Title

EVs for everyone? Identifying the likely early majority of electric vehicle adopters

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January 2024

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EVs for Everyone?

Identifying the Likely Early Majority of Electric Vehicle Adopters

Prepared for the
U.S. Environmental Protection Agency

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Table of Contents

Table of Figures

List of Tables

Executive Summary

The evolution of the BEV market, to date, reflects a number of developments, including: changing attributes of BEVs (e.g., more diverse models, greater range, nascent ability to provide backup power to homes, etc.) and their complementary charging infrastructure; alterations in consumers' assessments of the alignment between BEVs and their preferences and travel needs; and the roll-out of new BEV-supportive policies. Considering sales volumes of BEVs to date, the U.S. has passed through the "Innovator" stage of Roger's diffusion of innovations curve, and solidly into the "Early Adopter" market, with the "Early Majority" on the horizon. This paper attempts to bring the Early Majority into greater clarity, analyzing publicly available data to characterize its potential nature and size. We apply a framework of four related components of electric vehicle acceptance—awareness, access, approval, and adoption. The variables we examine primarily enable the "access" component of acceptance, and include characteristics of individuals and households. We also consider physical and economic/governmental aspects of the social system in which vehicle purchase decisions occur, with a focus on the spatial heterogeneity of both public charging density and laws and incentives. A key finding is that a substantial portion of U.S. households reflect a combination of apparent BEV acceptance enablers as demonstrated by the majority of current BEV adopters. We find that 46.9% of US household own a single-family home with reasonable charging capabilities, making the convenience and savings associated with BEV ownership feasible for nearly half of US households. Furthermore, 28% of those household also earn more than $100k annually, leaving them potentially well-positioned to become part of the Early Majority.

1. Introduction

It has now been approximately 13 years since the inception of the modern market for electric vehicles, following the roll out of the Nissan Leaf, shortly followed by battery electric (BEV) and plug-in hybrid (PHEV) models from a variety of other vehicle manufacturers including, Ford, Honda, Toyota, and market entrant Tesla. Based on the sales volumes of electric vehicles to date, the much of the U.S. is solidly within the “Innovator” stage of Roger’s (2003) diffusion of innovations curve; a number of individual states, such as California, are within the “Early Adopter” market and heading into the “Early Majority” (Figure 1). As national and state level greenhouse gas emissions targets depend in large part on further moving away from fossil fuel dependent transportation, identifying the likely populations who will compose the next group of BEV buyers (i.e., “Early Majority”) is a topic of interest among vehicle manufacturers, policy makers, transportation modelers, and a variety of others working at the intersection of energy, environmental, and social research areas.

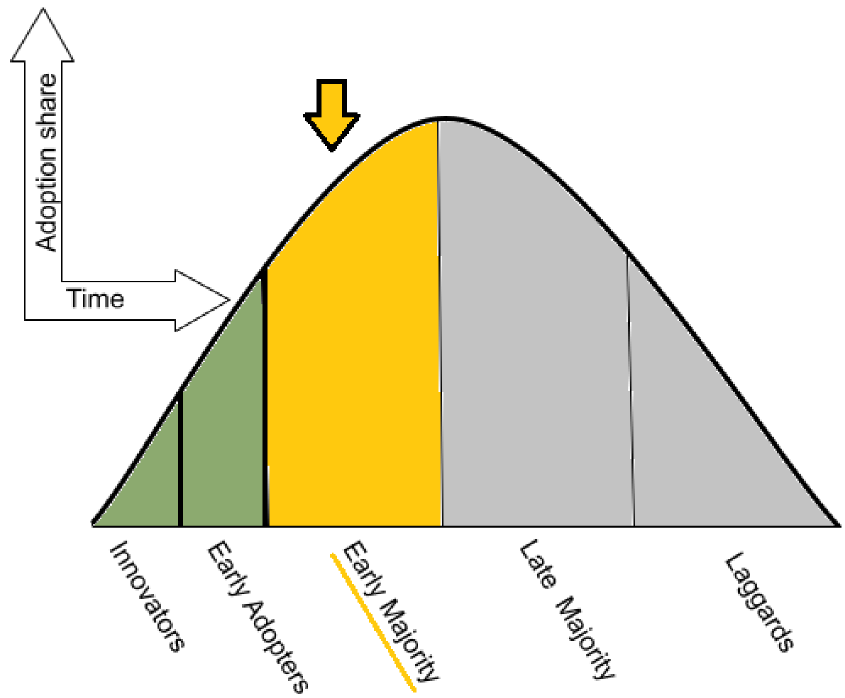

Figure 1. INNOVATION DIFFUSION CURVE
Note: adapted from Rogers 2003

The evolution of the BEV market, to date, reflects a number of developments, including: changing attributes of BEVs (e.g., more diverse models, greater range, nascent ability to provide backup power to homes, etc.) and their complementary charging infrastructure; alterations in consumers’ assessments of the alignment between BEVs and their preferences and travel needs; and the roll-out of new BEV-supportive policies. One signpost marking this evolution is the simple fact that while the first wave of BEVs were primarily compact vehicles, limited to a handful of models, as of mid-2023, over 70 BEV models are available for purchase in the U.S (Alternative Fuels Data Center, 2023a). At the same time, networks of electric vehicle service equipment (EVSE, or “charging infrastructure”) have continued to expand, driven both by private and public sector actions (Bellon & Leinert, 2021; Kurani, 2019; Tal et al., 2020). Although the demographic characteristics of the BEV-adopting population – who might be termed the Innovators and Early Adopters, in Figure 1 – have tended to be wealthy, white, and male with high educational attainment, the level of interest in BEVs today is less constrained (Brückmann et al., 2021; Hardman & Tal, 2021; Jia & Chen, 2021; Kurani, 2019; Kurani & Buch, 2021). In addition, while BEV adoption has been supported by a number of federal-, state-, local-, and utility-level programs over the years which improve the BEV value proposition (e.g., Carley et al., 2019; Jackman et al., 2022; Zambrano-Gutiérrez et al., 2018), the nature of U.S. policy support has undergone a sea change since the presidential signing of the Infrastructure Investment and Jobs Act (IIJA) (Public Law 117-58, also known as the “Bipartisan Infrastructure Law,” or BIL) in November 2021 and the Inflation Reduction Act (Public Law 117-169, IRA) in August 2022.

