SYSTEMIC CHALLENGES AND BARRIERS TO CONSUMER EV ADOPTION

INTRODUCTION TO THE ROOT CAUSE ANALYSIS

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ABSTRACT

Large-scale adoption of electric vehicles (EVs) in the United States can help address environmental challenges, reduce greenhouse gas emissions, improve public health, and lower dependence on foreign oil. While the United States has made significant strides in boosting consumer adoption of EVs, the current rate of adoption appears unlikely to meet the U.S. government's pledged goal of reducing CO_2 emission to 50% of 2005 levels by 2030, and ensuring that EVs represent at least 50% of all new vehicle sales by 2030.

The societal benefits of low carbon transportation scale directly with the levels of EV adoption. Public and private industry stakeholders now have a unique opportunity to collaborate on building efficient, effective, coordinated, and scalable efforts to increase EV adoption.

After rigorous analysis in collaboration with industry stakeholders, EPRI has identified six subject categories that influence EV adoption efforts, namely charging familiarity, consumer needs, ownership experience, consumer inertia, supply-chain inertia, and costs. Using these six categories, EPRI's Electric Transportation program is performing a detailed root-cause analysis of limitations on consumer adoption of EVs to delve deeper into the underlying causes. This is a necessary first step toward identifying ways to mitigate these barriers and accelerate the pace of new light-duty EV adoption in the United States.

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INTRODUCTION

EPRI's Electric Transportation research program gathers utilities, automakers, charging infrastructure companies, and other major national and international electric vehicle (EV) industry stakeholders to collaborate to solve key issues related to EVs. The high-level barriers described in this paper cut across all these industries. As a result, EPRI is uniquely positioned to perform a comprehensive root cause analysis for these EV adoption barriers. Research into the underlying barriers is likely to inform and potentially enhance collaborative EPRI EV research in the areas listed above. Several benefits cut across the various stakeholders—utilities, customers, communities, and society. This section summarizes these overall benefits, and the following section describes stakeholder-specific benefits (see Figure 1).

CROSS-CUTTING BENEFITS			
HIGHER VEHICLE ENERGY EFFICIENCY	VEHICLE PERFORMANCE IMPROVEMENT	MATURE ELECTRIC INFRASTRUCTURE	CONFLUENCE OF TRENDS: RIGHT TECHNOLOGY AT RIGHT TIME

STAKEHOLDER BENEFITS			
UTILITY BENEFITS	CONSUMER BENEFITS	COMMUNITY AND SOCIETY BENEFITS	ENVIRONMENTAL BENEFITS
Leverages grid investments	Improves vehicle performance	Reduces greenhouse emissions	Reduces carbon emissions
Uses utility capacity	Reduces vehicle TCO	Reduces foreign oil dependence	Reduces criteria emissions
Broadens cost allocation	Decreases vehicle operating costs	Promotes fuel diversity, security	

Figure 1. Summary of EV benefit types

Many of the benefits of EVs stem from their significantly higher energy efficiency, compared to gasoline-powered vehicles. According to the U.S. Department of Energy, "77–82% of the energy delivered to the electric plug is used to move an EV down the road, whereas only 12–30% of the energy put into a conventional car is used to move the car down the road" [1,2]. The implications of this disparity are threefold:

- EVs need much less "fuel" than conventional vehicles
- EVs are clean at the tailpipe, and cleaner than conventional vehicles from well to wheels
- "Fueling" EVs can be lower cost than fueling conventional vehicles

Although gasoline prices vary by region, by season, and due to international pressures, the cost of home charging is approximately equivalent to gasoline at $1/gallon ($0.26/liter). Table 1 shows the average cost to drive 30, 100, and 200 miles (48, 160, and 320 km) using electricity, compared to gasoline options. (Note that this table is based on a regular unleaded gasoline price of $2.78/gallon ($0.73/liter); gasoline prices are increasingly volatile due to a variety of factors.)

EVs also present a fundamental performance improvement, compared to their gasoline counterparts. The characteristics of EV motors are fundamentally a better match to consumer driving habits (e.g., instantaneous torque needed, low engine noise, etc.).

MILES DRIVEN	GASOLINE COST	ELECTRICITY COST HOME CHARGING	ELECTRICITY COST PUBLIC CHARGING LEVEL 2	ELECTRICITY COST PUBLIC CHARGING DC FAST
30	$3.33	$1.33	$2.70	$3.10
100	$11.12	$4.44	$8.99	$10.33
200	$22.24	$8.89	$17.99	$20.66

[1] *These calculations assume an average U.S. light-duty vehicle efficiency of 25 mpg (11 kmpl) and a regular unleaded gasoline price of $2.78/gallon ($0.73/liter) (U.S. Energy Information Administration 2021 Summer Forecast); an average electric vehicle efficiency of 3 miles/kWh (4.8 km/kWh); an average U.S. residential electricity price of $0.1334 (U.S. Energy Information Administration, February 2021); and an average value of $0.27/kWh and $0.31/kWh for public level 2 and DC fast charging, respectively.*

Table 1. Average cost to drive 30, 100, and 200 miles (48, 160, and 320 km) using electricity, compared to gasoline [3]

EVs leverage a mature electric infrastructure (the grid) that is ubiquitous. Trillions of dollars in existing, highly reliable electricity delivery infrastructure serves nearly every home and business in the United States. Moreover, this supply chain infrastructure is an effective "carrier," enabling delivery of a range of "fuels" for end uses of electricity (e.g., EVs), including an increasing penetration of renewable resources. All that is needed for an EV to tap into this infrastructure is the so-called "last 50 feet"—the EV charger, the charging cord, and, in the case of commercial charging power, some nearby supporting equipment. What's more, significant strides in availability of various charging speeds and locations (e.g., home, public, etc.) provide significant charging flexibility for EV users. In contrast, alternative transportation options in discussion (e.g., hydrogen, biodiesel, and natural gas) are starting with a far less mature or complete infrastructure for delivery to all end users. Projected growth in electrical distribution capacity needed to accommodate increasing EV loads does not significantly exceed capacity growth that the industry has addressed in the past (e.g., with the introduction of electric air conditioning units). With adequate advance planning, most distribution systems are likely to be able to accommodate EV loads. However, challenges remain, which are largely related to time and cost allocation.

