APPENDIX A:
ELECTRIC VEHICLES 101

Light-duty Vehicle Basics

Electric vehicle (EV) is a term for any car that uses an electric engine for locomotion. There are several types of EVs, depending on whether the vehicle has an internal combustion engine (ICE) that supports the electric motor. More details on each type are outlined below

Table 1. Comparison of Types of Electric Vehicles

Electric Vehicle Type	Power Source	Travel Range
Battery Electric Vehicle (BEV)	Electric Motor	80 – 345 miles
Plug-in Hybrid Electric Vehicle (PHEV)	Electric Motor + Gasoline Engine	350 – 600 miles
Hybrid Electric Vehicle (HEV)	Electric Motor + Gasoline Engine	350 – 600 miles

Battery Electric Vehicle (BEV)

A BEV or all-electric vehicle is powered by an all-electric motor and does not require gasoline. Instead, BEVs are fueled by plugging into charging stations where energy is stored in the battery to be used when the car is running. Distances that a BEV can travel on a single charge range from 80 to 345 miles, with longer distances promised in the future through continual advancements in technology. Recharging can take anywhere from 30 minutes to 12 hours depending on the type of charger, size of the battery, and level of depletion in the battery (Drive Change. Drive Electric., 2019).

Plug-In Hybrid Electric Vehicle (PHEV)

A PHEV provides a combination of both an electric motor and a gasoline engine. PHEVs use energy from the electric motor until the battery charge runs out, which can occur between 15 to 50 miles, at which point, the gasoline engine takes over. The distance that a PHEV can travel on a single charge and full tank of gasoline ranges between 350 and 600 miles. The battery is charged similarly to the BEV through a plug, and the fuel tank is filled by traditional gas station (Drive Change. Drive Electric., 2019).

Hybrid Electric Vehicle (HEV)

An HEV has both an electric motor and a gasoline ICE. In these vehicles the ICE is used to power an electric generator, which in turn powers the electric motor. The benefit of this set up is that the ICE can run at a constant speed, greatly increasing the vehicle's fuel efficiency compared to traditional ICE vehicles. However, the battery in these vehicles cannot be charged by an external electricity source, so the vehicle always relies on the ICE.

Resources

- The U.S. Department of Energy's online Find a Car tool allows users to browse available EVs and explore fuel economy, safety ratings, and other specs.
- Xcel Energy's online EV comparison tool allows users to compare EVs by range, price, or a personalized Match Score.
- The International Energy Agency (IEA) Global EV Outlook 2021 online report provides of auto manufacturers' announcements related to electric light-duty vehicles, such as General Motors' plans to offer only electric light-duty vehicles by 2030.

Charging Stations

EV charging stations are broken out into three categories to indicate the speed at which the vehicle is charged: Level 1, 2, and 3. Level 3 chargers are also known as DC fast chargers. The sections below detail the appropriate application for each charger type. Keep in mind that faster charging is nearly always associated with higher infrastructure and fuel costs.

Residential Charging Stations

There are two types of chargers that residents can install in their homes (shown in Table 2). A brief explanation is outlined, along with the pros and cons of each type. All currently available electric vehicles can use either charger type.

Table 2. Residential Electric Vehicle Charging Types

	LEVEL 1	LEVEL 2
Electric Current (AC)	120 volts; 20 amps	208/240 volt; 30 amps
Charging Rate (mile range per hour of charging)	4 to 6	25 to 40
Benefits	• Uses standard residential wall outlet • Little to no investment in infrastructure required	• Quicker charging • Some models have available Wi-Fi controls to allow residents to take advantage of time-of-day electric rates • In the case of multifamily housing, controls could be managed by a property manager.
Drawbacks	• Slower charging rate, but usually sufficient for residents who charge overnight	• Requires 240 Volt outlet or hardwired charger • Electrician likely required to install • Higher infrastructure cost investment
Estimated Costs (does not include any necessary electrical upgrades)	Low to no cost	$500 to $2,000 (US DOE, 2019)

Resources

- Xcel Energy’s Home Charging Advisor online tool estimates costs to install and power a Level 2 home EV charging station.