With all of this change afoot, the primary objective of this report is to describe the potential nature and size of the Early Majority U.S. BEV-adopting population, as the last of so-called "early adopters" are expected to have entered the PEV market by the mid-2020's (U.S. Environmental Agency, 2023). To this end, we perform an exploratory analysis of the characteristics of U.S. new car-buying households, with particular attention to enabling characteristics associated with BEV “acceptance.” We adopt a framework of four related components of electric vehicle acceptance—awareness, access, approval, and adoption – as articulated in Jackman et al. (2022), a peer-reviewed, comprehensive literature review of U.S. plug-in electric vehicle acceptance, jointly authored by Environmental Protection Agency and Lawrence Berkeley National Laboratory. The BEV enabling characteristics identified in Jackman et al. are derived from studies of the choices and behaviors of current BEV owners (e.g., innovators and early adopters) and on the self-reported preferences of adopters and non-adopters.

We are interested in factors that increase the feasibility of BEV acceptance, which we here refer to as “BEV readiness” for brevity, although the variables we examine primarily contribute to the “access” component of acceptance. Note that although Jackman et al. (2022) looked at enablers of plug-in electric vehicle acceptance, which includes plug-in hybrid electric vehicles (PHEVs), we do not here include PHEV acceptance.

The report proceeds as follows: in section 2, we describe our methods, including our research framing, data sources, and exploratory analytical approach. Our results are presented in section 3. In section 4, we conclude with a discussion of our findings.

2. Methods

2.1 Theoretical Framing

We apply the “4As” framing of electric vehicle acceptance put forth in Jackman et al.’s (2022) peer reviewed report for the U.S. EPA. Jackman et al. identified the following BEV-enabling characteristics of new car buyers and the contexts in which they make purchase decisions:

Consumer *characteristics of individuals and households*: these include demographics (e.g., high income, high educational attainment), household characteristics (e.g., single family home, home owner) and vehicle usage characteristics (e.g., multicar household). In our exploratory analysis, we examine: household income, educational attainment, residence in a single-family home, home ownership, presence of a garage, presence of an outlet near parking, number of household vehicles.

Aspects of the *vehicle purchase decision context*: these include *attributes of vehicles* available for purchase (e.g., vehicle body types available as BEVs) and contextual conditions of the *systems in which vehicles are used* (e.g., abundance of public charging stations). In our exploratory analysis, we examine: public charger density, presence of state and local incentives for BEV and/or EVSE purchase.

The presence of any single enabler increases the likelihood of BEV acceptance. The intersection of several enablers likely further increases the probability of BEV acceptance, including the likelihood of adoption. In this paper, we document the presence of enablers and combinations of enablers among vehicle consumers. We do not attempt to quantify the relationship between enablers, individually or in combination, and BEV acceptance

We apply terminology established in Fujita et al. (2022) in order to easily distinguish whether we are discussing the traits of people, vehicles, or the contexts in which vehicle purchase and use take place. Under this terminology, *consumers* select vehicles based on their purchase *criteria* (i.e., what they need or desire from a vehicle); these criteria can be influenced by consumer *characteristics* including demographics, psychographics, aspects of their housing situation, etc. *Vehicles* will be deemed acceptable or not depending on how their *attributes* align with consumer purchase criteria. These purchase decisions are made within the context of broader social *systems* (e.g., government, market, social, physical), which can also contribute to a consumer's vehicle selection.

2.2 Data Sources

We evaluated a number of publicly-available datasets to assess their ability to shed light on the BEV readiness of the U.S. population. Data sources include the U.S. Energy Information Administration Residential Energy Consumption Survey (RECS), the U.S. Department of Transportation Federal Highway Administration’s National Household Travel Survey (NHTS), the U.S. Census Bureau’s American Housing Survey (AHS), and the U.S. Department of Energy’s Alternative Fuels Data Center. These data relate either to characteristics of households previously identified to be enablers of EV acceptance or enabling conditions such as charging availability and supportive policies (i.e., “systems”).

Energy Information Administration: The U.S. Energy Information Administration collects and maintains a variety of energy-related datasets, including consumption and end uses of energy and energy prices. EIA provides information on the prices and consumption of crude oil, gasoline, diesel, and other fuels (U.S. Energy Information Administration, 2023b). Prices (dollars per gallon) are reported for all grades of gasoline on a weekly basis, spanning the period of 1990 to 2023. Prices are reported for the U.S. average, major regions, and several individual states and cities. Populations of Census Divisions, from current Census data, can be used to determine the number of people facing high versus low gasoline prices. The EIA also provides information on the prices and consumption of electricity by sector (U.S. Energy Information Administration, 2023a). Average residential electricity price per kilowatt-hour is reported annually for each of 1,483 utilities, along with the number of customers. Populations of states, from current Census data, can also be used to estimate the number of people facing high versus low electricity prices. However, as many utilities offer (or require) time-of-use pricing schedules for BEV users, it is unclear how well average prices reflect the difference in BEV fueling cost. We note the availability of these electricity and fuel price data, but do not further investigate them here.

The EIA’s Residential Energy Consumption Survey (RECS) is an extensive nationally representative survey that covers detailed aspects of energy use, housing attributes, household demographics, holdings of various types of energy-using equipment, and in recent years, ownership and charging of BEVs (U.S. Energy Information Administration, 2020). RECS data provide an opportunity to assess the current correlation between EV adoption and a number of the enabling factors described above. We examine six variables in RECS: educational attainment, type of housing unit, presence of a garage, home ownership versus rental, presence of electricity access near residential parking, and household income.

U.S. Department of Transportation Federal Highway Administration (FHWA): The FHWA conducts the National Household Travel Survey (NHTS), which describes travel by U.S. residents, weighted to be nationally representative at the household level (Federal Highway Administration, 2017). The NHTS includes a detailed travel day record, as well as more general depiction of housing, demographics, transportation use, vehicle ownership, and a variety of additional variables. It is intended for use in U.S. transportation planning. The most recent version was conducted in 2017 and several historical versions are available as well. NHTS data provide an opportunity to assess the current correlation between EV adoption and a number of the enabling factors described above. We focus on four NHTS variables in the Results section: household income, educational attainment, home ownership versus rental, and number of household vehicles.

U.S. Census Bureau: The U.S. Census Bureau produces a number of data products of relevance to assessing the BEV readiness potential of the Early Majority of BEV-adopters, in addition to the comprehensive decennial census. These include the American Community

Survey (ACS) and the American Housing Survey (AHS) (U.S. Census Bureau, 2021). Both include variables reflecting demographics and household characteristics (e.g., ownership, household size, housing type) and can be weighted at the household- or person-level.

