Navigating Options for Transportation Electrification and Solar Charging: Steps and Lessons Learned in Montana Communities

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5 Climate Smart Missoula

NREL Technical Monitor: Sara Farrar

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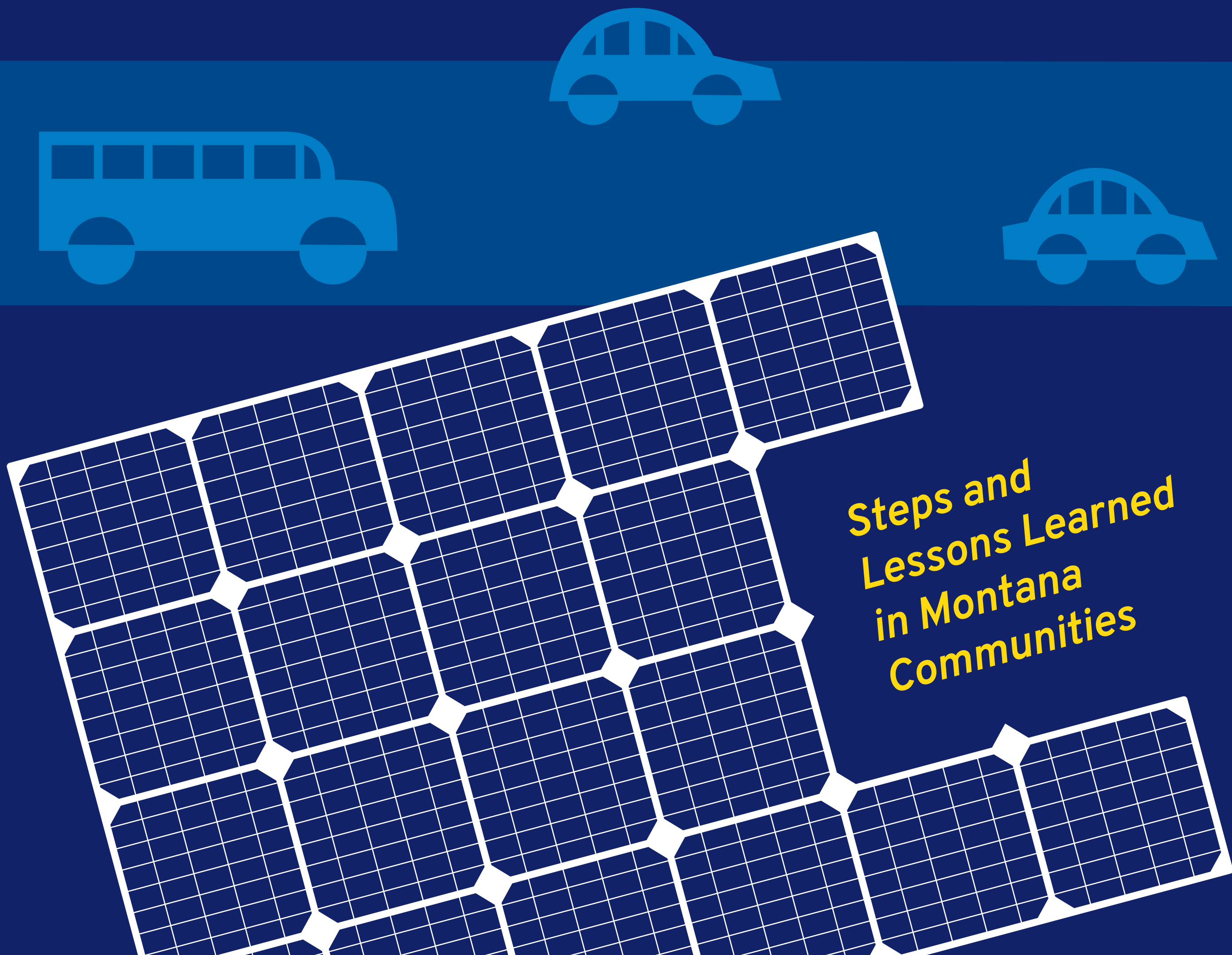
Navigating Options for Transportation Electrification and Solar Charging



Steps and Lessons Learned in Montana Communities

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Montana Solar Energy Innovation Network Team

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- Chase Jones, City of Missoula
- Natalie Meyer, City of Bozeman
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Acronyms

AC	Alternating Current
BEB	Battery Electric Bus
BEV	Battery Electric Vehicle
CNG	Compressed Natural Gas
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
DC	Direct Current
GHG	Greenhouse Gas
IOU	Investor-Owned Utility
IPCC	Intergovernmental Panel on Climate Change
NREL	National Renewable Energy Laboratory
PSC	Public Service Commission
PV	Photovoltaic
REC	Renewable Energy Certificate
ZEV	Zero Emissions Vehicle

Introduction

This document is intended to assist communities who are considering investing in electric transportation. It can assist communities engage stakeholders, prioritize community goals, assess electric transportation options, and navigate complex decisions about deploying zero emission electric transportation in their community. It covers technological, economic and environmental aspects of the transition to electric vehicles (EV), and highlights the specific considerations related to the deployment of renewable energy technologies (e.g., distributed solar) in combination with EV supply equipment (EVSE, e.g., charging stations). There are many important decisions to make and questions for communities to ask themselves as they consider electric vehicle types, charging infrastructure, and electricity generation options. This guide will help communities assess:

- Which stage in the decision-making process they are in with respect to EV deployment
- Questions they can explore to guide their decisions about EV deployment
- How to engage key stakeholders on EV deployment options
- Tradeoffs and benefits of various electric transportation options and;
- Synergies of pairing electric vehicle charging and renewable energy generation technologies.

The analysis and lessons learned presented in this roadmap are intended to serve as a template and guide for similarly situated communities across the country who want to prepare for and play a role in the electrified transportation future.

This guide is a product of the efforts of a team comprised of the Montana Renewable Energy Association, the Montana Energy Office at the Department of Environmental Quality, Climate Smart Missoula and the three communities of Missoula, Bozeman and Whitefish (The Montana team). These stakeholders worked together over a period of 18 months to conduct analysis and community outreach as part of the Solar Energy

Innovation Network, which is led by the National Renewable Energy Laboratory.[1] Each of the participating communities have different priorities and goals related to renewable energy, sustainability, and reducing emissions. The diversity that these three communities brought to the project has contributed to a more holistic view of the considerations and challenges of communities investigating electric transportation options, including pairing charging with renewable energy.

Each of the three communities had different questions they were trying to answer related to electric transportation options. These questions helped determine what "stage" of electric transportation deployment each community was in. The stages and associated questions that were identified through work with these communities are:

Stage 1: What are our options for electric transportation?

Stage 2: What clean transportation technologies are right for our community?

Stage 3: How can our community most effectively deploy electric vehicles?

This document provides background information on electrifying transportation, costs and benefits of electric vehicle technologies, and pairing electric vehicles with renewable energy. It also helps communities assess at what stage in the electric transportation decision-making process they are, and then walks through steps to help answer the key questions in each of the stages.

Several electric vehicle policy and technology guidance documents have been developed by, government agencies, national labs, non-governmental organizations, and private companies in recent years, in addition to analyses conducted on different electric transportation sectors and options (public transit, fleet vehicles, personal vehicles, etc.). This document is intended to complement those resources by serving as a tool to help communities prioritize investments and analyze different electric transportation use cases. Section 2.4 aggregates existing studies on costs and

[1] Learn more about the Solar Energy Innovation Network here: https://www.nrel.gov/solar/solar-energy-innovation-network.html.

benefits of four different electric transportation use cases to help communities compare these use cases, prioritize limited resources and make investments.

The electrification of the transportation sector is a broad topic with many facets, and many topics are not covered in detail in this document. Resources for the following areas of interest are provided in Section 8:

- The myriad of electric mobility options, including autonomous electric vehicles
- State-level policies to support electric vehicle adoption
- Integrating renewable energy with light duty electric vehicle charging
- Vehicle-to-grid integration of electric vehicles
- City-level policies to support electric vehicle adoption and charging infrastructure deployment
- Utility rate designs for electric vehicles

Section 1

Background on Electric Vehicle Deployment

Over the last five years, the U.S. electric vehicle market growth rate has exceeded forecasted estimates. There are approximately 900,000 light duty electric vehicles in the United States accounting for about 1.2% of vehicles on US roadways.

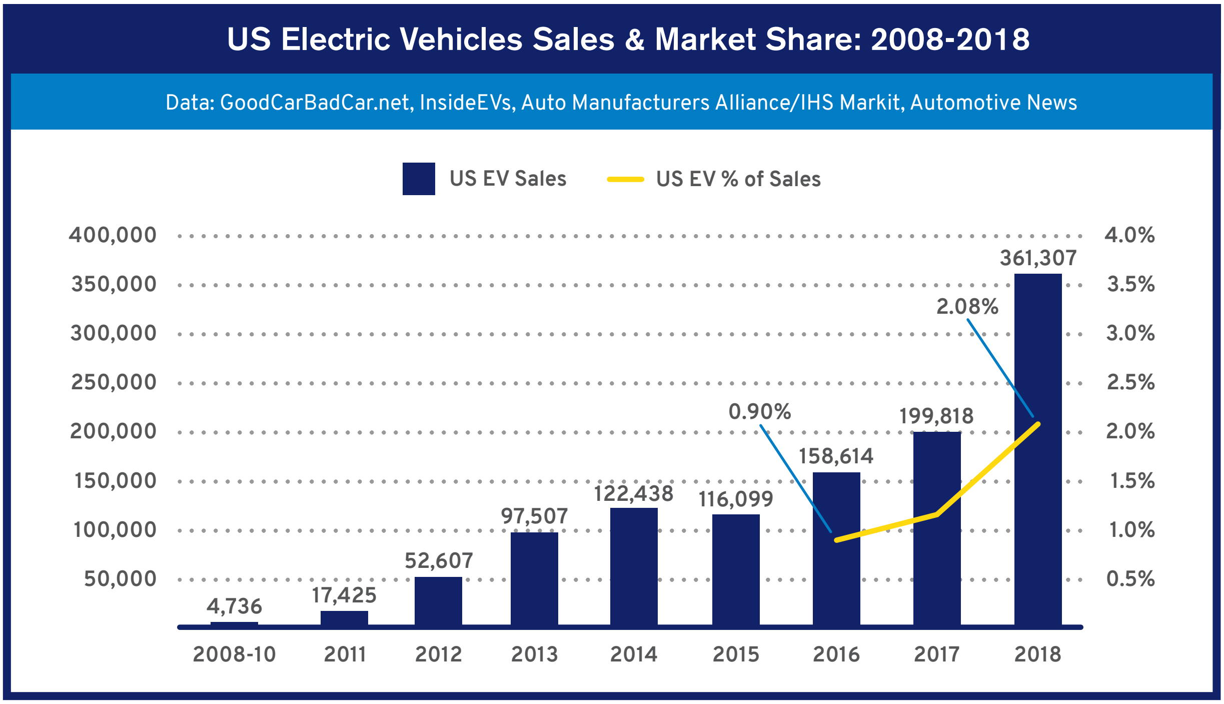

Figure 1 — US Electric Vehicles Sales & Market Share: 2008-2018[2]

According to Inside EV's 2018 December Plug-In EV Sales Report Card, electric vehicles reached a record of over 300,000 new U.S. vehicle sales in 2018, an increase of over 80% from 2017. As seen in Figure 1, they made up just over 2% of total vehicle

[2] McDonald, Loren. EV Adoption.com. 2019.

sales. The Tesla Model 3 was responsible for the majority of 2018 sales (Figure 2); other automakers are entering the electric vehicle market with new models and have made commitments to make more electric models available within the next five to

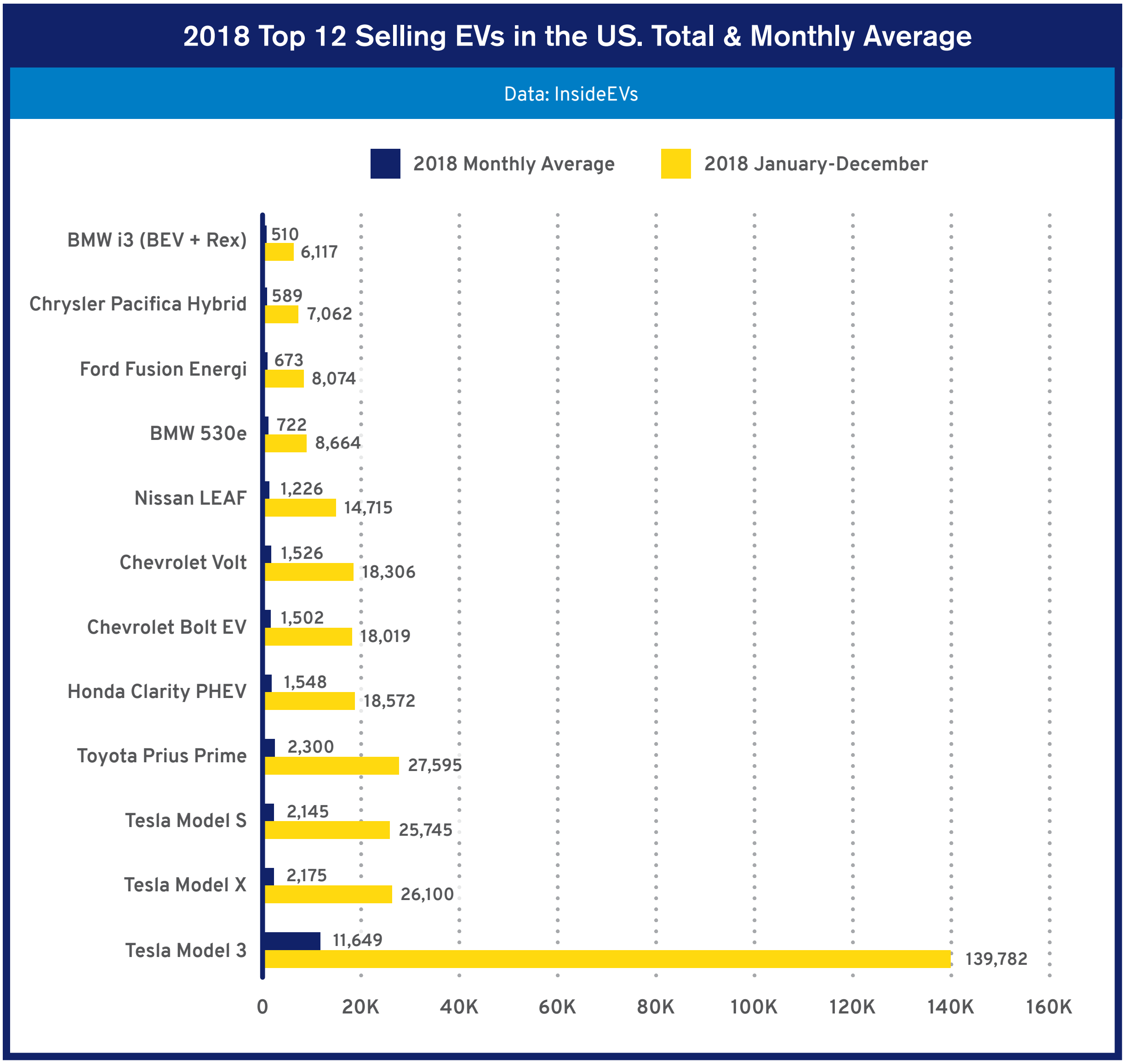

Figure 2 — 2018 Top 12 Selling EVs in the US. Total & Monthly Average[3]

[3]McDonald, Loren. EVAdoption.com. 2019.

ten years. Several factors are causing the rapid growth of the electric vehicle market, including more availability and diversity of vehicle models, declining costs of lithium ion batteries, increasing vehicle range, and policies and incentives at the state and local levels.

Growth in electric transportation is not just limited to light duty vehicles. Battery electric transit buses are replacing diesel buses in a number of cities across the world. There were over 385,000 electric transit buses on the road globally in 2018. China is by far the largest market for battery electric buses with about 99% of all bus sales.[4] Of the 65,000 public transit buses in the US today, about 340 are electric with at least another 1,200 transit buses on order. In California, seven transit agencies have committed to 100% zero-emission bus fleets by 2040. At least 21 transit agencies across the country have or plan to buy electric buses by 2020.[5]

1.1 Policy Options to Support Electric Transportation

While this document does not recommend specific policies, it is important for communities to understand existing policies and policy options that can support electric transportation. State and city level policies and incentives are helping advance electric vehicle adoption. According to a rubric developed by the National Association of State Energy Officials, reducing the upfront costs of vehicles through tax credits and other incentive mechanisms has been the most effective policy for increasing electric vehicle adoption.[6] Electric vehicle policies usually fall under one of the stated policy goals listed in Table 1. The table contains a representative but not exhaustive list of policies for each category.

(See Table 1 on next page)

[4] McKinsey Center for Future Mobility, "Fast Transit: Why Urban E-Buses Lead Electric-Vehicle Growth", September 2018.

[5] Bloomberg New Energy Finance, "Electric Vehicle Outlook 2019", May 2019. Available at: https://about.bnef.com/electric-vehicle-outlook/

[6] National Association of State Energy Officials and Cadmus, "PEV Policy Evaluation Rubric." September 2018.

Electric Transportation Policy Examples		
POLICY GOAL[8]	**POLICY TYPES**	
Sending Long-term Signals to Markets	• EV Deployment Targets • Zero Emission Vehicle Mandates	• Commitment to Electrify Public Fleets
Reducing Electric Vehicle Operating Costs	• Residential Electric Vehicle Electricity Rates and Programs • Favorable EV Road Usage Fee Rate (gas tax substitute) • License/Registration Tax Exemption • Smart Meter Program Tied to EV Ownership	• High Occupancy Vehicle (HOV) Lane Access • Preferred Parking • Toll Fee Waivers • Free Ferry Rides • Preferred Airport Pick-Up/ Drop-Off
Improving Economic Viability of Electric Vehicle Charging Infrastructure	• Financial Incentive for EVSE Installation	• Enable Return on Investment for DC Fast Charging Installations • Competitive Market for EVSE
Improving Electric Vehicle and Infrastructure Planning	• EV and EVSE Readiness Plans at Multiple Jurisdictional Levels • EV-Ready Building Codes and Zoning Ordinances	• Streamlined EVSE Permitting Procedures
Increasing Awareness and Education	• Educational and Marketing Campaigns	• Utilities Permitted to Spend Money on Education and Communication Material
Reducing Upfront Costs	• EV Purchase Rebate • EV Purchase Tax Credit	• Group Buy Program • Intergovernmental Agreement on Approved EV Vendor List

Table 1 — Electric Transportation Policy Examples[7]

[7] Adapted from "PEV Policy Evaluation Rubric"

[8] Policy categories drawn from: National Association of State Energy Officials and Cadmus, "PEV Policy Evaluation Rubric." September 2018

Cities play an important role in shaping the growth of electric vehicles due to their ability to provide financial and other incentives, their control over purchasing and operation of municipal fleets, and oversight over public spaces and public transportation.[9] Table 2 below includes examples of specific policies that cities have implemented to encourage electric vehicle adoption.

