Road to a Fossil Free Washington

How Electric Vehicles and Renewable Energy Can Repower Washington State

Environment Washington Research & Policy Center

Frontier Group

Road to a Fossil Free Washington

How Electric Vehicles and Renewable Energy Can Repower Washington State

ENVIRONMENT WASHINGTON RESEARCH & POLICY CENTER

FRONTIER GROUP

Written by:

Gideon Weissman
Frontier Group

Bruce Speight
Environment Washington Research & Policy Center

December 2017

Acknowledgments

Environment Washington Research & Policy Center and Frontier Group thank Joni Bosh and Michael Breish of the NW Energy Coalition, Clark Williams-Derry of the Sightline Institute, and Michelle Kinman of Environment California Research and Policy Center. Thanks to Frontier Group intern Dugan Becker for his research of Washington local energy data. Thanks also to Tony Dutzik and Elizabeth Berg of Frontier Group for editorial support.

Environment Washington Research & Policy Center thanks the Bullitt Foundation for making this report possible. The authors bear responsibility for any factual errors. The recommendations are those of Environment Washington Research & Policy Center. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

Environment Washington Research & Policy Center is a 501(c)(3) organization. We are dedicated to protecting Washington's air, water and open spaces. We investigate problems, craft solutions, educate the public and decisionmakers, and help Washingtonians make their voices heard in local, state and national debates over the quality of our environment and our lives. For more information about Environment Washington Research & Policy Center or for additional copies of this report, please visit www.environmentwashingtoncenter.org.

Frontier Group provides information and ideas to help citizens build a cleaner, healthier and more democratic America. Our experts and writers deliver timely research and analysis that is accessible to the public, applying insights gleaned from a variety of disciplines to arrive at new ideas for solving pressing problems. For more information about Frontier Group, please visit www.frontiergroup.org.

Layout: Harriet Eckstein
Cover photo: Courtesy of A&R Solar

Contents

Executive Summary

Washington's transportation system is powered almost entirely by fossil fuels. Our dependence on oil for transportation pollutes our air and water, contributes to global warming, and results in people from Seattle to Spokane sending billions of dollars a year out of the state and out of the country to purchase fossil fuels.

There is a better way. By switching to electric vehicles (EVs) that can run on renewable energy, Washington can clean our environment, meet our climate goals, and build a vibrant clean energy economy that uses energy produced here at home. At the same time, widespread adoption of electric vehicles can help Washington bring more renewable energy online—further reducing our dependence on fossil fuels to heat and power our homes and businesses.

Washington has the wind and solar resources to meet all of our energy needs, while also powering an electrified, emission-free transportation system in which our existing vehicle fleet is fully replaced with electric cars, trucks and buses. The time has come for Washington to aggressively expand the use of electric vehicles... and to ensure that they are fueled by energy from the sun and wind by setting strong goals for production of renewable energy.

Powering transportation with clean energy can help Washington meet our biggest environmental challenges.

- **Air pollution** – Vehicle exhaust is a leading source of the air pollution that contributes to smog and can worsen asthma.[1] More than one third of Washington residents are in an age group or have a medical condition that puts them at greater risk from air pollution.[2]

- **Water pollution** – By reducing or eliminating the need for the petroleum supply chain, EVs can reduce risks to water posed by spills during the extraction, transportation, and refining of oil. EVs generally do not require motor oil, and reduce the use of other oil-based lubricants, which are major components of runoff pollution.[3] A 2010 study found that at least 21 million pounds of oil, grease, and petroleum runoff pollution enter the Puget Sound each year.[4]

- **Global warming** – Transportation is by far the largest source of global warming pollution in Washington state, with double the emissions of any other sector of the economy.[5] Driving accounts for more than half of global warming emissions in 55 of Washington's 281 cities and towns.[6] A 2016 report commissioned by the state of Washington concluded that, to achieve an 80 percent reduction in emissions by 2050, passenger transportation "must shift from internal combustion engine (gasoline) vehicles to a fleet almost entirely composed of electric vehicles."[7]

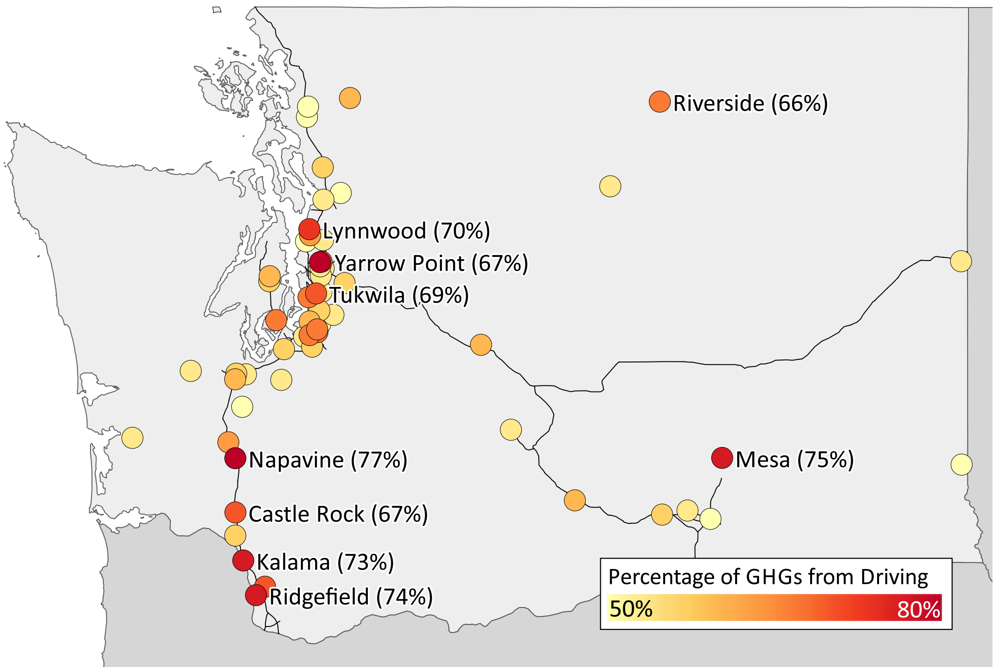
Driving accounts for more than half of global warming emissions in 55 of Washington's 281 cities and towns.

Electric vehicles are ready to move Washington.

- Hundreds of thousands of battery electric vehicles are already on the road across the country—including 25,000 in Washington, the third most of any state in the country.[8] The number of EVs on Washington's roads

Washington has 25,000 EVs, third most of any state in the country.

Figure ES-1. Washington Cities and Towns Where Driving Accounts for Majority of Global Warming Emissions



has doubled since the end of 2014.[9] There are at least 15 models of all-electric vehicles on the market, capable of meeting a variety of travel needs.[10]

- There are nearly 700 public EV charging stations across Washington, in cities and along major highways throughout Washington.[11]

- EVs can be integrated quickly into new transportation services like carsharing and ridehailing networks that reduce the burden of car ownership and make our cities better places to live. Cities including Indianapolis and Los Angeles have begun experimenting with EV carsharing, and Seattle carsharing company ReachNow has between 80 and 90 EVs in its vehicle fleet.[12]

- Electric, battery-powered buses and freight trucks are starting to come to market. In 2016, King County Metro put its first electric bus on the road, and in 2017 the agency ordered up to 73 more electric buses, potentially the largest electric bus order in North America.[13] Although electric freight is in its infancy, Tesla, Cummins (a leading company for diesel and natural gas freight engines) and Nikola Motor have all announced electric semi-trucks.[14]

Washington has the clean energy resources to power our transportation system.

- If Washington were to power all of our cars and trucks with electricity, electricity consumption in the state would increase by about 46 percent, assuming no other changes in electricity demand or travel.[15]

Just 5.5 percent of Washington's wind and solar energy potential could power all current state electricity demand, plus the estimated demand from a fully electrified vehicle fleet.

Figure ES-2. Just 5.5 Percent of Washington's Wind and Solar Potential Could Power Current Electricity Demand Plus Estimated Demand from a Fully Electrified Vehicle Fleet[19]

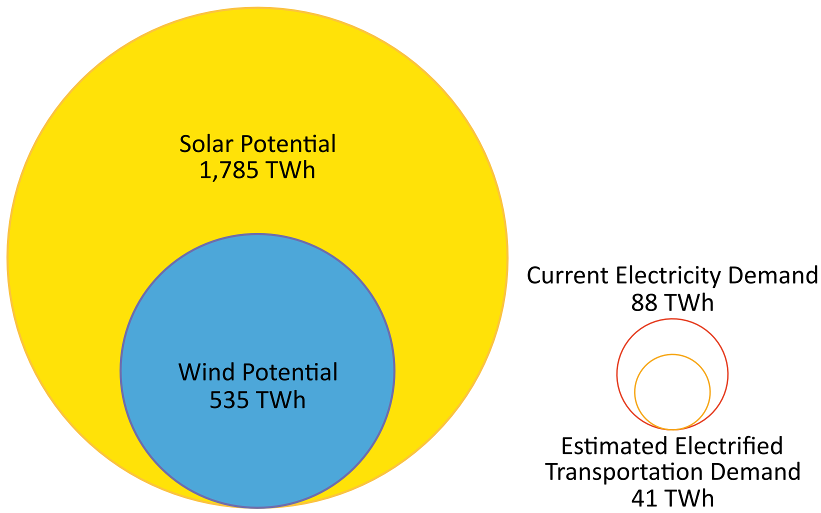
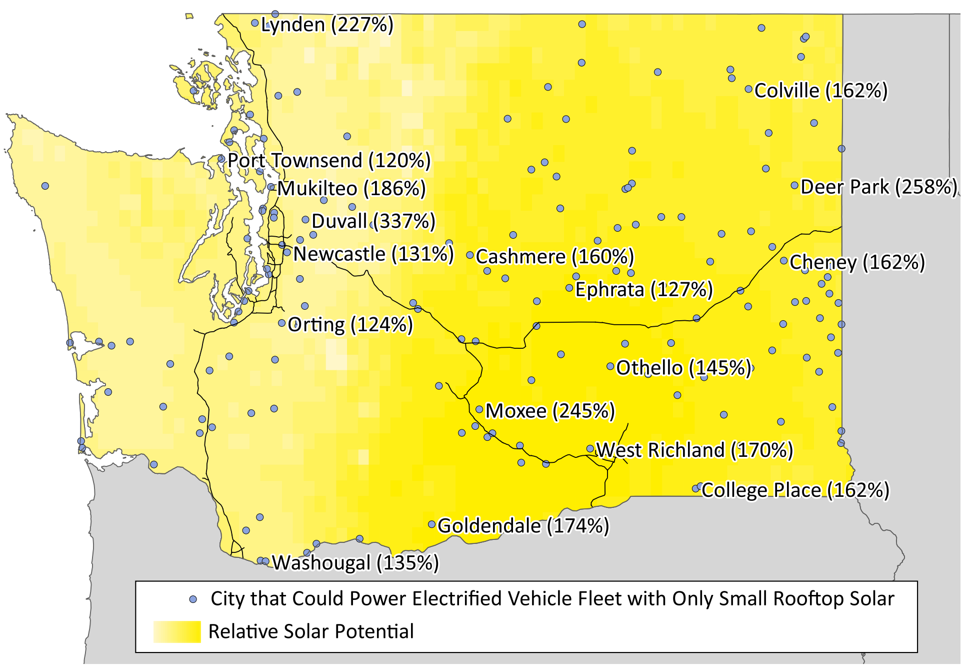


Figure ES-3. Map of 167 Washington Cities and Towns that Could Power Electrified Vehicle Fleet with Only Small Rooftop Solar



Map shading represents relative solar potential.

- Any increase in electricity generation needed to meet the energy demand for an electrified transportation system could be met using clean, renewable energy. In fact, Washington's solar potential is equivalent to 20 times the state's current electricity demand, and its wind potential is equivalent to six times the state's current demand.[16] Just 5.5 percent of Washington's wind and solar energy potential could power all current state electricity demand, plus the estimated demand from a fully electrified vehicle fleet.[17]

- Many cities and towns in Washington have the renewable energy potential to meet the needs of an electric transportation system. Of Washington's 281 cities and towns, 167 could produce more electricity from small rooftop solar installations than would be needed to power all electrified vehicle transportation within municipal limits (assuming that all of that power is dedicated to transportation).[18] Solar energy generated on medium and large buildings, along with solar and wind energy generated outside urban areas, can meet additional electricity demand.

