits are outlined below. These have been picked to represent various demographics, their use cases, and perceptions of EV ownership and charging. Ricardo formed teams of 4-5 individuals to discuss each persona. This structure helps describe individual character choices with regards to their daily habits and preferences. A short outline of these personas is mentioned below. [Details will be found towards the end of the report.](#)



**Michael** represents the top demographic of today’s EV buyer: an affluent, white, 37-year-old man living in the California Bay Area with the EV as a second vehicle. Michael’s character is chosen to demonstrate the behavior of a large section of today’s EV owners.



**Shou** is a 49-year-old Asian American man who also owns an EV as a secondary vehicle. His travel needs are limited, and he prefers public transport to driving. Shou’s character serves to help understand the benefit of owning an EV when car travel is limited.



**Raj** is a 28-year-old electrical engineer of Indian origin who lives in an apartment with a common, shared EV charging station. Raj is much younger than the average age of EV owners, and the EV is his only car.



**Millicent** is a 68-year-old African American woman who lives on a fixed income and owns an EV as her primary vehicle. Millicent’s character brings to light the reasoning to own an EV as a means to show her devotion to the eco-conscious ideology. She is one of the rare examples who does not use fast chargers and charges at home on a Level 1 charger.



**Amy** is a 43-year-old white woman who owns her electrician business and is a prospective buyer of an electric pickup truck. The total cost of operation of an electric truck is attractive given her high daily mileage. Her character helps understand the requirements that need to be met in order to cater to the prospective buyer that finds the current EV infrastructure unsatisfactory.

# METHODOLOGY

In compiling this report, Ricardo has researched the following:

1. **Public domain resources, including published surveys; federal, state, and local government publications; cross-functional organization publication; scholarly articles; university/institute publications; national lab publications; public policies; and press reports**
2. **Existing Ricardo studies on user preferences for future mobility (e.g., Ricardo’s ongoing engagement with the California Air Resources Board)<sup>1</sup>**
3. **Supplemental persona creation to exemplify individual preferences**

Throughout the report, the terms *PEV*, *BEV*, and *EV* are used frequently. A *PEV* within this report refers to a combination of both plug-in hybrid electric vehicles (PHEVs) and BEVs. The term *PEV* is primarily used when the study particularly involves both PHEVs and BEVs. The terms *BEV* and *EV* are used interchangeably when referring to BEVs.

The term *PHEV*, in this report, refers to vehicles that use batteries to power an electric motor and use another fuel, such as gasoline, to power an ICE. BEVs or EVs are defined, within this report, as vehicles that have an electric motor instead of an ICE.



The EV Project mentioned in this report refers to the study conducted by the Idaho National Laboratory (INL) in partnership with Electric Transportation Engineering Corporation, Nissan, General Motors, and more than 10,000 other city, regional, and state governments, electric utilities, other organizations, and members of the public.<sup>2</sup> They deployed over 12,000 AC Level 2 (208-240V) charging units and over 100 dual-port DCFC in 20 metropolitan areas. Approximately 8,300 Nissan Leafs, Chevrolet Volts, and smart EQ fortwo vehicles were driven over 125 million miles, and charging-related data for over 4 million charging events was captured between January 1, 2011, and December 31, 2013. This was the largest deployment and evaluation project of EVs and charging infrastructure.

<sup>1</sup> Ricardo, “Ricardo awarded key heavy-duty zero-emissions vehicle project by CARB,” news release, October 24, 2021, <https://ricardo.com/news-and-media/news-and-press/ricardo-awarded-key-heavy-duty-zero-emissions-vehi>.

<sup>2</sup> “AVTA: The EV Project,” Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, <https://www.energy.gov/eere/vehicles/avta-ev-project>.

# PROJECT REPORT

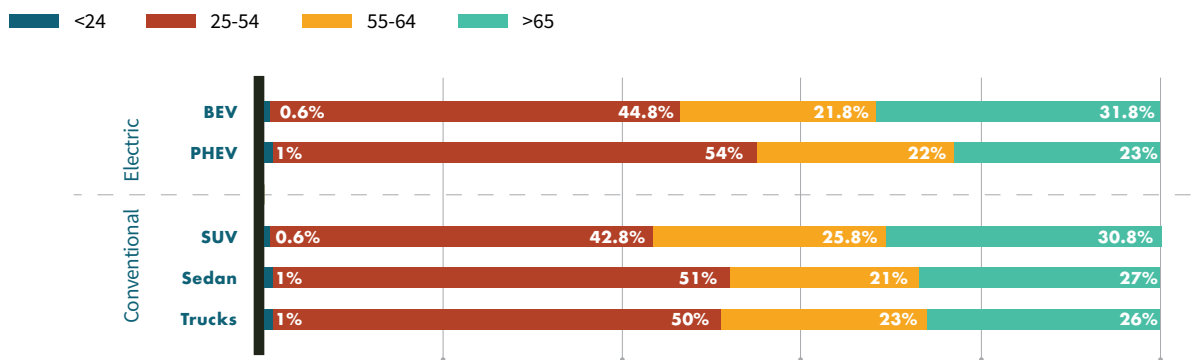
## WHO IS THE CUSTOMER?

### DEMOGRAPHICS

PEV buyers tend to follow the general trend of new car buyers. The dominant age group for PEV buyers across the board is 25-54 years old, according to Hedges Company’s 2019 survey (Figure 1).<sup>3</sup>

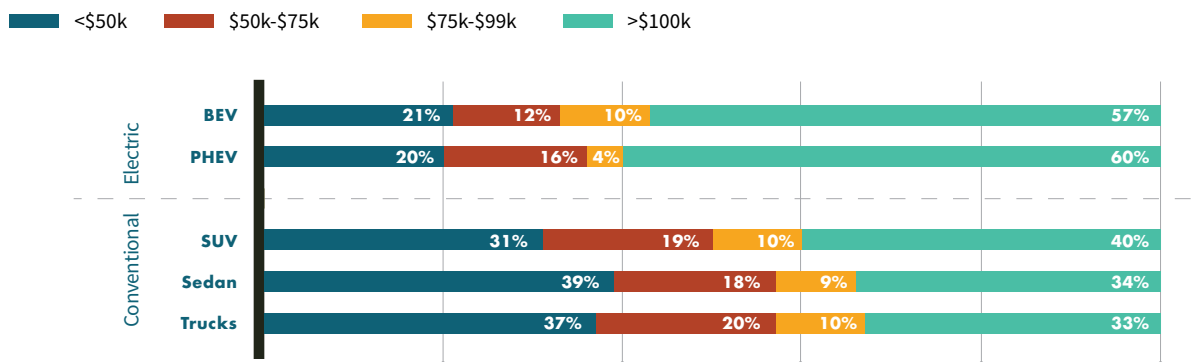
The most dominant annual household income bracket amongst PEV buyers is “greater than \$100,000.” For conventional vehicles, buyers are almost evenly split between “less than \$50,000” and “greater than \$100,000” annual household income (Figure 2).<sup>4</sup> The average household annual income of most EV owners is found to be between \$125,000 and \$150,000, according to the same survey.<sup>5</sup>

FIGURE 1: SPLIT OF NEW CAR BUYERS BASED ON AGE GROUP (2019)



Source: “New Car Buyer Demographics 2020 (Updated),” Hedges & Company (rounded numbers used in some cases)

FIGURE 2: SPLIT OF NEW CAR BUYERS BASED ON ANNUAL HOUSEHOLD INCOME BRACKET (2019)



Source: “New Car Buyer Demographics 2020 (Updated),” Hedges & Company

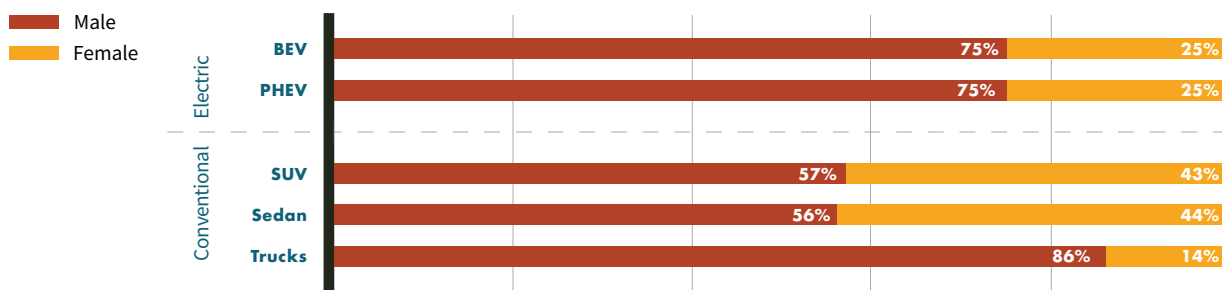
3 “New Car Buyer Demographics 2020 (Updated),” Hedges & Company, accessed October 5, 2020, <https://hedgescompany.com/blog/2019/01/new-car-buyer-demographics-2019/>.

4 “New Car Buyer Demographics 2020 (Updated)”

5 Christopher Butler, “Electric Vehicle Prices Finally in Reach of Millennial, Gen Z Car Buyers,” CNBC, October 20, 2019, updated: October 21, 2019, <https://www.cnbc.com/2019/10/20/electric-car-prices-finally-in-reach-of-millennial-gen-z-buyers.html>.

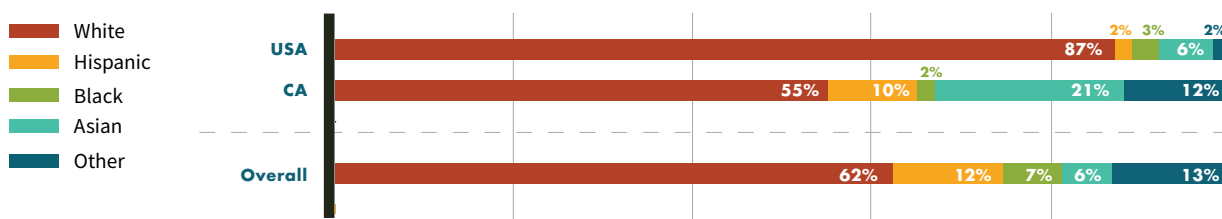


**FIGURE 3: SPLIT OF NEW CAR BUYERS BASED ON GENDER (2019)**



Sources: “New Car Buyer Demographics 2020 (Updated),” Hedges & Company; Farkas et al., Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States

**FIGURE 4: SPLIT OF PEV BUYERS BASED ON ETHNICITY (USA 2014, CA 2018, OVERALL 2015)**



Note: U.S. sample population is 379 EV owners

Sources: Farkas et al., Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States; Erich Muehlegger and David Rapson, Impacts of Vehicle Policy: Who Buys New and Used Alternative Vehicles?; Statista Research Department, Structure of New Vehicle Buyers in the United States, Distributed by Ethnicity Between January and May of 2014 and 2015

As shown in Figure 3,<sup>6</sup> PEV buyers, similar to conventional-fuel truck buyers, are mostly male.<sup>7</sup> Sport utility vehicles (SUV) and sedans have a more balanced distribution amongst male and female buyers.<sup>8</sup>

As shown in Figure 4,<sup>9</sup> PEV buyers nationally in the U.S. are mostly white (87%) according to a study conducted by Morgan State University.<sup>10</sup> The distribution of the white population is slightly elevated in comparison to the distribution of the U.S. population, with 75% white, 13% Black or African American, 6% Asian, and 6% others.<sup>11</sup> Black or African American ethnicity, however, appears to be underrepresented amongst EV buyers. However, in California, according to a survey conducted by the University of California, Davis, and the National Center for Sustainable Transportation, while the distribution of buyers also is mostly white, Asian American PEV buyers appear to closely follow at 21%. This can also be attributed to the fact that California is one of the states with a higher population density of Asian Americans.<sup>12</sup>

6 “New Car Buyer Demographics 2020 (Updated);” Z. Andrew Farkas, Hyeon-Shic Shin, Seyedehsan Dadvar, and Jessica Molina, *Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States* (Charlottesville, VA: Mid-Atlantic Transportation Sustainability University Transportation Center, University of Virginia, February 2017), available at <http://www.matsutc.org/wp-content/uploads/2014/07/Environmental-and-Safety-Attributes-of-Electric-Vehicle-Ownership-and-Commuting-Behavior-Public-Policy-and-Equity-Consideration.pdf>.

7 “New Car Buyer Demographics 2020 (Updated)”

8 “New Car Buyer Demographics 2020 (Updated);” Farkas et al., *Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States*

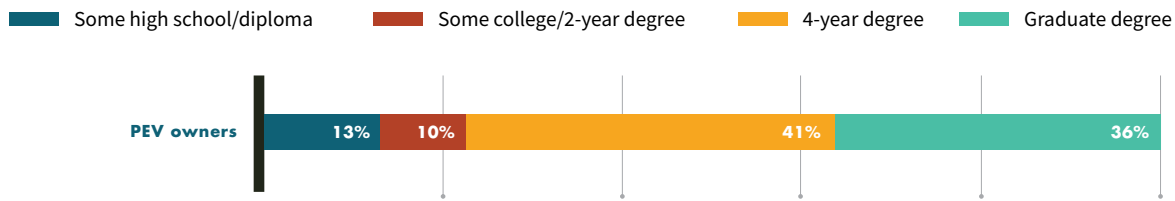
9 Farkas et al., *Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States*; Erich Muehlegger and David Rapson, *Impacts of Vehicle Policy: Who Buys New and Used Alternative Vehicles?*, prepared by Morgan State University (National Center for Sustainable Transportation, University of California Davis, February 2018), available at <https://escholarship.org/uc/item/0tn4m2tx>; Statista Research Department, *Structure of New Vehicle Buyers in the United States, Distributed by Ethnicity Between January and May of 2014 and 2015*, May 2016, accessed October 20, 2020, <https://www.statista.com/statistics/549852/structure-of-new-vehicle-buyers-united-states-by-ethnicity/>.

10 Farkas et al., *Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States*

11 “2019: ACS 1-Year Estimates Detailed Tables” (Table ID C02003, Universe: Total Population, Survey/Program: American Community Survey), United States Census Bureau, accessed October 29, 2020, available at <https://data.census.gov/cedsci/table?q=race&g=0100000US04000.001&tid=ACSDT1Y2019.C02003&moe=false&tp=true&hidePreview=true>.

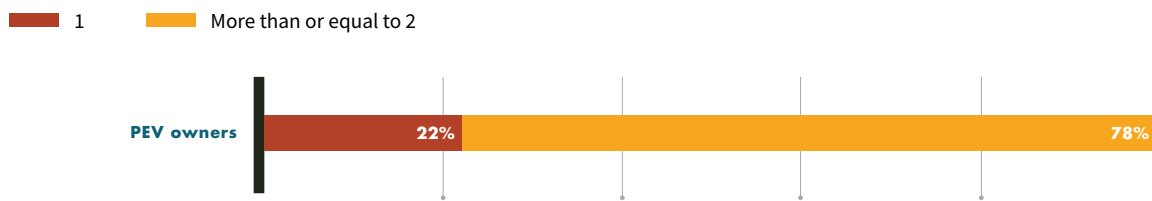
12 “2019: ACS 1-Year Estimates Detailed Tables”

**FIGURE 5: SPLIT OF PEV OWNERS BASED ON EDUCATION LEVEL (2017)**



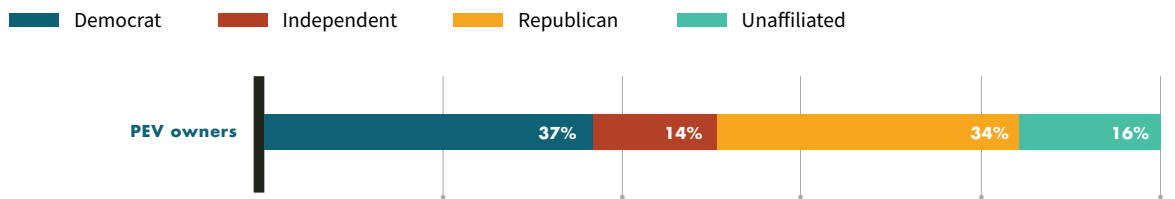
Source: Farkas et al., Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States

**FIGURE 6: SPLIT OF PEV OWNERS BASED ON NUMBER OF VEHICLES IN HOUSEHOLD (2020)**



Source: Ellen Edmonds, “AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns”

**FIGURE 7: POLITICAL AFFILIATION OF PEV OWNERS (2017)**



Source: Farkas et al., Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States

Most PEV owners have at least a four-year degree according to the survey conducted by Morgan State University (Figure 5).<sup>13</sup>

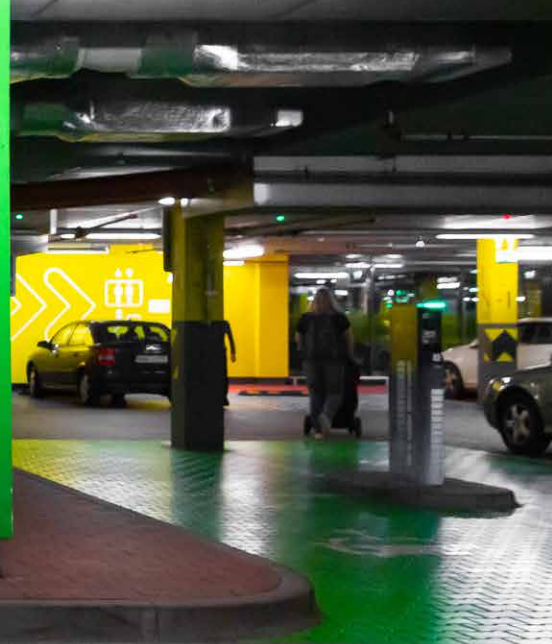
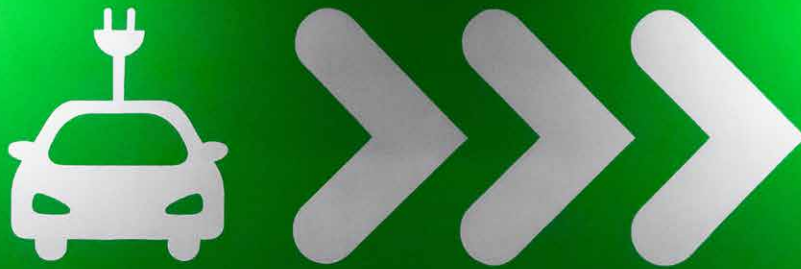
In a survey conducted by Morgan State University in 2017, it was observed that slightly more Democrats owned PEVs compared to Republicans (Figure 7).<sup>15</sup>

AAA’s survey of EV owners revealed that 78% of them also owned a gas-powered car (Figure 6).<sup>14</sup>

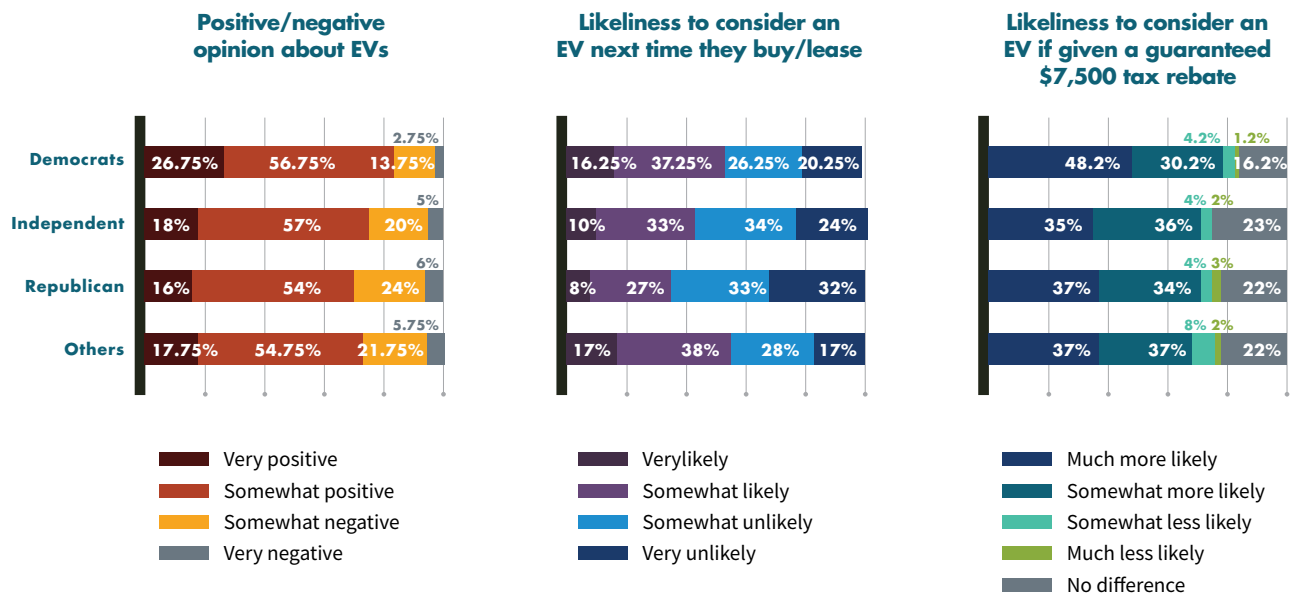
<sup>13</sup> Farkas et al., *Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States*

<sup>14</sup> Ellen Edmonds, “AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns,” AAA, January 22, 2020, <https://newsroom.aaa.com/2020/01/aaa-owning-an-electric-vehicle-is-the-cure-for-most-consumer-concerns/>.