EVs represent the confluence of several trends that make it the right technology at the right time. The core technology component that limited cost-effectiveness and performance in the past—EV batteries—have declined in cost and increased in output. This trend is expected to continue as EV adoption increases. The electric power infrastructure is evolving toward renewables, microgrids, advanced metering, improved grid automation, and other advances that strengthen its ability to host EVs. As the electric grid incorporates more renewable generation, this is automatically incorporated into the carbon reduction capability of EVs; there is no equivalent process for carbon reduction in the conventional vehicle space. This means that while a single EV produces benefits for its user, many EVs produce benefits for utilities, communities, and society in general, including cleaner air and can support downward pressure on electric rates.

BENEFITS OF ELECTRIC VEHICLES

This section summarizes the benefits of EVs to four defined areas: utilities, consumers, communities and society, and the environment.

Utility Benefits

Benefits of EV adoption for electric utilities may include:

- Leveraging investment in the existing utility grid for the generation, transmission, and bulk distribution of electricity
- Making use of capacity on the utility system in overnight periods
- Enabling reduced electric rates if implemented strategically, and enabling broader cost allocation across the utility customer base
- Aligning utility efforts with public advocacy groups, environmental awareness groups, and state policy makers on mutually beneficial EV initiatives
- Reinforcing the role of utilities as a trusted resource for information on EVs and EV charging
- Aligning EV charging infrastructure with grid modernization efforts

Consumer Benefits

Benefits of EV adoption for consumers may include:

- Improving vehicle performance compared to gasoline-fueled cars, including quieter operation and, in some cases, higher instantaneous torque and acceleration
- Reducing total cost of ownership compared to gasoline-fueled cars—a benefit that improves as more miles are driven
- Decreasing the vehicle maintenance cost and increasing the cost stability of vehicle fuel
- Decreasing the overall costs of consumer goods, via lower overall transportation costs
- Broadening customer choice in transportation technologies, as increased adoption stimulates vehicle manufacturers to diversify offerings
- Enhancing consumer resilience by using the EV to power the home during outages (vehicle-to-building or V2B)
- Putting more money in the consumer's pocketbook

Community and Society Benefits

Benefits of EVs to communities and society can include:

- Reducing greenhouse gas emissions. Because transportation in the United States primarily depends on fossil fuels, the U.S. Environmental Protection Agency (EPA) reports that transportation is responsible for 29% of greenhouse gases, more than any other sector [4]. When electricity is generated using renewable resources, EV use can displace CO_2 emissions from gasoline-powered vehicles. As the electric grid incorporates more clean generation, these benefits are transferred to transportation.
- Reducing dependence on foreign oil. The transportation sector accounts for approximately 30% of total energy needs and 70% of petroleum consumption [5]. Increased EV adoption can reduce this dependence by decreasing petroleum consumption in the transportation sector.
- Promoting fuel diversity and energy security through a more stable and available domestic fuel.
- Improving sustainability by reducing greenhouse gas emissions, potentially more economically than alternative methods.
- Supporting U.S. economic growth in the global production of electric drives, batteries, and other supply-chain items.
- Improving urban air quality and human health.

Environmental Benefits

Fuel-Related Benefits: Carbon Emissions

Overall, the energy industry has already made significant strides toward reducing carbon emissions. Across the U.S. economy, annual energy-related carbon emissions declined 1 gigaton (Gt) by early 2020 [6] from a peak high of just below 6 gigatons in 2005 [7].

The United States has pledged to reduce CO_2 emission to 50% of 2005 levels by 2030. This will require tripling the rate of decarbonization from the 1 Gt reduction over the last 15 years to a 1 Gt reduction in each of the next three five-year periods [8]. To help achieve this, the Biden administration has established the goal of ensuring that EVs represent at least 50% of all new vehicle sales by 2030 [9].

CO_2 emissions from internal combustion engine cars depend on the carbon content of the fuel used and the fuel economy of the cars. The latter, in turn, depends on the vehicle fuel efficiency and vehicle use (e.g., urban or highway driving).

For gasoline-powered cars, the emission rate is about 19.4 lb/gallon (2.32 kg/l) [10]. This corresponds to a total of 11,330 lb (5126 kg) of CO_2 emission per year for a car that averages 25 miles/gallon (11 kmpl) with average daily driving of 40 miles (64 km).[1] Widespread EV adoption can be a significant step toward reducing these emissions and mitigating climate change[2]:

- Widespread electric transportation powered by a cleaner grid has the potential to reduce greenhouse gases by as much as 77% by 2050 [6].
- In some cases, even when electric power is provided by fossil-fueled plants, EV emissions are lower than those of a similar-sized gasoline-powered vehicle [11].

Fuel-Related Benefits: Criteria Emissions

EVs can also reduce criteria emissions, which impact human health in urban areas. Nitrogen oxide (NO_X) and sulfur oxide (SO_2) emission rates depend, to a great extent, on exhaust control technologies and vehicles driving cycles (e.g., urban versus highway). The average emission rates that an Argonne National Laboratory model produced are 0.069 grams (0.0024 oz) of NO_X per mile and 0.006 grams (0.00021 oz) of SO_2 per mile for a standard 25 mpg (11 kmpl) gasoline-powered vehicle [14].