Of Washington's 281 cities and towns, 167 could produce more electricity from small rooftop solar installations than would be needed to power all electrified vehicle transportation within municipal limits.

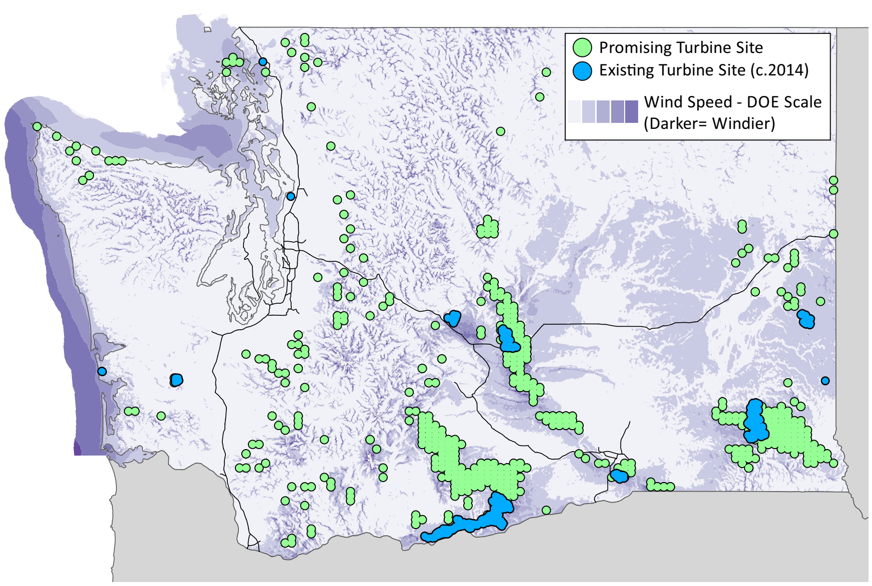
Electric vehicles can expand Washington's ability to eliminate fossil fuels from our power supply and our buildings.

- Electric vehicles can help accommodate the daily variations in the availability of energy sources such as solar and wind power, potentially speeding Washington's ability to transition to clean energy.

- By managing charging to absorb excess solar and wind power from the grid, EVs can limit the amount of renewable energy that goes wasted and improve the economics of renewable energy development.[20] Smart charging will also allow EVs to briefly reduce or halt charging in order to avoid overtaxing the grid.

- When not in use, EVs can also feed energy back into the grid, either to help meet energy demand, or to provide "ancillary grid services" to aid grid reliability and stability.[21] These functions can reduce the need for certain grid investments. Compensating vehicle owners for this service could also speed EV adoption, as could allowing EV owners to sell used EV batteries for use as grid energy storage.

Figure ES-4. Many of Washington's Promising Wind Turbine Sites Are in Southern and Eastern Washington[26]



A transition to EVs and clean energy would benefit Washingtonians across the state.

- Washington spends nearly $10 billion annually on gasoline and diesel made from oil products that are extracted and imported from out of the state or out of the country.[22] In a transportation system powered by clean energy, much of that money would stay in Washington.

- Already, the nearly 9,000 wind and solar jobs in Washington exceed the number of people employed in the oil and gas industries.[23] Solar energy in Washington has already led to $375 million in investments, and Washington is home to 157 solar companies.[24]

- Eastern Washington in particular would benefit from investment in wind and solar farms, since it is home to the bulk of the state's renewable energy potential. To date, wind farms have primarily been built in southern and southeastern Washington, and the wind industry has been responsible for $6 billion in investment, 3,000 jobs, and 10 manufacturing facilities in the state.[25]

Washington has the potential to replace its current reliance on fossil fuels with clean, renewable energy, including for repowering transportation. Doing so will bring enormous benefits to the state – including making Washington a leader in the fight to prevent the worst impacts of global warming.

To accelerate the change to renewable energy and electric vehicles, state policymakers should take steps including:

- Setting ambitious and enforceable renewable energy goals.

- Removing barriers to renewable energy, including by increasing the amount of net metering that utilities must offer their customers.

- Adopting the zero-emission vehicle program, currently in place in 10 states, which requires automakers to sell an increasing number of zero-emission vehicles, including EVs.

- Creating and expanding incentives to promote consumer and commercial adoption of EVs and EV charging infrastructure.

- Supporting community adoption of electric mass transit vehicles, for example by providing technical assistance or helping communities secure grants.

- Expanding EV charging infrastructure across the state.

- Removing any barriers to EV ownership, including Washington's $100 annual electric vehicle registration fee.[27]

- Working to create a smarter, more modern electric grid capable of integrating large amounts of renewable energy, and that can support charging an electrified transportation fleet.

- Creating pilot programs to integrate EVs and renewable energy, including the creation of vehicle-to-grid charging networks.

- Compensating owners of EVs and charging networks for services provided to the grid, and encouraging the development of a secondary market for used vehicle batteries as a grid energy storage.

Local policymakers also have a variety of tools at their disposal to drive adoption of clean energy, including:

- Cutting red tape, including by making building codes more friendly to solar energy installations.

- Installing charging infrastructure.

- Creating clean energy building codes that require or encourage clean energy installations or charging infrastructure.

- Using clean energy for public buildings and fleets.

- Incentivizing clean energy and EVs.

- Setting community clean energy goals.

Introduction

Electric vehicles are ready to break out in Washington.

Today's electric vehicles (EVs) are a far cry from the limited options of low-range electric vehicles of even a decade ago. Now a consumer buying an EV can choose from sleek, ultra-fast sports cars, full-size SUVs, and quick urban compact models. New batteries can provide driving distances upwards of 300 miles, and recharge rapidly with advanced charging equipment. And as always, EVs emit no vehicle exhaust on the road.

At the same time, clean energy sources such as wind and solar energy have also burst onto the scene. Like EVs, these technologies have gone from novelty to mainstream over the past decade. Here in Washington, wind and solar energy now generate enough electricity to power 700,000 Washington homes.[28]

Like the classic Reese's peanut butter cup commercials that touted chocolate and peanut butter as "two great tastes that taste great together," electric vehicles and renewable energy complement one another in transitioning Washington to a cleaner energy system. Renewable energy makes electric vehicles cleaner, while electric vehicles open up new possibilities for expanding the amount of renewable energy on the grid (and better utilizing existing renewable resources).

Each of these technologies has benefits on its own. Renewable energy from the sun and wind reduces air pollution, creates economic opportunities in cities and towns across the state, and helps us to meet our state's climate goals. Electric vehicles clean the air in our cities and reduce the billions of dollars we send out of the state (and often out of the country) each year to buy oil and gas for our vehicles.

Together, however, electric vehicles and renewable energy can work to help Washington move toward the vision of powering our economy with 100 percent clean, renewable energy.

This report documents the promise and potential of electric vehicles powered with renewable energy to transform our transportation system and clean up our electric grid. While recent advances in both technologies are promising, taking full advantage of their transformative potential will require bold action. Now is the time for the public and policymakers to lead.

Powering Transportation with Clean Energy Can Help Washington Meet its Biggest Environmental Challenges

Washington's dependence on fossil fuels for transportation is the root of many of our state's most pressing environmental challenges. Every year, Washingtonians drive 60 billion miles, consuming more than 39 billion gallons of gasoline and diesel fuel, in the process, fouling our air and contributing to global warming.[29]

By replacing conventional vehicles with electric ones—and powering those vehicles with clean energy from the wind and sun—Washington can address its most pressing challenges, while bringing benefits across the state.

EVs Can Reduce Air and Water Pollution

Vehicle exhaust is a leading source of air pollution in Washington state, contributing to the formation of smog, which aggravates health problems such as asthma.[30] According to the EPA, nationwide, the transportation sector is responsible for:[31]

- Over 50 percent of emissions of nitrogen oxides, which contribute to the smog that aggravates respiratory diseases like asthma, and also contribute to acid rain.[32]
- Over 30 percent of emissions of volatile organic compounds, which contribute to smog.[33]
- Over 20 percent of emissions of particulate matter, which can cause premature death from heart and lung disease and aggravates respiratory diseases like asthma.

Washington has among the highest rates of asthma in the nation.[34] More than 600,000 people in Washington, including 120,000 children, suffer from asthma, and each year asthma is the underlying cause of death for nearly 100 people.[35] In 2015, Seattle and Spokane had 43 and 40 days with elevated levels of smog pollution, respectively.[36] Smog can trigger asthma attacks.[37]

Fossil fuel-powered cars and trucks are obvious contributors to air pollution, but their role in polluting waterways is less understood. The oil supply chain that delivers gasoline or diesel fuel to vehicles—including the extraction, transportation and processing of fuels—causes enormous damage to waterways. It has been responsible for countless devastating spills across the country, including the 1984 Columbia River spill, in which the damaged oil tanker *Mobiloil* leaked as much as 233,000 gallons of fuel oil, killing thousands of seabirds.[38] Conventional vehicles are also responsible for large volumes of runoff pollution, from leaking grease, motor oil, and other fluids.[39] A 2010 study found that at least 21 million pounds of oil, grease, and petroleum runoff pollution enter the Puget Sound each year.[40]

A transition to EVs would reduce both air and water pollution. Electric vehicles emit no exhaust on city streets, where it is most harmful to Washington residents. And a transition to EVs would reduce runoff pollution because EVs generally do not require motor oil, and reduce the use of other oil-based lubricants, which are major components of runoff pollution.[41]

EVs Can Reduce Global Warming Pollution

Global warming poses an existential threat to people in Washington state and around the world. In the Pacific Northwest, for example, unchecked global warming could result in sea levels rising as high as four feet by 2100, threatening the 218 square miles of the region—including much of Puget Sound—that lies within 3.3 feet of current high tide.[42]

Figure 1. The Threat of Sea Level Rise to Seattle

Credit: National Climate Assessment

According to Washington's most recent greenhouse gas inventory, for 2013, transportation accounted for 43 percent of global warming emissions in the state, more than any other sector, and nearly double the second highest sector (Residential/Commercial/Industrial). Emissions from on-road gasoline and diesel use accounted for 30 percent of all emissions, also more than any other sector of the economy. Driving also accounts for more than half of global warming emissions in 55 of Washington's 281 cities and towns. [43] Many of the municipalities where driving accounts for the highest share of emissions have a major highway running through them, including many towns along Interstate 5 in southern Washington. Driving emissions are for driving within town lines, as opposed to emissions for vehicles registered within town lines.

Table 1. Washington Towns and Cities where Driving Accounts for Highest Percentage of Global Warming Emissions[45]

City	Annual Global Warming Emissions from Driving (Tons)	Percentage of Total Emissions
Hunts Point	10,643	78%
Napavine	26,760	77%
Mesa	4,757	75%
Ridgefield	46,494	74%
Kalama	36,803	73%
Lynnwood	576,897	70%
Tukwila	541,395	69%
La Center	25,654	68%
Castle Rock	22,247	67%
Yarrow Point	6,402	67%

A transition to EVs would dramatically reduce these emissions. A Union of Concerned Scientists study estimated that even given the emissions from charging an EV using the northwest United States' current energy grid, a typical EV's global warming impact is equivalent to a gas-powered vehicle that gets 94 miles per gallon.[46]

An EV charged using wind or solar energy would produce no emissions from travel, only from vehicle manufacturing. By powering manufacturing with renewable energy—as in the case of Tesla's "Gigafactory" battery plant—lifetime emissions could be further reduced.[47]

A 2016 report commissioned by the state of Washington concluded that, to achieve an 80 percent reduction in emissions by 2050, passenger transportation "must shift from internal combustion engine (gasoline) vehicles to a fleet almost entirely composed of electric vehicles."[48] All three of the pathways envisioned by the report for achieving deep emission reductions assumed 1 million electric vehicles on the road during the time frame 2030 to 2035.[49]

Figure 2. Washington Cities and Towns Where Driving Accounts for Majority of Global Warming Emissions[44]