<sup>15</sup> Farkas et al., *Electric Vehicle Ownership Factors, Preferred Safety Technologies, and Commuting Behavior in the United States*



**FIGURE 8: VIEWS ON EVS GROUPED BY POLITICAL AFFILIATION (2019)**

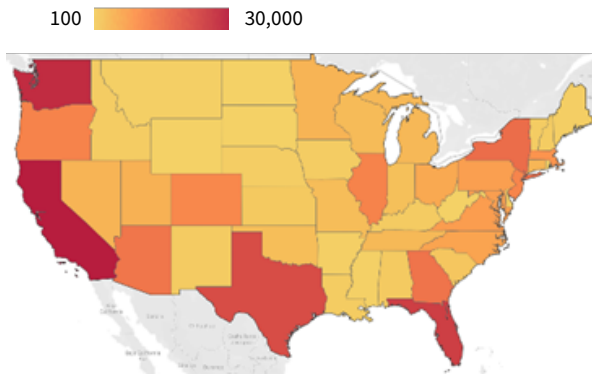


Source: "National Poll Results," Climate Nexus (rounded numbers used in some cases)

In a study conducted by Climate Nexus, Democrats viewed EVs slightly more favorably than Republicans (Figure 8).<sup>16</sup> When asked about the likelihood to consider purchasing or leasing an EV next time, approximately 53% Democrats and approximately 35% Republicans responded affirmatively. When asked if they would consider buying or leasing an EV if they were offered a guaranteed \$7,500 tax rebate, their responses changed dramatically: 78% Democrats and 71% Republicans said they are likely to consider one.

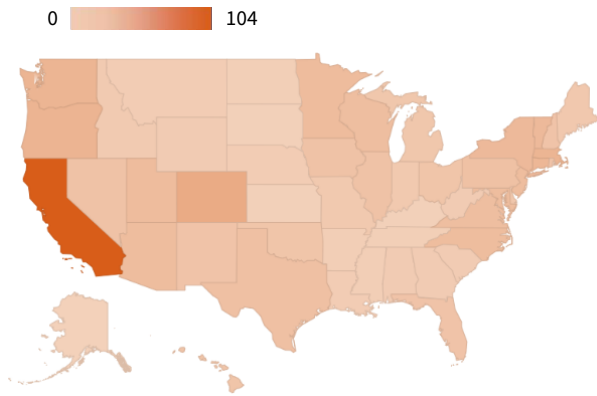
16 "National Poll Results," Climate Nexus, 2015, <https://climatenexus.org/wp-content/uploads/2015/09/EV-Poll-Results.pdf>.

**FIGURE 9: HEATMAP OF BEV POPULATION BASED ON NUMBER OF REGISTRATIONS BY STATE (2018)**



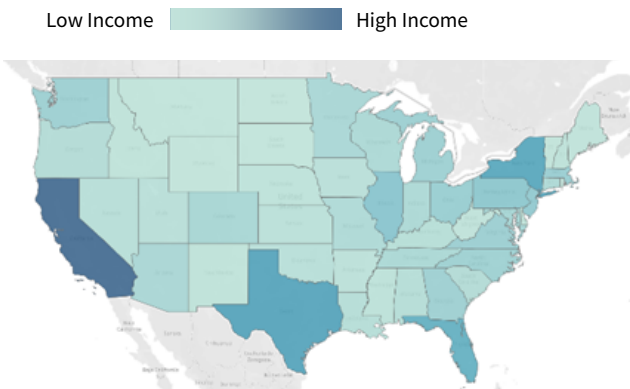
Note: Total registrations in California is 256,000 but the legend ends at 30,000 to highlight the variation in other states.  
 Source: “Electric Vehicle Registrations by State,” National Renewable Energy Laboratory

**FIGURE 11: EV LAWS AND INCENTIVES (2020)**

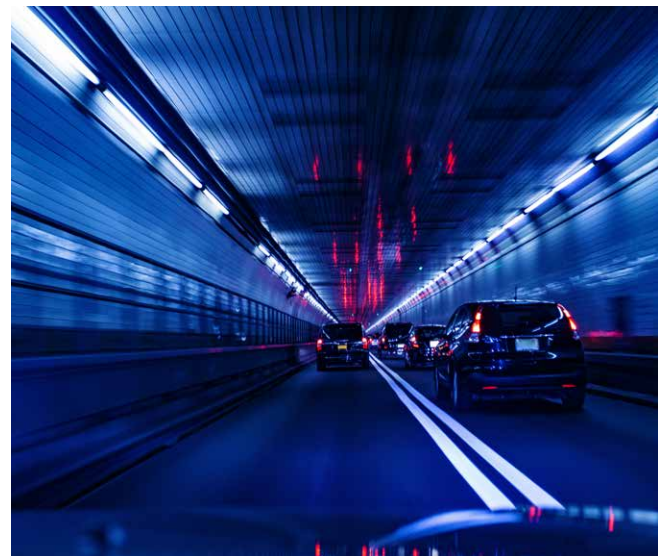


Note: Darker color indicates a greater number of laws and incentives; California leads at 104.  
 Source: “Electric Vehicle Laws and Incentives by State” (chart), “Maps and Data — Electric Vehicle Laws and Incentives by State” (webpage), Alternative Fuels Data Center

**FIGURE 10: INDIVIDUAL INCOME BY STATE (2018)**



Note: Darker color indicates a larger sum of individual income.  
 Source: “SOI Tax Stats — Individual Income Tax Statistics — 2018 ZIP Code Data (SOI),” Internal Revenue Service



Distribution of BEVs is concentrated along the ZEV (zero-emission vehicle) belt (Figure 9).<sup>17</sup> BEV registrations in California in 2018 were approximately 256,000, which was roughly equal to the BEV registrations in all other states combined (approximately 286,000).<sup>18</sup>

This distribution appears to correspond with individual income in each state (Figure 10)<sup>19</sup> and the EV policies and incentives in each state (Figure 11).<sup>20</sup> When compared to the overall number of vehicles registered by state, EVs constitute a very small percentage (Figure 12).<sup>21</sup>

17 “Electric Vehicle Registrations by State,” National Renewable Energy Laboratory, printed March 7, 2020, updated August 2020, accessed October 20, 2020, available at <https://afdc.energy.gov/data/10962>.  
 18 “Electric Vehicle Registrations by State;” “U.S. Automobile Registrations in 2018, by State,” Statista, March 2021, <https://www.statista.com/statistics/196010/total-number-ofregistered-automobiles-in-the-us-by-state/>.  
 19 “SOI Tax Stats — Individual Income Tax Statistics — 2018 ZIP Code Data (SOI),” Internal Revenue Service, 2018, accessed October 20, 2020, available at <https://www.irs.gov/statistics/soi-tax-stats-individual-income-tax-statistics-2018-zip-code-data-soi>.  
 20 “Electric Vehicle Laws and Incentives by State” (chart), “Maps and Data — Electric Vehicle Laws and Incentives by State” (webpage), Alternative Fuels Data Center, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, accessed October 22, 2020, available at <https://afdc.energy.gov/data/10373>.  
 21 “Electric Vehicle Registrations by State;” “U.S. Automobile Registrations in 2018, by State”



**Distribution of BEVs is concentrated along the ZEV (zero-emission vehicle) belt.**

**BEV registrations in California in 2018 were approximately 256,000, which was roughly equal to the BEV registrations in all other states combined (approximately 286,000).**

Despite having the highest number of EV registrations in the U.S., California’s BEV population still comprises only approximately 1.7% of the state’s overall vehicle registrations (Figure 12). In each of the 10 states with the most EV registrations, those registrations constituted less than 1% of all state vehicle registrations in 2018.

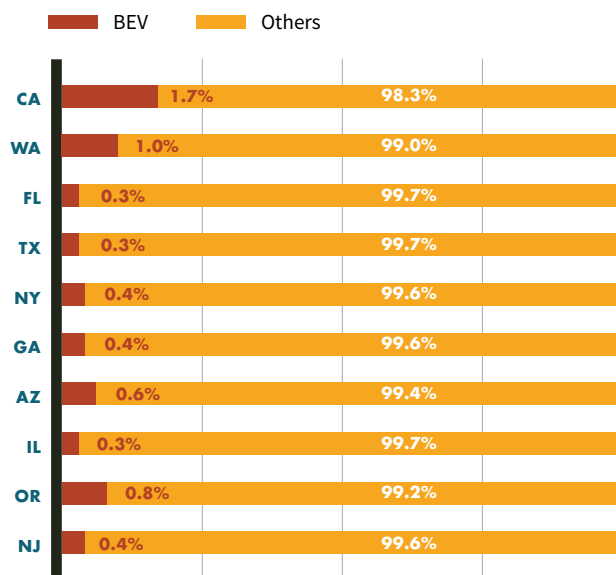
### Daily commute lengths of PEV drivers

According to the Federal Highway Administration, in 2017, self-estimated annual mileage indicates an average daily commute between 20 and 35 miles.<sup>22</sup> For EV drivers, however, the average daily commute length is estimated to be between 31 and 39 miles.<sup>23</sup> One reason for this observed trend could be BEVs have a lower cost of fuel and maintenance compared to an ICE-powered vehicle — estimated by AAA as 57% lesser and 65% lesser, respectively. Most EV owners also own a second vehicle in the household, which could be a conventional vehicle. Given the cheaper operating cost of a BEV compared to a conventional vehicle, owners might prefer to use the BEV for a higher number of trips.<sup>24</sup> Another reason could be that the constant increase of both average EV battery range and charging infrastructure has reduced range anxiety for drivers.

### EVOLUTION OF EV BUYER DEMOGRAPHICS AND BEHAVIOR OVER THE PAST 10 YEARS

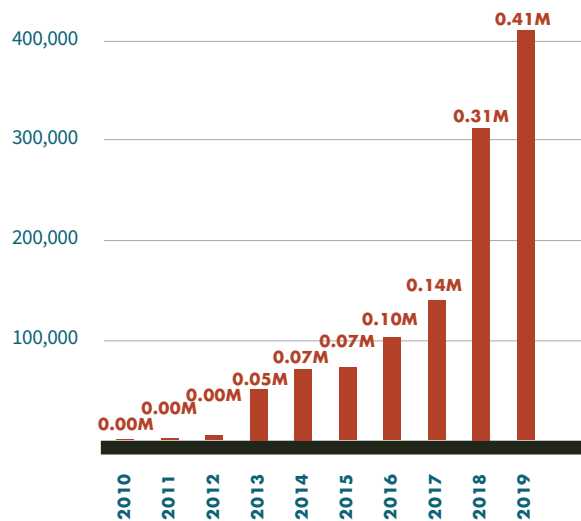
BEV production in the U.S. has been experiencing exponential growth aided by falling battery prices.<sup>25</sup> The spike in 2018 coincides with the Tesla Model 3 introduction (Figure 13).<sup>26</sup>

**FIGURE 12: SPLIT OF VEHICLE REGISTRATIONS BY STATE (TOP 10) (2018)**



Source: “Electric Vehicle Registrations by State;” “U.S. Automobile Registrations in 2018, by State”

**FIGURE 13: BEV PRODUCTION IN THE U.S. (2010-2019)**



Source: IHS Markit

22 N. McGuckin and A. Fucci, *Summary of Travel Trends: 2017 National Household Travel Survey* (Washington, DC: Federal Highway Administration, July 2018), available at [https://nhts.ornl.gov/assets/2017\\_nhts\\_summary\\_travel\\_trends.pdf](https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf).

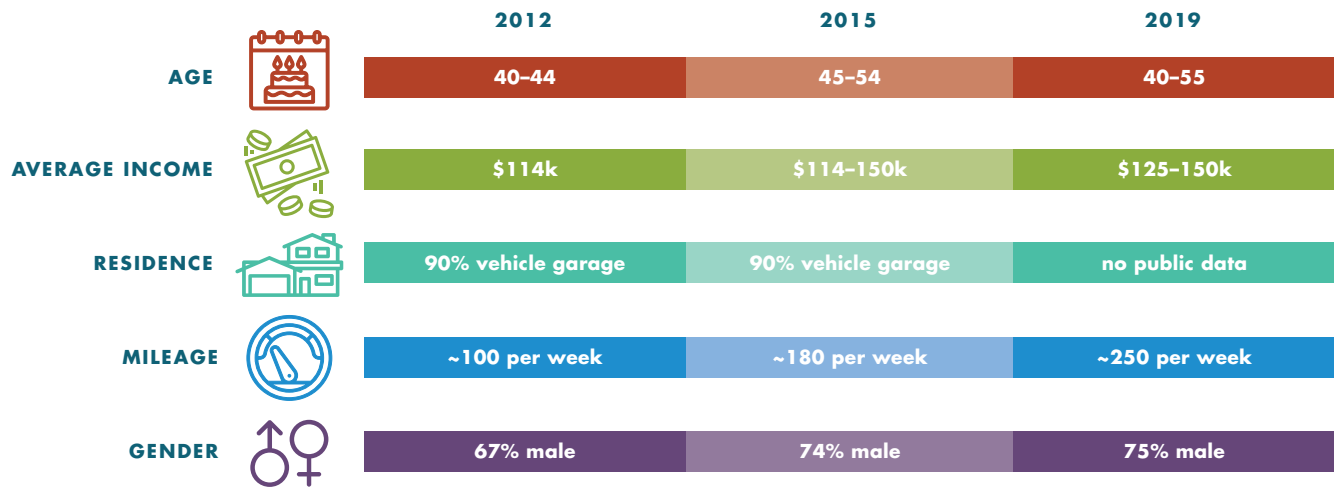
23 Ellen Edmonds, “AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns”; Daniel Boston and Alyssa Werthman, “Plug-in Vehicle Behaviors: An Analysis of Charging and Driving Behavior of Ford Plug-In Electric Vehicles in the Real World,” *World Electric Vehicle Journal* 8 (2016): 926-935, <https://doi.org/10.3390/wevj8040926>.

24 Ellen Edmonds, “AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns”

25 Colin McKerracher, Ali Izadi-Najafabadi, Aleksandra O’Donovan, Nick Albanese, Nikolas Soulopoulos, David Doherty, Milo Boers, et al, *Electric Vehicle Outlook 2020* (Bloomberg New Energy Finance, 2020), <https://about.bnef.com/electric-vehicle-outlook/>.

26 IHS Markit, subscription-only database and forecast utility, accessed October 1, 2020, <https://ihsmarkit.com/>

**FIGURE 14: EVOLUTION OF KEY EV BUYER DEMOGRAPHICS (2012-2021)**



The PEV buyer’s age group has stayed the same over the years (Figure 14).<sup>27</sup> The average household annual income has been consistently over \$100,000.<sup>28</sup> Most PEV owners have had a garage with an outlet to charge their vehicle.<sup>29</sup> PEV buyers have mostly been male.<sup>30</sup> Mileage traveled, however, has increased from 100 miles a week to 250 miles a week over the past 10 years.<sup>31</sup> This could be attributed to the fact that both the average battery range on a typical EV and the charging infrastructure have been growing constantly, which helps ease range anxiety for buyers. In addition to this, the cost of operating an EV is less than that of a conventional vehicle,

encouraging drivers to drive their EVs more than their other conventional vehicle(s).<sup>32</sup>

The EV fleet has grown over the past 10 years where commercial fleet operators have gained more experience in deploying EVs in the field. EV usage in the commercial sector has evolved from limited-use transit bus applications to medium- and heavy-duty vehicles, delivery vans, and light-duty trucks.<sup>33</sup> A very recent example to this is Amazon’s 2020 investment in Rivian to provide vans for its fleet.<sup>34</sup>

27 Deloitte Consulting LLP, *Gaining Traction: A Customer View of Electric Vehicle Mass Adoption in the U.S. Automotive Market*, 2010, <https://www.yumpu.com/en/document/read/4198231/gaining-traction-a-customer-view-of-electric-vehicle-mass-adoption-in>; Chris Woodyard, “Study: Electric Car Buyers Are Younger but Richer,” *USA Today*, May 4, 2015, updated May 7, 2015, <https://www.usatoday.com/story/money/cars/2015/05/04/truecar-study-electric-cars-richer/26884511/>; “EV Consumer Survey Dashboard,” California Clean Vehicle Rebate Project, accessed October 5, 2020, available at <https://cleanvehiclerebate.org/eng/survey-dashboard/ev/>; Daniel Boston and Alyssa Werthman, “Plug-in Vehicle Behaviors”; “New Car Buyer Demographics 2020 (Updated)”

28 Electric Power Research Institute, Inc., *Plug-In Electric Vehicle Multi-State Market and Charging Survey*, February 26, 2016, available at <https://www.epri.com/research/products/000000003002007495>; Deloitte Consulting LLP, *Gaining Traction*; Christopher Butler, “Electric Vehicle Prices Finally in Reach of Millennial, Gen Z Car Buyers”

29 Electric Power Research Institute, Inc., *Plug-In Electric Vehicle Multi-State Market and Charging Survey*, February 26, 2016, available at <https://www.epri.com/research/products/000000003002007495>. Deloitte Consulting LLP, *Gaining Traction*

30 Deloitte Consulting LLP, *Gaining Traction*; Mark Kane, “Annual Electric Miles Traveled Varies Widely For 8 Plug-In Electric Cars,” *InsideEVs*, May 16, 2015, <https://insideevs.com/news/325893/annual-electric-miles-traveled-varies-widely-for-8-plug-in-electric-cars/>.

31 Deloitte Consulting LLP, *Gaining Traction*; Mark Kane, “Annual Electric Miles Traveled Varies Widely For 8 Plug-In Electric Cars”; Ellen Edmonds, “AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns”






32 Ellen Edmonds, “AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns”

33 Ricardo research

34 Annie Palmer, “Amazon Debuts Electric Delivery Vans Created with Rivian,” *CNBC*, October 8, 2020, updated October 8, 2020, <https://www.cnbc.com/2020/10/08/amazon-new-electric-delivery-vans-created-with-rivian-unveiled.html>.



**FIGURE 16: EXPECTED EVOLUTION OF KEY EV BUYER DEMOGRAPHICS (2021-2030)**

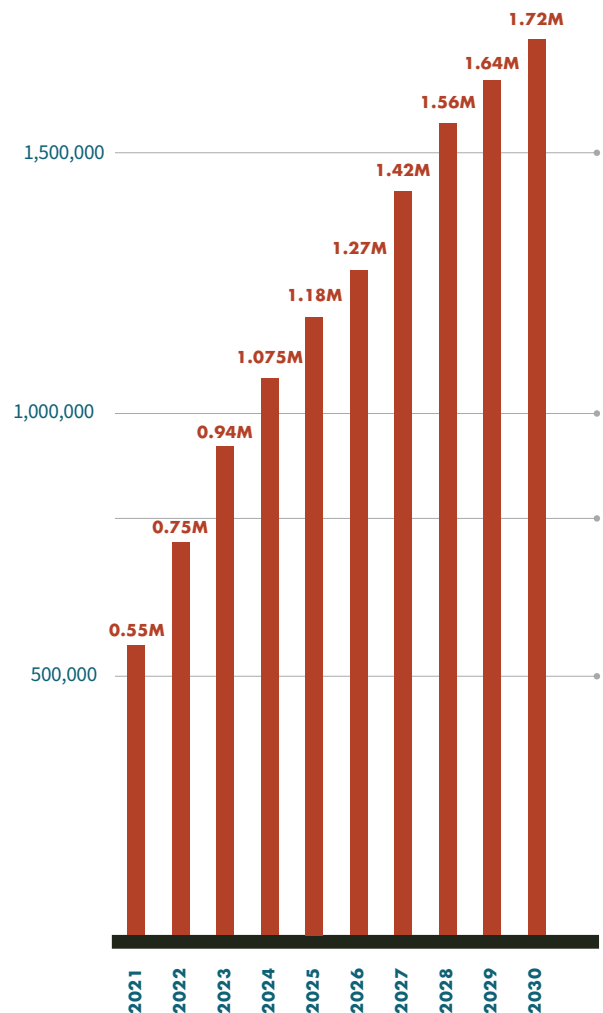
	2021	2025	2030
<b>AGE</b> 	The average age is expected to normalize with the broader new-vehicle buyer trend.		
<b>AVERAGE INCOME</b> 	Average income bracket is expected to drop down from the current bracket as EVs become more affordable.		
<b>RESIDENCE</b> 	Number of EV drivers with no provision to charge at home is expected to increase as availability of public charging points increases along with the range of vehicles.		
<b>MILEAGE</b> 	Driving pattern is expected to be similar to the way ICE vehicles are driven.		
<b>GENDER</b> 	Gender distribution is expected to be more balanced with the launch of new vehicles in various segments with better range estimators.		

**ANTICIPATED EVOLUTION OF EV BUYER DEMOGRAPHICS AND BEHAVIOR OVER THE NEXT 10 YEARS**

BEV production is expected to steadily grow within the next decade. At some point, BEVs are expected to reach price parity with ICE vehicles (Figure 15).