The ACS is an annual survey that covers aspects of jobs and occupations, educational attainment, home ownership, and other demographics and household characteristics; it supplements the decennial Census, with questions relating to education, employment, internet access, and transportation. We evaluated the variables available in the ACS and determined that, as its most relevant variables of educational attainment, household income, number of vehicles, and number of housing units in structure were also captured by other datasets, we would not proceed with detailed analysis of the ACS at this time, though we note its potential for future analysis related to enabling BEV acceptance.

The AHS is a longitudinal housing unit survey that is conducted biennially; samples were redrawn in 1985 and 2015. The AHS focuses on the quality and cost of housing in the U.S., including the condition of homes, cost of maintaining homes, demographics and characteristics of residents; the geographical unit of analysis is the state or metro area. The longitudinal nature of this dataset allows for consideration of within-household changes over time, in contrast to the ACS, which does not follow specific households. We examine four variables from the AHS: educational attainment, household income, number of units in housing structure, and availability of vehicle parking.

Alternative Fuels Data Center: The U.S. Department of Energy's Alternative Fuels Data Center (AFDC) provides a variety of information and data on alternative and renewable fuels, including electric vehicles and charging infrastructure. These data are available through interactive tools, calculators, and mapping applications The AFDC is intended to be a dynamic online hub that provides resources for transportation decision makers.

The Alternative Fueling Station Locator (AFSL) is a regularly-updated database that includes the locations and attributes of all public and commercially owned private electric vehicle charging stations (Alternative Fuels Data Center, 2023b). Charging station locations are defined by State, city, and ZIP code, as well as latitude/longitude coordinates. Station attributes include number of Level 1, Level 2, or fast charging ports, any restrictions on use, and whether the station is part of a charging network. Stations are verified at least every other year and non-operational stations are flagged within the data. The AFSL includes these data in a mapping tool that provides both station locations and "fuel corridors," which are highway routes that have public charging stations available 50 or fewer miles apart. We analyze three variables from the AFDC's EV charging station dataset: port counts for level 1, level 2, and DC fast chargers, restricted to public charging that has not been flagged as retired from service. Through geospatial analysis, these data can be aggregated to any level of geography to assess the density of public EV charging for any given population. While we do not further investigate it here, the fuel corridors information could be used to calculate the length of fuel corridor roadway in each area, as an additional metric of the quantity of public charging in an area. We here focus on objective metrics, setting aside interpretation of the density or quantity of charging ports that equate to “sufficient” availability to enable BEV acceptance.

The AFDC also includes an annually updated database of state and federal laws and state, utility, and federal incentives related to alternative fuel (including electric) vehicles, air quality, vehicle efficiency, and other transportation-related topics (Alternative Fuels Data Center, 2023c). Information on incentives is obtained from state offices either through their websites or via direct communications. These data include the state or utility offering the incentive, the type of incentive (e.g., tax credit, rebate, non-monetary), and who is eligible for the incentive (e.g., individuals, company fleets). Combined with state and/or utility service area populations, these data can be used to estimate the total population that can access BEV-supportive incentives. We here consider incentives at the state level, but further investigation at a more refined level of geography would provide a more accurate assessment of the size of populations with EV enabling incentives available to them. In this initial assessment, we do not distinguish between the types of incentives, although different populations may not benefit identically across incentive types (e.g., tax credits are more valuable to those with a higher tax burden). We evaluate one variable from the AFDC’s laws and incentives dataset: count of laws and incentives by state relevant to BEVs.

2.3 Exploratory Analysis

By and large, the results presented below reflect a snapshot of descriptive statistics for the variables of interest within the datasets described above. Weights were applied according to the sampling design, per the guidance associated with each dataset. In developing likely BEV adoption scenarios, our descriptive statistics were able to be logically extended in several ways. The presence of an enabling factor is expected to increase the likelihood of BEV acceptance, including adoption, and the intersection of several enablers may further support BEV readiness. Thus, the populations that exhibit enabling characteristics or experience enabling conditions may find BEV ownership feasible and more desirable. For example, given that BEVs are more common in multicar households, households that own their own homes, and high-income households, those households may well comprise some portion of the early majority through their next vehicle purchase, especially as vehicle offering diversify in body styles, price points, and other attributes. Such a coalescence of enablers is depicted in the example in Figure 2.

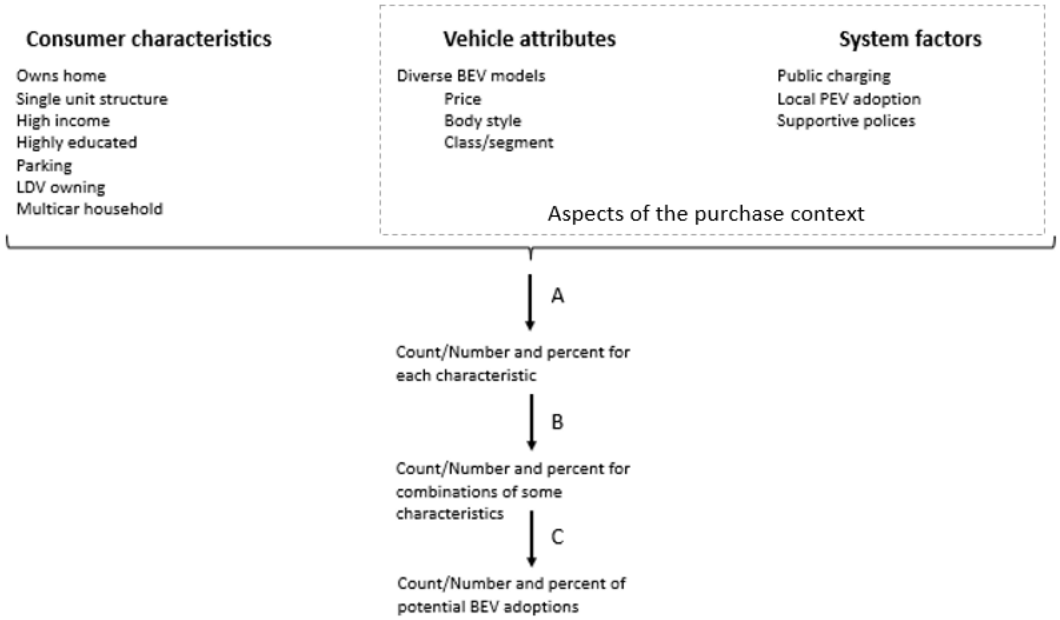

Figure 2. FRAMEWORK OF INTERSECTING BEV-READINESS ENABLERS

3. Results

Three of our datasets provide a variety of variables relating to household characteristics, while two relate to the systems supporting BEV adoption and use. We first compare what our exploratory analysis of RECS, NHTS, and AHS imply about the BEV-readiness of U.S. households based on the prevalence of enabling characteristics. Next, we turn to an examination of the system-level enablers of charging infrastructure and policies.