According to an American Lung Association study, “the widespread transition to zero-emission transportation technologies could produce emission reductions in 2050 that could add up to $72 billion in avoided health harms.” The report projects that in 2050, 6300 lives will be saved, 93,000 asthma attacks will be avoided, and 416,000 lost work days will be avoided due to significant reductions in transportation-related pollution [15].

[1] *However, this only accounts for the emissions directly generated by the vehicles (i.e., tank-to-wheels). The CO_2 emission rate related to the production of gasoline (i.e., well-to-tank) is an additional 6.0 lbs/gallon (0.72 kg/l) [11], which increases the total emissions to almost 15,000 lbs (6800 kg) per year.*

[2] *EPRI and the Natural Resources Defense Council published a paper in 2016 that describes best practices for projecting emissions of greenhouse gases from the grid [13].*

ACHIEVING BROADER EV ADOPTION

This section summarizes the current status of EV adoption and the process of increasing adoption.

While the benefits of increased EV adoption to all stakeholders are compelling, reaping these benefits on a large scale will not be easy. Some factors have helped move stakeholders toward achieving these benefits; for example, federal investment of $7.5 billion in EV-related development includes a national EV charging infrastructure and more consumer rebates for EV purchases. However, rapid, significant changes in the makeup of the automotive industry, supply chains, and infrastructure have posed a range of growing pains for utilities, consumers, and communities. At the same time, the need to achieve broader EV adoption presents an opportunity for public and private industry stakeholders to collaborate on building efficient, effective, coordinated, and scalable EV adoption efforts.

EV adoption rates are already rising and are currently estimated to reach approximately 29.5% of new car sales in 2030, which is impressive but short of the Biden administration's goal [16]. Understanding and resolving consumer barriers to EV adoption is mission critical for the electric power industry, automotive industry, and government agencies.

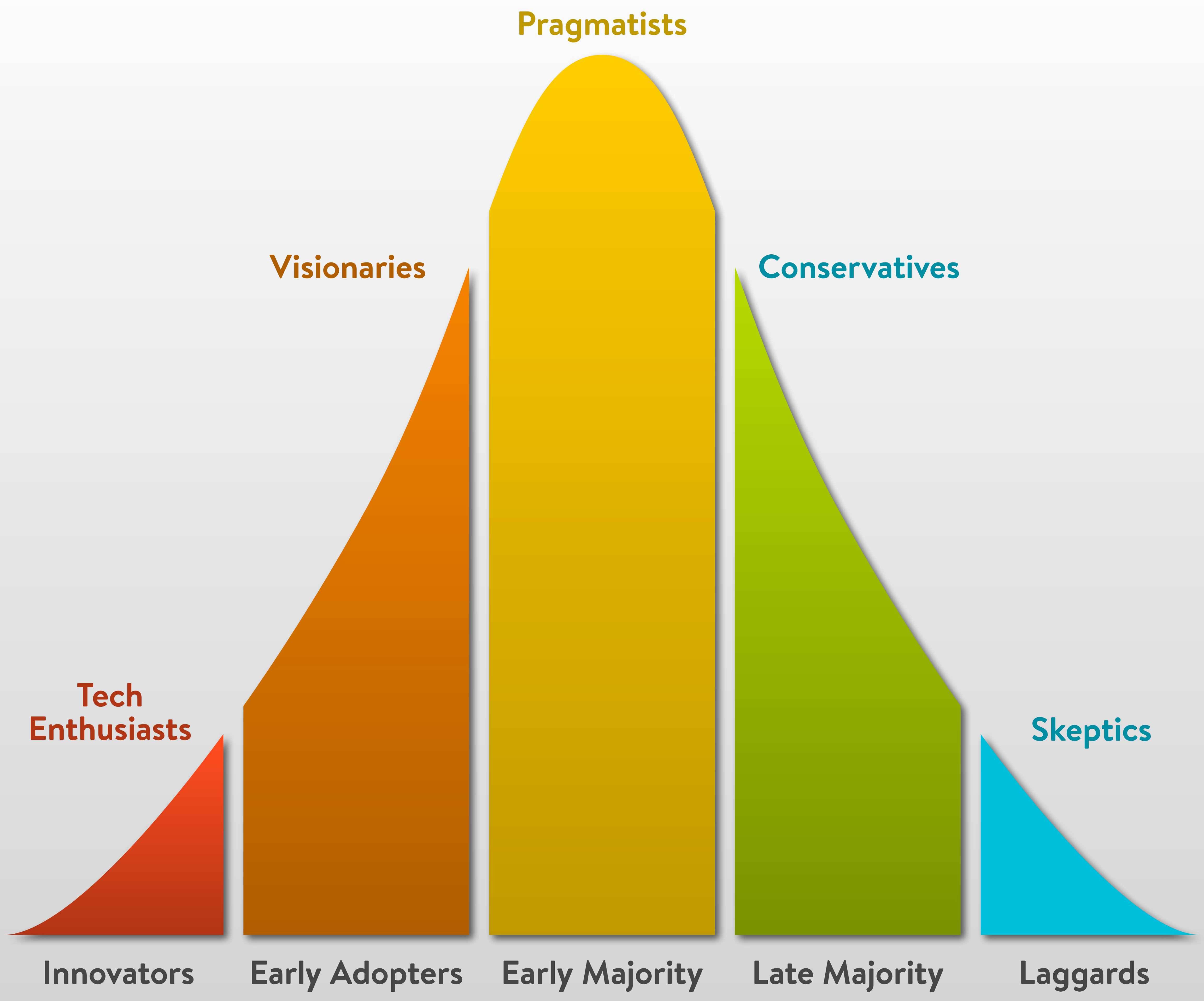


Figure 2. EVs remain low on the product adoption curve

Accelerating EV adoption means moving beyond and appealing to a broader audience than just the "innovators" portion of the production adoption curve (see Figure 2). Part of appealing to a broader audience is ensuring that current buyers, who take the "risk" of EV purchase, have a positive experience and spread the news. More generally, the sales conversion process consists of four stages: awareness, familiarity, consideration in last purchase, and purchase (see Figure 3). Innovators may be open to a different body style than their original purchase. Conversely, mass market EV adopters are more likely to insist on the body style they want. Potential EV buyers need to be converted through each stage.

