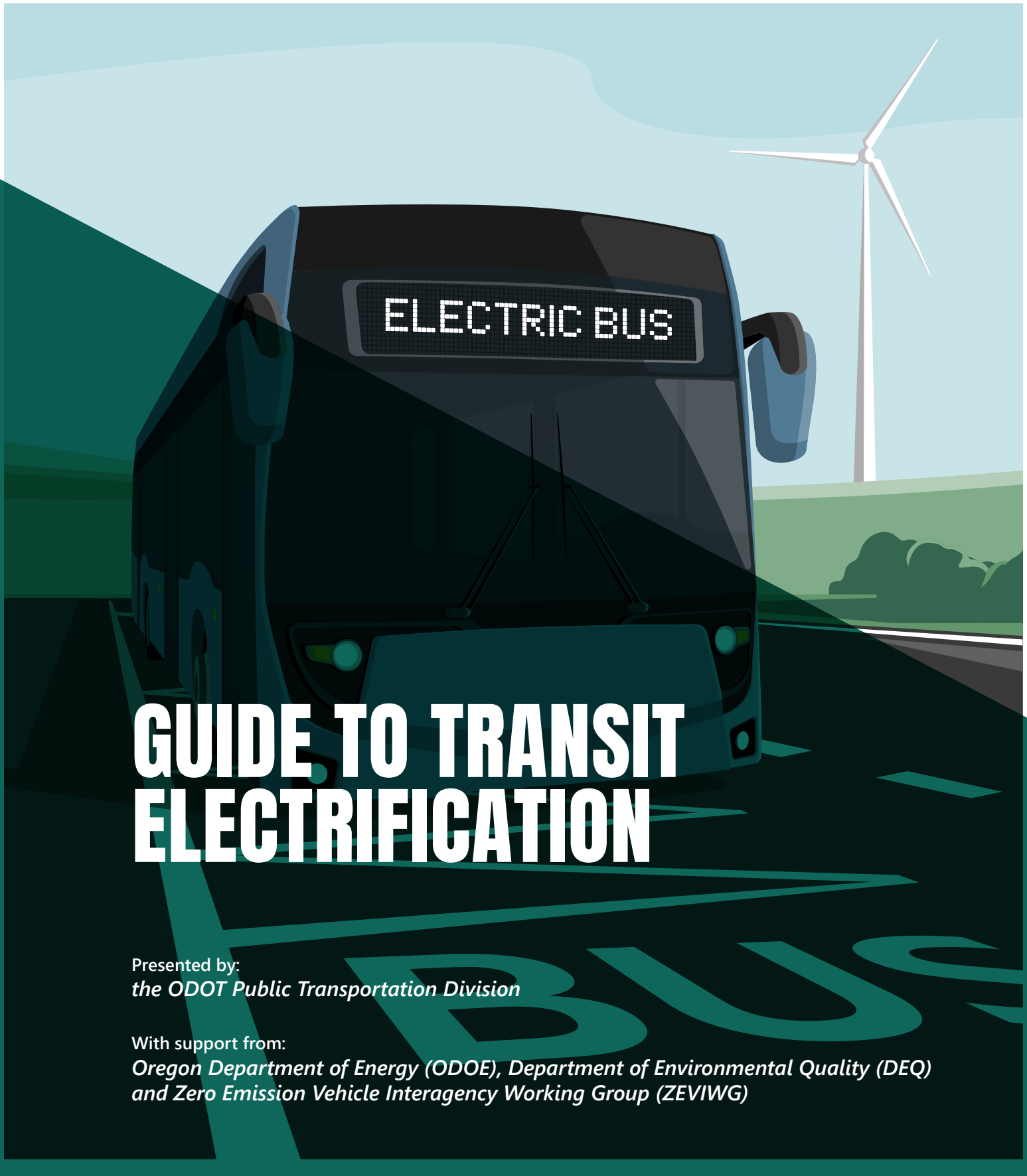
Oregon Department of Transportation



GUIDE TO TRANSIT ELECTRIFICATION

Presented by:
the ODOT Public Transportation Division

With support from:
Oregon Department of Energy (ODOE), Department of Environmental Quality (DEQ) and Zero Emission Vehicle Interagency Working Group (ZEVIWG)

Photos used courtesy of local transit authorities.

Oregon Department of Transportation

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PURPOSE OF THE GUIDE

This guide is designed to provide transit agencies with information and recommendations for vehicle electrification.

In 2017, Governor Brown issued Executive Order 17-21, which directs state agencies to accelerate zero emission vehicle adoption in Oregon to reduce greenhouse gas emissions. As directed by the Executive Order, the Zero Emission Vehicle Interagency Working Group (ZEVIWG) was formed to coordinate and achieve the goals outlined in the Executive Order. Participating agencies include the Oregon Department of Transportation (ODOT), the Oregon Department of Energy (ODOE), the Public Utility Commission (PUC), the Department of Environmental Quality (DEQ), and the Department of Administrative Services (DAS).

One of the goals identified in the Executive Order is "providing partners with information on electric vehicle use and functionality." The Executive Order directs ODOT to work with ODOE, PUC, and DEQ to "develop tools, information, and best practices to assist transit agencies when making decisions about zero emission vehicle bus technology adoption in transit fleets." ODOT lead the ZEVIWG's creation of this informational guide for transit agencies and the development of the Electric and Alternative Transit Bus Lifecycle Cost Analysis Tool, with support from the other ZEVIWG agencies.

The guide accompanies a quantitative tool to analyze different fuel types for transit buses: The Electric and Alternative Fuel Transit Bus Lifecycle Cost Analysis Tool.

In addition to the guide, ODOT and ODOE have created the Electric and Alternative Fuel Transit Bus Lifecycle Cost Analysis Tool, in coordination with DEQ. To use the Analysis Tool, a transit agency inputs information about their fleet, schedule, and budget, and the Analysis Tool provides a summary of estimated costs for different transit bus fuels or technologies. The Analysis Tool compares bus and fuel infrastructure costs, fuel costs, maintenance costs, and environmental costs for buses that rely on different types of diesel, propane, natural gas, and electricity.

The Electric and Alternative Fuel Transit Bus Lifecycle Cost Analysis Tool is available on ODOT's Public Transportation, Transit Fleet Electrification Webpage: oregon.gov/ODOT/RPTD/Pages/Electrification.aspx.

This edition of the guide covers battery electric buses, but future versions will cover other alternative fuels.

This guide summarizes lessons learned from transit agencies in Oregon that have already piloted or deployed electric buses; incorporates information from state, national and international studies on electric buses; and provides advice for transit agencies that are interested in electrification. The guide also includes links to other helpful resources.

This edition of the guide addresses battery electric buses, which are propelled by electric energy stored in batteries and periodically recharged. Other types of electric buses, such as hydrogen fuel cell buses, are currently under development. As these technologies advance and become more widely available, future versions of the guide may address other types of electric buses. In this edition, the term "electric bus" refers to a battery electric bus.

Although this first edition of the guide only covers electrification, other alternative fuels can also help reduce greenhouse gas emissions and benefit communities. The feasibility of transit electrification depends on many variables, including local conditions, budgets, staff resources, and prior experience. Electric buses are not the right solution for every transit agency. Future versions of this guide will cover other options, such as natural gas and clean diesel.

Courtesy of Lane Transit District

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1. ELECTRIC TRANSIT BUSES: AN EMERGING TECHNOLOGY

Transit agencies around the world are now using battery electric transit buses.

Bloomberg New Energy Finance estimates that in 2017, there were about 385,000 electric buses in operation around the world, and that number has only continued to climb.