3.1 Summary of Household Characteristics (RECS, NHTS, AHS)

RECS: Analysis of RECS data revealed that a large percentage of U.S. households have at least one BEV-enabling characteristic. RECS identifies households that own or lease electric vehicles (BEV HH), making it possible to characterize household and resident characteristics in a comparison between BEV-owners and general U.S. households (Table 1 Column A). In keeping with the findings of previous publications, an analysis of RECS data shows that current BEV-owning households are more likely than the average U.S. household to: (1) reside in a single-family home; (2) own their home; (3) have access to a garage; (4) have access to electricity near a designated parking place; (5) have high household income; and (6) have high educational attainment.

When widening our perspective to RECS data on the overall U.S. population, we note the large percentages of U.S. households with individual BEV-adoption enabling conditions. A majority (62%) of U.S. households reside in single family homes, while 67% own their homes. When several enabling factors are combined, we see from the RECS data that 48% of U.S. households reside in a single-family home that they own, and also have a garage or parking with access to electricity. This set of characteristics is shared by 75% of current BEV owners, which suggests that as many as 48% of households – estimated by the Census Bureau in 2021 to number more than 124 million – are good candidates for owning and maintaining a BEV, including charging at home.

Table 1. Exploratory Analysis of Key Household-Level Variables

	(A) RECS		(B) NHTS			(C) AHS
Factor	**U.S. Households # (% of US HH)**	**BEV Households # (% of BEV HH)**	**U.S. Households # (% of US HH)**	**LD Households # (% of LD HH)**	**BEV Households # (% of BEV HH)**	**U.S. Households # (% of US HH)**
Have 1+ vehicle	–	–	107,641,493 (91.1%)	107,329,396 (100.0 %)	414,297 (100 %)	–
Have 2+ vehicles	–	–	67,993,920 (57.5%)	**67,949,688 (63.3%)**	**381,361 (92.1%)**	–
Household has a BEV	1,822,310 (1.5%)	1,822,310 (100.0%)	–	–	–	–
Single family home (Both Own & Rent)	77,067,692 (62.4%)	1,458,986 (80.1%)	–	–	–	81,744,237 (57.5%)
Own home (Any house unit type)	82,920,129(67.1%)	1,572,008 (86.3%)	74,518,546 (63.0%)	72,763,428 (67.8%)	355,446 (85.8 %)	–
Have garage (Any house type, own or rent)	51,794,088 (41.9%)	1,173,166 (64.4%)	–	–	–	85,362,755 (60.0%)
Have outlets within 20ft of parking (Own or rent)	67,826,991 (54.9%)	1,522,055.7 (83.5%)	–	–	–	–
Single family home & home owner with garage OR outlet	**59,839,111 (48.4%)**	**1,369,561 (75%)**	–	–	–	–
Home charging (EV owners)	–	1,385,302 (76%)	–	–	–	–
Education >= bachelor's degree	53,473,433 (43.3%)	1,376,637 (75.5%)	62,762,250 (53.1%)	59,706,068 (55.6%)	346,304 (83.6 %)	47,549,993 (33.4%)
Annual Gross Income	< $15k: 11.7% $15 -24.9k: 8.4% $25 -34.9k: 9.9% $35-49.9k:12.2% $50-74.9k:18.7% $75-99.9k:12.0% $100-149.9k:13.4% >$150k: 13.7%	< $15k: 3.8% $15 -24.9k: 2.7% $25 -34.9k: 4.4% $35-49.9k:4.2% $50-74.9k:11.5% $75-99.9k:11.9% $100-149.9k:17.1% >$150k: 44.6%	< $15k: 13.5% $15 -24.9k: 9.8% $25 -34.9k: 10.0% $35-49.9k:12.4% $50-74.9k:16.5% $75-99.9k:12.3% $100-149.9k:14.7% >$150k: 10.7%	< $15k: 8.3% $15 -24.9k: 8.2% $25 -34.9k: 9.0% $35-49.9k:11.5% $50-74.9k:15.5% $75-99.9k:11.6% $100-149.9k:14.0% >$150k: 10.1%	< $15k: 1.0% $15 -24.9k: 3.4% $25 -34.9k: 0.8% $35-49.9k:3.9% $50-74.9k:12.3% $75-99.9k:9.2% $100-149.9k: 22.8% >$150k: 46.0%	Mean: $88,520, Median: $62,000

Notes: Light Duty (LD) Households are a subset of US households with light duty vehicles, defined specifically as one the following vehicle types: Automobile/Car/Station Wagon; Van including mini, cargo and passenger; SUV and Pickup Trucks. "BEV Households" exclude PHEVs and hybrid vehicles.

While current BEV owners have been repeatedly shown to have higher-than-average incomes, we note that high income in not necessarily required for BEV ownership. Upon closer examination of RECS income data, we note that 45 % of BEV income owners have household incomes above $150K and the 25th percentile income level of current BEV owners is in the range of $50 - 75k, which is an income level met by approximately 60% of the U.S. population in general.

