Comparison: Real World Cost of Fueling EVs and ICE Vehicles

Second Edition

Higher Energy Prices in 2021 Give Some EVs a Fueling Cost Advantage

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1. Introduction

The automobile industry is on the cusp of the biggest transition in fundamental technology since the early 1900s. In the first decades of the 20th century, gasoline-powered vehicles won the technology race against competitors that included electric, steam, and horse-powered carriages. Now, in the third decade of the 21st century, electric vehicles are ascendant. Automakers, as well as state and federal governments, are projecting rapid increases in the sales and use of electric vehicles.

However, consumer adoption of electric vehicles (EVs) has been slow. In calendar year 2021, battery electric vehicles accounted for less than 3% of new vehicle sales in the United States. As we prepare this second edition early in 2022, EV sales remain at 3.1% of the US market.¹

Consumers face a technology change that affects vehicle usage, features, and costs. In this report, we compare the cost of fueling electric vehicles with their familiar internal combustion engine (ICE) counterparts. These recurring costs represent a significant share of the total cost of owning and operating a vehicle.

Anderson Economic Group began a rigorous analysis of the real-world consumer market for electric vehicles in 2020. We knew that the cost of fueling these vehicles would be an important part of consumer purchasing decisions. However, we were not satisfied with the handful of calculations that were publicly available at the time. These ignored some of the costs for one type of vehicle while including them for the other—giving a distorted view of the choice consumers face.²

We began by stating clear principles, including recognizing all categories of costs for both types of vehicles and considering the real-world costs for a variety of households.

- For principles followed in this study, refer to Exhibit A: “Principles Guiding This Analysis” on page 3.

¹ Fourth quarter 2021 EV sales penetration was 3.1%, with supply chain problems depressing vehicle sales and production. See the Anderson Economic Group Auto Dashboard at https://www.andersoneconomicgroup.com.
² See “Comparison With Other Reports on EV Fueling Costs” on page 34.
Two of these principles deserve particular mention:

**Including a Range of Consumers**

Electric vehicle adoption in the United States has, thus far, been dominated by affluent households in metro areas. These consumers generally have much higher incomes than the median American household. They are also more likely to own their own home, and to benefit from the federal income tax credit available when purchasing many new EV models.

A large share of recent public discussion regarding electric vehicle adoption focuses on these affluent early adopters. However, manufacturers are extending product lines and introducing new EVs intended for the entire population. Furthermore, our national policy to support EV adoption is motivated by a desire to transition a large share of the active fleet from internal combustion engine vehicles to electric vehicles.

For these reasons, we consider a range of users, including people in rural areas, people without garages, and people who purchase used cars.

**Information that Reflects the Driving Experience**

We consider the cost of fueling from the driver’s perspective by consulting information that reflects the actual driver experience, including:

- The time required to refuel EVs and ICE vehicles, for which we make use of stopwatch measurements.
- The cost of commercial charging, the variation among fees, and the data on commercial charging yields from multiple providers.
- The infrastructure available for commercial charging.
- Reports from EV drivers that reflect their experiences with the reliability, time, and costs of charging.
- Tax laws in multiple states and for the United States.
- Consumer-focused auto industry practices, including the segments within similar vehicles are presented to the public, and the typical purchase prices within those segments.
- Government data on mileage for both ICE vehicles and EVs.
EXHIBIT 1. Principles Guiding This Analysis

A. We include all categories of fueling costs for both types of vehicles.

A fair comparison must include all categories of costs for both EVs and ICE vehicles. This applies to costs that are bundled with other purchases and to those charged separately.

B. We consider a wide range of households and drivers.

The United States has over 200 million vehicles on the road. These are registered to people living in cities, suburbs, and rural areas; to working class, middle class and wealthy households; and to those who have one car parked on the street as well as three cars parked in a garage. Some were bought new, some were bought used. Some have had extensive repairs, others are like new.

We consider a wide range of use cases, including renters, one-car families, residents of rural areas, and people who cannot afford to purchase a new car.

C. We respect consumer choice.

Consumers should choose the vehicle that is right for them. We hope our analysis will give them useful information to make this choice, but we respect their right to select a vehicle that best meets their needs.

D. We consider the driver’s experience.

We examine the costs of fueling from the driver’s perspective. Thus, we take into account time burdens, variations in living and working arrangements, and costs imposed through taxes, installation, and commercial charging fees.

E. We recognize broader issues, but focus on quantifying costs.

The transition to electric vehicles involves broad societal questions, including the net environmental costs of different types of vehicles; sources of both electrical power and petroleum; the vulnerability and environmental costs of battery production elements, and others.

We recognize the importance of these broader questions. However, this report remains focused on the cost of fueling.
The first edition of this report received widespread coverage in the news media and among the EV community. We reviewed dozens of articles and over 1,000 comments from readers around the country.

We noted two topics that came up repeatedly: the use cases for EV drivers, including how and where they charged; and the differences in energy costs over time or across states. Perhaps the most notable reader comment was: “I charge at home all the time, except when I travel!”

This feedback motivated multiple improvements in this edition. First, we now use full-year data for 2019, 2020, and 2021, and explicitly estimate costs for different years. Second, we significantly expand the number of use cases, and present calculations for each one on the power consumed from residential and commercial sources. Third, add a geographic analysis of the charging infrastructure, and make use of operating data from charging services.

• See Exhibit 2, “Improvements in the Second Edition” on page 5.

Importantly, we did not alter the underlying principles followed in our research. In particular, in this edition as in the last, we count every category of cost for both types of vehicle, and use real-world data that reflects a range of driver experiences.

• See Exhibit 1, “Principles Guiding This Analysis” on page 3.
EXHIBIT 2. Improvements in the Second Edition

A. Expanded use cases.

In the first edition, we presented three use cases for EV drivers and three for ICE vehicle drivers. In this edition, we significantly expand the number of use cases for electric vehicles. The broader number of use cases allows readers to select the use case that is closest to their own situation. As in the first edition, we use three EV and three ICE vehicle use cases as benchmarks.


In this edition, we make use of data from 2019, 2020, and 2021. In the most recent year for which we have complete data, electricity prices increased, but gas prices increased dramatically. The cost of installing residential chargers and road tax rates also changed.

This second edition allows the reader to compare costs over multiple years.

C. Geographic and Operational Analysis of Charging Infrastructure.

In this edition, we include a geographic analysis of the charging and fueling infrastructure in a metro area, which informs the assumptions regarding deadhead miles and fueling modalities. We also include data on yields and frequency from commercial charging providers.

D. Minor improvements in data, calculations, and assumptions.

We made some minor improvements in this edition, such as:

- Heat losses: We now use separate values for AC and DC chargers.
- Deadhead miles: We now assume different average distances for L2 and fast DC commercial chargers.
- Power from residential and commercial chargers: We now calculate these directly based on charging frequency in each use case.
- State road taxes: We now specify these by state, and discuss policy issues related to federal and state road taxes.

E. Discussion of Infrastructure and Policy Issues.

Our first edition brought to light a number of infrastructure and public policy issues that affect EV drivers and costs. In this edition, we have a section that discusses several of these, including state and federal road taxes, distribution of subsidies and credits, and safety issues.
2. Findings

**Finding 1. There are four categories of costs for fueling vehicles.**

There are four categories of direct monetary costs for fueling both EVs and ICE vehicles. A fair comparison must include all four.

**Four Categories of Costs.** Consumers incur four categories of direct monetary costs for both electric and internal combustion engine vehicles. These four categories are:

1. The cost of the underlying energy,
2. The excise taxes charged for roads,
3. The cost of the pump or charger, and
4. The cost of driving to and from the fueling station, known as “dead-head miles.”

**Using Consistent Assumptions for Both Types of Vehicles.**

To properly compare the cost of fueling electric vehicles with that for internal combustion engine vehicles, we must account for all four categories of costs for both types of vehicles.

- See Table 1, “Four Categories of Direct Monetary Costs of Fueling EVs and ICE Vehicles,” on page 7.

A fair comparison also requires a consistent set of assumptions for both types of vehicles.

- See “Consistent Assumptions for EVs and ICE Vehicles” on page 8.

**Avoiding the Error of Comparing Different Sets of Costs.** It is a simple matter to calculate part of the fueling costs of an EV, but nearly all of the costs for an ICE vehicle. This can be done by comparing only the cost of electricity for EVs, but the costs of fuel, pumps, and road taxes for ICE vehicles. While this is a simple calculation, it is neither accurate nor fair.

**Analysis Required for Fair Comparison.** Properly comparing these costs requires the analytical steps we undertake in this report, including separating energy, taxes, and operating costs. Both this edition and the first edition follow the principle of including all comparable costs for both kinds of vehicles.

- See “Methodology for Estimating Monetary Costs” on page 27.
- See also “Principles Guiding This Analysis” on page 3.
Comparison: Real World Cost of Driving EVs and ICE Vehicles

Anderson Economic Group, LLC Findings

3. This method significantly understates the relative fueling costs of EVs, by neglecting cost categories that are included for ICE vehicles. It also frequently misses a portion of the electrical costs that represent heat losses in charging, and ignores the higher electricity prices paid by EV drivers using commercial chargers.

On top of this, this method misses an advantage for those EV drivers that can regularly charge at home, and therefore avoid much of the deadhead miles needed to reach commercial gas stations.

See Exhibit 5., “Representative Analyses of EV and ICE Fueling Costs” on page 36, and the Finding “Commercial charging is necessary for most Americans who drive electric vehicles.” on page 11

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TABLE 1. Four Categories of Direct Monetary Costs of Fueling EVs and ICE Vehicles

<table>
<thead>
<tr>
<th></th>
<th>EVs</th>
<th>ICE Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Energy costs</td>
<td>These cover electricity provided and charged at residential or commercial utility rates. They include the per-kWh charge and any session or time charges, along with electricity lost through heat during the charging process.</td>
<td>1+2+3. Retail price of gasoline or diesel fuel. Includes energy costs, road taxes, and the cost of operating the pump.</td>
</tr>
<tr>
<td>2. Excise taxes for roads</td>
<td>EV highway registration taxes. These vary by state and weight of vehicle.</td>
<td></td>
</tr>
<tr>
<td>3. Cost of charger</td>
<td>Cost of operation for commercial charger, or cost of installing and operating a residential charger. The cost of operating a commercial charger is embedded in the fee charged to the consumer.</td>
<td></td>
</tr>
<tr>
<td>4. Deadhead miles</td>
<td>Driving distance to and from charging stations. This is zero when home charging, but often considerable when using commercial chargers, and varies significantly.</td>
<td>Driving distance to and from gas stations. This is typically short in most areas of the country due to the ubiquity of gas stations.</td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group (2021) research.
EXHIBIT 3. Consistent Assumptions for EVs and ICE Vehicles

Regular Use Consistent with Actual Driving Patterns in the USA
We assumed the vehicle was in regular use and was driven 12,000 miles per year, plus any additional miles needed to reach commercial gas or charging stations.

- See the Finding “Commercial charging is necessary for most Americans who drive electric vehicles.” on page 11.
- See also Table B-2, “Direct Monetary Costs of Fueling ICE and EVs Using 2021 Energy Prices,” on page B-11.

Benchmark Use Cases Derived from Commonly Purchased Vehicles
Our representative vehicles included EV and ICE cars in segments used by most American households. We use these to identify benchmark use cases that represent a range of US drivers.

- See Table B-1, “ICE Vehicles and EVs in Different Consumer Segments, 2021,” on page B-3.

Range of Charging Modalities
EV drivers choose between home and commercial chargers depending on their residence, infrastructure availability, work commute, and other factors. Because these vary widely among drivers, we created an array of use cases to represent a large share of actual owners.

- See Table B-7, “Charge Added to Battery Under Different Use Cases,” on page B-15.

Deadhead Miles for Both Types of Vehicles
We accounted for the burden of deadhead miles for both EVs and ICE vehicles. The burdens were estimated in a manner consistent with the different use cases.

All Categories of Costs for Both Types of Vehicles
We used data on all four categories of costs, for both types of vehicles.

- See “There are four categories of costs for fueling vehicles.” on page 6. See also Table 1, “Four Categories of Direct Monetary Costs of Fueling EVs and ICE Vehicles,” on page 7.
Finding 2. EV driving imposes significant time burdens

EV drivers experience fueling time burdens that can be five to ten times higher than those for comparable ICE vehicles. The time burden is higher because fueling an EV commonly requires both more time per session and more sessions.

Fueling a vehicle imposes a time burden as well as monetary costs. For ICE vehicle drivers, the time burden is usually limited to occasional visits to a nearby gas station. Our stopwatch measurements confirm that such visits can often be accomplished within five minutes.

However, for EV drivers, the fueling time burden is considerably larger. To compound this burden, the range of EVs now in active use is significantly shorter than that of most ICE vehicles. Thus, for the same number of miles, charging an EV both takes much longer and must occur more often than it would for a comparable ICE vehicle.

Time-Consuming Tasks for Fueling Vehicles

Tasks and related time burdens involved in fueling electric vehicles include:

- **Charging or Pumping.**
  This is the most obvious time burden, and the one that captures the most attention. For EVs, we include only the time spent waiting at commercial chargers as a burden, presuming that charging time at residences do not impose a significant burden. For ICE vehicles, we presume all pumping is done at commercial stations, and include the time.