Electric Transportation Policy Examples		
Transportation Electrification Policies	**Cities**	
Zero or low emission vehicle sales targets	• Los Angeles, CA • Columbus, OH • New York City	• London, England • Oslo, Norway
Transit bus fleet upgrade commitments	• Seattle, WA	• Washington, D.C.
Electric Vehicle-Ready Codes and Ordinances	• Atlanta, GA • Palo Alto, CA	• San Francisco, CA • Denver, CO
Streetlight and Power Pole Charging Access	• Seattle, WA • Lancaster, CA	• Los Angeles, CA
Right-Of-Way Charging on Public Sidewalks	• New Orleans, LA	• Seattle, WA
Free parking for electric vehicles at eligible parking locations	• Cincinnati, OH • Salt Lake City, UT	• San Jose, CA
Streamlined EVSE permitting processes	• Chicago, IL • Oakland, CA	• Denver, CO

Table 2 — Examples of EV-Related Policies and Cities That Have Adopted Them[10]

[9] Cadmus, "Pathways to EV: Preparing Cities for the transition to Electric Vehicles." June 2018.
[10] Sierra Club, "AchiEVe: Model State & Local Policies to Accelerate Electric Vehicle Adoption." June 2018.

1.2 Transportation Sector Greenhouse Gas Emissions

According to the Intergovernmental Panel on Climate Change (IPCC), global emissions in transportation increased by 2.5% annually between 2010 and 2015. This makes transportation the fastest growing greenhouse gas emissions sector in the world. In most countries, including the United States, the largest source of transportation-related greenhouse gas emissions is passenger cars and light duty trucks, which account for over half of the emissions from the transportation sector.

Since 2015, the transportation sector has generated the largest share (28.9% as of February 2019) of greenhouse gas (GHG) emissions in the United States.[11] Figure 3 shows total U.S. GHG Emissions by Sector. While energy efficiency and cleaner sources of energy generation are reducing greenhouse gas emissions from the electricity sector, emissions for the transportation sector continue to rise in both absolute and relative terms.

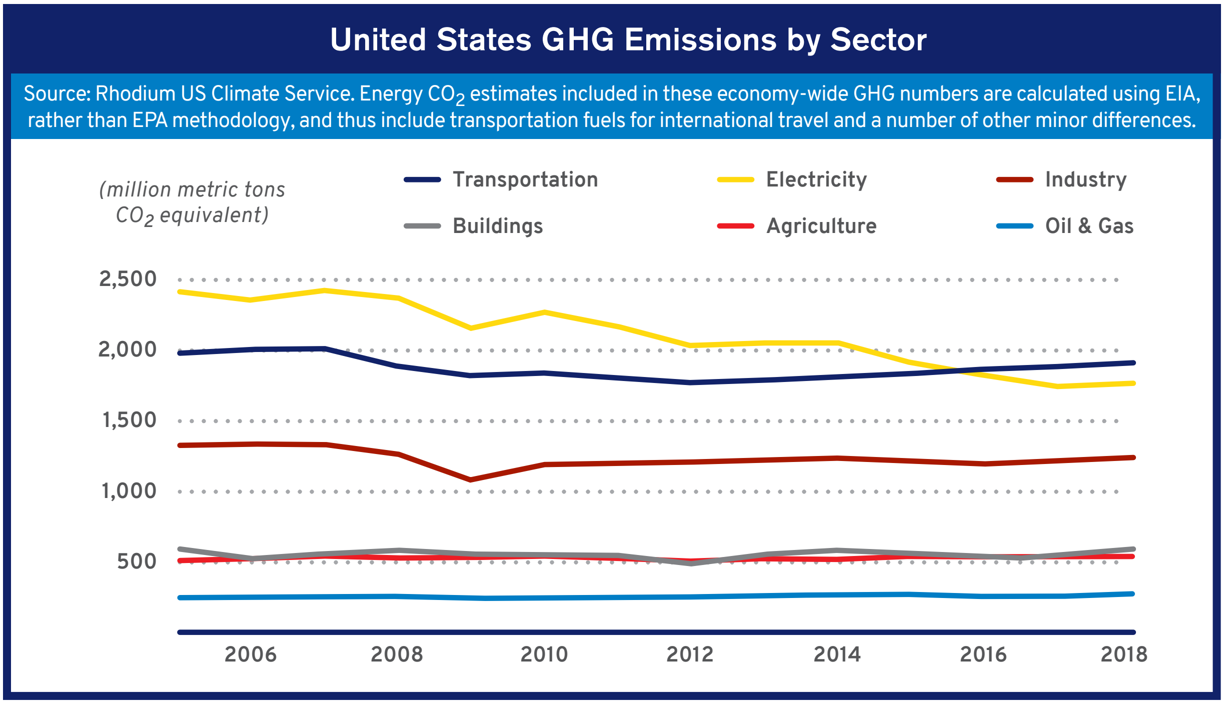

Figure 3 — United States GHG Emissions by Sector[12]

[11] U.S. Environmental Protection Agency, “Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017.” February 2019.

[12] Rhodium Group. “Final US Emissions Estimates for 2018.” May 31,2019. Available: https://rhg.com/research/final-us-emissions-estimates-for-2018/

The increase in transportation emissions is largely due to an increase in the vehicle miles travelled (VMT) by personal light duty vehicles, which make up the bulk of transportation sector emission as shown in Figure 4. At the state level, transportation is responsible for the largest share of statewide greenhouse gas emissions in nearly half states.[13] In Montana, transportation is the second largest contributor, with just over 25% of statewide greenhouse gas emissions. Within urban areas and cities, transportation contributes to direct and localized air pollution and emissions. For example, in Bozeman, Missoula, and Whitefish, the transportation sector is a major source of greenhouse gas emissions and is also responsible for other air pollutants such as nitrogen oxides (NOx), which contribute to smog and negatively impact air quality and public health. This is discussed further in the case studies later in this document.

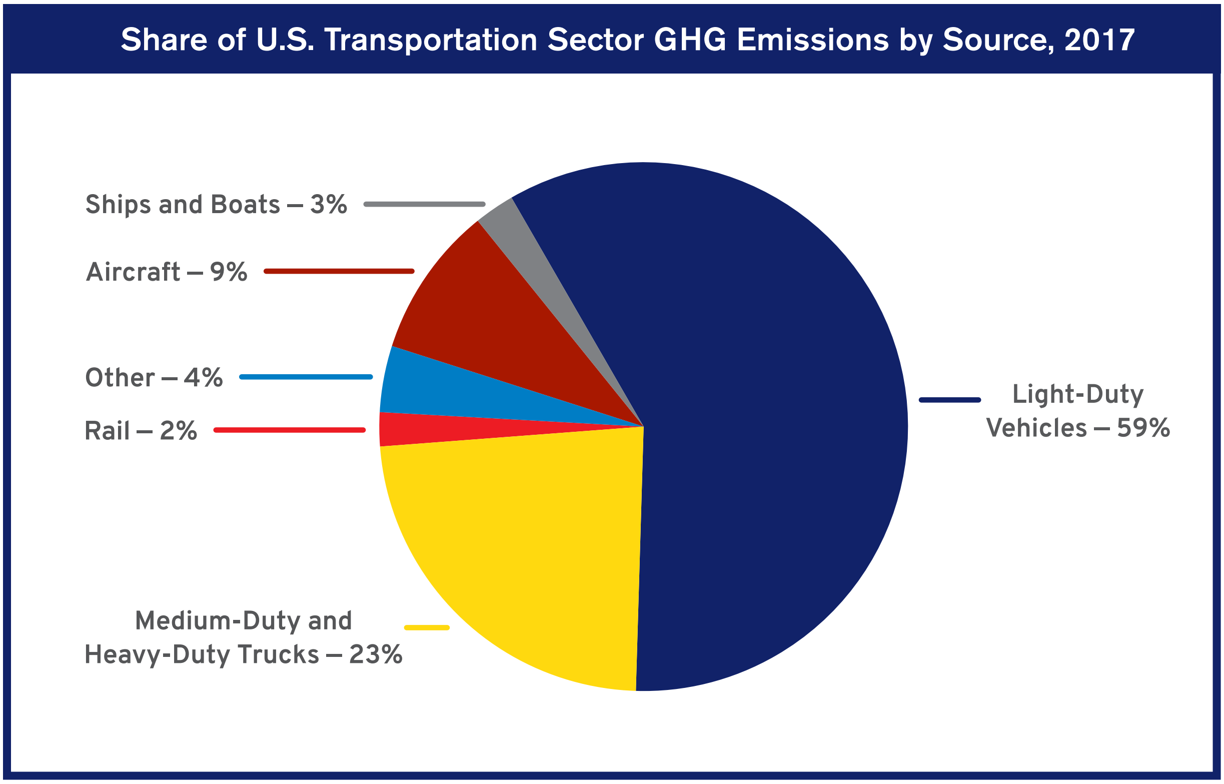

Figure 4 – Share of U.S. Transportation Sector GHG Emission by Source[14]

[13] Energy Information Administration. "Energy Related Carbon Dioxide Emissions by State, 2005-2016". February 2019.
[14] United States Environmental Protection Agency. "Fast Facts on Transportation Greenhouse Gas Emissions." Available: https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

Section 2

Electric Transportation: Benefits and Opportunities

Transitioning transportation away from petroleum-based fuels and towards electric vehicles has economic, environmental and societal benefits:

- **Economic benefits** are benefits that can be quantified in terms of dollars, revenue, and income generated or money saved.
- **Environmental benefits** are those that have a positive impact on air, land, water and other natural resources. These can include reduced greenhouse gas emissions and other pollutants.
- **Societal benefits** are those that benefit people and their welfare and can include reduced healthcare costs, or increased access to transportation.

The benefits of electric vehicles are unique for every community and depend on what type of vehicles are deployed, the energy source(s) for the electricity charging the vehicles in each location, how electric vehicles are used and even what time of day the vehicles are charging. Table 3 below summarizes electric vehicle benefits and critical factors that impact each benefit.

Summary of Electric Vehicle Benefits and Critical Factors Impacting Each Benefit

CRITICAL FACTORS	BENEFITS		
	Economic Benefits	Environmental Benefits	Societal Benefits
Vehicle Type	✓	✓	✓
Electricity Resource Mix		✓	✓
Location of Charging	✓		
Time of Charging	✓	✓	

Table 3 — Summary of Electric Vehicle Benefits and Critical Factors Impacting each Benefit

2.1 Economic Benefits

Economic benefits are an important consideration for switching to electric vehicles from petroleum-based transportation fuels. These benefits depend on the type of vehicle, the cost of electricity, the efficiency of the vehicle and the time of day that the vehicle is charging.

The cost to fuel an electric vehicle depends on the cost of electricity per kilowatt-hour (kWh) and the efficiency of the vehicle. The national average cost of electricity in the U.S. is about 10 cents per kWh.[15] On average, the efficiency of an electric vehicle is 3 miles/kWh, and the average fuel cost is 3.3 cents per mile.[16] Compared to a gasoline price of $3.00 per gallon with a gasoline vehicle fuel efficiency of 22 miles per gallon, it would cost 13 cents per mile to fuel the gas vehicle. That is over four times as expensive as the electric vehicle in this general case.

Despite their higher upfront costs, electric vehicle options typically have lower fuel and maintenance costs due to the mechanical simplicity of electric motors compared to internal combustion engines. Maintenance costs for electric vehicles are lower due to cost savings on oil changes, transmissions, mufflers, and brake parts (due to an electric motor doing most of the braking which reduces wear and tear on brake pads and rotors). A recent study estimated that the maintenance cost savings of a passenger electric vehicle is less than $1,500 for the first 100,000 miles driven.[17]

Non-electric vehicle owners may also see economic savings from higher adoption rates of electric vehicles, if vehicle charging load is managed properly on the grid. As more electric vehicles are added and charged on the grid, more electricity must be sold. As sales increase, a utility's revenues increase while its fixed costs are spread across a greater number of kilowatt-hours. This can help decrease the per kilowatt-hour rate charged to customers, if the utility does not incur too many costs in meeting this additional demand. If electric vehicle charging is managed appropriately to

[15] EIA. "Electric Power Monthly." 27 January 2020. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

[16] Idaho National Laboratory. "Comparing Energy Costs per Mile for Electric and Gasoline-Fueled Vehicles." https://avt.inl.gov/sites/default/files/pdf/fsev/costs.pdf

[17] Inside EV's. "EV vs. ICE Maintenance the first 100,000 miles." https://insideevs.com/news/317307/ev-vs-ice-maintenance-the-first-100000-miles/

happen outside of utility peak demand periods, such as via time-of-use (TOU) rates. These rates incentivize consumption when electricity supply is least strained, customers could pay no additional costs for the utility to invest in new generation and transmission resources to support the new demand from electric vehicles. A 2019 study conducted for two utilities in California (Pacific Gas & Electric and Southern California Edison) found that revenues from electric vehicle charging on TOU rates exceeded system costs by $584 million dollars, as seen in Figure 5. This savings can help lead to downward pressure on utility rates.[18] Electric vehicles can also create new economic development opportunities and help keep money in the local economy. A 2013 analysis of U.S. Energy Information gasoline fuel data found that over 80% of the cost of a gallon of gas immediately leaves the local economy.[19]

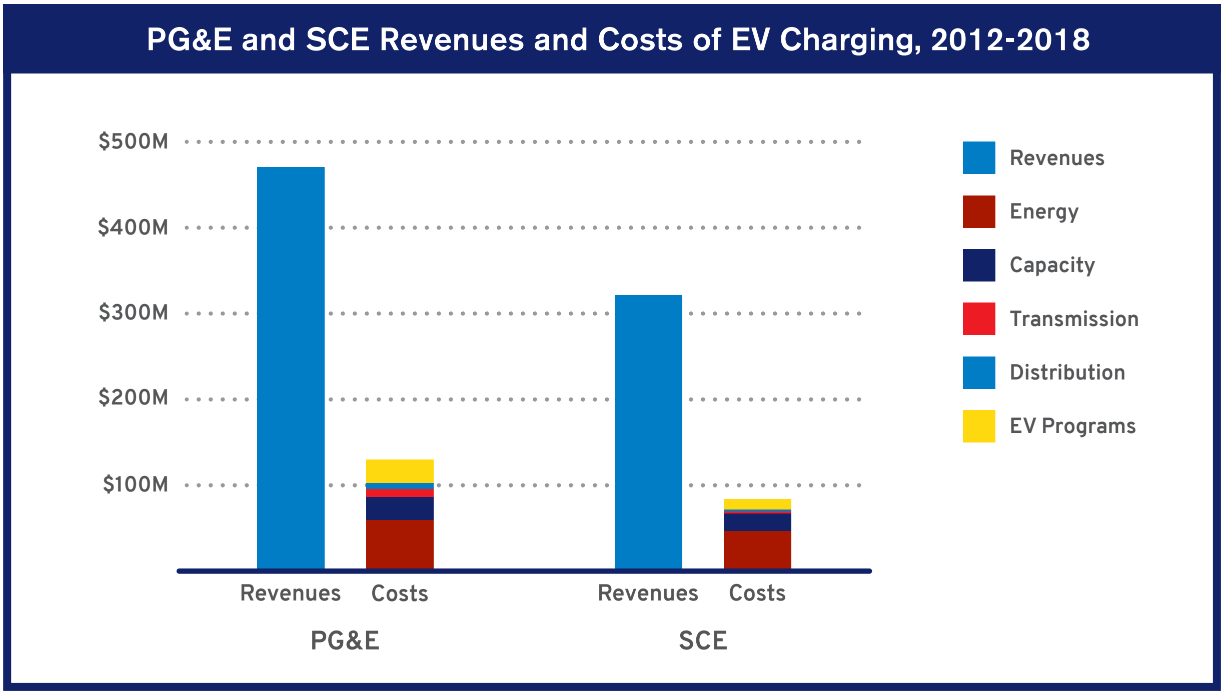

Figure 5 — PG&E and SCE Revenues and Costs of EV Charging, 2012-2018

[18] Frost et al., Synapse Energy Economics, "Electric Vehicles are Driving Rates Down." June 2019
[19] Todd J. et al., "Creating the Clean Energy Economy: Analysis of the Electric Vehicle Industry." 2013.

2.2 **Environmental Benefits**

As communities evaluate investing in electric vehicles and infrastructure, another important consideration includes emissions reduction and improved air quality. Electric vehicles have immediate air quality benefits because they produce zero tailpipe emissions. However, their impact on total emissions reductions depends on the type of vehicle, the vehicle's efficiency, timing of vehicle charging, and — importantly — the current mix of electricity supply on the utility grid. An electric vehicle is only as clean as the electricity used to charge it.

Gas and diesel vehicle emissions remain the same over the life of the vehicle, or can even increase over time as vehicle emission controls and other parts wear down. In contrast, the emissions associated with an electric vehicle depend only on the fuel used to generate the electricity charging the vehicle. For that reason, they can decline as cleaner energy sources are added to the electricity grid. A recent Union of Concerned Scientists analysis based on electricity emissions data from the EPA and fuels production data from Argonne National Lab found that in 66% of the country, the lifecycle greenhouse emissions of electric vehicles are lower than gas vehicles based on average annual regional grid emissions.[20] Evaluating emissions on a regional grid basis may provide a snapshot of electric vehicle lifecycle emissions, but it is not necessarily the whole picture. It is important to understand that emissions impacts depend on vehicle type, each utility's energy generation resource mix, and where and when the vehicles are charging. The carbon intensity of a utility's electricity generation mix has the greatest impact on total emissions associated with electric vehicles.[21]

2.3 **Societal Benefits**

There are myriad societal benefits that can come from replacing conventional gas and diesel vehicles with electric options. These benefits include, but are not limited to, reduced healthcare costs, reduced dependence on foreign oil, improved access to

[20]Union of Concerned Scientists, "New Data Show Electric Vehicles Continue to Get Cleaner," March 8, 2018. Available at: https://blog.ucsusa.org/dave-reichmuth/new-data-show-electric-vehicles-continue-to-get-cleaner?_ga=2.83059862.1221349624.1569532544-2094870610.1553634056

[21]McLaren, et al. "Emissions associated with Electric Vehicle Charging: Impact of Electricity Generation Mix, Charging Infrastructure Availability, and Vehicle Type." National Renewable Energy Laboratory. April 2016.

transportation for low and moderate income citizens, and reduced traffic congestion. A 2015 National Academy of Sciences study found that lifetime health cost impacts from particulate emissions associated with gas and diesel light duty vehicles is over $1,800 per vehicle.[22] Electric vehicles can also reduce U.S. dependence on foreign oil by reducing domestic demand for oil and thereby improve national security. Like economic benefits, the societal benefits of electric vehicles can depend on the type of vehicle and the electricity resource mix powering the vehicles.

Increasing public access to electric transportation by investing in battery electric buses is an opportunity to maximize societal benefits of vehicle electrification. Public transit, generally, reduces traffic congestion and helps manage increased transportation demand issues associated with population growth. Electric transit buses can further decrease the harmful impacts of greenhouse gas emissions and other pollutants by reducing the vehicle miles travelled by light duty vehicles. Switching from diesel to electric transit buses can help reduce direct public health impacts of diesel exhaust and emissions on low-income, senior citizens, and other vulnerable populations. Further discussion of the benefits of electric transit buses are included in Section 5 of this document.

2.4 Selecting Electric Vehicle Options That Achieve the Desired Benefits

Communities have different reasons for encouraging a transition to electric transportation. Based on their specific goals, communities may seek to prioritize electric transportation options that optimize a combination of the economic benefits, the societal benefits, and the environmental benefits. It is important that implementers of transportation policies engage with stakeholders to set priorities, analyze options and decide how to best achieve their specific goals and maximize the desired benefits.