Insights may be gained by exploring why consumers have historically not moved from one stage to the next (e.g., not moved from consideration to purchased). Solutions to address one stage of the customer journey may not result in impacts to all stages of the customer journey. For example, customer awareness campaigns may not impact consumers moving from the consideration phase to the purchase phase.

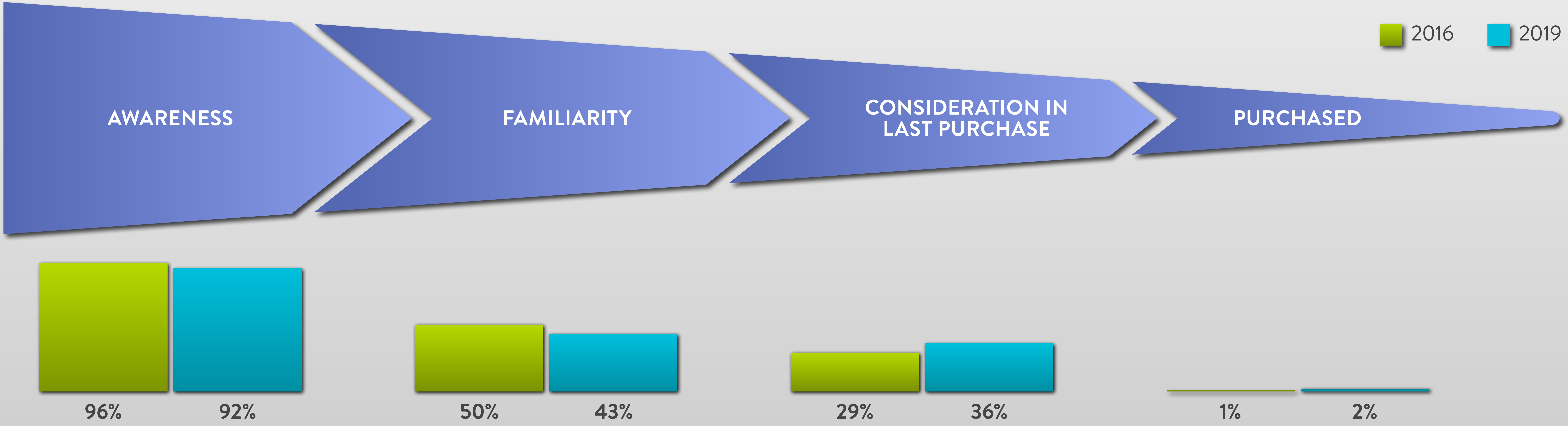


Figure 3. The four stages of the sales conversion process, with percentages of U.S. consumers in each stage in 2016 and 2019 [17].

INDUSTRY TRENDS

Many technological advances, economic incentives, policy incentives, and policy initiatives and improvements are planned or already in place to support the growth of the U.S. EV market. These include investments in charging infrastructure technology, expanding charger availability, vehicle performance improvements, decreasing battery and vehicle costs, broader EV availability and variety, and financial incentives and tax credits.

Increasing EV Infrastructure. Infrastructure to support EVs is growing rapidly, especially utility infrastructure. As of September 2021, infrastructure commitments across North America included 105 different EV infrastructure programs by 61 utilities in 38 states. The combined costs of these infrastructure investments are estimated at approximately $3.6 billion.

In Figure 4, states and provinces where at least one utility has committed to increasing EV infrastructure are displayed in blue. Many utilities serve states that have lower EV adoption rates, compared to the national average. Successful utility programs in these states can help increase general customer acceptance throughout the nation.