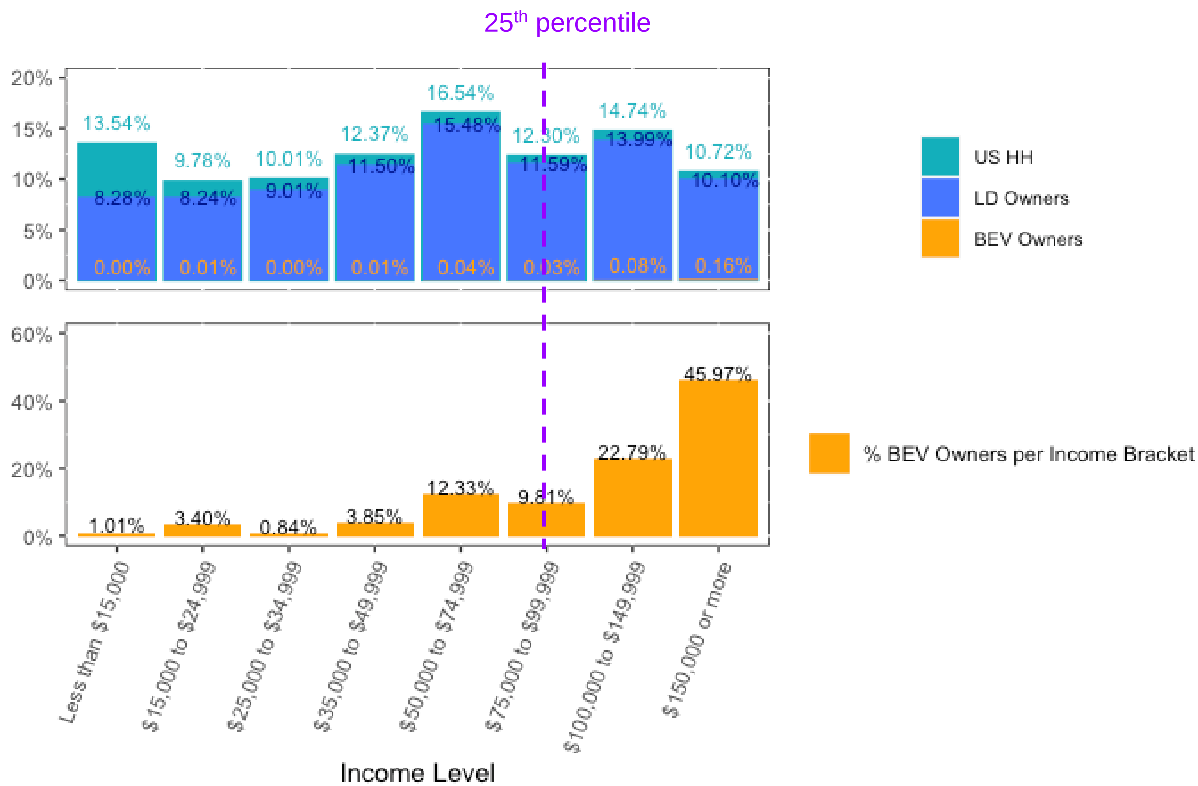

Figure 3. TOTAL US AND BEV-OWNER INCOME DISTRIUBTIONS IN RECS

NHTS: Continuing with the focus on household income, as with RECS, we see from the NHTS data that BEV owners as of 2017 were quite likely to be at the higher end of the income distribution, with more than 45% of BEV owners reporting household income of $150k or more. However, the 25th percentile of income of existing BEV owners falls within the income bin of $75-99k, a level met by a substantial number of U.S. households, particularly those that already own vehicles (Figure 4).

The NHTS identifies the number of household vehicles, so we are able to analyze three different categories of interest: all households (U.S. Households), households with at least one light-duty vehicle (Light Duty (LD) Households), and households that own a BEV (BEV Households). As noted for the RECS data, NHTS data reveal that current BEV-owning households are more likely to own their home and have higher educational attainment than the average U.S. household. Additionally, we see that BEVs are most often found in households with more than one vehicle; 92% of current BEV owners have two or more vehicles. Over 60%

of light-duty vehicle owning households (nearly 60% of all U.S. households) own two or more vehicles, which is one previously identified enabler of BEV adoption.

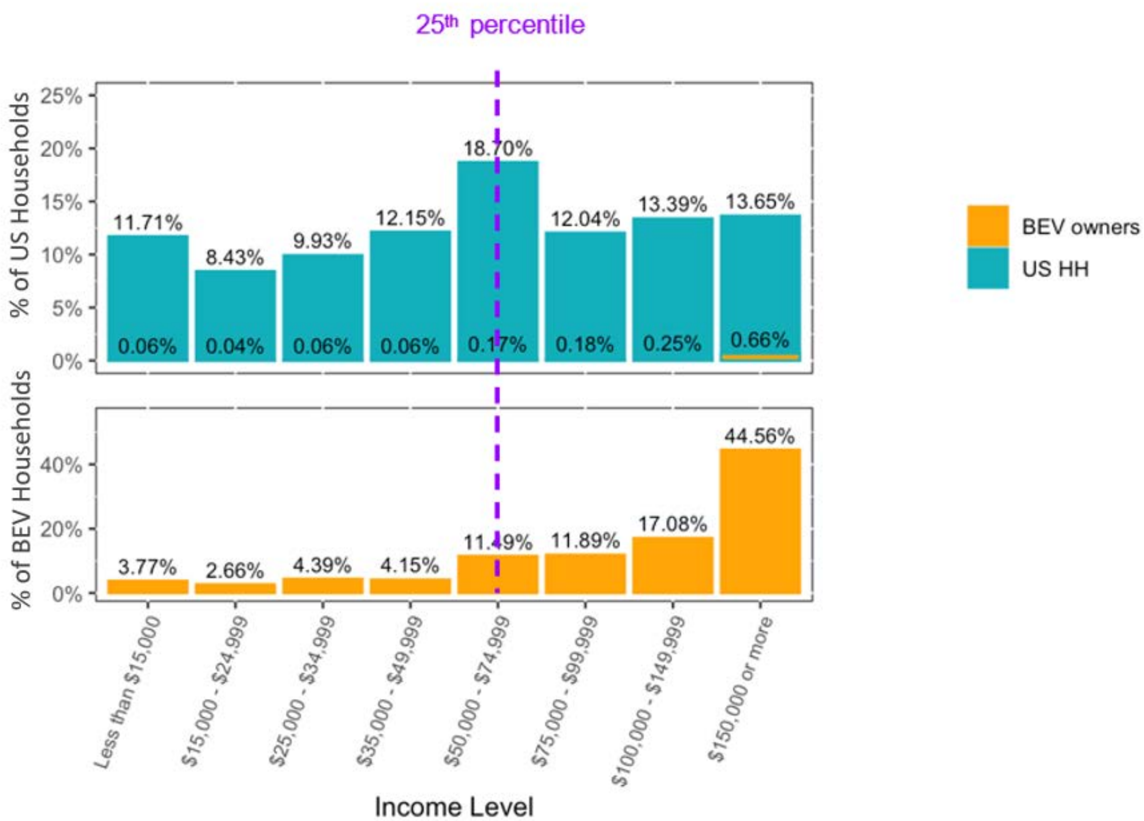

Figure 4. US, LIGHT-DUTY VEHICLE OWNER, & BEV-OWNER INCOME DISTRIBUTIONS (NHTS)

AHS: Although the AHS does not include vehicle-related variables, it does include several demographic and household characteristics across a large and representative sample of the U.S. population, against which we can compare the RECS and NHTS results (Table 1 (C)), as further addressed in the Discussion section below.

3.2 Summary of Systems-Level BEV Enablers

Charging infrastructure variation: One aspect of the broader social *systems* (e.g., government, market, social, physical) which can contribute to a consumer's choice to adopt a BEV is the physical availability of charging infrastructure. Brown et al. estimated the density of charging ports per EV and identified substantial variation in this metric between states (Brown et al., 2023). We here used AFDC data to examine variation in charging port availability across zip codes.