There are many electric transportation and vehicle charging options that communities can choose to invest in. Some of these options include providing banks of charging

[22] National Academy of Sciences, "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use", Table 7-3 Monetized Damages Per Unit of Energy Related Activity. 2009.

stations, electric buses for the city or university, electric municipal fleet vehicles, or electric ride-hailing vehicles (e.g. Uber and Lyft) and electric ride sharing services (e.g. Car2go, Zipcar, etc.). Powering any of these vehicles with electricity from renewable energy resources has different benefits and tradeoffs that communities should consider and prioritize based on their community goals.

Electric transportation “use cases” can be distinguished by the type of vehicle (e.g. light duty, heavy duty), type of charging infrastructure (e.g. Level 2, Level 3 — see box below), and its charging and use profile (e.g. workplace, fleet, multi-unit housing, ride-hail, etc.). There are numerous electric transportation and zero emission charging options. Therefore, it is important for communities to assess the availability of, and potential market for, certain types of vehicles and uses before evaluating them. Some use cases, such as light duty fleet and workplace charging, may have similar charging and use patterns, benefits, and tradeoffs.

Electric Vehicle Charging Equipment

Currently available electrical vehicle charging equipment is broken out into three basic levels. The biggest difference between them is the voltage supply, which dictates how quickly the vehicle can be charged.

Level 1 Charging
These provide 120V of alternating current (AC) power. These can be plugged into any wall outlet, and are primarily used in residential settings. They generally provide 2-5 miles of range per hour of charging. They are commonly referred to as “trickle chargers” because of their low voltage and longer charge times.

Level 2 Charging
Level 2 charges provide 240V of AC power, which makes them suitable for both residential and commercial use. They typically provide 10-20 miles of range per hour of charge. These are commonly used for public charging stations.

Level 3 Charging
More commonly known as “DC fast chargers.” Level 3 charging equipment provides 480V of direct current (DC) power. This allows for much faster charging, generally allowing 60-80 miles of range per 20 minutes of charging. These are generally used only in commercial settings.

The Montana team selected four different use cases that were feasible for each community to consider based on input from team members and stakeholders in each community:

- **Light duty vehicle public charging:** Passenger vehicles for personal use, charging at publicly accessible electric vehicle charging stations and locations Public charging can be free or require payment for use.
- **Light duty vehicle fleet charging:** Passenger vehicles for public or private fleet use, charging at locations available to fleet vehicles only.
- **Transit bus on-route charging:** Electric transit buses charging at locations along routes, usually at locations when they are stopping to drop off and pick up passengers. On-route charging requires higher direct current power charging to deliver power in a short amount of time.
- **Transit bus charging at the bus depot:** Electric transit bus charging that happens at the bus depot, usually overnight. Chargers can be alternating current or direct current and can operate at lower power levels.

Prior to meeting with each community, the Montana team evaluated economic, environmental, and societal benefits for each use case by qualitatively assessing their ability to produce these benefits. These included:

- Reducing traffic congestion
- Increasing equity/accessibility
- Emission reduction
- Economic benefits for the user
- Economic benefits for the owner
- Co-locating with renewable energy

The matrix shown in Table 4 describes how well each of the four use cases produces these benefits. Green indicates the use case typically achieves the benefit. Yellow indicates the use case sometimes achieves the benefit. Red indicates the use case does not achieve the benefit.

Summary of Benefits of Four Electric Vehicle Use Cases						
USE CASES	**BENEFITS**					
	Reduced Traffic Congestion	Increased Equity and Accessibility	Reduced Emissions	User Economic Benefits	Owner Economic Benefits	Renewable Energy Co-Location
Light Duty Vehicle Public Charging	✗	●	●	✓	✓	✓
Light Duty Vehicle Fleet Charging	●	●	●	✗	✓	✓
Transit bus On-route Charging	✓	✓	✓	●	✓	●
Transit bus Depot Charging	✓	✓	✓	●	✓	✓

Table 4 — Summary of Benefits of Four Electric Vehicle Use Cases

2.4.1 Light Duty Vehicle Public Charging

Light duty vehicles are both the largest and fastest-growing source of transportation GHG emissions. In the United States, cars and light duty trucks are responsible for 60% of transportation sector GHG emissions, and the number of vehicle miles travelled (VMT) by light duty vehicles increased by nearly 46% between 1990 and 2017. In 2017, light duty passenger vehicles travelled over 2.7 trillion miles in aggregate[23] and emitted 2.6 million metric tons of carbon dioxide (CO_2). By investing in publicly accessible charging stations for light duty vehicles, communities can help support passenger vehicle electrification. In communities where EV adoption rates are

[23] Energy Information Administration, Annual Energy Outlook, 2019

relatively low, it may not be cost-effective for private entities to own and operate charging stations. This is because recovering equipment, installation and operating cost of an EVSE is difficult without charging extremely high usage fees from a small number of EV drivers. These investments can also help reduce emissions contributed by internal combustion engine (ICE) vehicles. According to the Department of Energy's Alternative Fuels Data Center, electric cars, on average, create half as much carbon pollution as a conventional ICE vehicle.[24] For individual communities, pollution levels will largely depend on the type of fuel used to generate the electricity charging the electric vehicles. Still, public charging stations at locations visible to the public can help increase awareness of electric vehicles and help address a barrier for people without access to electric vehicle charging at home or at work. Table 5 demonstrates how well the light duty vehicle public charging use case will achieve certain intended benefits.

Summary of Benefits/Tradeoffs for Light Duty Vehicles Public Charging

USE CASES	BENEFITS					
	Reduced Traffic Congestion	Increased Equity and Accessibility	Reduced Emissions	User Economic Benefits	Owner Economic Benefits	Renewable Energy Co-Location
Light Duty Vehicle Public Charging	✗	○	○	✓	✓	✓

Table 5 — Summary of Benefits/Tradeoffs for Light Duty Vehicles Public Charging

In this use case, investing in publicly accessible charging infrastructure for light duty electric vehicles creates direct economic benefits for individual vehicle owners by shifting EVSE deployment costs from the individual to the public. Public investment may be necessary in communities where EV adoption rates are low and charging infrastructure is not cost-effective for private entities. One factor communities should

[24] Department of Energy Alternative Fuels and Data Center. "Emissions from Hybrid and Plug-In Electric Vehicles." https://afdc.energy.gov/vehicles/electric_emissions.html

consider is the upfront costs of electric vehicles are still relatively high, so the individuals who could benefit from these charging stations are presently limited by that high cost barrier. Lower-income individuals may not immediately benefit from public charging stations, because the up-front cost of an electric vehicle may be prohibitive. As upfront costs of new electric vehicles decline, and the used electric vehicle market develops, more drivers will be able to take advantage of community investment in public charging stations.

Investing in charging stations to support light duty vehicles does not by itself help reduce traffic congestion, or address land use and other issues associated with passenger vehicles for personal use. Replacing ICE vehicles with electric passenger vehicles does not necessarily reduce vehicle miles travelled, or the total number of vehicles on the road. Communities trying to address traffic congestion may want to prioritize electric transportation use cases that support public or shared transportation options.

An important benefit of public charging for light duty vehicles is that it can be easier to co-locate distributed solar and storage with electric vehicle charging stations. Public charging for light duty vehicles is typically available at central parking areas that are more conducive to on-site solar arrays for vehicle charging. This is due to the ability to site smaller solar arrays on the roof of centrally located parking garages, or to install charging stations with solar arrays overhead that can also provide shade for parked vehicles. The size of the array will influence the ability to impact demand spikes. Generally, the solar array will not be able to meet the entire demand of the charging station, especially for Level 2 or Level 3 chargers. Installing solar in proximity to electric vehicle charging infrastructure can still help reduce or eliminate demand spikes and increases in peak load caused by daytime charging.[25] For some communities, co-locating renewable energy and electric vehicle charging stations is important to gaining community support for vehicle electrification, as it helps demonstrate that electric vehicles are being powered by local, renewable energy resources rather than fossil fuels.

[25] National Renewable Energy Laboratory, "Distributed Solar Photovoltaics for Electric Vehicle Charging: Regulatory and Policy Considerations, September 2014.

2.4.2 Light Duty Fleet Vehicle Charging

Electric vehicle charging infrastructure to serve light duty vehicles in public and private fleets is another use case communities may want to consider. Fleet vehicles typically have predictable routes and their use can be scheduled more consistently than privately owned vehicles. This provides fleet owners with the ability to schedule electric fleet in-service periods and charging times to align with times of day when it is more advantageous from traffic congestion, power system stability, electricity price, or emissions perspectives. For example, certain fleet vehicles could be scheduled to charge during the middle of the day when there is more solar energy production and to avoid certain peak times of the day when energy demand is highest on the electric grid. Charging infrastructure for fleets can also be centrally located, making it easier to plan and install a relatively small number of charging stations per vehicle and benefit from economies of scale. Table 6 demonstrates how well the light duty vehicle fleet vehicle charging use case will achieve certain intended benefits.

Summary of Benefits/Tradeoffs for Light Duty Fleet Vehicle Charging						
USE CASES	**BENEFITS**					
	Reduced Traffic Congestion	Increased Equity and Accessibility	Reduced Emissions	User Economic Benefits	Owner Economic Benefits	Renewable Energy Co-Location
Light Duty Vehicle Fleet Charging	○	○	○	✗	✓	✓

Table 6 — Summary of Benefits/Tradeoffs for Light Duty Fleet Vehicle Charging

Another advantage of electric fleet vehicles is that the overall operating cost can be lower. The most important consideration for fleet owners is often total cost of vehicle ownership, including vehicle fuel and maintenance costs. In a survey of fleet owners across public and privately-owned fleets, 74% of respondents indicated that lower and less volatile operating costs across the service life of a vehicle would be the most important drivers of their decision to purchase electric vehicles over other fuels for their fleets (See Figure 6).[26] In contrast, private vehicle owners may be more concerned with the vehicle's upfront cost over ongoing ownership costs. Certain fleet vehicles, particularly light duty trucks, drive several thousand more miles per year than vehicles for personal use. Higher annual mileage can help lower total operating cost per mile and maximize the return on investment achieved for electric vehicles. Figure 7 shows the total cost of ownership of comparable ICE and electric models of light duty vehicle.

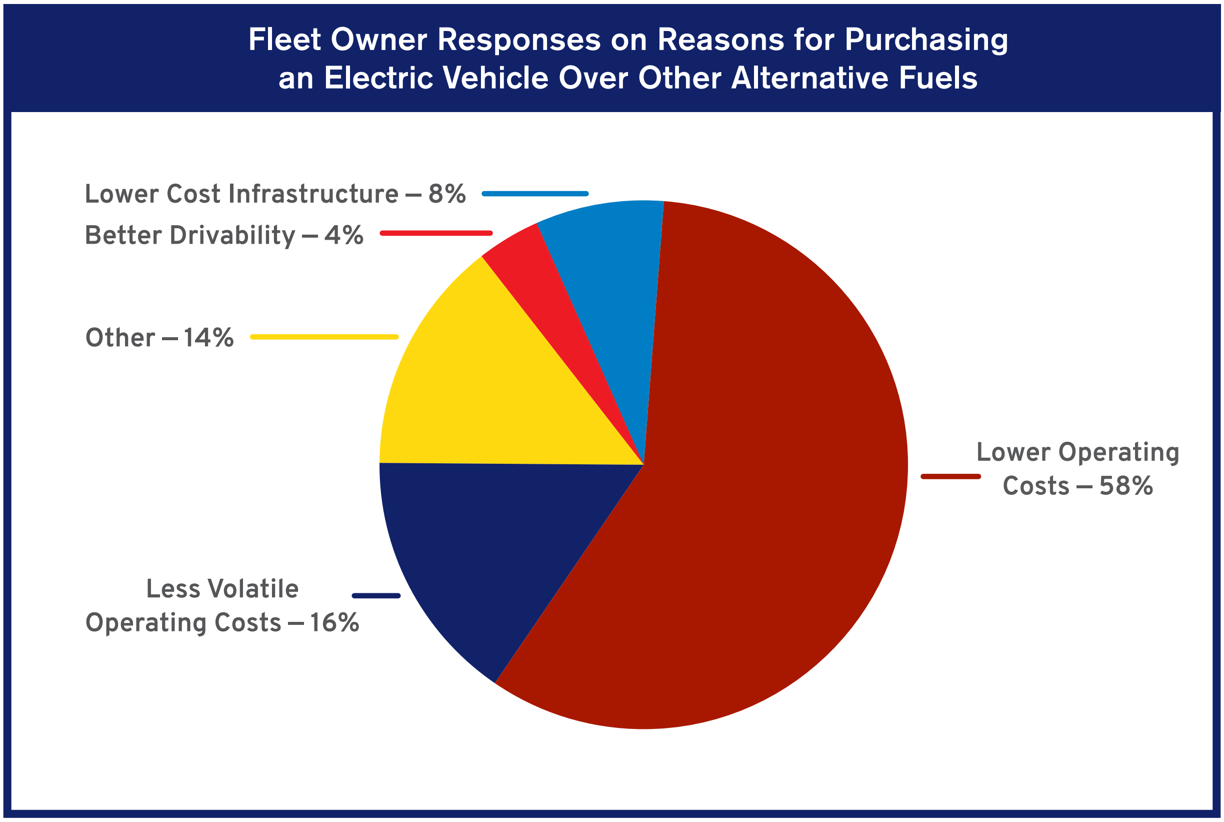

Figure 6 – Fleet Owner Responses on Reasons for Purchasing an Electric Vehicle over Other Alternative Fuels

[26]FleetAnswers.com "Vehicle Trends and Maintenance Costs Survey," 2012. Available at: http://www.fleetanswers.com/sites/default/files/Dow%20Kokam%20Survey%20Report_0.pdf

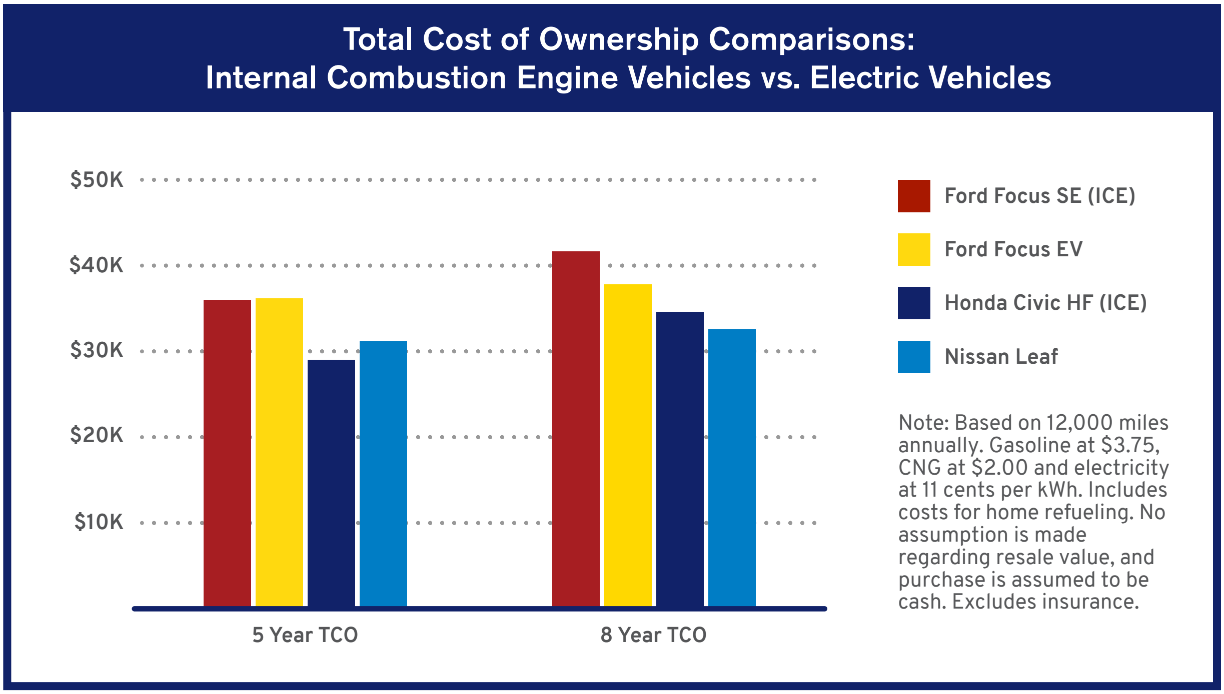

Figure 7 — Comparison of Total Cost of Ownership (TCO) for ICE and EVs[27]

It is important to note that the economic benefits of fleet electrification go to the fleet owners and not the individual EV operators. Also, if electric vehicle charging infrastructure is placed at locations to accommodate fleet vehicles, it may not be visible to the public and the education and public awareness benefits of light duty vehicle charging stations may not be realized.

2.4.3 Transit Bus Use Cases

Public transit buses offer significant opportunities for electrification. More than 340 electric buses are currently operating in the United States, with another 1,200 electric transit buses on order.[28] States and some of the nation's largest cities have committed to electrify their bus fleets, including New York City to electrify its 5,700 buses by

[27]Electrification Coalition, "Roadmap: Transitioning Municipal Fleets to Alternative Fuel Vehicles", May 2014

[28]Dan Raudebaugh, Center for Transportation and the Environment "The State of Zero Emission Buses," Bus Rapid Transit Conference, LA Metro. Available at: http://onlinepubs.trb.org/onlinepubs/Conferences/2018/BRT/DRaudebaugh.pdf, September 2019.

2040 and Los Angeles to electrify its 2,500 buses by 2030.[29, 30] Investment in electric transit buses and associated charging infrastructure can support public transportation priorities. Public transit buses reduce traffic congestion and address issues of equity and accessibility to transportation. Some of these issues include affordability of vehicle ownership and access to employment opportunities, healthcare, and other essential services. Investing in public transit can help remove economic and accessibility barriers for low-income households, seniors, those with disabilities, students, and other disadvantaged groups. Transit buses also help reduce vehicle miles travelled by personal light duty vehicles, which can result in significant reductions in criteria pollutants.

Additionally, there are direct public health benefits of electrifying public transit. All those who ride or are in proximity to public transit will avoid exposure to harmful tailpipe emissions from diesel buses, which currently comprise about 50% of transit buses in the U.S.[31] Older diesel vehicles emit criteria pollutants such as nitrogen oxides and particulate matter. These pollutants have health and environmental impacts that disproportionately affect sensitive populations (children, pregnant women, seniors, and those with respiratory illnesses or cardiac conditions). One study in the Northeast and Mid-Atlantic regions demonstrated that electrifying heavy duty diesel vehicles, such as transit buses, resulted in 33 times greater nitrogen oxide reduction and 7.5 times greater reduction in particulate matter per mile than electrifying gasoline powered light duty vehicles.[32]

The three partner communities in Montana prioritized transit buses as their preferred electrification use case because of the benefits that public transit provides for both underserved residents and for the community at large. Also, each of the communities is trying to address increased traffic congestion due to relatively rapid population

[29] Electrive. "New York to Electrify Complete Bus Fleet" 1 May 2018. https://www.electrive.com/2018/05/01/new-york-to-electrify-complete-bus-fleet/

[30] Streetsblog LA. "Metro Votes To Buy Pilot Electric Buses, Approves 2030 Full Electric Plan." 27 July 2017. https://la.streetsblog.org/2017/07/27/metro-votes-to-buy-pilot-electric-buses-approves-2030-full-electric-plan

[31] American Public Transportation Association, "2017 Public transportation Fact Book," March 2018. Retrieved from: https://www.apta.com/resources/statistics/Documents/FactBook/2017-APTA-Fact-Book.pdf

[32] Lowell, D., Saha, A., and Van Atten, C. "Decarbonizing transportation: The benefits and costs of a clean transportation system in the Northeast and mid-Atlantic region. Concord, MA: M.J. Bradley and Associates. Retrieved from: https://www.ucsusa.org/sites/default/files/attach/2018/10/UCS_Final_Report_FINAL_11Oct18.pdf

growth. Each community ranked benefits of reducing vehicle miles travelled and traffic congestion in their top priorities. Electrifying and expanding public transit can provide co-benefits that are appealing to communities.

