Electric Vehicles

Electric-propulsion technology is rapidly replacing combustion engines for clean, efficient transportation. Electric vehicles (EVs) reduce harmful air pollution, greenhouse gas (GHG) emissions, and noise. Battery electric vehicles (BEVs) use no liquid fuel, relying on an all-electric drive train, and are refueled by plugging into an external electricity source. Plug-in hybrid EVs (PHEVs) can fully operate on a battery pack for a limited range before an on-board internal combustion engine (ICE) powers the drivetrain. PHEV batteries are recharged by plugging into an external electric power source. Hybrid electric vehicles (HEVs) combine an internal combustion engine with an electric drivetrain. HEVs are not recharged from an external electric power source like PHEVs; they rely on an electric generator to recharge the vehicle's batteries.

Generally speaking, all versions of EVs offer reduced emissions compared to ICE vehicles, even when the source of electricity is not renewable (see Table 1). That said, BEVs offer the added opportunity to substitute 100% renewable electricity for fossil fuel gasoline, which maximizes the GHG-benefits of EVs. It is important to note battery electric technology to replace diesel vehicles and equipment is not currently available. Therefore, this information sheet focuses on the GHG reduction potential from replacing light-duty gasoline powered vehicles with BEVs.

Best Practice

Description of Alternative Practice(s)

BEVs supplied with 100% renewable electricity is one of the largest GHG reduction opportunities currently available to address fossil gasoline emissions from ICE vehicles. EV technology is market-ready and cost competitive (especially from a life-cycle basis) for mid-sized sedans and similarly expected for the light-duty pick up and SUV market by 2025. Note: "market-ready" does not imply readily available for procurement, particularly given the supply chain issues present at the time of writing. Depending on the timing and need for vehicle purchase, HEV or PHEV may also provide significant benefit compared to ICE vehicles powered by fossil gasoline.

The United State Environmental Protection Agency reports the following advantages for EVs compared to gasoline vehicles:[1]

- **Energy efficient.** EVs convert over 77% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12%–30% of the energy stored in gasoline to power at the wheels.
- **Performance benefits.** Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than ICE.
- **Reduced energy dependence**. Electricity is a domestic energy source.
- **Environmentally friendly.** EVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear-, hydro-, solar-, or wind-powered plants create no air pollutants.

[1] https://www.fueleconomy.gov/feg/evtech.shtml

Current downsides and barriers to implementation for BEVs include:

- **First costs** of vehicles is greater compared to conventional fossil gasoline vehicles.
- **Range** of EVs and available charging infrastructure can be limited and may not always align with Oregon Department of Transportation (ODOT) operational needs. It is important to note that vocational use of vehicles is different than general public use. For example:
  - Tools and gear are commonly transported in ODOT vehicles that add significant weight.
  - Onsite power may be needed from ODOT vehicles.
  - ODOT vehicles need to operate under adverse weather conditions.

  All of these factors reduce range and could increase fuel cost per mile if commercial charging is required.
- **Vehicle types** currently available are non-existent or severely limited for the SUV and pickup truck vehicle types.
- As of this writing, **supply chain issues** are prevalent in automobile manufacturing which limit ODOT purchasing options.

Relationship to other Best Practices

Purchase or production of 100% renewable electricity maximizes the climate benefits of EVs. Renewable electricity procurement should be prioritized to support and enhance vehicle and equipment electrification (see the Renewable Electricity information sheet for details). However, the Union of Concerned Scientists found powering EVs with fossil fuel electricity sources still leads to overall improved efficiency. Even in states that use fossil fuels to generate electricity, average EV MPGs are still greater than average on road fossil fuel powered fuel economy.[2] Table 1, to the right, compares electricity generated from various sources and shows, even using coal, the average MPG equivalent is still 35% greater than the average fuel economy of an on-road light-duty vehicles in the U.S. (i.e., 22.2 MPG in 2019 according to the U.S. Bureau of Transportation Services).[3]

Table 1: Comparison of EV climate impacts based fuel.