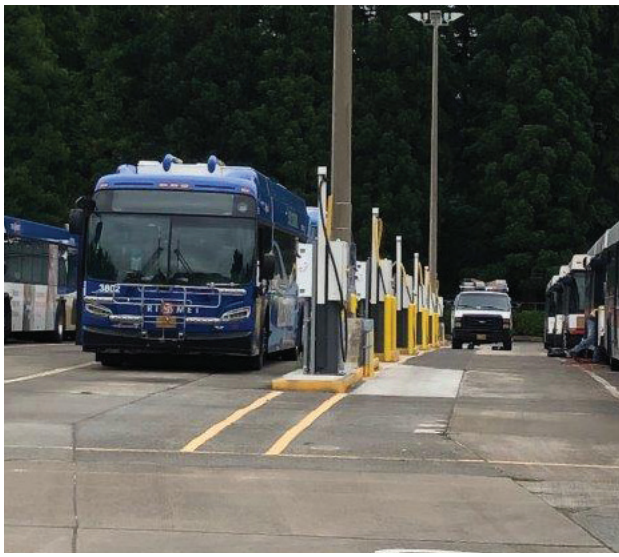
China manufactures and operates the majority of electric buses, but Europe and the United States have seen increasing demand for and production of electric buses over the past few years. In 2017, the United Kingdom had approximately 1,560 battery electric transit buses, and the United States had over 360. While electric buses still make up a small proportion of the total fleet, more transit agencies are pursuing fleet electrification.

Four transit agencies in Oregon have already tested or deployed electric buses.

As of April 2020, four transit agencies in Oregon have piloted or deployed electric buses:

1. TriMet in the Portland Metro Area.
2. South Metro Area Regional Transit (SMART) in Wilsonville.
3. Lane Transit District in Lane County.
4. Josephine Community Transit, which serves Josephine County and part of Jackson County.

The four transit agencies have experience working with four different electric bus manufacturers and have installed two different kinds of charging infrastructure, with Josephine Community Transit planning to install a third new type of charger. This guide compiles advice and lessons learned from each of these transit agencies.



Electric TriMet bus charging at a Portland Metro area charging station.

Transit Agencies in Oregon Pursuing Electrification (2020)

Transit Agency	TriMet	South Metro Area Regional Transit (SMART)	Lane Transit District	Josephine Community Transit
Service Area	Portland Metropolitan Area	Wilsonville	Lane County	Josephine County and part of Jackson County
Electric Bus Manufacturer	New Flyer	Proterra	BYD/New Flyer*	Gillig retrofit
Number of Electric Buses	5	2	2 (2 year pilot)*	2
Type of Charging	Depot plug-in, en route pantograph	Depot plug-in	Depot plug-in	Depot plug-in, planning for inductive charging at depot

***Note:** Lane Transit District has concluded their BYD pilot test and has begun the process to acquire a total of 11 New Flyer battery electric buses that will be added to their fleet.*

Oregon can benefit from early transit electrification, but electric buses are still an emerging technology with obstacles to overcome.

Transit agencies considering electrification are blazing a new trail. Electric buses are an emerging technology, and transit agencies must be prepared for technical and logistical challenges on the road to electrification. The four Oregon transit agencies, for example, report they encountered many logistical challenges to buying and operating electric buses.

Nevertheless, early adopters reap the benefits of switching to electric buses, gain valuable experience in an emerging field, and contribute to the growing body of knowledge on transit electrification. Given time and knowledge, electric buses can successfully meet community public transit needs.

The chart below outlines some of the benefits and current challenges of electric bus adoption. The guide goes into more detail about these topics in later sections.

Benefits	Challenges
• Reduces greenhouse gas emissions and other air pollutants. • Improves health of employees, passengers, and community. • Reduces noise pollution. • Likely to reduce fuel costs in the long term; potential cost savings depend on the type of charging infrastructure. • Likely to reduce maintenance costs in the long term.	• Lack of staff familiarity with electric drive trains, charging infrastructure, and electricity pricing. • Design flaws in bus or charging infrastructure technology, lack of interoperability between buses and charging infrastructure. • Equipment supply chains are still maturing, which can lead to longer waits for new parts. • May increase fuel costs in the short term. • May increase maintenance costs in the short term. • Higher upfront costs for buses and infrastructure.

It's important to learn from other early adopters, but keep in mind that another transit agency's experience with electric buses may substantially differ from yours.

Results vary depending on local characteristics like the carbon intensity of electricity, electricity pricing, size of the service area and length of routes, service model, space constraints at the bus yard, and more.

2. POTENTIAL BENEFITS OF ELECTRIC BUSES

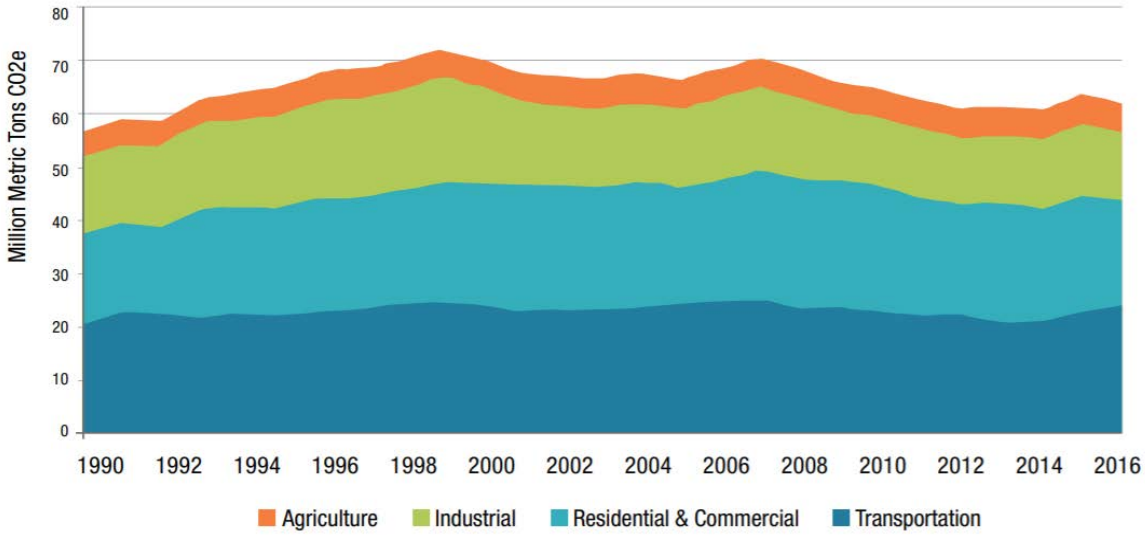
Electric buses reduce greenhouse gas emissions.

According to the U.S. Environmental Protection Agency, transportation generates more than 28% of national greenhouse gas emissions, more than any other sector. This includes all forms of transportation, including personal vehicles, public transit, and freight.

In Oregon, our electricity grid is cleaner that other parts of the country. As a result, our greenhouse gas emissions from transportation are a higher percentage of total emissions: 39%.

The takeaway is clear: To reach long-term greenhouse gas reduction goals, Oregon needs to reduce emissions from the transportation sector.

Oregon Statewide Sector-Based Greenhouse Gas Emissions: 1990-2016



Source: Oregon Global Warming Commission 2018 Biennial Report

Public transit helps reduce a community's carbon footprint, regardless of fuel source. While transit accounts for a small portion of the sector's greenhouse gas emissions, one diesel transit bus can produce approximately 2,400 grams of carbon-dioxide equivalents per mile, five to six times the amount produced by a typical passenger vehicle. However, research shows the per capita emissions from transit, including transit buses, are lower than for personal vehicles. As transit agencies transition toward electrification, the climate change benefits of transit will only increase.

Electric buses are better for the climate than diesel, natural gas, and diesel-hybrid buses because they produce zero tailpipe emissions and fewer life cycle emissions.

For example, in 2018 TriMet calculated that in Portland General Electric's (PGE) service area, switching from a diesel bus to an electric bus would result in an overall emissions reduction of 57%.