Companies such as Volkswagen and Volvo expect to generate at least 40% of their sales from EVs by 2025; most other auto OEMs are expected to follow this trend.<sup>35</sup> By 2030, up to 40% of all new car sales could be EVs.<sup>36</sup> Given that the number of available EV segments is expected to broaden, the cost of owning an EV is forecast to be on par with a conventional vehicle, and charging infrastructure is estimated to grow to meet the demand,<sup>37</sup> the EV buyer demographic could normalize with the new car buyer over the next 10 years (Figure 16).

**FIGURE 15: EXPECTED BEV PRODUCTION IN THE U.S. (2021-2030)**



35 Tim Levin, "All the Things Carmakers Say They'll Accomplish with Their Future Electric Vehicles Between Now and 2030," *Business Insider*, January 28, 2020, <https://www.businessinsider.com/promises-carmakers-have-made-about-their-future-electric-vehicles-2020-1>.

36 McKerracher et al, *Electric Vehicle Outlook 2020*; U.S. Drive, *Summary Report on EVs at Scale and the U.S. Electric Power System*, November 2019, <https://www.energy.gov/sites/prod/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf>.

37 Hao Wu, Genevieve Alberts, James Hooper, and Bryn Walton, *New Market. New Entrants. New Challenges. Battery Electric Vehicles* (London, UK: Deloitte LLP, 2019), <https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-battery-electric-vehicles.pdf>.



According to a survey conducted by Volvo, more than half of respondents said they are likely to purchase an EV if the price is the same as an ICE vehicle.<sup>38</sup> The industry expectation that EV to ICE price parity may be realized in the coming decade would mean that EVs could be affordable to a broader consumer base.

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## The EV fleet is expected to grow in the upcoming years, primarily driven by state mandates. California and 27 other states have hybrid or EV fleet requirements, acquisition goals, or a stated preference for purchasing hybrid or EVs to be used in the state's fleet.

This will increase the probability of buyers with an annual household income of less than \$100,000 to consider an EV for their next vehicle, thus pushing the average EV owner income bracket down from where it currently sits.

Bloomberg New Energy Finance predicts the ratio of EVs to public charging points is expected to reach 40-50 EVs per public charging point by 2040,<sup>39</sup> and as hardware costs fall and technology is commoditized, Wood Mackenzie predicts that there could be as many as 1.2 million public charging points in North America by 2030.<sup>40</sup> This increase in availability of public chargers could help potential consumers without access to a charger at home consider buying an EV.

Potential owners are inclined to purchase a BEV if it delivers a range of approximately 320 miles.<sup>41</sup> Given that Americans drive an average of 260 miles a week,<sup>42</sup> potential BEV buyers expect to get at least a week of driving range on a single charge. Many vehicles today offer more than 200 miles of range,<sup>43</sup> and the trend has been constant growth in BEV range. BEVs are expected to be driven like liquid-fuel-powered vehicles today, so the driving distance on a BEV is expected to be on par with the overall trend.

There appears to be a balanced distribution between the two genders in purchases of SUVs and sedans, however, the average EV customer is predominantly male.<sup>44</sup> According to a study by the University of California, Davis, amongst other reasons, female EV early adopters largely distrusted the range estimator.<sup>45</sup> There could be more female EV drivers when newer technology enables more accurate range predictors and perhaps better range as well.

The EV fleet is expected to grow in the upcoming years, primarily driven by state mandates. California and 27 other states have hybrid or EV fleet requirements, acquisition goals, or a stated preference for purchasing hybrid or EVs to be used in the state's fleet.<sup>46</sup> For example, California's 2020 mandate requiring 5-9% of 2024 model year trucks, based on class, to be ZEVs is expected to expand to have 30-50% of trucks to be ZEVs by 2030 and 100% where feasible by 2045.<sup>47</sup>

38 Volvo Car USA, *The State of Electric Vehicles in America*, February 26, 2019, <https://www.media.volvocars.com/us/en-us/media/documentfile/249123/volvo-reports-the-state-of-electric-vehicles-in-america>.

39 McKerracher et al., *Electric Vehicle Outlook 2020*

40 Jason Deign, "Up to 40 Million EV Charging Points Forecast Worldwide by 2030," *Green Tech Media*, August 9, 2018, <https://www.greentechmedia.com/articles/read/electric-vehicle-charging-points-40-million-gtm>.

41 Castrol, *Accelerating the EVolution: The Tipping Points to Mainstream Electric Vehicle Adoption*, 2020, [https://www.castrol.com/content/dam/castrol/master-site/en/global/home/technology-and-innovation/electric-vehicle-adoption/accelerating\\_the\\_evolution\\_study.pdf](https://www.castrol.com/content/dam/castrol/master-site/en/global/home/technology-and-innovation/electric-vehicle-adoption/accelerating_the_evolution_study.pdf).

42 "Average Annual Miles per Driver by Age Group," Federal Highway Administration, U.S. Department of Transportation, March 29, 2018, accessed October 15, 2020, available at <https://www.fhwa.dot.gov/ohim/onh00/bar8.htm>.

43 Dave Vanderwerp, "EV Range: Everything You Need to Know," *Car and Driver*, May 22, 2020, <https://www.caranddriver.com/shopping-advice/a32603216/ev-range-explained/>.

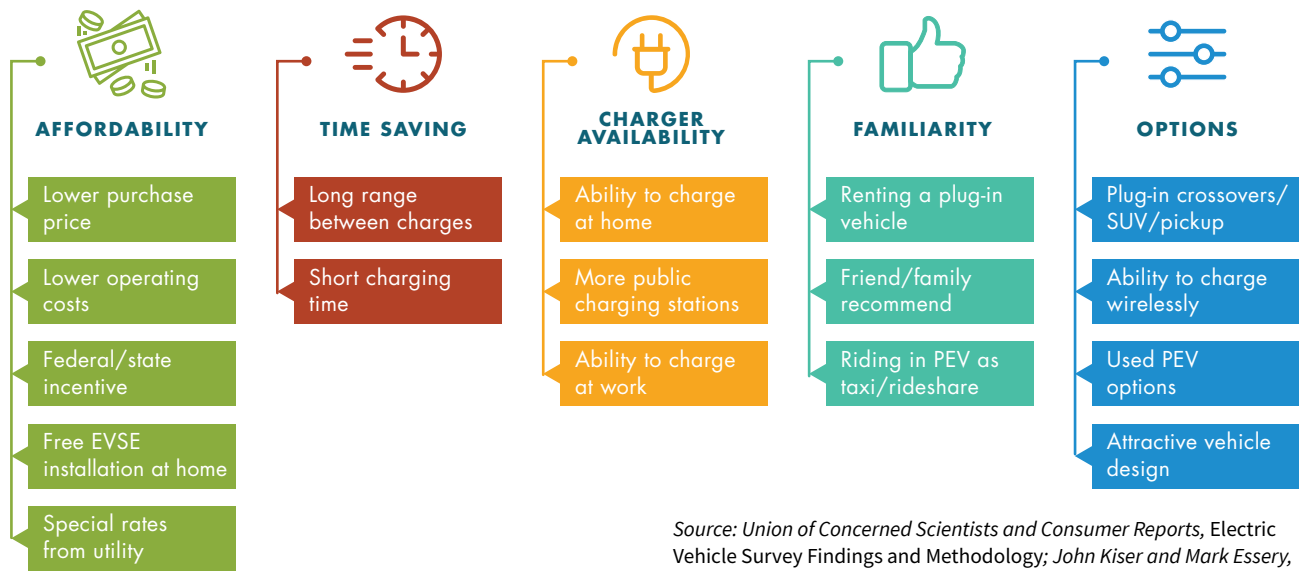
44 "New Car Buyer Demographics 2020 (Updated)"

45 Nicolette Capereello, Jennifer TyreeHageman, and Ken Kurani, "Engendering the Future of Electric Vehicles: Conversations with Men and Women" (presentation, Women's Issues in Transportation 5th International Conference, Paris, France, April 14-16, 2014) available at <https://phev.ucdavis.edu/wp-content/uploads/2017/08/2014-UCD-ITS-RP-14-101.pdf>.

46 Kristy Hartman and Emily Dowd, "State Efforts to Promote Hybrid and Electric Vehicles," National Conference of State Legislatures, September 26, 2017, <https://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx>.

47 David Shepardson and Nichola Groom, "California Passes Landmark Mandate for Zero Emission Trucks," Reuters, June 25, 2020, <https://ca.reuters.com/article/idUSKBN23W31N>.

FIGURE 17: FACTORS INFLUENCING LIKELINESS OF PEV PURCHASE (2017-2019)



Source: Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*; John Kiser and Mark Essery, *Is There a Target Market for Electric Vehicles?*

### DEMOGRAPHIC CHARACTERISTICS AND THEIR RELATIONSHIP WITH EV OWNERSHIP AND BEHAVIOR

Currently, EVs are predominantly sedans or hatchbacks, which may not cater to the requirement of SUV, truck, and minivan drivers. In a 2019 study, the Union of Concerned Scientists (UCS) and Consumer Reports reported a strong consensus (72%) that PEVs should be produced in other forms,<sup>48</sup> so they may address the requirements of drivers of these vehicles.

In the same study, approximately half of all prospective EV buyers reported a belief that the federal government should invest money to help consumers buy PEVs. In addition, this belief is more prevalent in people of color (62% people of color versus 53% of all new car buyers).<sup>49</sup>

Another key theme is that younger people between the age of 25 and 34 may not be able to afford EVs due to factors such as student debt, wage stagnation, and lack of access to home charging or at-home parking. Some report using public transportation to be more practical than owning a car.<sup>50</sup>

PEV buyers appear to value affordability by means of a lower purchase price, lower operating costs, and federal and/or state support, amongst others (Figure 17).<sup>51</sup> They expect a PEV to be time-saving by charging quickly and having a long range. Charger availability at home and in public places appears important to prospective PEV buyers. Some of those surveyed feel that familiarity with the technology could encourage a purchase,<sup>52</sup> such as while renting a PEV and riding in a PEV ride-share or taxi. Potential buyers value choices in form and attractive vehicle design, amongst other factors, that could help them decide to purchase an EV.

48 Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*, July 2019, [https://advocacy.consumerreports.org/wp-content/uploads/2019/07/ConsumerReports-UnionofConcernedScientists-2019-EV\\_Survey-7.17.19.pdf](https://advocacy.consumerreports.org/wp-content/uploads/2019/07/ConsumerReports-UnionofConcernedScientists-2019-EV_Survey-7.17.19.pdf).

49 Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*

50 Christopher Butler, “Electric Vehicle Prices Finally in Reach of Millennial, Gen Z Car Buyers”

51 Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*; John Kiser and Mark Essery, *Is There a Target Market for Electric Vehicles?*, Ipsos, March 27, 2017, [https://www.ipsos.com/sites/default/files/2017-04/ipsos-marketing-target-market-electric-vehicles.PD\\_\\_0.pdf](https://www.ipsos.com/sites/default/files/2017-04/ipsos-marketing-target-market-electric-vehicles.PD__0.pdf).

52 Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*

Decision making for adoption of EVs in commercial fleet applications is deeply rooted in viable business case and the ability to meet operational requirements. Hence, TCO and the payback period are key metrics considered by fleets, which are impacted by EV price, cost of infrastructure, operational cost savings, and residual value at the end of the vehicle's primary usage. Vehicle uptime, duty cycle, range, and payload requirements are other major factors that fleets take into consideration. EVs have penetrated several commercial vehicle on-highway and off-highway applications, such as transit buses, school buses, medium-duty delivery vans, yard trucks, forklifts, and heavy-duty on-highway trucks. However, currently commercial EVs are predominantly used for local operations, often involving stop-and-go duty cycles, where the vehicles return to base and rely on private charging infrastructure owned and operated by the fleet.<sup>53</sup>

### DIFFERENCE IN TRIPS TAKEN IN EVS VERSUS LIQUID-FUEL VEHICLES

Early adopters found that limited battery range and lack of widespread availability of public chargers made longer trips more difficult in EVs. According to an AAA study, the average EV owner drives 39 miles a day.<sup>54</sup> This is slightly more than the national average of all vehicles, which is between 20-35 miles a day.<sup>55</sup> In general, more miles are driven today in an EV than in a conventional liquid-fueled vehicle, and drivers have started treating EVs like they would treat a conventional liquid-fueled vehicle. This is different from the situation a few years ago when the average

number of miles driven in an EV had been roughly 15 miles a day.<sup>56</sup> This has been largely attributed to the increased range on EVs and availability of EV chargers, instilling confidence in drivers to drive longer miles, especially because operational expense for EVs is lower than that for gasoline vehicles.

To compare this difference in operational expense, in 2019, the U.S. national average price of gas was \$2.5 per gallon.<sup>57</sup> The average fuel economy of a gas vehicle (average of short wheelbase light vehicle in 2019) is 24.1 mpg.<sup>58</sup> Based on the above, one mile costs 9.6 on gas. The average cost of retail residential electricity was 13.04 per kWh in 2019,<sup>59</sup> and the average fuel efficiency of a BEV is 32.63 kWh per 100 miles,<sup>60</sup> or 0.3263 kWh per mile. This implies one mile on electricity costs 4.25, which is roughly less than half of the cost to travel in a gas-powered vehicle.

Many states allow PEVs to use high-occupancy vehicle, or HOV, lanes, cutting drivers' commute times by a significant portion and helping them make a statement about their "tech-savvy-ness" or their environmental consciousness. This gives drivers more reasons to drive a PEV, especially when they have more than one vehicle in their household.

One major difference in EV driving behavior is that long trips are mostly planned with charging locations in mind, as opposed to a conventional vehicle's ability to re-fuel at almost any gas station, which far outnumber the number of available charging stations.

53 Ricardo research

54 Ellen Edmonds, "AAA: Owning an Electric Vehicle is the Cure for Most Consumer Concerns"

55 N. McGuckin and A. Fucci, *Summary of Travel Trends: 2017 National Household Travel Survey*; Daniel Boston and Alyssa Werthman, "Plug-in Vehicle Behaviors"

56 Deloitte Consulting LLP, *Gaining Traction*

57 "Gasoline and Diesel Fuel Update," Petroleum & Other Liquids, U.S. Energy Information Administration, accessed October 23, 2020, available at <https://www.eia.gov/petroleum/gasdiesel/>.

58 "Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles," Bureau of Transportation Statistics, <https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles>.

59 "Average Retail Price of Electricity, United States, Annual," Electricity Data Browser, U.S. Energy Information Administration, available at <https://www.eia.gov/electricity/data/browser/#/topic/7?agg=2,0,1&geo=g&freq=A&start=2001&end=2019&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&motype=0> (data accessed for year 2019).

60 "New All-Electric Vehicles," Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, accessed October 16, 2020, <https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=3&year1=2019&year2=2021&vtype=Electric&srctype=newAfv&tabView=0&pageno=1&sortBy=Comb&rowLimit=10> (fuel efficiency of all current BEVs were averaged).

## WHEN AND WHERE DOES THE CUSTOMER RECHARGE?

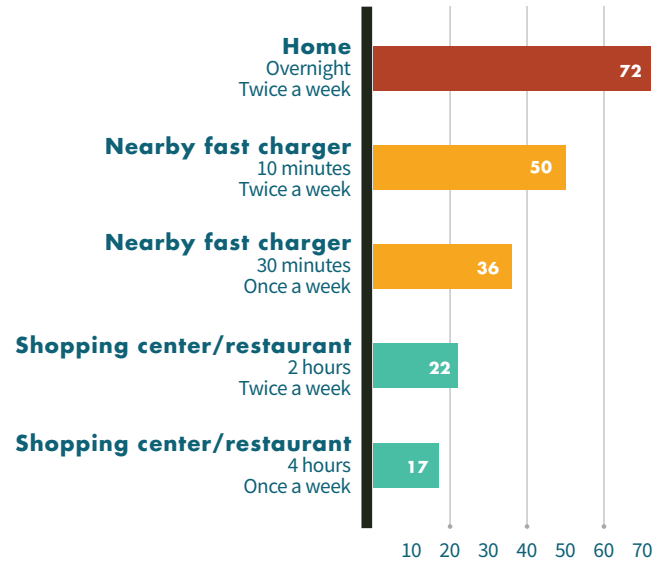
### EV DRIVERS' CHARGING FREQUENCY

As the battery range of vehicles increases with every new model year, the confidence among EV owners is increasing, which is noted in the downward trend of charging frequency (Figure 18).<sup>61</sup> The average EV owner driving a 2016 or 2017 model year vehicle charged approximately once a day as opposed to EV drivers with vehicles of a 2011 model year that required to be recharged approximately twice a day (43 times a month). 2021 model year vehicles are predicted to not be very different from 2016 and 2017 model year vehicles and are expected to be charged roughly once a day. This trend, however, could see a slight rise as the number of public chargers increases. People are likely to plug in even when their EV has enough charge to complete the trip because of factors such as availability, convenience, and value (see “EV Drivers’ Preferred Recharge Location”).

The UCS and Consumer Reports found that most prospective PEV buyers would prefer to charge twice a week, overnight, at home (Figure 19).<sup>62</sup>

They also found that prospective EV buyers who are people of color are more likely to find charging options outside the home to be more convenient, compared to all prospective car buyers combined.<sup>63</sup>

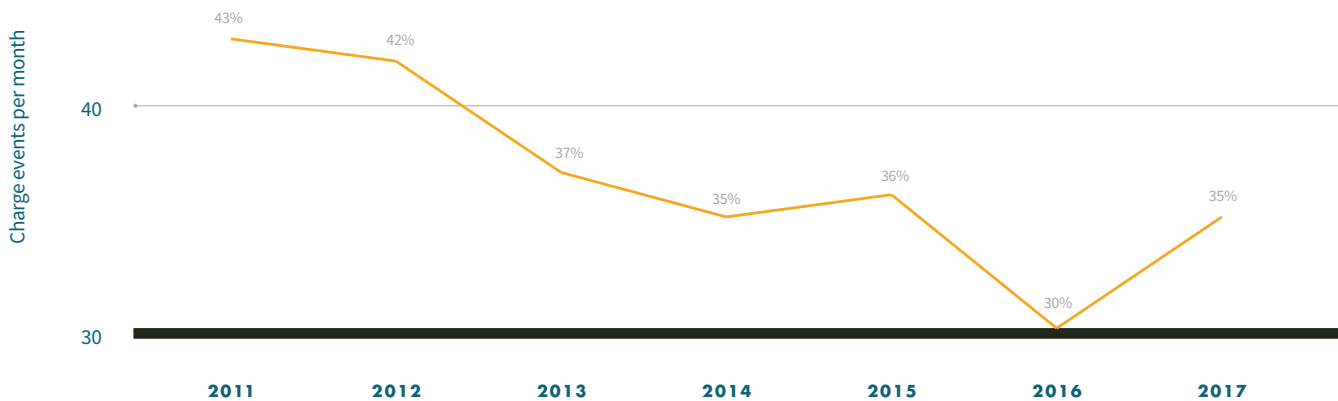
**FIGURE 19: CHARGING OPTIONS PERCEIVED TO BE MOST CONVENIENT BY PROSPECTIVE PEV BUYERS (2017)**



Note: Percentage represents proportion of respondents rating option as “completely convenient” or “very convenient”

Source: Union of Concerned Scientists and Consumer Reports, Electric Vehicle Survey Findings and Methodology

**FIGURE 18: AVERAGE RECHARGE EVENTS PER MONTH BY MODEL YEAR**



Note: Data includes U.S. and Canada

61 Eric Schmidt, “The Key to Increasing EV Adoption Is Hidden in EV Driving and Charging Data,” FleetCarma, January 24, 2018, available at <https://www.fleetcarma.com/key-increasing-ev-adoption-hidden-ev-driving-charging-data/>.