- **Connecting and disconnecting.**
  Both commercial chargers and gasoline pumps require payment, which takes a small amount of time. EV chargers typically require additional time for establishing a safe electrical connection and for confirming the account credentials of the vehicle.

- **Traveling to and from the charging station.**
  There are currently far fewer EV charging stations than gasoline stations. Thus, the deadhead miles that EV drivers must drive tend to be much higher than for drivers of ICE vehicles. Conversely, EV drivers who can rely upon home charging save some of this time.

- **Additional time due to unreliability.**
  EV chargers are much less reliable that gasoline pumps. Software problems, account set up problems, cold and hot weather issues, infrequent maintenance, blockage by other vehicles, and difficulties connecting and making payment are commonly reported by EV drivers.
drivers. EV drivers today are, in effect, paying an additional penalty while the technology and mechanisms are being improved.

Estimating Time Burdens

We observed fueling times using stopwatch and timer measurements for both EVs and ICE vehicles. As noted above, the time burden consists of:

- Time spent at commercial chargers or fueling stations, including connection and fueling time, plus an allowance for the unreliability of commercial EV chargers;
- Time to drive the deadhead miles needed to reach commercial charging stations or gas stations.

We did not include charging time or deadhead miles for residential charging.

- See also Table 5, “Tasks Required to Fuel EVs and ICE Vehicles,” on page 41, and “Methodology for Estimating Time Burdens” on page 39.

| TABLE 2. Typical Monthly Time Burden for Drivers in US Metropolitan Areas, 2021 |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Entry ICE Commercial fueling | Mid-Price ICE Commercial fueling | Luxury ICE Commercial fueling | Mid-Price EV Mostly Home Charging | Luxury EV Mostly Commercial Charging | Luxury EV Mostly Home Charging |
| Typical time burden to fuel a regularly-used vehicle, per month | 1 hour or less | 1 hour or less | 1 hour or less | ~ 3 hours | ~ 12 hours | ~ 3 hours |


Note: Time burdens include charging or pumping time at commercial stations; time to make payment; time to connect and disconnect; and time for mileage driven to reach commercial chargers or gas stations. Time at commercial chargers includes an allowance for occasional unreliability.

See also “Consistent Assumptions for EVs and ICE Vehicles” on page 8, and “Methodology for Estimating Time Burdens” on page 39.
Finding 3. Commercial charging is necessary for most Americans who drive electric vehicles.

Most EV drivers must rely on commercial as well as residential charging. This is due to the large number of miles driven by most Americans away from their homes; and the larger yields provided by commercial chargers. Furthermore, the available housing data suggest that about half of American households have housing arrangements that do not allow them to rely upon regular use of a home charger.

Real-world living and driving conditions require commercial charging.

Most EV drivers must rely upon commercial charging for some of their fueling. This is evident from all of the following:

A. Most US drivers exceed 12,000 miles of driving per year.

Extensive data on driving patterns in the United States indicate that typical automobile owners drive well over 12,000 miles per year, and working age adults often drive 15,000 miles or more. This number of miles is difficult to support with only home charging.

B. The majority of miles are driven in mid-length and longer trips.

Short trips constitute the majority of trips taken by US drivers. However, the majority of miles are put on typical vehicles in mid-length and longer trips. In general, drivers away from their residence must use commercial chargers. Because a majority of miles driven in the United States are in mid-length or longer trips, U.S. drivers must regularly rely upon chargers away from their home.
C. Commercial chargers provide the power needed for mid-length and longer trips.

Many EVs require at least 37 kWh of battery energy for a trip of 100 miles or more.\textsuperscript{7} This amount of power can be supplied by commercial fast DC chargers in less than an hour. However, a home L1 charger does not produce this amount even in an overnight session.\textsuperscript{8}

- See Table B-6, “Charge Per Session From Different Charging Modalities,” on page B-14.

D. Data from commercial charging services confirms usage among American drivers.

Data from the largest commercial charging providers confirms that a large amount of power is already being purchased by EV drivers. While there are gaps in these data, the evidence suggests demand is growing.

- See “Commercial Charging Usage” on page B-6 in the Appendix.

E. About One-Half of American Households Live in Housing that Allows for Regular Home Charging

A large share of Americans live in owner-occupied housing units. A further large share of these have a garage or carport. For a subset of these, cost, electrical service, or space limits make installation of a home charger possible and cost-effective. For others, including those that have access to a carport or garage but not sufficient control over the space, regular use of a home charger is impractical or impossible.

We do not have precise data on the number of drivers that live in housing where regular use of an EV charger is possible or practical.

\textsuperscript{7} Trips of this type account for approximately 15% of vehicle miles traveled in the United States. For comparability between EV and ICE vehicles, and to be consistent with our representative vehicles in each segment, we use fuel economy data on specific models, from the same source, for both gas and electric vehicles.

\textsuperscript{8} For example, a commercial DC fast charger operating at 75 kWh produces approximately 25kWh in about one-third of an hour. This contrasts with a home L1 charger that may produce 8 kWh or less, even after charging for 10 hours.

As we note, actual charging sessions involve heat losses, and power that varies throughout the session. Temperature, reliability, battery condition, and other factors also affect the ability to charge. Thus, these figures illustrate ideal conditions.

- See Table B-6, “Charge Per Session From Different Charging Modalities,” on page B-14
However, the available demographic data suggest that, for about half of American households, it is a viable option. For the other half, it appears to be a difficult or impossible choice.

- See “Regular Home Charging is Not a Viable Option for Around Half of American Households” on page B-7.

F. Automakers confirm the importance of commercial charging.

Automakers routinely include a commercial charging subscription with the purchase of a new electric vehicle. By bundling this service, manufacturers signal their belief that the buying public needs commercial charging.

Thus, the available data on housing, on charging, and on driving all confirm that commercial charging is necessary for the majority of American drivers.

“Mostly Home Charging” Implies Use of Commercial Chargers.

It is common to read that “most” EV charging utilizes residential chargers. While the majority of charging sessions may now occur at home chargers, that does not mean that the majority of the power comes from residential chargers. Even drivers that commonly use a home charger could be getting more than half of their power from a commercial charger.

- See “Power Added to EV Battery in Different Use Cases” on page 20.

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9. While this is commonly asserted, it has neither a consistent meaning nor a clearly defined source.

See “Are “Most Charging Sessions” at Residences?” on page B-8.

10. As noted, this is because commercial chargers typically provide more, and often much more, power per session than residential chargers. See “Charging Modality” on page 33.

Drivers can readily observe the fraction of time they use a residential charger, but they must perform mathematic calculations and record data to estimate the share of power that comes from different sources. For this reason, drivers tend to report the share of charging sessions that originated at home. Consistent with this practice among drivers, we name use cases (such as “mostly home charging”) based upon what drivers can readily observe.
Finding 4. Gasoline prices fluctuate much more than electricity prices, and increased dramatically in 2021.

Both gasoline and electricity prices are directly affected by the cost of energy resources such as petroleum. However, gasoline prices fluctuate much more than electricity prices. In 2021, gasoline prices spiked upward while electricity prices increased modestly.

Impact of Higher Energy Prices

Energy is the first category of costs for both EVs and ICE vehicles. The cost of energy is strongly affected by market prices for coal and petroleum, as well as for wind, solar, hydro, and nuclear power. All of these power sources are used to fuel electric vehicles, whereas petroleum accounts for almost all of the energy going into ICE vehicles.¹¹

Both electric utility rates and petroleum prices rose in 2021. However, the retail price of gasoline and diesel rose much more than utility rates.

- See Figure 4, “Fuel Prices Per Unit, 2019-2021,” on page 23.

These increases strongly impact the cost of fueling. Because gasoline prices grew faster than utility rates, energy cost changes affected ICE vehicles more than they affected EVs in 2021. This pattern continues to hold in early 2022.

¹¹ Delivering gasoline or diesel fuel in a retail environment requires considerable electricity for refining, distribution, and retail sale. Therefore, electricity costs have some effect upon retail prices charged for gasoline and diesel fuel.
Finding 5. The cost of fueling mid-priced electric vehicles remained slightly higher than for comparable ICE vehicles in 2021.

In 2021, the cost to fuel a typical mid-priced ICE vehicle for 100 miles was about $10.40. By comparison, the cost to fuel a mid-priced EV for the same distance was about $10.80.

That cost advantage for mid-priced ICE vehicles in 2021 is consistent with our previous conclusion using 2020 prices. For these vehicles, the true costs of chargers, road taxes, electricity at commercial and residential chargers, heat losses and deadhead miles made fueling a mid-priced electric vehicle more expensive than a comparable ICE vehicle for most drivers. However, the cost advantage narrowed sharply in 2021.

Costs for Benchmark Mid-Priced Vehicles. For our benchmark mid-priced models, the direct monetary cost of fueling EVs was still higher than for ICE vehicles in 2021. In fact, the typical cost to drive 100 miles was about $10.80 for an EV, but $10.40 for a comparable ICE vehicle. This narrow cost disadvantage of about $0.40 per 100 miles remains even after 2021’s higher gas prices.

• For 2021 driving costs, see Figure 2, “Direct Monetary Costs, Mid-Priced Segment, ICE Vehicles and EVs,” on page 21.
• See Table 3, “Direct Monetary Costs of Fueling EVs and ICE Cars, 2021,” on page 19.

Consistent Assumptions and Real-World Use. As noted above, our benchmark use cases reflect the real-world demands, infrastructure conditions, and prices faced by a majority of American households. These include driving 12,000 miles a year, paying state road taxes, and paying for all categories of fueling costs. We apply these consistently for drivers of both types of vehicles.

• See Table 1, “Four Categories of Direct Monetary Costs of Fueling EVs and ICE Vehicles,” on page 7.
• Figure 2, “Direct Monetary Costs, Mid-Priced Segment, ICE Vehicles and EVs,” on page 21.
• See Table 3, “Direct Monetary Costs of Fueling EVs and ICE Cars, 2021,” on page 19.
Finding 6. The cost of fueling luxury electric vehicles was lower than for comparable ICE vehicles in 2021.

In 2021, the cost to fuel a luxury electric vehicle was lower than for a comparable ICE vehicle, especially for drivers that could regularly use a home charger. The cost to fuel a luxury ICE vehicle for 100 miles was over $17, while a luxury EV driven by a homeowner who could regularly use a home charger was less than $12. A luxury EV driver who relied primarily on commercial chargers would pay fueling costs approximately 60 cents less than a luxury ICE car driver per 100 miles.

Luxury vehicles are typically require more fuel than mid-priced cars. Thus, they are more sensitive to gasoline prices.

Costs for Benchmark Luxury Vehicles. Using energy prices in 2021, the cost to fuel a typical luxury ICE vehicle for 100 miles grew to $17.70, while a luxury EV cost only about $17.17 for drivers that rely primarily upon commercial chargers. This gives the luxury EV driver a cost advantage of around 60 cents per 100 miles. For those that can regularly use home chargers, the cost advantage was $6 per 100 miles.

- See Figure 3, “Direct Monetary Costs, Luxury Segment ICE Vehicles and EVs,” on page 22.
- See Table 3, “Direct Monetary Costs of Fueling EVs and ICE Cars, 2021,” on page 19.
- Table B-3, “Direct Monetary Costs of Fueling EVs and ICE Cars for 100 Purposeful Miles, 2019-2021,” on page B-12.

Consistent Assumptions and Real-World Use. As noted above, our benchmark use cases reflects the real-world demands, infrastructure conditions, prices, and taxes. We apply these consistently for drivers of both types of vehicles.

- See “Four Categories of Direct Monetary Costs of Fueling EVs and ICE Vehicles” on page 7.
- See also the exhibit “Principles Guiding This Analysis” on page 3.

Note on Costs in Prior Years

Gasoline prices were much higher in 2021. These increases outstripped price increases in electricity and in the costs of installing home chargers.

- See “Fuel Prices Per Unit, 2019-2021” on page 23.
Finding 7. For drivers of pickup trucks and entry-priced vehicles, ICE vehicles were the only option in 2021.

A large share of US households rely on pickup trucks and entry-priced cars. There were no comparable electric vehicles in these segments during 2020 or 2021. However, we calculated these costs for representative ICE vehicles, and anticipate that competing models in the pickup truck segment will be introduced soon.

Additional Segments: Pickup Trucks and Entry-Priced Cars

A large share of US households rely on pickup trucks and entry-priced cars. There were no comparable electric vehicles in these segments during 2020, and we did not calculate costs for in those segments in the first edition. For this edition, we again evaluated the available pickup trucks and entry-priced vehicles in 2021.

- See “Vehicle Segments” on page B-1; and
- Table B-1, “ICE Vehicles and EVs in Different Consumer Segments, 2021,” on page B-3.

We again found no electric vehicles provided in sufficient numbers during the year 2021. However, given the importance of these segments to American drivers, and the impending introduction of multiple EV models in the pickup truck segment, we have included them in this edition. As with other vehicles, we use the same real-world assumptions, and follow the same principles of fair comparison.

For these segments, we found the following costs in 2021:

**Pickup trucks.** Using the same categories of costs and assuming real-world driving requirements, a typical ICE pickup truck driver would pay about $15 for 100 miles of driving. There were insufficient EV trucks in the market in 2021 to offer pickup drivers a viable alternative. However, we expect an onslaught of truck models from Ford, Rivian, General Motors, and others in 2022.

See “Vehicle Segments and Cost Factors” on page B-1.