In a recent study of public EVSE, Wood et al. (2023) conceived of the EV charging network as akin to a tree, with visible (e.g., public charging at destinations and corridors as the branches and the trunk, respectively) and hidden (e.g., private charging at homes and certain workplaces as the roots). Both the visible and invisible charging infrastructure are relevant to a consumer's acceptance of BEVS, with exposure to visible, public charging infrastructure raising consumer awareness of BEVs, even for non-BEV owners, while access to private infrastructure like home charging is particularly important to the practical decision to consider and purchase a BEV.

Here we examine the spatial heterogeneity of charging infrastructure to gain insight into the potential BEV-readiness of the likely Early Majority. Using AFDC data, we explored the variation in the density of public charging infrastructure across U.S. zip codes. Table 2 includes the total number of level 1, level 2, and DCFC ports, as well as a summary of the distribution of public EVSE density.

Figure 5 further demonstrates the spatial variation in EVSE availability, focusing on level 2 ports. At present, we set aside the question of what constitutes "sufficient" charging density, as this variable is expected to be contingent on a variety of other factors. The top 1% of zip codes in terms of charger port density, which falls in a more residential/mixed use zip code, has a density of 40 ports per 1,000 residents. This density drops off rapidly, with the top 10% equating to about 3 ports per 1,000 residents, and the median is approximately 0.5 ports per 1,000 residents (Table 2, Figure 6).

Table 2. Exploratory Analysis of AFDC Variables

	Level 1 ports	**Level 2 ports**	**DC Fast ports**
National total	2,934	118,571	30,737

Percentile (Charger Port Density)	**Total number of ports per 1000 population**	**Population of associated zip codes**
top 1%	40.00	36,000
top 10%	3.03	6,900,000
25%	1.13	30,800,000
median	0.45	86,900,000
75%	0.19	154,000,000
90%	0.09	198,000,000

Sources: AFDC and Census population by zip code

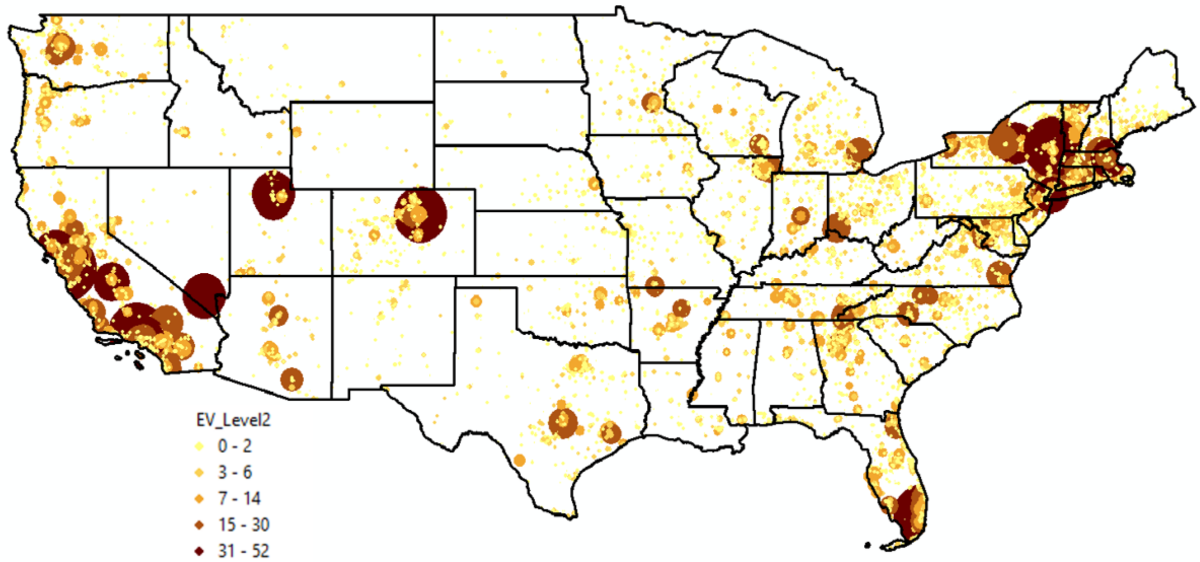

Figure 5. VARIATION IN LEVEL 2 EV CHARGER PORT AVAILABILITY ACROSS THE U.S.
Note: color and size coded to emphasize higher numbers of ports, Source: AFDC as of 2023

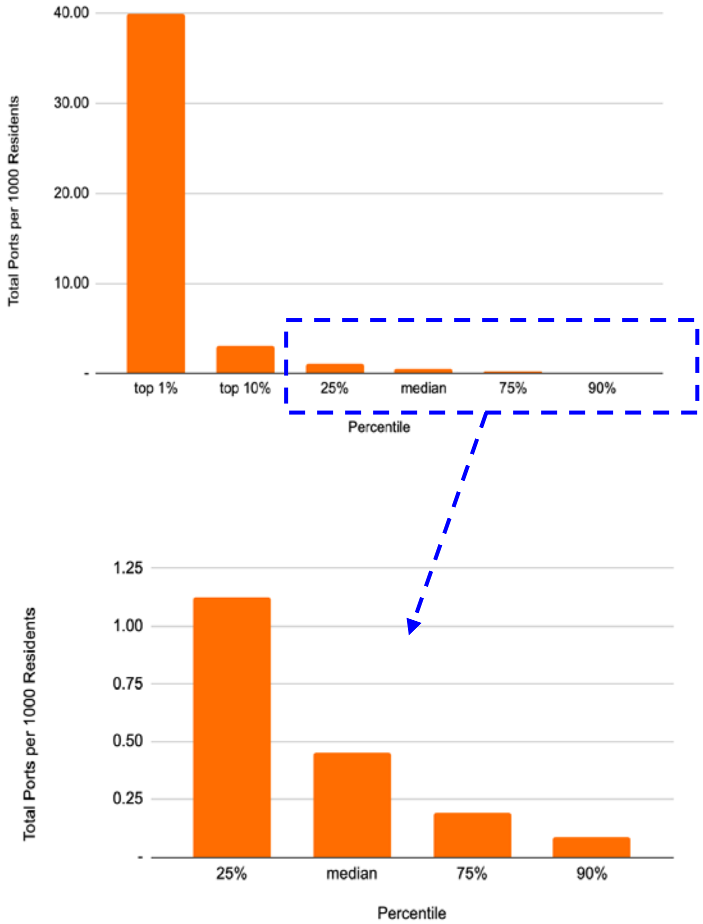

Figure 6. PUBLIC CHARGING PORTS PER 1000 RESIDENTS
Note: Summarized at zip code level, Source: AFDC as of 2023

Laws and Incentives Summary: Another aspect of the broader social *systems* (e.g., government, market, social, physical) which can contribute to a consumer's choice to adopt a BEV is the presence of laws and/or incentives supporting BEV adoption. The presence of laws and/or incentives supporting EV purchase and use is not uniform across the U.S., which can affect the nature of the emerging Early Majority. Incentives may be provided at the federal, state, local municipality, or utility level. The types of incentive embedded in EV enabling laws and programs vary, including tax credits or rebates for vehicle purchase, high-occupancy vehicle lane permits, tax exemptions, specialized electricity rate structures, etc. In a number of locations, several types of incentives are available simultaneously.