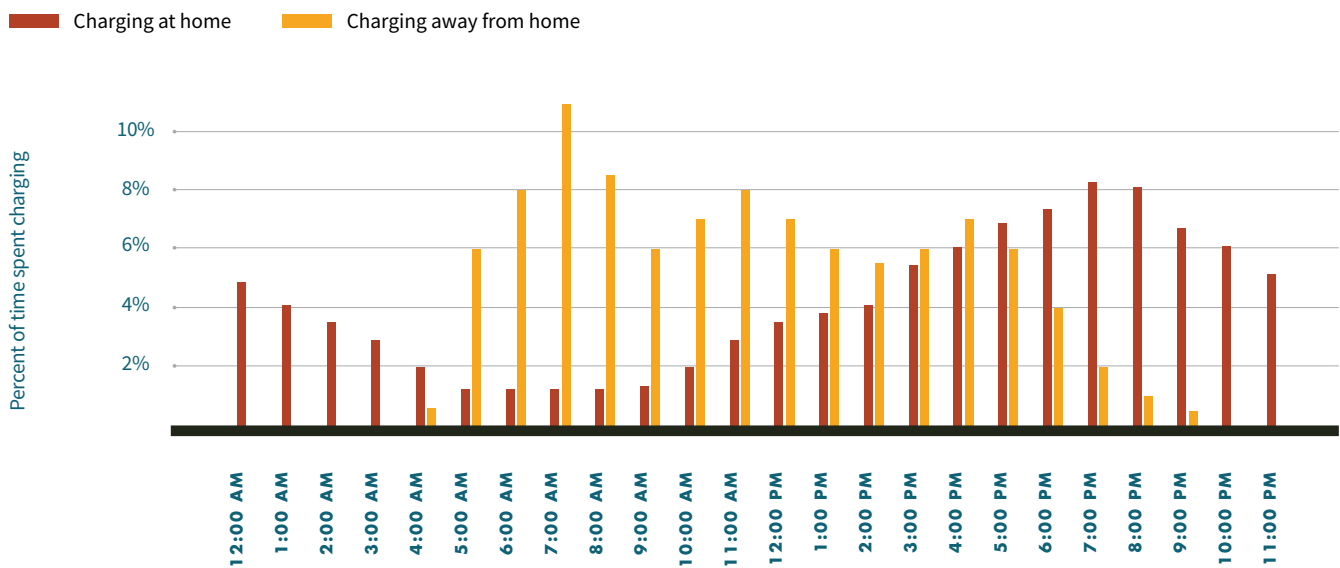
62 Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*

63 Union of Concerned Scientists and Consumer Reports, *Electric Vehicle Survey Findings and Methodology*





**FIGURE 20: ESTIMATE: PERCENTAGE TIME SPENT CHARGING AT A GIVEN POINT IN TIME DURING THE DAY (2017)**



Note: Away includes charging at work and at public charging stations

Source: American Public Power Association, A Public Power Guide to Understanding the U.S. Plug-in Electric Vehicle Market

The American Public Power Association in their 2017 study predicted that uncontrolled, aggregate EV charging could have a vehicle recharging profile as depicted in [Figure 20](#).<sup>64</sup> They suggest that to avoid rising EV charging rates, utilities may need to incentivize consumers to charge in non-peak periods.<sup>65</sup>

EV commercial fleet customers operate in a hub-and-spoke network and tend to exclusively recharge their vehicles at their base. Their charging schedule largely depends on their operation shifts. Vehicles operating day shift, such as transit buses, school buses, and delivery trucks, are typically plugged in at the end of the shift for overnight charging. However, opportunity charging has also been observed in certain applications such as yard facilities and transit bus routes, particularly where the vehicle operation tends to be very busy and the window for charging is narrow.<sup>66</sup>

64 American Public Power Association, *A Public Power Guide to Understanding the U.S. Plug-in Electric Vehicle Market*, 2017, available at [https://www.amea.com/wp-content/uploads/2018/08/understanding\\_the\\_us\\_plug-in\\_electric\\_vehicle\\_market\\_2017\\_digital\\_final.pdf](https://www.amea.com/wp-content/uploads/2018/08/understanding_the_us_plug-in_electric_vehicle_market_2017_digital_final.pdf).

65 American Public Power Association, *A Public Power Guide to Understanding the U.S. Plug-in Electric Vehicle Market*

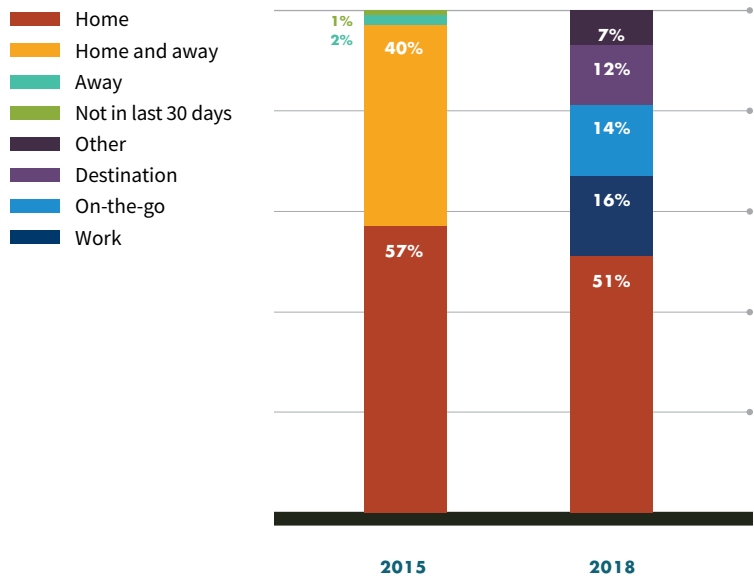
66 Ricardo research

### EV DRIVERS' PREFERRED RECHARGE LOCATION

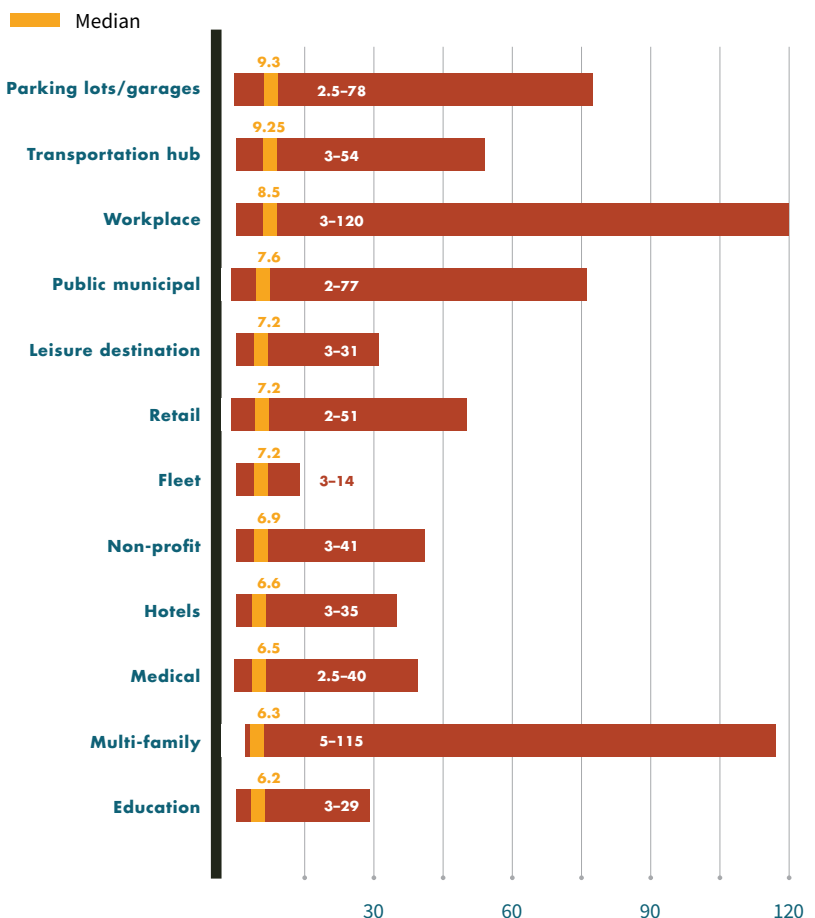
A few years ago, EV charging occurred 80% of the time at home, according to the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (Figure 21).<sup>67</sup> Among survey participants, 57% exclusively charged at home and 40% claimed to recharge at home and away in 2015.<sup>68</sup> In 2018, 67% of those surveyed charged either at home or at work and the remaining third of the participants charged elsewhere.<sup>69</sup>

The DOE, INL, and others conducted an EV Project study between 2011 and 2013 (Figure 22).<sup>70</sup> Charging events by site per week exhibit a large range; however, the median was around nine events per week. The most used parking lot charges were those located in downtown areas. Workplace charging and chargers located in multi-family complexes were also amongst the most used.

**FIGURE 21: AVERAGE PEV CHARGING FREQUENCY BY LOCATION**



**FIGURE 22: AVERAGE NUMBER OF CHARGING EVENTS PER SITE PER WEEK FOR LEVEL 2 EVSE (2012-2014)**



Source: John Smart, "EV Charging Infrastructure Usage in Large-scale Charging Infrastructure Demonstrations: Public Charging Station Case Studies for ARB"

67 "Charging at Home," Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, accessed on October 20, 2020, available at <https://www.energy.gov/eere/electricvehicles/charging-home>.

68 Electric Power Research Institute, Inc., *Plug-In Electric Vehicle Multi-State Market and Charging Survey*

69 Volvo Car USA, *The State of Electric Vehicles in America*

70 John Smart, "EV Charging Infrastructure Usage in Large-scale Charging Infrastructure Demonstrations: Public Charging Station Case Studies for ARB," (presentation, Plug-in Electric Vehicle Infrastructure Information Gathering Meeting, July 15, 2014), available at <https://avt.inl.gov/sites/default/files/pdf/EVProj/EVInfrastructureUsageARBJul2014.pdf>.

Although, the majority of recharging was done at home and/or at work, INL found that many DCFC that were open to the public experienced heavy usage by both inter-city and in-town traffic, and a relatively smaller number of Level 2 chargers saw constant high usage.<sup>71</sup> Public Level 2 chargers in locations where vehicles are parked for longer periods of time, such as shopping malls, airports, commuter lots, and downtown parking lots with easy access to a variety of venues, were amongst the ones that were most used during the period of study.<sup>72</sup> Since this study was conducted between 2011 and 2013, a similar study could be commissioned to understand current preferences.

EVs operated by commercial fleets are charged exclusively at their bases using private charging stations owned and operated by the fleets. However, availability of public charging stations in the future can help alleviate the financial burden and responsibilities of installing charging infrastructure to some extent; some fleets may rely completely on public charging stations while others may

consider those as an option for extending the range if the battery state-of-charge is low during regular operations. However, this is going to require the industry to use standard charging protocol and the network of public charging stations to be reliable and available. Private charging stations are still expected to be predominant charging locations amongst commercial fleets, particularly the early adopter large fleets. But adoption of EVs in mass market and smaller commercial fleets may spur the growth of public charging station networks.<sup>73</sup>

Amazon plans to have 10,000 electric delivery vehicles by 2022 and 100,000 by 2030 to help meet its goal of achieving carbon neutrality by 2045 as part of its Climate Pledge.<sup>74</sup> In order to meet this goal, Amazon would need to switch their middle-mile transport fleet to EVs as well. Amazon and their delivery partners currently install charging stations at home base for their last-mile delivery fleet, but to meet the extended range requirements for middle-mile delivery, they may need to use public infrastructure on highways.<sup>75</sup>

71 John Galloway Smart and Shawn Douglas Salisbury, *Plugged In: How Americans Charge Their Electric Vehicles* (Idaho Falls, ID: Idaho National Laboratory on behalf of the U.S. Department of Energy Office of Scientific and Technical Information, January 7, 2015), <https://doi.org/10.2172/1369632>.

72 John Galloway Smart and Shawn Douglas Salisbury, *Plugged In: How Americans Charge Their Electric Vehicles*

73 Ricardo research

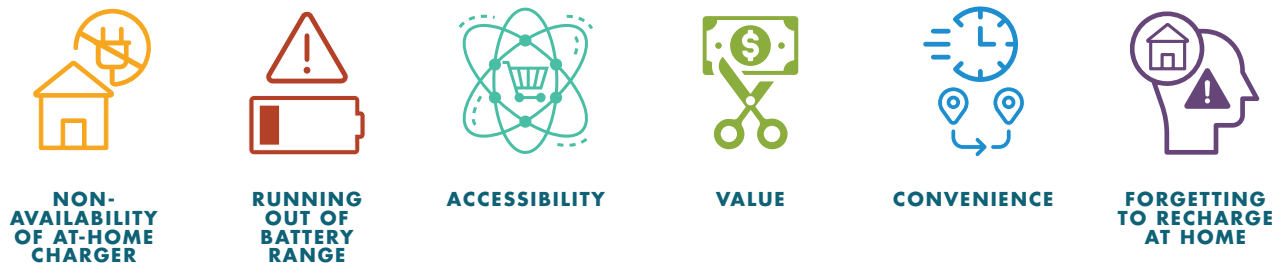
74 Mary Meisenzahl, "Amazon Just Revealed Its First Electric Delivery Van of a Planned 100,000-Strong EV Fleet — See How It Was Designed," *Business Insider*, February 3, 2021, <https://www.businessinsider.com/amazon-creating-fleet-of-electric-delivery-vehicles-rivian-2020-2>.

75 Ricardo research

**Many DCFC that were open to the public experienced heavy usage by both inter-city and in-town traffic, even though most recharging was done at home and/or at work. In comparison, a relatively smaller number of Level 2 chargers saw constant high usage.<sup>71</sup>**



**FIGURE 23: FACTORS INFLUENCING EV DRIVERS’ DECISION TO RECHARGE AT PUBLIC CHARGER VERSES HOME OR WORK**



EV drivers tend to mostly recharge at home and/or work. A few factors that prompt using public chargers include the following (Figure 23):

- 1) **Nonavailability:** Drivers who do not have access to a charger at home or at work must recharge at public charging stations.<sup>76</sup>
- 2) **Running out of range:** Drivers who exceed the range of the vehicle battery on any given day may need to visit a public fast charging station.<sup>77</sup>
- 3) **Accessibility:** Charging stations’ availability at places where drivers would park anyway, such as shopping malls, restaurants, grocery stores, etc., where it takes only a few seconds to plug in, encourages drivers to use a public charger.<sup>78</sup>
- 4) **Value:** A driver may choose the value of using a public charger that is free of cost.<sup>79</sup>
- 5) **Convenience:** EV chargers are usually nearer to the entrance of public amenities, thus drivers receive preferential treatment.<sup>80</sup>
- 6) **Forgetting to charge at home:** Drivers who forget to charge their car at home might have to rely on a public charging station to maintain daily travel plans.<sup>81</sup>

### FACTORS THAT INFLUENCE A RECHARGE OCCASION

Charging occurs predominantly either at home or at work and typically overnight, similar to when users recharge their cellphones when there is a guaranteed downtime. Some drivers plug in at workplaces when chargers are available and free of cost. Drivers may plug in to public chargers when the charger is available for free to get more value by virtue of free electricity, to access priority parking in an otherwise crowded parking lot, and when the charger is available at locations where they would have parked anyway. Since most BEV drivers drive well within the battery range for most of their travel requirements, a public charger is only unavoidable while making trips longer than the battery range would permit.

Conventional vehicle drivers, on the other hand tend to base their refueling preference on time, necessity, and cost, amongst other factors. According to the National Motorist Association, citing an Esurance survey, 32% of drivers wait until their gas light turns on to fill up their tank, although drivers over age 55 tend to fill up while their tank is still half full. Participants claim to put off getting gas because they

76 Hauke Engel, Russell Hensley, Stefan Knupfer, and Shivika Sahdev, “Charging Ahead: Electric-Vehicle Infrastructure Demand,” McKinsey and Company, August 8, 2018, <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand>.

77 Engel et al., “Charging Ahead: Electric-Vehicle Infrastructure Demand”

78 Mal Skowron, “Smart EV Charging Habits,” *The Energy Consumer Bulletin*, Green Energy Consumers Alliance, May 8, 2020, <https://blog.greenenergyconsumers.org/blog/smart-ev-charging-habits>.

79 Electric Power Research Institute, Inc., *Plug-In Electric Vehicle Multi-State Market and Charging Survey*

80 New York State Energy Research and Development Authority and Transportation and Climate Initiative, *Siting and Design Guidelines for Electric Vehicle Supply Equipment*, November 2012, [https://www.transportationandclimate.org/sites/default/files/EV\\_Siting\\_and\\_Design\\_Guidelines.pdf](https://www.transportationandclimate.org/sites/default/files/EV_Siting_and_Design_Guidelines.pdf).

81 Hauke Engel et al., “Charging Ahead: Electric-Vehicle Infrastructure Demand”

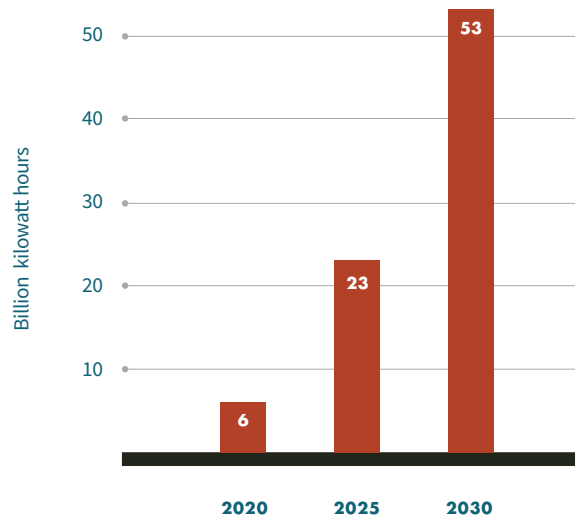
do not have enough funds for a full tank (30%) or they are too busy to fill up and perceive getting gas as inconvenient (26%).<sup>82</sup>

NACS: The Association for Convenience & Fuel Retailing found that nearly 40 million Americans fill up every day, and 59% of respondents said that price dominates where they purchase fuel, but quality of fuel, food, and employees aid their decision.<sup>83</sup> They also found that 33% of consumers prefer to purchase fuel during the evening rush as opposed to the morning rush, when 22% of the respondents fueled up. Many drivers age 65 or more tend to fill up midday while most drivers who purchase gas in the morning are between the ages of 35 and 49.

**CHARGING INFRASTRUCTURE REQUIREMENT**

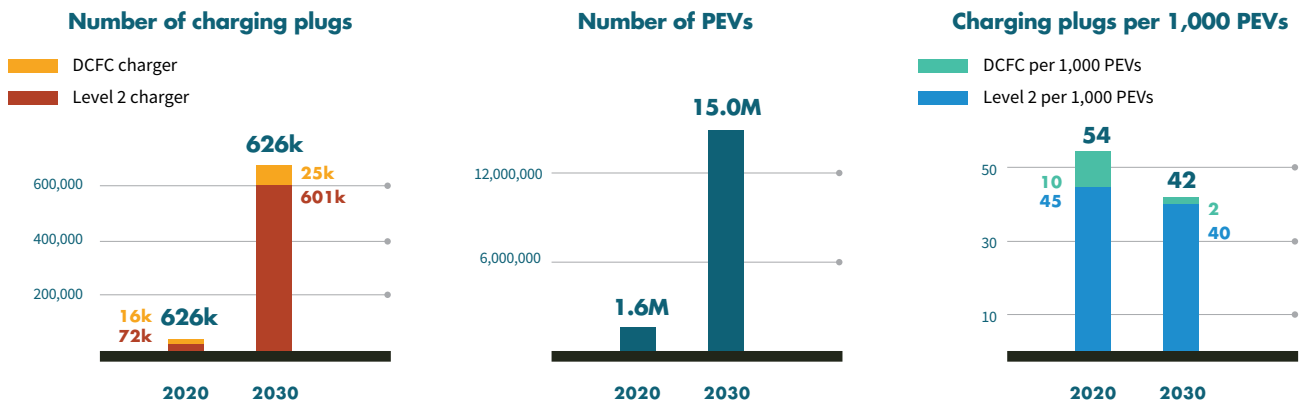
McKinsey predicts that the PEV-related energy demand would go up almost tenfold by 2030 (Figure 24).<sup>84</sup> This falls in line with the prediction that there could be between 12 and 15 million PEVs by 2030 — up by nearly 10 times of today’s 1.6 million PEVs (Figure 25).<sup>85</sup>

**FIGURE 24: CHARGING ENERGY DEMAND PREDICTION FOR PERSONAL EVS IN BILLION KILOWATT-HOURS**



Note: Annual mileage is estimated at 18,095 km and battery efficiency estimated at approximately 20 kWh per 100 km.

**FIGURE 25: CURRENT INFRASTRUCTURE AVAILABILITY AND 2030 FORECAST OF PUBLIC CHARGERS**



Note: 2020 PEV numbers are estimated based on the assumption that all PEVs sold since 2010 are still in operation; 2020 data is accurate as of August 2020 and does not estimate PEV sales through the end of the year nor infrastructure developed through the end of the year.

82 Karlie Kramer, “When Do You Fill Up Your Gas Tank?,” National Motorists Association, October 22, 2019, <https://www.motorists.org/blog/when-do-you-fill-up-your-gas-tank/>.

83 NACS, *Consumer Behavior at the Pump*, Consumer Insights series, March 2019, <https://www.convenience.org/Topics/Fuels/Documents/How-Consumers-React-to-Gas-Prices.pdf>.

84 Engel et al., “Charging Ahead: Electric-Vehicle Infrastructure Demand”

85 Eric Wood, Clément Rames, Matteo Muratori, Sessa Raghavan, and Marc Melaina, *National Plug-In Electric Vehicle Infrastructure Analysis* (U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, September 2017) <https://www.nrel.gov/docs/fy17osti/69031.pdf>; “FOTW #1153, September 28, 2020: Cumulative Plug-In Vehicle Sales in the United States Reach 1.6 Million Units,” U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, September 28, 2020, <https://www.energy.gov/eere/vehicles/articles/fotw-1153-september-28-2020-cumulative-plug-vehicle-sales-united-states-reach>; Thibaut Abergel, Till Bunsen, Marine Gorner, Pierre Leduc, Sarbojit Pal, Leonardo Paoli, Seshadri Raghavan, et al. *Global EV Outlook 2020: Entering the Decade of Electric Drive?* (International Energy Agency, June 2020) <https://webstore.iea.org/download/direct/3007>.