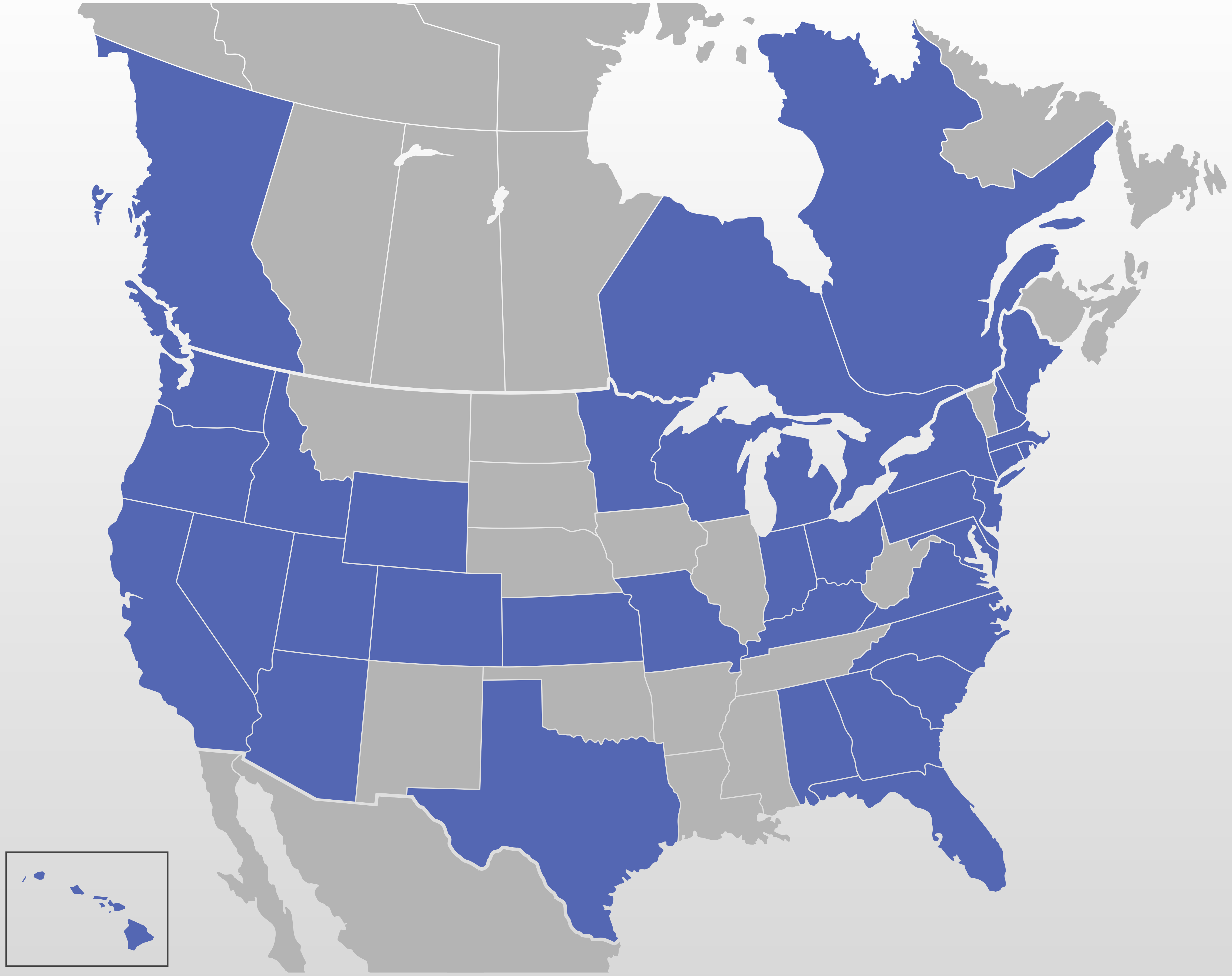


Figure 4. North American states and provinces where utilities have committed to building EV infrastructure are displayed in blue

Public Charger Availability. The number of public chargers in the United States is growing: As of August 2022, 26 states have at least 1000 public charging stations, and the United States overall has 109,770 charging station locations with a total of 141 charging connectors [18,19]. However, to support an estimated 26 million EVs in the United States in 2030, some estimates of needed public and workplace chargers top 2 million (at least a 20-fold increase) [20].

Vehicle Performance Improvements. Recent breakthroughs and improvements in EV technology, availability, and variety are increasing the appeal of EV ownership. For example, EV battery range has more than tripled from 2011 to 2022 (see Table 2) [20].

Battery size and charging speed have improved as well. The speed at which an EV charges depends on both the battery size and type of charger. At-home charging using a standard 120-V outlet can take hours, while a 240-V fast charger can take less than 30 minutes to add 40 miles of range [21].

Decreasing Battery and Vehicle Costs. Currently, the purchase price of a new EV is generally higher than a comparable gasoline-powered vehicle, largely due to the cost of batteries [22]. Current EVs rely on lithium-ion battery packs. In 2020, lithium-ion battery cells cost approximately $137 per kWh, which represents an 89% reduction from their 2010 costs of $1100 per kWh. Lithium-ion batteries are becoming less expensive, and some forecasts predict they will drop to $92 per kWh by 2024 and as low as $58 per kWh by 2030. Future technologies and improvements in battery chemistry and battery pack design may help further reduce costs [23]. A 2019 paper from the International Council on Clean Transportation (ICCT) predicts EV initial cost parity within 5–10 years [24].