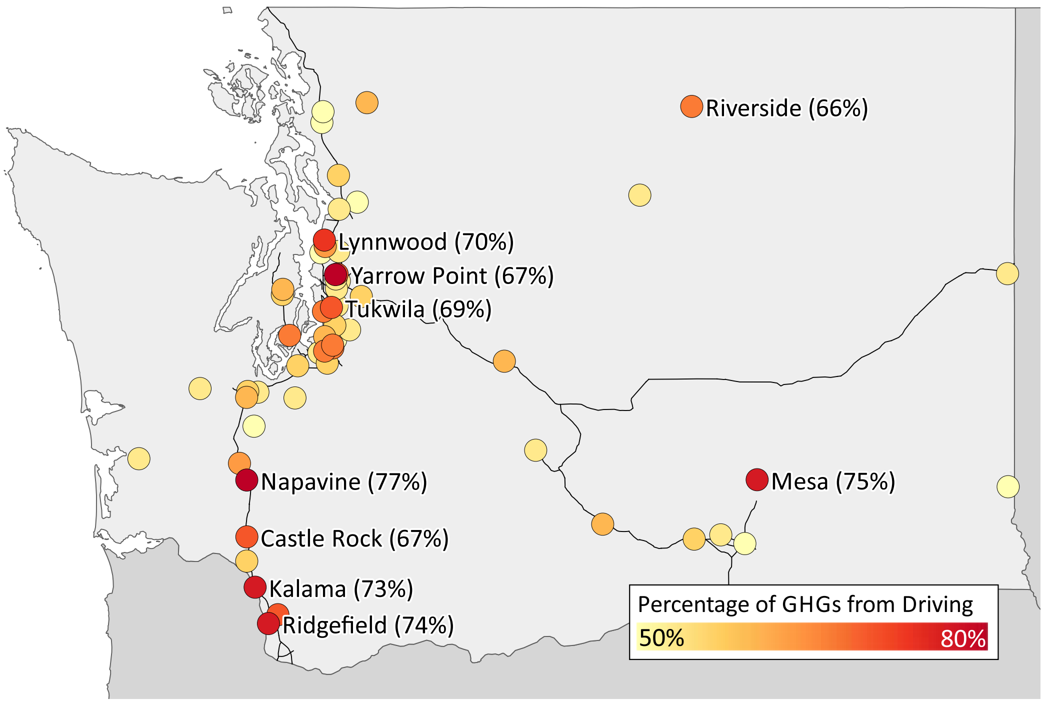
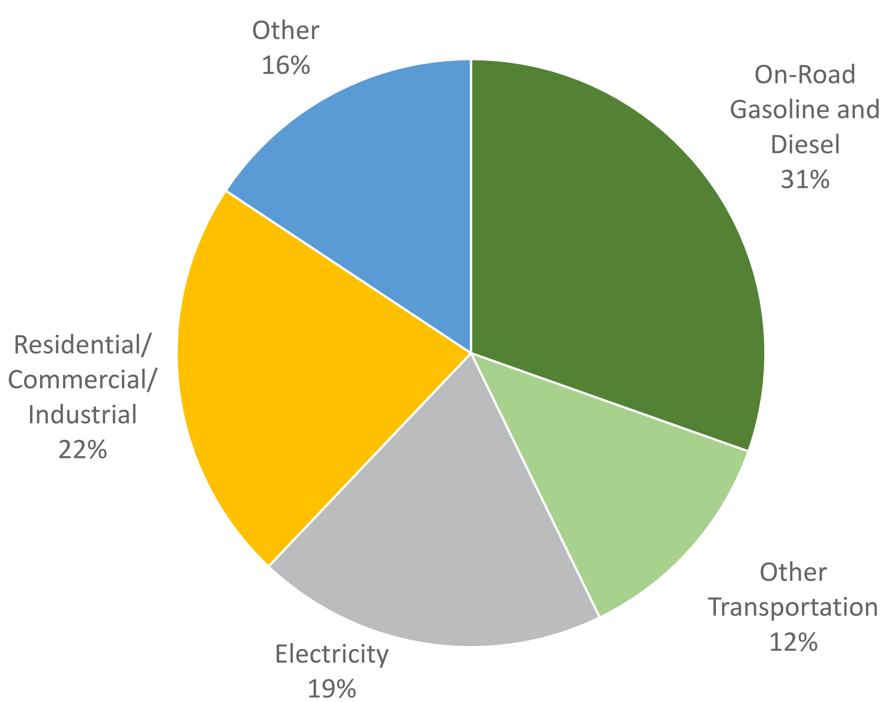


Figure 3. In Washington, Driving Accounts for More Global Warming Pollution than any Sector of the Economy[50]



Electric Vehicles Are Ready to Move Washington

The first modern EVs did not appear on American roads until the late 2000s, and as late as 2010 the number of EVs—including plug-in hybrids—on American roads numbered only in the hundreds.

Today, hundreds of thousands of EVs are already on the road across the country—including 25,000 in Washington, third most in the country, and twice as many as at the end of 2014.[52] According to the U.S. Department of Energy's State and Local Energy Data website, the towns and cities home to the highest percentage of EVs in the state are in the Puget Sound region. (See Figure 5.)

There are at least 15 models of all-electric vehicles on the market, capable of meeting a variety of travel needs.[53] More EV models are planned for the years ahead, including an electric SUV from Ford, and Volvo's first EV. And Automakers Volvo, Daimler AG (parent company of Mercedes-Benz), Volkswagen, and General Motors have all announced plans to incorporate at least some form of electrification into their entire vehicle line-ups in the years ahead.[54]

Despite relatively fast adoption, EVs still only account for around one in 100 private vehicles, and even less when accounting for trucks and public vehicles.[55] However, a number of technological, cost and other developments have primed Washington for a rapid transition to an electric fleet.

Figure 4. The Number of EVs in Washington Is Steadily Growing[51]

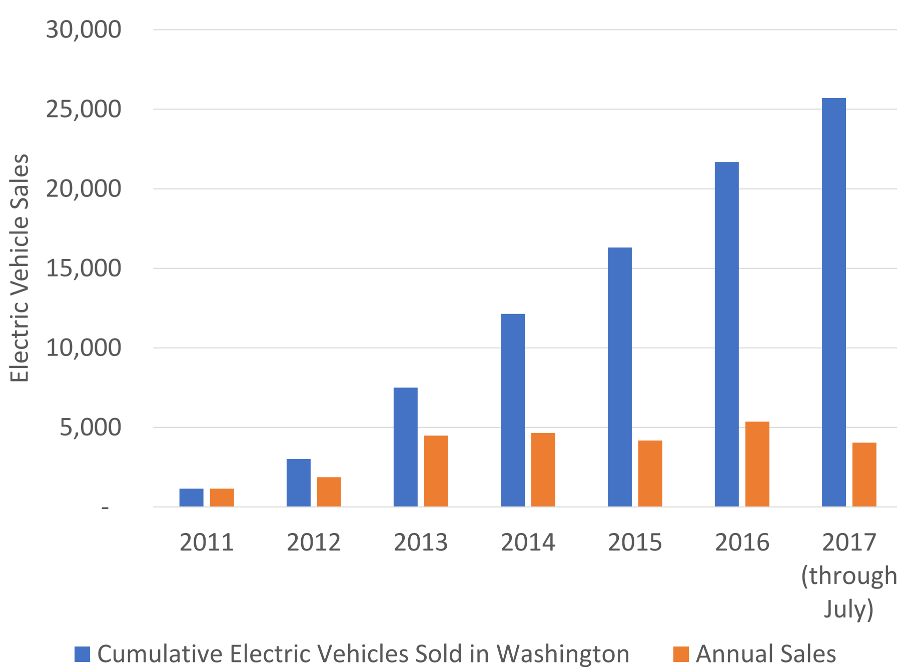
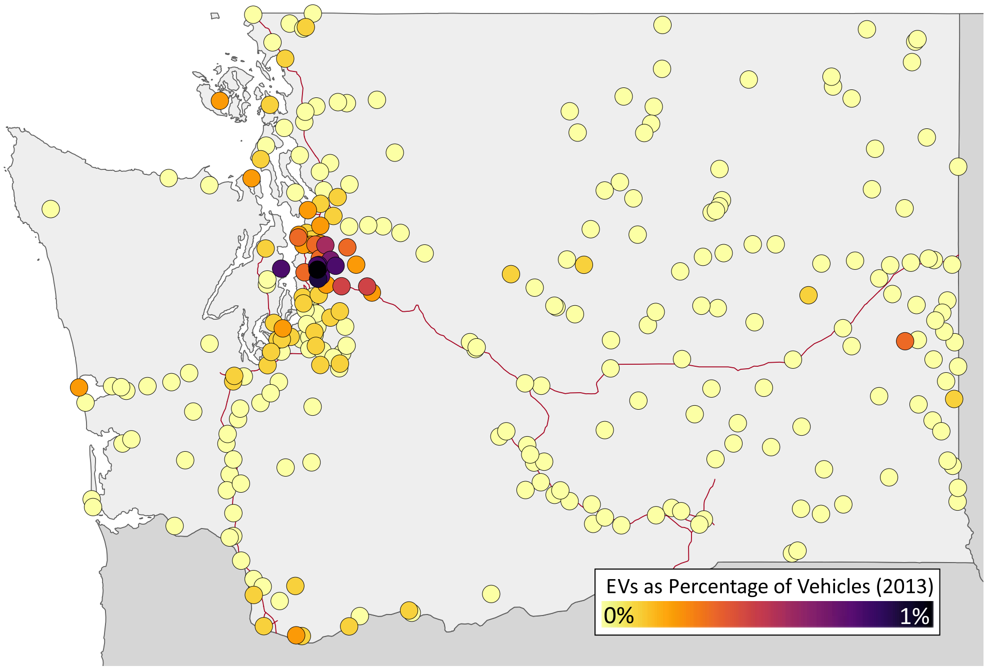


Figure 5. EVs in Washington State[56]



Darker circles represent EVs as percentage of light-duty vehicles, as of 2013; 2016 percentages would be higher, but data is not readily available.

Table 2. Washington Towns and Cities with Highest Percentage of Electric Vehicles (as of 2013)[57]

City	Percentage of Light-Duty Vehicles that Are EVs
Medina	0.7%
Mercer Island	0.7%
Sammamish	0.6%
Bainbridge Island	0.6%
Hunts Point	0.6%
Clyde Hill	0.6%
Beaux Arts Village	0.6%
Yarrow Point	0.6%
Redmond	0.5%
Bellevue	0.4%

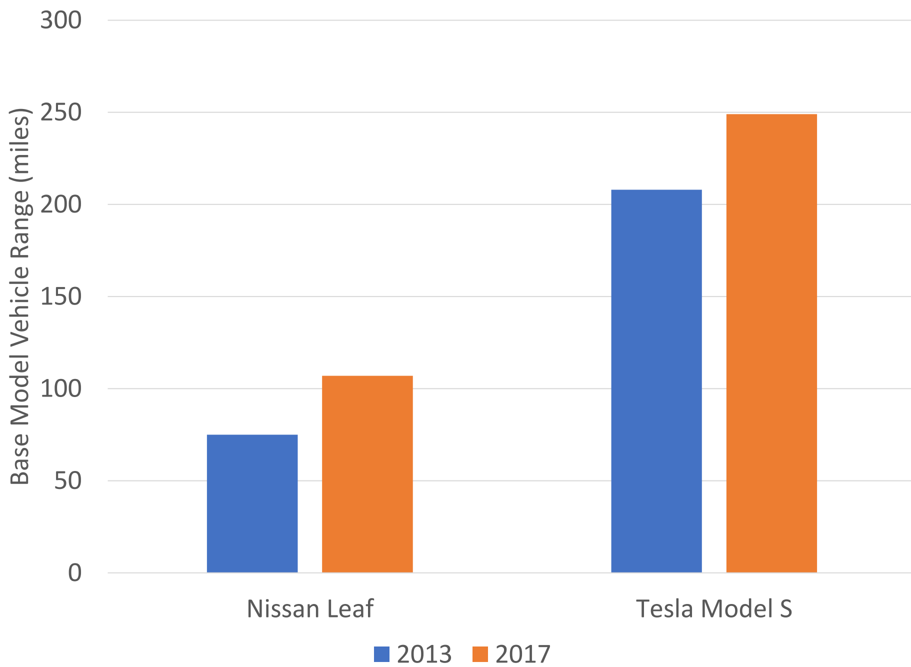
EV Technology Is Improving and Prices Are Falling

Thanks in large part to improvements in battery technology, today's EVs are vastly improved from the low-range vehicles of 10 or 20 years ago. From 2013 to 2017, the base model range of the Tesla Model S grew from 208 to 249 miles per charge, while the Nissan Leaf grew from 75 to 107 miles per charge.[58] The 2018 Leaf will offer a range of 150 miles, and an extended range model of Tesla's Model S offers a range of 351 miles.[59]

New technology is also enabling rapid charging of EV batteries. Tesla claims that vehicles charged at its Supercharger charging stations can gain 170 miles of range in as little as 30 minutes.[60] Fast EV charging is rapidly improving, and prototypes of new fast charging systems have been demonstrated by a number of companies.[61]

As EV range has increased, prices have fallen. From 2010 to 2016, battery prices fell by 80 percent.[63] And

Figure 6. EV Vehicle Range Is Rising[62]



in 2016 alone, the price per mile of range for new EVs fell by 6 percent.[64] The consulting firm McKinsey and Company predicts that prices will continue to fall, and that within the coming decade unsubsidized EVs will reach cost parity with gas vehicles.[65] When accounting for the low cost of owning an EV—as a result of low maintenance and fuel costs—as well as financial incentives, in some cases EVs are already cost-competitive with conventional vehicles.[66]

Low-cost, high-capacity batteries can also help Washington meet the challenge of charging an electrified vehicle fleet without harming the reliability of the grid. EVs—particularly those using fast-charging stations – consume large amounts of energy quickly, and charging many at once has the potential to strain grid capacity. One strategy for dealing with such a problem is to build batteries into chargers themselves.[67] Such batteries would not require rapid charging, and could charge during periods of low demand—and could then rapidly charge EVs on demand without affecting the grid. A network of battery-powered chargers would also have the benefit of supplying the grid with energy storage, further aiding gird reliability.