Commercial Charging Stations

Level 2 and Level 3 chargers are most appropriate for commercial applications since vehicles are generally parked for shorter periods of time than in residential applications. Many commercial chargers also come equipped with software that allows the user to control when vehicles are charging and may facilitate payment in public applications. Table 3 shows the advantages and disadvantages of Level 2 and Level 3 chargers.

Table 3. Level 2 and 3 Charging Infrastructure

	LEVEL 2	LEVEL 3/DC Fast Charger
Electric Current	208/240 volt; 30 amps (AC)	480 volts DC
Charging Rate (mile range per hour of charging)	25 to 40	Up to 180
Benefits	• More economical than Level 3 • Safe for long term use	• Fastest charging option available
Drawbacks	• Slower charging	• Very expensive to purchase and install • Can cause degradation to EV batteries with prolonged use
Estimated Costs (does not include any necessary electrical upgrades)	$2,000 to $8,500 (US DOE, 2019)	As high as $50,000

Resources

- Xcel Energy's step-by-step guide for property owners interested in providing charging in commercial or multifamily properties.
- The U.S. Department of Energy maintains webpages for workplace charging, public charging, and multifamily charging, with information on planning, signage, operations and maintenance of charging stations.

Benefits of EVs

The popularity of electric vehicles is continuously rising, and many communities are looking to find ways to promote electric vehicle adoption. Some of the benefits of conversion to electric vehicles are described below.

Reduce GHG Emissions

Electric vehicles can significantly decrease the GHG emissions associated with on-road transportation, which overtook electricity generation as the largest source of GHG emissions in the US in 2017 (Environmental Protection Agency, 2019). The amount of savings depends on the electricity generation mix of your local electricity grid. According to one report, in 2025 a BEV charging station in the Denver Metro Area could reduce NOx emissions by 84 percent, VOC emissions by 99 percent, and greenhouse gas emissions by 49 percent compared to a new gasoline vehicle (Denver Environmental Health, 2020). Regardless of Xcel Energy's existing generation profile, national trends suggest that electric utilities are improving emissions from electricity generation at a faster rate than fuel economy is improving in ICE vehicles. Electric vehicle charging can be paired with residential roof-top solar, commercial solar parking structures, or community solar to further reduce associated GHG emissions.

Resources

- The U.S. Department of Energy publishes vehicle emission estimates, by state, through the Alternative Fuels Data Center.

Energy Independence

Over 65% of the petroleum imported by the US in 2018 was used for transportation fuel. Transitioning to electric vehicles shifts the fuel source to fuels that are more likely to be domestic (e.g., coal, nuclear, natural gas, and renewable energy). Transitioning to electric vehicles is an important strategy for reducing dependence on fuel imports and isolating transportation costs from the volatile petroleum market. (Office of Energy Efficiency and Renewable Energy, 2018).

Air Quality

Use of traditional ICE vehicles contribute to Ozone and fine particulate (PM2.5) creation, especially along heavily traveled routes. These pollutants have been linked to respiratory problems such as asthma and premature death for people with chronic exposure. These pollutants are significantly reduced in the case of HEVs and PHEVs and are eliminated in BEVs. One study of the Houston area found that moderate to complete vehicle electrification would reduce ozone by 1-4 ppb and PM2.5 by 0.5-2 µgm-3. This change is estimated to prevent 114-246 premature deaths annually, as well as to significantly reduce asthma exacerbation by 7,500 cases and reduce school loss days by 5,500 (Pan, et al., 2019).

Resources

- Argonne National Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) online tool compares air pollutants from new alternative fuel vehicles and gasoline (light-duty) and diesel (heavy-duty) vehicles.
- The U.S. Environmental Protection Agency (EPA) AirCompare maps provide information on air pollutants by county and how those pollutants impact people with asthma, older adults, young children, and other population groups.