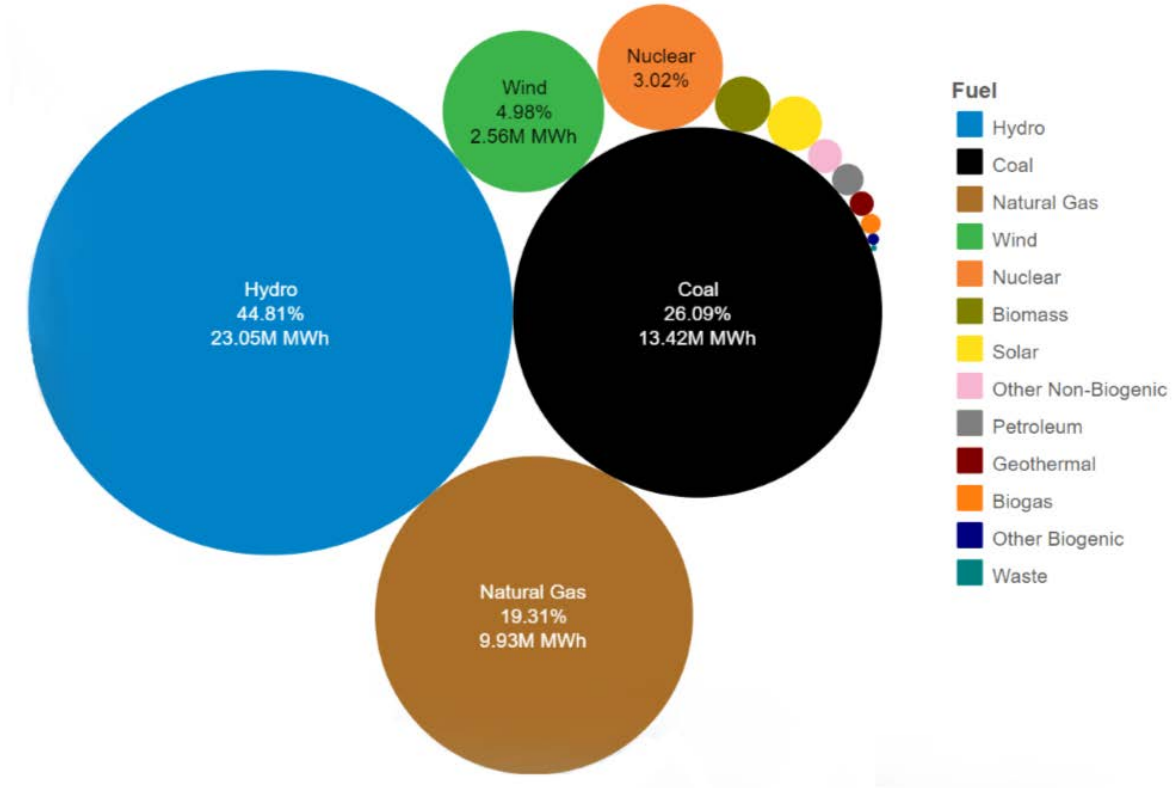
A utility's electricity mix may change over time, which will in turn change the emissions reduction, and some utilities may offer the option use cleaner energy sources. In 2019, TriMet committed to powering their electric buses through 100 percent wind energy, made possible by PGE's Clean Wind renewable energy program.

The total reduction in greenhouse gas emissions depends on the sources of electricity that supply your local utility. In Oregon, over half of our electricity comes from clean resources that do not emit greenhouse gases, such as hydropower, solar, and wind. The precise mix of renewable and non-renewable sources varies by location and utility.

For information about the carbon intensity of electricity in your area, see ODOE's webpage on Oregon's electricity mix. You can also contact your local utility.

Sources of Electricity Used In Oregon

Information derived from 2017 utility generation, contract purchase, and market purchase data for electricity used in Oregon. The reported total for 2017 is 51.4 million MWh.



Source: Oregon Department of Energy

Electric buses are healthier for employees, customers and the community.

Fossil fuel-powered buses pollute the air and contribute to the formation of ground-level ozone. These pollutants can harm transit employees, passengers, and entire communities. Diesel exhaust is classified as a potential cancer agent by the U.S. Environmental Protection Agency and has been linked to higher risk of lung and bladder cancer. Inhaling diesel exhaust can also cause respiratory diseases and exacerbate existing conditions such as asthma.

Electric buses have no tailpipe emissions, so they don't release harmful air pollutants. As a result employees, customers and the community breathe cleaner, healthier air.

Electric bus charging station.

Electric buses reduce noise pollution.

A study in Germany showed that an electric bus can be up to 14 decibels quieter than a conventional bus. This reduction is noise pollution leads to limited noise exposure for bus drivers, passengers and neighborhoods, especially along lower-speed routes. Passengers on Wilsonville's SMART service have reported that they appreciate the quieter ride and are even able to take phone calls during the commute.

Electric buses may reduce fuel costs.

In the long run, electric buses are expected to have lower fuel costs than buses that rely on other fuel sources. Diesel prices, for example, are more volatile than electricity prices, even when factoring in that electricity prices vary based on time of day, season, location and utility provider.

Pilot deployments across the country have tested this "cheaper than diesel" theory. Initial results have been mixed: some transit agencies reported reduced fuel costs, while others reported that demand charges have made electricity more expensive. (See the "Understanding Your Costs" section below for tips on how to reduce your utility bill.)

Your best course of action is to talk with your local utility early about ways to keep electricity costs low.

Electric buses may reduce maintenance costs.

Most light-duty electric vehicles are easier and less expensive to maintain than their gasoline-powered counterparts. One of the main reasons is because electric vehicles have fewer moving parts that need service or replacement. They don't need engine oil, spark plugs, air filters, and myriad other parts. It's a similar story with electric buses vs diesel buses.

As the industry matures, electric bus maintenance costs may be even lower than they are now. (See the section on "Selecting & Negotiating with a Bus Manufacturer" for information on maintenance issues encountered by early adopters of electric buses.)

3. INITIAL FACTORS TO CONSIDER

Transit electrification is a long-term commitment.

Electrification requires significant investment in vehicles, infrastructure, and staff training. It also requires ongoing commitment from transit agency staff.

For example, Josephine Community Transit stressed the need to stay up to date on developments in transit electrification. Manufacturers continue to advance technology, early adopters provide new insights and best practices as they gain more experience, and electrification policies change at the federal, state, and local level.

Reach out to others with experience and expertise.

All four Oregon transit agencies that have already adopted electric buses had the same recommendation: get in touch with folks who have done this before. Specifically:

- Arrange calls with other jurisdictions who are further along in the process.
- Tour those jurisdiction's facilities, if possible.
- Join the Zero Emission Bus Resource Alliance.
- Attend conferences such as the annual U.S. Zero Emission Bus Conference.
- Work with an experienced consultant.

TriMet electric bus charging at a station, as part of a project with Portland General Electric.

For example, TriMet, SMART, and Lane Transit District retained a nonprofit to assist with transit electrification. Josephine Community Transit also recommends working with a consultant. All four transit agencies offer to share their experiences and lessons learned with other jurisdictions considering electric buses.

Contact your electric utility for technical assistance early in the process, before making any irreversible investments.

Your local electric utility will be your fuel provider, so it's important to build a relationship with them early in the process. Discuss the electrification process with them before you've made any financial commitments and ask for their assistance in your planning process.

For example, Josephine Community Transit contacted Pacific Power over a year before receiving their electric buses, and found this to be beneficial.

Your utility may be able to help you determine the best locations to install charging infrastructure. They may also be able to advise you on technical and permitting requirements. The utility's work schedule may impact your own plans, so coordinate with them as you develop your timetable.

Your local utility may or may not have experience with electric bus charging infrastructure. Make sure you understand their expertise and capabilities, and if possible, establish their role and responsibilities in your electrification effort and create a joint project charter. If the project or the partnership with your utility is unique, your utility may need to seek authorization from the Oregon Public Utility Commission.

Examine your route and hours of service.