Electric Buses Are Here and Electric Freight Transport Is on the Horizon

A battery electric bus in King County. In 2016, King County Metro put its first electric bus on the road, and in 2017 the agency ordered up to 73 more electric buses from the company Proterra, in one of the largest electric bus orders in North America so far. Credit: Flickr user Atomic Taco (CC BY-SA 2.0)

Electrifying transportation in Washington can include freight and public transportation vehicles, which account for more than half of all vehicles registered in the state.[68] Freight trucks in particular consume enormous amounts of fuel. Nationally, freight trucks make up just 4.2 percent of vehicles yet consume 25 percent of on-road fuel.[69] Fortunately, electric, battery-powered buses are already on our roads, and electric freight transportation is close to market.

Electric buses are rapidly coming to market around the world. Globally, there were about 345,000 battery electric buses in operation by the end of 2016, double the number from 2015.[70] And Washington state is already becoming an electric bus leader. In 2016, King County Metro put its first electric bus on the road, and in 2017 the agency ordered up to 73 more electric buses from the company Proterra, in one of the largest electric bus orders in North America so far.[71] According to Proterra, many of its buses can charge in just 10 minutes—and can charge faster, in some cases, than diesel buses can refill with fuel.[72] Electric buses also require far less frequent maintenance than natural gas buses, and run almost silently, reducing noise in crowded urban areas.[73]

Electric freight transportation, although still in its infancy, is moving quickly toward market. Tesla, Cummins (a leading company for diesel and natural gas freight engines) and Nikola Motor Company have all announced electric semi-trucks.[74]

Electric pickup trucks are also on the horizon, important because pickup trucks make up one out of every six vehicles sold in the country.[75] The company Workhorse has demonstrated pre-production versions of its electric pickup truck, and plans to start production in late 2018.[76] A Tesla pickup truck is also rumored to be in development.[77] In March 2017, Seattle joined an effort to help accelerate the introduction of heavy-duty electric vehicles, joining 30 other cities in asking automakers to provide information on the cost and feasibility of providing electric vehicles for municipal fleets.[78]

Electric vehicle technology is now also being used for more specialized heavy- and medium-duty applications. In 2014, Chicago began using the nation's first electric garbage truck, which saves more than 2,500 gallons of gasoline per year.[79] And in 2017, the Los Angeles company Chanje began selling medium-duty electric delivery trucks.[80]

EV Charging Infrastructure Is Spreading across Washington and the Country

EV charging station in Custer, Washington. Credit: WSDOT Flickr

Over the last decade, Washington's charging infrastructure has steadily increased, giving EV owners increasing confidence that they will be able to charge wherever they go. As of September 2017, there were 690 public EV charging stations in Washington, including 140 in Seattle.[81] Nationally, there are more than 16,000 chargers, including all along Interstate 90 from Seattle to Boston, and along the entirety of Interstate 5 from Canada to Mexico.

More charging stations are being installed. The state currently plans to build 15 more charging stations along Washington's biggest highways, including Interstate 5 between Everett and Chehalis, and Interstate 90 east of Snoqualmie Pass.[82] Carsharing company ReachNow is planning to build 20 publicly-available fast charging stations in Seattle, which will be able to accommodate five cars each.[83] And many private homes and businesses have installed their own fast-charging equipment, including with support from utility-run pilot programs.[84]

New Shared Mobility Services Can Speed EV Adoption in Cities While Improving Urban Life

Recent years have seen the rise of new "shared mobility" services that give urban residents new options to travel, enabling some to forgo car ownership. These services typically use smartphone

Figure 7. EV Charging Stations in Washington[85]

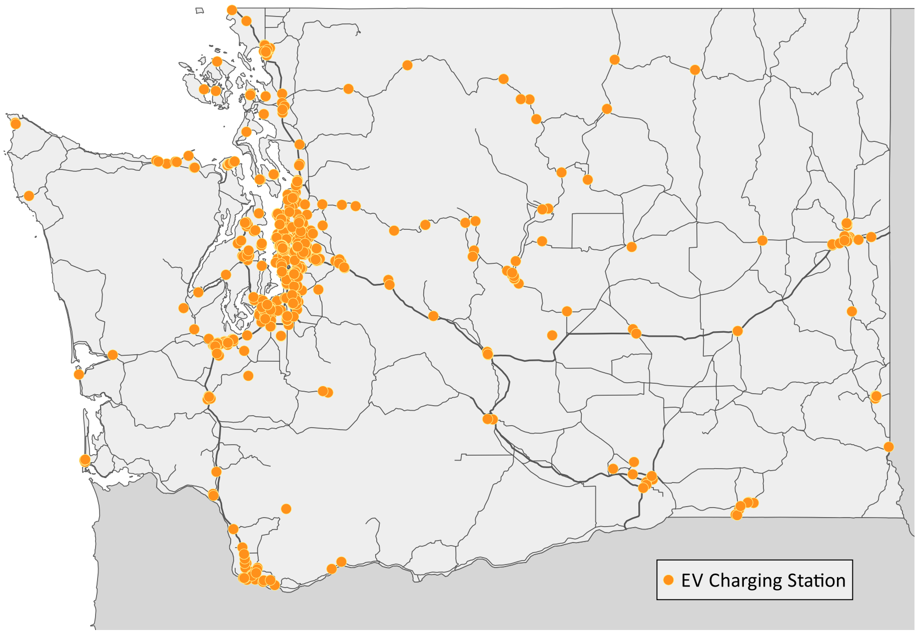


Table 3. Washington Towns and Cities with Highest Number of EV Chargers[86]

City	Number of EV Chargers
Seattle	141
Bellevue	57
Tacoma	36
Renton	30
Olympia	23
Kirkland	22
Spokane	19
Vancouver	19
Issaquah	14
Redmond	13

technology to enable easy and flexible car trips. They also can make rapid adoption of EVs cheaper and easier, while improving urban life.

Because shared mobility services allow many people to share a single vehicle, just a few new electric vehicles can replace conventional vehicles for many people at once. Shared mobility services are already beginning to adopt electric vehicles, including here in Washington. In Seattle, carsharing company ReachNow has between 80 and 90 EVs in its fleet of approximately 700 vehicles.[87] For its customers, the price to rent an EV is the same as for any other vehicle, and ReachNow's prices are comparable to other carsharing services in the city.[88] As previously noted, ReachNow is also planning to build 20 publicly-available charging stations in Seattle, which will be able to accommodate five cars each.[89]

Because many shared mobility services have a specific use—short rides in urban environments—they can utilize smaller vehicles with more limited battery capacity, which may be easier and cheaper to deploy in large numbers.

In addition to speeding EV adoption, a switch to electric, shared mobility can bring quality-of-life benefits to cities. Reduced car ownership means fewer vehicles clogging city streets, opening new possibilities for converting space from parking to parks, paths, and other uses to improve city life. A transition away from car ownership can also reduce overall driving, reducing congestion and pollution, and easing the move away from fossil fuels.

Washington Has the Clean Energy Resources to Power Its Transportation System

Rooftop solar installation on the IKEA in Renton, Washington. Photo courtesy of A&R Solar.

To fully reap the environmental benefits of an electrified transportation system, Washington must power EVs with clean, renewable energy like wind and solar power. Washington has the clean energy resources to do so.

In total, according to a U.S. Department of Energy analysis of renewable energy potential, Washington's solar potential is equivalent to 20 times the state's current electricity demand, and its wind potential is equivalent to six times the state's current demand.[90]

Washington would only need a fraction of the state's vast wind and solar potential to power an electrified transportation system. Assuming that driving levels and current electricity demand stay the same, Washington would need to consume 46 percent more electricity than it does currently to power a fully electrified vehicle fleet, including both light- and heavy-duty vehicles.[91]

Any increase in electricity generation needed to meet the energy demand for an electrified transportation system could be met using clean, renewable energy. Just 2 percent of Washington's wind and solar energy potential could supply all of the electricity needed for an electrified transportation system.[92] And just 5.5 percent of Washington's wind and solar energy potential could supply the electricity needed to meet all current demand, plus an electrified transportation system.[93]

Many cities and towns in Washington have the renewable energy potential to meet the needs of an electric transportation system using only solar energy generated on solar energy systems installed on rooftops. Of Washington's 281 cities and towns, 167 could produce more electricity from small rooftop solar installations than would be needed to power all electrified vehicle transportation within municipal limits, assuming that all of that power is dedicated to transportation.[94] (The Department of Energy only makes rooftop solar projections readily available

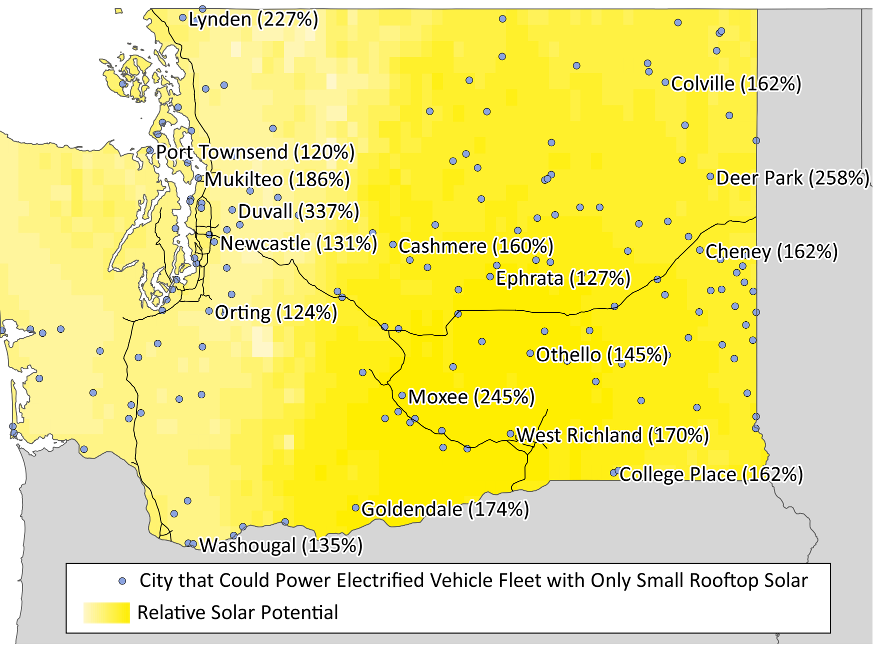
Table 4. Washington Cities and Towns with Most Small Building Rooftop Solar Potential[97]

City	Small Building Rooftop Solar Generation
Seattle	1,111
Tacoma	485
Vancouver	466
Spokane	410
Bellevue	259
Yakima	226
Kent	224
Everett	214
Renton	212
Spokane Valley	210

for small buildings, those with a footprint smaller than 5,000 square feet.)[95] Solar energy generated on medium and large buildings, along with solar and wind energy generated outside urban areas, can meet additional electricity demand.