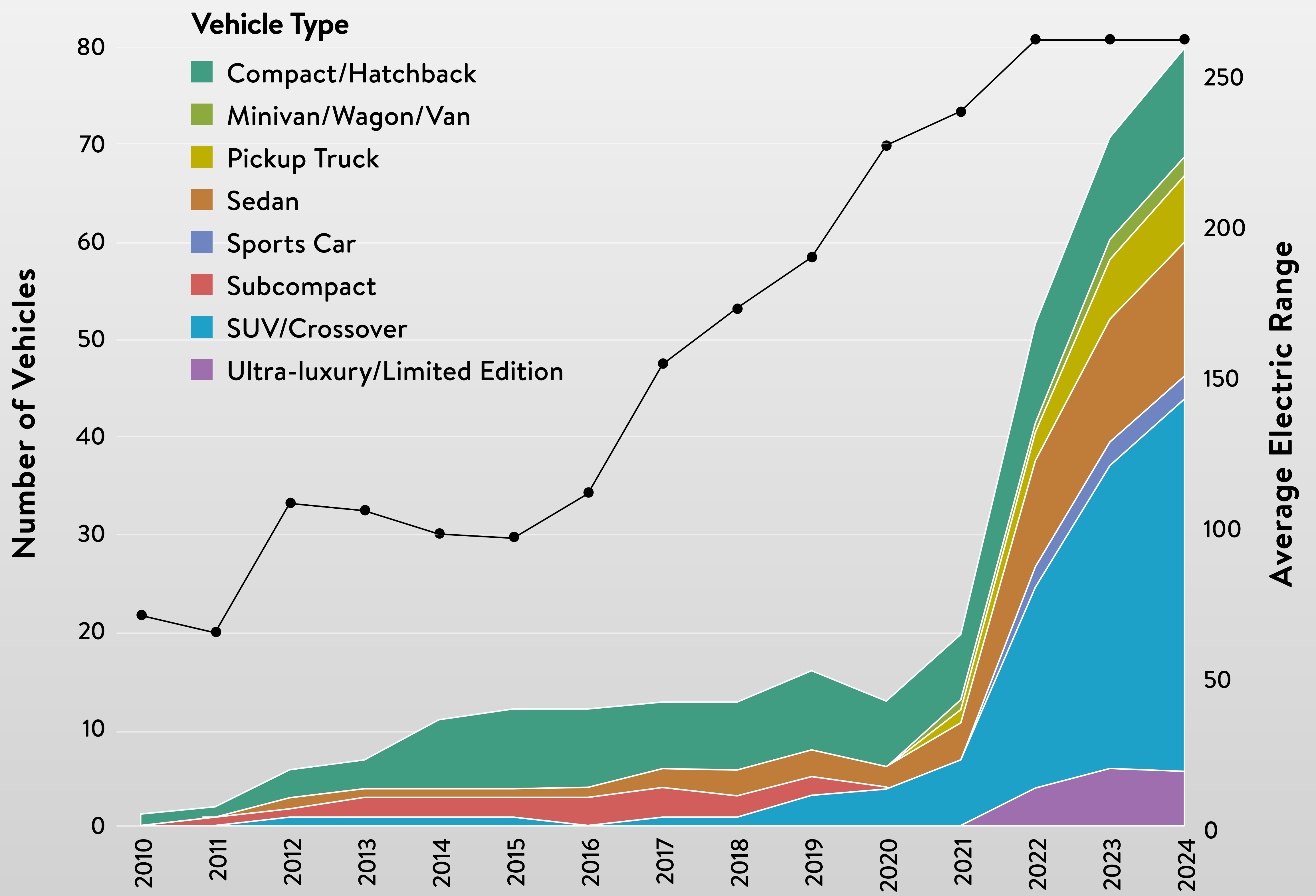


Figure 5. Annual average range of battery EVs (2011–2022) Source: EPRI

EV Availability and Variety. The number of available EV models is significantly expanding—a trend that will likely continue due to automaker competition—with a wide range of price points and features entering the market. In November 2021, automakers such as Ford, Mercedes-Benz, General Motors, and Volvo pledged to work toward phasing out sales of new gasoline- and diesel-powered vehicles in “leading markets by 2035 and worldwide by 2040” [25]. In 2021, 48 different EV models were available for sale [26].

Vehicle Production Improvements. EVs can provide benefits to vehicle production due to their relatively simple design. EVs have fewer moving parts than internal combustion engine (ICE) vehicles. There is significant potential for reuse of major parts (e.g., motors and electronic controllers) between widely differing vehicles, which is not possible in ICE manufacturing [27]. Additionally, many parts required for EVs (e.g., battery cells) are relatively easy to standardize, which can help automate production and potentially decrease costs as learning progresses. Although EV production costs of like vehicles remain higher than ICE counterparts, this gap is expected to close as automakers design dedicated EV platforms, further consolidate powertrain designs, and increase the volume of production. This, in turn, can expand the market potential for EVs [28].

EV Tax Credits and Incentives. Most types of EV incentives increase consumer adoption rates, and EV incentives are widely credited for high adoption rates in Europe and Asia [29]. In the United States, the greatest numbers of EVs are in cities that have aggressive government and utility incentive and education programs. Currently, 45 states and the District of Columbia provide some utility or state incentives for certain EVs, although the number, type, and financial elements vary considerably by state [30]. Federal funding has also been allocated for purposes of stimulating EV market adoption.

State-level zero emission vehicle (ZEV) regulations are also delivering results. In these states, the new EV adoption rate is around 11% compared to the national new EV adoption rate of 6.6%. [31]. Currently, 14 states (mostly in the northeast and far west) and the District of Columbia have adopted California’s emissions standards that require manufacturers to sell a certain number of ZEVs per year [30].

RESEARCH GAP: IDENTIFYING ROOT CAUSES OF CONSUMER BARRIERS

This section first summarizes consumer barriers to EV adoption that organizations have identified in various recent studies. Then, this section describes the EPRI methodology for identifying major categories of barriers to EV adoption, summarizes the six categories, and summarizes the type of expected results from future deeper dives into these categories.

Understanding Consumer Trends

Despite the many improvements in EV technology and increasing government incentives, the pace of EV adoption in the United States is inadequate to meet stated decarbonization goals [34]. While 39% of Americans today indicate they would consider purchasing an EV, the overall market share of EVs in the United States is currently about 6.6%. To meet climate goals, utilities, communities, and policy makers need to identify, fully understand, and mitigate the underlying reasons that consumers who are considering EVs continue to purchase gasoline-powered cars [34].

Organizations such as McKinsey & Company, Deloitte, and BloombergNEF[3] have conducted meaningful studies and surveys to identify broad consumer barriers to EV adoption. Broad barriers include vehicle variety, vehicle costs, vehicle driving range, consumer charging concerns, and consumer hesitancy to adopt new technology.

[3] *Additional organizations include YouGov, the International Council on Clean Transportation, Resources for the Future, the Center for Sustainable Energy, the Alternative Fuels Data Center, and others.*

Study Methodology

While identifying these general consumer concerns is an important first step in improving market awareness, they are insufficiently precise to fully understand why consumers are relatively slow to adopt EVs. Such in-depth understanding requires a meticulous root cause analysis. The root causes are likely to be numerous, complex, and regionally diverse. Furthermore, a range of factors that cut across industries, stakeholders, and governments may influence or impact each underlying cause.