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12. There were very small numbers of Rivian and GMC electric trucks recorded as sold in calendar year 2021. However, these were not sufficient to offer U.S. households the opportunity to purchase competing models during the year.
Entry-priced cars. For ICE vehicles in this category, drivers incurred about $10 in fueling costs per 100 miles. We found no electric cars that had purchase prices within the entry-priced category.

- See Figure 7, “Summary of Fueling Costs for Car and Pickup Truck Segments, 2021,” on page 26.
- See “Vehicle Segments and Cost Factors” on page B-1.
## TABLE 3. Direct Monetary Costs of Fueling EVs and ICE Cars, 2021

<table>
<thead>
<tr>
<th></th>
<th>Entry ICE Commercial Fueling</th>
<th>Mid-Priced ICE Commercial Fueling</th>
<th>Luxury ICE Commercial Fueling</th>
<th>Mid-Priced EV Mostly Home Charging</th>
<th>Luxury EV Mostly Commercial Charging</th>
<th>Luxury EV Mostly Home Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Per Year for 12,000 Purposeful Miles</td>
<td>$1,218.03</td>
<td>$1,240.59</td>
<td>$2,111.74</td>
<td>$1,295.21</td>
<td>$1,906.68</td>
<td>$1,388.36</td>
</tr>
<tr>
<td>Cost Per 100 Purposeful Miles</td>
<td>$10.15</td>
<td>$10.34</td>
<td>$17.60</td>
<td>$10.79</td>
<td>$15.89</td>
<td>$11.57</td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group (2022) research.

Four categories of fueling costs are included for both types of vehicles: energy costs; costs of the charger or pump; road taxes; and deadhead miles.a

Use cases are based on consistent assumptions about driving distances and representative charging modalities.b

Base data include: consumer logbooks and AEG market research (commercial charging prices and charging modalities); US Census (housing information); AEG stopwatch and distance measurements to fast DC chargers; ESRI and DoE (charger locations and related geography); EIA (gasoline and electricity prices); State of Michigan, NCSL, and other sources (fuel excise taxes and EV registration taxes).

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a. See Table I, “Four Categories of Direct Monetary Costs of Fueling EVs and ICE Vehicles,” on page 7
b. See the Mostly Commercial (“Res25percentL1”) and Mostly Home (“Res75percentL2”) use cases in Table B-7 on page B-15, and “Vehicle Segments” on page B-1.
Figure 1. Power Added to EV Battery in Different Use Cases

Power by Charging Modality

- Power added to battery by charging modality, for each use case

Total Monthly Power

- Total Power added to battery, for each use case

Share of Power by Charging Modality

- Residential Share
- Commercial Share

Source: Anderson Economic Group (2021) research.
Figure 2. Direct Monetary Costs, Mid-Priced Segment, ICE Vehicles and EVs

Direct Monetary Costs of Fueling Mid-Priced ICE Vehicles and EVs
Cost per 100 miles: Dozen Representative EV Use Cases, 2021 Energy Prices

Source: Anderson Economic Group (2021) research; all vehicles driving 12,000 purposeful miles per year; EIA (gasoline and residential utility prices); AEG (use cases and commercial charging rate); gasoline and additional EV registration taxes as levied in the state of Michigan.
Figure 3. Direct Monetary Costs, Luxury Segment ICE Vehicles and EVs

Direct Monetary Costs of Fueling Luxury ICE Vehicles and EVs
Cost per 100 miles: Dozen Representative EV Use Cases, 2021 Energy Prices

Source: Anderson Economic Group (2021) research; all vehicles driving 12,000 purposeful miles per year; EIA (gasoline and residential utility prices); AEG (use cases and commercial charging rate); gasoline and additional EV registration taxes as levied in the state of Michigan.
Comparison: Real World Cost of Driving EVs and ICE Vehicles

Figure 4. Fuel Prices Per Unit, 2019-2021

Fuel Prices for ICE Vehicles and EVs

2019 Energy Prices

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Price per gallon</th>
<th>Price per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Regular</td>
<td>$2.46</td>
<td></td>
</tr>
<tr>
<td>Gasoline Premium</td>
<td>$3.04</td>
<td></td>
</tr>
<tr>
<td>Diesel Regular</td>
<td>$2.96</td>
<td>$0.16</td>
</tr>
<tr>
<td>Electricity Residential</td>
<td>$0.43</td>
<td>$0.16</td>
</tr>
</tbody>
</table>

2020 Energy Prices

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Price per gallon</th>
<th>Price per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Regular</td>
<td>$2</td>
<td></td>
</tr>
<tr>
<td>Gasoline Premium</td>
<td>$2.62</td>
<td></td>
</tr>
<tr>
<td>Diesel Regular</td>
<td>$2.43</td>
<td>$0.16</td>
</tr>
<tr>
<td>Electricity Residential</td>
<td>$0.43</td>
<td>$0.16</td>
</tr>
</tbody>
</table>

2021 Energy Prices

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Price per gallon</th>
<th>Price per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Regular</td>
<td>$3.32</td>
<td></td>
</tr>
<tr>
<td>Gasoline Premium</td>
<td>$3.96</td>
<td></td>
</tr>
<tr>
<td>Diesel Regular</td>
<td>$3.6</td>
<td>$0.17</td>
</tr>
<tr>
<td>Electricity Residential</td>
<td>$0.43</td>
<td>$0.16</td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group (2021) research; EIA (gasoline and residential utility prices in Michigan).
Notes: Gasoline prices are per gallon; electricity prices are per kWh; dashed lines refer to average prices of gasoline and residential electricity over the three years.
Figure 5. Relative Costs of Fueling ICE Vehicles and EVs, 2019-2021

Relative Costs of Fueling ICE Vehicles and EVs, 2019-2021

Cost per 100 miles: 2019 Energy Prices

- Entry ICE Commercial: $7.5
- Mid-Priced ICE Commercial: $7.64
- Luxury ICE Commercial: $13.5
- Mid-Priced EV Mostly Home: $10.05
- Luxury EV Mostly Commercial: $16.19
- Luxury EV Mostly Home: $10.78

Cost per 100 miles: 2020 Energy Prices

- Entry ICE Commercial: $6.09
- Mid-Priced ICE Commercial: $6.21
- Luxury ICE Commercial: $11.62
- Mid-Priced EV Mostly Home: $10.19
- Luxury EV Mostly Commercial: $16.02
- Luxury EV Mostly Home: $10.93

Cost per 100 miles: 2021 Energy Prices

- Entry ICE Commercial: $10.15
- Mid-Priced ICE Commercial: $10.34
- Luxury ICE Commercial: $17.6
- Mid-Priced EV Mostly Home: $10.79
- Luxury EV Mostly Commercial: $15.89
- Luxury EV Mostly Home: $11.57

Source: Anderson Economic Group (2021) research; all vehicles driving 12,000 purposeful miles per year; EIA (gasoline and residential utility prices); AEG (use cases and commercial charging rate); gasoline and additional EV registration taxes as levied in the state of Michigan.
Figure 6. Time Burden of Fueling ICE Vehicles and EVs

Time Burden of Fueling ICE and EVs
Hours of Time Spent on Refueling per Month, Benchmark Segments

Composition of Time Burdens

Source: Anderson Economic Group (2021) research; base data from consumer logbooks (prices and charging modalities); stopwatch measurements of time.
Comparison: Real World Cost of Driving EVs and ICE Vehicles

Figure 7. Summary of Fueling Costs for Car and Pickup Truck Segments, 2021

Cost of Fueling Electric and Internal Combustion Engine Vehicles
Direct Monetary Costs per 100 miles, 2021

<table>
<thead>
<tr>
<th>Segment</th>
<th>ICE</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry-Priced ICE Cars</td>
<td>$10.15</td>
<td>Insufficient Vehicles in Market</td>
</tr>
<tr>
<td>Mid-Priced ICE Cars</td>
<td>$10.34</td>
<td>Mostly Home Charging: $10.79, Mostly Commercial Charging: $14.34</td>
</tr>
<tr>
<td>Luxury ICE Cars</td>
<td>$17.6</td>
<td>Mostly Home Charging: $11.57, Mostly Commercial Charging: $15.89</td>
</tr>
<tr>
<td>ICE Trucks</td>
<td>$15.09</td>
<td>Insufficient Vehicles in Market</td>
</tr>
<tr>
<td>Mid-Priced EV Cars</td>
<td>$14.34</td>
<td></td>
</tr>
<tr>
<td>Most Common EV Cars</td>
<td>$10.79</td>
<td></td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group (April 2022), "Comparison: Real World Cost of Fueling EVs and ICE Vehicles, Second Edition."

Notes: Costs are calculated for vehicles driving 12,000 purposeful miles per year, using price data for gasoline and residential utility rates from EIA for 2021; AEG data for use cases and commercial charging rates; and gasoline prices and EV road taxes as levied in the State of Michigan. For ICE vehicles, the cost of operating pumps is embedded in the energy costs.
3. Methodology for Estimating Monetary Costs

FOUR CATEGORIES OF COSTS

For each use case, we estimate four categories of costs:

A. The cost of the underlying energy

For ICE vehicles, the cost of the underlying energy, the road taxes, and the cost of operating the pump are bundled into the retail price of gasoline or diesel fuel. Almost all ICE vehicle refueling is done at commercial gas stations, thus making the retail price of gasoline or diesel fuel a straightforward indication of fueling costs.

For EV drivers, each category must be estimated separately, with per-kWh prices that are different. Furthermore, the consumer cost for heat losses in the charging process must be taken into account.

B. The cost of the pump or charger

Almost all fueling for ICE vehicles is done at commercial gas stations, where the price of the pump is bundled into per-gallon charges.

At commercial EV chargers, the cost of the equipment is bundled into the fee charged to the customer. At residential chargers, it must be accounted for separately.

C. The excise taxes charged for roads

Excise taxes to pay for roads are imposed on the gasoline and diesel fuel by all 50 states, and an additional federal excise tax is imposed nationally. These are bundled into the price of gasoline or diesel fuel.

Similar road taxes are imposed on EVs by a little over half of US states. These vary considerably and are likely to change.13

D. The cost of driving to a fueling station, known as “deadhead miles”

Most ICE vehicle drivers incur a very small cost of driving to a commercial gasoline station to re-fuel. Given the very large number of these stations and their convenient locations, this cost is often small enough to ignore in calculating the cost of fueling.

For EV drivers, the situation is much different. When home charging, EV owners save the cost of driving to a fueling station. However, when a commercial charger is needed, drivers must typically travel farther to refuel than they would if they drove an ICE vehicle. On top of this, the much lower range of EVs typically requires more refueling sessions than needed for ICE vehicles.

13. There is considerable debate within states on imposing new, or increasing existing, road taxes on EVs.
USE CASES

We chose six use cases for which to calculate the cost of fueling vehicles. These use cases represent a wide variety of driving and refueling habits among American households. Each use case includes a type of vehicle and a refueling modality.

- See Table 4, “Benchmark Use Cases,” on page 29.

For both types of cars, each use case represents annual mileage and trips consistent with actual American driving patterns.

- See “Using Consistent Assumptions for Both Types of Vehicles.” on page 6.

Benchmark Cases Illustrate Many, but Not All, Uses in America

There are over 100 million vehicles registered in the United States. Our benchmarks represent a large share of these use cases. However, no set of benchmark use cases can possibly describe the myriad ways Americans fuel and drive their vehicles.

In particular, the benchmark use cases we present here do not represent:

- People who drive very efficient ICE vehicles over long mileage.
- People who drive low mileage in their EVs, then use gas cars for longer trips.
- People who drive very expensive vehicles, or who purchased older vehicles that are no longer offered new.
- Vehicles not currently offered for sale or lacking reported range and fuel economy figures.

Lack of Available EV Models

A lack of EV models limits consumer choice in the truck and entry-priced segments.

- See “Vehicle Segments” on page B-1.

Subjective Price Categories

We relied primarily on price and features to distinguish between entry-priced, mid-priced, and luxury vehicles. We note two limitations on this:

- EVs and ICE vehicles have fundamental differences in vehicle design, powertrain, and weight, and are not perfectly comparable. For example, EVs typically have better acceleration, less interior space, heavier weight, and lower range than comparably-priced ICE vehicles.
• Prices in the automotive market change over time, and increased considerably in 2021 and early 2022. These price changes include both features and underlying costs. Furthermore, the concept of “luxury” vehicles is inherently subjective. Thus, indicative price points for these categories will change over time.