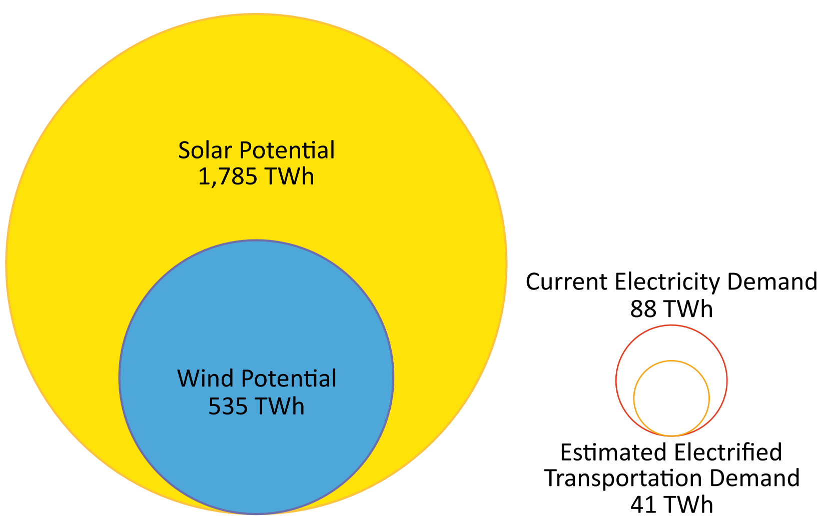
Along with an expansion of renewable energy resources, achieving a clean transportation system will require the creation of a smarter and more robust grid that can ensure electricity is available when and where it is needed.[96]

Figure 8. Map of 167 Washington Cities and Towns that Could Power Electrified Vehicle Fleet with Only Small Rooftop Solar



Yellow shading represents relative solar potential.

Figure 9. Just 5.5 Percent of Washington's Wind and Solar Potential Could Power Current Electricity Demand Plus Estimated Demand from a Fully Electrified Vehicle Fleet



Electric Vehicles Can Help Washington Rapidly Adopt Clean Energy

Washington can transition to a reliable electric grid powered largely or entirely by renewable energy according to numerous studies from governmental, academic, and nonprofit research institutions.[98]

However, accommodating the daily variations in the availability of energy sources such as solar and wind power will require building a smarter, more resilient electric grid. Electric vehicles, with high capacity batteries that are frequently connected to the grid, can play a role in this effort, both by managing charging schedules, and by feeding energy back into the grid.

By managing charging to absorb excess solar and wind power from the grid, EVs can limit the amount of renewable energy that goes wasted and improve the economics of renewable energy development.[99] Smart charging will also allow EVs to briefly reduce or halt charging in order to avoid overtaxing the grid.

When not in use, EVs may be able to feed energy back into the grid, either to help meet energy demand, or to provide "ancillary grid services" to aid grid reliability and stability.[100] One reason so-called "vehicle-to-grid," or V2G, technology is useful is that personal commuting vehicles follow their owners – and their

Washington Needs Wind and Solar Energy to Power a Clean, Electrified Transportation System

Thanks to the hydropower resources that generate nearly 70 percent of its electricity, Washington boasts one of the lowest-carbon electric grids in the country.[105] However, to create an electrified transportation system, and to move past dirty sources of energy once and for all, Washington will need to build clean, renewable sources of power, particularly wind and solar.

First, wind and solar energy are necessary for permanently ending Washington's reliance on fossil fuels. In 2017, coal and natural gas produced 14 percent of Washington's electricity.[106] Burning fossil fuels to generate electricity accounts for approximately one-fifth of Washington's global warming emissions – and eliminating them from our electric grid is necessary to achieve a low or zero carbon future.[107]

Second, to supply the energy for an electrified transportation system, Washington may need to expand its generation of electricity. (See "Washington Has the Clean Energy Resources to Power Its Transportation System," page 18.) By using wind and solar energy, Washington can expand its power capacity, achieve its global warming emission goals, and protect the health and safety of all Washingtonians.

energy demand – providing power where it is needed, at both home and work. By supplying power where it is needed, energy losses from transmission and distribution are reduced. And when EVs are plugged in at home in the evening, those with leftover energy can provide power to the home during periods of high energy demand (and potentially high energy prices) and lowest solar output, aiding the grid and saving owners money. Once energy demand lowers late at night, the vehicle can be recharged.[101]

Such V2G charging could also speed EV adoption, if vehicle owners are compensated for the energy they feed to the grid. As *Time* magazine put it: "What if your parked car could earn money?"[102] Additionally, allowing EV owners to sell used EV batteries as energy storage devices could enhance the economics of EV ownership.

A number of pilot programs are already demonstrating how EVs can contribute to a renewable grid. At Los Angeles Air Force Base, a V2G system has successfully created a system with 34 battery-powered vehicles (including plug-in hybrids) and 77 charging stations.[103] In Europe, Nissan and power company Enel have installed V2G chargers in pilot projects in the UK, Italy, and Denmark, including 100 in the UK.[104]

A Transition to EVs and Clean Energy Would Benefit People across Washington

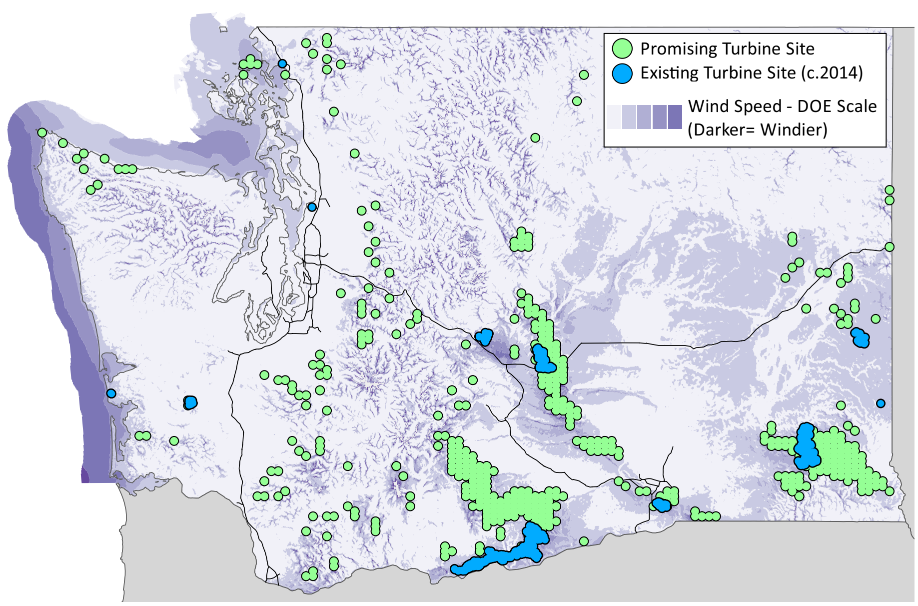
Washington would likely see economic benefits from a transition to EVs and clean energy. Today, most energy consumed in Washington comes from fossil fuels extracted out of the state and out of the country—including gasoline and diesel, on which Washingtonians spend nearly $10 billion every year.[108]

Already, the nearly 9,000 wind and solar jobs in Washington exceed the number of people employed in the oil and gas industries.[109] Small-scale solar installations on rooftops of homes and businesses create jobs right in the communities where installations take place. Wind turbines and utility-scale solar farms need to be manufactured and maintained.

A transition to clean energy means investment in new electric vehicles, charging infrastructure, solar panels, wind turbines and grid upgrades, not to mention investment in the energy efficiency improvements that will most likely be part of a clean energy transition. Solar energy in Washington has already led to $375 million in investments, and Washington is home to 157 solar companies.[110] Building up charging infrastructure will also create jobs and investment. Even though commercial EV charging is in its infancy, the industry is growing fast. For example, Aerovironment—a leader in the emerging EV charging space—saw its sales revenues increase by 74 percent in the first quarter of 2017 alone, reaching a total of $11.3 million.[111]

Eastern Washington in particular could benefit from investment in large wind and solar farms, since it is home to the bulk of the state's renewable energy potential. To date, wind farms have primarily been built in southern and southeastern Washington, and the wind industry has created more than $6 billion in investment, more than 3,000 jobs, and 10 manufacturing facilities in the state.[112] For rural and agricultural communities, wind development can be an important economic force. According to the National Renewable Energy Laboratory, "in communities in which farming is the only large industry, the installation of wind farms creates another industry that becomes a large percentage of the local tax base and contributes to local businesses."[113] For Dayton, in southeastern Washington, wind energy is a major part of the local economy, providing the city with both jobs and tax revenue.[114]

Figure 10. Many of Washington's Promising Wind Turbine Sites Are in Southern and Eastern Washington[115]



Conclusion and Recommendations

Clean, renewable energy and electric vehicles promise enormous benefits to Washington, with the ability to move us away from dirty fossil fuels, resulting in cleaner air and water and reduced global warming emissions.

Washington has the energy resources and the technology to repower both its transportation system and its electric grid. Washington has vast solar and wind energy potential, enough to produce many times as much power as the state consumes each year. Clean energy technology has rapidly advanced and come down in price in recent years. And pilot projects in the state and around the world are demonstrating the feasibility of advanced new technologies, from electric buses to vehicle-to-grid applications.

By acting decisively to transition to clean energy and an electrified transportation system, Washington can bring benefits to its residents, and become a global leader in the efforts to prevent the worst impacts of climate change. Changes at the state and local levels can create important progress.

At the state level, policymakers should:

- Speed adoption of **wind and solar energy** by:
    - Setting ambitious and enforceable goals. This includes strengthening the state's Renewable Energy Standard, which currently requires Washington utilities to obtain just 15 percent of their electricity from new renewable resources by 2020.[116]
    - Removing barriers to renewable energy. For example, policymakers should increase the amount of net metering that utilities must offer their customers, so that more rooftop solar owners can receive fair credit for the energy they provide to the grid. Policymakers should also create and expand programs that provide rebates, grants, and tax credits toward clean energy installations, and ensure that state implementation of the federal Public Utility Regulatory Policies Act (PURPA) provides long-term certainty and fair compensation for renewable energy development.
- Speed adoption of **electric vehicles** by:
    - Adopting the zero-emission vehicle program, currently in place in 10 states, which requires automakers to sell an increasing number of zero-emission vehicles, including EVs. Washington should also join other states with the program in cooperative efforts to ensure effective implementation.[117] Efforts should include public education and outreach, as a lack of public knowledge about EVs, incentives and charging availability is a major barrier to EV adoption.[118]
    - Creating and expanding incentives to promote consumer and commercial adoption of EVs and EV charging infrastructure. Incentives can be financial (like Washington's current EV tax exemption) or otherwise, like free or reduced-cost city parking for EVs. Such programs should ensure that all communities in Washington are able to access EVs and the health and environmental benefits they deliver.
    - Supporting community adoption of electric mass transit vehicles, for example by providing technical assistance or helping communities secure grants.
    - Expanding EV charging infrastructure across the state. Opportunities likely exist for working with utilities in this effort. Cities can also create requirements for new and renovated buildings to incorporate charging infrastructure. Policymakers should also ensure that all electric utilities can take part in plans to expand charging infrastructure.

- Removing any barriers to EV ownership, including Washington's $100 annual electric vehicle registration fee.[119] Washington should continue to raise money for EV infrastructure improvements, but not in ways that discourage EV adoption.

- Amplify the **mutual benefits of EVs and clean energy** by:

    - Working to create a smarter, more modern electric grid capable of integrating large amounts of renewable energy, and that can support charging an electrified transportation fleet. Smart rate design and demand response should also be used to encourage EV charging behaviors that are most supportive of a stable, renewably powered grid.

    - Creating pilot programs to integrate EVs and renewable energy, including the creation of vehicle-to-grid charging networks, solar- and battery-powered EV charging stations, and systems for networked and managed smart EV charging.

    - Compensating owners of EVs and charging networks for services provided to the grid, and encouraging the development of a secondary market for used vehicle batteries as a grid energy storage.