Investing in electric transit buses and associated charging infrastructure has benefits and tradeoffs for communities to consider. First, communities should consider current operation and routes of the buses, and how these factors impact the type of charging infrastructure that would be most appropriate. Charging infrastructure for public transit typically falls into two use cases: 1) overnight charging at the depot, or 2) on-route charging. Each serves different purposes and has associated benefits as well as tradeoffs to consider.

2.4.3.1 Transit Bus On-route Charging

Key factors affecting when, where and what type of charging infrastructure is best for electric transit buses include the mileage of existing bus routes, how many buses are operating, how often the buses operate, and how much charging time buses will need while they are in-service. On-route charging infrastructure for electric transit buses typically has much higher upfront costs than overnight charging at the depot. This is because on-route charging is generally done at higher power rates (up to 500kW), which is faster, but can lead to expensive utility demand charges[33] and thus higher operating costs.

However, overnight depot charging may be insufficient for buses and routes that need to operate frequently, must drive more miles, and cannot have long interruptions in charging. Another consideration is that the higher power rate and use throughout the day, including during peak times, can have greater impacts on the grid and may require utility investment in grid upgrades. Table 7 demonstrates how well the transit bus on-route charging use case will achieve certain intended benefits.

To help reduce economic costs due to utility demand charges associated with on-route charging, transit agencies can consider deploying several electric buses. Cost-

[33]Demand charges are utility fees that are assessed based on the peak load, or maximum kilowatts, consumed in a specific time period. Most often, a special demand charge or fee ($/kW) is assessed based on the highest single hour of energy use throughout your billing period. Demand charges and rate design are discussed further in section 5.4.2.

Summary of Benefits/Tradeoffs for Transit Bus On-Route Charging

USE CASES	BENEFITS					
	Reduced Traffic Congestion	Increased Equity and Accessibility	Reduced Emissions	User Economic Benefits	Owner Economic Benefits	Renewable Energy Co-Location
Transit bus On-route Charging	✓	✓	✓	○	✓	○

Table 7 — Summary of Benefits/Tradeoffs for Transit Bus On-Route Charging

benefit analysis on transit bus charging for potential electric transit buses in Bozeman concluded that Bozeman would need to deploy at least six electric buses to replace six diesel buses in their current fleet using existing routes to mitigate the demand charges from on-route bus charging. This is because the costs are spread across the operating budgets of multiple buses.[34]

Analysis for Foothills Transit in Los Angeles County found similar results. Figure 8 below shows that 6-8 buses was the optimum number the transit agency needed to deploy in their fleet to achieve similar or lower demand charges using on-route charging rather than depot charging.[35]

Communities may also want to consider the feasibility of co-locating on-route charging infrastructure with renewable energy and/or energy storage. This is discussed later in section 3.0.

(See Figure 8 on next page)

[34] Cost-benefit analysis was done using a discounted cash-flow analysis using a baseline utility billing information for the Bozeman bus depot, average purchase price of an electric bus and electric vehicle supply equipment (EVSE) from TCRP Synthesis 130, “Battery Electric Buses- State of the Practice,” 2018, and annual EVSE operation and maintenance costs from: https://www.nrel.gov/docs/fy17osti/67698.pdf

[35] Eudy, L. and Jeffers, M. “Foothill Battery Electric Bus Demonstration Results: Second Report” National Renewable Energy Laboratory, June 2017.

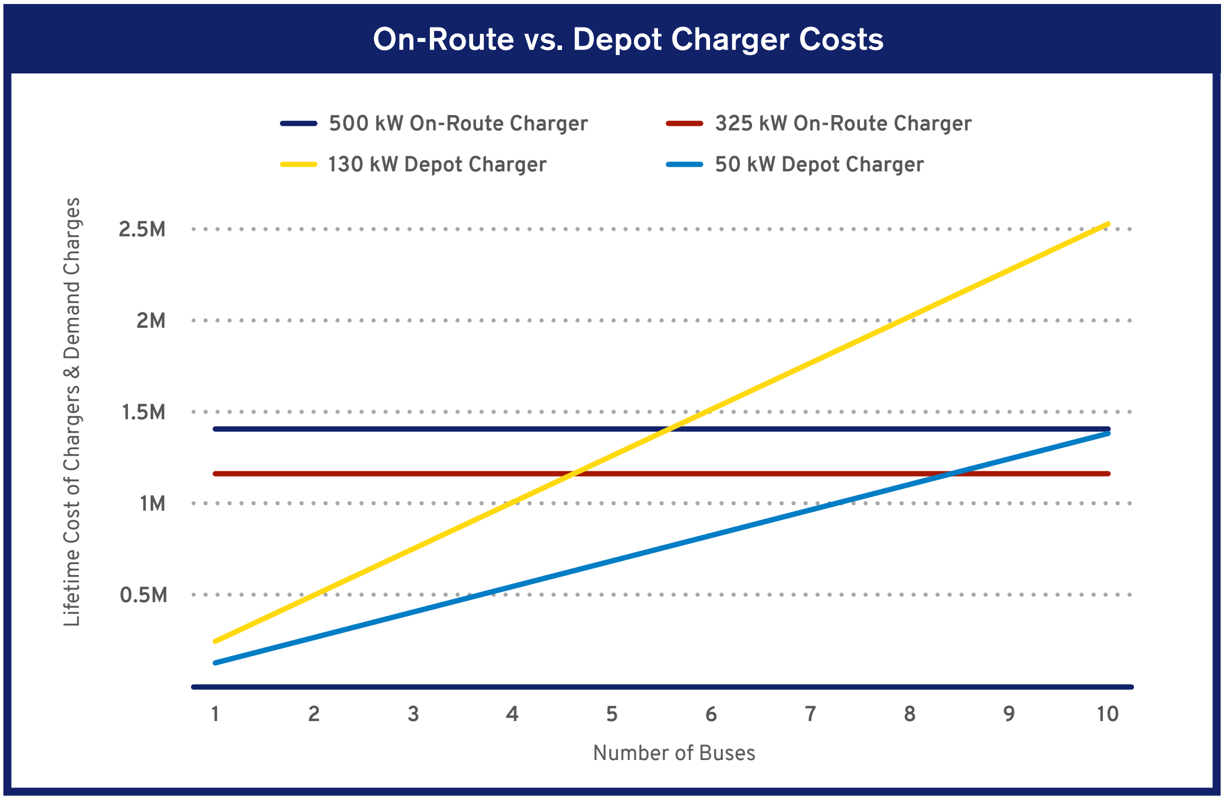

Figure 8 — Comparison of lifetime costs of charging equipment and demand charges for different transit buses and charging scenarios

2.4.3.2 Overnight Charging at the Bus Depot

Charging buses overnight at the bus depot or other central location has advantages and disadvantages for communities and transit agencies to consider. The Montana Solar Powered Transportation Project analyzed overnight charging of transit buses in Missoula. Results of the analysis can be found in the Missoula Case Study (section 4.3) included in this document. Table 8 demonstrates how well the transit bus depot charging use case will achieve certain intended benefits.

In general, slower overnight charging from Level 1 or Level 2 charging equipment can allow electric buses to be effective substitutes for conventional buses without requiring faster on-route charging. Battery charging can be done at a lower power rate (below 100kW), which can help reduce the impact of demand charges. Since charging is done at predictable, off-peak hours (overnight), it can also reduce impacts

Summary of Benefits/Tradeoffs for Transit Bus Depot Charging						
USE CASES	BENEFITS					
	Reduced Traffic Congestion	Increased Equity and Accessibility	Reduced Emissions	User Economic Benefits	Owner Economic Benefits	Renewable Energy Co-Location
Transit bus Depot Charging	✓	✓	✓	●	✓	✓

Table 8 — Summary of Benefits/Tradeoffs for Transit Bus Depot Charging

to the grid and make interconnection easier. Lower costs associated with charging infrastructure and lower costs to "fuel" the buses help increase the economic value proposition for transit bus owners and operators. Overnight charging may be the best initial strategy for transit agencies as they transition their diesel buses to electric.

One tradeoff with overnight charging is that the bus battery must be sized so that the bus can operate all day without having to stop to charge. Typically, this means the battery must be large enough to store sufficient energy to cover 100 miles in all types of conditions. Larger battery sizes increase the cost of the bus and increase the bus's curb weight, potentially decreasing overall operating efficiency.[36]

Co-locating solar PV and storage with transit bus charging at the depot may have fewer space and land use constraints than with on-route charging, but co-location at the depot is still challenging. Energy storage would be a necessary component in the overnight charging use case if a community wants to charge the buses with solar energy. This, of course, adds to the upfront cost associated with charging the buses (see Missoula case study in section 4.3). Bus depots may also be space constrained. Adding a large, on-site solar array and energy storage may not be feasible.

The next section describes some benefits, costs and opportunities specifically associated with pairing PV technology with electric vehicle charging infrastructure.

[36] U.S. Department of Transportation, Federal Transit Administration, "Peak Demand Charges and Electric Transit Buses," October 2014.

Section 3

Deployment of Solar Photovoltaics for Electric Vehicle Charging

Installing solar PV technology in conjunction with electric vehicle charging infrastructure has the potential to enhance the benefits of electric vehicles. Solar PV can provide a clean, locally produced fuel, reduce the customer's cost of purchasing electricity for charging, and provide benefits for the overall electric grid. There are several configurations to consider when integrating solar with electric vehicles, which can be grouped into direct charging and indirect charging scenarios.

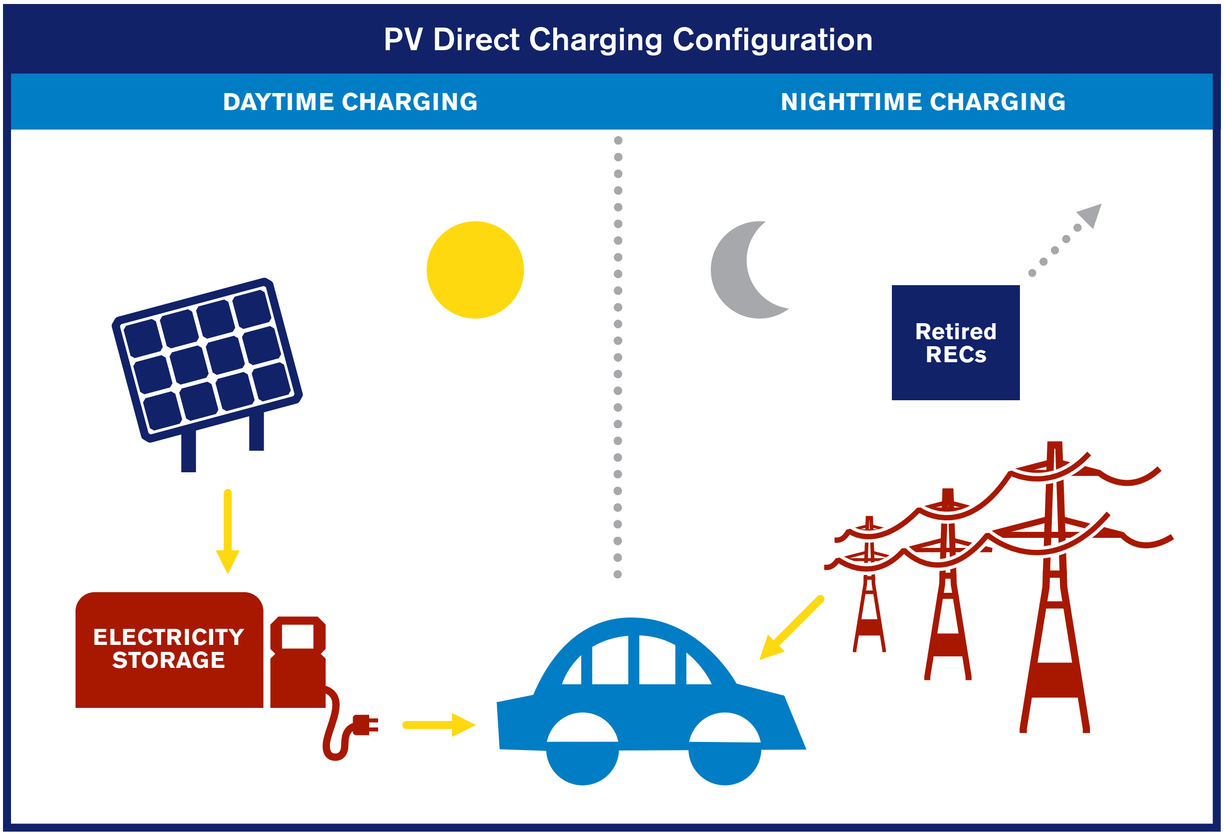

Figure 9 — PV Direct Charging Configuration[37]

[37]Cory et al, "PV and PEV Co-Deployment Considerations." National Renewable Energy Laboratory. 2019.

In direct charging scenarios, the PV energy is flowing directly to the EVSE (Figure 9). This includes configurations in which a battery or other device is used to store energy for use when needed. In order to claim zero emissions, the owner would need to purchase and retire renewable energy certificates (RECs) to cover the load not provided by the solar energy connected to the EVSE.[38]

In indirect PV charging scenarios, the EVSE is designed to pull energy from the grid, to which the on-site solar PV sends its energy as well (Figure 10). Solar energy is integrated into the grid separately to offset or virtually charge the vehicle. Similar to the direct charging scenarios, the owner must own and retire RECs that cover the full load to truly claim the vehicle is 100% powered by solar.

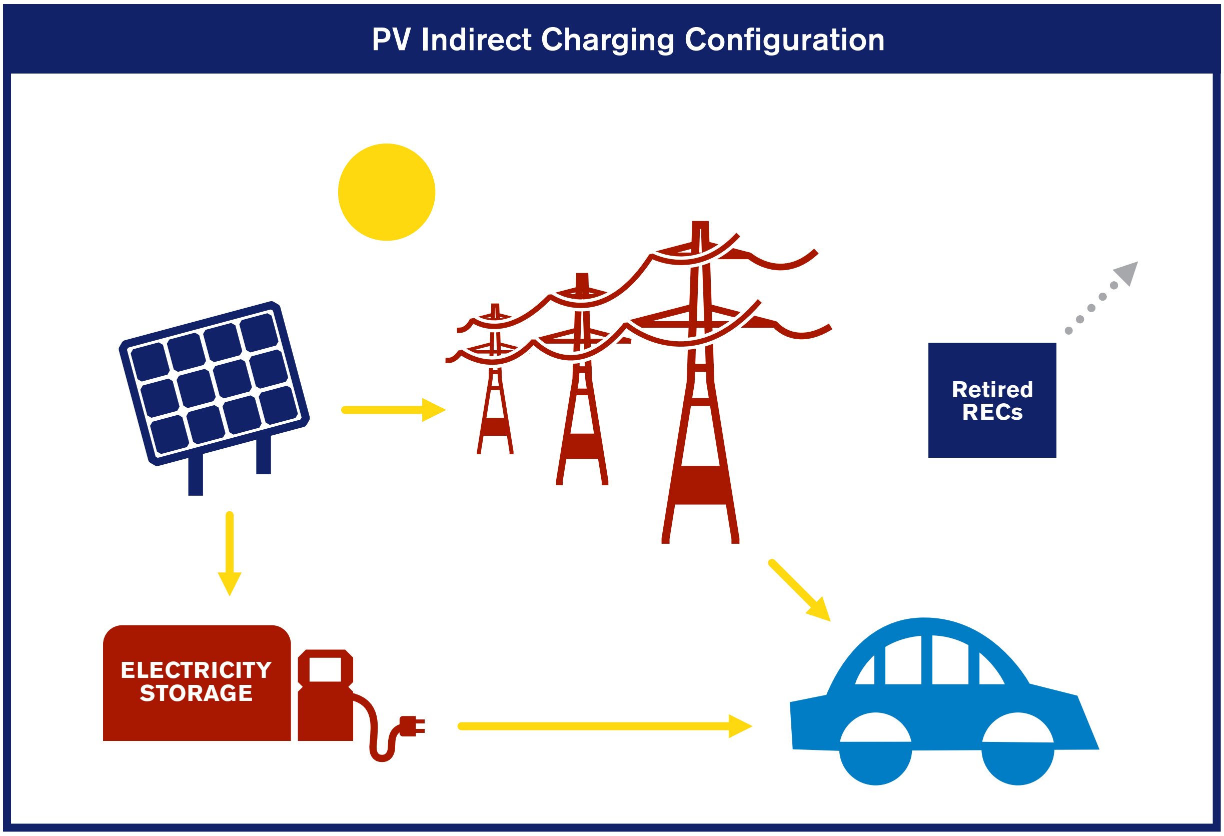

Figure 10 — PV Indirect Charging Configuration

[38] Environmental Protection Agency: https://www.epa.gov/greenpower/renewable-energy-certificates-recs

Each scenario presents different benefits and trade-offs. The sections below highlight potential benefits and impacts of pairing PV and EV charging technologies. To harness these benefits, a community should assess their options for how to pair EVSE with renewable energy and storage. A discussion of those questions and best practices is provided in Section 5.3.1.

3.1 Economic Benefits

Integrating solar PV into electric vehicle charging can create economic benefits at both the individual level and the grid-wide level.

3.1.1 Individual Customer Savings

Powering electric vehicles with solar PV can create new forms of cost savings to consider as part of the transition from conventional fuels to electrically powered vehicles. As discussed in this document, cost savings will be dependent upon the cost of electricity provided to the charging infrastructure as well as the utility rate design. Since these savings will be acutely sensitive to the relevant utility territory, a cost-benefit analysis of this scenario should be conducted as part of the decision-making process on integrating solar and/or storage with the EVSE. This cost-benefit analysis should include the value of energy exported to the grid, according to what is offered by the utility (e.g., net metering).[39]

3.1.2 Grid Impacts

Daytime charging can benefit the larger grid by shifting load away from the evening peak. An early evening peak is common among utilities even in the absence of electric vehicles. However, a surge in load from EVs has potential to produce a second evening system peak, which will stress the grid and increase the need for more generation by the utility. This may increase costs to the utility, and thus to customers. Daytime charging can mitigate this surge by shifting evening EV loads to daytime hours that coincide with peak PV energy production. To fully realize this benefit, drivers will need to adopt daytime charging as part of their routine and plan their travel schedules accordingly. There may still be a desire or need to charge in the evening, but mitigating that need by providing daytime charging options is an important step in enabling this grid benefit.