Filtering AFDC data specific to BEV-related policies, we identify 13 states that have 13 or more enabling policies (Table 3); this number of policies was selected because it appeared to be a natural break point, after which policies per state dropped off rapidly. Considering the state-level population according to 2020 U.S. Census data, these top 13 states in terms of available EV incentives include approximately 135 million people, or 41% of the total U.S. population. Note that 25 states have 6 or fewer BEV-related policies.

Table 3. Top States in terms of BEV incentives

State	Number of BEV Laws and/or Incentives	State Population (Census 2020)
CA	53	39,538,223
CO	18	5,773,714
WA	18	7,705,281
AZ	16	7,151,502
MD	16	6,177,224
MA	15	7,029,917
MI	15	10,077,331
MN	15	5,706,494
NJ	15	9,288,994
NY	15	20,201,249
OR	15	4,237,256
VA	14	8,631,393
CT	13	3,605,944

3.3 Cross-Dataset Comparison

This section focuses on calibrating across datasets which appear to have overlapping coverage of some of the variables we are most interested in with respect to consumer characteristics, namely RECS, NHTS, and AHS. Overall, the trends across these datasets are similar, with the exception of the educational level of BEV drivers.

Household Income Distribution: As household income is provided by several datasets collected by different entities at slightly different times, we compare distributions across these datasets to identify any variations. In Figure 7, we compare RECS (2020), NHTS (2017), and AHS (2021). We note that the income distributions are broadly similar, although AHS has a somewhat higher percentage of high-income households ($100k and above).

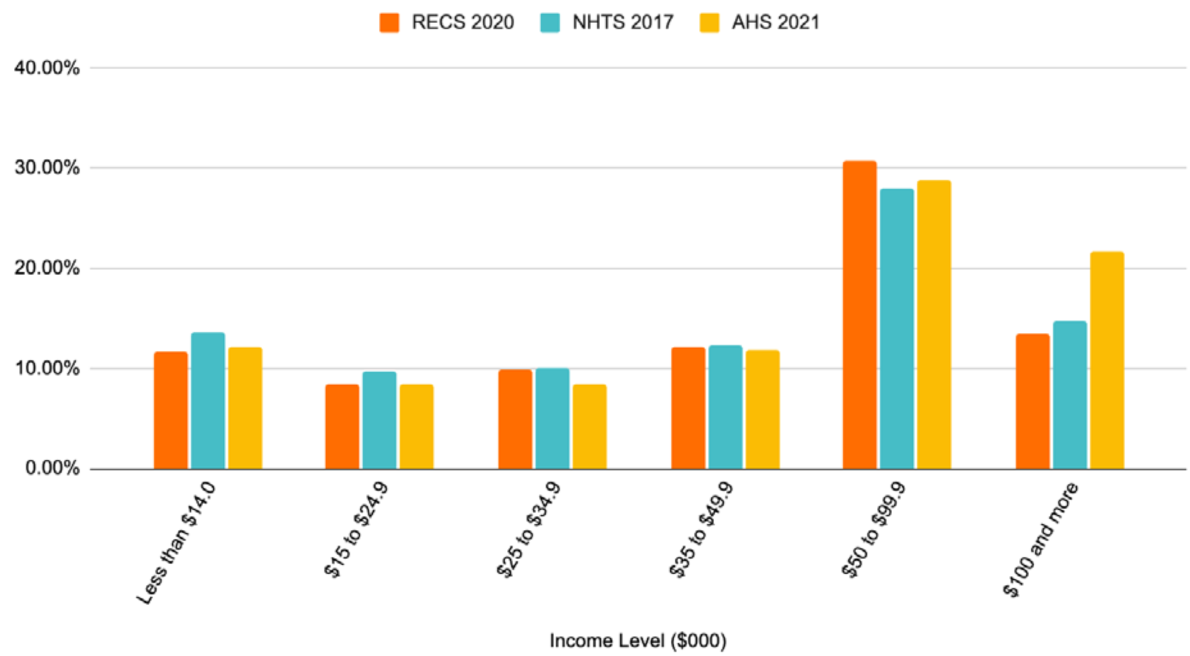

Figure 7. US INCOME DISTRIBUTION COMPARISION: RECS, NHTS, AND AHS

Home Ownership: Both RECS and NHTS provide home ownership status variables. Here we show the shares of renters versus homeowners for the full U.S. population, as estimated through each survey. RECS and NHTS results differ slightly, but both provide evidence of an approximate split of ⅔ of the population owning homes and ⅓ renting (Figure 8).

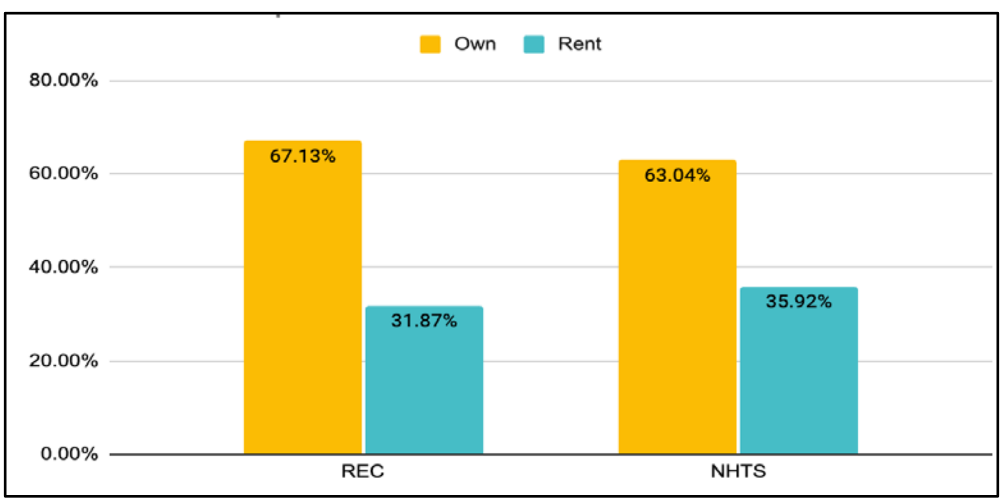

Figure 8. HOME OWNERSHIP RATE COMPARISON: RECS AND NHTS

Educational Attainment: AHS, RECS and NHTS report the educational attainment level of the respondent. Given that BEV adoption, to date, is associated with a high level of education, we focus on households with at least one member holding a bachelor's or advanced degree. In Figure 9, we compare the percentage of total U.S. households with educational attainment of a bachelor's degree or more across the three datasets, finding moderate variation (ranging from

33% in AHS to 53% in NHTS). This may relate to the way that each survey constructs its questions regarding education. As RECS and NHTS also note BEV ownership, we are able to compare the educational attainment of BEV households between these two surveys.