Local policymakers also have a variety of tools at their disposal to drive adoption of clean energy. Local policymakers should work to:

Cut red tape. Local governments have a number of tools to reduce barriers standing in the way of clean energy adoption. For example, Kansas City, Missouri, was recognized by the Department of Energy's national SolSmart program for lowering the costs and time involved in switching to solar energy, by allowing consumers to complete their solar energy permitting process entirely online and making its building code more friendly to solar energy installations. Two Washington cities – Bellevue and Edmonds – have also been recognized by SolSmart for reducing local barriers to solar energy.[120]

Installing charging infrastructure. Publicly accessible EV charging stations are critically important in cities, where many residents lack access to a private garage for charging their vehicles. Cities can take a leading role in building such charging infrastructure. For example, New York City has committed to invest $10 million in its city EV charging network, with the goal of adding enough capacity to charge 12,000 vehicles each week.[121]

Creating clean energy building codes. Local governments can require that new construction includes clean energy. For example, San Francisco requires that new buildings under 10 stories install solar energy systems, and starting in 2018 "new construction will be required to have electrical infrastructure capable of supplying electricity for electric vehicle charging at 100% of new parking spaces."[122]

Using clean energy for public buildings and fleets. Cities can set an example for clean energy adoption by installing solar panels on municipal rooftops and municipal property, and by using EVs for public fleets. Seattle currently has a goal of achieving 40 percent electrification of its municipal light-duty vehicle fleet, and of installing 200 chargers for fleet vehicles.[123] Cities across the country have demonstrated clean energy installations on public buildings. Salt Lake City has onsite solar at 14 municipal properties, including on fire and police stations.[124]

Incentivizing clean energy and EVs. Offering consumers rebates or tax refunds for EV purchases can have a significant impact on EV sales.[125] Riverside, California, offers its residents a $500 rebate for EVs purchased in the city limits.[126]

Setting clean energy goals. Dozens of cities across the country have made commitments to obtain the bulk or the entirety of their energy from clean, renewable sources. [127] In June 2017, more than 250 city leaders at the U.S. Conference of Mayors unanimously approved a resolution supporting local clean energy, calling on cities to establish "a community-wide target of powering their communities with 100 percent clean, renewable energy by 2035."[128] That same month, Edmonds became the first city in Washington to commit to achieving 100 percent clean energy.[129]

Methodology

Estimating energy needs of an electrified transportation system.

This analysis provides an estimate of the electricity needed to power an electrified transportation system. The estimate does not take into account a wide variety of variables that will likely change the electricity required for a real-world system, including changes in transportation habits, efficiency, and population. The estimate of additional electricity demand (46 percent) is in line with, or higher than, similar calculations done by other analyses.[130]

The estimate assumes that one-third of the energy currently produced using gasoline and diesel would be required to provide the same transportation in electric vehicles. This is based on research showing that electric vehicles are approximately three times as efficient as comparable conventional vehicles, largely due to the fact that far less energy is wasted as heat in an electric vehicle. According to the Department of Energy, gasoline vehicles "only convert about 17 to 21 percent of the energy stored in gasoline to power at the wheels" while EVs "convert about 59 to 26 percent of the electrical energy from the grid to power at the wheels."[131] In diesel engines, heat waste is comparable to gasoline engines.[132]

Energy currently used to provide road transportation was based on two sources. Energy consumed as motor gasoline for the transportation sector comes from the Energy Information Administration's State Energy Data System (SEDS). The energy estimates provided there include all motor gasoline consumed by the transportation sector, and this analysis assumes that all energy was used in road vehicles. Since SEDS does not differentiate between transportation sector diesel used in road vehicles and in trains, energy consumed as diesel was estimated based on diesel gallons used for road transportation ("on highway"), from the Energy Information Administration (EIA).[133] Gallons were converted to energy assuming 5.768 million British thermal units (Btu) per barrel, from EIA SEDS Appendix B.[134]

The energy content of both gasoline and diesel in Btu were converted to kilowatt-hours for comparison with Washington's current electricity consumption, assuming 0.29 watt-hours per Btu. Washington electricity consumption was found in the EIA electricity data browser, available there as total retail sales of electricity.[135]

Appendix

Table A-1. Washington City and Town Emissions, Energy and Transportation Data[136]

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Aberdeen	36% (121)	82% (182)	1 (67)
Airway Heights	33% (144)	60% (213)	0 (N/A)
Albion	4% (278)	817% (24)	0 (N/A)
Algona	65% (13)	17% (273)	1 (67)
Almira	10% (259)	2,075% (10)	0 (N/A)
Anacortes	9% (262)	77% (190)	3 (38)
Arlington	42% (91)	76% (191)	1 (67)
Asotin	33% (142)	485% (40)	0 (N/A)
Auburn	50% (56)	35% (245)	10 (13)
Bainbridge Island	26% (179)	117% (148)	3 (38)
Battle Ground	38% (108)	114% (149)	0 (N/A)
Beaux Arts Village	7% (268)	669% (30)	0 (N/A)
Bellevue	53% (44)	26% (264)	57 (2)
Bellingham	38% (111)	52% (226)	12 (11)
Benton City	56% (32)	81% (183)	1 (67)
Bingen	13% (249)	82% (180)	0 (N/A)
Black Diamond	47% (64)	74% (194)	0 (N/A)
Blaine	7% (269)	54% (223)	1 (67)
Bonney Lake	49% (58)	79% (186)	0 (N/A)
Bothell	54% (37)	28% (259)	8 (17)
Bremerton	61% (22)	34% (248)	6 (22)
Brewster	33% (147)	158% (111)	0 (N/A)
Bridgeport	15% (243)	280% (64)	1 (67)
Brier	25% (181)	192% (93)	0 (N/A)
Buckley	47% (67)	89% (176)	0 (N/A)
Bucoda	23% (196)	287% (60)	0 (N/A)
Burien	40% (97)	87% (178)	3 (38)
Burlington	52% (50)	30% (254)	2 (52)
Camas	16% (238)	107% (158)	2 (52)
Carbonado	6% (272)	2,469% (7)	0 (N/A)
Carnation	18% (218)	304% (55)	0 (N/A)
Cashmere	27% (176)	160% (110)	0 (N/A)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Castle Rock	67% (9)	26% (263)	1 (67)
Cathlamet	28% (174)	152% (116)	0 (N/A)
Centralia	45% (74)	58% (215)	4 (32)
Chehalis	63% (17)	16% (274)	0 (N/A)
Chelan	36% (117)	96% (171)	4 (32)
Cheney	25% (183)	162% (108)	0 (N/A)
Chewelah	21% (208)	260% (71)	0 (N/A)
Clarkston	31% (158)	106% (160)	1 (67)
Cle Elum	61% (21)	43% (234)	1 (67)
Clyde Hill	42% (85)	27% (261)	0 (N/A)
Colfax	25% (187)	234% (78)	0 (N/A)
College Place	39% (100)	162% (107)	0 (N/A)
Colton	32% (149)	261% (70)	0 (N/A)
Colville	22% (204)	162% (109)	0 (N/A)
Conconully	11% (255)	1,656% (13)	0 (N/A)
Concrete	44% (81)	69% (200)	1 (67)
Connell	33% (138)	71% (196)	0 (N/A)
Cosmopolis	18% (217)	230% (80)	0 (N/A)
Coulee City	20% (210)	249% (75)	1 (67)
Coulee Dam	33% (140)	155% (114)	0 (N/A)
Coupeville	17% (226)	276% (66)	0 (N/A)
Covington	54% (40)	71% (195)	0 (N/A)
Creston	28% (167)	295% (58)	0 (N/A)
Cusick	16% (240)	1,396% (15)	0 (N/A)
Darrington	19% (214)	505% (39)	0 (N/A)
Davenport	18% (222)	297% (57)	1 (67)
Dayton	16% (236)	285% (61)	0 (N/A)
Deer Park	18% (219)	258% (72)	0 (N/A)
Des Moines	35% (129)	103% (166)	2 (52)
DuPont	31% (153)	144% (121)	1 (67)
Duvall	19% (215)	337% (50)	1 (67)
East Wenatchee	38% (107)	80% (185)	1 (67)
Eatonville	30% (162)	168% (104)	0 (N/A)
Edgewood	44% (82)	57% (217)	0 (N/A)
Edmonds	29% (163)	163% (106)	10 (13)
Electric City	31% (156)	203% (88)	0 (N/A)
Ellensburg	28% (166)	117% (147)	5 (26)
Elma	47% (63)	70% (198)	0 (N/A)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Elmer City	47% (66)	91% (175)	0 (N/A)
Endicott	11% (257)	1,983% (11)	0 (N/A)
Entiat	23% (199)	56% (222)	0 (N/A)
Enumclaw	28% (170)	132% (128)	0 (N/A)
Ephrata	40% (99)	127% (135)	0 (N/A)
Everett	54% (38)	29% (257)	12 (11)
Everson	36% (119)	118% (145)	0 (N/A)
Fairfield	23% (193)	324% (52)	0 (N/A)
Farmington	6% (273)	2,650% (6)	0 (N/A)
Federal Way	59% (24)	32% (251)	3 (38)
Ferndale	33% (136)	34% (249)	0 (N/A)
Fife	55% (33)	13% (276)	3 (38)
Fircrest	45% (77)	62% (210)	0 (N/A)
Forks	36% (118)	111% (150)	1 (67)
Friday Harbor	17% (231)	321% (53)	1 (67)
Garfield	13% (248)	784% (26)	0 (N/A)
George	15% (244)	209% (86)	0 (N/A)
Gig Harbor	64% (16)	17% (272)	3 (38)
Gold Bar	45% (75)	53% (224)	1 (67)
Goldendale	18% (216)	174% (101)	0 (N/A)
Grand Coulee	36% (120)	107% (156)	0 (N/A)
Grandview	44% (79)	87% (177)	0 (N/A)
Granger	61% (19)	37% (240)	0 (N/A)
Granite Falls	27% (177)	184% (98)	0 (N/A)
Hamilton	59% (23)	58% (216)	0 (N/A)
Harrah	17% (224)	837% (22)	0 (N/A)
Harrington	15% (242)	560% (38)	0 (N/A)
Hartline	25% (180)	2,186% (9)	0 (N/A)
Hatton	1% (280)	2,304% (8)	0 (N/A)
Hoquiam	30% (160)	118% (144)	0 (N/A)
Hunts Point	78% (1)	5% (280)	0 (N/A)
Ilwaco	44% (80)	119% (141)	0 (N/A)
Index	No data available	No data available	No data available
Ione	16% (233)	232% (79)	0 (N/A)
Issaquah	58% (26)	30% (256)	14 (9)
Kahlotus	17% (230)	788% (25)	0 (N/A)
Kalama	73% (5)	22% (268)	0 (N/A)
Kelso	56% (30)	22% (267)	0 (N/A)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Kenmore	39% (104)	97% (170)	1 (67)
Kennewick	42% (87)	68% (203)	3 (38)
Kent	57% (28)	19% (271)	6 (22)
Kettle Falls	22% (200)	133% (127)	0 (N/A)
Kirkland	48% (60)	36% (243)	22 (6)
Kittitas	7% (270)	630% (32)	0 (N/A)
Krupp	18% (221)	1,285% (18)	0 (N/A)
La Center	68% (8)	32% (252)	0 (N/A)
La Conner	10% (258)	352% (47)	1 (67)
Lacey	53% (43)	45% (233)	8 (17)
LaCrosse	5% (275)	3,540% (3)	0 (N/A)
Lake Forest Park	41% (92)	101% (167)	0 (N/A)
Lake Stevens	52% (52)	77% (187)	0 (N/A)
Lakewood	58% (25)	26% (262)	1 (67)
Lamont	12% (253)	4,581% (2)	0 (N/A)
Langley	16% (235)	281% (62)	4 (32)
Latah	28% (169)	561% (37)	0 (N/A)
Leavenworth	27% (175)	172% (102)	4 (32)
Liberty Lake	55% (34)	35% (244)	0 (N/A)
Lind	9% (264)	712% (28)	0 (N/A)
Long Beach	23% (194)	268% (68)	2 (52)
Longview	12% (252)	75% (192)	2 (52)
Lyman	36% (125)	107% (159)	0 (N/A)
Lynden	18% (220)	227% (81)	0 (N/A)
Lynnwood	70% (6)	14% (275)	3 (38)
Mabton	25% (186)	380% (46)	0 (N/A)
Malden	8% (266)	1,428% (14)	0 (N/A)
Mansfield	4% (277)	4,896% (1)	0 (N/A)
Maple Valley	33% (141)	181% (99)	1 (67)
Marcus	25% (188)	349% (49)	0 (N/A)
Marysville	41% (95)	68% (202)	1 (67)
Mattawa	31% (155)	132% (129)	0 (N/A)
McCleary	53% (46)	59% (214)	0 (N/A)
Medical Lake	24% (191)	280% (63)	0 (N/A)
Medina	54% (41)	86% (179)	0 (N/A)
Mercer Island	54% (42)	45% (231)	10 (13)
Mesa	75% (3)	26% (265)	0 (N/A)
Metaline	36% (123)	197% (89)	0 (N/A)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Metaline Falls	1% (279)	3,355% (4)	0 (N/A)
Mill Creek	48% (61)	63% (208)	0 (N/A)
Millwood	32% (148)	61% (211)	0 (N/A)
Milton	65% (14)	30% (253)	0 (N/A)
Monroe	33% (135)	70% (197)	1 (67)
Montesano	39% (101)	104% (165)	0 (N/A)
Morton	22% (207)	129% (132)	0 (N/A)
Moses Lake	39% (102)	52% (225)	2 (52)
Mossyrock	35% (127)	121% (139)	0 (N/A)
Mount Vernon	52% (53)	48% (230)	5 (26)
Mountlake Terrace	63% (18)	36% (242)	1 (67)
Moxee	25% (182)	245% (76)	0 (N/A)
Mukilteo	17% (229)	186% (97)	2 (52)
Naches	55% (35)	80% (184)	0 (N/A)
Napavine	77% (2)	11% (278)	0 (N/A)
Nespelem	28% (171)	823% (23)	0 (N/A)
Newcastle	35% (130)	131% (131)	0 (N/A)
Newport	26% (178)	155% (113)	0 (N/A)
Nooksack	45% (76)	210% (85)	0 (N/A)
Normandy Park	13% (251)	465% (42)	0 (N/A)
North Bend	47% (62)	60% (212)	1 (67)
North Bonneville	38% (109)	119% (142)	0 (N/A)
Northport	13% (247)	254% (74)	0 (N/A)
Oak Harbor	36% (124)	106% (162)	1 (67)
Oakesdale	23% (198)	655% (31)	0 (N/A)
Oakville	35% (132)	108% (154)	0 (N/A)
Ocean Shores	25% (189)	105% (164)	0 (N/A)
Odessa	13% (250)	714% (27)	0 (N/A)
Okanogan	46% (70)	134% (126)	0 (N/A)
Olympia	56% (29)	30% (255)	23 (5)
Omak	37% (116)	99% (168)	1 (67)
Oroville	25% (190)	135% (124)	0 (N/A)
Orting	37% (115)	124% (138)	0 (N/A)
Othello	18% (223)	145% (120)	0 (N/A)
Pacific	64% (15)	19% (269)	0 (N/A)
Palouse	21% (209)	215% (83)	0 (N/A)
Pasco	51% (54)	57% (219)	3 (38)
Pateros	54% (39)	127% (136)	1 (67)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Pe Ell	23% (197)	616% (34)	0 (N/A)
Pomeroy	28% (168)	429% (43)	0 (N/A)
Port Angeles	45% (73)	67% (204)	5 (26)
Port Orchard	57% (27)	39% (239)	3 (38)
Port Townsend	20% (212)	120% (140)	6 (22)
Poulsbo	42% (84)	65% (206)	6 (22)
Prescott	14% (246)	1,297% (17)	0 (N/A)
Prosser	22% (203)	205% (87)	0 (N/A)
Pullman	29% (165)	93% (174)	4 (32)
Puyallup	56% (31)	40% (237)	9 (16)
Quincy	24% (192)	126% (137)	2 (52)
Rainier	32% (150)	192% (92)	0 (N/A)
Raymond	53% (48)	63% (209)	0 (N/A)
Reardan	42% (90)	255% (73)	0 (N/A)
Redmond	39% (103)	29% (258)	13 (10)
Renton	53% (47)	34% (246)	30 (4)
Republic	8% (267)	237% (77)	1 (67)
Richland	55% (36)	50% (229)	2 (52)
Ridgefield	74% (4)	33% (250)	4 (32)
Ritzville	4% (276)	1,724% (12)	2 (52)
Riverside	66% (12)	77% (188)	0 (N/A)
Rock Island	42% (88)	108% (155)	0 (N/A)
Rockford	43% (83)	149% (118)	0 (N/A)
Rosalia	16% (239)	592% (35)	1 (67)
Roslyn	16% (241)	267% (69)	0 (N/A)
Roy	53% (45)	51% (228)	0 (N/A)
Royal City	22% (206)	351% (48)	0 (N/A)
Ruston	22% (201)	174% (100)	0 (N/A)
Sammamish	40% (98)	118% (146)	3 (38)
SeaTac	66% (11)	13% (277)	5 (26)
Seattle	39% (105)	37% (241)	140 (1)
Sedro-Woolley	41% (93)	110% (152)	0 (N/A)
Selah	39% (106)	98% (169)	0 (N/A)
Sequim	41% (94)	69% (199)	3 (38)
Shelton	42% (89)	64% (207)	2 (52)
Shoreline	52% (51)	57% (218)	7 (20)
Skykomish	47% (65)	146% (119)	1 (67)
Snohomish	37% (113)	93% (172)	1 (67)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Snoqualmie	22% (202)	188% (95)	5 (26)
Soap Lake	20% (213)	470% (41)	0 (N/A)
South Bend	47% (69)	128% (133)	0 (N/A)
South Cle Elum	16% (237)	3,007% (5)	0 (N/A)
South Prairie	36% (122)	93% (173)	0 (N/A)
Spangle	11% (256)	630% (33)	0 (N/A)
Spokane	45% (78)	39% (238)	18 (8)
Spokane Valley	34% (133)	41% (236)	2 (52)
Sprague	31% (157)	336% (51)	0 (N/A)
Springdale	47% (68)	139% (122)	0 (N/A)
St. John	5% (274)	1,353% (16)	0 (N/A)
Stanwood	32% (151)	107% (157)	0 (N/A)
Starbuck	6% (271)	847% (21)	0 (N/A)
Steilacoom	37% (114)	154% (115)	0 (N/A)
Stevenson	33% (145)	150% (117)	1 (67)
Sultan	30% (159)	106% (161)	1 (67)
Sumas	8% (265)	195% (90)	0 (N/A)
Sumner	42% (86)	24% (266)	1 (67)
Sunnyside	35% (131)	111% (151)	0 (N/A)
Tacoma	37% (112)	45% (232)	36 (3)
Tekoa	9% (263)	317% (54)	0 (N/A)
Tenino	50% (55)	75% (193)	0 (N/A)
Tieton	23% (195)	397% (45)	0 (N/A)
Toledo	16% (234)	221% (82)	0 (N/A)
Tonasket	25% (184)	186% (96)	1 (67)
Toppenish	28% (173)	156% (112)	0 (N/A)
Tukwila	69% (7)	7% (279)	3 (38)
Tumwater	61% (20)	27% (260)	3 (38)
Twisp	33% (143)	195% (91)	1 (67)
Union Gap	46% (71)	42% (235)	0 (N/A)
Uniontown	52% (49)	82% (181)	0 (N/A)
University Place	33% (137)	109% (153)	2 (52)
Vader	17% (228)	692% (29)	0 (N/A)
Vancouver	45% (72)	56% (221)	20 (7)
Waitsburg	29% (164)	210% (84)	0 (N/A)
Walla Walla	33% (146)	118% (143)	7 (20)
Wapato	35% (128)	139% (123)	0 (N/A)
Warden	10% (260)	297% (56)	0 (N/A)