In 2019, electric buses advertised a starting range of up to about 200 miles. But extreme high or low weather temperatures can affect that range. In the hottest and coldest months, range can diminish by as much as 25%, due to less efficient battery operation and the need for extra power to keep the interior cabin temperatures moderate.

Transit agencies located in areas with significant winter temperature changes can consider adding an auxiliary heater to preserve range. However, these heaters tend to be diesel powered, meaning the buses would no longer have zero tailpipe emissions.

In addition to temperature, topography, quality of roads, and the number and duration of stops can also reduce the range of an electric bus. Batteries will also lose capacity through use and aging. Confirm whether the advertised range reflects ideal or typical weather and real world route conditions, and calculate your needs accordingly.

If the range of your preferred electric bus isn't compatible with your current route, it may still be possible to provide equivalent service with an electric bus. Jurisdictions have found creative solutions to make electric buses work for them.

For example, SMART altered their route to create a midday layover in case the buses needed to recharge at the depot. In mild weather, there's no need to recharge at

midday, but this redundancy may prove essential for the colder months. Josephine Community Transit also changed their service plan: one electric bus operates in the morning and then returns to the depot at midday, when the second begins its route. Others, such as TriMet, use on-route charging to extend the range of their electric buses.

Decide whether to pursue a pilot program, a limited deployment, or a full-scale deployment.

Oregon transit agencies have taken different approaches depending on their program goals and budgets.

TriMet plans to buy one of several kinds of electric buses and test the performance of each bus in pilot deployments before making a decision on a larger investment in fleet electrification. Josephine Community Transit has a smaller budget and smaller fleet, so they purchased two buses to deploy in full-time operation.

Consider your strategy for handling the worst case scenario and how that could influence your decision about the number of buses to purchase. For example, some agencies have temporarily removed buses from operation for extended periods. This was most commonly due to unexpected maintenance or software patches, or because drivers were unable to connect a bus to a charger.

The decision to pilot or deploy electric buses may determine your funding opportunities. Understand the requirements of your potential funding sources before making a decision.

Courtesy of Josephine Community Transit.

Choosing a pilot vs a deployment may affect your access to different funding opportunities. For example, some Federal Transit Administration grants are tailored for deployments but not pilots. Funding can be a nuanced subject, and it's important to identify your funding sources, and understand their requirements, before you make a decision about your type of program.

Seek to incorporate equity and social justice into your plans for electrification.

In Oregon and across the U.S., low-income families and people of color are more likely to live in areas with disproportionately high concentrations of air pollution. Consequently, people in these communities are also more likely to suffer from pollution-related health complications, including chronic illnesses such as asthma and life-threating conditions such as cancer. Switching to electric buses could help reduce local air pollution and result in better health outcomes for underrepresented communities.

Many transit agencies have committed to reducing air pollution in communities that have historically borne a disproportionate burden. For example, TriMet is prioritizing the deployment of non-diesel buses on routes serving low-income neighborhoods and communities of color. TriMet began its initial electric bus trial at its Merlo Operations Facility. Future electric buses will be deployed out of the Powell Operations Facility, where the garage provides service to many routes in neighborhoods that are home to low-income families and people of color. Provided that the initial trials are successful and funding is secured, TriMet will locate additional electric buses at the Powell Operations Facility until that garage has reached capacity.

Equity considerations should be a factor in both initial trials and full deployments of electric buses. In the long run, experts expect electric buses will be healthier, less expensive, and more reliable; all of which will benefit underrepresented communities.

That said, if you trial electric buses in transit-dependent communities, you must have a solid plan for responding to unexpected service interruptions. Results from initial trials show that at this early stage in development, electric buses are often less reliable than diesel or natural gas buses. Electric buses may be unavailable a higher percentage of the time because the technology is still improving, supply chains are still maturing, and transit staff need time to familiarize themselves with new systems.

Disadvantaged communities tend to be more dependent on transit for access to jobs, education, and essential services. Service interruptions to their vital mode of transit, without a plan to rectify them, could put these residents in a precarious position.

Plan to receive the buses and test the charging infrastructure at roughly the same time.

Timing is important. If you install charging infrastructure too early, technology may have improved b by the time you acquire the buses. Conversely, don't get the buses too early, because then they may be sitting idle while you install the chargers.

The buses will need to be onsite to test the charging infrastructure and confirm interoperability. (For more information on ensuring your buses and chargers are interoperable, see the section below on "Selecting and Installing Charging Infrastructure.") Vendors typically will attempt to coordinate bus delivery with the final inspection of the charging infrastructure to avoid delaying the final payment.

Build time into your procurement schedule for training drivers, maintenance workers, and other staff.

Many electric bus manufacturers will offer a week or two of introductory training for drivers and maintenance staff as part of the bus purchase agreement, but plan for additional time to train staff and build familiarity with the new systems.

Oregon transit agencies have found that training to drive an electric bus is similar to training to drive any new bus model, with added focus on energy conservation. Training schedules may depend on the type of charging infrastructure you choose to install, however.

For example, drivers will likely require more practice to be able to consistently park buses underneath pantograph chargers. (For more information on charging options, see the section on Selecting and Installing Charging Infrastructure.) Similarly, the maintenance training schedule will depend on staff familiarity with electrical equipment. If your organization has little or no experience with high-voltage equipment (e.g., diesel-hybrid or electric buses), it will be essential to invest in appropriate training and to adopt best safety practices.

Be prepared to work with your union representatives to update the tasks that drivers and/or other personnel need to perform, such as tasks associated with the charging process. For example, you will need to determine who is responsible for charging the bus, including both connecting to and disconnecting from the charger.

In addition to drivers and maintenance staff, other personnel may also need time to train for a new system. For example, if your agency doesn't have a process for tracking electricity consumption, you may have to develop one. As a result, staff may require training on a new process for entering fuel tickets. Ensure buy-in to the process throughout your organization.

You should also prepare to address staff concerns about procedures and safety. For example, TriMet created new safety certifications for overhead chargers, including ones to address evacuation, electric and magnetic interference, and potential safety concerns if a charger were to fail or fall.

4. UNDERSTANDING YOUR COSTS

Electric buses have higher upfront costs, but are expected to have lower lifecycle costs.

Electric buses have higher purchase costs than other options, but studies predict that they will have lower total lifecycle costs than all other options. (See the Electric and Alternative Fuel Transit Bus Lifecycle Cost Analysis Tool.)

The price of electric buses is expected to decrease over the next few years, in large part because battery costs continue to decline. You may be able to reduce the up-front costs by leasing the electric battery rather than buying it. Grant programs can also help cover the higher upfront costs of transit electrification.

In December 2019, the California Electric Transportation Coalition and the National Resources Defense Council published a report on the costs of medium- and heavy-duty vehicles. The report includes calculations based on the initial purchase prices of buses, which are included in the table below.

Table II-1. 2019 Buts Initial Purchase Price Assumptions in 2019$

	Diesel	Diesel Hybrid	Electric	Natural Gas	Hydrogen
Transit Bus	$476,000	$691,000	$753,000	$544,000	$1,100,000
Articulated Bus	$887,000	$1,087,000	$1,200,000	$952,000	N/A
School Bus A	$100,000	$150,000	$275,000	$130,000	N/A
School Bus C	$105,000	N/A	$300,000	$135,000	N/A

These numbers were discussed with multiple bus manufacturers, who noted that the prices may have changed slightly by the time of publication, but agreed with the relative price comparison across technologies. Contact bus manufacturers for current prices. Note that the prices above reflect the cost of the base bus without any additional infrastructure.

You will need to invest in charging infrastructure.

Initial infrastructure costs include charging equipment, supporting electrical hardware, infrastructure installation, and employee retraining. The total infrastructure costs will depend on the type of charger you choose, and whether you are pursuing a pilot or large-scale deployment.