### TABLE 4. Benchmark Use Cases

<table>
<thead>
<tr>
<th></th>
<th>Entry ICE Commercial Fueling</th>
<th>Mid-Priced ICE Commercial Fueling</th>
<th>Luxury ICE Commercial Fueling</th>
<th>Mid-Priced EV Mostly Home Charging</th>
<th>Luxury EV Mostly Commercial Charging</th>
<th>Luxury EV Mostly Home Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indicative Purchase Prices</strong></td>
<td>&lt; $30k</td>
<td>$30k-$45k</td>
<td>&gt;$45k</td>
<td>$30k-$45k</td>
<td>&gt;$45k</td>
<td>&gt;$45k</td>
</tr>
<tr>
<td><strong>Indicative Fuel Economy</strong></td>
<td>33 mpg</td>
<td>32.4 mpg</td>
<td>22.7 mpg</td>
<td>3.9 mi/kWh</td>
<td>3.5 mi/kWh</td>
<td>3.5 mi/kWh</td>
</tr>
<tr>
<td><strong>Refueling Habits</strong></td>
<td>Gas station</td>
<td>Gas station</td>
<td>Gas station</td>
<td>25% of charging sessions at commercial charging stations</td>
<td>75% of charging sessions at commercial charging stations</td>
<td>25% of charging sessions at commercial charging stations</td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group (2022) research and use case definition; fuel economy from the EPA; pricing data from manufacturer’s websites.

a. These figures represent indicative price levels for base models of new cars, before taxes and fees, as of the end of 2021. Prices change in the automobile market regularly, and involve both features and costs. See “Subjective Price Categories” on page 28. See also “Vehicle Segments” on page B-1.

b. Fuel economy, for both ICE and EVs, depends on driving style, conditions, and specific models. For luxury and sport models within both the EV and ICE segments, the actual mileage can be substantially less than indicated in the table for the broad category. We use an average of EPA suggested fuel economies for vehicles listed under each consumer segment of Table B-1 on page B-1. For consistency, we use the same source for both EVs and ICE vehicles.

c. All ICE vehicles are assumed to be refueled at commercial gasoline stations. Refueling of EVs vary depending on use case. See the Mostly Commercial (“Res25percentL1”) and Mostly Home (“Res75percentL2”) use cases in Table B-7 on page B-15, and “Vehicle Segments” on page B-1.

d. Note that the share of charging sessions is not equivalent to the share of power received from commercial and residential chargers. See “Energy Costs” on page 32 and “Charging Modality” on page 33.
Comparison: Real World Cost of Driving EVs and ICE Vehicles

**STEPS TO ESTIMATE COSTS**

Each of the four categories of costs can vary based on an individual’s driving patterns.

**A. Energy Costs**

The biggest share of fueling costs for both ICE vehicles and EVs is the cost of the energy itself. For ICE vehicles, that includes gasoline or diesel fuel paired with the cost to refine and deliver it to the fueling station. For electric vehicles, the cost includes two components:

1. *Commercial and residential electricity:* The large majority of EV drivers use both commercial and residential chargers. Thus, the cost to fuel an EV includes some mix of residential and commercial electric power rates.

2. *Heat loss:* Charging a battery involves a loss of power to heat and other inefficiencies. Nearly all residential chargers, and most commercial chargers, provide alternating current (AC) power to the vehicle. Converting that into direct current (DC) generates heat.

For residential charging, between 80% and 92% of the electricity used by the charging system ends up as useful energy in the battery. Careful calculations include that efficiency loss.\(^\text{14}\) By contrast, very little fuel is lost in typical ICE vehicle refueling.\(^\text{15}\)

Charging modality—the manner in which an EV driver charges his or her vehicle—varies widely among drivers. For example, many automobile owners cannot charge at home because they do not own or control a garage space. Others can install home chargers and rely upon them regularly. Many drivers regularly travel outside of their local area, and therefore must rely upon commercial charges regardless of their ability to charge at their residence.

Our analysis takes this diversity into account by including multiple use cases.

- See Finding 3., “Commercial charging is necessary for most Americans who drive electric vehicles.” This appears on page 11.
- See also “Charging Modality” on page 33.

**B. Road Taxes**

In all states, the retail price of gasoline includes federal, state (and sometimes local) excise taxes. These typically fund road maintenance and construction.

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\(^{14}\) See “Commercial and Residential Electric Power Costs” on page 32, and “Heat Loss in Charging” on page 32.

\(^{15}\) See “Evaporation Loss at Gasoline Pumps” on page 32.
While EVs drive the same roads as ICE vehicles, they do not incur the road taxes imposed on gasoline and diesel fuels. To compensate, many states require EV owners to pay additional auto registration taxes to maintain the roads. These vary considerably, with some states imposing no road taxes on EVs.

C. Cost of Fuel Pumps or Chargers

The price of installing and operating a gasoline or diesel fuel pump is embedded in the retail price of the fuel. The fueling station charges an increment over the cost of the fuel itself to compensate for the cost to operate the pump.

The same applies to commercial electric chargers. Providers similarly include in their fees an increment to cover the cost to install and operate the charger.

For residential charging, the EV owner must cover the cost of the electrical vehicle supply equipment (EVSE). This equipment is commonly called a “charger,” although technically most home EVSE does not meet the formal definition of an electric charger.16

The home EVSE may be included in the purchase cost of a new EV, it may be an optional purchase from the EV manufacturer, or it may be purchased separately. It may also require professional installation.

- See “Costs of Home EV Chargers” on page B-4.
- See also Finding 3., “Commercial charging is necessary for most Americans who drive electric vehicles.” This appears on page 11.

D. Deadhead miles

As noted previously, service stations are ubiquitous in much of the US. Indeed, there are over 100,000 such stations operating in the country. ICE vehicle owners must drive deadhead miles to reach a fueling station. However, in areas where stations are plentiful, the burden is typically quite small.

For EV owners, the situation is much different. When home charging, they save the cost of driving to a fueling station. However, when EV drivers need a commercial charger, they often must travel significantly farther than the typical ICE vehicle driver to refuel.

Because charging modalities vary tremendously, we calculate both deadhead miles and energy costs for a variety of use cases.

- See “Deadhead Miles” on page B-5.

ENERGY COSTS

Commercial and Residential Electric Power Costs

Consumers utilize both residential and commercial chargers. As we describe below, fueling time and costs vary considerably among these chargers. They also vary by charging speed and by charger type.

Our analysis estimates the costs of residential and commercial charging separately. For home charging, we assume residential rates (including “time of use” rates for some homes). For commercial charging, we calculate a cost that represents the sum of per-kWh charges, subscription fees, per unit time, and per session costs.

In Michigan, for example, the cost for residential charging was about $0.17 per kWh in 2021. For commercial charging it was around $0.43 per kWh.17

Heat Loss in Charging

Charging and discharging a battery involves energy loss in the form of heat. These losses are captured in the “charging efficiency” fraction, which we apply to both residential and commercial charging.18 Including this small (but significant) loss is essential for a fair comparison between ICE and EV fueling costs.

Most of the charging cost analyses we reviewed omitted this step. A handful, including an analysis published by electrek, include it. The electrek analysis of Tesla charging costs calculates an efficiency rate between 80% and 90% for residential AC chargers, and between 90% and 99% for fast DC chargers.19

Evaporation Loss at Gasoline Pumps

Some loss occurs from spillage and evaporation at the pump when refueling ICE vehicles. We were unable to find a useful estimate comparable to the efficiency factor we use for EVs. However, the following two sources provide some indication of magnitude.

Hilbert, et al. (2015) used a 0.1% factor as an allowance for hydrocarbon release during fuel storage and transfer at gas stations. This would include more than losses at the point of fueling.

18.See discussion of charging efficiency under “Heat Loss in Charging” on page 32.
As an indication of an upper bound, some states allow “Motor Fuel Evaporation Deductions” in calculating excise tax on fuels. These take into account refining, transportation, storage, and fueling stations. For southern US states, these deductions range from 0.004 percent up to 3 percent of the original taxable amount. See Southern Legislative Conference (2019).

**CHARGING MODALITY**

ICE vehicles are primarily refueled at gas stations (aside from some rare exceptions of farm or construction site vehicles). EV drivers, however, choose between two modes of refueling: residential and commercial.

The cost of electricity is a weighted sum of the price charged by the two types of chargers, with the weights being the amount of power consumed.\(^{20}\) Due to the significant difference in electricity unit prices at residential and commercial chargers, a driver’s choice of charging modality strongly affects the total cost of refueling.

We describe a number of representative use cases for charging under different modalities in Table B-7, “Charge Added to Battery Under Different Use Cases,” on page B-15.

**BUNDLED COSTS**

For both EVs and ICE vehicles, some costs are bundled into the price of other goods and services. To properly compare these two types of vehicles, we include the same cost categories for both as follows:

A. Bundled Charging Equipment

Most new EVs are sold with minimal charging equipment.\(^{21}\) Some argue that, because it is bundled, the cost of this equipment should be ignored. This fails logically because:

- Manufacturers such as Tesla and Ford routinely sell charging equipment separately from the cost of a vehicle. Other suppliers, such as ChargePoint, JuiceBox, Siemens, and Clipper Creek, also offer their options to consumers.
- Many vehicles are purchased used. Because charging equipment can be separated from the vehicle, we cannot presume that every used vehicle is re-sold with the same equipment.

\(^{20}\) It is an error to use the number of charging sessions as weights. Given the number of EV driver comments on the first edition of this report that noted their share of residential charging sessions, it may be a common one.

\(^{21}\) Some claim all EVs are sold with L1 chargers at no extra cost. This is simply untrue. For example, one of the authors purchased a model year 2020 EV with an extra-cost charger.
The consumer pays for all equipment included in a vehicle purchase, whether it is listed as an extra-cost option or included in the base price. This is true for wheels, motors, seats, fuel tanks, batteries, etc. It is also true for charging equipment.

B. Bundled Charging Services

Today, many manufacturers bundle new EVs with the limited use of a specific charging service. For example:

- Vehicles sold by US dealers representing Volkswagen Group (including VW, Audi, and Porsche) typically bundle service with Electrify America.22
- Vehicles sold by Tesla have access to the Tesla network of chargers. However, purchasers of the popular Model Y only have access to Tesla’s superchargers on a Pay Per Use basis.23
- Vehicles sold by General Motors dealers typically allow the purchaser to use a charger at the dealership, when available. In November 2021, GM announced a program to encourage the installation of “as many as 40,000 level 2 chargers across the US and Canada” to address “charging deserts.”24

C. “Free” Charging Services

Some municipalities, colleges, and businesses offer “free” charging for a limited time in specific places. These services are often combined with parking, offered as a convenience to shoppers, or provided as a benefit to employees or visitors. In some cases, a portion of the service is provided “free” and a portion charged at commercial rates. These involve a cost that must be paid by users in some fashion, whether it is embedded in property taxes, tuition, consumer prices, or investor burdens. In effect, the taxpayers, students, or customers pay these costs, including those that do not drive EVs.

Consistent with our principles of including the direct costs, we include these as priced using commercial rates.

The purpose of this report is to provide a proper and fair comparison between the costs of fueling ICE vehicles and EVs.

- See “Principles Guiding This Analysis” on page 3.

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22. A fact sheet for the VW ID.4 lists a three year allowance for charging at Electrify America locations.
23. Tesla’s Charging web page offers multiple charging equipment purchase options.
Consistent with this principle, we take into account all four categories of costs, and do so consistently for EVs and ICE vehicles.

- See again Finding 1., “There are four categories of costs for fueling vehicles.” This appears on page 6.

As noted previously, it is an error to compare some costs for EVs with all costs for gasoline and diesel-fueled cars. However, this commonly occurred prior to the publication of the first edition of this report in 2021. Most of these reports also ignored the much higher cost of commercial charging, and some ignored heat losses.

- See Exhibit 5., “Representative Analyses of EV and ICE Fueling Costs” on page 36.

EXHIBIT 4. Representative Analyses of EV and ICE Fueling Costs

Representative past analyses, with comments on costs not included, are:


B. Consumer Reports (2020): Includes the cost of commercial charging and estimates an annual EV savings of about $1,000. *Ignores heat loss, road tax, charger costs, and deadhead miles.*

C. Model3 Guru (2021): Estimates that a base Tesla Model 3 costs less than half the cost to fuel a comparable BMW 3-series sedan per year ($481 versus $1,029, based on Ohio costs and default values for gasoline and electricity). *Ignores commercial charging costs, heat loss, road tax, charger costs, and deadhead miles.*

D. Sivak (2018) for the University of Michigan Transportation Institute: Calculates only the direct electricity costs (using residential rates) and gasoline costs (using retail prices of gasoline) for various states. *Ignores commercial charging costs, heat loss, road tax, charger costs, and deadhead miles.*

E. Borlaug (2019): This more sophisticated analysis includes the amortized cost of a residential charger, and recognizes charging efficiency losses borne by residential charger users. *Ignores commercial charging costs, road tax, and deadhead miles.*
While this analysis properly accounts for four categories of direct monetary costs for both EVs and ICE vehicles, there are a handful of known costs that we do not itemize or include, such as:

A. *Phantom Drain.*

Electric vehicles and ICE vehicles require a certain amount of electric power while they are not being actively driven. We do not include this in our analysis.

B. *Electrical Power Usage While Charging.*

EV drivers commonly use vehicle features while at a commercial charger. These include lights, heater or air conditioner, electric seats, and music or an infotainment system. In addition, EVs typically use internal systems to monitor the charging process.

For EV drivers, the cost of use while fueling is much higher than for ICE vehicles. For safety reasons, gasoline-powered cars must be turned off while refueling, and many stations require the driver to be outside the vehicle in view of the pump while fueling. Moreover, the very short time required to fill a gas tank means any usage during that time is small.

We ignore this category of costs.

C. *Battery Degradation.*

All vehicle batteries degrade over time. With battery-electric vehicles, however, the battery is a primary system and its degradation is a costlier matter. We do not calculate this cost in our analysis.

As stated at the beginning of this report, our purpose is to estimate the real world costs of electric vehicles, and compare them apples-to-apples with those for similar ICE vehicles.

• See “Principles Guiding This Analysis” on page 3.