Electricity source	Well-To-Wheels EV Miles Per Gallon Equivalent (mpg_{ghg})
Coal	30
Oil	32
Natural Gas	54
Solar	500
Nuclear	2,000
Wind	3,900
Hydro	5,800
Geothermal	7,600

Real World Examples

Many local government fleets around Oregon are transitioning to EV passenger sedans:

- City of Eugene – Developed purchasing policy requiring the purchase and use of EVs before all other types of vehicles. Exemptions are available for emergency and others on an as-needed basis but require review and defense in front of a fleet management board. This policy was put in place to comply with the City of Eugene's Climate Recovery Ordinance that required carbon

[2] For details see https://blog.ucsusa.org/dave-reichmuth/plug-in-or-gas-up-why-driving-on-electricity-is-better-than-gasoline/

[3] For details visit https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles

neutral operations by 2020 via operational change and the purchase of carbon offsets for remaining emissions.

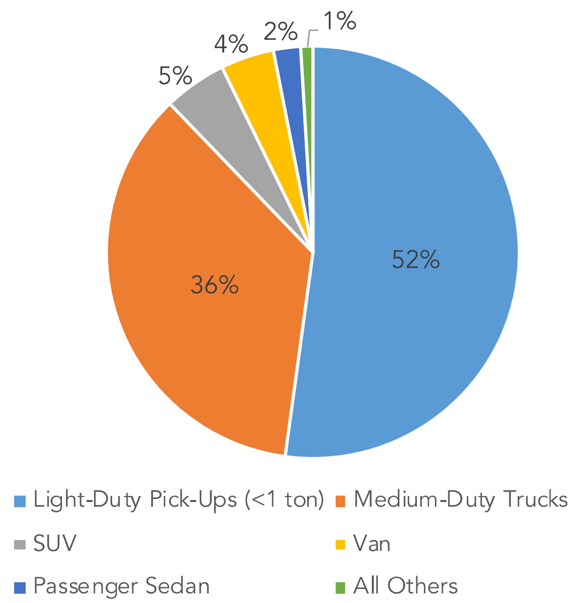
- State of Oregon - House Bill 2027 (passed in the 2021 Legislative Session) requires state agencies to purchase light-duty, zero-emission vehicles by 2025, unless the agency finds it is not feasible for the specific use the vehicle is intended.[4]
- City of Portland – Developed an electric vehicle strategy for City operations.[5]

Current Conditions & GHG Inventory Results

Fuel use by ODOT vehicles and equipment is critical · support the construction, operation and maintenan of Oregon's state highway system. In Fiscal Years (F 2017 - 2019, ODOT used an average of one milli gallons of fossil gasoline annually. This translates about 10,000 MT CO_2e of GHG emissions per yea About 5,700 MT CO_2e of this total are from light-du sedans, pickup trucks, and SUVs.

As is shown in Figure 1 to the right, fossil gasoline used predominately by ODOT's fleet of light-du pickup trucks (<1 ton) and medium-duty trucks wi smaller quantities used by light-duty SUVs a passenger sedans.

Figure 1: Comparison of fuel use by vehicle category.



ODOT's fleet, as of FY2020, includes five BEV sedar six PHEVs; ten HEVs; and 135 conventional I vehicles for a total of 146 sedans. Electric sedans we driven 80,000 total miles in FY 20, compared to ICE sedans at almost 1,000,000 miles. Beyond sedans, gasoline-powered pickup trucks and SUVs were driven an additional 12,000,000 miles during the same time-period. These usage patterns indicate providing access to EVs may not be enough. The range of BEVs currently owned by ODOT is limited, which naturally limits their use. However, range limitations do not explain why available HEVs and PHEVs are not being used before ICE sedans. A combination of EV-first policies and more funding to develop training and outreach programs may be necessary to increase use.

Table 2: ODOT FY2020 fleet data and mileage.

FY2020	Vehicle Count	Annual Vehicle Miles	Ave Miles per Vehicle
Cargo Van (fossil gasoline)	51	481,941	9,450
EV's (Full Battery Electric)	5	1,906	381
PHEV's (Plug-in Hybrid Electric Vehicle)	6	31,851	5,309
LEV's (Hybrids or over 40 MPG efficiency)	10	46,603	4,660
Passenger Van (fossil gasoline)	50	362,470	7,249
Pickup (fossil gasoline)	794	10,108,054	12,731
Sedans (fossil gasoline)	135	982,341	7,277
SUV (fossil gasoline)	197	1,673,292	8,494

[4] A zero-emission vehicle means a battery electric vehicle, a plug-in hybrid vehicle or a hydrogen fuel cell vehicle or any type of vehicle defined by the State Department of Energy or the Environmental Quality Commission by rule as a "zero-emission vehicle". The adopted bill can be found here: https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/HB2027/Enrolled