Lower Fuel and Maintenance Costs

While cost savings vary based on vehicle type, driving patterns, and geographic region, the average driver spends about half as much money in fuel and maintenance costs when they drive an EV (compared to a traditional ICE). This can be a significant savings, as about 20% of US household income is spent on transportation costs. One study concluded that Xcel Energy customers who are EV owners will see additional annual savings between $260-$276 (MJB & A, 2019). To maximize fuel cost savings, be sure you understand Xcel Energy's electricity rates and adjust your charging patterns accordingly (Office of Energy Efficiency and Renewable Energy, 2019)

What Affects My Cost of Electricity?

There are two charges that may be applicable to your electricity use.

1. **Total Use Charge (kWh):** This is a measurement of the total amount of electricity used in the month (measured in kilowatt-hours).

   a. **Time-of-Day Rates:** Some utilities vary the cost per kWh by the time of day - with lower rates overnight when the electrical demand of the community is less. This provides an excellent opportunity for additional cost savings for EV owners who can charge at home overnight. Some charging stations and most vehicles allow the owner to program charging times, to automatically take advantage of these rates.

2. **Peak Demand Charge (kW):** This charge is based on the maximum amount of power that is used at any one time during the month. These charges are generally only seen in larger commercial rates. A facility should be cognizant, when installing charging stations, of the impact on their peak demand charges - as it can significantly increase the cost of charging if it impacts the facility's peak demand charge. A business can consider metering their electric vehicle charging separately or scheduling fleet charging overnight to help manage cost.

Resources

- The U.S. Department of Energy's (DOE) Vehicle Cost Calculator uses basic information about your driving habits to calculate total cost of ownership.
- For residential customers, Xcel Energy's Home Charging Advisor online tool estimates costs to charge an EV at home.
- For commercial customers, your Xcel Energy representative can help you understand your local rates and offer ways to minimize electricity charges related to charging your electric vehicle(s).

Real and Perceived Barriers to EV Adoption

1. **Vehicle Type:** Currently most plug-in electric vehicle (PEVs) are small sedans, but small sedans are declining in popularity. In 2017, 42% of people stated that their next vehicle would be a sedan - down from 45% in 2016. (National Renewable Energy Laboratory, 2017)

2. **Vehicle replacement cycles:** New vehicle technology is slow to be incorporated into a community's vehicle fleet since many people don't replace their vehicles frequently. A survey found that 46% of people plan to replace a vehicle over the next 3 years. Of these vehicle purchases, about 40% of people responded that they probably or definitely would purchase a new vehicle, which will also delay uptake of electric vehicles since the supply of used PEVs is limited. (National Renewable Energy Laboratory, 2017).

3. **Awareness:** In the 2017 study, over 50% of people were not able to name a specific make and model of a PEV.

4. **Exposure:** Often first-hand exposure to a new technology is a precursor to the purchase of that technology. As of 2017, 40% of people had owned, driven, or sat in a PEV.

5. **Public Opinion:** The number of people who believe that EVs are not as good as traditional gasoline vehicles has been declining, with the number down to 35% in 2017; but about 20% were unsure. Still, over half of the people surveyed stated they would not purchase or lease an EV.

6. **Range:** The median range that consumers said would be required, in order for them to purchase an EV, was 300 miles (while the current average range of most vehicles is around 200 miles).

7. **Charging availability:** Only 8% of surveyed people said they could charge their vehicle at work, and 16% said they could charge their vehicle at other locations they frequent. 54% said they could plug in their vehicle at home most days.

8. **Purchase Price:** Initial vehicle price is the largest deterrent for most people. Most people (66%) stated that they expect to spend $30,000 or less on their next vehicle. Both the Chevy Volt and Chevy Bolt are within this range after the federal tax credit is applied. (National Renewable Energy Laboratory, 2017). Battery prices, the main factor driving EV price, has been steadily decreasing which has been driving down the incremental cost of EVs. The price of EVs is expected to be similar to internal combustion engine vehicles by the mid-2020s. (BloombergNEF, 2019)

Reasons to Purchase/Lease an EV	Percentage of respondents (trend from 2016)
Better for the environment	84% (down from 87%)
Save money on fuel costs	83% (up from 79%)
Better for national security	63% (up from 62%)
Better performance	34% (up from 29%)
Cutting edge technology	60% (same)