Unfortunately, little or no research details specific, actionable, underlying causes of limited consumer adoption of EVs. Deeper insights into the complex interactions of consumer attitudes and motivations, technology adoption considerations, and other factors are needed.

To address this need, EPRI surveyed the relevant literature, interviewed subject matter experts (SMEs) in the electric power industry and auto industry, and identified six categories of barriers to consumer adoption of EVs. For each barrier category, the project team asked themselves the question of why EV adoption is not advancing rapidly. In effect, this enabled the team to reverse engineer or backout the underlying category of barrier.

The project team plans to produce papers with more in-depth analyses of each of the following defined categories of barriers (in the order listed, not necessarily in order of importance):

- Charging familiarity
- Consumer needs
- Ownership experience
- Consumer inertia
- Supply chain inertia
- Costs

This paper summarizes each of these categories below, but the team may modify them as it conducts more research.

Charging Familiarity

This barrier category addresses consumer uncertainty, confusion, hesitancy, and lack of familiarity with EV charging, as well as the lack of public charging visibility. This category affects any stakeholder that can help decrease charging uncertainty, including auto dealerships at the point of sale, public advocacy groups, utilities, and others.

Currently, 78% of Americans think finding an EV station is difficult [35], whereas gas stations are ubiquitous. Many consumers are hesitant to embrace the paradigm shift from gas stations to home and public charging. They are uncertain about the availability of home charging, especially in multifamily dwellings. At the same time, many consumers are confused about the various EV charging speeds and required connectors, and they typically do not know who they can trust to provide the information they need about charging. Consumer confidence in the EV charging system is a crucial element in their decision to purchase an EV; without it, many consumers are unlikely to seriously consider acquiring an EV due to word of mouth marketing (WOM).

Consumer Needs

This barrier category addresses consumers' vehicle needs and preferences, concern about lack of preferred model availability, frustration with complicated purchase processes, and other consumer needs. This category primarily affects auto dealerships and automakers, but also any other stakeholder that can help increase customer awareness and familiarity with ways that EVs can meet consumer needs.

Consumers want their preferences to be satisfied, including vehicle features, vehicle capabilities for a variety of uses, and vehicle brand and image. Many consumers express frustration at lack of availability of the model and combination of features that they desire, as well as a purchase process that they perceive to be more complex, compared to buying an ICE vehicle. This category also includes the inability of auto dealerships to meet consumer needs during the purchasing process. These dealerships may have inadequate readiness to sell, need EV sales training and incentives such as maintenance packages, and may have a longer EV sales process. Due to the significant upfront investment involved, consumers are unlikely to purchase a vehicle that fails to meet their various needs, especially if they perceive that ICE vehicles meet these needs.

Ownership Experience

This barrier category addresses consumers' anxiety about EV range, concerns about the charging experience, uncertainty about vehicle maintenance and repairs, and other aspects of the EV ownership experience, after the initial purchase. This category affects any stakeholder that can help educate consumers about the experience they can expect after they purchase an EV. This can include public advocacy groups, as well as peers who can attest firsthand to the ownership experience.

Typical mass-market EVs can drive 200–300 miles (320-480 km) per charge [36], which is less range than most ICE vehicles. Consumer concerns about EV range include their desire to be able to drive without restrictions or advanced planning, cold weather impacts on EV range and charging availability, and real-world versus published range figures. The charging experience presents uncertainties related to lack of public charging infrastructure, difficulty using this infrastructure, and anxiety over the charging process itself. Many consumers are also uncertain about the maintenance and repair needs of an EV (including battery life), compared to corresponding ICE vehicle needs, with which they are quite familiar. Given that many EV purchasers will own their vehicle for several years, these owners' perceived expected experience during this long period must be positive to increase EV adoption.

Consumer Inertia

This barrier category addresses various factors related to consumers' inertia—their inherent change-averse nature—especially to a consumer product as fundamental and important in their life as their family transportation. Factors in this category include consumers' over-attachment to the status quo, perception of being forced to change, and lack of awareness. This category affects any source that consumers trust (e.g., auto dealerships, utilities, NGOs, OEMs, etc.) to help them make a decision that is outside of their normal experience [37].

Generally, the more a consumer perceives behavior to be a social norm, the more likely they are to perform the behavior [38]. Because 65% of Americans have never driven an EV or do not know anyone who drives an EV [35], most consumers simply do not view EV purchases as an accepted social norm. Consumer resistance to accepting advice from untrusted sources includes skepticism of touted EV benefits, limited peer support to validate EV claims, and anxiety over reliance on an unproven supply chain. Lack of consumer awareness can include lack of interest in cars or innovation, limited exposure to EVs, misinformation about EVs, and lack of up-to-date and unbiased information on EVs. Inertia and resistance to change are powerful forces to overcome, but must be effectively addressed to boost EV adoption.

Supply Chain Inertia

This barrier category addresses various limitations and uncertainties related to the EV manufacturing process, as well as policy issues that can slow EV adoption. The policy makers themselves need to collaborate to resolve the latter issues, while auto industry associations and other entities that automakers trust need to collaborate to address the former issues.

Manufacturing issues include the time and investment needed to develop and adopt new vehicle production tooling and scale the battery supply chain [39], uncertain profitability of new vehicle platforms, and market-protection instincts to support legacy ICE vehicle investments. Despite these limitations, 13 new EV battery plants are planned in the United States in the next five years, and eight of these are joint ventures between automakers and battery companies [40].