[5] https://www.portland.gov/sites/default/files/2019-07/final_electric-vehicle_report2016_web.pdf

Market Study

Availability and Access

Currently available EVs already provide a cost-effective substitute for gasoline passenger sedans with ranges over 250 miles (such as the Hyundai Kona and Chevy Bolt). Within the next five-years it is widely anticipated many cost-effective EV pickups and SUVs will be commercially available. Table 3, below, summarizes known products with cost, range and anticipated availability.[6] Particularly of interest, given ODOT's use of pickup trucks, are the Ford Lightning and Chevy Silverado which have relatively long-range batteries at a price point greater than, but comparable to conventional pickup truck prices. Other vehicles included are to illustrate product offering, but are not intended to imply all these vehicles would align with ODOT's operational needs (e.g. GMC Hummer EV). A compressive list of new & upcoming vehicles is available at https://www.fueleconomy.gov/feg/evnews.shtml.

EV availability for purchase by public agencies is a significant issue as of this writing due to supply chain issues resulting from the pandemic and combined with a still developing EV battery supply chain and related production capacity. These issues are anticipated to significantly effect new EV vehicle production in the near-term (one to three years). This supply issue will likely have negative impacts on the pace of implementation for electric vehicle transition, particularly for public fleets with existing price agreements.

Table 3: Summary of near-term pickup and SUV EV products and costs.

Name	Price	Range	Availability
Trucks			
Ford F-150 Lightning[i]	$40,000	230-300 Miles	2022
Rivian R1T[ii]	$67,500	300-400 miles	2022
Chevy Silverado EV[iii]	$50,000+	400+ Miles	2024
GMC Hummer EV[iv]	$80,000-$112,595	350 Miles	2024
SUVs[v]			
Chevy Bolt EUV[vi]	$37,500	247+ miles	Currently available
Kia Niro EV[vii]	$40,000	239 Miles	Currently available
Volvo Recharge[viii]	$55,300	223 Miles	Currently Available
Rivian R1S[ix]	$75,000	316 Miles	2022
GMC Hummer EUV[x]	$80,000-$112,595	350 Miles	2024

[i] https://www.cnet.com/roadshow/news/2022-ford-f-150-lightning-electric-pickup-truck-specs-pricing/
[ii] https://rivian.com/r1t
[iii] https://www.chevrolet.com/electric/upcoming-all-electric-silverado
[iv] https://gmauthority.com/blog/gm/gmc/gmc-hummer-ev/
[v] https://insideevs.com/car-lists/electric-suvs/
[vi] https://www.chevrolet.com/electric/bolt-euv
[vii] https://www.kia.com/us/en/niro-ev
[viii] https://www.volvocars.com/us/v/cars/xc40-electric
[ix] https://rivian.com/r1s

Two important notes that impact ODOT's ability to purchase EVs:

1. ODOT is limited to procure vehicles listed on the State of Oregon price agreement - not all of the vehicles listed in Table 3 are on this list.[7]
2. Market availability does not equate to available for public agencies like ODOT. For example, at the time of this writing, ODOT is not able to purchase a Toyota Prius because suppliers are focused on selling their top-end models over previously-negotiated, lower-profit government vehicles. This situation could last several years.

Cost

EVs often have greater initial costs versus comparable ICE vehicles. Costs can vary widely depending on brands and models selected for comparison. For the purpose of this info sheet, it is assumed the marginal premium for light-duty EVs is $20,000 per vehicle (over the next 10-15 years).[8] While these premiums are appropriate based on current pricing, it is widely anticipated light-duty EVs will reach cost parity with ICE vehicles within five years without the help of incentives.[9]

There are also additional costs for EV chargers and related electrical upgrades depending on facility location and operational demands. Costs vary depending on type of charger and other upgrades that may be needed to support charger installation. ODOT reports the following for infrastructure costs:[10]

- An average cost of $3,500 per charging head
- Installation costs of $5,532 per charging head
- Annual service fees of $240 per charger head
- Additional, site-specific costs for upgrading power, trenching, ADA compliance, signage, etc.