Although approximately 70%-80% of charging takes place at home or at work,<sup>86</sup> EVs are expected to be driven like present-day ICE vehicles.<sup>87</sup> A study by Navigant Research estimates that 95 DCFC stations along major highway corridors would enable travel across the U.S. and that 408 DCFC stations would suffice to meet long-distance travel needs of EVs in the 100 largest metropolitan areas of the U.S.<sup>88</sup> Analysis by the National Renewable Energy Laboratory (NREL) in 2017 found that DCFC stations would be required to be spaced 70 miles apart on average to provide BEV drivers access across the U.S. interstate system. Their analysis further revealed that to dispel range anxiety concerns, BEV drivers in cities and towns must never be more than three miles from a DCFC, requiring 8,200 charging stations (25,000 plugs) across the U.S. for a 15 million PEV projection.<sup>89</sup>

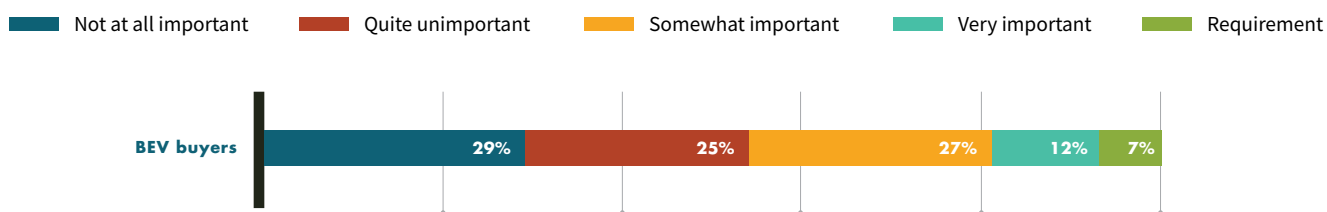
This number appears to be the bare minimum since automotive OEMs are already partnering with charging providers to install DCFC stations. As an example, General Motors alone in partnership with EVgo will add 2,700 DCFC stations by 2025.<sup>90</sup>

### WHY DOES THE CUSTOMER CHOOSE A PARTICULAR PUBLIC RECHARGING FACILITY?

#### LEVEL 2 CHARGING AVAILABILITY'S INFLUENCE ON CONSUMER PERCEPTION OF AVAILABILITY, CAPACITY, AND CONVENIENCE COMPARED TO DCFC EQUIPMENT

In CleanTechnica's survey of current and potential EV drivers, 46% of respondents feel that DCFC is not "very important" and 54% felt it was "very important" or a "requirement" (Figure 26).<sup>91</sup> In a different study, CleanTechnica found that approximately 70% of BEV drivers used DCFC only a few times a year (Figure 27).<sup>92</sup> In the same study, approximately 42% of non-Tesla BEV drivers think the current EV charging network is "very adequate," and approximately 33% think it is "somewhat adequate."

**FIGURE 26: IMPORTANCE OF DCFC WHEN BUYING A BEV (2016)**



Note: Surveyed participants from the U.S. (approximately 75%), Canada (approximately 8%), and the U.K. and Australia (<10% combined)  
 Source: CleanTechnica, *Electric Car Drivers: Desires, Demands, and Who They Are*

86 "Charging at Home," Office of Energy Efficiency and Renewable Energy; Volvo Car USA, *The State of Electric Vehicles in America*

87 Eric Wood et al., *National Plug-In Electric Vehicle Infrastructure Analysis*

88 Navigant Research, "408 High-Power DC Charging Stations Would Meet Long-Distance Travel Needs for Battery Electric Vehicles in the Top 100 U.S. Metropolitan Areas," *Guidehouse Insights*, June 21, 2016, <https://guidehouseinsights.com/news-and-views/408-highpower-dc-charging-stations-would-meet-longdistance-travel-needs-for-battery-electric-vehicle>.

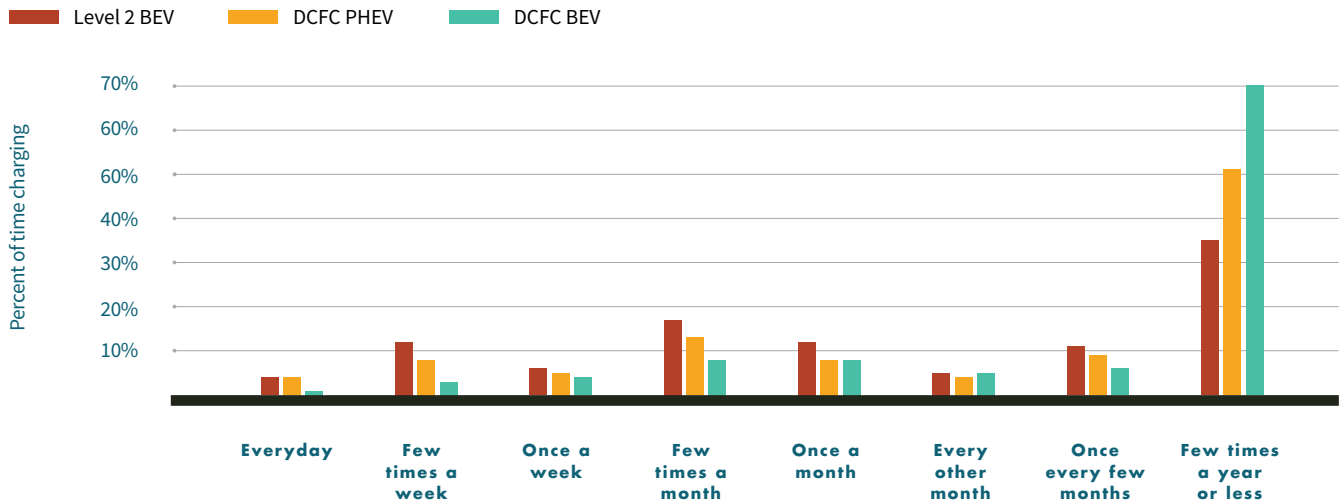
89 Eric Wood et al., *National Plug-In Electric Vehicle Infrastructure Analysis*

90 John Voelcker, "GM to Fund Expansion of EVgo Fast-Charging Network For Electric Cars," *Charged Electric Vehicles Magazine*, July 31, 2020, <https://chargedevs.com/news/gm-to-fund-expansion-of-evgo-fast-charging-network-for-electric-cars/>.

91 CleanTechnica, *Electric Cars: What Early Adopters and First Followers Want*, 2015, available at <https://future.cleantechnica.com/reports/electric-cars-what-early-adopters-and-first-followers-want>.

92 CleanTechnica, *Electric Car Drivers: Desires, Demands, and Who They Are*, 2016, available at <https://cleantechnica.com/files/2017/05/Electric-Car-Drivers-Report-Surveys-CleanTechnica-Free-Report.pdf>.

**FIGURE 27: FREQUENCY OF PUBLIC CHARGER USAGE BY PERCENTAGE (NORTH AMERICAN NON-TESLA DRIVERS) (2017)**



Source: CleanTechnica, Electric Car Drivers: Desires, Demands, and Who They Are

Tesla, as of August 2020, owned 8,509 Superchargers (equivalent to DCFCs) and 11,685 Destination Charging locations (equivalent to Level 2 chargers), which makes the Tesla network approximately 54% of all DCFCs in the U.S. and approximately 16% of all Level 2 chargers. Non-Tesla EV drivers currently have access to approximately 7,000 DCFCs and approximately 60,000 Level 2 chargers.<sup>93</sup>

These data points suggest that current EV owners are not deterred by today’s EV infrastructure; rather, they have found ways to use EVs around potential infrastructure limitations. For mass adoption, it is important to understand the views of buyers who do not consider EVs today. This can be pursued with a targeted survey toward those individuals.

93 “FOTW #1153, September 28, 2020: Cumulative Plug-In Vehicle Sales in the United States Reach 1.6 Million Units”

**Current EV owners are not deterred by today’s EV infrastructure; finding ways to use their EVs around potential infrastructure limitations.**



## INFLUENCE OF CHARGING EQUIPMENT BRAND<sup>94</sup>

EV drivers' selection of a particular brand of charger can be influenced by the following factors:

- 1) **Built-in equipment:** Vehicles like the Hyundai Ioniq and Chevrolet Bolt EV usually either have a ChargePoint or similar charge card in the glovebox of the vehicle when bought new.<sup>95</sup> Many drivers, since the charge card is already available, tend to use the corresponding brand of charging network. Tesla, with the charging application integrated into the infotainment system, allows for seamless operation within its network. Nissan Leafs ship with an EZ Card that allows the driver to use chargers operated by ChargePoint, Blink, Network from Car Charging Group, AeroVironment, and NRG EVgo.<sup>96</sup>
- 2) **Familiarity:** Charging network providers like ChargePoint and Blink also make home chargers.<sup>97</sup> When a consumer has one of them installed at home, familiarity with the home charger could bias their choice of a public charger used especially when they are new to owning EVs.
- 3) **Dependability:** Consumer Reports notes that some networks are more dependable than others and that chargers at newer stations can be out of service.<sup>98</sup>
- 4) **Availability:** ChargePoint has more than 35,000 Level 2 chargers in the U.S., which is just shy of the combined total of all other networks' Level 2 chargers combined.<sup>99</sup> However, networks are



not uniformly distributed throughout the country. Hence, a customer's choice could sometimes be based on availability, rather than by choice. For example, in Alaska, out of the 39 available Level 2 plugs, only eight are operated by ChargePoint and 24 are non-networked.<sup>100</sup> So, an EV owner in Alaska might prefer signing up with ChargePoint to have access to eight chargers, which is more convenient than signing up individually with various standalone providers that operate each of the other chargers.

- 5) **Charging host:** A customer may prefer to use a particular charger network based on their needs and habits. For example, a customer who shops at a particular grocery store, where a charger of a certain network is installed, might choose to use that particular network for their charging needs because they go there anyway and plugging in would be an added convenience.

<sup>94</sup> The topic discussed in this section of the report has limited public domain data, so inference is based on relevant knowledge and experience.

<sup>95</sup> Jeannie Lam, "Everything You Need to Know About the Hyundai Ioniq Electric," ChargePoint, February 20, 2017, <https://www.chargepoint.com/blog/everything-you-need-know-about-hyundai-ioniq-electric/>.

<sup>96</sup> Nissan North America, "Nissan Launches Programs to Make Leaf Charging Free and "EZ," news release, ChargePoint, April 2014, <https://www.chargepoint.com/about/news/nissan-launches-programs-make-leaf-charging-free-and-ez/>.

<sup>97</sup> Gabe Shenhar and Jeff S. Bartlett, "How to Choose the Best Home Wall Charger for Your Electric Vehicle," *Consumer Reports*, September 30, 2020, <https://www.consumerreports.org/hybrids-evs/how-to-choose-the-best-home-wall-charger-for-your-electric-vehicle/>.

<sup>98</sup> Jeff Plungis, "How the Electric Car Charging Network Is Expanding," *Consumer Reports*, November 12, 2019, <https://www.consumerreports.org/hybrids-evs/electric-car-charging-network-is-expanding/>.

<sup>99</sup> "Alternative Fueling Station Locator," Alternate Fuels Data Center, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, accessed October 29, 2020, <https://afdc.energy.gov/stations/#/analyze>.

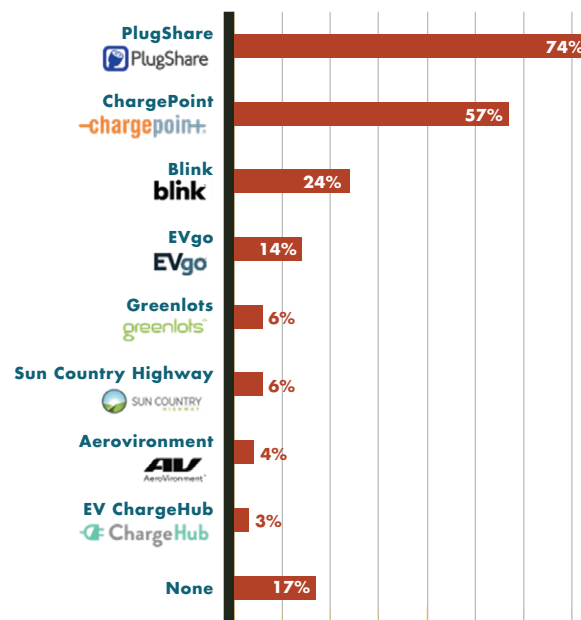
<sup>100</sup> "Alternative Fueling Station Locator," Alternate Fuels Data Center

CleanTechnica found that PlugShare was the most popular app — it had been used by 74% of the participants (Figure 28).<sup>101</sup>

Various sources point to the fact that on average PEV drivers rely on public charging stations for only 20%-33% of their charging needs, and the remaining 67%-80% of charging happens at home or at work.<sup>102</sup> More than 80% of drivers use only three public locations or fewer for their charging needs away from home and work. Cumulatively, approximately 38% of all PEVs sold were Tesla vehicles before 2019,<sup>103</sup> and in 2019, 58% of all PEVs sold were Tesla vehicles. Tesla has their Superchargers network integrated onto the infotainment system, negating the need for an app. Based on this, it would be safe to assume that fewer than 5% of EV drivers use apps on a daily or frequent basis to locate charging stations. It is likely that EV owners download at least one of these apps, and app usage is likely to be more frequent when in a new location (Figure 29).<sup>104</sup>

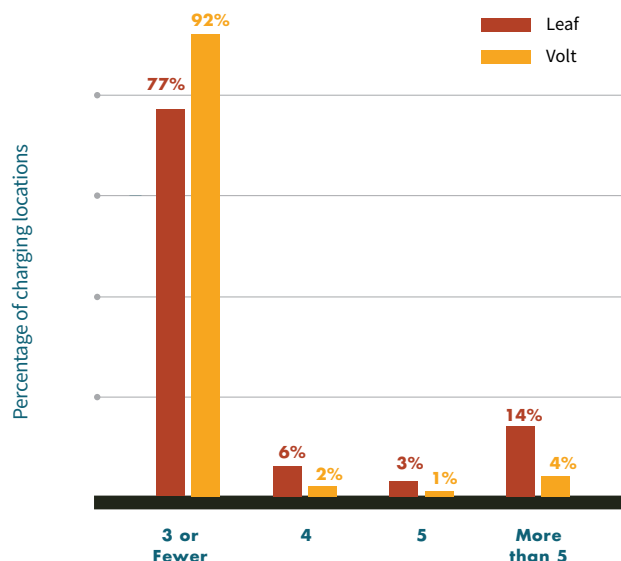
Going forward, OEMs are likely to provide similar attributes to Tesla’s in-vehicle point-to-point trip-planning feature. As more owners use their EVs for long-distance travel, the need for trip planning and finding public charging will increase. However, use of such in-vehicle features as opposed to smartphone apps would depend on which method provides seamless ease of use. OEMs could also plan to integrate smart routing into their interface; with availability of data such as power output and vehicle state-of-charge, the in-car navigation system could optimize the route by planning a stop at a faster charging station to reduce overall trip time.

**FIGURE 28: WEBSITES/APPS FOR NORTH AMERICAN EV OWNERS TO LOCATE EV CHARGING STATIONS (2017)**



Source: CleanTechnica, *Electric Cars: What Early Adopters and First Followers Want*

**FIGURE 29: NUMBER OF AWAY-FROM-HOME LOCATIONS WHERE DRIVERS DO MOST CHARGING (2011-2014)**



Note: Data collected between 2011 and 2014

Source: John Galloway Smart and Shawn Douglas Salisbury, *Plugged In: How Americans Charge Their Electric Vehicles*

101 CleanTechnica, *Electric Cars: What Early Adopters and First Followers Want*

102 Volvo Car USA, *The State of Electric Vehicles in America*; “Charging at Home,” Office of Energy Efficiency and Renewable Energy

103 “U.S. Plug-in Electric Vehicle Sales by Model” (chart), “Maps and Data — U.S. Plug-in Electric Vehicle Sales by Model” (webpage), Alternate Fuels Data Center, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, accessed October 10, 2020, <https://afdc.energy.gov/data/10567>.

104 John Galloway Smart and Shawn Douglas Salisbury, *Plugged In: How Americans Charge Their Electric Vehicles*



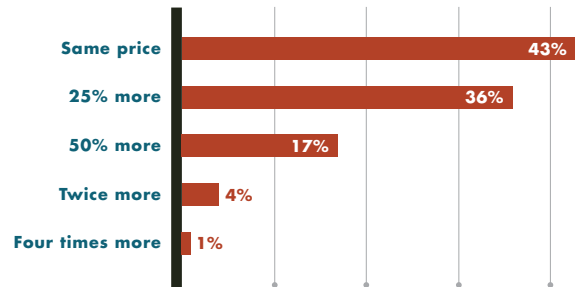
## HOW DO CUSTOMERS INTERACT WITH CHARGING EQUIPMENT?

### EV CONSUMERS' WILLINGNESS TO PAY FOR CHARGING SERVICES AND THE INFLUENCE OF PRICE IN THIS PERCEPTION

ESource, in their survey of current and potential PEV owners, found that 57% of respondents are willing to pay a premium to use a DCFC, and 22% of respondents are willing to pay a premium of 50% or more for access to a DCFC (Figure 30).<sup>105</sup> When asked to compare EV charging to paying for gas, 70% of respondents perceived that they pay the same or less to charge an EV as compared to buying gas (Figure 31).<sup>106</sup>

In this same study, ESource further found that 44% of PEV owners are willing to pay between \$1-\$2 per hour to use a public charger with an assumption that at-home charging is valued at \$0.75 per hour (Figure 32).<sup>107</sup> The willingness is observed to steadily decline at rates greater than \$2 per hour. Potential PEV owners, on the other hand, appear to be more price sensitive — their willingness to pay for public charging peaks at \$1 per hour and declines at higher prices, and 12% of respondents claim that they would not use a public Level 2 charger.<sup>108</sup>

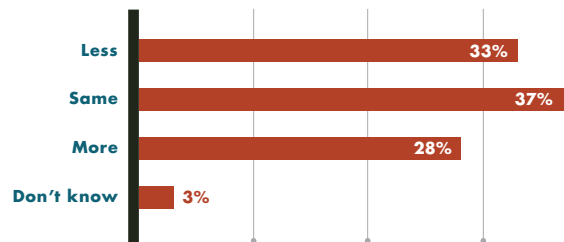
**FIGURE 30: AMOUNT RESPONDENTS WOULD PAY FOR A DCFC COMPARED TO A LEVEL 2 CHARGER (2020)**



Note: Data includes U.S. and Canada respondents who own or are considering owning a PEV

Source: Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”

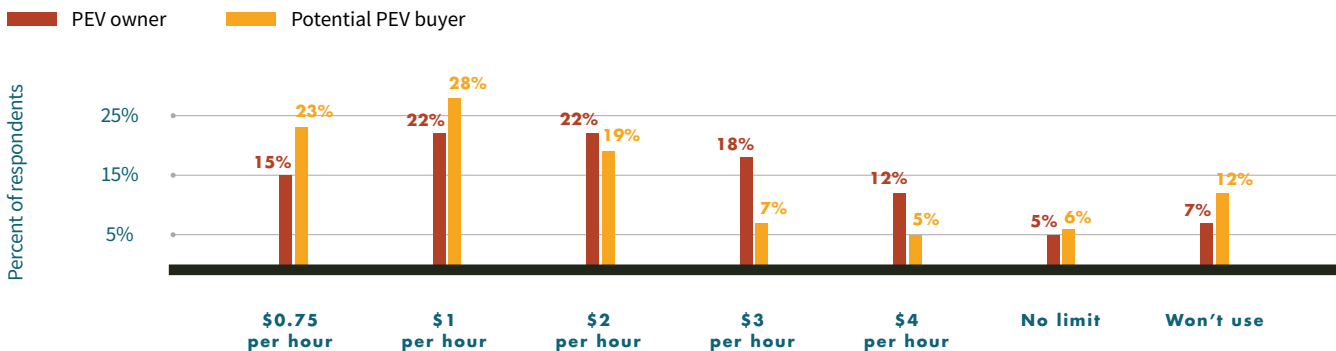
**FIGURE 31: AMOUNT RESPONDENTS PERCEIVE THEY PAY TO CHARGE A PEV COMPARED TO BUYING GAS (2020)**



Note: Data includes U.S. and Canada respondents who own a PEV

Source: Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”

**FIGURE 32: AMOUNT RESPONDENTS ARE WILLING TO PAY FOR PUBLIC LEVEL 2 CHARGING ASSUMING COST TO CHARGE AT HOME IS \$0.75 PER HOUR (2020)**



Note: Data includes U.S. and Canada respondents

Source: Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”

<sup>105</sup> Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?” ESource, September 1, 2020, <https://www.esource.com/429201ebtf/ev-charging-and-pricing-what-are-consumers-willing-pay>.