[39] More on net metering from the Solar Energy Industries Association: https://www.seia.org/initiatives/net-metering

Pairing electric vehicles with solar can help flatten the “duck curve”.[40] The so called “duck curve” is a description of the impact of large amounts of distributed generation (such as solar PV) on the grid. Figure 11 shows this phenomenon. During the daytime, net load drops significantly as distributed solar PV provides large amounts of energy to the grid. Later, evening loads begin to rise from people returning home after work, just as the sun begins to go down. The solar energy tapers off and is no longer able to help meet the increasing load. This increase in evening load in tandem with a decrease in solar production creates a large ramp-up of net load that requires an increase in generation. This can put stress on grid and supply resources as grid operators rush to meet the load and maintain electricity quality.

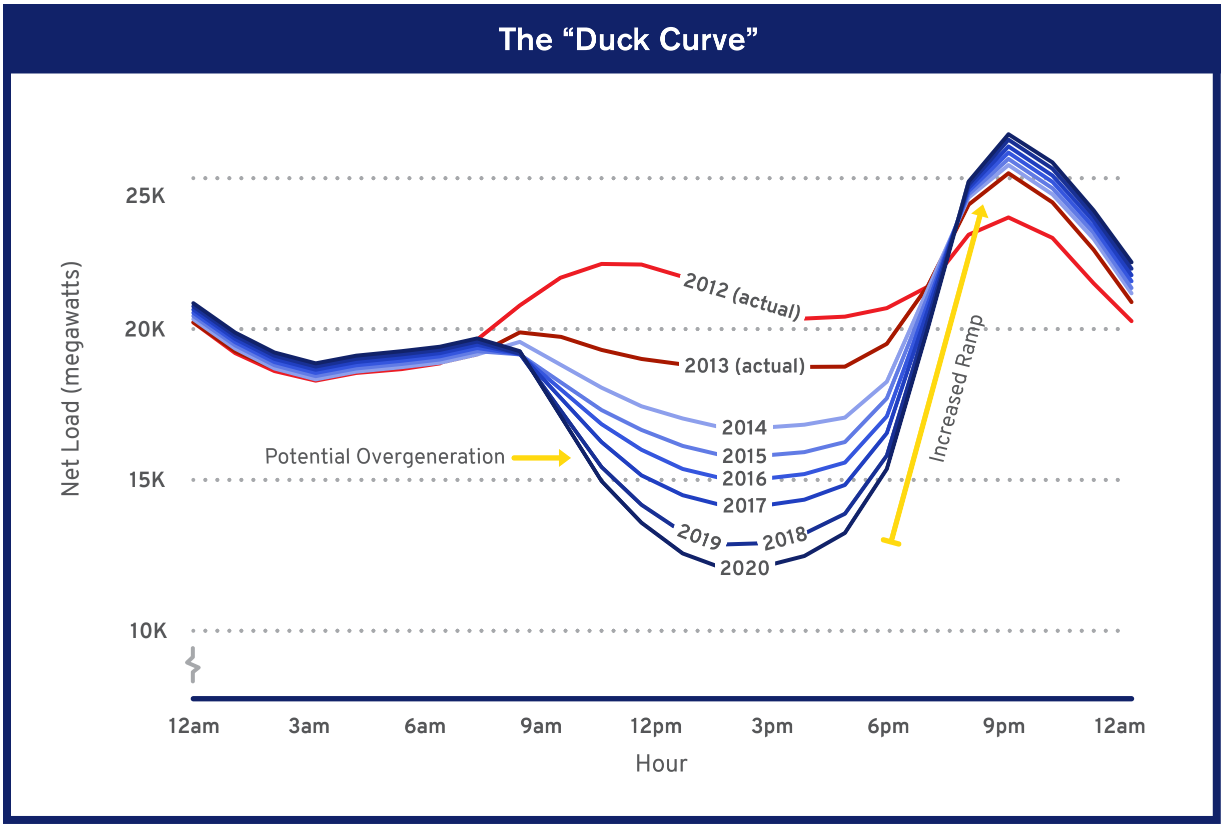

Figure 11 — The “Duck Curve” (Lowenthal, 2014)

[40] See: Lowenthal, Richard. “You’ve Got to Charge Your EV While the Ducks Are Quacking: Electric Vehicles and the Duck Curve”. Greentech Media. April 21, 2014

Daytime charging with electric vehicles can help even out the duck curve. It can increase daytime electricity demand, reducing the total load reduction occurring during daytime hours. Charging vehicles during the day can also reduce the need to charge those EVs during early evening peak hours. As mentioned above, daytime charging will require shifts in vehicle charging habits in order to realize these benefits, and consumers may still have a need or desire for evening charging. Still, by reducing early evening charging and increasing daytime load, the grid would experience a more level daily load profile and reduce the need for ramping supply resources.

3.2 Environmental Benefits

An electric vehicle is only as clean as the electricity powering it. If electric vehicles are charged with electricity that is generated by fuel sources that produce large amounts of pollution, the environmental benefit of switching from traditional vehicles to electric vehicles is reduced. Some utility jurisdictions are integrating more solar, wind, hydro, and other low-emission technologies into utility supply mixes, thus reducing the emissions associated with consuming grid power. In addition, EV customers may have the option to install solar PV and/or energy storage technologies directly with vehicle charging infrastructure to provide a clean fuel alternative to the larger grid's supply mix.

If the electricity provided via the grid is relatively carbon intensive, customer efforts to install solar PV in conjunction with electric vehicle charging infrastructure can help ensure the transition to EVs achieves the intended emissions benefits. Figure 12 below demonstrates the emissions differences among battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and conventional vehicles (CVs) in both a high carbon grid scenario and a low carbon grid scenario. As it demonstrates, light-duty electric vehicles charged on any electricity fuel mix have lower carbon emissions than gasoline powered vehicles, but electric vehicles charged on a low carbon grid provide greater carbon reductions. Charging the vehicles with solely renewable energy would achieve maximum reductions.

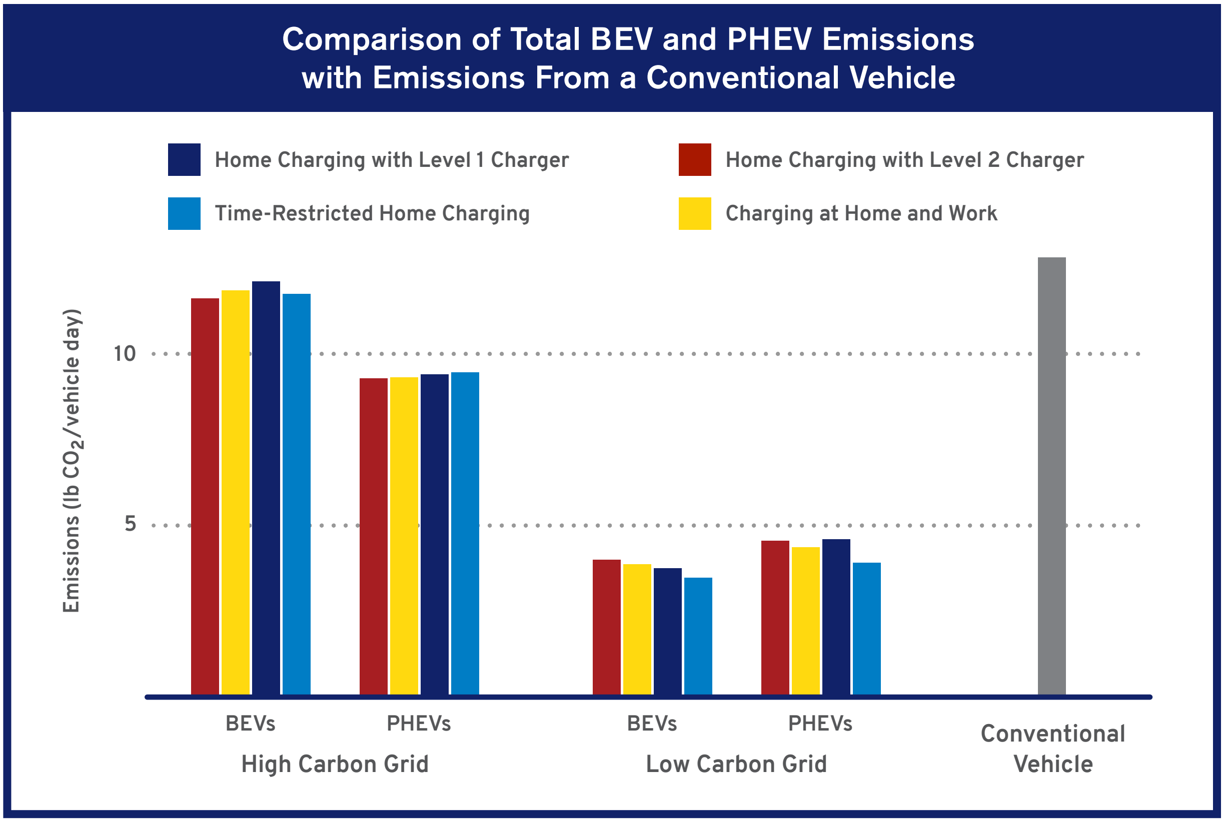

Figure 12 — Comparison of total BEV and PHEV emissions with emissions from a conventional vehicle on a high carbon grid (left) and a low carbon grid (right)[41]

3.3 **Societal Benefits**

Integrating solar into electric vehicle charging can positively impact grid resiliency, increase EV adoption, and otherwise increase the efficacy of electric vehicle operation. These benefits are discussed below.

3.3.1 Increasing Resiliency

Grid power outages can create issues for electric vehicle owners and operators. Without sufficient vehicle charge, EV drivers could be stranded without ways to get home or to access services in the event of a power outage. Integrating solar and/or

[41] McLaren et al, "Emissions Associated with Electric Vehicle Charging: Impact of Electricity Generation Mix, Charging Infrastructure Availability, and Vehicle Type." National Renewable Energy Laboratory. 2016.

storage into the EVSE can increase the resiliency of the system, allowing vehicles to be charged, even during grid outages. Maximizing this benefit will require a system design that enables charging even while the grid is down. This may require working with the utility to understand local interconnection laws and requirements. It is also likely to include specific technology requirements, such as islanding capabilities for the inverter. Islanding is a scenario in which a PV system will continue to power local loads connected to the inverter when the grid goes down. Typically, inverters are programmed with "anti-islanding" settings such that when the grid goes down the system is unable to send power to the grid. Allowing islanding would provide a way for EVs — and other loads as deemed safe and necessary—to be powered by PV systems even while the grid is down. These considerations should be discussed early in the development process to ensure the overall system design enables this type of charging, and that local interconnection and safety protocols allow for islanding.

3.3.2 Impact of Daytime Charging on EV Use and Adoption

Solar production hours overlap well with daytime charging. For private vehicle owners, daytime charging can increase their EV's daily potential mileage, thereby reducing range anxiety—one of the most significant barriers to EV adoption.[42] Common daytime charging scenarios include charging at workplaces and community hubs like shopping centers, where vehicles can be left for several hours to be charged and be fully ready for use when needed again. If the daytime charging stations are powered by solar PV, they can increase public awareness of EV environmental benefits in addition to the reduction of range anxiety, both of which promote EV use and adoption.

For transit vehicles, using solar PV for daytime charging can be more challenging. Electric transit vehicles are typically charged either on-route or at the depot. On-route charging uses fast-charging infrastructure, which demands a large amount of power. Even if the bus is on-route during the day, it may prove challenging for a solar array to provide sufficient power, even with a very large array. Charging transit vehicles with solar at the depot may also prove challenging since depot charging is often most sensibly performed overnight, after most routes are done for the day and when the sun is not shining. Pairing the solar PV array with energy storage can help overcome these issues. The impacts of storage are discussed in the next section.

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[42]National Renewable Energy Laboratory. "Distributed Solar Photovoltaics For Electric Vehicle Charging Regulatory And Policy Considerations." September 2014. Available: https://www.nrel.gov/docs/fy14osti/62366.pdf

3.4 **Impacts of Integrating Energy Storage**

Integrating energy storage with a solar PV array to charge electric vehicles can alleviate several of the issues identified above, including issues pertaining to overnight charging scenarios. Furthermore, storage can be very effective in managing and mitigating spikes in demand, be it from an evening surge of private vehicles being plugged in after commuting home (as discussed above) or from overnight charging of transit vehicles (addressed below).

Storage can provide the flexibility needed to integrate solar into a fast-charging scenario, such as on-route charging for transit vehicles and any short-term charging scenario for private vehicles.[43] The storage device can be charged while the vehicle is in-transit, and then discharged at a fast rate to provide the needed energy to the vehicle while it is stopped. This type of charging may require a large-capacity storage device, particularly for transit vehicles, which may be cost prohibitive.

For transit vehicles, storage may be more cost-effective for depot charging. In this scenario, the storage device will have all day to charge and will not need to discharge at such a fast rate. Storage can then be used overnight to mediate large spikes in energy demand caused by charging multiple transit vehicles at once. This may help save significant amount of financial resources by mitigating or avoiding demand charges. The cost savings will be greatly dependent upon the rate structure offered by the utility. Rate design, discussed later in this document, is a critical consideration before investing in electric vehicles of any type. Figure 13 below was produced as part of an analysis conducted for this project to demonstrate how the loads at a depot could be impacted by solar and energy storage technology. The storage component makes significant contributions to serving overnight depot charging loads, as shown by the red bars in Figure 13.

(See Figure 13 on next page)

[43]Muratori, et al. "Technology solutions to mitigate electricity cost for electric vehicle DC fast T charging." National Renewable Energy Laboratory and Idaho National Laboratory. March 2019.

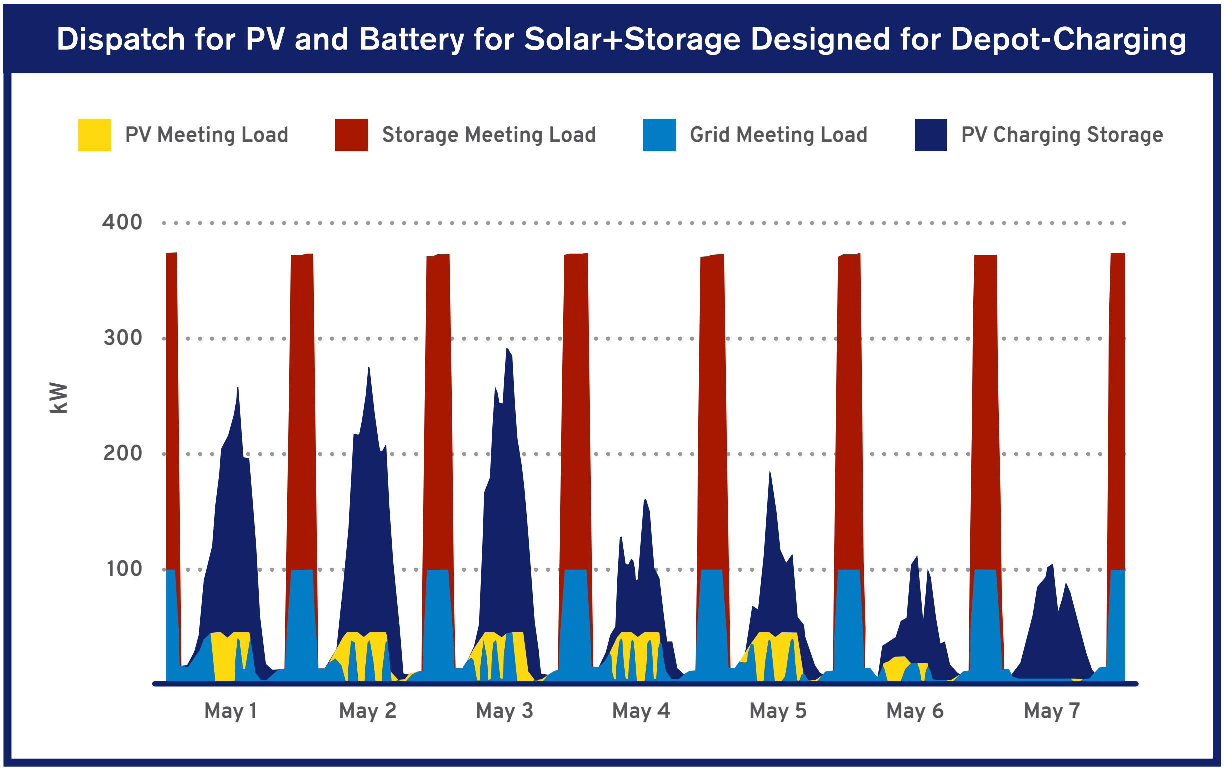

Figure 13 — Dispatch for PV and Battery for Solar+Storage Designed for Depot-Charging

Section 4

Determining Your Community's Stage of Electrifying Transportation

Before communities pursue investments in electric vehicles or infrastructure, it is important for them to identify where they are in the process of electric vehicle and infrastructure deployment and better understand their context in which these decisions are being made. This document reflects the Montana team's experience working with three communities in Montana. We partnered with Bozeman, Whitefish, and Missoula because they had important similarities and differences that helped inform a more robust and comparative analysis. After conducting outreach in each community, the team recognized that each community was trying to answer different questions about electric transportation and could use these questions to define three different stages as starting points for making electric transportation decisions.

The following describes each of the three stages and some of the defining characteristics of communities in each stage. Case studies of each of the three Montana communities follow the descriptions of each of these stages.

Stage 1: *What are our options for electric transportation?*

Defining characteristics:

- Growing community just starting to research information about deploying electric vehicles
- Community has set goals for reducing energy- or transportation-related emissions
- Public or shared transportation options are very limited or not available
- Resources are constrained

Stage 2: *What clean transportation technologies are right for our community?*

Defining characteristics:

- Growing community that has done initial analysis on electric vehicles, but is trying to find out answers to specific questions through detailed and targeted analysis

- Community knows what type of electric transportation it wants to invest in
- Community has set goals for reducing energy- or transportation-related emissions
- Public transportation options are available, but resources are constrained

Stage 3: *How can our community most effectively deploy electric vehicles?*

Defining characteristics:

- Community has already invested in electric transportation and there is some existing charging infrastructure
- Robust public transportation options are readily available
- Community has set goals and established high priority on reducing energy- or transportation-related emissions

4.1 Case Study: Whitefish, MT

Stage 1: *What are our options for electric transportation?*

Key questions:

- How should Whitefish approach greening transportation?
- What options should be considered to achieve community goals?
- How can electric vehicles, and specifically electric public transportation, lower emissions and mitigate traffic congestion?
- Could a partnership be developed between the city, national park (Glacier), and local ski resort (Whitefish Mountain Resort) to optimize implementation of battery electric buses?

Technical analysis undertaken:

- Considerations for battery electric bus deployment.
- Options for compressed natural gas (CNG), propane, and diesel hybrid electric public transit.
- Analysis of what EV bus options exist, which charging technologies may pair best, and what costs/benefits Whitefish should be aware of.

Electrifying Public Transportation from the Ground Up

The City of Whitefish was in Stage 1 of electric transportation development. The City has recently published a Climate Action Plan, and the community at large is building momentum towards increased renewable energy deployment, among other sustainability programs.

The City of Whitefish has a unique situation as a partner in this project: they do not have a municipal transportation system and have limited local public transit service. For this reason, Whitefish began their research with the most primary of questions: what 'green' transportation options should we consider? Whitefish has a population of approximately 7,500 people, which may be insufficient to support a robust public transportation system. However, the community's proximity to Whitefish Mountain—

a very popular ski resort—and to Glacier National Park opened the door to creative partnership opportunities. Further, despite being a small town (by population), the community suffers from traffic congestion due to the local tourism destinations. As they considered expanding a transit system, they sought to identify green transportation options and begin discussions on how they may be able to partner with shuttle routes to the ski area and Glacier National Park.