[6] Note: The "Range" column in Table 1 is the estimated range per the manufacturer. ODOT uses vehicles differently than the general public (e.g., working an incident scene with overhead flashing lights running, operation in extreme weather conditions, frequent and extended idle times, etc.). Therefore, the actual vehicle range experienced by ODOT are likely to be vastly different than the manufacturer's expectations.
[7] https://www.oregon.gov/das/Procurement/SiteAssets/Lists/PriceAgreements/EditForm/FleetPricing.docx
[8] Information provided by Oregon Department of Administrative Services – Fleet Department.
[9] See https://www.bloomberg.com/news/newsletters/2021-05-25/hyperdrive-daily-the-ev-price-gap-narrows.
[10] Per DAS 2020 ORS 276.255 report.

While initial purchase and infrastructure costs for EVs can be greater, fuel and maintenance costs are significantly lower than ICE vehicles. Table 4 shows per mile fuel costs for a variety of vehicle types in the ODOT fleet based on historic ODAS fleet data. Average light-duty ICE fuel cost is roughly $0.16 and BEV fuel costs are approximately $0.01 per mile. Note: EV fuel costs may be significantly greater (two to four times) for use of commercial chargers, depending on charger type and service provider. Maintenance costs for EVs are also anticipated to be significantly lower than conventional ICE vehicles due to reduced need for fluid changes and brake work. Default assumptions from Argonne National Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool indicate an average per mile maintenance & repair charge for light-duty gasoline-powered vehicles is $0.15 per mile compared to a BEV at $0.09 per mile.[11]

Table 4: Comparison of vehicle type fuel conomcy and available ODAS data on fuel costs.

Vehicle Type	Fuel Economy (MPG)	Fuel Cost per Mile
Cab-Chassis	11	$0.24
Cargo Van	14	$0.19
Battery Electric Sedan	110	$0.01
Plug-in Hybrid Electric Sedan	110 (electric) 42 (hybrid)	$0.06
Hybrid Electric Sedan	40	$0.07
Passenger Van	15	$0.17
Pickup (<1 ton)	13	$0.19
Sedans	22	$0.12
Station Wagon	18	$0.15
SUV	20	$0.13

To reduce initial costs a variety of financial incentives are available that further improve the lifecycle cost comparison for EVs. The following sections summarize available opportunities:

- **Oregon Clean Fuels Program Advanced Crediting**. Public fleets that have a plan to convert to an all-electric fleet within 15 years are eligible and may apply to receive the up to six years of the financial values of Clean Fuels Program credits.[12] For a fleet that travels 15,000 miles per year, the value of the advanced credits is estimated to be almost $26,000. It is important to note: funds generated from the Clean Fuels Program typically go into a general fund and are not dedicated to fleet budgets.
- The **Oregon Clean Vehicle Rebate Program** provides up to $2,500 standard rebate.[13] State fleet vehicles are limited to ten vehicle rebates per year.

Making the Transition (Lessons Learned)

Oregon public-agency fleet managers offered the following lessons and guidance:

- Utilize Clean Fuels Program financial incentives to help transition to an EV fleet.
- Plan for charging infrastructure and related electrical service to support EV transition. Maximize use of ODOT-owned chargers for lowest fuel costs, and minimize use of commercial chargers with higher rates.

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[11] https://greet.es.anl.gov/afleet
[12] For more details visit https://www.oregon.gov/deq/ghgp/cfp/Pages/Advance-Crediting.aspx.
[13] https://www.oregon.gov/deq/FilterDocs/evrebateapplication.pdf

- Create a vehicle purchasing policy that requires EVs as the default, except where the duty cycle excludes the operational abilities of an EV. (Many reported this policy as being a critical component to avoid challenges and biased preferences in the purchasing process.)
- Create a vehicle usage policy requiring the use of EVs before ICE vehicles when available and when it fits the activity need.
- Adequately fund fleet programs to:
  - Cover costs of necessary infrastructure upgrades and increased initial costs of EVs.
  - Enable adequate education and outreach to promote and instill a positive culture toward EVs.
- Consider the trade-offs between procuring early versions of EVs with minimal range versus waiting for EVs that have the range needed for ODOT operations.

GHG Reduction Potential & Cost Impacts

Life Cycle Considerations

Upstream production GHGs for EVs are greater compared to ICE. However, the Union of Concerned Scientists found upstream production emissions are quickly offset by emission reductions during use of EVs.[14] And again, while the best case scenario is to fuel an EV with 100% renewable power, EVs powered by ODOT existing mix of energy sources means less overall emissions than ICE vehicles.