Potential infrastructure expenses could include:

- Depot chargers and dispensers
- On-route or pantograph chargers.
- Appropriately sized transformers and switchgear.
- Hardware and software to manage electricity consumption.
- Additional land for charging infrastructure. Your local utility may even need to expand its distribution network or create a new substation, depending on your existing local infrastructure.

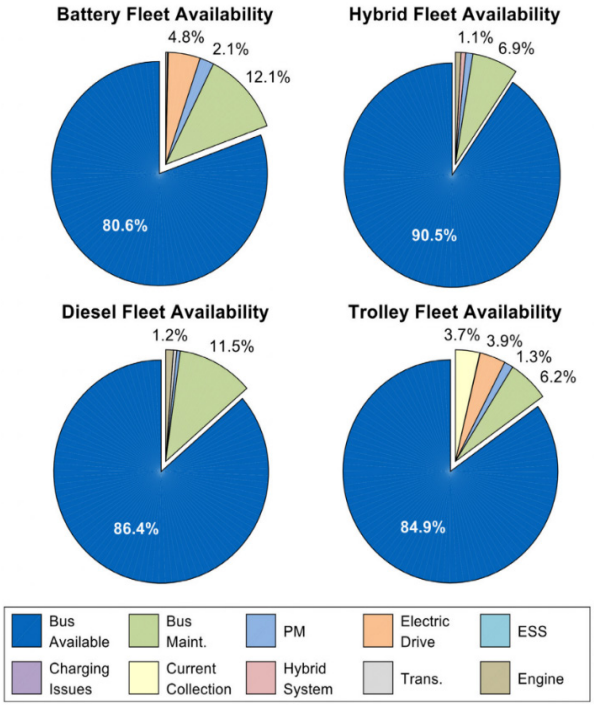
Maintenance costs may be lower, but budget for extra expenses as the industry matures.

You will also have ongoing maintenance costs for the charging infrastructure, too. In the long run, electric buses are expected to have lower maintenance costs than alternative buses, due to fewer moving parts and less regular maintenance needs.

In practice, transit agencies have had a mixed experience with maintenance issues, with some reporting lower costs and others reporting higher costs.

For example, the graphic below provides data from King County Metro, WA from April 2016 through March 2017. It shows how often King Country Metro had to remove buses from operation and why the buses were out of service.

King County Metro: Overall Availability for All Four Bus Fleets, April 2016 – March 2017



Source: Zero-Emission Bus Evaluation Results — King County Metro Battery Electric Buses (2018)

King County Metro's electric buses were unavailable 19.4% of the time, more often than either their diesel or hybrid buses. It was a similar story with maintenance and/or electric drive system concerns: the electric buses were out of service 16.9% of time, a higher rate than their diesel or hybrid counterparts.

These are some of the factors that can affect electric bus maintenance costs:

1. The bus and charger manufacturers.
2. Interoperability of the buses and chargers.
3. The warranty coverage for the buses, batteries and chargers.
4. Ongoing technical support from the manufacturer and their response time.
5. Familiarity of maintenance staff with electric bus maintenance requirements.

An electric bus showing the systems that power it.

Switching to electric buses may lower your fuel costs, but it could also increase them.

When the Chicago Transit Authority launched their first electric buses in 2014, staff estimated that electric buses would save them more than $24,000 per year in fuel costs compared to the diesel buses they replaced.

However, in 2016-2017, electric buses in King County, WA had higher per-mile fuel costs than diesel buses, in part due to high demand charges: electricity cost $0.57 per mile, whereas diesel cost $0.30 per mile. Similarly, County Connection in the San Francisco Bay Area reported that between June 2017 and May 2018, per mile electricity cost of $0.73 whereas diesel cost $0.40.

Preliminary evidence suggests that electric buses may have comparable or lower per-mile fuel costs compared to other alternative fuels. An electric bus pilot conducted by Foothill Transit in Los Angeles, California found that electric buses have slightly lower per-mile costs than CNG buses: $0.41 versus $0.51.

Contact your utility ahead of time to understand how switching to electric buses could impact your costs.

When you first begin to evaluate energy costs per mile, consider the number of miles driven compared to other vehicles in your fleet. With diesel buses, the fuel costs strongly correlate to the number of miles driven. In contrast, charging an electric vehicle may incur demand charges, which are a fixed cost. Therefore, if you initially drive the electric buses less while you gain familiarity with the technology, your energy costs per mile will be higher. (See the next section for more information about demand charges.)

Understand how your utility charges for electricity and what that means for your costs.

In general, electricity has a lower per-mile cost than other fuel options, but you may need to carefully structure your charging schedule to maximize the cost savings. Talk with your utility ahead of time to understand their commercial electricity rates and, and how your utility bill might change with the addition of electric buses in your fleet.

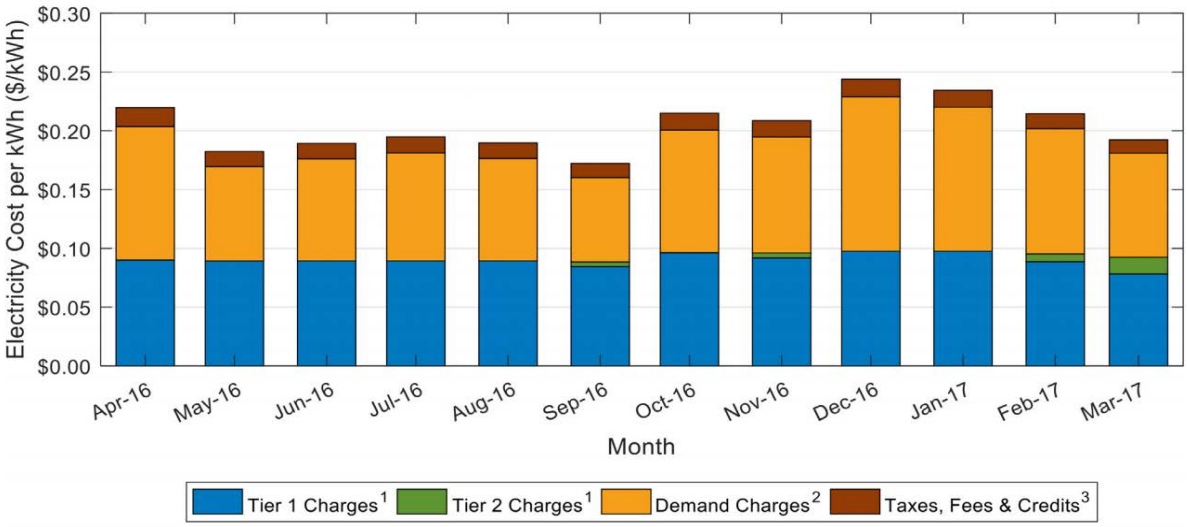
Your utility bill will include a consumption charge based on the amount of energy you used during the billing period. The utility may charge you a higher rate per kWh during on-peak hours, so you may want to arrange your schedule so that the buses charge during off-peak hours. Overnight charging is typically the least expensive option.

Your bill may also include demand charges. Demand charges are based on the maximum amount of power drawn over a given interval (often 15 minutes) during the billing period. The more power you draw at one time, the higher your demand charges will be. Some transit agencies with electric buses have found that demand charges equal or exceed consumption charges on their utility bills.

Utilities bill for demand charges because they need to be able to meet the peak cumulative demand for all their customers. Meeting peak demand can require utilities to make expensive infrastructure investments. Demand charges help cover the costs of these investments and encourage customers to spread out their electricity usage, lowering the peak cumulative demand for the entire grid.

If your utility relies on demand charges, you can lower your costs by scheduling charging sessions to limit electricity usage at any one time. Some charging equipment manufacturers offer software that can help manage charging for you by regulating and capping the total electricity draw while still ensuring buses are fully charged for their next route. Your utility may also be able to provide advice on balancing consumption charges and demand charges to lower your bill.