City	Share of Global Warming Emissions from Driving (Rank)	Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar (Rank)	Number of Charging Stations as of September 2017 (Rank)
Washougal	34% (134)	135% (125)	0 (N/A)
Washtucna	35% (126)	278% (65)	0 (N/A)
Waterville	12% (254)	581% (36)	1 (67)
Waverly	17% (227)	418% (44)	0 (N/A)
Wenatchee	25% (185)	105% (163)	8 (17)
West Richland	49% (59)	170% (103)	0 (N/A)
Westport	15% (245)	66% (205)	1 (67)
White Salmon	32% (152)	128% (134)	0 (N/A)
Wilbur	17% (232)	271% (67)	0 (N/A)
Wilkeson	31% (154)	292% (59)	0 (N/A)
Wilson Creek	17% (225)	1,148% (20)	0 (N/A)
Winlock	20% (211)	189% (94)	0 (N/A)
Winthrop	28% (172)	57% (220)	2 (52)
Woodinville	30% (161)	51% (227)	5 (26)
Woodland	49% (57)	34% (247)	1 (67)
Woodway	22% (205)	165% (105)	0 (N/A)
Yacolt	9% (261)	1,201% (19)	0 (N/A)
Yakima	41% (96)	69% (201)	2 (52)
Yarrow Point	67% (10)	19% (270)	0 (N/A)
Yelm	38% (110)	77% (189)	0 (N/A)
Zillah	33% (139)	131% (130)	0 (N/A)

Notes

1 Washington Department of Ecology, *Air Quality – Vehicles*, accessed 28 January 2017, archived at http://web.archive.org/web/20170128163006/http://www.ecy.wa.gov/programs/air/cars/Automotive_Pages.htm.

2 Ibid.

3 U.S. Environmental Protection Agency, *Non-point Source: Urban Areas*, accessed 20 September 2017, archived at http://web.archive.org/web/20170920174334/https://www.epa.gov/nps/nonpoint-source-urban-areas.

4 Eric de Place, Sightline Institute, *How Much Petroleum Enters Puget Sound in Stormwater?*, 13 January 2010, archived at http://web.archive.org/web/20171019155832/http://www.sightline.org/2010/01/13/how-much-petroleum-enters-puget-sound/.

5 Washington Department of Ecology, *Report to the Legislature on Washington Greenhouse Gas Emissions Inventory: 2010 – 2013*, October 2016, archived at http://web.archive.org/web/20170831125520/https://fortress.wa.gov/ecy/publications/documents/1602025.pdf.

6 Based on data from the Department of Energy's State and Local Energy Data (SLED). Local data was accessed through APIs available through the National Renewable Energy Laboratory. API documentation is available at https://developer.nrel.gov/docs/cleap/. Note that DOE estimates vehicle emissions based on driving within municipal boundaries for each city or town, as opposed to emissions for vehicles registered within that city or town. DOE estimates vehicle emissions based on its estimates for fuel consumption; the methodology for fuel consumption is available at https://widgets.nrel.gov/mea/commre/assets/fuel_use_analysis.pdf. View a local example of SLED greenhouse gas emission data, for Seattle, at https://apps1.eere.energy.gov/sled/#/results/emissions?city=Seattle&abv=WA&section=electricity&currentState=Washington&lat=47.6062095&lng=-122.3320708.

7 Ben Haley et al., Evolved Energy Research, *Deep Decarbonization Pathways Analysis for Washington State*, April 2017, archived at http://web.archive.org/web/20171002163338/http://www.governor.wa.gov/sites/default/files/DeepDecarbonizationPathwaysAnalysisforWashingtonSt.pdf.

8 Through July 2017. Data downloaded from the Auto-Alliance ZEV Sales Dashboard, accessed at https://autoalliance.org/energy-environment/zev-sales-dashboard/ on 19 October 2017.

9 Ibid.

10 Based on data for the Environmental Protection Agency's *Green Car Buying Guide* for 2017 car models, downloaded from http://www.fueleconomy.gov/feg/download.shtml on 31 October 2017.

11 Charging data downloaded from: Alternative Fuels Data Center, *Electric Vehicle Charging Station Locations*, accessed at https://www.afdc.energy.gov/fuels/electricity_locations.html on 1 October 2017.

12 Indianapolis' EV carsharing service is called BlueIndy, with more information available at https://www.blue-indy.com/. Los Angeles' service is called BlueLA, with more information available at https://www.bluela.com/. Reachnow EV fleet size: Sara Bernard, "20 New Electric Vehicle Charging Stations Planned for Seattle," *Seattle Weekly,* 15 May 2017, available at http://www.seattleweekly.com/news/reachnow-launches-first-of-20-electric-vehicle-charging-stations-in-seattle/.

13 Proterra, *Proterra Secures Largest Electric Bus Order in North America with King County Metro (press release)*, 18 January 2017, available at https://www.proterra.com/press-release/proterra-secures-largest-electric-bus-order-in-north-america-with-king-county-metro/.

14 Tesla Semi: Tesla, *Tesla Semi,* accessed 26 November 2017, archived at http://web.archive.org/web/20171126074116/https://www.tesla.com/semi/; Nikola Motors: Nikola Motors, *Nikola One*, accessed 30 September 2017, archived at http://web.archive.org/web/20170930050809/https://nikolamotor.com/one; Cummins: Joann Muller, "Cummins Beats Tesla to the Punch, Unveiling Heavy Duty Electric Truck," *Forbes*, 29 August 2017.

15 See Methodology.

16 Anthony Lopez et al., National Renewable Energy Laboratory, *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*, July 2012.