Consistent with these principles, we do not include credits or subsidies that are available only under certain conditions, only to certain purchasers, or only temporarily. For example, the federal purchase tax credits are only useful to those in certain income brackets, only for new vehicles, and only during certain time periods.\(^{26}\)

\(^{26}\)See “Specific Federal, State, and Utility Incentives” on page 38.
Focus on recurring real world costs. Recurring costs dominate expenses borne by automobile owners, including EV owners. Thus, focusing on these costs better indicates the ongoing burden drivers bear than would a focus on short-term, temporary, limited-availability incentives.

Incentives for ICE vehicles similarly excluded. Consistent with our purposes and treatment of EV fueling costs, we exclude ICE vehicle incentives and credits from our calculations. While currently much smaller than those available to EV owners, these do exist, including the federal purchase tax credits described below that apply to a number of vehicles (e.g., hybrids) with traditional ICE drive trains. Furthermore, the well-established procedures for deducting ICE vehicle business use costs may be more difficult to implement for EVs.

Specific Federal, State, and Utility Incentives. While the focus of this report is on recurring real-world costs, we encourage consumers to make use of applicable incentives and subsidies for both ICE vehicles and EVs, such as:

A. Federal purchase tax credits
B. State tax incentives
C. Utility incentives

Consumers should check carefully the terms, availability, and eligibility of these programs for their individual circumstances.

---

27. For example, sellers of automobiles, retailers of gasoline and diesel fuel, and credit card providers may offer rebates, discounts, or “free” gasoline.
28. As an example of the perverse results that including selected incentives would create, note that we could include the IRS section 30D credit for a eligible hybrid vehicle, but not for an ineligible new or used BEV.
4. Methodology for Estimating Time Burdens

It takes EV drivers significantly longer to charge at a commercial EV charger than it does to refuel a comparable ICE vehicle at a gas station, because each of these EV charging tasks imposes a time burden:

A. Connection, fueling, disconnection, and payment. This often involves syncing a smartphone app with the charger, making payment or account arrangements, and waiting for the charger to activate and begin charging. In some cases, it also involves setting up an application for a new charging network.

Time burden estimate: Using stopwatch measurements, we note it often takes 20 to 30 minutes to set up the charger and for the charging process to complete at a fast DC charger. Slower L2 chargers are much more common, but charging at these can take multiple hours. Moreover, an EV battery is not likely to be fully charged even after 30 minutes at a fast DC charger or four hours at an L2 charger.\(^\text{29}\)

B. Trips to a fueling location. These miles are sometimes known as deadhead miles, since their primary purpose does not get the driver to the desired destination.

Time burden estimate: We estimate that it takes about 15 minutes for a typical EV driver in a non-rural area to drive to a reliable DC fast charger. The drive to an L2 commercial charger may be shorter (due to their relative abundance compared to DC fast chargers), but again, L2s take significantly longer to charge a car.

C. Allowance for unreliability. EV drivers bear the burden of finding an available working charger. The recurring phenomenon of unreliable, non-working, or blocked (iced)\(^\text{30}\) chargers adds significantly to a driver’s time burden but is

\(^{29}\)This presumes a vehicle has more than 15% but less than 50% charge at the start of a session. For an L2 delivering 6 kW, charging for 4 hours may add 24 kWh to the battery. This is about one-third capacity for some EVs. Charging for 30 minutes at a 50 kWh fast DC charger might add a similar amount of charge. Actual charge varies as discussed under “Separating Direct Monetary Costs from Implicit Time Costs” on page 43.

\(^{30}\)While the phrase “iced” obviously refers to ICE vehicles, charging spaces are often blocked by EVs that are no longer charging.
commonly ignored in other analyses. Online forums are full of comments from drivers expressing frustration about these problems.\textsuperscript{31}

Time burden estimate: We estimate the time lost due to unreliability at about 15 minutes for every 1 in 20 functional charges.

**Summary of Time Burdens**

We estimated the time burdens incurred by typical drivers in metropolitan areas, given the tasks we identified. For drivers in rural areas or where EV charging infrastructure is weak, the figures here are likely to be underestimates.


\textsuperscript{31}For example, *PlugShare* (an online EV charging map) includes a “reliability rating” for each charging station that highlights its recent working condition and asks users to indicate that the charger did or did not work, and to report the highest charging speed achieved. A review confirms recurring reliability issues with commercial chargers, as well as differences in consumer-reported reliability for different applications and networks.

Recently, Ford Motor Company announced they would pay for “charging angels” to check on and fix non-working EV chargers. This is an implicit confirmation of the reliability problem. See Ramsey (2021).
## TABLE 5. Tasks Required to Fuel EVs and ICE Vehicles

<table>
<thead>
<tr>
<th>Connections, Fueling, Disconnection, and Payment</th>
<th>EVs</th>
<th>ICE Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>For home and commercial chargers, time to connect and disconnect a charger (EVSE).a This includes time for the charger to start up, sync with the vehicle, sync with the charging service, and begin charging,b and the disconnection time.c</td>
<td>Time to connect and disconnect a gas or diesel pump at a commercial station, make payment, and wait for the tank to fill.</td>
<td></td>
</tr>
<tr>
<td>For commercial chargers, time needed to authorize payment.d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For commercial chargers, time waiting for the charging process to complete.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of charging at a residence is assumed to impose no additional time burden.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trips to Fueling Location</th>
<th>EVs</th>
<th>ICE Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trips to a commercial charger or to a residence.</td>
<td></td>
<td>Trips to a commercial gas station.</td>
</tr>
<tr>
<td>Trips to residence are assumed to involve no additional time or distance burden on the user.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allowance for Unreliability</th>
<th>EVs</th>
<th>ICE Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional time required for charger breakdowns, software issues, mobile app syncing problems, user error, and failure of vehicle or charger to work properly.</td>
<td></td>
<td>Infrequent service interruptions at gas stations.</td>
</tr>
</tbody>
</table>

**Memo:**

**Tasks Not Included in Measured Time Burden:**

- Time to set up a credit card account.e
- Time to set up accounts for charging services (usually requires a mobile phone and credit card).f
- Time to acquire and maintain a mobile phone.
- Time to set up mobile phone app.
- Time to charge at residence.

**Source:** Anderson Economic Group research (2021); references cited in text of report.

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**a.** Electrical Vehicle Supply Equipment (EVSE) is the technical term for what is commonly referred to as a “charger.” See “EVSE and “Chargers”” on page B-4.

**b.** “Smart chargers,” including residential chargers, require a small amount of additional time to connect with a WiFi network. They may also require a password or other security information, and perform other functions that require a small amount of additional time.

**c.** Electric vehicles typically have safety mechanisms that clamp, and then release, the EVSE connector. Therefore, a short amount of time is needed for the vehicle to disconnect the circuit and release the charging connector.

**d.** Charging services (including Electrify America, ChargePoint, Blink, and EVgo) typically require the user to set up an account. This typically involves submitting a credit card, and often an initial deposit. An arrangement with one such service may be bundled into the price of a new EV.

**e.** Although it is possible to pay with cash at most gasoline stations, we assume that regularly fueling both EV and ICE vehicles requires a credit card.

**f.** A mobile phone is usually necessary to activate service at an EV charging station, but not at a gasoline station.
**IMPLICIT PRICING OF TIME BURDEN**

Placing a value or cost on lost time is an inherently subjective process, involving individual preferences. To provide some guide to these costs, we follow a long-practiced economics tradition of using a wage rate to implicitly value lost time.

**Underlying Theory.** The economic principle of *opportunity cost* recognizes that the requirement to do one task means you cannot do others. Thus, forcing drivers to use time for their charging tasks imposes an opportunity cost upon them, even if they do not see an immediate financial cost.

The value of time and importance of opportunity cost is evident throughout the economy. Examples include the ubiquitous practice of charging more for convenience or for immediate service; valet and short-term parking; express delivery; certain toll roads; and priority boarding on airlines.

**Implicit Time Prices.** For this report, we reference two implicit time prices:

- A state minimum wage, and
- A typical wage for a worker with sufficient income to qualify for a luxury segment vehicle loan.

Every driver will value his or her time differently. These are intended as broad reference points. Readers can assess a personal time burden based upon these parameters. We do not presume that drivers value their lost time at either of these rates, or that drivers earn wages at these rates.

**Implicit Time Costs at Two Reference Wage Rates**

As an aid to understanding the time burdens involved in fueling EVs and ICE vehicles, we calculated implicit time costs using reference wage rates. These translate the lost time to an implicit dollar cost. Using two wage rates as references, we can calculate the following implicit costs:

A. Minimum hourly wage of $9.65: At this rate, the fueling time cost for an EV driver can be equivalent to about $30 a month or more, and less than $10 for an ICE driver.

B. Hourly wage at a $70,000 annual salary: The average hourly wage for an individual earning $70,000 annually is about $33. This implies a fueling time cost of around $100 per month for an EV driver, and $30 for an ICE driver.

- See the implicit time cost comparison in Table 6 on page 43.
**Separating Direct Monetary Costs from Implicit Time Costs**

This report separates implicit time costs from direct monetary costs. Direct monetary costs are explicit, and can be objectively measured. Time burdens are inherently subjective. For these two reasons, we do not add the implicit time costs to the direct monetary costs.

**TABLE 6. Typical Fueling Time Burdens and Implicit Time Costs for Drivers in US Metropolitan Areas, 2021**

<table>
<thead>
<tr>
<th>Entry ICE Commercial Fueling</th>
<th>Mid-Priced ICE Commercial Fueling</th>
<th>Luxury ICE Commercial Fueling</th>
<th>Mid-Priced EV Mostly Commercial Charging</th>
<th>Luxury EV Mostly Commercial Charging</th>
<th>Luxury EV Mostly Home Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical hours spent fueling per month&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1 or less</td>
<td>1 or less</td>
<td>1 or less</td>
<td>2.79</td>
<td>11.44</td>
</tr>
<tr>
<td>Implied time cost per month (at hourly minimum wage of $9.65)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>$9.65 or less</td>
<td>$9.65 or less</td>
<td>$9.65 or less</td>
<td>$26.92</td>
<td>$117.41</td>
</tr>
<tr>
<td>Implied time cost per month (at hourly wage of $33)</td>
<td>$33.00 or less</td>
<td>$33.00 or less</td>
<td>$33.00 or less</td>
<td>$92.07</td>
<td>$401.50</td>
</tr>
</tbody>
</table>


<sup>a</sup> Time burdens include the three categories in “Driver Time Burdens” on page 39: charging time at a commercial charger, time to set up and disconnect a residential charger (but not the charging time); and time required to drive to a commercial charger or a gas station. Time spent at commercial chargers includes an allowance for occasional unreliability.

<sup>b</sup> Time costs are inherently subjective. These implicit wage rates are provided as reference points. See discussion in text.
5. Infrastructure and Policy Issues

POLICY ISSUES

Our expanding electric vehicle fleet will raise tax, regulatory, and safety issues that have been largely ignored until recently. These will soon impact both EV and ICE drivers, as well as taxpayers.

The following issues will become more important as electric vehicles become a larger part of the fleet:

A. Avoidance of road taxes by EVs under current laws.

As we note in “Steps to Estimate Costs” on page 30, all states and the federal government charge gasoline and diesel fuel taxes, commonly known as “road taxes.” These are intended to defray the cost of road maintenance. When levied on ICE vehicles, these bear a strong relationship to actual wear-and-tear on roads.

EVs currently avoid entirely the federal excise tax, and only some states levy replacement EV taxes. Over time, the gap between costs imposed on the road network and taxes paid by EV drivers will grow.

Furthermore, EVs are typically much heavier than comparably-sized ICE vehicles. To the extent this imposes additional wear and tear on roads, the gap is even larger. This creates an implicit subsidy from ICE drivers to EV drivers. As the size of the EV fleet grows, this subsidy, and the gap in funding, will become increasingly problematic.

B. Safety issues related to batteries.

Electric vehicles in current production often rely upon lithium-ion batteries. Lithium batteries pose serious fire risks, and have caused a number of dangerous consumer electronics incidents. The relatively small number of EVs on the road have also demonstrated fire risks related to lithium batteries, which are different and more severe than that posed by traditional gasoline and diesel vehicles.32

Additionally, the fire on the ship Felicity Ace was compounded by lithium-battery equipped EVs.33

32. “Battery fires, recalls threaten EV acceptance,” published in the Detroit News on March 16, 2022 details several examples, noting that “Batteries, if defective, can catch fire, burn for hours and release toxic fumes.”

C. Subsidies and use of charging equipment

The federal government and many states offer charging equipment subsidies.34 The 2021 federal “infrastructure” bill authorized another $2.5 billion in subsidies for alternative fueling centers, including EV chargers.35 These subsidies have widely varying provisions regarding access and placement. Some, such as the recent federal law, require open access and consideration of the needs of drivers in different areas. Others rely entirely on the initiative of the applicants. Even a casual perusal of the available charging sites reveals that their current alignment disproportionately benefits affluent metropolitan areas.36

As the EV fleet grows, there will be increasing attention to two issues that arise repeatedly with electric vehicles, namely their disproportionate purchase by affluent metropolitan households, and the ability to access charging infrastructure.

D. Inequities in tax incentives

The IRS section 30D purchase tax credit has been a powerful incentive for potential EV buyers. It allows a nonrefundable income tax credit for BEV and PHEVs purchasers, with manufacturer limits on the number of models. The structure of this credit raises two equity issues:

i. Should American taxpayers subsidize the purchase of vehicles that are unusually expensive and rely on a specific technology?

ii. Should US tax policy include a credit that is only useful for relatively affluent households?