King County Metro: Breakdown of Monthly Electric Utility Costs (2018)



1. Tier 1 electric rate is applied to the first 20,000kWh used per month; Tier 2 rate is applied to all additional energy
2. Demand Charges are incurred for charging rates > 50kW
3. "Taxes, Fees & Credits" includes all remaining utility bill items (positive & negative charges)

Source: Zero-Emission Bus Evaluation Results — King County Metro Battery Electric Buses (2018)

By reducing air pollutants and greenhouse gas emissions, electric buses reduce the economic and health impacts to your community and the entire state of Oregon.

Reducing air pollution can have broad social and economic benefits. Moving to alternative fuels decreases tailpipe emissions, which are associated with many detrimental health impacts such as cardiovascular disease, asthma, and cancer. By mitigating local air pollution, electric buses reduce a community's environmental and healthcare costs.

Greenhouse gases also have negative consequences for society: rising sea levels, more frequent heat waves, droughts, wildfires, water and food shortages, and more destructive weather events such as hurricanes. These consequences are called the "social cost of carbon." The social cost of carbon can be quantified and is incorporated into the Electric and Alternative Fuel Transit Bus Lifecycle Cost Analysis Tool.

Additionally, reductions in the carbon intensity of fuel can be translated into credits generated through the Clean Fuels Program. These credits can be sold and used to offset the other costs associated with switching fuels or technologies. (See the section on "Clean Fuels Credits" below for more information about how you may benefit from this program.)

5. SELECTING AND NEGOTIATING WITH A BUS MANUFACTURER

Consider whether to purchase a ready-made electric bus or to retrofit a conventional bus to be electric.

Three of the four transit agencies in Oregon purchased ready-made electric buses, while Josephine Community Transit retrofitted two 2004 Gillig buses. Josephine Community Transit settled on Gillig retrofits because:

1. They determined the retrofit would cost less than purchasing a new vehicle.
2. The Gillig buses were already familiar to drivers and mechanics.
3. Gillig is an established bus manufacturer with a proven product and pre-existing supply chains for parts.

Follow your usual procurement process as defined by your funding source, but remember the industry is still developing.

The process for procuring an electric bus is similar to the process for procuring any other kind of transit equipment: conduct industry research and work with manufacturers to arrange demonstrations. Three of the transit districts in Oregon hired consultants to help evaluate and select electric buses for purchase, while staff in Josephine Community Transit conducted research on their own.

The industry is still maturing, so electric bus options may be limited. Make sure the manufacturer is committed to improving their product and will continue to provide parts and technical support after the sale.

Courtesy of Josephine Community Transit.

When the buses arrive, perform your usual new bus tests, but also test the range to confirm the advertised miles per charge and test that the bus is compatible with your selected chargers. Remember that accurately testing the range can be difficult because seasonal temperature variations increase energy consumption and impact battery performance.

As discussed above, today's electric buses usually have higher upfront costs but are expected to have lower lifecycle costs. Make sure your procurement model incorporates the total cost of ownership, not just the upfront costs.

Define your technical specifications and negotiate for them.

You should negotiate with manufacturers on performance requirements for buses. The World Resources Institute recommends that transit agencies define technical requirements for both general "bus" components, such as air conditioning, heating, and the number and condition of seats, and for "electric bus" components, including the battery, electric engine, and transmission system.

Other important performance requirements to establish are:

1. The range, including variations based on route, passenger load, and temperature.
2. The availability of the vehicles, including limitations due to maintenance, repair, and issues with charging infrastructure.
3. Charging times and energy consumption, including variations based on temperature and charging station capabilities.

Research the known maintenance issues with your preferred electric bus.

In the long run, electric buses are expected to require less maintenance than other buses. At this stage -of technology development, some manufacturers have deep experience manufacturing buses but little experience with electric vehicles, or vice versa. This has led to differences in performance and maintenance issues across manufacturers.

In practice, the four Oregon transit agencies have had varying experiences with bus performance, charging, and maintenance. For example, one transit agency experienced only minor issues, which they considered typical and none of which affected the electrical components of the bus. In contrast, another agency identified both "bus" and "electric bus" problems, including uneven wear on the tires and suspension, as well difficulty connecting the buses and chargers.

Contact other transit agencies to learn more about their experiences with electric bus maintenance.

Identify and compare all the different financial implications of contracting with each manufacturer.

Manufacturers may have obscure, additional costs you haven't accounted for. Scrutinize the support offered by each manufacturer after the initial purchase, and choose what works best for you.

For example, you may have to purchase additional tools or data collection software to support and monitor your electric buses and charging infrastructure. Or some manufacturers may charge extra for training, which means you'll need to budget employee training time.

See the next section for advice on comparing warranties.

Compare warranties, especially for electric batteries.

Most heavy-duty transit buses, including electric buses, are Altoona tested and should remain structurally sound for 12 years or 500,000 miles. However, electric bus warranties can be complicated and vary from manufacturer to manufacturer. In some cases, the warranty on a particular component of the bus may be different than the general warranty.

Because the technology is new, it's uncertain how long an electric bus battery will retain its capacity and range; they could degrade quickly or they could outlast diesel buses.

Electric transit bus charging station.

Keep the following considerations in mind when comparing warranties:

- Does the warranty ensure the bus maintains the range in the original specifications?
- Does the warranty ensure the battery must retain 70-80 percent of its original capacity?
- Determine how to test the battery capacity and range. Can you test the bus yourself or does the manufacturer need to be involved in the testing?
- If a warrantied bus is no longer performing to standards, is the manufacturer required to restore the bus to its original capacity or to an acceptable capacity, such as 70-80 percent?

If you have selected a preferred bus but have concerns about the warranty, you might be able to negotiate with the manufacturer for changes to the warranty. You may also be able to lease the battery from the bus manufacturer, which would reduce upfront costs and allow you to take advantage of potential improvements in battery technology and vehicle range.

Protect yourself from delays and sub-standard equipment.

Involve your legal advisors early in the process. Discuss the risks of adopting new technology. Understand how to protect yourself from the consequences of delayed deliveries and buses that do not perform to standards.

Suggestions from transit agency directors, fleet managers and program managers:

- Ensure that you will not have to pay for the buses until you receive the full order, you certify the buses meet your performance requirements, and you accept the receipt.
- Be explicit about deadlines for bus and charging equipment delivery. Establish measures, such as liquidated damages, to protect your agency from the consequences of any delayed deliveries.
- Be explicit about service turnaround requirements, like the amount of time between notifying a manufacturer of a problem, and a service tech arriving to fix it.

Consult attorneys for legal advice on contracts, delivery, payment, and performance requirements.

Establish an end-of-life plan for the electric batteries.

Electric bus batteries contain potentially harmful chemicals, which makes their disposal complicated. If possible, confirm that the manufacturer will assume responsibility for battery disposal at the end of its useful life.

Used electric vehicle batteries may no longer be suitable for vehicle use, but it may be possible to repurpose them for other applications. For example, used batteries could be paired with solar panels to expand grid capacity. The batteries could store power generated during off-peak hours and help meet increased demand during peak usage periods.

Some companies have also established recycling centers for electric vehicle batteries that have degraded past their useful life. However, because electric bus technology is so new, the after-market utility and value of their batteries is still uncertain.

6. SELECTING AND INSTALLING CHARGING INFRASTRUCTURE

Understand your options: plug-in charging, inductive charging, and pantograph charging.

The need to install charging infrastructure is the primary difference between procuring an electric bus versus a bus that runs on any other type of fuel. You have three main options for electric bus charging infrastructure:

1. **Plug-in charging:** All four of the Oregon transit agencies rely at least partially on traditional plug-in charging at bus depots. Plug-in charging is a proven product with multiple manufacturers. This charging system provides the lowest per-unit cost and offers a range of charging rates, from slow to rapid. An electric bus can be fully charged in about 10 hours using a slow charger (15-22 kW) and 2-6 hours with a rapid charger (between 22-55 kW and 50-150 kW, depending on the charger).