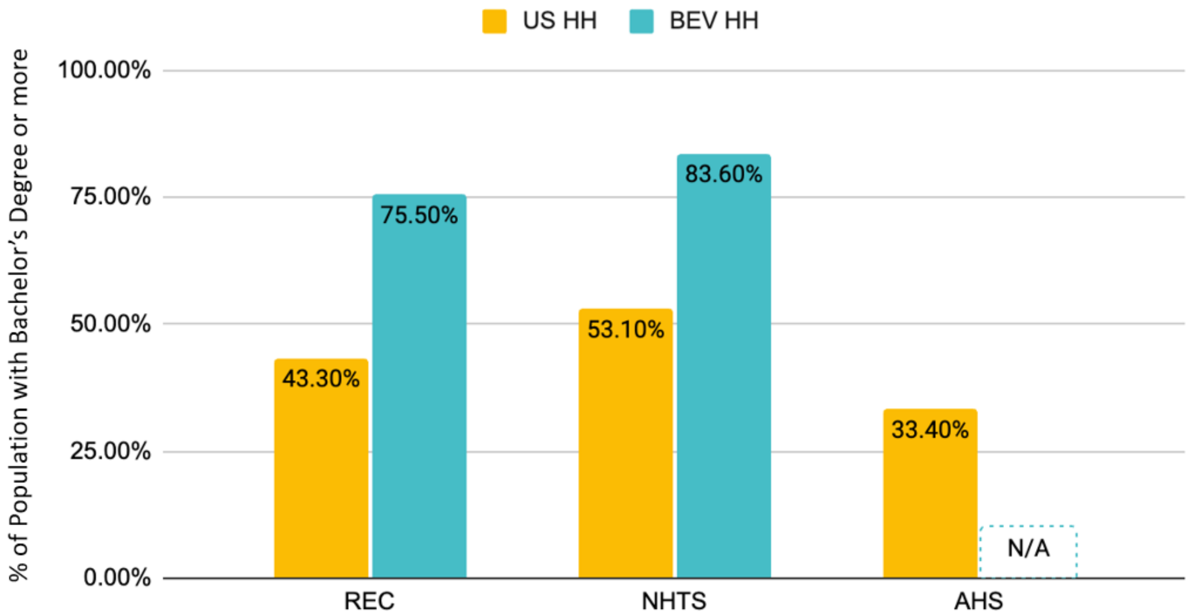

Figure 9. EDUCATIONAL ATTAINMENT COMPARISON: RECS, NHTS, AND AHS

4. Discussion: Analysis Highlights, Implications, and Future Work

We here highlight the most striking findings about the potential market for BEVs, summarizing the presence of enablers across the U.S. population. We assert that the "Early Majority" BEV adopter is likely to have at least one of the enablers of BEV acceptance working in their favor, including household characteristics and aspects of the systems surrounding them. We conclude with a brief discussion of the implications of our findings and the directions of future work on this topic.

Alignment of multiple BEV-readiness enabling factors: After subtracting households that already own BEVs, 46.9% of U.S. households own a single-family home with reasonable home charging capabilities. Of these, we note that 28% are high-income households ($100k or higher annual income), an additional factor that aligns with BEV adoption. Combining the factors of ownership of a single-family home, charging capability, and high income, we estimate that approximately 14% of total U.S. households share these multiple key characteristics with current BEV adopters – roughly 17 million U.S. households, based on the U.S. population as of 2021.

BEVs in multi-car households: Analysis of the NHTS dataset demonstrates that 92.1% of BEV owners have 2 or more cars. We calculate that 63.1% of non-BEV owning household have 2 or more cars. Assuming the pattern of households owning a BEV in addition to a non-BEV vehicle continues as BEV attributes evolve, the potential set of multicar households who do not currently own BEVs comprise a potential market roughly equal to 57.5% of total U.S. households, or roughly 71 million households.

BEVs and home ownership: Both RECS and NHTS confirm that the majority of current BEV owners are homeowners (86.3% of BEV owners in RECS; 85.8% of BEV owners in NHTS), as compared to approximately 67% of non-BEV owners who own their homes. Homeowners who do not yet own a BEV represent 61.6% of total U.S. households, or roughly 76 million households.

Income level and BEV ownership: Both RECS and NHTS report that 55% of BEV owners have incomes that are below $150k, with the 25th percentile income for BEV households approximately $75k. Looking at the full population, we find that 17% (RECS) to 22% (NHTS) of households, or roughly 21-22 million households, earn $75k or more.

Variation in public charging density: The total number of charging ports per capita varies dramatically by region. The zip codes with the highest density of public chargers have thousands of ports per 1,000 population; these are primarily non-residential areas with low population, such as the area surrounding the San Francisco International Airport. The density of public EVSE per 1,000 population within residential and mixed-use zip codes is wide-ranging, starting from the very small 0.09 charging ports per 1,000 people to 40 charging ports per 1,000, with a median of 0.45, as shown in Table 2.

Given the rapidly changing technological and policy features of the BEV market, including vehicle attributes, charging networks, and policy details, exploratory analyses such as the one we have presented in this paper can provide valuable snapshots of the PEV-readiness of what may become the Early Majority of PEV adopters. It can also be beneficial to policymakers concerned with understanding the population segments who may not yet be PEV-ready, whether they are “Late Majority” or “Laggards,” in Rogers’ terminology. Having estimates of the portion of the population that is well positioned to adopt EVs (and based on what characteristics) can give policy makers both a sense of what subsections of the population constitute the “low hanging fruit” and what subsections of the population are at risk of being left behind in the transition to vehicle electrification in the absence of additional support and accommodation.

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Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: KSF, MT; data collection, wrangling, analysis, interpretation, and visualization of results: KSF, NC; manuscript preparation: KSF, NC, MT. All authors reviewed and approved the final version of the manuscript.