The first question is a normative one addressed by the US Congress when the provision was adopted. The second one, however, has largely been left unexamined. The fact that the disproportionate share of EVs are high-priced luxury vehicles underlines a serious equity issue related to this tax law.

34. The federal government alternative fuel infrastructure tax credit authorized by Internal Revenue Code section 30C expired on December 31, 2021. Multiple states continue to provide subsidies. See US DoE Alternative Fuels Data Center, https://afdc.energy.gov/laws/10513, and https://afdc.energy.gov/laws/state. This is in addition to the Internal Revenue Code section 30D vehicle purchase credit.

35. Section 11101 of the Infrastructure Investment and Jobs Act, PA 117-58 of 2021, includes $2.5 billion in federal funds for electric, propane, natural gas, and hydrogen fueling stations. Other federal subsidies also exist.

36. The DoE alternative fuels data center and private services such as PlugShare allow examination of available chargers in different geographic areas.
**Geographic Analysis of Fast DC Charging Locations**

For our real-world cost comparison, we performed a geographic analysis of fast DC charger locations in various US states and metropolitan statistical areas. For example, we considered the number and location of fast DC chargers in the Lansing and Ann Arbor metropolitan statistical areas (MSAs) in Michigan. We compared these with the number and location of gasoline stations with convenience stores. Using a geographic information systems facility, we calculated the number of households within a 10-minute round trip of at least one such gas station or charger.

The results were instructive. For both MSAs, 90% of households were within a 10-minute round trip of a gas station with a convenience store. Only about 10% could reach a fast DC charger within a similar time.

- See Figure 5, “Population Within a 10-Minute Drive of Fueling Stations, Lansing Michigan,” on page 47.

In addition to the geographical analysis, we reviewed EV driver reports on forums, studied data from services such as PlugShare, and noted author experiences to estimate additional miles needed to refuel an EV.
EXHIBIT 5. Population Within a 10-Minute Drive of Fueling Stations, Lansing Michigan

Note: High power charging stations defined as plugs with an output of at least 50kW. Gas stations include convenience stores. Lansing MSA includes Ingham, Clinton, Eaton, and Shiawassee Counties.
Analysis: Anderson Economic Group
6. Authors and Contributors

Founded in 1996, Anderson Economic Group is one of the most recognized boutique consulting firms in the United States. Operating under the core values of professionalism, integrity, and expertise, Anderson Economic Group specializes in public policy, business strategy, and market analysis. The company has offices in East Lansing, Michigan and Chicago, Illinois.

The firm’s consultants have won five national awards for writing on business economics topics, including on the value of businesses, business location decisions, economics and presidential elections, and consumer demand for alcoholic beverages and cannabis products.

Representative past clients of Anderson Economic Group include:

**Automotive Companies.** Manufacturers and distributors including General Motors, Ford Motor Company, Honda Motor Company, Southeast Toyota; suppliers including JCI, BorgWarner, and ITT; trade associations including the Michigan Manufacturer’s Association, National Auto Dealers Association and Business Leaders for Michigan; and dealers and dealership groups representing Audi, Cadillac, Chevrolet, Chrysler, Ferrari, Ford, Genesis, Harley-Davidson, Hyundai, Kia, Lamborghini, Mercedes-Benz, MINI, Suzuki, and Toyota.

**Governments.** The Canadian federal government; the States of Michigan, North Carolina, Kentucky, New Jersey and Wisconsin; the Cities of Detroit, Cincinnati, and Sandusky; Oakland County, Michigan, and Collier County, Florida; and authorities such as the Detroit-Wayne County Port Authority.

**Higher Education Institutions.** Colleges and Universities including Michigan State University, University of Chicago, Wayne State University, and University of Michigan; and consortium including the University Research Corridor and Chicago’s Urban Campus.

**Labor Unions.** Labor Unions such as the National Education Association, Michigan Education Association, Michigan Manufacturers Association, and Service Employees International Union Local 503.

Visit AndersonEconomicGroup.com for more information.
Mr. Patrick Anderson founded Anderson Economic Group in 1996, and serves as the company’s principal and CEO.

Mr. Anderson is one of the nation’s foremost experts on the automotive industry. His expertise extends to manufacturers, franchisors and franchisees, and suppliers. He is frequently called upon to serve as an expert witness in industry disputes and important policy questions.

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- *Dr. Cristina Benton*, Anderson Economic Group, Director of Market and Industry Analysis
- *Lisa Wootton Booth*, Anderson Economic Group, Executive and Marketing Assistant
- *Sara Bowers*, Anderson Economic Group, Consultant
- *Shay Manawar*, Anderson Economic Group, Market and Industry Analyst
SUBSCRIBING TO THE EV TRANSITION SERIES

This report is second in the Anderson Economic Group EV Transition series. We anticipate that future reports will cover:

- Likely migration to EVs by consumer cohort.
- Detailed, segment-specific projections and comparisons of specific makes and models.
- Charging infrastructure and cost analyses for different geographic areas.
- State and federal policy, including subsidies and restrictions regarding ICE vehicles and EVs.

To subscribe to the Anderson Economic Group EV Transition Series, or to purchase access to larger data sets, please contact info@andersoneconomicgroup.com.
Appendix A. References


Comparison: Real World Cost of Driving EVs and ICE Vehicles

**Appendix B. Vehicle Segments and Cost Factors**

**VEHICLE SEGMENTS**

The automotive industry classifies vehicles by categories or segments. These segments represent two important dimensions of the consumer’s buying decision:

A. The use or utility of the vehicle, such as the ability to transport more people or haul cargo.

B. Features and price relative to other vehicles with similar utility.

We categorize vehicles into the following broad segments:

- Entry-priced cars and crossovers;
- Mid-priced cars and crossovers;
- Luxury cars and crossovers; and
- Light trucks, including pickup trucks and full-size SUVs.

These segments match longstanding industry practices, and have been used by Anderson Economic Group for well over a decade.37

**Limited EV Representation Across Consumer Segments**

We recognize limited EV representation in multiple segments:

A. Entry-priced EVs

   There are essentially no EVs in the entry-priced segment. A Nissan Leaf S plus, a compact hatchback EV with a 62 kWh battery, has a starting MSRP of $32,400.38 This is a considerably higher price than a comparably-sized ICE vehicle, for a car with much less range.39

   Entry-priced vehicles are an important segment, and the lack of EV options is a serious impediment to many buyers who would otherwise consider an EV.

37. These segments are further defined in the Anderson Economic Group’s Auto-motive Dashboard (andersoneconomicgroup.com/automotive-dashboard).

38. Based on 2022 model, retrieved January 2022 from nissanusa.com/vehicles/electric-cars/leaf.html. The website notes this price “excludes tax, title, license, options and destination charge.”

39. Comparison information from Edmunds notes the most popular version of the Leaf, the SV plus, starts at $36,425. Edmunds also notes that a Chevrolet Bolt EV in the basic (and most popular) trim has a starting MSRP of $31,995. Retrieved from edmunds.com/nissan/leaf and edmunds.com/chevrolet/bolt-ev/.
B. Light trucks
Light trucks are among the most popular vehicles sold in the United States. As of the end of 2021, there were only a tiny number of electric light trucks actually on the road in the US.

C. Crossovers
Consumers increasingly prefer vehicles that combine the utility of vehicles with considerable room, often with all wheel drive systems. These are commonly called “crossovers” today.

In other auto industry analyses, we separate crossovers from cars within a price segment. However, given the limited number of EVs in the market today, we have combined them in this report.

For two segments in this report, there were insufficient electric vehicles to provide a true comparison. For the third, we combined it with other cars. As the market for EVs develop, we anticipate that we will include additional segments.

39. A 2022 Chevrolet Equinox has an MSRP (before destination charge) of $25,800. A Chevrolet Trax has a starting MSRP of $21,400 and is closer in size to a Nissan Leaf. Prices retrieved in January 2022 from chevrolet.com/suvs/equinox/build-and-price/trim and chevrolet.com/suvs/trax.
**TABLE B-1. ICE Vehicles and EVs in Different Consumer Segments, 2021**

<table>
<thead>
<tr>
<th>ICE</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mid-Priced Cars</strong></td>
<td></td>
</tr>
<tr>
<td>Honda Accord</td>
<td>Nissan Leaf</td>
</tr>
<tr>
<td>Toyota Camry</td>
<td>Volkswagen ID.4</td>
</tr>
<tr>
<td>Chevrolet Malibu</td>
<td>Chevrolet Bolt EV</td>
</tr>
<tr>
<td></td>
<td>Tesla Model 3</td>
</tr>
<tr>
<td><strong>Luxury-Priced Cars</strong></td>
<td></td>
</tr>
<tr>
<td>BMW 530i</td>
<td>Porsche Taycan</td>
</tr>
<tr>
<td>Cadillac Escalade</td>
<td>Tesla Model S and Model X</td>
</tr>
<tr>
<td>Audi A6</td>
<td>Jaguar I-Pace</td>
</tr>
<tr>
<td>Porsche Macan</td>
<td>Audi e-Tron</td>
</tr>
<tr>
<td></td>
<td>Tesla Model Y</td>
</tr>
<tr>
<td><strong>Entry-Priced Cars</strong></td>
<td></td>
</tr>
<tr>
<td>Nissan Versa</td>
<td></td>
</tr>
<tr>
<td>Hyundai Accent</td>
<td></td>
</tr>
<tr>
<td>Kia Rio</td>
<td></td>
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<tr>
<td>Kia Forte</td>
<td></td>
</tr>
<tr>
<td>Subaru Impreza</td>
<td></td>
</tr>
<tr>
<td>Chevrolet Spark</td>
<td></td>
</tr>
<tr>
<td>Mitsubishi Mirage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>As of the end of 2021, no EVs sold in the US market met the criteria for “entry-priced” vehicles.</td>
</tr>
<tr>
<td><strong>Trucks</strong></td>
<td></td>
</tr>
<tr>
<td>Ford F-150</td>
<td>At the end of 2021, there were insufficient electric trucks available in the US market to perform a comparison. These electric trucks were being sold in limited numbers:</td>
</tr>
<tr>
<td>Chevrolet Silverado</td>
<td>GMC Hummer EV</td>
</tr>
<tr>
<td>Ram pickup</td>
<td>Rivian R1T</td>
</tr>
<tr>
<td>Toyota Tacoma</td>
<td></td>
</tr>
<tr>
<td>GMC Sierra</td>
<td></td>
</tr>
<tr>
<td>Nissan Frontier</td>
<td></td>
</tr>
<tr>
<td>Jeep Gladiator</td>
<td></td>
</tr>
<tr>
<td></td>
<td>We expect these electric trucks to be sold in 2022:</td>
</tr>
<tr>
<td></td>
<td>Ford F-150 Lightning</td>
</tr>
<tr>
<td></td>
<td>Chevrolet Silverado EV</td>
</tr>
<tr>
<td></td>
<td>GMC Sierra EV</td>
</tr>
</tbody>
</table>

*Source: Anderson Economic Group Research (2021)*
EVSE AND “CHARGERS”

The cost of acquiring and using the electric vehicle supply equipment (EVSE) is part of the cost to fuel an EV. For commercial charging, it is included in the price. For residential charging, it must be added separately.

Recognizing that the purchase of this equipment typically allows multiple years of use, we spread the cost of home EVSE over multiple years.

What is a “Charger?”

Residential and commercial EVSE supply electricity and other functions such as connections, validation, and certain safety procedures. However, AC power supplied to an EV by an L1 or L2 EVSE must typically be converted into DC power stored by a battery. This requires a charger that is normally inside the EV itself. Thus, while EVSE is ubiquitously referred to as a “charger,” when using an AC power source the actual battery charging is usually done by an inside-the-vehicle device.

Fast DC charging (sometimes called L3) does not require the same rectification (AC to DC) steps as L1 or L2 charging. For this activity, the use of the term “charger” is not consistent among the many sources we consulted. One article that evidences some controversy regarding the topic of “L3” and “Fast DC” charging is Kane (2019), citing the Weber State University (2016) presentation.

COSTS OF HOME EV CHARGERS

Drivers who charge at home must also pay for the installation and operation of a residential charger. In some cases, the cost of an L1 charger is bundled with the purchase price of a new vehicle. These are often operated at standard 120 voltage alternating current (120 VAC) by plugging them into a standard 3-prong plug (NEMA 5-15) on an available home circuit. Standard US home circuits are commonly rated at 15 amperes.40

40. The National Electrical Manufacturers Association, or NEMA, regulates electrical equipment in the US. The NEMA standard “5-15” refers to a voltage rating first, then an amperage rating. Standard US circuits are often called 110 volt and 120 volt interchangeably, or sometimes as “125V AC.” In actual usage, voltage fluctuates. Thus, the equipment is rated for a likely range. See, e.g., “What is a NEMA 5-15 Connector,” Americord, July 2021; https://www.americord.com/blog/what-is-the-nema-5-15-connector-how-does-it-work.
L2 chargers usually require the installation of a 240 VAC circuit, and often an additional circuit breaker and feed line. Similar circuits, many of which are rated at 15 or 30 amperes, are used for household washers and dryers.