Key Takeaways from the Technical Analysis

Fuel Costs

Various non-diesel fuel options and bus configurations all have pros and cons that need to be weighed against each other and need to be prioritized based on the community's transportation, climate, and energy goals. The technical analysis looked not only at battery-electric buses (BEBs), but also at CNG, and electric-hybrid buses. The City was primarily interested in BEBs but wanted to consider all available options. One important consideration was the energy use and the related equivalent fuel economy of the buses. It was important to ensure each technology could be expressed in the same units of fuel economy so they can factor into the short-term and long-term analyses of the full costs to operate the vehicles. The figure below compares fuel economy of electric buses. The "BEB High" scenario is a battery electric bus that uses 1.88kWh/mile. The "BEB Low" scenario is a battery electric bus that uses 2.3kWh/mile.

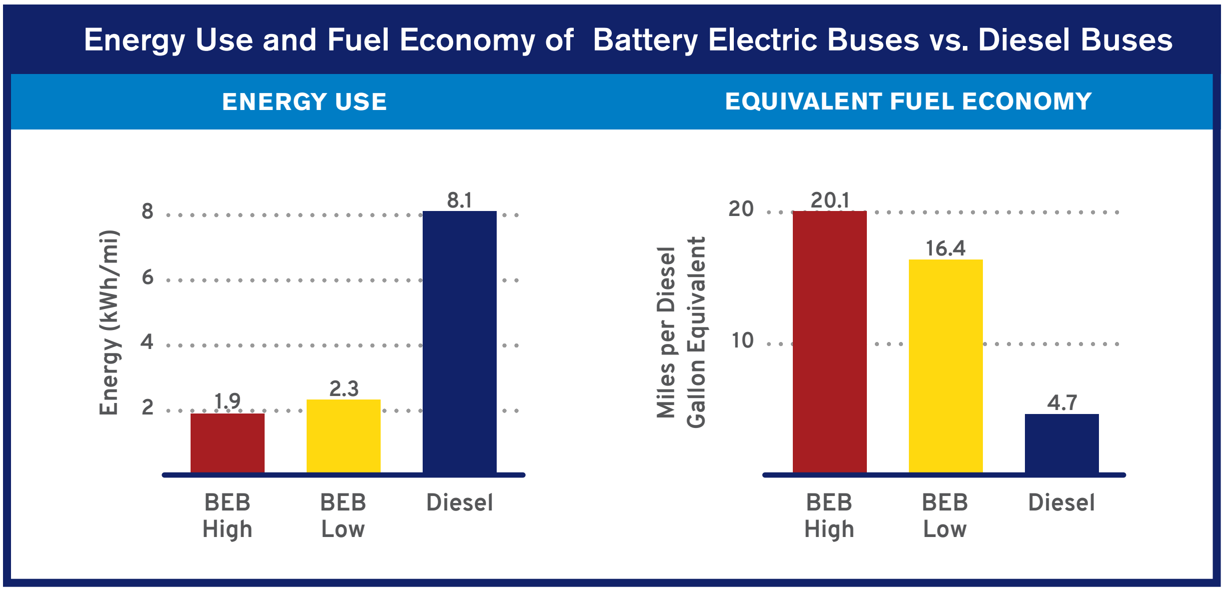

Figure 14 — Energy Use and Fuel Economy of Battery Electric Buses vs. Diesel Buses

Maintenance

In addition to the fuel costs, long term maintenance costs should be considered as well. Over time, BEBs will have lower long-term maintenance costs due to fewer mechanical parts. The battery will need servicing, but the first service is usually covered by warranty and thus does not impact the total cost to the owner/operator.

Creative Partnerships

Shuttles from downtown Whitefish run to the ski area during both the summer and winter months. In the past, shuttles have also run from downtown Whitefish to Glacier National Park during the summer months. As Whitefish looked to expand its municipal transit options, they looked at ways that they might be able to partner with the operator of these shuttle routes to increase operating efficiency of the buses. The owner/operator of an electric bus will see greater comparative savings compared to diesel buses the more the electric buses are used. Whitefish is a small town, and a local route may not provide enough operating time to get sufficient benefits out of a BEB. Whitefish is now considering a pilot project with local partners that could provide such a service that runs throughout Whitefish—helping to reduce traffic congestion and improve air quality—that would also extend to and combine with multiple additional routes. It could include a commuter route to nearby Kalispell and a shuttle service to Glacier National Park. These creative partnerships would allow the buses to operate efficiently while helping the community achieve its intended goals.

4.2 **Case Study: Bozeman, MT**

Stage 2: *What clean transportation technologies are right for our community?*

Key questions:

- How should Bozeman approach greening transportation?
- What options should be considered to achieve community goals?
- How can electric vehicles, and specifically electric public transportation, lower emissions and mitigate traffic congestion?

Technical analysis undertaken:

- Considerations for battery electric bus deployment.
- Options for compressed natural gas (CNG), propane, and diesel hybrid electric public transit.
- What EV bus options exist, which charging technologies may pair best, and what costs/benefits Bozeman should be aware of

Considerations when planning BEB deployment

In the comparison between CNG, propane, and battery electric buses (BEBs), Bozeman favored a more in-depth analysis of BEBs based on the local air quality benefits of the BEB's zero tailpipe emissions, reduced maintenance costs, and the availability of the technology in the region. The National Renewable Energy Laboratory (NREL) provided analysis of two on-route charged BEB fleets, which demonstrated overall lower maintenance costs for the first 43 months of service compared to diesel and CNG.

Based on these considerations, the team sought to better understand the specific challenges and opportunities associated with deploying BEBs. BEB routes require advanced planning to appropriately anticipate the placement of depot or on-route charging infrastructure. Designing initial infrastructure with the potential to scale up for future additions is key to controlling operational costs.

Once the power needs for the buses are determined, working with the utility to ensure sufficient power is available for local infrastructure should be an early deployment consideration. Understanding electricity rate structure, including demand charges and time of use charges, is important to modeling fuel costs.

Maintenance and staff training can be an unexpected upfront cost until staff become familiar with troubleshooting, diagnosis, and repairs. Operators will require continual training and route schedules must accommodate re-charge time for on-route bus charging.

Key Takeaways from Economic and GHG Analysis:

Act on Funding Opportunities

The availability of BEB grant funding is a considerable factor for fleets considering a transition to a BEB. In Bozeman, a grant for two of four BEBs would reduce the simple payback from 5.7 years to 6 months.

Maximize Miles Driven

When comparing BEBs with a diesel baseline, maximizing the BEB's miles driven per year improves the project's economics. Adding 11,000 miles per year over the baseline increased net present value (NPV) by $357,000 and reduced the payback period by 1.7 years.

Plan for Future On-Route Charger

Based on the long distances of Bozeman's current routes, buses would need two full charges per day, necessitating on-route fast charging. Using bus manufacturer Proterra's charging equipment, the on-route charger is less expensive once the fleet grows to over five buses. However, the cost differential associated with purchasing four depot chargers initially instead of one on-route charger increases the project NPV to $1.2M.

Based on a variety of changing needs, Bozeman opted to re-design their current routes in order to reduce the length of routes and plan for future growth of EVSE. Beginning with depot charging and planning for the addition of on-route charging or induction charging to extend route range would help operators improve project economics by increasing the annual miles driven.

Avoid Peak Demand Load

If on-route charging is optimally paired to avoid a 60kW peak load, the monthly demand charges drop $600 per month and NPV increases to $682,000.

Emissions Reductions

Under our baseline scenario, four diesel buses with a fuel economy of 4.7 miles per gallon (MPG) replaced by BEBs are expected to save 3,815,000 kg carbon dioxide equivalent (CO2e) over the 12-year average life of a bus. The savings vary from 1,907,501 to 6,663,340 kg CO2e based on the baseline MPG of the diesel, miles traveled per year, average life of the bus, and electric bus efficiency.

4.3 Case Study: Missoula, MT

Stage 3: *How can our community most effectively deploy electric vehicles?*

Key questions:

- How should Missoula operate its electric fleet?
- What are the cost impacts of different charging options?
- What emissions reductions can be achieved from different options?
- How can solar and/or storage be paired effectively and efficiently with Missoula's charging infrastructure?

Technical analysis undertaken:

- Analysis of cost, energy, and emissions savings for replacing diesel buses with battery electric buses
- Electricity cost impacts of different locations for the charging equipment (university vs bus depot, both vs on-route charging)
- Cost-optimal PV and/or storage sizing and emissions reductions impacts.

Integrating Electric Transportation Options

The focus of Missoula's project stemmed from its interest in understanding and advancing electrical transportation, particularly with its transit system's bus fleet. Further, through the project findings, they hope to educate the community about the environmental and economic benefits of electric transportation, especially considering additional renewable energy as part of the system and in alignment with local carbon reduction goals.

The top priority for project analysis revolved around the electric bus depot charging.

Key Takeaways from NREL Analysis

To answer these questions NREL conducted analysis, primarily using its REopt model*. Missoula now has a clearer picture of:

- Cost, energy, and emissions savings for replacing diesel buses with battery electric buses
- Electricity cost impacts of different physical locations for the charging equipment
- How to manage demand charges and electricity costs, considering time of use and rate structure possibilities and the impacts to the grid

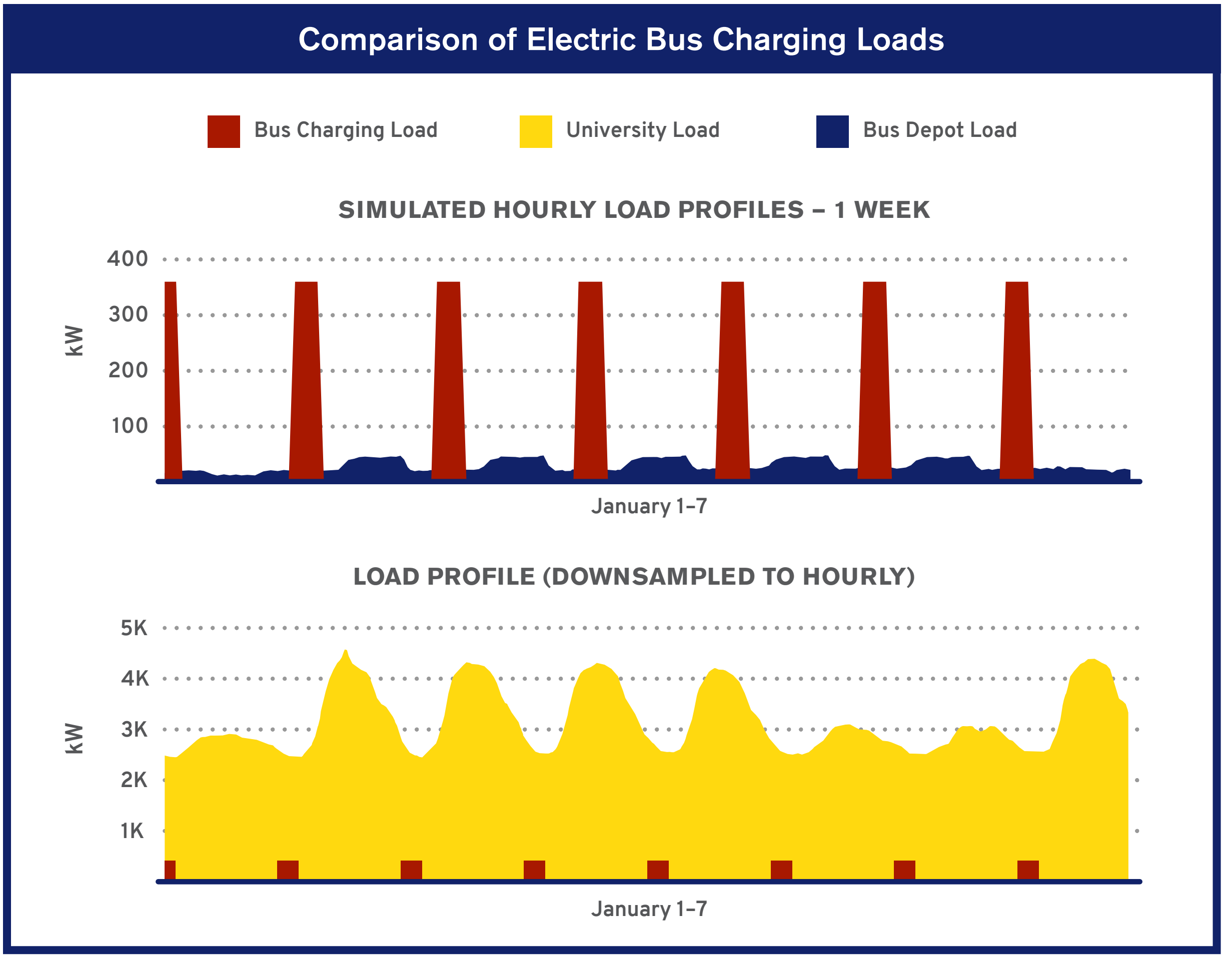

Figure 15 — Comparison of electric bus charging loads at standalone depot and university campus

- The potential of adding PV and storage to mitigate the costs of charging the electric bus fleet and how this reduces emissions

Mountain Line, the local transit authority, looked at multiple different options for where they could charge their buses. In Figure 15, the REopt model shows the impact of charging the buses at the current depot versus at the university. At the depot, the demand spikes significantly above the baseline load when the buses are charged, which in this case was overnight. This could lead to significant operating costs via demand charges.

In order to mitigate these charges, Mountain Line considered charging at a different location — the university. The University of Montana has a much higher base load, and as such would be significantly less affected by the demand from bus charging.

The Missoula stakeholders then worked with NREL to analyze the impact of adding solar and/or storage. The REopt modeling analysis showed that when net metered, a 50 kW PV system (the largest net-metered system currently allowed for this energy provider in Montana) appears marginally cost effective, allowing the site to generate enough solar electricity to serve 7% of total load on an annual basis. NREL ran multiple modeling scenarios with different restrictions on the inputs to the model. For example, in one scenario, the 50kW net metering cap restriction was removed. This scenario allowed Mountain Line to see what sized solar and/or storage systems would be needed to power the buses with 100% renewable energy. Another scenario in the model demonstrated a sensitivity by reducing the cost of storage. This helped Mountain Line understand how the current cost of storage is impacting the ability for a solar+storage configuration to be cost effective. The analysis showed that storage costs would have to be reduced by over 50% for storage to appear cost effective.

Utility Engagement is Paramount

The most significant take-away for Missoula has been the importance of engaging with the utility early in the process to best plan for increased electricity load and cost scenarios. This engagement allows Mountain Line and the utility to work in partnership to obtain needed data, monitor electricity in real-time, and work to develop a rate structure that can benefit both the transit system and the utility.

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*Elgqvist, Emma. "Economics of Solar PV and Stationary Storage for Electric Bus Charging in Missoula, Montana." National Renewable Energy Laboratory. 2019. Accessible: https://www.nrel.gov/docs/fy20osti/75272.pdf

Section 5

Working Through Each Stage of Electric Vehicle Deployment

After a community determines its stage of electric vehicle deployment, there is a series of key steps that can help prioritize electric transportation options, answer critical questions, and ultimately accelerate electric vehicle deployment. There are four steps that the Montana Team found to be helpful to the communities we worked with, which are detailed in Figure 14 below. Depending on where a community is starting and the questions they are trying to answer, they may want to begin at different steps. If a community is further along and has already determined stakeholder goals and priorities, it may be better to start with Step 2.

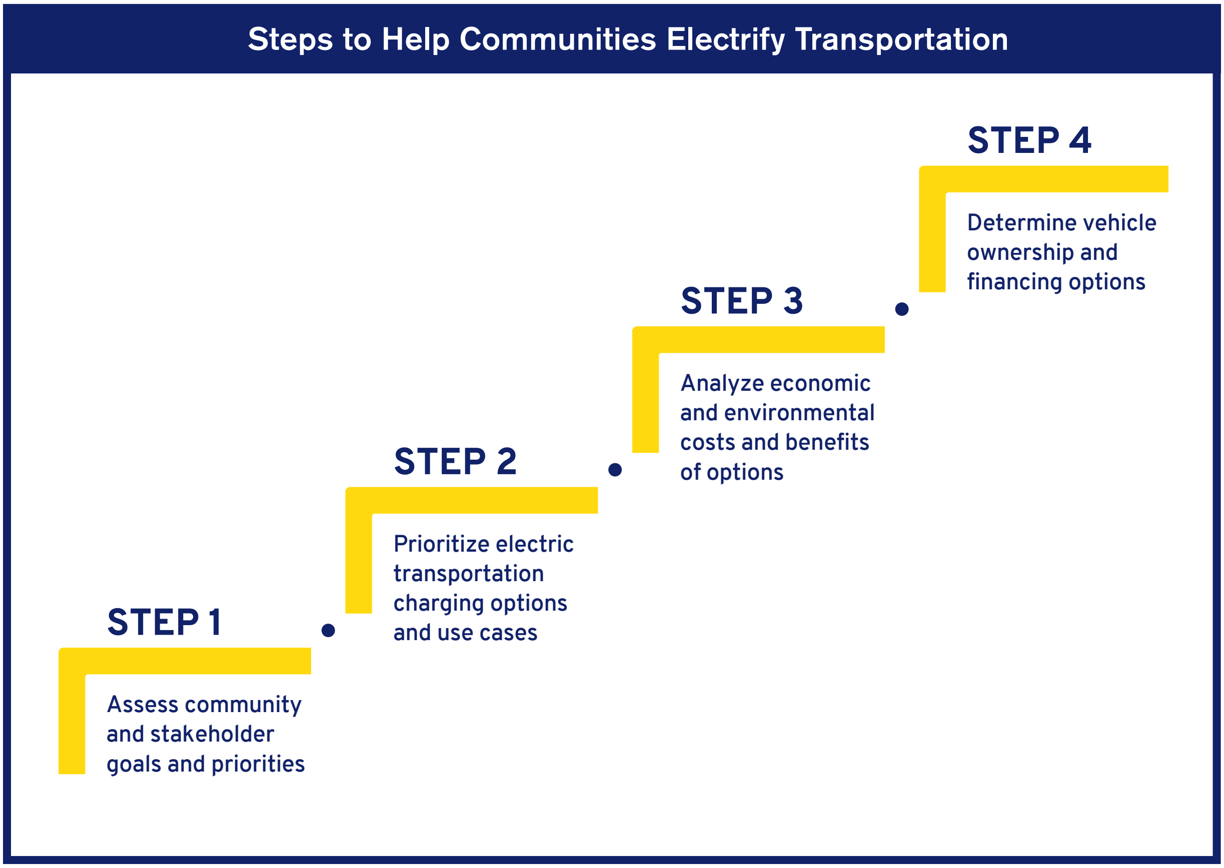

Figure 16 — Steps to Help Communities Electrify Transportation

5.1 Step 1: Assess Community and Stakeholder Goals and Priorities

Early on, the Montana team realized that it was critical to bring key community stakeholders to the table to bolster community buy-in and support for project goals and outcomes. This input helped ensure that communities were involved in decision-making processes from the project's formative stages and onward. Understanding community-specific context makes the implementation of electric transportation smoother and more effective. Several activities that the team conducted in preparation for community stakeholder meetings helped make those meetings more successful and ultimately allowed the team to identify priority projects in each community:

1. Identifying and inviting key stakeholders
2. Assessing community goals and priorities
3. Early engagement with the electric utility

5.1.1 Identifying and Inviting Key Stakeholders

Transportation planning and energy resource planning both involve diverse sets of stakeholders and interests. Bringing these transportation and energy stakeholders together is critical to effectively plan and execute electric transportation projects. Prior to meeting with each community, the Montana team identified key stakeholders and grouped them into stakeholder types (see the stakeholder map in Figure 17 below). Even small communities can contain numerous stakeholders with diverse opinions and the power to impact the trajectory of a given community planning and transportation project. It is important to consider each of their roles in electric transportation planning decisions so that a project's outcomes can match its desired results.