<sup>106</sup> Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”

<sup>107</sup> Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”

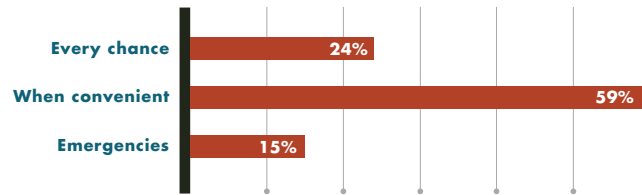
<sup>108</sup> Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”



**Fifty-seven percent of respondents are willing to pay a premium to use a DCFC.**

**Potential PEV owners, on the other hand, appear to be more price sensitive — their willingness to pay for public charging peaks at \$1 per hour.**

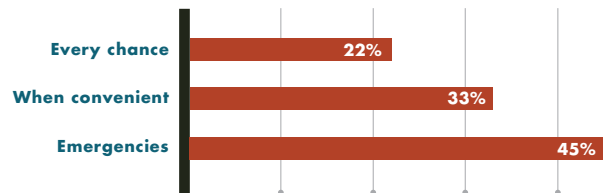
**FIGURE 33: FREQUENCY OF USAGE WHEN RESPONDENTS ARE TOLD DCFC IS AVAILABLE AT A PREMIUM (2020)**



*Note: Data includes U.S. and Canada respondents who own or are considering owning a PEV.*

*Source: Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”*

**FIGURE 34: FREQUENCY OF USAGE WHEN RESPONDENTS ARE TOLD DCFC IS AVAILABLE AT A PREMIUM AND ABOUT THE POSSIBILITY OF BATTERY DEGRADATION (2020)**



*Note: Data includes U.S. and Canada respondents who own or are considering owning a PEV.*

*Source: Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”*

When participants were asked how frequently they would use a DCFC if they had to pay a premium, 59% responded they would use it when convenient and 24% said they would plug in at every chance (Figure 33).<sup>109</sup> This response changed drastically when informed about the possibility of battery degradation with DCFC.<sup>110</sup> In that case, 45% said they would only use a DCFC in an emergency (up from 15%), and 33% said they would plug in when convenient (down from 59%) (Figure 34).<sup>111</sup>

<sup>109</sup> Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”

<sup>110</sup> Idaho National Laboratory, *DC Fast Charge Effects on Battery Life and Performance Study – 50,000 Mile Update*, April 15, 2014, [https://www.energy.gov/sites/prod/files/2015/01/f19/dcfc\\_study\\_fs\\_50k.pdf](https://www.energy.gov/sites/prod/files/2015/01/f19/dcfc_study_fs_50k.pdf).

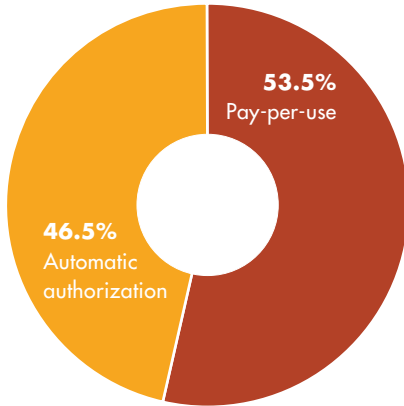
<sup>111</sup> Bill LeBlanc, “EV Charging and Pricing: What Are Consumers Willing To Pay?”



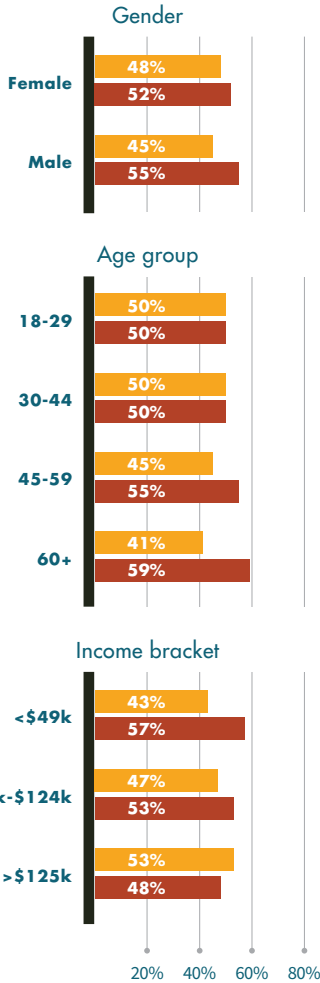
**FIGURE 36:**  
PAYMENT AUTHORIZATION TYPE PREFERENCE WHEN CHARGING IN PUBLIC (2016)

- Pay-per-use
- Automatic authorization

Payment Authorization Type



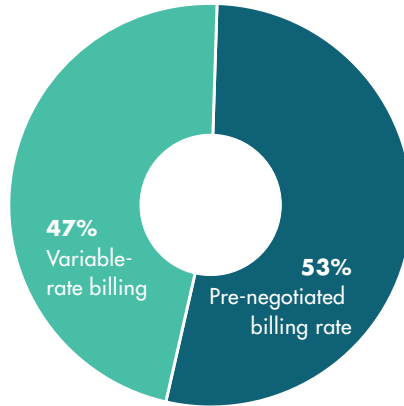
Split by demographic



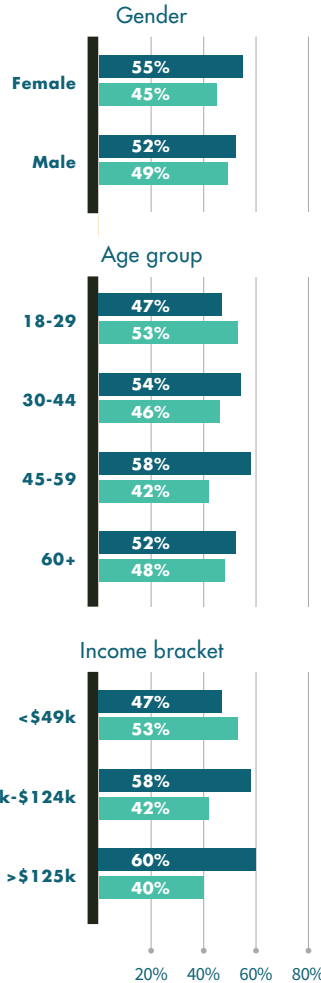
**FIGURE 37:**  
PRICING TYPE PREFERENCE WHEN CHARGING IN PUBLIC (2016)

- Pre-negotiated billing rate
- Variable-rate billing

Pricing Type



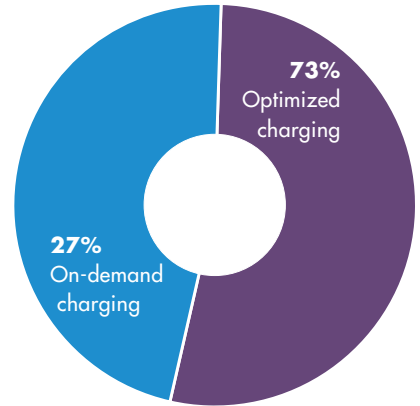
Split by demographic



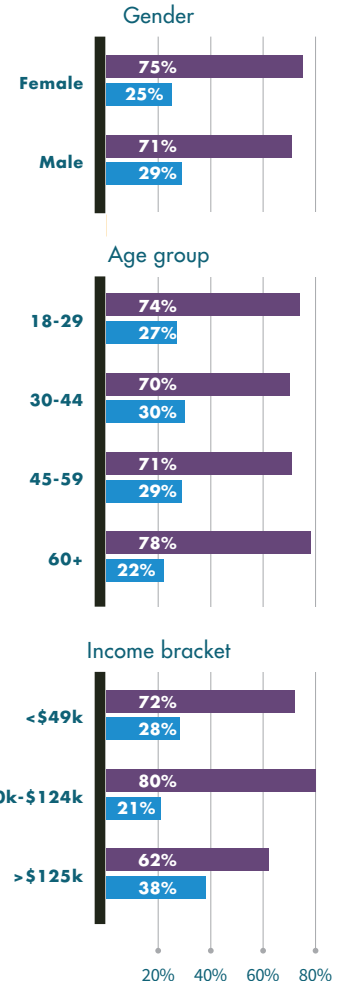
**FIGURE 38:**  
COST AND ENERGY DEMAND PREFERENCE WHEN CHARGING IN PUBLIC (2016)

- Optimized charging
- On-demand charging

Cost And Energy Demand



Split by demographic

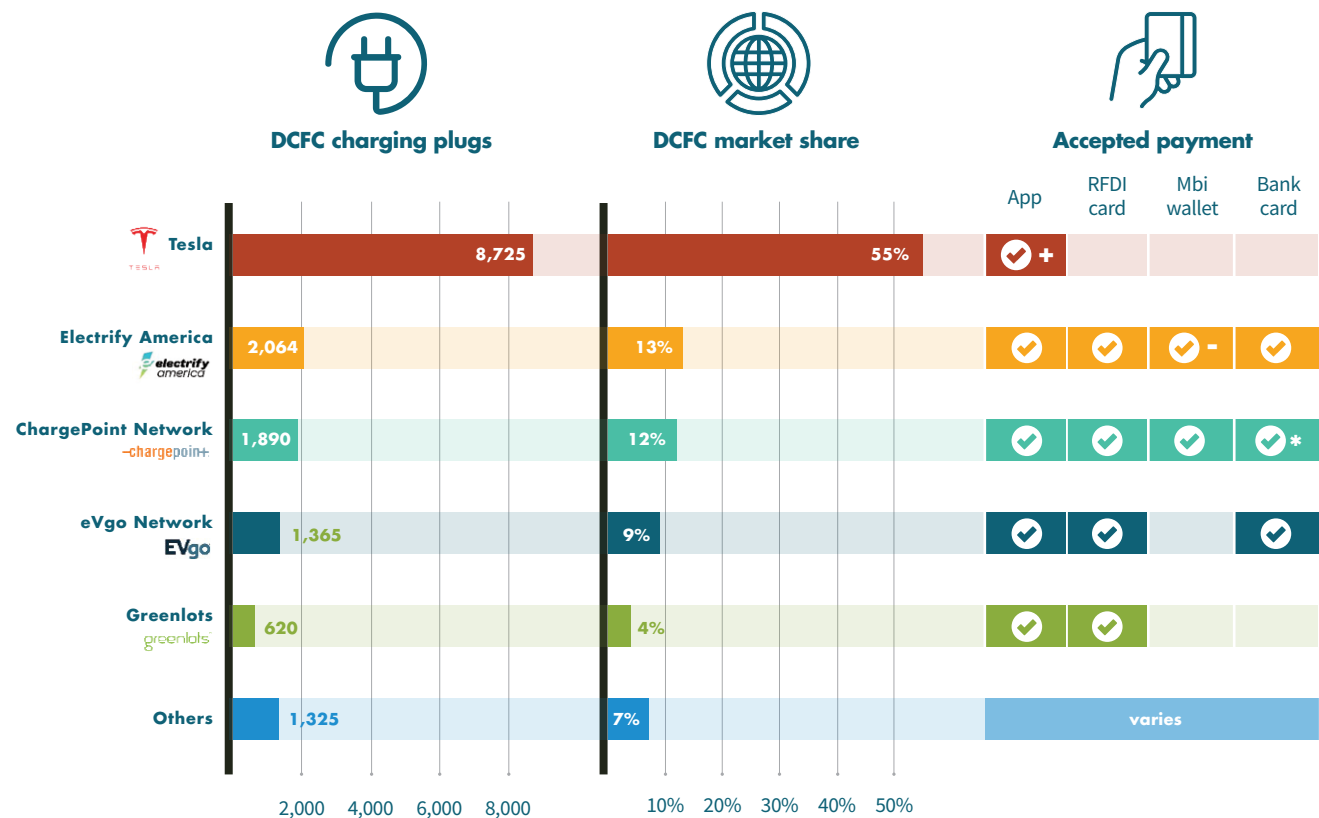


Source (Figures 36-38): Brandon Schoettle and Michael Sivak, Consumer Preferences for the Charging of Plug-in Electric Vehicles

## EV CONSUMERS' COMFORT WITH THE VARIOUS PAYMENT OPTIONS

The top five networks make up approximately 93% of all DCFC chargers in the U.S. The payment methods offered by these networks, when analyzed, appear to all support in-app payments, excluding Tesla's Supercharger network (Figure 39).<sup>118</sup> Tesla Superchargers identify the vehicle and charge the account on file when a charging occasion is initiated. Tesla's Supercharger network forms 55% of the DCFC network in the U.S. but is not accessible to drivers of other vehicles.<sup>119</sup> Excluding the Tesla network, the other major providers also accept RFID authentication via their membership card according to their respective websites. Electrify America, ChargePoint, and EVgo also accept payments directly from a credit card at the charger, and the former two also support mobile payment like Apple Pay and Samsung Pay.<sup>120</sup>

**FIGURE 39: INFOGRAPHIC OF TOP DCFC NETWORKS, NUMBER OF PLUGS, U.S. DCFC MARKET SHARE, AND ACCEPTED PAYMENT TYPES (2020)**



- + Integrated into the interface, and funds are withdrawn automatically from linked source
- Since tap credit cards are accepted, mobile wallets like Apple Pay and Google Pay would work as well
- \* Only RFID tap-enabled credit cards are accepted at the station

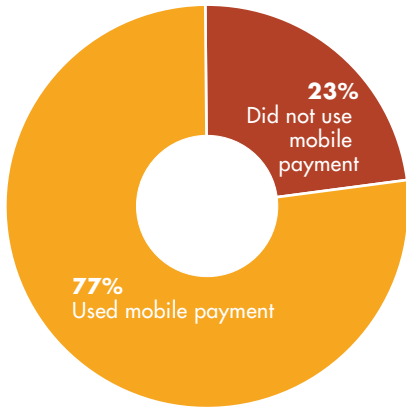
Source: "Alternative Fueling Station Locator," Alternate Fuels Data Center

118 "Alternative Fueling Station Locator," Alternate Fuels Data Center; "Supercharging," Support, Tesla, accessed October 18, 2020, <https://www.tesla.com/support/supercharging>; "Pricing and Plans for EV Charging," Electrify America, accessed October 18, 2020, <https://www.electrifyamerica.com/pricing/>; "EV Driver Support," ChargePoint, accessed October 18, 2020, <https://www.chargepoint.com/en-ca/support/driver-faq/>; "EVgo Charging 101," EVgo, accessed October 18, 2020, <https://www.evgo.com/pricing/>; "What You Can Do With Our Mobile App," EV Drivers, Greenlots, accessed October 18, 2020, <https://greenlots.com/ev-drivers/>.

119 "Alternative Fueling Station Locator," Alternate Fuels Data Center

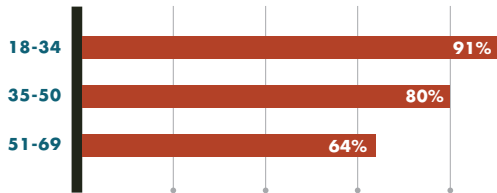
120 "Pricing and Plans for EV Charging," Electrify America; "EV Driver Support," ChargePoint; "EVgo Charging 101," EVgo

**FIGURE 40: PERCENTAGE OF RESPONDENTS WHO HAVE USED MOBILE PAYMENT (AUGUST 2018 TO AUGUST 2019)**



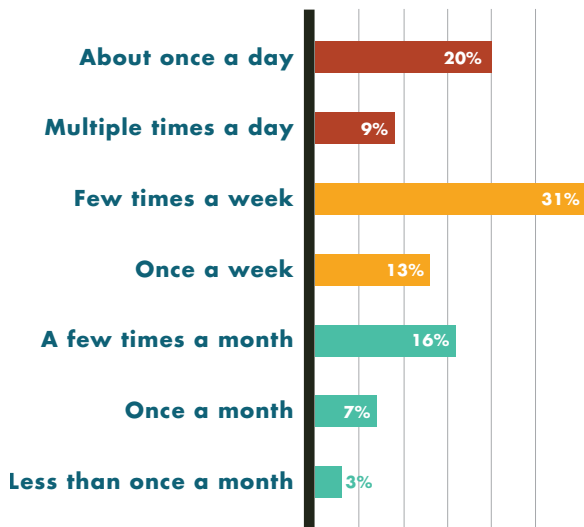
Source: Lindsay Anan et al., Are Convenience and Rewards Leading to a Digital Flashpoint?

**FIGURE 41: PERCENTAGE BY AGE GROUP OF RESPONDENTS WHO HAVE USED MOBILE PAYMENT (AUGUST 2018 TO AUGUST 2019)**



Source: Lindsay Anan et al., Are Convenience and Rewards Leading to a Digital Flashpoint?

**FIGURE 42: PERCENTAGE OF U.S. CUSTOMERS WHO MAKE MOBILE PAYMENTS (2019)**



Source: Jamie Gonzalez-Garcia and Kelly Dilworth, "Online and Mobile Payment Statistics"



In a survey conducted by McKinsey in the U.S. between August 2018 and August 2019, 77% of all respondents used mobile payment (Figure 40)<sup>121</sup> with 80% mobile payment users within the ages of 35 and 50 (Figure 41).<sup>122</sup> The top EV demographic of between the ages of 40 and 55 overlaps with this user base. A separate 2019 survey by Pymnts found that 73% of respondents made mobile payments at least once a week (Figure 42).<sup>123</sup> It may be safe to assume that EV users are currently comfortable with the available payment method choices.<sup>124</sup>

121 Lindsay Anan, Deepa Mahajan, and Marie-Claude Nadeau, *Are Convenience and Rewards Leading to a Digital Flashpoint? Insights from McKinsey's 2019 Digital Payments Survey* (San Francisco, CA: McKinsey and Company, October 2019), <https://www.mckinsey.com/~media/mckinsey/industries/financial%20services/banking%20blog/are%20convenience%20and%20rewards%20leading%20to%20a%20digital%20flashpoint/mckinsey-2019-digital-payments-survey.ashx>.

122 Lindsay Anan et al., *Are Convenience and Rewards Leading to a Digital Flashpoint?*

123 Jamie Gonzalez-Garcia and Kelly Dilworth, "Online and Mobile Payment Statistics," CreditCards.com, April 20, 2020, <https://www.creditcards.com/credit-card-news/online-payment-statistics-1276/>.

124 Jamie Gonzalez-Garcia and Kelly Dilworth, "Online and Mobile Payment Statistics"



## WHAT DO CUSTOMERS DO AT FACILITIES WHILE CHARGING?

### DWELL TIME AT PUBLIC CHARGERS AND THE FEATURES THAT COULD INFLUENCE THAT DWELL TIME

Potential EV consumers expect to spend between 30 minutes and 1 hour at a charging station.<sup>125</sup> The average fleet customer wants to spend 36 minutes on average.<sup>126</sup> This is on par with the global average of 31 and 36 minutes respectively (Figure 43).<sup>127</sup>

A few trends emerge when analyzing the prevalent factors that influence the dwell time at a public charger:

- 1) **EV drivers dwell 20 minutes longer than non-EV drivers:** Kohls found that EV drivers, when provided on-premise car charging facility, spend 20 minutes more in the store than non-EV drivers; Target found EV drivers spend more than three times longer in the store.<sup>128</sup>
- 2) **Highway rest stops may have less incentive to purchase EV fast chargers if not charging a fee:** Business owners pay demand-based electricity rates. Having a free on-premise DC charger and the corresponding quick charge time translated to lesser dwell time and thus lesser revenue but a high electricity bill for the business (see following discussion on cost of installation for the business).<sup>129</sup>
- 3) **Shoppers are eager to leave when businesses charge drivers:** When charging is outsourced to third-party operators, charging becomes five times the cost and thus shoppers become clock watchers and are eager to leave as soon as they have enough power to do so.<sup>130</sup>
- 4) **When drivers are charged a session fee, the dwell time increases by 20% on average:** For Blink chargers, prior to the onset of charges, an average session lasted 19.5 minutes. When a session fee was levied, users tended to stay 20% longer, presumably to get more value.<sup>131</sup> This billing structure is outdated, and customers are now billed by the energy used.

**FIGURE 43: FACTORS AND FEATURES THAT INFLUENCE OVERALL EXPECTED DWELL TIME AT PUBLIC CHARGERS**



**EV drivers spend 20 minutes more than non-EV drivers in department stores while charging**



**Highway rest stops may have less incentive to purchase EV fast chargers if not charging a fee**



**Shoppers are eager to leave when businesses charge drivers**



**When drivers are charged a session fee, dwell time increases by 20% on average**

Source: Jim Burness, "Don't Let Someone Else's Profit Center Ruin Your Amenity"

125 Deloitte, 2020 Global Automotive Consumer Study: Tracking Key Changes in the Automotive Industry, 2019, available at <https://www2.deloitte.com/us/en/pages/manufacturing/articles/automotive-trends-millennials-consumer-study.html>; Castrol, Accelerating the EVolution

126 Castrol, Accelerating the EVolution

127 Jim Burness, "Don't Let Someone Else's Profit Center Ruin Your Amenity," National Car Charging, July 12, 2015, <https://www.nationalcarcharging.com/blogs/news/48795587-dont-let-someone-elses-profit-center-ruin-your-amenity>; David Thill, "The Need For Charging Stations Is Clear, But Who Should Own Them Is Not," Energy News Network, February 15, 2019, <https://energynews.us/2019/02/15/midwest/the-need-for-charging-stations-is-clear-but-who-should-own-them-is-not/>; John Galloway Smart and Shawn Douglas Salisbury, Plugged In: How Americans Charge Their Electric Vehicles

128 Jim Burness, "Don't Let Someone Else's Profit Center Ruin Your Amenity"; ChargePoint, "Leading Retailer Partners with ChargePoint to Attract and Retain Loyal Customers," news release, 2015, <https://www.chargepoint.com/files/casestudies/cs-retail.pdf>.