The cost of a residential charger may be included in the purchase price of a new EV, it may be an optional purchase from the EV manufacturer, or it could be purchased separately. Installation of an L2 charger usually requires the services of an electrician. Consistent with the principles guiding this analysis, we account for these costs whether they are bundled with other services or not.

- See “Principles Guiding This Analysis” on page 3.

**ROAD TAXES**

The retail price of gasoline includes excise taxes that support road construction and maintenance. The retail cost of electricity does not. As a result, some states impose additional registration taxes on EVs to ensure that EV drivers pay a road tax burden that is (at least roughly) similar to that of ICE vehicle drivers.

Michigan, for example, levies an additional registration cost between $135 and $235 for most electric vehicles, depending on weight. California levies about $100, while Texas is considering a fee between $190 and $400. Some states are considering fees up to $1,000. As EV sales increase, we expect every state to impose some kind of road usage fee or similar charge for EV drivers.

**DEADHEAD MILES**

Poor EV charging infrastructure in the United States means drivers typically expend *deadhead miles* to get to a fast DC charger. The deadhead miles burden is compounded by the fact that EV chargers are significantly less reliable than gas pumps.

41. L1 chargers are often included in the purchase price of a new EV. This practice is not uniform across manufacturers, nor over time. As more EVs enter the used market, EV owners purchase new cars, and charger technology and options change, we expect automobile buyers will be given more options for buying or not buying a bundled charger with a new car.

42. In addition to the cost of the charger itself, professional installation and additional electrical equipment are commonly required.

43. See also “Road Taxes” on page 5.
Comparison: Real World Cost of Driving EVs and ICE Vehicles

By comparison, most metropolitan-area ICE vehicle drivers (and many rural drivers) have ready access to one or more convenient gas stations that require few, if any, deadhead miles.

RESIDENTIAL ELECTRICITY RATES AND TIME OF USE RATES

Our analysis presumes that a fraction of US consumers are subject to residential Time of Use (ToU) rates, which are intended to discourage electricity use during peak demand hours.

We expect the expansion of ToU rates will affect future charging behavior, especially among those who primarily rely upon residential chargers. However, the use of these rates was not yet commonplace in the time periods we analyzed for this report.

COMMERCIAL CHARGING USAGE

The three largest US commercial charging networks—ChargePoint, Electrify America, and Tesla—have all witnessed increased demand since 2018. For instance,

- ChargePoint witnessed an increase in number of sessions by 25.9% between 2017 and 2020. In the same period, average yield from charging sessions increased by about 33%. Its network of L2 and fast DC chargers yielded an average of 11.61 kWh in 2020.
- Electrify America achieved a 24.7% increase in energy distributed per charge session between 2019 and 2020. Its network of mostly fast DC chargers yielded average of 23.14 kWh in 2020.

44. The term “deadhead” has been used to describe the driving distance for empty trucks since at least the early 1990s. In recent years, use of the term has been extended to ride-sharing programs, public transit, and now electric vehicles.

45. Driver reports on EV forums are full of comments related to the problems of finding a reliable charger and the lack of fast DC chargers. The burden of finding chargers on trips can be acute. Some charging applications (e.g., PlugShare 2021) offer trip planning with user-adjustable parameters regarding how many miles a driver is willing to go off their intended route (e.g., deadhead miles) to find a charger. Electric vehicles themselves typically have sophisticated applications to estimate the range available on the current charge, as well as assistance in finding chargers to use on a trip.


• The Tesla Supercharger network doubled its usage between 2018 and 2019, and reported about 64,000 daily charge sessions. Its network of exclusively fast DC chargers yielded an average of 36 kWh in 2019.49 50

Regular Home Charging is Not a Viable Option for Around Half of American Households

A single-family residence with a garage is a commonly-assumed housing arrangement for EV drivers. Indeed, it is common among the relatively affluent portion of the population who purchased an EV through 2021.

However, many Americans live in housing units where the installation of a home charger in a controlled garage space is not physically possible, or would represent in impractical cost burden. Consider the following demographic data:

• US Census data for 2020 indicate that out of 122.4 households in the United States. Of these, 78.8 million households lived in owner-occupied housing units. This appears to be a durable characteristic of living arrangements, as 2014 data from a different survey provide an similar picture.51

• The most recent US Census data on housing is from 2019. Within the 122.8 million households overall, (and 79.5 million households that own their dwelling unit), 64.9 million households are in owner-occupied housing units with a garage or carport.52 This implies that slightly more than one-half of the households in the United States have a living arrangement in which they would be likely to have the opportunity to install and regularly use a home charger.

50.The Verge (2019). “Tesla’s first big V3 Supercharger expansion is already happening in Canada.”
51.US Census data on households and tenure in their housing unit indicate that, as of 2014, 79.6 million households were in owner-occupied units, and 43.6 million were renters. The source for these data is US Census Bureau, CPS Annual Social and Economic Supplements.
52.US Census Bureau, American Housing Survey. The 2019 data were the latest available as of March 2022.
Within those that live in owner-occupied homes with a garage or carport, some will not be able to install home chargers due to limitations on electrical service or space. Some will not be able to pay for the costs of such an installation (which may require running additional service lines or rewiring of a portion of the unit.) On the other hand, within those that live in renter-occupied housing, some households would be able to install and regularly use a home charger.

The number of households is a useful, but imperfect predictor of the number of drivers. However, using households as an indication of drivers, these data suggest that roughly half of American households have a viable option of regular home charging, and about half do not.

**Corroborating Information**

Other data corroborate this demographic observation.

- Examples of commuters with predictable driving patterns corroborate the conclusion that the majority of drivers travel away from their home regularly.53
- See the Finding “Commercial charging is necessary for most Americans who drive electric vehicles.” on page 11.

**Are “Most Charging Sessions” at Residences?**

It is common to read that “most” EV charging is done at residential chargers.54 There are two major problems with this assertion: first, it does not have a clear meaning; and second, it is often based on an unspecified source.

**The Meaning of “Mostly Home” Charging.** One possible meaning of the assertion “most charging is done at home” is that most charging sessions occur at home. This is undoubtedly true for many EV drivers. At least one of our benchmark use cases for EV drivers in both the first and second edition of this report presumed a driver that, for most charging sessions, plugged in at home.

53. For example, a typical driver with a 20-mile round trip commute for 220 days each year will commute a total of 4,400 miles. This driver then travels another 10,000 miles to reach the national average. A worker with a 40-mile round trip commute every workday for 48 weeks uses 9,600 miles just for commuting, much of which is beyond the local area.
However, because power is typically provided to the battery at much higher rates with commercial chargers, the number of charging sessions is not proportional to the amount of power provided by source. Thus, even drivers that use a home charger more than a commercial charger can end up paying commercial prices for the majority of the power they purchase.

- See “Power Added to EV Battery in Different Use Cases” on page 20.
- See also “Energy Costs” on page 32 and “Charging Modality” on page 33.

**A Recurring Unspecified Source.** An additional problem with the contention that “80% of charging occurs at home” is that it is often unsupported by any evidence in the publication. Sometimes, it is attributed to an undated document from the Department of Energy, with no author or publication number. To the extent this document can be identified, it does not appear on the US DoE website.55 Finally, since the document is not available and has no date, it is not clear whether its authors did, or could, have taken into account recent data on EV usage.

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54. Examples include NDRC (2019), which assumes that because the average drive per day in the US is less than the range of a typical EV, most charging can occur at home. It therefore extrapolates that “being dependent on public charging, as we were on our road trip, is the exception—not the norm.” Other examples include MyEV (2022), “Most EV owners charge at home;” Voelker (2021), “80% of EV charging is done at home;” Consumers Power (2021), “Over 80% of all EV charging happens at home;” and PWC (2021). None of these provide a specific basis for the “80%” figure. Some include a reference to an unnamed report attributed to the Department of Energy, which is presumably the U.S. Department of Energy. (See the further discussion of an unnamed, undated DoE document, below.)

A variation on this claim, also usually unsupported by an explicit reference, is that 80% of EV charging is done at home or work.

55. One citation to a document like this is in a publication from NREL (a unit of the US Department of Energy), “Incorporating Residential Smart Electric Vehicle Charging in Home Energy Management Systems, by Blonsky et al., no. CP-5D00-7840 (April 2021). This report sources a similar claim to “‘Charging at Home—Department of Energy’ [Online]” with no date or author, and no publication number. The URL listed for this document in the Blonsky, et al., report was blank in both February and March 2022.
Reliance on Actual Data

It may be that, as explained above, most charging sessions in recent years occurred at home. However, in order to estimate costs for real-world drivers, we must make use of information that allows us to calculate those costs. Given that we have actual data on the commercial charging, actual demographic data on housing, and actual data on mileage driven away on mid-length and longer trips, we have relied upon that data.
TABLE B-2. Direct Monetary Costs of Fueling ICE and EVs Using 2021 Energy Prices

<table>
<thead>
<tr>
<th></th>
<th>Entry ICE</th>
<th>Mid-Priced ICE</th>
<th>Luxury ICE</th>
<th>Mid-Priced EV</th>
<th>Luxury EV</th>
<th>Luxury EV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>Commercial</td>
<td>Commercial</td>
<td>Mostly Home</td>
<td>Mostly Commercial</td>
<td>Mostly Home</td>
</tr>
<tr>
<td>Purposeful miles per year</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Deadhead miles per year</td>
<td>(a) 96</td>
<td>96</td>
<td>96</td>
<td>255</td>
<td>1,327</td>
<td>284</td>
</tr>
<tr>
<td><strong>Total miles per year</strong></td>
<td><strong>12,096</strong></td>
<td><strong>12,096</strong></td>
<td><strong>12,096</strong></td>
<td><strong>12,255</strong></td>
<td><strong>13,327</strong></td>
<td><strong>12,284</strong></td>
</tr>
<tr>
<td>Fuel economy: miles per gallon</td>
<td>(b) 33</td>
<td>32.4</td>
<td>22.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(c) -</td>
<td>-</td>
<td>-</td>
<td>3.9</td>
<td>-</td>
<td>3.5</td>
</tr>
<tr>
<td>Fueling efficiency ratio</td>
<td>(d) 1</td>
<td>1</td>
<td>1</td>
<td>0.91</td>
<td>0.93</td>
<td>0.89</td>
</tr>
<tr>
<td>Fuel units used</td>
<td>(e) 366.5</td>
<td>373.3</td>
<td>532.9</td>
<td>3,523.9</td>
<td>4,083.4</td>
<td>3,936.2</td>
</tr>
<tr>
<td>fractions: home share per unit</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.80</td>
<td>0.10</td>
<td>0.80</td>
</tr>
<tr>
<td>fractions: commercial share per unit</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.20</td>
<td>0.90</td>
<td>0.20</td>
</tr>
<tr>
<td>Residential cost of fuel (per unit)</td>
<td>$ -</td>
<td>$ -</td>
<td>$ -</td>
<td>$ 0.17</td>
<td>$ 0.17</td>
<td>$ 0.17</td>
</tr>
<tr>
<td>Commercial cost of fuel (per unit)</td>
<td>(f) 3.32</td>
<td>3.32</td>
<td>3.96</td>
<td>0.43</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>Weighted average cost per unit</td>
<td>3.3</td>
<td>3.32</td>
<td>3.96</td>
<td>0.23</td>
<td>0.40</td>
<td>0.23</td>
</tr>
<tr>
<td>Energy costs</td>
<td>(g) 1,044.5</td>
<td>1,063.9</td>
<td>1,856.8</td>
<td>781.4</td>
<td>1,498.3</td>
<td>870.9</td>
</tr>
<tr>
<td>Road taxes</td>
<td>(h) 163.8</td>
<td>166.9</td>
<td>238.2</td>
<td>135.0</td>
<td>135.0</td>
<td>135.0</td>
</tr>
<tr>
<td>Cost of chargers</td>
<td>(i) -</td>
<td>-</td>
<td>-</td>
<td>364.1</td>
<td>120.0</td>
<td>364.1</td>
</tr>
<tr>
<td>Cost of deadhead miles</td>
<td>(j) 9.7</td>
<td>9.8</td>
<td>16.8</td>
<td>14.7</td>
<td>153.4</td>
<td>18.4</td>
</tr>
<tr>
<td><strong>Total fueling cost per year</strong></td>
<td><strong>1,218.03</strong></td>
<td><strong>1,240.59</strong></td>
<td><strong>2,111.74</strong></td>
<td><strong>1,295.21</strong></td>
<td><strong>1,906.68</strong></td>
<td><strong>1,388.36</strong></td>
</tr>
<tr>
<td>Cost per purposeful mile</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Fueling cost per 100 purposeful miles</strong></td>
<td><strong>$ 10.15</strong></td>
<td><strong>$ 10.34</strong></td>
<td><strong>$ 17.60</strong></td>
<td><strong>$ 10.79</strong></td>
<td><strong>$ 15.89</strong></td>
<td><strong>$ 11.57</strong></td>
</tr>
</tbody>
</table>

Sources: Anderson Economic Group (2021) research using assumptions listed; base data from consumer logbooks (prices and charging modalities); EIA (gasoline prices); excise taxes and additional registration taxes as levied by the State of Michigan.

(a) For ICE vehicles, we assume deadhead miles at 2 miles per trip (at 4 trips per month). For EVs, we assume 6 miles per trip for a commercial L2 charger, and 10 miles per trip to a commercial fast DC charger. For number of trips for EV charging sessions, refer to "Table B-7: Charge Added to Battery Under Different Charging Use Cases" of the report.