The Montana Team conducted stakeholder meetings within each community: Whitefish, Bozeman, and Missoula. Prior to these meetings, the team worked with a community point person to develop a stakeholder invitation list. In each of the three communities, key stakeholders at the meetings included city planning, sustainability, and community development office staff; representatives from electric utilities (including both investor-owned and electric cooperatives); and representatives from

Montana Solar Powered Community Transportation Initiative Key Stakeholders			
COMMUNITY ORGANIZATIONS	**LOCAL GOVERNMENT**	**STATE GOVERNMENT**	**TRANSPORTATION**
Montana Renewable Energy Association	City of Bozeman	Montana Energy Office	UM Transportation Companies
Climate Smart Missoula	City of Missoula	Public Service Commission	Streamline (Bozeman)
Bozeman Partners (MSU, YTCC)	City of Whitefish	Montana Department of Commerce	Mountain Line (Missoula)
Missoula Climate Partners	Bozeman Transportation Planners	Legislature	KAL/WF Transit (Eagle Transit)
Climate Smart Glacier Country	Missoula Transportation Planners	The Governor's Office	Xanterra
NW Energy Coalition			Proterra

TECHNICAL ASSISTANCE	ENERGY PROVIDERS	OTHER STAKEHOLDERS
National Renewable Energy Laboratory	NorthWestern Energy	Solar Installers
Rocky Mountain Institute	Flathead Electric Cooperative	Consumer Council
Regulatory Assistance Project		

Figure 17 — Key Stakeholders for the Montana Solar Powered Transportation Initiative

public transportation companies. Montana's two largest state university campuses are in Missoula and Bozeman, so university transportation and sustainability staff were also invited to the community meetings. Stakeholders in each community differed slightly depending on the size of the community and the status of electric transportation investment. The input of local experts and relevant stakeholders allows the project team to cross-reference the possibilities for electric transportation with projects that would be of interest to the community and be supported by key decision-makers and advocates. Initial meetings with stakeholders in each community also helped to identify individuals who could be solar powered electric transportation project "champions," the most effective people to coordinate with as the team helped the communities plan for and implement projects.

5.1.2 Assessing community goals and priorities

Electric transportation decisions should be grounded in goals and priorities that have already been established by each community. Many communities record their visions and goals in official planning documents, often including plans for economic or population growth, transportation, sustainability, and climate action. Prior to conducting the community meetings, the Montana team reviewed relevant plans for each community. The team documented and summarized high level economic and environmental goals, which were then grouped into four major categories and mapped to potential benefits from electric transportation. These categories of community goals include:

- Decreasing pollutant emissions to improve air quality and mitigate climate change impacts
- Increasing renewable energy resources
- Decreasing traffic congestion by improving public transit
- Expanding sustainable community economic development opportunities

At each community meeting, the team presented a community goal and project benefit comparison matrix, mapping goal statements identified in the review of each plan with these four categories. An example of the matrix for Bozeman, Montana is in Table 9 below. Each section represents one of the four categories of goals and associated benefits.

Bozeman Community Goals and Benefits Alignment	
AIR QUALITY, EMISSIONS REDUCTION, CLIMATE CHANGE MITIGATION	
Transportation Plan	Promote transportation projects plans and programs that encourage reducing fuel consumption and reducing vehicle miles traveled, thereby minimizing air pollution.
Strategic Plan	Help address climate change by taking steps to reduce the City's GHG emissions
Community Climate Action Plan	Reduce emissions to 10 metric tons per capita by 2020
Municipal Climate Action Plan	Increase fuel efficiency of the City vehicle fleet and increase the average fuel efficiency standard
Community Plan	Help address climate change by taking steps towards reducing the City's GHG emissions
INCREASE RENEWABLE ENERGY RESOURCES	
Strategic Plan	Increase supply of clean and renewable energy
Community Climate Action Plan	Adding alternative energy production to the list of recommendations is necessary to reduce energy use and change sources of Bozeman's energy
DECREASE TRAFFIC CONGESTION THROUGH INCREASED TRANSIT	
Transportation Plan	Efficient travel and increased mobility are desirable
Strategic Plan	Encourage transportation options that reduce consumption
Community Climate Action Plan	Allocate funding for Streamline bus service
SUSTAINABLE ECONOMIC DEVELOPMENT	
Transportation Plan	Bozeman provides a stable economic base for a variety of services and industry
Strategic Plan	Foster clean, renewable energy businesses

Table 9 — Bozeman Community Goals and Benefits Alignment

5.1.3 Early Engagement with the Electric Utility

Engaging directly with the electric utility provider is a critical step in any transition from conventionally fueled vehicles to electrified transportation. Utilities were identified as a key stakeholder to attend the community meetings because their rules and rates define many relevant cost boundaries for electric transportation projects. However, some discussions with utilities are best kept as dialogues, as technical topics such as requirements for interconnection and rate design may not be as appropriate for a community-wide stakeholder group.

Utilities across the country are recognizing that growth in electric vehicles is an opportunity for load growth, which supports their business model; yet not all utilities support managing and powering this new load with solar PV and storage. Lack of utility support could pose substantial challenges to this transition. Rate designs for electric vehicle charging could make EV projects that are paired with solar (and storage) less economical. Lack of utility support could also make it much more challenging to propose pilot projects to the state's regulatory commission. Bringing the utility on board as a supportive partner is therefore important to ensure a beneficial partnership and successful electric transportation initiatives. This section focuses on providing information and some questions to consider before engaging with a utility, as well as suggested best practices.

Utility Engagement Best Practices

Before meeting with the utility, research the utility's positions and activities that relate to electric vehicles, solar energy, and storage.

This may require speaking with others in the state who have worked more closely with the utility. It is important to know this information going into a meeting to manage discussions and craft requests appropriately. For example, if a utility is already fully supportive of developing electric vehicle infrastructure and pairing it with solar PV, conversations about a pilot project can be more open. If a utility has historically shown resistance to those ideas, then the conversation may need to begin with a discussion of how the utility could benefit from increased EVs and how solar PV and storage can help realize those benefits. At the meeting, consider asking the utility representatives if they have already researched EV technologies and their impact on the utility business model and grid operations. This is a good way to begin conversations in a meeting and allow the utility to share their input and perspectives.

Determine the objectives for engaging with the utility and share them with the utility.

It is important to discuss what the objectives are for engaging with the utility. These can be high-level and more long-term, such as "support for a pilot project." As with any stakeholder, the utility's goals and motivations for participating in the project may be slightly different than the team's. Bringing a stakeholder on board requires recognition of those differences and strategies to tailor the project(s) accordingly.

Creating objectives for utility participation in the overall project will help guide stakeholder engagement at a high level, but it is important to also determine objectives for individual interactions, such as meetings and roundtables. It is unlikely that the discussion will cover each of the project objectives at the first meeting. It may be that project goals must be addressed over the course of several meetings and interactions with the utility and their staff. This may be especially true when seeking participation from a more resistant partner. It is also important to note that this process is iterative, and objectives should be reassessed after each interaction to ensure they have not shifted based on new information.

Determine clear and realistic requests of the utility and desired outcomes of the meetings.

These requests and outcomes are more specific than the high-level objectives. An example of a specific outcome would be "sharing load profile data" or "a firm agreement to meet again after the initial meeting." This ensures there is no confusion about what the request and helps move the project forward. Again, these should be shared with the utility so that there is no confusion.

Consider how a pitch for specific use cases will affect objective(s) and request(s).

When developing the objectives and requests, it is important to factor in the type of use case (or multiple use cases) being considered. Different charging scenarios will have different impacts on the utility's business model and on the grid. For example, workplace charging for a fleet of vehicles means increased load during the day, but will likely be Level 1 or Level 2 charging, which will mean a low but extended increase in load during those hours. This may have a relatively small impact on the utility's grid and on their electricity sales. In contrast, consider transit vehicles charging either overnight at a depot (using Level 2 chargers) or during the day with on-route charging (likely Level 3 chargers). Both may create large spikes in demand, with the overnight charging happening during off-peak hours and the on-route charging happening during increased daytime loads.

Solar PV and storage may alter these impacts. For example, a solar and storage system integrated into a transit depot can mitigate overnight spikes in demand by providing stored solar energy to meet that load. This may offset not only the need for increased demand, but may offset any revenues for the utility from off-peak demand charges. Be prepared to discuss these scenarios with the utility staff.

If possible, identify a staff member who is a champion for EV, solar, and/or storage issues.

A great first point of contact would be a utility staff member who is working on electric vehicles, solar, and/or storage. Not all utilities have an individual specifically assigned to those tasks. It is helpful to Identify who would be the best individual to connect with at first. For example: staff who work with interconnection, demand-side management programs, and/or distributed energy resources.

It can be helpful to ask that person who else they think should be in an initial meeting or on an initial call. This will help make sure the right people are present for the first meeting. It is also recommended, and completely reasonable, to request that certain staff are in the meeting. For example, if the agenda includes discussing a pilot project and addressing rate design, it would be beneficial to have the regulatory affairs and/or government affairs staff in the meeting. Meeting objectives can drive who should be present at the meeting.

Send meeting materials well in advance.

Materials should include the agenda for the meeting, as well as any background information that will be discussed. This will be especially important for any high-level staff and any attendees who may not be as familiar with these issues. They should be given time to familiarize themselves with the topics and identify questions ahead of time.

5.2 Step 2: Prioritize Electric Transportation and Charging Options and Use Cases

The Montana team's goal was to help communities identify and prioritize electric transportation benefits to help inform investment decisions in different transportation use cases. Rather than asking community stakeholders whether they support one electric transportation option over another (i.e. light duty vehicles, transit buses, or fleet vehicles), the stakeholders ranked the benefits associated with electrifying transportation. At each stakeholder meeting, goals identified in each of the community plans were presented on a flip chart. Stakeholders were then asked to review these goals and add any they thought were missing. Each attendee was then given two dots stickers, which they used to identify which two goals they thought should be priorities for the community. Table 10 shows the results of these exercises.

Summary of Community Priority Dot Voting Results			
	TOTAL VOTES		
	Bozeman	Missoula	Whitefish
Increase Renewable Energy Resources	3	8	0
Air Quality/Emissions Reduction/ Climate Change Mitigation	10	8	3
Decrease Traffic Congestion Through Increased Transit	11	4	11
Sustainable Economic Development	6	1	0
Community Engagement*	-	-	3
Maintain Community Character*	-	-	2
Education and Outreach*	-	1	-

Table 10 — Summary of Community Priority Dot Voting Results

*These categories were not part of the original exercise. They were added by stakeholders during community meetings.

By ranking these goals, community stakeholders helped the team understand which electric transportation benefits would be most important to the community and use that information to prioritize the types of electric transportation projects to pursue. In Bozeman, for example, the top two goals were to decrease traffic congestion and improve air quality by reducing emissions. An interesting take-away from the voting exercise was the extent to which the communities differed in their top priorities. For example, in Whitefish "increasing renewable energy resources" was not a top priority. Several stakeholders noted that this was not because the community did not support renewable energy, but rather that Whitefish's current energy supply from Flathead Electric Cooperative is nearly 90% renewable (mostly hydropower), so the community chose to prioritize other goals and benefits.

Following this community goal ranking activity, the team worked with community members to prioritize the benefits and tradeoffs of specific electric transportation and charging applications. This ranking exercise helped to understand that all three communities wanted to prioritize electric transit buses because the benefits associated with electric transit buses were ranked by stakeholders as their highest priority. The transit bus use cases were the most closely aligned with community priorities of reducing traffic congestion and reducing emissions (see Table 4, page 23).

5.3 Step 3: Analyze Economic and Environmental Costs and Benefits of Vehicle and Charging Options

After determining the electric transportation options (light duty vehicles, fleet vehicles, public transit, etc.) that the community wants to prioritize, stakeholders can conduct a more in-depth environmental and economic analyses to help answer key questions about where to charge, when to charge, and options for charging the vehicles with renewable energy.

Each of the three participating Montana communities prioritized electric transit buses, so the technical analysis for each community focused on answering questions about the environmental and economic impacts of deploying electric buses in each community. However, the level of analysis differed based on the community's present stage of electrifying transportation. A summary of the analysis for each community is included in the case studies (section 4).

For communities in Stage 1 who are trying to answer basic questions such as what green transportation options to consider, a higher-level analysis that summarizes key considerations and information from other communities can be most helpful. One of the key considerations for communities interested in investing in transit buses is long term maintenance costs of different fueling options.

Communities in Stage 2 may have already decided to invest in electric transportation and infrastructure, but have not settled how to operate electric transit and maximize economic and environmental benefits. In this case, a net-present-value economic analysis can be performed to consider the economic benefits of investing in certain electric transit options, while environmental analysis can evaluate emissions impacts of various electric vehicle deployment and operational scenarios. Key tracked variables include the number of electric buses deployed, the number of annual vehicle miles travelled, which routes to deploy electric buses on, and the type of charging infrastructure. Analysis for Bozeman determined that all of these factors had an impact on the net-present-value, payback period, and emissions reductions from deploying electric buses. With the impacts of these variables quantified, the community becomes better equipped to choose the electric transportation investment that most closely matches its priorities.

Communities in Stage 3 may have already invested in electric transportation and have needs related to understanding what emission reductions can be claimed from deploying the electric vehicles, when and where to optimally charge the vehicles, and what options are available for charging the vehicles with renewable energy. Answering these questions requires more in-depth energy planning and optimization analysis that evaluates vehicle energy load profiles, distributed energy resource technology options, utility costs, and rate design. The National Renewable Energy Laboratory's Renewable Energy Integration & Optimization (REopt) is a useful tool that can help communities evaluate options for sizing distributed energy resources to support electric vehicle charging.[44] The REopt tool produced the analyses for the Missoula case study.

[44] For more information on the REopt model and its outputs, visit: https://reopt.nrel.gov/

5.3.1 Assess Options for Pairing EVSE with Renewable Energy and Storage

As discussed earlier in the document, an electric vehicle is only as clean as the electricity powering it. Below are important questions and best practices when considering how to power the vehicles.

Determine who the utility is, their fuel mix, and the emissions from their fuel mix.

This is an important first set of data to obtain, especially if emissions reduction goals are a driving factor in the community's decision to electrify transportation. Knowing the fuel mix will help understand the emissions created by charging the electric vehicle. Regional fuel mixes are available online via the Energy Information Administration and others, but it will always be more accurate to get specific fuel mix information from the community's electricity provider. Many provide this information publicly in annual reports or other documents. Information is also available through the Department of Energy's Alternative Fuels Center[45] and the National Renewable Energy Laboratory. A good resource for emissions information for different types of electricity supply resources (e.g. coal, natural gas, wind, solar) is the U.S. Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID).[46] It is important to compare the emissions of the electricity supply mix to the emissions of conventional fuels currently powering the fleet (diesel, CNG, gasoline, etc.). The comparison can then be extended to a scenario in which the vehicles are powered with 100% renewables to understand the maximum available emissions reductions.

Determine the amount of electricity used by the EVSE that should be offset with solar PV and/or storage.

Every community will have different transportation, renewable energy, emissions, and transportation goals. Further, each will have a different prioritization of those goals. Many communities are seeking ways to reduce emissions to a specific target, while others are pursuing a 100% clean energy supply. These community goals and their hierarchy are important parameters to identify and can influence decision making on

[45] U.S Department of Energy Alternative Fuels Data Center. "Emissions from Hybrid and Plug-In Electric Vehicles": https://afdc.energy.gov/vehicles/electric_emissions.html

[46] U.S. Environmental Protection Agency Emissions & Generation Resource Integrated Database. https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

solar and storage integration. These goals will drive the size of the solar and storage systems considered, and will influence perspectives on designing cost analysis results. If a community is seeking to power vehicles with 100% clean energy, it is important to consider how much grid power the electric vehicles will require and the fuel mix generating that power.

Ask what is the most cost-effective solar and storage use case to achieve the emissions and renewable energy goals associated with these electric vehicles.

If the goal is to power the vehicles with a percentage of clean energy (e.g. 100% or 50%), then the electricity needed to do that will be the key driver of how large of a solar PV array and/or storage system you will need. However, if there is not a specific target — e.g., the intent is to offset as much of the electricity with renewables as possible—then there is more flexibility in the size of the system. In either scenario, it will be important to conduct a cost analysis to determine the most cost-effective system size to purchase. It may be necessary to integrate the solar PV and/or storage in phases over time.

Identify the benefits of co-locating the solar array with the EVSE.

Co-locating the solar PV array with the same meter as EVSE can be ideal for many reasons. Co-location ensures the electricity generated by the solar array is used to power the charging equipment, and not simply sent elsewhere on the grid. If the array is not co-located, it becomes more difficult to claim that the electricity powering the vehicles is 100% renewable. Importantly, co-location can also provide benefits to public awareness and outreach campaigns. The visual connection between the solar array and the EVSE can help drive awareness of the electric vehicles and their impact on the community.

An important consideration for co-location will be the size of the PV array that is needed to achieve the identified offset goals. The physical size of the array may not be compatible with the available space on-site or near the EVSE. The National Renewable Energy Laboratory's REopt tool can inform this decision. The REopt tool can model an optimal mix of renewable energy, conventional generation, and energy storage technologies to meet cost savings and energy performance goals.[47] Missoula used this

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[47] Learn more about the National Renewable Energy Laboratory REopt tool at https://reopt.nrel.gov/

tool to analyze the costs and benefits of using solar PV and storage to power a fleet of buses charging at a depot. For more, see the Missoula Case Study (section 4.3).

If co-location is not viable, there are other options to offset the increased electrical load caused by the EVs. For a business or organization operating the EVSE, buying into a shared solar PV array or signing a solar power purchase agreement could help virtually power the EVs with solar energy.[48, 49] Another option would be to consider signing up for a green tariff program, if one is offered by the utility.[50, 51] This may not fully offset the additional EV load, but could help achieve the renewable energy goals associated with the EV transition and investment. Purchasing renewable energy credits is another option to consider.[52]

5.4 Step 4: Determine Electric Vehicle Costs, Ownership and Financing Options

After communities have considered and analyzed what type of electric transportation and charging infrastructure they want to invest in, they can then consider the upfront costs and operating costs of the vehicles and associated infrastructure, the impact of utility rate design, and financing options that are available.