Reasons NOT to Purchase/Lease an EV	Percentage of respondents (trend from 2016)
Technology is not dependable	28% (down from 35%)
Not available in vehicle segment	24% (down from 32%)
Too expensive	51% (down from 55%)
Poor performance	24% (down from 26%)
Unable to charge at home	30% (no data in 2016)
Unable to charge away from home	48% (no data in 2016)

EV FAQS

1. Are EVs affordable?

a. Today, most electric vehicles cost a little more to purchase than their traditional counterparts, but typically cost about half as much to operate and maintain. EVs require little to no maintenance, and electricity is cheaper and cleaner than gasoline or diesel fuel. Plus, there are many incentives to purchase an EV, such as federal tax incentives. Look for additional discounts through special promotions, such as "group-buys" where dealers offer electric vehicles at a lower price to incentivize a large volume of sales.

2. How far can an EV travel on one charge?

a. Typical battery range is between 80-350 miles. Visit the U.S. Department of Energy's Find a Car online tool to find an EV that would best suit your needs.

3. Are electric trucks and SUVs available?

a. There are already more than 50 electric SUV models available, and several auto manufacturers including Ford, GMC, and Tesla are in the process of releasing electric trucks. Without the burden of a traditional motor, electric vehicles can offer lots of torque, so you can expect electric trucks to provide all the power you need.

4. How do winter conditions affect EVs?

a. Extreme cold can impact the range in EVs by 25-30%. The additional heating needed for passenger comfort during extreme cold requires more energy than more moderate temperatures and cold batteries do not hold their charge as well. However, temperature-control technology is improving to compensate for some of these issues. Several models are now available with battery heaters or other technology to improve efficiency in cold climates.

5. Where can I charge my EV?

a. The easiest way to find charging stations is to use websites like the U.S. Department of Energy Alternative Fueling Station Locator, or apps like PlugShare and OpenCharge that let you filter by charger type, price, and other features.

6. How long will it take to charge my EV?

a. Charging can take anywhere from 20 minutes to 12 hours depending on the type of battery, how empty the battery is, and the type of charger. Level 2 chargers, the most common type at public charging stations, typically provides 10-25 miles of range per hour of charge.

7. Are EVs better for the environment?

a. *Tailpipe emissions (local air pollution)*: When internal combustion engine (ICE) vehicles turn gasoline into power, they produce harmful byproducts (e.g., nitrogen oxide, carbon monoxide, particulate matter) that are released from the vehicle's tailpipe. Tailpipe emissions from traditional vehicles produce greenhouse gas emissions and can lead to local air pollution by contributing to smog and haze. In turn, this air pollution can cause or worsen health problems, such as asthma and chronic bronchitis. Unlike ICE vehicles, EVs do not produce any tailpipe emissions and therefore can benefit local air quality and public health.

b. *Fuel production emissions (global pollution)*: When taking a more holistic look, both EVs and ICE vehicles produce emissions related to the production of fuel (gasoline or diesel for ICE vehicles and electricity for EVs). In the case of gasoline and diesel fuel production, emissions are produced through the extraction, refining, and transportation of fuel to pumping stations. When it comes to EVs, there are emissions associated with the generation of electricity used to charge cars. The difference in emissions associated with fuel production varies greatly depending on the source of electricity generation. Still, research suggests that EVs have lower greenhouse gas emissions than ICE vehicles, even based on current electricity generation. This is largely because much of the electricity produced in the US comes from cleaner sources like natural gas, wind, and solar. As the cost of renewable electricity generation continues to plummet, and both utilities and states commit to increasing the percentage of renewables in their supply, the greenhouse gas emissions associated with charging EVs will decline over time. See the Department of Energy (DOE) Alternative Fuels Database for more information on comparing greenhouse gas emissions associated with EVs and ICE vehicles.

c. *Manufacturing and end-of-life emissions and other environmental impacts*: Environmental impacts and greenhouse gas emissions are associated with the manufacture and disposal of any vehicle. However, the lithium-ion batteries in current EVs pose specific social, economic, and environmental challenges related to the materials used to produce them. Battery materials sourcing and recycling are the top supply chain impacts to be addressed. There is significant ongoing research and commercial development aimed at both reducing the amount of cobalt and other materials used in EV batteries, while also improving options for battery reuse (building and grid storage) and recycling (for example the DOE ReCell Advanced Battery Recycling Project).