End of life battery management at present also represents a lifecycle issue for EVs. As of this writing no standard physical or chemical specifications in the marketplace exist for recycling the cells, modules, or battery systems. Many public agencies and private companies are working to improve battery design which speeds performance improvements and lowers production costs, but currently makes recycling labor intensive with limited opportunity for mechanization and makes the value of recovery inconsistent. Overtime design choices and specification will likely converge allowing recycling systems an easier path to economies of scale and economic viability, but at present recycling poses economic challenges. See the Department ReCell Advanced Battery Recycling for more information.[15]

Until a national recycling strategy is well understood, best practice for lifecycle battery management include policies to maximize battery life using appropriate charging and operational practices, such as:

- Battery takeback in vehicle contracting;
- Work with private partners to reuse battery pack at the end of useful vehicle life (e.g., stationary energy storage at ODOT buildings);
- Support Oregon Department of Environmental Quality (ODEQ) to establish Oregon producer takeback programs.

[14] For details visit [14] For details see https://blog.ucsusa.org/dave-reichmuth/plug-in-or-gas-up-why-driving-on-electricity-is-better-than-gasoline/
[15] Dor details visit https://recellcenter.org.

GHG Impacts

ODEQ reports 100% renewable electricity from wind and solar produces zero tailpipe and lifecycle GHG emissions (MT CO2e / kWh). Thus, electrification of ODOT's light-duty fleet, paired with 100% renewable electricity, has the potential to reduce 100% of ODOT's owned sources of light-duty vehicle GHG emissions by about 7,000 MT CO2e per year. Table 5, below, summarizes ODOT's fleet vehicle types that use gasoline and are first in line to have market-ready products available within two years.

Table 5: Summary of ODOT's vehicles, baseline vehicle miles, and GHG emissions.

Vehicle Type	Vehicle Count	Baseline 2019 Vehicle Miles Traveled	Baseline 2019 Emissions (MT CO2e)	Emissions per Vehicle (MT CO2e / vehicle)
Light-Duty Gasoline (E10) Powered Vehicles	1,257	14,000,000	7,000	5.6

Cost Impacts

The marginal cost benefits or impacts of EV ownership versus conventional ICE vehicles varies significantly depending on several factors, including:

- Vehicle initial costs.
- Available financial incentives.
- EV charging and related infrastructure needs.

ODAS Fleet anticipates a premium of $32,600 per EV:

- $20,000 per vehicle for incremental costs
- $9,000 per vehicle for charger and installation
- $3,600 per vehicle over 15-years for charger subscription services

The marginal cost to transition ODOT's light-duty fleet to EVs over the next 15 years is roughly $41 million with an annual cost of $2.7 million over those 15 years. These costs assume no Federal or State financial incentives for vehicles or chargers. EV cost savings for reduced fuel and maintenance savings are estimated at (-$37 million over 15 years) or about -$2.5 million per year. Thus, the net costs to transition to EVs is estimated to be $3.9 million over 15 years (in 2019 dollars).

Using this net value and 15-year emissions reductions of 105,000 MT CO_2e[16] the cost of carbon reduction is estimated at $37 per one (1) MT CO_2e. If average EV electricity costs are decreased from $0.04 to $0.03 per mile, the cost of carbon reduction is reduced from $37 to $10 per one (1) MT CO_2e. The fuel cost used in this financial analysis is 4x greater than existing ODAS data. This increase assumption is included to be conservative around unknown factors related to vehicle fuel economy and actual charging costs, particularly for commercially-owned Level 3, DC-Fast Chargers. That said, it is conceivable these costs assumptions will decrease in the future. This could be accomplished by strategic installation of ODOT-owned chargers that fit operational needs to limit use of commercial chargers. Similarly, if Oregon's EV

[16] 7,000 MT CO_2e / year * 15 years = 105k MT CO_2e

rebate were available to 100% of state agency EVs purchases each year, it would reduce the first cost for light-duty vehicles ($2,500 per vehicle) which have the effect of reducing the net lifecycle cost of carbon reduction to $0 per one (1) MT CO_2e.

See the following bullet points and tables for the assumptions and sources used to generate the analysis presented above.