   At depots, transit agencies often install one charger per bus, but you may be able to use one charger for multiple buses. You can mount plug-in chargers on a pole, pedestal, roof, or gantry, depending on your depot configuration and the amount of space available.

   Plug-in chargers are often used for slow overnight charging, although they can also be used to top up a charge if the bus returns to the depot during the day. If you plan to use plug-in chargers overnight, create a charging plan to identify the most cost-effecting charging schedule and to ensure that all the buses are fully charged between service times.

2. **Pantograph charging:** A pantograph charger creates an electrical connection between the bus and an overhead power supply using an extendable, articulated arm and has a power output of 150-450 kW. If your bus needs to top-up its charge during the route, overhead pantograph charging might be a good option for you.

   You can use a pantograph "down charger," where charge rails are installed on the roof of the bus and the pantograph system is installed on the overhead mast, or a pantograph "up charger," where the components are reversed.

   TriMet uses pantograph chargers for rapid charging at stops along its bus route. Pantograph chargers can also be configured to recharge buses overnight, similar to a plug-in charging system but without cords. For example, King County Metro in Washington State recommends using pantograph down chargers at depots. (See pg. 13 of their Battery-Electric Bus Implementation Report.)

TriMet electric bus using overhead pantograph charging at a stop along its route.

Note: Drivers may need additional training to use pantograph chargers.

3. **Inductive charging:** Inductive charging is another type of depot charging. Buses park over coils embedded in the roadway, and the coils wirelessly charge the bus.

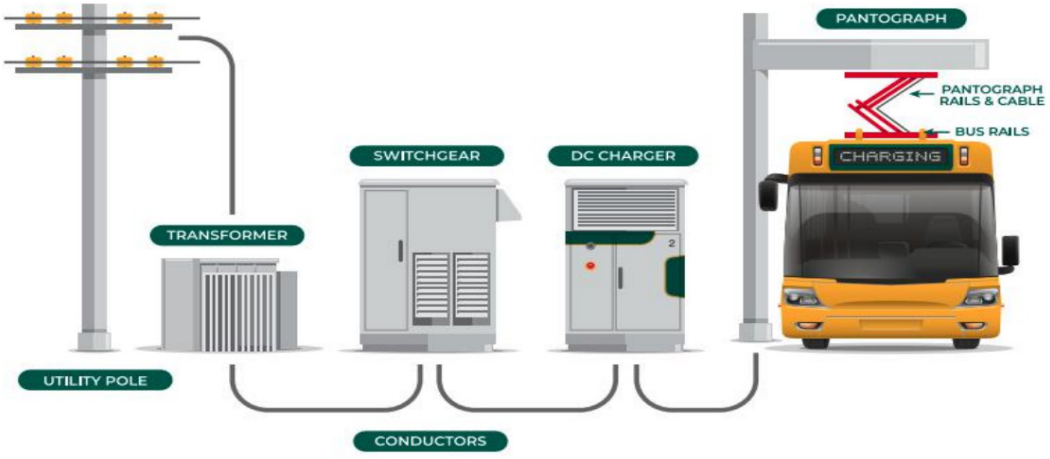
   Inductive charging has several advantages:

   - Easy to use: drivers only need to park over the charging pad.
   - No risk of charger damage because the coils are safely embedded in the road.
   - Employees can't forget to plug in a bus with inductive charging, nor can an inductive charger be accidentally unplugged.

   Note: drivers may need additional training to be able to consistently park directly over the inductive charging pad.

In general, the faster the charge, the more expensive the electricity. Before selecting a type of charger, contact your utility for input on associated costs, billing needs, and infrastructure upgrades such as additional conduits.

High Level Charging Infrastructure Schematic



Source: King County Metro's Battery Electric Bus Implementation Report — Interim Base and Beyond (2020)

Define technical specifications for your charging infrastructure.

Determine how much power your charging stations will require, and run cost models to understand the planned use case and electricity cost implications.

In general: higher power ratings charge buses more quickly, but will cost more, including higher demand charges from your utility provider. Lower power ratings may not fully charge a bus overnight, but will save you money. Experts recommend erring on the side of a higher charge rate.

Your technical specifications should also include:

- Standard safety features for charging stations.
- Capability to monitor charging stations and collect data from them.
- Interoperability standards (addressed in the next section).

Consider implementing smart charging software, which can help you manage charging schedules. This will minimize the cost of charging and ensure your buses are fully charged for their next trip.

Ensure that your chargers are truly interoperable with your electric fleet.

Interoperability standards help to incorporate future proofing into long-term transit planning. It is important to be able to grow your electric transit fleet, continually exploring new technology, and be able to have choices.

Transit agencies recommend using buses and charging infrastructure manufactured or represented by the same company. This approach gives you the highest chance of interoperability between buses and chargers. It's not a foolproof approach, however; in some cases, a charger displaying the bus manufacturer's label could still have come from a third party. Verify with the manufacturer the origin of parts or services they offer.

If purchasing everything from one manufacturer isn't feasible, that's OK. Interoperability is still possible with initial planning. Many transit agencies have piloted buses made by one manufacturer and later purchased buses made by a different manufacturer. This approach works best if you initially purchase standardized chargers and plugs that are compatible with multiple manufacturers.

You should also extensively test that your separate systems are interoperable. Pay close attention to potential software issues, too; different buses and charging systems can sometimes have a hard time communicating. Note that testing interoperability can take weeks or even months if you are using a new, untested combination of buses and chargers.

Place chargers strategically.

Where you put your chargers matters, now and in the future. Factors to consider:

- Coordinate and plan with your Facilities Management Department.
- Determine if you need additional permits or special inspections to install charging infrastructure.
- Check with your utility about the best place to install the chargers, electrical gear, and/or transformer, and that you have sufficient power capacity on site.
- Make sure you have enough space for the chargers you need now, and ones you may need in the future, should you decide to expand your electric bus fleet.
- If you plan to add electric buses your fleet, consult with your utility about the possibility of increased demand.

Ensure that you can accurately track the electricity consumption of your electric buses.

You will likely need to distinguish electricity consumed by buses vs electricity consumed by other facilities.

Tracking them separately has two advantages: it gives you more accurate data collection and measurements of key performance indicators, and is required for registration for any federal or state incentive program, like the Oregon Clean Fuels Program.

Some transit agencies opt to install a separate meter for the charging infrastructure. Others, such as Lane Transit District, have used a single meter but developed new methods of tracking electricity consumption and allocating expenses. You will need to consider many variables when deciding whether to install an additional meter. Discuss your options with your local utility.

7. PUTTING ELECTRIC BUSES INTO OPERATION

Engage with first responders before putting electric buses into operation.

When light-duty electric vehicles first hit the roads, first responders were not trained to identify and appropriately respond to accidents involving electric vehicles. This failure to educate and coordinate put first responders in even greater danger.

To combat this, contact local first responders to discuss safety measures and training. For example, Josephine Community Transit has conducted training with first responders in both Jackson and Josephine Counties. Similarly, TriMet completed training with first responders, front line supervisors, and dispatchers.

Some electric bus manufacturers provide their own first responder training or guides. Contact the manufacturers for more information about their safety training. The National Fire Protection Association also maintains a list of emergency response guides provided by manufacturers.

Ensure buses and infrastructure are on time and operational before conducting public outreach.

Wait to publicize your plans until you are certain when the buses and charging infrastructure will be fully tested and operational. Announcements about electric buses have generated public interest and excitement, but you only get once chance

South Metro Area Regional Transit (SMART) electric transit bus, Wilsonville, Oregon.

to make a good first impression with the public. Unexpected delays in deployment could disappoint enthusiastic would-be passengers and public officials.

Encourage bus drivers to practice energy-efficient driving.

The range of an electric bus depends on many factors, but one of the most important is behavior of the driver. Encourage your bus drivers to drive more economically which will save electricity and extend the range of the bus. One transit agency recommends offering bonuses to the "most energy efficient" driver every month to incentivize drivers to learn to be more efficient and create friendly competition.