(b) Average of EPA-reported combined fuel economies for ICE vehicles listed in different consumer segments of "Table B-1: ICE Vehicles and EVs in Different Consumer Segments, 2021" on page B-3 of the report.

(c) Average of EPA-reported combined fuel economies for EV vehicles listed in different consumer segments of "Table B-1: ICE Vehicles and EVs in Different Consumer Segments, 2021" on page B-3 of the report.

(d) Adjusts for energy lost as heat from the battery and charger at the time of charging. It is approximately the fraction of power delivered to the EV battery from the power transmitted by the charger. See "Energy Costs" on page 29 of our report.

(e) Gasoline prices are an average of monthly fuel prices in 2021 as reported EIA data. Commercial charging rates at ChargePoint, Electrify America, Greenlots, and EVgo stations; rates shown on PlugShare, ChargePoint, and Greenlots apps for Jan-Aug 2021.

(f) Refer to "Road Taxes" in "Table B-8: Assumptions and Data Sources Used in the Report".

(g) Refer to "Cost of Residential Chargers" in "Table B-8: Assumptions and Data Sources Used in the Report".
Comparing Real World Cost of Driving EVs and ICE Vehicles

Table B-3. Direct Monetary Costs of Fueling EVs and ICE Cars for 100 Purposeful Miles, 2019-2021

<table>
<thead>
<tr>
<th>Entry ICE</th>
<th>Mid-Priced ICE</th>
<th>Luxury ICE</th>
<th>Mid-Priced EV</th>
<th>Luxury EV</th>
<th>Luxury EV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial fueling</td>
<td>Commercial fueling</td>
<td>Commercial fueling</td>
<td>Mostly Home Charging</td>
<td>Mostly Commercial Charging</td>
</tr>
<tr>
<td>2019</td>
<td>$7.50</td>
<td>$7.64</td>
<td>$13.50</td>
<td>$10.04</td>
<td>$16.18</td>
</tr>
<tr>
<td>2020</td>
<td>$6.09</td>
<td>$6.20</td>
<td>$11.61</td>
<td>$10.18</td>
<td>$16.02</td>
</tr>
<tr>
<td>2021</td>
<td>$10.15</td>
<td>$10.33</td>
<td>$17.59</td>
<td>$10.79</td>
<td>$15.88</td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group (2022) research using assumptions listed in the note below and “Methodology for Estimating Monetary Costs” on page 27; base data from consumer logbooks (commercial charging prices and charging modalities); EIA (gasoline and electricity prices); excise fuel taxes and additional EV registration taxes as levied in the State of Michigan.

Note: (a) Direct monetary costs for ICE and EV vehicles refers to the first four categories of costs in Table B-2 “Direct Monetary Costs of Fueling ICE and EVs Using 2021 Energy Prices,” on page B-11, namely the cost of fuel/electricity, cost of charger, registration or gasoline taxes, and deadhead miles.

(b) Gasoline price used for calculations is the average of monthly prices from 2021; commercial EV charging prices were collected between Jan-Aug 2021.

(c) “Mostly Commercial Charging” scenario implies 75% of the monthly charging sessions (not the charge added to a battery) were at a commercial charging station; the remaining 25% were using a residential L1 charger. See “Res25percentL1” scenario in Table B-7 on page B-15.

(d) “Mostly Home Charging” scenario implies 75% of the monthly charging sessions (not the charge added to a battery) were using a residential L2 charger. The remaining 25% were at a commercial charging station. See “Res75percentL2” scenario in Table B-7 on page B-15.
Comparison: Real World Cost of Driving EVs and ICE Vehicles

### TABLE B-4. Estimation of Implicit Time Burden as of 2021

<table>
<thead>
<tr>
<th>Purposeful miles per year</th>
<th>12,000</th>
<th>12,000</th>
<th>12,000</th>
<th>12,000</th>
<th>12,000</th>
<th>12,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deadhead miles per year</td>
<td>96</td>
<td>96</td>
<td>96</td>
<td>255</td>
<td>1,327</td>
<td>284</td>
</tr>
<tr>
<td>Total miles driven per year (a)</td>
<td>12,096</td>
<td>12,096</td>
<td>12,096</td>
<td>12,255</td>
<td>13,327</td>
<td>12,284</td>
</tr>
</tbody>
</table>

**Connection, Fueling, Disconnection and Payment Time**

- **Residential refueling (hours):**
  - Entry ICE: 0.52
  - Mid-Priced ICE: 0.34
  - Luxury ICE: 0.58

- **Commercial refueling (hours):**
  - Entry ICE: 1.63
  - Mid-Priced ICE: 8.51
  - Luxury ICE: 1.82

<table>
<thead>
<tr>
<th>Travel time to a Fueling Location (b)</th>
<th>0.23</th>
<th>0.23</th>
<th>0.23</th>
<th>0.61</th>
<th>3.16</th>
<th>0.68</th>
</tr>
</thead>
</table>

| Allowance for Unreliability             | 0    | 0    | 0    | 0.03 | 0.16 | 0.03 |

| Total monthly hours spent on the refueling process | 0.83 | 0.83 | 0.83 | 2.79 | 12.17 | 3.12 |

**Assumptions for each scenario:**

**Monthly sessions**

- **Gas station:**
  - Entry ICE: 4
  - Mid-Priced ICE: 4
  - Luxury ICE: 4

- **Residential charging:**
  - Entry ICE: -
  - Mid-Priced ICE: -
  - Luxury ICE: -

- **Commercial L2 charging:**
  - Entry ICE: -
  - Mid-Priced ICE: 6.5
  - Luxury ICE: 4.3

- **Commercial FDC charging:**
  - Entry ICE: -
  - Mid-Priced ICE: 1.6
  - Luxury ICE: 8.5

**Refueling time**

- **Gas station:**
  - Entry ICE: 0.15
  - Mid-Priced ICE: 0.15
  - Luxury ICE: 0.15

- **Residential charger:**
  - Entry ICE: -
  - Mid-Priced ICE: 0.08
  - Luxury ICE: 0.08

- **Commercial L2 charger:**
  - Entry ICE: -
  - Mid-Priced ICE: 1.00
  - Luxury ICE: 1.00

- **Commercial Fast DC charger:**
  - Entry ICE: -
  - Mid-Priced ICE: 0.50
  - Luxury ICE: 0.50

**Deadhead miles per session**

- **Gas station:**
  - Entry ICE: 2
  - Mid-Priced ICE: 2
  - Luxury ICE: 2

- **Residential charger:**
  - Entry ICE: -
  - Mid-Priced ICE: -
  - Luxury ICE: -

- **Commercial L2 charger:**
  - Entry ICE: -
  - Mid-Priced ICE: 6
  - Luxury ICE: 6

- **Commercial Fast DC charger:**
  - Entry ICE: -
  - Mid-Priced ICE: 10
  - Luxury ICE: 10

**Non-functional EV charger penalty time (c)** | 0.25 |
**Non-functional EV charger frequency (d)** | 1 in 20 |

**Sources:** Anderson Economic Group (2021) research using assumptions listed; base data from consumer logbooks (prices and charging).

**Notes:**

(a) Residential charging time (other than connection and disconnection) is counted as zero time-burden.
(b) Time spent on deadhead miles is calculated assuming the vehicle covers deadhead miles at an average of 35mph.
(c) Time spent driving to an EV charger to find it non-functional (including not working, not working properly, or blocked ["iced"]).
(d) Frequency of finding an EV charger that is non-functional for any reason.
### TABLE B-5. Estimation of Implicit Time Cost as of 2021

<table>
<thead>
<tr>
<th>Charger Type</th>
<th>Total Monthly Hours Spent on Refueling Process (a)</th>
<th>Time Cost Per 100 Miles at Minimum Wage (b)</th>
<th>Time Cost Per Month at Minimum Wage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry ICE Commercial Fueling</td>
<td>0.83</td>
<td>$0.80</td>
<td>$8.00</td>
</tr>
<tr>
<td>Mid-Priced ICE Commercial Fueling</td>
<td>0.83</td>
<td>$0.80</td>
<td>$8.00</td>
</tr>
<tr>
<td>Luxury ICE Commercial Fueling</td>
<td>0.83</td>
<td>$0.80</td>
<td>$8.00</td>
</tr>
<tr>
<td>Mid-Priced EV Mostly Home Charging</td>
<td>2.79</td>
<td>$2.69</td>
<td>$26.92</td>
</tr>
<tr>
<td>Luxury EV Mostly Commercial Charging</td>
<td>12.17</td>
<td>$11.74</td>
<td>$117.41</td>
</tr>
<tr>
<td>Luxury EV Mostly Home Charging</td>
<td>3.12</td>
<td>$3.01</td>
<td>$30.07</td>
</tr>
</tbody>
</table>

*Memo:* Time-cost per month at a $33/hour wage rate

*Assumptions:*
- Michigan minimum wage per hour (c) $9.65
- Hourly wage rate at $70,000/year $33.00

**Sources:** Anderson Economic Group (2021) research using assumptions listed; see Table B-4.

**Note:** Implicit time costs are not included in direct monetary costs.

**Notes:**
- (a) See Table B-4.

### TABLE B-6. Charge Per Session From Different Charging Modalities

<table>
<thead>
<tr>
<th>Charger Type</th>
<th>Typical Session Duration (hours)</th>
<th>Approx. Charge in One Hour (kWh)</th>
<th>Approx. Charge Added in One Session (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential L1</td>
<td>10.0</td>
<td>0.8</td>
<td>7-8</td>
</tr>
<tr>
<td>Residential L2</td>
<td>7.0</td>
<td>6.0</td>
<td>36</td>
</tr>
<tr>
<td>Commercial L2</td>
<td>2.0</td>
<td>6.0</td>
<td>12</td>
</tr>
<tr>
<td>Commercial Fast DC</td>
<td>0.5</td>
<td>65</td>
<td>30</td>
</tr>
</tbody>
</table>

*a. Charge added to a battery is not a simple product of the maximum charge per unit of time and the amount of time. This is due to changing power as the battery warms or exceeds 85% (especially for fast DC chargers), and heat losses.*

**Source:** Anderson Economic Group research (2021).
### TABLE B-7. Charge Added to Battery Under Different Use Cases

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Number and Share of Sessions</th>
<th>Share of Power Added by Source (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residential</td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L1</td>
<td>L2</td>
<td>%</td>
</tr>
<tr>
<td>AllResL2</td>
<td>N/A</td>
<td>10.5</td>
<td>100</td>
</tr>
<tr>
<td>AllResL1</td>
<td>30</td>
<td>N/A</td>
<td>100</td>
</tr>
<tr>
<td>Res90percentL2</td>
<td>N/A</td>
<td>9</td>
<td>90</td>
</tr>
<tr>
<td>Res90percentL1</td>
<td>30</td>
<td>N/A</td>
<td>90</td>
</tr>
<tr>
<td>Res85percentL2</td>
<td>N/A</td>
<td>8</td>
<td>84</td>
</tr>
<tr>
<td>Res85percentL1</td>
<td>25</td>
<td>N/A</td>
<td>85</td>
</tr>
<tr>
<td>Mostly Home benchmark Res75percentL2</td>
<td>N/A</td>
<td>8</td>
<td>73</td>
</tr>
<tr>
<td>Res75percentL1</td>
<td>24</td>
<td>N/A</td>
<td>75</td>
</tr>
<tr>
<td>Res50percentL2</td>
<td>N/A</td>
<td>7</td>
<td>54</td>
</tr>
<tr>
<td>Res50percentL1</td>
<td>13</td>
<td>N/A</td>
<td>50</td>
</tr>
<tr>
<td>Res25percentL2</td>
<td>N/A</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Mostly Commercial benchmark Res25percentL1</td>
<td>4</td>
<td>N/A</td>
<td>25</td>
</tr>
<tr>
<td>AllCommercial</td>
<td>N/A</td>
<td>N/A</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Anderson Economic Group research (2021)

Note: (a) For charging power added per session, see Table B-6, “Charge Per Session From Different Charging Modalities,” on page B-14.

(b) The number of charging sessions in each use case were estimated to meet the minimum charging requirements for the required number of miles. See “Consistent Assumptions for EVs and ICE Vehicles” on page 8.
### TABLE B-8. Assumptions and Data Sources Used in the Report

<table>
<thead>
<tr>
<th>Road Taxes</th>
<th>For ICE vehicles, excise taxes on fuels for road maintenance are included in the retail price of gasoline. Calculated at 26.3 cents per gallon Michigan state gas tax, and 18.4 cents per gallon federal fuel tax. For EVs estimated based on tax levied by the State of Michigan for vehicles &lt; 8,000 lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Residential Chargers</td>
<td>Costs of home chargers applies only to EVs used in home charging. We assume an L1 charger costs $600 and L2 charger (with installation in 2021) costs $1,820.40. These costs are amortized over 5 years. We arrive at the costs associated with an L2 charger in 2021 from benchmarking the 2019 costs at $1600 using BLS’ “Producer Price Index by Commodity: Construction (Partial): New Nonresidential Building Construction (WPU801)” index. The $1600 figure in 2019 was based on AEG review of estimated costs posted by utilities on their websites. These costs will be adjusted over time when more information becomes available.</td>
</tr>
</tbody>
</table>