8. How clean is the electricity I am using to charge my EV?

a. The sustainability of EVs largely depends on the source of the electricity generated and used to charge the vehicle. Currently, EVs charged in Xcel Energy territory use electricity from an energy mix that ranges from 37 to 62% carbon free and are expected to be 100% carbon-free electricity by 2050. Communities outside Xcel Energy territory can find out how their electricity source affects EV emissions by visiting the U.S. DOE's electric emissions tool.

9. How sustainable are EV batteries?

a. *Battery production emissions*: Differences in battery materials and production techniques, including the location and the energy mix for production, affect the overall sustainability of EV batteries. A battery produced using coal-fired electricity, for example, will have significantly higher emissions than one produced using cleaner power. In total, analyses of battery production (including the extraction of component minerals) suggest that emissions from manufacturing an EV battery are roughly equivalent to the emissions from manufacturing the rest of the vehicle. Some experts suggest that these emissions represent approximately 5-15% of the total life-cycle emissions of an EV in many locales, although these estimates can vary widely. The good news is that new production technologies are developing, and the overall electrical grid is becoming less carbon intensive. Some experts anticipate a 50% reduction in an EV's life-cycle emissions by 2030, and by one estimate of a fully renewable future grid EVs could eventually produce at least 90% fewer life-cycle emissions than do ICE vehicles.

b. *Battery production social impacts*: Certain challenges are particularly connected with mining for minerals, such as cobalt, used in EV batteries. Unregulated cobalt mining in the Democratic Republic of Congo (DRC), which produces more than half of all mined cobalt, is linked to regular risk of injury and death due to mine collapse, lung disease from particle inhalation, and child labor concerns (with weak enforcement of health and safety standards or child labor rules). It is important to note that fossil fuel exploration and extraction has also been associated with similar human rights abuse, conflict, and corruption. The average scores on the Resource Governance Index for oil-producing countries (47 out of 100) and mineral-producing countries (48 out of 100) are virtually identical, signaling that misgovernance, specifically related to child labor, remains a challenge in both sectors.

c. *Battery lifespan*: Electric vehicle (EV) batteries are designed for extended life; but, as with any other rechargeable battery, they will degrade over time. Federal regulations require that every battery in an EV sold in the U.S. come with a warranty providing coverage for a minimum of eight years or 100,000 miles. However, current estimates predict that an EV battery will last 10–20 years before it needs to be replaced. EV drivers can maximize battery life by avoiding high temperatures, overcharging, completely draining the battery, and aggressive driving patterns. After the battery's first life is over, it can be reused for energy storage, telecommunications backup services, and other applications before it needs to be recycled.

10. When should I consider replacing my existing gas-powered vehicle with an EV?

a. From a cost perspective: Total cost of ownership for a vehicle includes purchase or lease price, fuel/electricity, maintenance, and insurance. Due to low fuel/electricity and maintenance costs, owning an EV is often less expensive (over several years) than owning an ICE vehicle. Visit the U.S. DOE online Find a Car tool to explore potential savings for various EV models. As the EV market grows, so will used EV options, further improving cost-benefit analysis.

b. From an environmental perspective: Normally, it is best not to replace products unnecessarily. This is because the greenhouse gas emissions related to most things we purchase (e.g., clothing, furniture) come from the energy used to manufacture and ship the items. However, products that consume fossil fuels for power (e.g., vehicles, furnaces, and lawn mowers) produce emissions every time they are turned on. An ICE vehicle will produce 8 to 10 times more emissions from driving than from its manufacture. Therefore, replacing ICE vehicles sooner, with EVs, can significantly improve overall emissions and air quality.