5.4.1 Upfront Costs and Maintenance

Electric vehicles typically have higher upfront costs than conventional vehicles, primarily due to the cost of batteries. While the upfront cost premium is offset over time by the lower fuel and maintenance costs of EVs, high upfront costs remain a common barrier to EV investment. The upfront cost of light duty electric vehicles can range from hundreds to several thousand dollars more than conventional vehicles. These comparisons carry over to heavy duty vehicles, with electric transit buses and trucks sometimes costing over twice as much as their diesel counterparts. Income tax credits, rebates, and other incentives can help lower these upfront costs. Communities

[48] Department of Energy, Energy Efficiency and Renewable Energy. Community and Shared Solar: https://www.energy.gov/eere/solar/community-and-shared-solar

[49] Montana Solar Community Project: http://mtsolarcommunity.mt.gov/

[50] Heeter, Jenny. “Utility Green Tariff Programs in the U.S.: Overview and Opportunities for Cost”. June 19, 2019. National Renewable Energy Laboratory. Available: https://www.nrel.gov/docs/fy19osti/74211.pdf

[51] Environmental Protection Agency: https://www.epa.gov/greenpower/utility-green-tariffs

[52] Environmental Protection Agency: https://www.epa.gov/greenpower/renewable-energy-certificates-recs

should comprehensively examine the EV purchase incentives available to them, and then evaluate the savings due to lower fuel and maintenance costs for EVs. A study by the University of Michigan found that electric vehicles cost less than half as much to operate as gasoline vehicles in all 50 states.[53] Fuel cost estimates require a deeper analysis of the applicable electricity prices, as described below.

5.4.2 Operating Costs: Impact of Utility Rate Design

The way customers are billed for electricity can have a significant impact on the operating costs of electrical vehicles. Most residential electric utility rates are primarily based on the volume of electricity used. This is the number of kilowatt-hours used over the billing period. Assuming an EV owner is not subject to a special utility rate, the cost of charging an electric vehicle at home is relatively simple to estimate: the number of kilowatt-hours needed to charge the vehicle multiplied by the average cost of electricity per kilowatt-hour.

The situation changes for commercial utility customers, often significantly. At workplace and public charging stations, EV charging costs are dependent on several factors, including the utility rate design, the configuration of the charging stations (e.g. whether they share electricity meters with buildings), the timing of vehicle charging, and the business model being used to offer EV charging. The utility rate design can significantly influence the configuration and the business model, since it impacts the economics of both.

Commercial sector utility rates have volumetric charges like those in the residential sector, based on the number of kilowatt-hours used during a billing period. Like the residential sector, the cost per kilowatt-hour may be constant (flat rate), may increase as more electricity is used (block rate) or may change during different times of day or in different seasons (time-of-use rate). Some commercial sector utility rates have a demand charge element in addition to other charges. Demand charges are assessed based on the peak load, or maximum kilowatts, consumed by the facility in a specified time period. Demand charges associated with EV charging are determined by combining the load profile of the vehicles being charged with the load profile of any

[53] Sivak, M. and B. Schoettle, "Relative Costs of Driving Electric and Gasoline Vehicles in the Individual U.S. States," January 2018.

other loads (e.g. building loads) on the same electricity meter. The type of EV charger and the way charging is managed both impact the resulting charging load profile. For example, Level 3 (or DC fast charging) stations typically have higher peak loads, since they charge at higher rates to charge vehicles faster. Unless the charging load is overshadowed by a building load on the same meter or otherwise offset, high demand charges can be triggered by Level 3 chargers. Level 2 charging draws lower power, so demand charges can be less of a barrier for those stations.

As shown in the Missoula Case Study (section 4.3), the transit agency considered charging electric transit buses at the depot as well as at the university. At the university, the spikes in demand from EV charging were effectively hidden behind the university's high amount of daily energy use. Increasing the demand charges for the university was not a concern in this scenario. However, the separately-metered bus depot has a much smaller load profile than the university, and the spikes in demand from charging the buses would result in significant demand charges for the facility.

It is important that communities work with their utilities early on to determine the impacts of utility rate design, charger configuration, and the business model that will be used to provide EV charging. There may also be concerns regarding grid impacts of deploying EVSE that can be surfaced in these early conversations. If barriers are identified early, there may be opportunities to engage the utility in exploring alternative rate designs that provide win-win solutions.

Pairing electric vehicle charging with solar PV may also help customers avoid demand charges, but there are important considerations.

If electric vehicle charging load corresponds with solar production (i.e. during the middle of the day), then co-locating solar on the same electricity meter as the electric vehicle load could offset the peak demand associated with the charging stations. For solar to result in demand charge savings, the demand charge would also have to be coincident with system peak. If vehicle charging occurs during the evening, or if the demand charge is non-coincident with system peak, then solar PV integration would not reduce demand charges. Under these circumstances, communities may want to evaluate the role of battery storage in reducing demand charges from charging electric vehicles.

However, even for vehicle charging that is coincident with solar, demand charges are based on the highest demand over the billing period, so the intermittency of solar resources may not decrease demand charges as much as expected. Depending on demand charge structures, if the high demand coincides with a cloudy day or snow covers the solar panels, any demand charge reduction benefit of the solar system could be negated. Pairing the solar PV system with a battery energy storage system that is designed to discharge during periods of high EV load and low solar production could address this challenge. As battery prices decline, this option may become more economically attractive to charging station investors.

5.4.3 Vehicle Ownership and Financing Options

The total cost of electric vehicles and associated charging infrastructure can vary based on several factors. Recovering upfront and operating costs may be a challenge, particularly while electric vehicle adoption rates are relatively low. How to finance electric vehicles and infrastructure is often one of the first questions that communities ask.

Incentives for privately-owned light duty electric vehicles that can help lower the upfront cost include state and federal tax credits, rebates, and group purchasing programs. Utilities, state and local governments, and nonprofits can provide rebates to consumers who want to purchase electric vehicles. These rebates and incentives make EV models more cost-competitive with internal-combustion-powered models. For example, Delaware's Clean Electric Vehicle Rebate Program offers rebates of $2,500 for consumers who purchase EVs through participating dealerships.[54]

Group buy programs have been implemented in other communities and have inexpensively and successfully led to increased electric vehicle adoption. The Southwest Energy Efficiency Project has developed an Electric Vehicle Group Buy Program Handbook[55] that discusses case studies and lessons learned from several electric vehicle group buy programs. The City of Fort Collins and Drive Electric Northern Colorado (DENC), a local non-profit, have an electric vehicle group buy program available to community members. The program provides steep discounts, at

[54] Delaware Division of Climate, Coastal, & Energy. "The Delaware Clean Vehicle Rebate Program." https://dnrec.alpha.delaware.gov/climate-coastal-energy/clean-transportation/vehicle-rebates/

[55] Southwest Energy Efficiency Project, "The Electric Vehicle and Photovoltaic Power Purchase Handbook," Available at: http://www.swenergy.org/data/sites/1/media/documents/publications/documents/Power_Purchase_Handbook.pdf

times more than 50%, on certain makes and models of electric vehicles. The discounts are negotiated with local car dealerships and auto manufacturers. The City and DENC are responsible for coordinating the marketing campaign in the community to educate the public and promote the discount.

Financing and leasing for electric fleet vehicles and transit buses are also beginning to emerge as the market develops for these EVs. Investing in fleet vehicles can help communities achieve greenhouse gas emissions reduction goals as well as lead by example and promote awareness of EV benefits. Collective purchasing is one option for local governments that want to support fleet electrification. Like group buy programs for private vehicles, collective purchasing helps reduce vehicle costs through economies of scale. In this model, a local or state government agency will typically lead a solicitation effort and conduct a single bid and evaluation process that results in an approved vendor list for specific types of EVs. Alameda County and nine other California jurisdictions' Local Government Electric Vehicle Fleet Project provides a good example of a collective purchasing program.[56] Other financing options for fleets including leasing the vehicles, leasing the batteries, and expanding Energy Performance Contracting (EPC) policies to allow for investments in fleet vehicles. EPC is a tool typically used by public entities to finance energy-saving improvements at public buildings. Expanding this policy to include fuel and operational savings helps qualify fleet vehicles for these contracts, providing a pathway to favorable financing based on the operational cost savings of EVs.

Grant programs can also provide some purchase and financing assistance to transit agencies and local governments purchasing electric buses and other large electric vehicles. Examples include federal grant programs such as the Federal Transit Administration's Low-No Emissions Grant Program, the U.S. Department of Transportation's Congestion Mitigation Air Quality program, and Volkswagen Environmental Mitigation Settlement funds administered by state agencies.

Unique arrangements with electric bus manufacturers are emerging for transit agencies to finance the cost of the transit buses. The Park City, Utah transit agency was the first to enter into an agreement to lease their bus batteries from bus

[56] Georgetown Climate Center, "Capturing the Federal EV Tax Credit for Public Fleets: A Case study of Multi-Jurisdictional Electric Vehicle Fleet Procurement in Alameda County, California" April 2017.

manufacturer Proterra, Inc. Batteries are the most expensive component of the electric buses and experience decreased performance over time. This arrangement allows Park City to reduce the risk and cost associated with purchasing the buses. Leased batteries can also be exchanged over time, which helps extend the life of the battery electric buses. Park City purchased six electric buses in 2017 under this leasing arrangement. The lease payment for the first 6 years for each bus is $196,000, or about $33,000 per bus per year.

5.4.4 Financing Electric Vehicle Infrastructure

Like electric vehicles, electric vehicle supply equipment (EVSE) can also present an upfront cost that can be a barrier to deployment. Under conditions where EV adoption rates are relatively low, it may be difficult for station owners to recover the cost of installation and EVSE equipment through revenues collected from vehicles charging at these stations. In some cases, station owners and EVSE site hosts may offer EV charging free to users to prioritize the promotion of EV adoption over near-term revenue collection. As with vehicles, there are also options to help lower upfront costs by financing charging stations.

One option is for the utility to invest in EVSE, which can take many forms. Utilities can help support in electrical supply and all electricity management components necessary for the EVSE to operate as intended, but not the EVSE itself. This is called the "make-ready" investment. In this scenario, the utility is not the owner or operator of the charging equipment. Another model is that the utility invests in everything, including the charging station. In this case, the utility would be the owner and operator of the charging equipment. Finally, utilities can help fund all construction costs as well as provide an incentive for charging, such as a customer rebate, to promote use of the EVSE. For regulated utilities, any arrangements in which the utility contributes to EVSE investment typically need to be approved by public utility commissions.

Electric vehicle infrastructure costs can also be funded through Volkswagen Environmental Mitigation State Trust funds, state and federal tax credits, and local, non-profit and other rebates. Other financing options include equipment leases, bulk purchasing programs, and Energy Performance Contracts for charging stations, as discussed above for EV financing options.

Section 6

Pilot Project Considerations

6.1 General Considerations

Pilot projects and demonstrations are a useful way to test out and refine programs, policies and project designs before committing significant resources to a larger effort. The Rocky Mountain Institute (RMI) provides a helpful distinction between "pilot" projects and "demonstration" projects, as seen in Figure 18 below.[57] According to RMI, a pilot project should focus on answering technical questions before moving on to more business-focused demonstration. Pilot projects are usually conducted before demonstration projects. Demonstrations, then, are designed to validate the business case for moving from small-scale tests to fully integrated market deployment and can test all topic areas in an integrated project. RMI suggests that project leads make use of both pilots and demonstrations to maximize learning and prepare for eventual full-scale deployment.

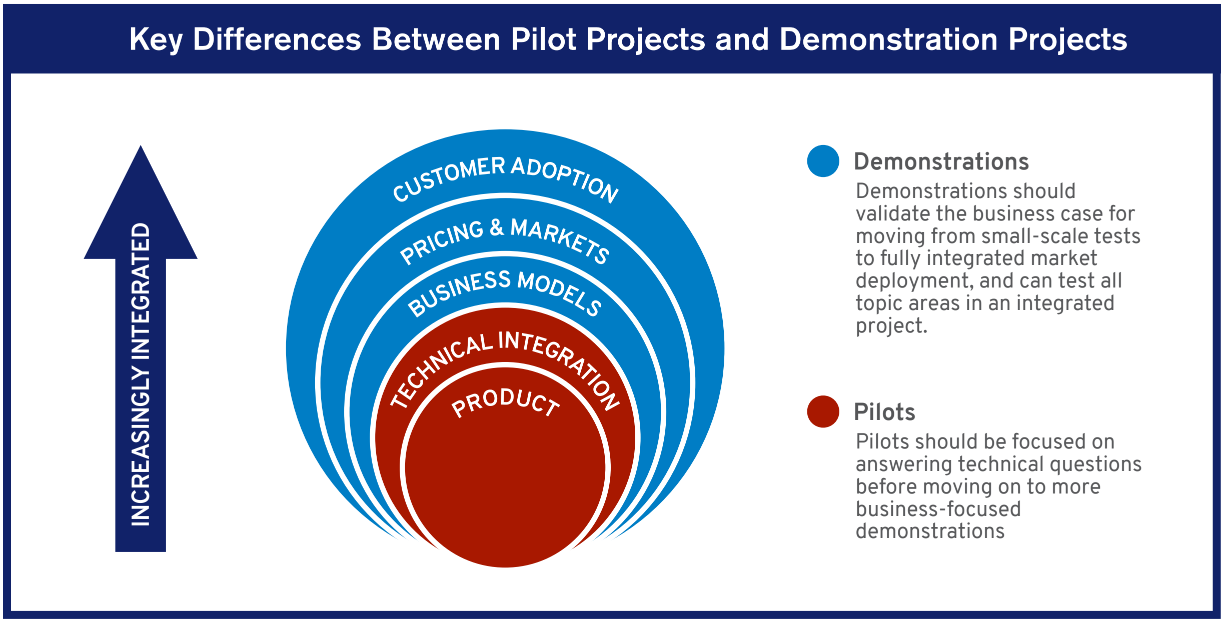

Figure 18 — Key differences between pilot projects and demonstration projects

[57] Fairbrother, Courtney, Leia Guccione, Mike Henchen, and Anthony Teixeira. Pathways for Innovation: The Role of Pilots and Demonstrations in Reinventing the Utility Business Model. Rocky Mountain Institute, 2017. https://rmi.org/insight/pathways-for-innovation/

If one goal of the pilot project is to address electric vehicle utility rate structures, it is critical to meet with the utility, define the request for what role they should play, and determine the value proposition from their perspective.

It is also critical to define what the long-term goals of the pilot project are going to be, the questions the pilot project is going to answer, and the data that need to be gathered before, during, and after pilot project implementation.

After implementing a pilot project, it is important to track indicators of success and metrics for evaluating pilot project outcomes. This evaluation process helps provide a consistent feedback loop and informs future projects in other communities.

6.2 Missoula Electric Transit Bus Pilot Project Development: Preliminary Lessons Learned

This section details early lessons learned from the development of the Missoula, pilot project that features six battery-electric buses using depot-charging infrastructure. Stakeholders, including Missoula's transit agency and the electric utility, continue to work out the final details and design of an electric transit pilot project.

Project goals and key performance indicators should be established early so that the project design can support their monitoring and evaluation.

Mountain Line, Missoula's transit agency, is developing a list of key metrics and indicators before launching the pilot project and ensuring the technology and systems are in place that can provide useful and actionable data. Mountain Line is reaching out to other stakeholders and researching other pilot projects to see which indicators were most useful and how they were tracked.

Financial indicators may need to be hyper-localized.

Financial goals and performance indicators relate to the agency's costs and how they compare to other vehicle alternatives, such as diesel or compressed natural gas. While capital costs for electric buses are higher than alternatives at today's market prices, pilot projects to date have suggested that transit agencies will see lower energy and maintenance costs and perhaps lower overall lifecycle costs. However, since actual costs are highly contingent on local factors, energy and maintenance costs should be tracked and monitored on a per-mile basis to inform future capital and financial planning.

Before beginning a pilot project, the transit agency should have a clear understanding of their utility rate structure and the pattern of charging that will minimize their costs.

Energy costs for electric buses can vary significantly depending on the utility rate structure and the charging pattern. In most cases, the optimal charging pattern is one that spreads the charging out evenly throughout the day and minimizes the number of buses charging at any one given time.

Installing EVSE on a separate electric meter and aligning the service periods with regular financial reporting periods (i.e. calendar months) can facilitate tracking of energy costs and improve the accuracy of the collected data.

If a separate meter is not possible, then a system of smart chargers can be installed to enable the electricity used by the buses to be decoupled from other uses. For most transit agencies, the tracking of maintenance costs and vehicle usage is standard practice and will not require new or revised processes.

To monitor and evaluate progress towards environmental goals, transit agencies need to work with their utility to understand the source of the energy that powers their buses.

An important component of the value proposition of electric buses is the expected reductions in greenhouse gases and other emissions. Because the sources of energy production can vary significantly throughout the day, efforts should be made to obtain this information at the highest time-resolution possible. Common time-resolutions include 1-hour, 15-minute, or 5-minute intervals.

Since electric bus technology is still relatively new, and operating characteristics can vary significantly depending on weather conditions, it is important for transit agencies to monitor operational performance and optimize over time.

Every transit agency aims to get the most usage possible out of the fleet of vehicles. At a minimum, agencies should track on-road maintenance calls, out-of-service hours, and energy use per mile. Examining this information over time, in combination with blocking schedules and historical weather information, can help reveal trends and enable smooth system performance throughout the year.

Section 7
Conclusion

Communities of all sizes are increasingly interested in reducing emissions from the transportation sector to help improve air quality and meet climate and other sustainability goals. Electrifying light duty vehicles, transit buses, and other vehicles presents a promising opportunity for communities to address large and increasing emissions from the transportation sector. Powering electric vehicles with renewable energy, particularly solar PV with storage, can help ensure that vehicle electrification further reduces emissions.

This document is intended to help communities engage stakeholders, prioritize community goals, assess electric transportation options, and navigate complex decisions about deploying zero emission electric transportation in their community.

This document draws from experience working with three communities in Montana, but is applicable to similar communities across the country that are exploring electrifying transportation options. By following the steps and lessons learned outlined in this document, communities will be better equipped to make strategic and informed decisions regarding electric transportation investments in the present and future.

Section 8
Additional Resources

Autonomous Vehicles, Mobility Options

Corwin, S. and Pankratz, D. “Forces of Change: The Future of Mobility Options” Deloitte Insights, 2017. Available at: www2.deloitte.com/us/en/insights/focus/future-of-mobility/overview.html

Vehicle to Grid Integration of Electric Vehicles

Steward, D. “Critical Elements of Vehicle-to-Grid (V2G) Economics” National Renewable Energy Laboratory. September 2017.

Integrating Renewable Energy with Light Duty Electric Vehicle Charging

Ross, B., et al. "Solar Power + Electric Vehicle Charging: Capturing Synergies in Minnesota." Great Plains Institute, September 2020. Available at: www.betterenergy.org/wp-content/uploads/2020/10/Solar-Power-Electric-Vehicle-Charging-.pdf

State-Level Policies to Support Electric Vehicle Adoption

Lunetta, M. and Stainken, K. “AchiEVe: Model State and Local Policies to Accelerate Electric Vehicle Adoption Version 2.0.” June 2018.

Saha, D. “State Strategies for Advancing the Electric Vehicle Marketplace.” Council of State Governments. December 2018.

City-level Policies to Support Electric Vehicle Adoption and Charging Infrastructure Deployment

Cadmus, “Pathways to EV: Preparing for the proliferation of electric vehicles” June 2018.

Utility Rate Design for Electric Vehicles

Farnsworth, D. et al. “Beneficial Electrification of Transportation” Regulatory Assistance Project. January 2019.

Fitzgerald, G. and Nelder, C. “DCFC Rate Design Study for the Colorado Energy Office” Rocky Mountain Institute. August 2019.