Costs

For EV purchasers, the elephant in the room is cost—primarily the down payment and monthly payment. Any entity that can provide unbiased cost information to consumers is a key player here.

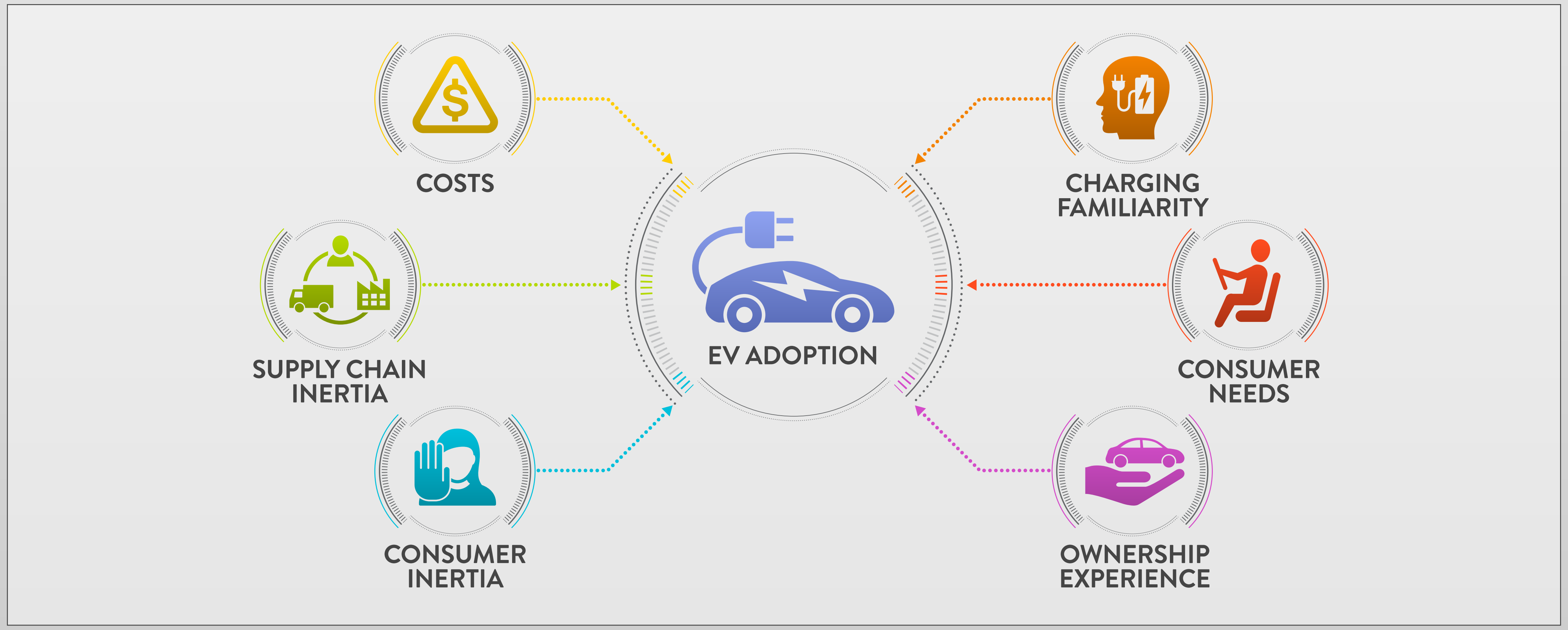
Recent studies show that, on average, the total cost of ownership (including upfront cost, insurance, maintenance, repair, and disposal) of an EV purchased today is lower than a corresponding ICE vehicle [39,42]. Despite this reality, the sometimes larger upfront cost of an EV compared to an ICE vehicle dissuades many would-be EV purchasers. Most consumers focus on the monthly payment of the vehicle, rather than the lifecycle cost. Consumers also are concerned about the uncertainty of future fuel cost savings, potential rapid depreciation due to technology obsolescence in a rapidly evolving market, uncertain battery replacement costs, and uncertainty of continued EV incentives at both the federal and state level.

THE NEXT STEPS AND EXPECTED RESULTS

In next steps, the EPRI project team will produce possible actionable items, questions for stakeholders, and research needs. To do this, the team has built out a preliminary yet comprehensive root cause analysis—building on the six categories identified in this paper—and has incorporated feedback and input on this analysis from utilities, auto industry representatives, and other stakeholders in a webinar and by other means. The team will then document this root cause analysis by developing six deeper-dive white papers—one for each of the barrier categories to EV adoption described in this paper. **These papers will serve to assemble, organize, and specify the underlying causes of barriers to EV options in these six areas. These papers will represent the first such comprehensive assembly and organization of this information.**

This analysis will feed back into the EV adoption goal and identify gaps in needed information. The team will then gather needed information by reaching out to electric power industry and auto industry SMEs, as well as other secondary sources. The next steps will be to identify and prioritize research priorities, identify areas in which EPRI can perform needed industry research, and develop plans to address key challenges to EV adoption. The team will also recommend which stakeholder types can most effectively implement recommended actions.

An important later step involves monitoring actions and markets using defined key performance indicators to monitor progress toward reducing and alleviating the barriers to EV adoption. Throughout this process, the team will document insights gained and recommendations developed in various forms that are most useful to various defined audiences. This entire effort aims to effectively and in a timely manner identify the root causes of limited EV adoption, identify actions to alleviate these limitations, suggest various stakeholder implementation of these actions, and monitor progress to this end. **The ultimate goal is to help utilities, customers, communities and society, and the environment realize the many benefits of accelerated EV adoption described in this paper.** The papers will address the barriers in no particular order or relevance; the project will separately address each barrier in a similar manner.



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