Cost Impact Assumptions:

- EV vehicles average a 15-year lifespan
- EV marginal cost: $20k per light-duty ICE vehicle substitution (average price over next 10-15 years). Source: ODAS DAS 2020 ORS 276.255 report.
- Charger installation costs: $9k per ICE vehicle substitution ($3,500 for equipment and $5,500 for installation). Source: ODAS DAS 2020 ORS 276.255 report.
- Annual charger subscription: $240 per charger per year, or $3,600 total per EV over average 15-year vehicle lifespan. Source: ODAS DAS 2020 ORS 276.255 report.
- State financial incentives: $0. These incentives are limited - if available at all - to state fleets per interviews with subject matter experts. The state rebate is limited to ten vehicles per year and advanced Clean Fuels Programs credits revenue typically goes to general fund, not fleet department budgets.
- Light-duty ICE fuel cost (per VMT): $0.16 per mile
- Light-duty EV fuel cost (per VMT): $0.04 per mile (adjusted upward by 4x to address concerns related to usage of commercial chargers and lower efficiencies of vocational use of EVs).
- Light-duty ICE maintenance and repair costs (per VMT): $0.15 per mile (source: AFLEET).
- Light-Duty EV maintenance and repair costs (per VMT): $0.09 per mile (Source: AFLEET).
- A 10% premium is added to the per mile fuel cost for EVs to account for additional costs incurred by ODOT for the purchase of 100% renewable electricity from utilities.

Table 6: Summary of EV marginal costs and savings

Summary of EV Marginal Vehicle & Charger Costs						
Metric	Activity Unit (ODOT 2019 Light-Duty Vehicle Count)	EV Vehicle Marginal Cost (Average for Light-Duty)	EV Charger Marginal Cost	EV Charger Subscription Costs	Financial Incentives (Available to State Fleets for Vehicles and Chargers)	Total EV Marginal Costs
Per Vehicle	1	$ 20,000	$ 9,000	$ 240	$ -	$ 32,600
Annual Cost	84	$ 1,676,000	$ 754,200	$ 20,112	$ -	$ 2,731,880
15-Year Total	1257	$ 25,140,000	$ 11,313,000	$ 4,525,200	$ -	$ 40,978,200
Summary of Fuel, Maintenance & Repair Costs						
Metric	Activity Unit (ODOT 2019 Vehicle Miles Traveled)	ICE Baseline Fuel Costs	EV Fuel Cost	ICE Baseline Maintenance & Repair Costs	EV Maintenance & Repair Costs	Total EV Marginal Savings
Per Vehicle Mile	1	$ 0.16	$ 0.04	$ 0.15	$ 0.09	$ (0.18)
Per Vehicle	167,601	$ 26,816.23	$ 7,374.46	$ 25,140.21	$ 15,084.13	$ (29,498)
Annual Cost	14,045,000	$ 2,247,200	$ 617,980	$ 2,106,750	$ 1,264,050	$ (2,471,920)
15-Year Total	210,675,000	$ 33,708,000	$ 9,269,700	$ 31,601,250	$ 18,960,750	$ (37,078,800)
					Per EV Net Cost	**$ 3,102**
					Annual EV Net Cost	**$ 259,960**
					15-Year EV Net Total	**$ 3,899,400**

Recommendations

- Develop a fleet electrification and charging infrastructure plan with dedicated staff and funding for implementation.
- Regarding implementation of Executive Order 17-21 and HB 2027 (2021), focus on passenger sedans in the near-term and rapidly adopt EVs in the pickup and SUV categories as models become available that meet the service needs of the agency.
- Plan for and install EV charging infrastructure at ODOT facilities.
- Engage with ODEQ Clean Fuels Program to get advance payments on vehicles.
- Partner with the state's investor-owned utilities (i.e., Pacific Power and PGE) to procure 100% renewable electricity to ensure maximum GHG reduction benefits.
- Develop a policy requiring the use of EVs before any other vehicle type. Track progress using vehicle miles traveled reporting, by vehicle class, in ODAS biennial report on Fleet and Parking Services. Track vehicle miles traveled, by ODOT vehicle types to track progress toward maximizing use of EVs and minimizing use of conventional gasoline powered vehicles. Complimentary tracking could include the percent of renewable electricity purchased to power the vehicles.
- Partner with DAS to regularly update statewide price agreement to ensure new BEVs and PHEVs are available for purchase.