129 David Thill, "The Need for Charging Stations Is Clear, But Who Should Own Them Is Not"

130 Jim Burness, "Don't Let Someone Else's Profit Center Ruin Your Amenity"

131 John Galloway Smart and Shawn Douglas Salisbury, Plugged In: How Americans Charge Their Electric Vehicles



**This data could help support the conclusion that EV drivers tend to spend more time at facilities and in turn spend more money at the host.**

Target, in its pilot program in collaboration with ChargePoint, noted that with the introduction of EV charging stations on-site, the average dwell time was 72 minutes per session, which was 50 minutes greater than the average dwell time of 22 minutes without EV charging stations. Drivers also spent approximately \$1 per minute more on average at the store, and the gross additional revenue was estimated to be around \$56,000 while the cost of electricity for the charger was estimated to be \$430 during the test period.<sup>132</sup>

According to the Bureau of Labor Statistics, on average, the time spent by customers making consumer goods purchases was approximately 52 minutes (including transit time),<sup>133</sup> and Atlas Public Policy’s study for the New York State Energy Research and Development Authority found that the average charging duration per session, at retail

locations in New York City, recorded an average of 2 hours and 36 minutes of dwell time despite an average charging duration lasting only two hours during the session.<sup>134</sup> Similarly, Origins, a cosmetics retailer, while using a new business model that included methods to increase customer dwell time, found a 20%-40% boost in their revenue from increased customer dwell time.<sup>135</sup> This data could help support the conclusion that EV drivers tend to spend more time at facilities and in turn spend more money at the host.

In National Car Charging’s 2019 survey of PEV drivers, 81% of respondents said that availability of a charging station at businesses makes them more loyal to the business.<sup>136</sup> EV charging stations can boost business by building the retailer’s “green” image and in turn attracting new customers while building customer loyalty.<sup>137</sup>

<sup>132</sup> ChargePoint, “Leading Retailer Partners with ChargePoint to Attract and Retain Loyal Customers”

<sup>133</sup> Bureau of Labor and Statistics, U.S. Department of Labor, “American Time Use Survey — 2019 Results,” news release, June 25, 2020, <https://www.bls.gov/news.release/pdf/atus.pdf>.

<sup>134</sup> New York State Energy Research and Development Authority, *Assessing the Business Case for Hosting Electric Vehicle Charging Stations in New York State*, June 2019, <https://atlaspolicy.com/wp-content/uploads/2019/09/19-31-Business-Case-for-Hosting-Charging-Stations.pdf>.

<sup>135</sup> Melissa Fulenwider, “The Rising Influence of the ‘Slow Shopping Theory,’” *Business Today Online Journal*, February 14, 2016, <https://journal.businesstoday.org/online/2017/the-rising-influence-of-the-slow-shopping-theory>.

<sup>136</sup> Margaret-Ann Leavitt, “Do EV Charging Stations Make for More Loyal Customers? Survey Says: They Certainly Do.,” National Car Charging (article published on LinkedIn), June 17, 2019, <https://www.linkedin.com/pulse/do-ev-charging-stations-make-more-loyal-customers-survey-leavitt/>.

<sup>137</sup> Brian W. Blaesser and Sorrell E. Negro, “Electric Vehicle Charging Stations — Retail Primer Update,” International Council of Shopping Centers, accessed October 23, 2020, available at <https://www.icsc.com/newsletters/article/electric-vehicle-charging-stationsretail-primer-update>.

**TABLE 1: COST OF OPERATION PER HOUR AT VARIOUS CHARGING LEVELS (DIRECTIONAL ESTIMATES)**

CHARGER TYPE AND ENERGY	CAPITAL COST	CAPITAL COST				
		Electricity cost [A]	Amortization of capital [B]	Depreciation [C]	COST INCURRED BY HOST	
					First 5 years [A]+[B]+[C]	Next 5 years [A]+[C]
Level 2 (7.7 kW)	\$2,500	\$0.82	\$0.17	\$0.07	\$1.06	\$0.89
Level 2 (12.25 kW)	\$3,700	\$1.31	\$0.25	\$0.10	\$1.66	\$1.41
Level 2 (16.8 kW)	\$4,900	\$1.79	\$0.34	\$0.13	\$2.27	\$1.93
Level 3 (50 kW)	\$27,900	\$5.34	\$1.92	\$0.77	\$8.02	\$6.11
Level 3 (150 kW)	\$87,800	\$16.02	\$6.03	\$2.41	\$24.46	\$18.43
Level 3 (350 kW)	\$139,000	\$37.38	\$9.55	\$3.82	\$50.75	\$41.20

Note: Assumption of charging use for amortization and depreciation is eight hours per day every day through the year. Higher and lower costs are assigned to higher and lower powered chargers and the mid-value is the average of the two in terms of power and cost. Costs and prices are directional estimates. Cost of charger does not include “make-ready costs” (e.g., transformers) and service/maintenance costs. Costs assumed are average cost. Level 2 12.25 kWh charger cost is estimated as average cost of Level 2 charger based on upper and lower limits.

However, for the business, the cost of installing a public Level 2 charging station could be between \$2,500 and \$4,900, depending on the location of installation, and a DCFC can cost between \$20,000 and \$150,000 per station.<sup>138</sup> The average cost of commercial electricity in 2019 was 10.68¢ per kWh.<sup>139</sup> Power draw on a Level 2 charger can range from 7.7 to 16.8 kW,<sup>140</sup> and DCFC can range between 50 kW to 350 kW. Table 1 summarizes the expense per hour to host at various charging levels. Amortization and depreciation are calculated with an assumption of eight hours use every day of the year. Salvage value is calculated at 20% of overall cost.

Given the charge time to get an EV to 80% at a fast charger is around 20 to 30 minutes, the cost of operation of a 150-kWh charger is approximately \$7-\$12 (Table 1). Highway rest stop businesses are typically convenience stores. The average pre-tax profit margin of a convenience store is 3.2%,<sup>141</sup> which means that the driver should spend at least \$312 (assuming \$10 operation cost) for the convenience store to break even and far more for it make a profit. To put this in perspective, the average driver spends between \$8 and \$11 per visit.<sup>142</sup>

138 Chris Nelder and Emily Rogers, “Reducing EV Charging Infrastructure Costs,” Rocky Mountain Institute, 2019, <https://rmi.org/ev-charging-costs>.

139 “Average Retail Price of Electricity, United States, Annual,” Electricity Data Browser

140 “Guide on Charging Your Electric Vehicle at Home,” ChargeHub, accessed October 23, 2020, <https://chargehub.com/en/home-charging-guide-electric-vehicles.html>.

141 “Convenience Stores,” “Food and Beverage Stores,” “Benchmarks,” The Retail Owners Institute, accessed October 27, 2020, <https://retailowner.com/Benchmarks/Food-and-Beverage-Stores/Convenience-Stores>.

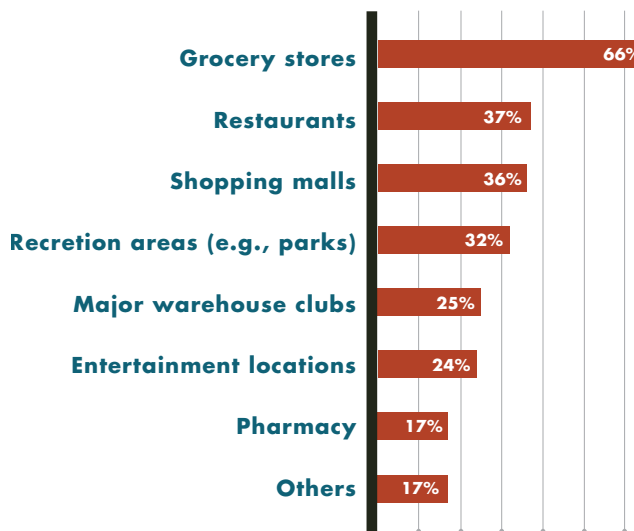
142 Brandon Logsdon, “A 2020 Outlook on Convenience Store Retail Trends,” *Convenience Store News*, January 29, 2020, <https://csnews.com/2020-outlook-convenience-store-retail-trends>.

FEATURES AND AMENITIES THAT ARE MOST DESIRED BY EV DRIVERS, USED DURING A CHARGING SESSION, AND COULD INFLUENCE DRIVERS TO USE CHARGING STATIONS FREQUENTLY

Consumer Reports and UCS found that 66% of the participants in their 2019 survey viewed grocery stores to be most convenient to have a charging station.<sup>143</sup> The broad majority seemed to support having a charging station where they would spend longer periods of time anyway. This was also the finding in the study conducted by INL and the DOE in which shopping malls, airports, commuter lots, and downtown parking lots with easy access to a variety of venues were amongst the most used public charger locations. As shown in (Figure 44),<sup>144</sup> INL and the DOE further found that Level 2 charging sites at retail stores, shopping malls, parking lots, and garages demonstrated the potential to support seven to 11 charges a day.<sup>145</sup>

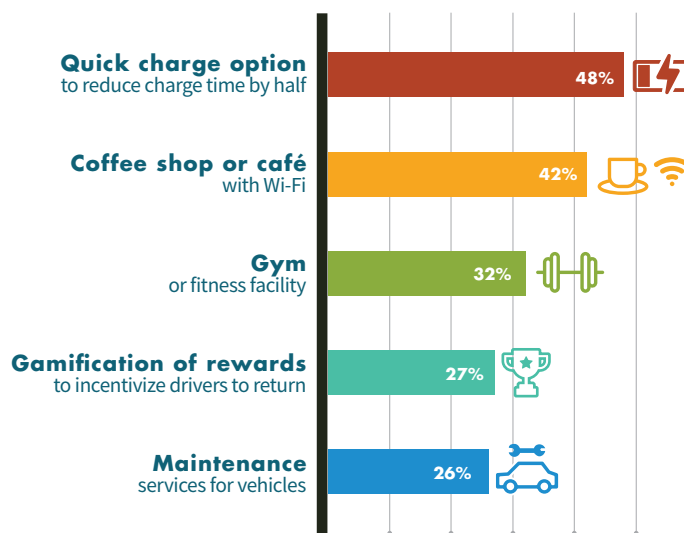
Volvo, in their 2018 study, found that among the most desired charging station features, the option to quickly charge a vehicle in half the time topped the list. Having a coffee shop with Wi-Fi to increase productivity during the downtime was the second preferred option, and having a gym to work out was number three on the list. An interesting observation was that 27% of the respondents felt that “gamification of rewards” would encourage them to use the chargers more often. A quarter of the participants also felt the need for maintenance services to be provided on-site (Figure 45).<sup>146</sup>

FIGURE 44: EV CHARGING LOCATIONS PERCEIVED TO BE MOST CONVENIENT BY POTENTIAL EV CUSTOMERS (2019)



Source: Union of Concerned Scientists and Consumer Reports, Electric Vehicle Survey Findings and Methodology

FIGURE 45: FEATURES MOST DESIRED AT EXISTING EV CHARGING LOCATIONS (2019)



Note: Participants chose more than one option  
 Source: Volvo Car USA, The State of Electric Vehicles in America

143 Union of Concerned Scientists and Consumer Reports, Electric Vehicle Survey Findings and Methodology

144 Union of Concerned Scientists and Consumer Reports, Electric Vehicle Survey Findings and Methodology

145 John Galloway Smart and Shawn Douglas Salisbury, Plugged In: How Americans Charge Their Electric Vehicles

146 Volvo Car USA, The State of Electric Vehicles in America



FEATURES AND AMENITIES THAT YIELD THE GREATEST INFLUENCE OVER AN EV DRIVER’S DECISION REGARDING WHERE TO CHARGE

A few key factors that influence a driver’s decision in choosing where to charge are (Figure 46):

- 1) **Dependability:** Some networks appear to be more dependable than others. Chargers at newer stations have been found to be out of service.<sup>147</sup>
- 2) **Convenience:** Drivers are less likely to plug in at work if they have to pay to charge or if they have to move the vehicle after charging (and the rule was enforced).<sup>148</sup>
- 3) **Cost of use:** Most Blink public units started charging a fee after September 2012 while ChargePoint units were free through the end of the DOE’s EV Project. Usage of ChargePoint units had been increasing at a faster rate than Blink.<sup>149</sup>
- 4) **Need for travel:** Drivers who plugged in away from home generally traveled more, logging 72% more daily miles on electricity compared to drivers who didn’t charge at home. Most used chargers that tended to be closer to highway exits.<sup>150</sup>

147 Jeff Plungis, “How the Electric Car Charging Network Is Expanding”  
 148 Eric Schmidt, “The Key to Increasing EV Adoption Is Hidden in EV Driving and Charging Data”  
 149 Eric Schmidt, “The Key to Increasing EV Adoption Is Hidden in EV Driving and Charging Data”  
 150 Eric Schmidt, “The Key to Increasing EV Adoption Is Hidden in EV Driving and Charging Data”

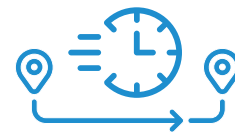
FIGURE 46: KEY FEATURES AND AMENITIES THAT INFLUENCE EV DRIVERS’ CHOICE OF CHARGER



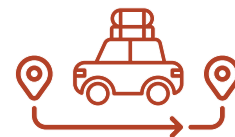
DEPENDABILITY



COST OF USE



CONVENIENCE



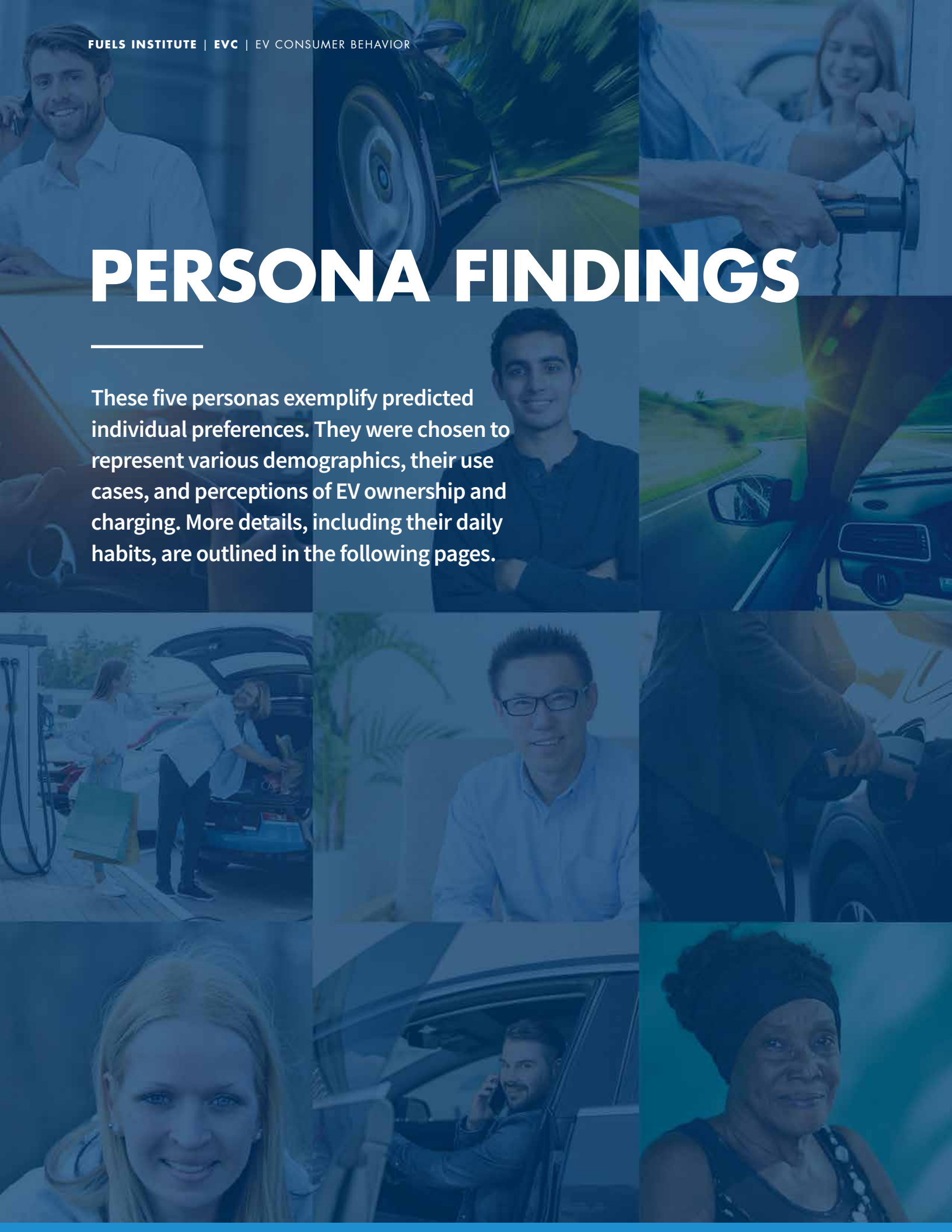
NEED FOR TRAVEL

Consumer Reports and UCS found that 66% of the participants in their 2019 survey viewed grocery stores to be most convenient to have a charging station.

# PERSONA FINDINGS

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These five personas exemplify predicted individual preferences. They were chosen to represent various demographics, their use cases, and perceptions of EV ownership and charging. More details, including their daily habits, are outlined in the following pages.



PERSONA FINDINGS

# Michael

Affluent Middle-Aged White Male With BEV As Secondary Vehicle Living in the California Bay Area With Access to At-Home Charging



OVERVIEW

Michael is an affluent middle-aged white man who owns more than one vehicle. He fits the most common EV owner demographic and exemplifies their typical EV-related behavior. He lives in the ZEV-populous Bay Area region of California, considers driving a Tesla to be a status symbol, and likes being associated with cutting-edge technology.

Michael generally charges at home and uses free charging at his workplace parking lot. He uses public chargers when they are free and when the charge time fits his schedule. Michael only recharges with a DCFC when unavoidable and prefers the Tesla network since the ecosystem is integrated within the vehicle and the smartphone app. He also limits himself to using Level 2 chargers because of the

potential battery degradation from frequently using a DCFC. This could be another aspect to consider when designing EV charging infrastructure — this is in line with the current projection of 96% of public chargers being Level 2 ([Figure 25](#)). Michael does not choose a particular gym based on the availability of charger, exemplifying that people may not switch loyalty to a business solely based on the availability of a public charger.

For long trips, Michael chooses to fly as opposed to road-trip, or he and his family use the gasoline-powered SUV. Michael might consider an electric SUV if the DCFC network along highways was denser and the charging time was much lower.

PERSONA DESCRIPTION

- 37-year-old male
- Owns Tesla Model 3, second car (\$60,000); first car is a premium SUV
- Lives in the Bay Area, California
- Married, two kids (below age 6)
- Director at a technology company
- \$400,000 household income
- Owns a house with garage and usually charges at home at night
- One-and-a-half hour commute to and from work everyday
- Occasional road travel out of the city
- Workplace has free charging
- Nanny comes in on the weekend for four hours once a month so that Michael and his wife can step out for dinner and shopping using the Tesla



## PERSONA FINDINGS: MICHAEL

### TRAITS

#### TYPE OF CUSTOMER

- Considers driving a Tesla to be a status symbol
- Is undergoing a mid-life crisis and taking time for self-care and family care
- Values the green credential that comes with owning an EV
- Likes being on the cutting-edge of technology
- Identifies as an early tech adopter
- Likes “cool” things
- Identifies as a beta tester of new tech
- Prefers flying to road travel for long trips

#### RECHARGE HABITS

- Recharges at home every or every other night
- Recharges at public parking that provides free parking and free electricity
- Plugs in when parking is closer to the building
- Recharges primarily at home and work (free charging) and at hotels when on trips
- Does not wait until the battery is nearly empty and always keeps it topped up
- Would use a public charger if there happens to be a saturation in the residential energy market or if urban housing has the facility to plug in

#### CHOOSING A PARTICULAR CHARGING FACILITY

- Only recharges using a Level 2 DCFC when almost empty and unavoidable
- Would prefer to charge within the Tesla network that is integrated in the vehicle’s interface
- Charges for free at the high-end shopping mall or an upscale restaurant when he goes out with his wife on a weekend (monthly)

#### INTERACTION WITH A PUBLIC CHARGING STATION

- Primarily recharges at home or work and has limited opportunity to use public chargers
- Would plug in if free of charge and if he plans to spend some time at that location
- Prefers using the Tesla Supercharger network if necessary but limits himself to Level 2

#### TIME SPENT AT A PUBLIC CHARGING STATION

- Would prefer to have a charging station at a gym or somewhere he is likely to spend time
- Would not choose a gym because of the availability of a charger, but having one would be good
- Would pay to charge at a public charger if it means he can park closer in a crowded lot
- Would use a public charger if there aren’t other parking lots nearby
- Uses the gasoline SUV for road trips with family



## PERSONA FINDINGS

## Shou

Affluent, Middle-Aged Asian American Male With BEV As Secondary Vehicle Living With At-Home Charger Who Frequents a Metropolitan City



## OVERVIEW

Shou represents a slightly different demographic where the vehicle is often driven locally and occasionally to a metropolitan city. Shou, like Michael, primarily charges his car at home, but since he runs a business from home, his travel needs are lighter than Michael's.

Shou enjoys having an environmentally conscious image and appreciates the hassle-free ownership experience involved in driving an EV. Switching to an EV has not greatly impacted his travel habits because most of his trips are running errands around town. He prefers to take the bus or train instead of driving whenever convenient. When he does travel longer distances, he plans his trips around chargers and chooses to stay at hotels with a Level 2 charger to charge overnight. Shou's example of charging at the hotel where he stays overnight is in line with the observations that 1) the most used chargers are those at locations where people tend to park for long periods of time and 2) customers are attracted to businesses that provide an on-premise charger (see [“Dwell Time at Public Chargers and the Features That Could Influence That Dwell Time”](#) for an analysis of the profitability of this use case).