8. FUNDING OPPORTUNITIES

Determine if the buses are compliant with Buy America provisions and the FTA's Altoona Testing Program.

If you plan to use federal grants to help cover the cost of the electric vehicles, it's important to establish whether the buses comply with Buy America and Altoona requirements before contracts are executed. Transit agencies reported that some bus manufacturers did not meet these requirements.

FTA LOW-NO Grant

The FTA Low or No Emission Vehicle Program (LOW-NO) grants provide funding to state and local governments for purchasing or leasing zero-emission and low-emission transit buses. LOW-NO grants can also be used to fund the purchase and installation of charging infrastructure.

Eligibility is restricted to states, Indian Tribes, and recipients of FTA Section 5307 grants, so transit agencies often partner with the state or nearby cities to apply. For more information about the LOW-NO program, see the FTA website.

Three transit agencies in Oregon used LOW-NO grants to fund their electrification projects.

Other FTA Grants

In the past, the FTA has offered additional one-time grants that could support transit electrification projects. For example, in 2017 nonprofits could apply for Zero Emission Research Opportunity (ZERO) funding to conduct research, demonstrations, testing, and evaluation of zero-emission vehicles and related technology for public transportation. As of April 2020, ZERO funding is not available.

FAST Act Congestion Mitigation and Air Quality (CMAQ) Improvement Program Funding

Two transit agencies in Oregon used CMAQ funds to procure electric buses. The CMAQ program provides funding to areas that face challenges achieving or maintaining the National Ambient Air Quality Standards (NAAQS) for ozone, carbon monoxide, or particulate matter. For more information about CMAQ, see the FHWA website and CMAQ fact sheet.

Two transit agencies in Oregon used CMAQ funding for their electrification efforts.

Clean Fuels Credits

In Oregon, when a transit agency installs charging infrastructure for fueling electric buses and utilizes electricity from this charging infrastructure to power the buses, the transit agency will have the option to participate in the Oregon Clean Fuels Program.

By substituting electricity for gasoline or diesel and thereby lowering the carbon intensity of your fuel, you generate Clean Fuel Credits. You can then sell your credits to regulated parties who need Clean Fuels Credits to comply.

The number of credits generated depends on the carbon intensity of the electricity provided by your utility. The ability to generate Clean Fuel Credits and monetize them can help offset higher upfront costs of transit electrification. For more information about how to participate in the Clean Fuels Program, visit the Department of Environmental Quality's website.

Note: If you partner with your utility, it's also possible for your utility to claim the Clean Fuels Credits generated through use of your charging stations, and in return lower your electricity bill or upfront costs. Discuss this with your utility at the outset.

Three Oregon transit agencies currently participate in the Clean Fuels program.

Statewide Transportation Improvement Fund (STIF)/Special Transportation Fund (STF)

The Statewide Transportation Improvement Fund provides a dedicated source of funding to expand public transportation to access jobs, improve mobility, relieve congestion and reduce greenhouse gas emissions.

- 90% of STIF funds are distributed to qualified entities based on taxes paid within their geographic area.
- 9% is awarded through two competitive grant processes.
- 1% helps fund ODOT's Technical Resource Center.

The Special Transportation Fund provides a continuing source of revenue in support of transportation services for older adults and individuals with disabilities. STF funds are distributed to 33 eligible transit districts and the nine federally recognized Indian Tribes in Oregon. The majority of STF funds are allocated based on the local population or an established minimum allocation, whichever is more. The remainder of the funds is distributed through a competitive grant program.

ODOT is currently in the process of consolidating the STIF and STF programs. See ODOT's website for more information about the STIF and STF programs.

SMART used STF funds as local match for the FTA Low-No Grant.

PGE Drive Change Fund

In 2019, PGE launched the Drive Change Fund, a competitive grant program that supports diverse transportation electrification projects, including electric transit buses, in the communities PGE serves. PGE intends to make the fund an annual program, and it's supported by the sale of Oregon Clean Fuels Program credits.

For more information about the Drive Change Fund, see PGE's website.

Check for general public transportation funding opportunities.

The Oregon Department of Transportation maintains a list of public transportation funding opportunities. They apply to public transit broadly and are not earmarked for transit electrification or electric bus procurement.

The FTA also regularly provides grants for public transportation projects, including the Urbanized Area Formula grants (Section 5307), Formula Grants for Rural Areas grants (Section 5311), State of Good Repair grants (Section 5337), and Bus and Bus Facilities Formula grants (Section 5339). See the FTA website for a complete list of upcoming grant opportunities.

For example, both Lane Transit District and Josephine Community Transit used Section 5339 funds. Lane Transit District also used Section 5307 and Section 5337 grants.

Consider partnering with your local utility.

For example, TriMet and PGE partnered on their transit electrification pilot project. PGE contributed financially to the project. PGE also owns and has responsibility for all the charging equipment on TriMet property.

9. RESOURCES

Oregon Climate Change Data

2018 Biennial Report to the Legislature for the 2019 Legislative Session
Oregon Global Warming Commission, December 2018

Pilot Evaluations & Preliminary Results

Battery-Electric Bus Implementation Report: Interim Base and Beyond
King County Metro, January 2020

Foothill Transit Agency Battery Electric Bus Progress Report
Leslie Eudy and Matthew Jeffers
National Renewable Energy Laboratory, May 2019

Comparison of Medium- and Heavy-Duty Technologies in California
ICF, with the Union of Concerned Scientists, Earthjustice, BYD, Ceres, and NextGen Climate America on behalf of the California Electric Transportation Coalition and the Natural Resources Defense Council, December 2019

Electric Buses in America: Lessons from Cities Pioneering Clean Transportation
James Horrox and Matthew Casale
U.S. PIRG Education Fund, Environment America Research & Policy Center, Frontier Group, October 2019

Zero-Emission Bus Evaluation Results: County Connection Battery Electric Buses
Leslie Eudy and Matthew Jeffers
National Renewable Energy Laboratory, December 2018

Zero-Emission Bus Evaluation Results: King County Metro Battery Electric Buses
Leslie Eudy and Mathew Jeffers
National Renewable Energy Laboratory, February 2018

King County Metro Battery Electric Bus Demonstration: Preliminary Project Results
U.S. Department of Transportation, Federal Transit Administration, May 2017

Transit Electrification Guides

8 Steps for Success in Adopting Electric Buses
Metro, May 2020

Guidebook for Deploying Zero-Emission Transit Buses
Meredith Linscott and Amy Posner
Center for Transportation and the Environment, April 2020

Preparing to Plug in Your Bus Fleet: 10 Things to Consider
Edison Electric Institute, The American Public Power Association, The National Rural Electric Cooperative Association, and The American Public Transit Association, December 2019

How to Enable Electric Bus Adoption in Cities Worldwide: A Guiding Report for City Transit Agencies and Bus Operating Entities
Xiang Li, Camron Gorguinpour, Ryan Sclar, and Sebastian Castellanos
World Resources Institute, May 2019

Electric Utility Investment in Truck and Bus Charging: A Guide for Programs to Accelerate Electrification
Union of Concerned Scientists, April 2019

Battery Electric Buses 101
Center for Transportation and the Environment
APTA Sustainability Workshop, 2017

Studies and Reports

Barriers to Adopting Electric Buses
Ryan Sclar, Camron Gorguinpour, Sebastian Castellanos, and Xiang Li
World Resources Institute, May 2019

Accelerating Bus Electrification: A Mixed Method Analysis of Barriers and Drivers to Scaling Transit Fleet Electrification
Kelly Blynn, John Attanucci
World Transit Research, May 2019

Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2
Bloomberg New Energy Finance, March 2018

Plans and Strategies

Seattle City Light Transportation Electrification Strategy
Lynn Daniels, Brendan O'Donnell
Rocky Mountain Institute, July 2019

Non-Diesel Bus Plan
TriMet, September 2018