Shou's charging behavior is influenced by factors discussed in [“EV Drivers' Preferred Recharge Location”](#) although the majority of his charging is done at home, he tends to plug in when a charger is available, free, and convenient and if it helps secure a good parking spot. Shou's EV purchase included a ChargePoint card and he has received good customer service from the charge company, so he is loyal to that particular charger brand. Shou is also loyal to ChargePoint because he doesn't want to sign up for several charging apps. However, he uses the PlugShare app to scout for free chargers. He would prefer to be in a coffee shop with free Wi-Fi to increase his productivity during the downtime while charging, but during the current pandemic, he sits in the car.





## PERSONA FINDINGS: SHOU

### PERSONA DESCRIPTION

- 49-year-old male
- Owns Chevy Bolt as a second car; the first car is a minivan (primarily driven by his wife)
- Lives in New Jersey within the New York City metro area
- Married, two kids (in college)
- Owns a home-based financial firm
- \$200,000 household income
- Owns a house with garage and usually charges at home
- Drives the Bolt in the evenings and over the weekend
- Frequently travels to Manhattan
- Prefers public transport when convenient

### TRAITS

#### TYPE OF CUSTOMER

- Grown children no longer live at home, so he downsized the second car
- Environment-conscious image
- Appreciates the lower fuel cost with an EV
- Enjoys hassle-free ownership and prefers a low-maintenance vehicle
- Does not drive enough to justify having two cars and is considering selling the minivan
- Travel has not changed since switching to an EV — primarily uses it to travel around town and to the train station

#### RECHARGE HABITS

- Mostly recharges at home unless traveling
- Plans trips around chargers, and for work-related road trips, prefers to stay overnight in hotels offering Level 2 charging
- Would make long trips if the one-way distance is well within the car's range

- Prefers to use public chargers if charging is free and he has the time; otherwise he will only use a public charger if the car is running out of range
- Will charge while grocery shopping if it's free and he can get a good parking spot
- Very low tolerance to wait for a public charger because he can charge at home

#### CHOOSING A PARTICULAR CHARGING FACILITY

- Only recharges at Level 2 charger because DCFC on the Bolt is an optional extra (\$700-\$1,000)
- Prefers ChargePoint since the vehicle came with their charge card and they have good customer service
- Finds it a hassle to sign up for multiple apps
- Checks for free chargers on PlugShare

#### INTERACTION WITH A PUBLIC CHARGING STATION

- Prefers free charging unless out of range
- Finds signing up for new apps annoying
- Would prefer to pay through the app

#### TIME SPENT AT A PUBLIC CHARGING STATION

- Tries to get work done when waiting — prefers a café with Wi-Fi and outlets to plug in
- Needs a place to sit down and eat, a clean bathroom, and a convenience store
- Chooses to stay in the car while charging during the pandemic
- Would shop at a grocery store or a gas station's convenience store if there were available chargers

PERSONA FINDINGS

# Raj

Middle-Class Young Male of Indian Heritage With BEV As Primary Vehicle for a 20-Mile Commute Who Lives in an Apartment Building with Shared Chargers



OVERVIEW

Raj is a little shy of the \$100,000 annual household income bracket that makes up the dominant demographic. Being younger than the average age group of today’s EV drivers and living in an apartment without access to a private charger makes Raj stand out among EV buyers. However, living in a major city with a 20-mile commute in stop-and-go traffic makes him an ideal candidate to own an EV.

Raj typically charges at his workplace every day because a charger isn’t always available at home. He plans his trips around chargers when traveling between cities. Raj, like Michael and Shou, enjoys the green image that comes with driving an EV. Although Raj would switch grocery stores for free charging, he would not consider switching his tennis club for another one with a free charger.

This accentuates the possibility that while a free charger can promote business at some places, at others it would only remain a nicety. This could, however, become a necessity as the EV adoption rate increases in the future. Raj is well educated and mindful of the fact that frequent use of DCFC could accelerate battery wear. He ensures his recharging habits maintain the battery’s optimum charge level to extend battery life. This behavior could become commonplace amongst the more enthusiastic owners and eventually could pressure the infrastructure market to address this requirement by incorporating a means to monitor and control charging level and speed. Raj is, in general, unwilling to pay for charging. When unavoidable, he expects payments to be seamless.

PERSONA DESCRIPTION

- 28-year-old male
- Owns Tesla Model 3
- Lives in Chicago, Illinois
- Single
- Electrical/electronics engineer
- \$90,000 household income
- Lives in a rental apartment complex with two charging plugs
- Commutes 20 miles daily
- Occasionally road-trips with friends
- Relatives live in Ann Arbor, Michigan, and he visits once every three months; there is no charger at his destination
- Plays tennis three times a week



## PERSONA FINDINGS: RAJ

### TRAITS

#### TYPE OF CUSTOMER

- Charges at work every day
- Plans road trips based on Superchargers
- On trips to Ann Arbor, charges for 20 to 30 minutes in both directions
- Supports the “green” theme
- Appreciates getting “fuel” for free
- Enjoys status symbol of driving a Tesla

#### RECHARGE HABITS

- Mostly charges at work because the charger at home is not always available
- Would plug in whenever possible but is mindful to not charge above the “safe” range of the battery
- A battery level of less than 35% is his trigger point to plug in, and he calculates the way back to his regular locations or plugs in as soon as he can

- Plugs in even at a Level 1 charger for free “fuel”
- Would switch grocery stores for a priority spot and free charging
- Would not switch tennis clubs for a free charger
- Plugs in when there is an EV-only parking structure that’s closer to where he wants to be

#### CHOOSING A PARTICULAR CHARGING FACILITY

- On the highway, would prefer a DCFC but wouldn’t complain about having a Level 2 elsewhere
- Around town, does not plug in to a DCFC unless he must because of battery degradation
- Safety of the vehicle is more important than the identity of the charger or the host
- Prefers to use the car’s interface, but uses EVgo and ChargePoint when not using Tesla EVSE

#### INTERACTION WITH A PUBLIC CHARGING STATION

- Reluctant to pay for charging, which should be as seamless as possible if he must pay
- Would pay a premium to use renewable energy

#### TIME SPENT AT A PUBLIC CHARGING STATION

- Aims to spend 20 to 30 minutes at a charger and call friends and family when charging
- Needs facilities similar to those at a conventional gas station — bathroom, coffee, and snacks
- Would like nearby services such as free Wi-Fi (streaming level), charging ports, gym, and games (similar to Dave and Busters)
- Would extend his stay at a public charger if there were a treadmill, shower, and food

PERSONA FINDINGS

# Millicent

Retired Environmentally Conscious African American Female on a Fixed Income With a BEV As a Primary Vehicle With an At-Home Charger



OVERVIEW

Millicent, who is on a fixed income and has predictable traveling patterns, prefers to take the train when going downtown but travels in her EV to promote environmentally conscious behavior among her circle of influence. She considers her EV to be more of a political statement than a transportation choice.

Millicent has limited daily traveling needs and charges mostly at home on a Level 1 charger. She uses public chargers to promote awareness of EVs. She enjoys conversations with like-minded people whom she often meets at these public chargers. Although she does not need to use a public charger

very often, she expects to see a lot more chargers in her community for the people who would need to use them. She is not very tech-savvy and does not use apps to find chargers. She only uses chargers that she’s seen or are at places that she frequently visits. She treats her car like a gasoline-engine powered car, which reflects the anticipation that as EV adoption becomes more widespread, EVs will be treated like today’s conventional vehicles. Facilities and amenities offered at public chargers do not affect Millicent’s frequency or duration of usage of those public chargers.

PERSONA DESCRIPTION

- 68-year-old female
- Drives used Chevy Bolt
- Lives in Orlando, Florida
- Living alone; her adult children live in the Chicago metro area
- Retired elementary school teacher
- \$60,000 fixed pension
- Owns a house with garage
- Leaves house only a few times a week
- Takes the train when traveling downtown
- Involved in both the civil rights and environmental justice movements in her youth and wants to make purchasing choices that are aligned with her values



## PERSONA FINDINGS: MILLICENT

### TRAITS

#### TYPE OF CUSTOMER

- Involved with community and church and volunteers at the local library
- Environmentally conscious
- Owning an EV is more of a political than a transportation choice; she cares about how air pollution is disproportionately affecting her community and feels that she is making a difference through her choice of transportation
- Only person in her social circle to own an EV
- Travel has not changed since switching to an EV and remains minimal

#### RECHARGE HABITS

- Mostly charges at home (Level 1 charger)
- Uses free public chargers at the library and around town to bring awareness to onlookers; identifies as an advocate for EVs

- Plugs in at readily available chargers for conversations with like-minded people
- Is proud of not using a gas station in years
- Would like to see more chargers in the community so that they are accessible to people who drive more than she does

#### CHOOSING A PARTICULAR CHARGING FACILITY

- Does not know the difference between Level 1, Level 2, and DCFC and doesn't see a need to know
- Does not use an app to find chargers but plugs in when she finds one or already knows where one is; not tech-savvy and treats EV similar to a gas car

#### INTERACTION WITH A PUBLIC CHARGING STATION

- Is not willing to pay for charging
- If needed, she would prefer paying with a credit card rather than an app due to privacy sensitivity

#### TIME SPENT AT A PUBLIC CHARGING STATION

- Charging is not a top priority and plugs in if the charger is free and available at a location she is visiting anyway
- Facilities and amenities at public chargers do not affect her perception



## PERSONA FINDINGS

## Amy

White Businesswoman Who  
Drives a Work Truck and Could  
Potentially Buy an Electric Truck



## OVERVIEW

Amy is an example of what a prospective EV owner would expect and need beyond the current EV infrastructure and systems. Current EV drivers tend to adapt to the infrastructure and systems that are available to them, and their expectations are constrained by the current situation. Amy, who uses a work truck as her primary vehicle and is a potential EV buyer, demonstrates how the market can prepare for the requirements of a commercial small business' EV.

Amy currently drives a Ford F-150. She views having an electric pickup truck as being a potential advertisement for industry of solar panel installation. Unlike bigger commercial establishments that tend to charge exclusively at their work bases, Amy would charge her truck at home and at public chargers as needed. Amy's requirement is for the battery range to last the entire workday, which appears plausible given the current trajectory of EV battery range. She expects the truck to be reliable and cannot change her driving patterns based on the availability of chargers. She expects to be part of the EV360 program in Austin because the program's fixed low monthly subscription costs would make her fuel

expenses not only predictable but also significantly lower than her current fuel cost. This in turn would help reduce the overall cost of EV ownership, a significant factor in Amy's EV adoption decision. Austin's EV360 program could act as a role model for other cities and states in encouraging EV adoption.

Amy would plan to charge at home at the end of the workday, but if she needed to charge up before that, she would need to use a DCFC every time because any downtime during the day could result in lesser revenue earned. This would be in spite of fully understanding the implications of frequent use of DCFCs. She would prefer to have Wi-Fi at charging stations to improve productivity but would not want to wait any longer than she has to for charging the vehicle.



## PERSONA FINDINGS: AMY

### PERSONA DESCRIPTION

- 43-year-old female
- Drives a Ford F-150
- Lives in Austin, Texas
- Single
- General electrician/solar installer
- \$150,000 business income
- Open to buying an EV, but nonavailability and her lifestyle don't currently support EV ownership
- Views EV ownership as an advertising element in line with her business
- Needs ability to plug in and use tools on-site
- Dreams of having a mini workshop in the truck bed, avoiding the need to travel back and forth to her workshop

### TRAITS

#### TYPE OF CUSTOMER

- Views EV to be a potential advertisement element to her business
- Would need battery range to last the entire workday
- Is extremely range anxious because the truck is her livelihood and she depends on 100% uptime
- Travel habits are not expected to change in order to accommodate charging habits when owning an EV
- Goes on road trips with friends

#### RECHARGE HABITS

- Would charge overnight at home (Austin's EV360 program promotes free home charging)
- During the workday, would not have much downtime to use a public charger unless running out of range, and would always need a DCFC

- Would plug in while running errands as an advertisement for her business and would pay a reasonable cost to plug in even if she doesn't need to
- Fuel-cost conscious and would make use of subsidized/free home charging

#### CHOOSING A PARTICULAR CHARGING FACILITY

- Would only plug in if it's a long workday and she is running out of charge
- Would prefer a DCFC and would be willing to pay a reasonable premium to avoid downtime
- Would prefer to use the network for the card supplied with the truck upon purchase, but would switch providers if the network is unreliable
- Would prefer using a network with which she has an existing relationship, such as the company that installs her home charger

#### INTERACTION WITH A PUBLIC CHARGING STATION

- Would prefer being charged per kWh
- Prefers to use a seamless system to pay, such as charge cards, so that her receipts stay in one place for easy business expensing

#### TIME SPENT AT A PUBLIC CHARGING STATION

- Would prefer to be at a station that offers Wi-Fi and outlets to catch up on work
- Would like a drive-in with Wi-Fi while charging
- Would prefer not to wait any longer than she must for charging

# CONCLUSIONS

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**This report discusses the behavior of today's EV drivers and their evolution over the past 10 years and into the next 10 years. Although best efforts were made to incorporate the latest and most accurate data in this study, the EV landscape has been changing rapidly and is continuing to do so.**

**Battery range has tripled since 2010, vehicle nameplates have increased from three to more than 20, and Level 2 charging locations have grown from approximately 1,000 to more than 70,000. This rapid development renders conducted research outdated very quickly.**

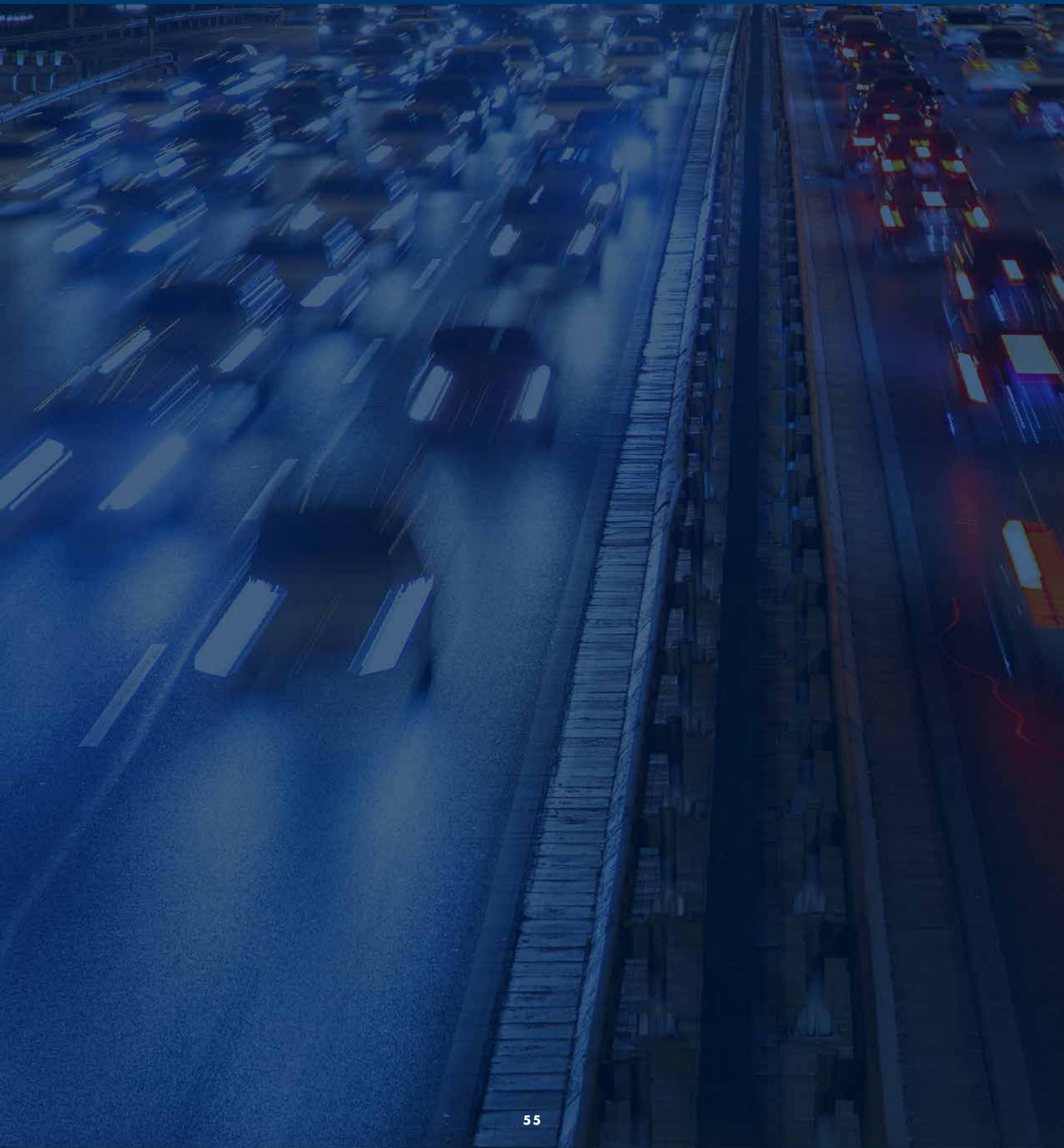
Technology has evolved, and the mindset of consumers has evolved to now view their EVs as a gadget that is not very different from their cellphone. The vast majority however are still concerned about the limitation of battery range, the need to plan ahead to charge their vehicle (unlike gasoline vehicles), and that battery degradation over time can limit their mobility. There is yet another group of the population that is not served by the current lineup of vehicles: People who want to buy a pickup truck or a minivan have very limited electric options, if any.

Travel habits of EV drivers today perhaps hide the deficiencies in the charging infrastructure amenities since they choose to purchase an EV knowing the infrastructure in place. This will change once EVs become more affordable, as more choice is available, as the charging infrastructure grows to instill confidence in range-anxious minds, and, most importantly, as the average driver's mindset changes to understand and embrace EV technology.

Understanding the mindset of today's drivers by means of studies helps make better, more informed choices in planning out infrastructure requirement for the future. Although many factors have a predictable trend, such as falling battery prices, improved range, and denser charging infrastructure, nuanced factors such as comfort of available infrastructure, features, and amenities that could influence a driver's decision to spend time at a charging station, recharging habits, and selection of chargers would continually be applicable for buyers who are not considering an EV purchase today but are likely to do so over the next few years.

Targeted surveys and interviews to capture near-term, mid-term, and long-term EV buyers' opinions with regards to the questions outlined in this report are necessary to ensure a robust view of how the charging infrastructure and surrounding amenities should involve. Additionally, direct feedback from EV manufacturers, charging station providers, fleet managers, and business entities such as grocery stores, shopping malls, highway stops, restaurant owners, park-and-rides, and other would be necessary to understand their plans to evolve the EV charging and consumer experience ecosystem. These items should be addressed in subsequent research.

# APPENDIX



# Abbreviations

<b>BEV</b>	battery electric vehicle
<b>DCFC</b>	direct current fast charger/charging
<b>DOE</b>	Department of Energy
<b>EV</b>	electric vehicle
<b>EVSE</b>	electric vehicle supply equipment
<b>ICE</b>	internal combustion engine
<b>INL</b>	Idaho National Laboratory
<b>kWh</b>	kilowatt-hour
<b>NREL</b>	National Renewable Energy Laboratory
<b>OEM</b>	original equipment manufacturer
<b>PEV</b>	plug-in electric vehicle
<b>PHEV</b>	plug-in hybrid electric vehicle
<b>RFID</b>	radio-frequency identification
<b>SUV</b>	sport utility vehicle
<b>TCO</b>	total cost of ownership
<b>UCS</b>	Union of Concerned Scientists
<b>ZEV</b>	zero-emission vehicle



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## About the Electric Vehicle Council

The Electric Vehicle Council is a non-advocacy organization whose mission is to coordinate the efforts of organizations actively engaged in supporting the deployment of EV charging infrastructure. The EV Council works to distribute existing research and education materials to amplify and enhance its value to the market, as well as conducts original research to fill gaps in knowledge and further educate interested stakeholders concerning the opportunities, challenges, and successful strategies associated with the installation and operation of EV charging stations.

For more information on the Electric Vehicle Council and a current list of members, please visit: [fuelsinstitute.org/Councils/Electric-Vehicle-Council](https://fuelsinstitute.org/Councils/Electric-Vehicle-Council)

## About the Fuels Institute

The Fuels Institute, founded by NACS in 2013, is a 501(c)(4) non-profit research-oriented think tank dedicated to evaluating the market issues related to vehicles and the fuels that power them. By bringing together diverse stakeholders of the transportation and fuels markets, the Institute helps to identify opportunities and challenges associated with new technologies and to facilitate industry coordination to help ensure that consumers derive the greatest benefit.

The Fuels Institute commissions and publishes comprehensive, fact-based research projects that address the interests of the affected stakeholders. Such publications will help to inform both business owners considering long-term investment decisions and policymakers considering legislation and regulations affecting the market. Research is independent and unbiased, designed to answer questions, not advocate a specific outcome. Participants in the Fuels Institute are dedicated to promoting facts and providing decision makers with the most credible information possible so that the market can deliver the best in vehicle and fueling options to the consumer.

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