17 See Methodology for details on transportation demand estimate. State wind and solar potential based on: Anthony Lopez et al., National Renewable Energy Laboratory, *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis,* July 2012. Washington current electricity consumption: Energy Information Administration, Electricity Data Browser, accessed 10 October 2017, available at https://www.eia.gov/electricity/data/browser/#/topic/

18 This calculation used similar assumptions used for calculating statewide electricity demand for a statewide electrified transportation system, explained in detail in the Methodology. Current energy demand for driving was estimated based on current gas and diesel fuel consumption in each town and city. Data on fuel consumption and small solar potential comes from the Department of Energy's State and Local Energy Data, accessed using the National Renewable Energy Laboratory's API, for which documentation is available at https://developer.nrel.gov/docs/cleap/. Fuel consumption (gallons of gas and diesel) were converted to energy assuming 120,476 Btu per gallon of gasoline, and 137,452 Btu per gallon diesel, based on: U.S. Energy Information Administration, *Energy Units and Calculators*, archived at http://web.archive.org/web/20171003231730/https://www.eia.gov/energyexplained/index.cfm?page=about_energy_units. Note that DOE estimates fuel consumption for driving within municipal boundaries for each city or town, as opposed to consumption for all vehicles registered within that city or town. The methodology that DOE used for calculating local fuel use is available at https://widgets.nrel.gov/mea/commre/assets/fuel_use_analysis.pdf.

19 See note 17.

20 Julia Pyper, "How Electric Vehicles Are Becoming a Tool for Grid Stability," *Greentech Media,* 21 November 2016, archived at http://web.archive.org/web/20171015233943/https://www.greentechmedia.com/articles/read/How-EV-Are-Becoming-a-Tool-for-Grid-Stability-duck-curve.

21 Eric Sortomme and Mohamed A. El-Sharkawi, "Optimal Scheduling of Vehicle-to-Grid Energy and Ancillary Services," *IEEE Transactions on Smart Grid*, DOI: 10.1109/TSG.2011.2164099, March 2012.

22 2015 motor gasoline expenditures for the transportation sector: U.S. Energy Information Administration, *Table E13. Transportation Sector Energy Expenditure Estimates, 2015*, archived at http://web.archive.org/web/20171019155850/https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_ex_tra.html.

23 U.S. Department of Energy, *2017 U.S. Energy and Employment Report,* January 2017, archived at http://web.archive.org/web/20170314054128/https://energy.gov/sites/prod/files/2017/01/f34/ 2017%20US%20Energy%20and%20Jobs%20Report%20State%20Charts%202_0.pdf.

24 Solar Energy Industries Association, *Solar State by State*, map accessed at https://www.seia.org/states-map on 10 October 2017.

25 Jobs: See note 23; investment and manufacturing: American Wind Energy Association, *U.S. Wind Energy State Facts*, accessed at https://www.awea.org/state-fact-sheets on 10 October 2017.

26 Existing wind turbine data downloaded from: U.S. Geological Survey, *Onshore Industrial Wind Turbine Locations for the United States*, accessed at https://pubs.usgs.gov/ds/817/ on 10 October 2017; wind power class geo data downloaded from: National Renewable Energy Laboratory, *Wind Prospector Map*, accessed at https://maps.nrel.gov/wind-prospector/ on 10 October 2017.

27 Washington's EV registration fee law: *Revised Code of Washington 46.17.323*, available at http://app.leg.wa.gov/RCW/default.aspx?cite=46.17.323.

28 Washington home energy use: U.S. Energy Information Administration, *2015 Average Monthly Bill- Residential*, accessed at http://www.eia.gov/electricity/sales_revenue_price/xls/table5_a.xlsx on 10 October 2017; 2016 Washington wind and solar generation available at: U.S. Energy Information Administration, *Electricity Data Browser,* accessed at https://www.eia.gov/electricity/data/browser/ on 12 October 2017.

29 Miles driven: Federal Highway Administration, *Highway Statistics 2015 - Functional System Travel - 2015 (1) Annual Vehicle – Miles*, December 2016, archived at http://web.archive.org/web/20170831095429/https://www.fhwa.dot.gov/policyinformation/statistics/2015/vm2.cfm; diesel: U.S. Energy Information Administration, *Sales of Distillate Fuel Oil by End Use*, 12 May

2016, available at https://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm; gasoline: U.S. Energy Information Administration, *Refiner Motor Gasoline Sales Volumes*, 2 October 2017, available at https://www.eia.gov/dnav/pet/pet_cons_refmg_d_SWA_VTR_mgalpd_a.htm.

30 See note 1

31 U.S. Environmental Protection Agency, *Health and Environmental Effects of Particulate Matter (PM),* 1 July 2016, archived at http://web.archive.org/web/20171013185401/https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm.

32 U.S. Environmental Protection Agency, *Basic Information about NO2*, 8 September 2016, archived at http://web.archive.org/web/20171018054426/https://www.epa.gov/no2-pollution/basic-information-about-no2.

33 U.S. Environmental Protection Agency, *Volatile Organic Compound (VOC) Control Regulations*, 10 April 2017, archived at http://web.archive.org/web/20171020134828/https://www3.epa.gov/region1/airquality/voc.html.

34 Washington State Department of Health, *Asthma Data*, accessed 25 January 2017, archived at http://web.archive.org/web/20170125111541/http://www.doh.wa.gov/DataandStatisticalReports/DiseasesandChronicConditions/AsthmaData.

35 Ibid.

36 Elizabeth Ridlington and Travis Madsen, Frontier Group and Environment America, *Our Health at Risk: Why Are Millions of Americans Still Breathing Unhealthy Air?*, Spring 2017.

37 Michael Guarnieri and John R. Balmes, "Outdoor Air Pollution and Asthma," *Lancet*, 383(9928):1581-1592, DOI: 10.1016/S0140-6736(14)60617-6, 3 May 2014.

38 Eric de Place and Ahren Stroming, Sightline, *Fifty Years of Oil Spills in Washington's Waters*, 12 January 2015, archived at http://web.archive.org/web/20170415071351/http://www.sightline.org/2015/01/12/fifty-years-of-oil-spills-in-washingtons-waters/.

39 See note 3.

40 See note 4.

41 See note 3.

42 U.S. Environmental Protection Agency, *Climate Impacts in the Northwest*, 22 December 2016, archived at http://web.archive.org/web/20170813200903/https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-northwest_.html.

43 See note 6.

44 Ibid.

45 Ibid.

46 Rachael Nealer et al., Union of Concerned Scientists, *Cleaner Cars from Cradle to Grave*, November 2015.

47 Tesla's solar powered Gigafactory: Jordan Golson, "Tesla Will Power Its Gigafactory with a 70-Megawatt Solar Farm," *The Verge,* 11 January 2017.

48 See note 7.

49 Ibid.

50 See note 5.

51 See note 8.

52 Ibid.

53 See note 10.

54 Andrew Hawkins, "GM Will Release At Least 20 All-Electric Cars by 2023," *The Verge,* 2 October 2017.

55 EVs in Washington: See note 8; total vehicle registrations: U.S. Federal Highway Administration, *Highway Statistics 2015: State Motor-Vehicle Registrations – 2015*, January 2017, archived at http://web.archive.org/web/20170831082644/https://www.fhwa.dot.gov/policyinformation/statistics/2015/mv1.cfm.

56 Data on EVs as percentage of light-duty vehicles for 2013 comes from the Department of Energy's State and Local Energy Data (SLED), accessed using the National Renewable Energy Laboratory's API, for which documentation is available at https://developer.nrel.gov/docs/cleap/. Although SLED EV data for 2016 recently became available on a city-by-city basis, it is not yet available for bulk download through NREL's API.

57 Ibid.

58 Stefan Knupfer et al., McKinsey and Company, *Electrifying insights: How Automakers Can Drive Electrified Vehicle Sales and Profitability*, January 2017.

59 Nissan, *The All-New 2018 Nissan Leaf: Raising the Bar for Electric Vehicles (Press Release)*, 5 September 2017,available at http://nissannews.com/en-US/nissan/usa/channels/2018-LEAF-Las-Vegas-U-S-Reveal/releases/the-all-new-2018-nissan-leaf-raising-the-bar-for-electric-vehicles. Tesla: Tesla, *Model S,* accessed 20 October 2017, archived at http://web.archive.org/web/20171020144248/https://www.tesla.com/models.

60 Tesla, Charging, accessed 13 September 2017, archived at http://webarchive.org/web/20170913054226/https:www.tesla.com/charging.

61 Examples of fast-charging development: Mariella Moon, "StoreDot Demos EV Battery that Reaches a Full Charge in 5 Minutes," *Engadget,* 12 May 2017; Phoenix Contact, *Charging Electric Vehicles at 350,000 Watts*, 5 October 2016.

62 See note 58.

63 Ibid.

64 International Energy Agency, *Energy Snapshot: Average EV Price and Range*, 11 September 2017, archived at http://web.archive.org/web/20171004002937/http://www.iea.org/newsroom/energysnapshots/average-ev-price-and-range.html.

65 See note 58.

66 Gideon Weissman and Michelle Kinman, Frontier Group and Environment California, *Drive Clean and Save*, July 2016.

67 Colin Murphy, NextGen Policy*, The Power of Cheap Batteries, or, How I Learned to Stop Worrying and Love Fast Chargers,* 11 September 2017, archived at http://web.archive.org/web/20171019155916/https://nextgenpolicy.org/blog/cheap-batteries-ftw/.

68 U.S. Federal Highway Administration, *Highway Statistics 2015: State Motor-Vehicle Registrations – 2015*, January 2017, archived at http://web.archive.org/web/20170831082644/https://www.fhwa.dot.gov/policyinformation/statistics/2015/mv1.cfm.

69 U.S. Department of Transportation Bureau of Transportation Statistics, *Freight Facts and Figures 2017*, 13 October 2017, available at https://www.bts.gov/product/freight-facts-and-figures.

70 International Energy Agency, *Global EV Outlook 2017*, 2017, archived at http://web.archive.org/web/20171002180043/https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.

71 See note 13.

72 Jonathan Gitlin, "There's a New Patent-Free Fast Charging System for Electric Buses," *Ars Technica,* 8 July 2016, archived at http://web.archive.org/web/20170919142811/https://arstechnica.com/cars/2016/07/proterra-develops-fast-charging-for-buses-opens-up-the-patents/.

73 U.S. Department of Transportation, *Zero Emissions Bus Benefits*, accessed 14 September 2017, archived at http://web.archive.org/web/20170914222325/https://www.transportation.gov/r2ze/benefits-zero-emission-buses.

74 See note 14.

75 Sophie Yeo, "Electric Cars Are Taking Off. What's the Problem with an Electric Pickup Truck?," *Washington Post,* 30 August 2017.

76 Fred Lambert, "Workhorse Unveils its Plug-in Electric W-15 Pickup Truck: $52,000 and 60 kWh Battery Pack," *Electrek,* 3 May 2017, archived at http://web.archive.org/web/20170606233028/https://electrek.co/2017/05/03/workhorse-plug-in-electric-pickup-truck/.

77 Fred Lambert, "Elon Musk Hints at Tesla 'Pickup Truck' as a 'Mini Tesla Semi'," *Electrek,* 16 September 2017, archived at http://web.archive.org/web/20170929130932/https://electrek.co/2017/09/16/elon-musk-tesla-pickup-truck/.

78 David Gutman, "Seattle Joins Effort to Press for Production of Electric Heavy-Duty Vehicles for City Fleets," *The Seattle Times,* 23 March 2017.

79 Motiv Power Systems, *First All-Electric Garbage Truck in North America, Developed by Motiv Power Systems, Hits the Road in Chicago* (press release), 16 September 2015, archived at https://www.prnewswire.com/news-releases/first-all-electric-garbage-truck-in-north-america-developed-by-motiv-power-systems-hits-the-road-in-chicago-275253371.html

80 Russ Mitchel, "A New All-Electric Delivery Truck Is on the Way, and It's Not from Tesla," *Los Angeles Times,* 10 August 2017.

81 See note 11.

82 David Gutman, "Washington State to Spend $1M on Electric-Vehicle Charging Stations," *Seattle Times,* 7 September 2017.

83 Sara Bernard, "20 New Electric Vehicle Charging Stations Planned for Seattle," *Seattle Weekly,* 15 May 2017, available at http://www.seattleweekly.com/news/reachnow-launches-first-of-20-electric-vehicle-charging-stations-in-seattle/.

84 Including programs run by Puget Sound Energy and Avista: PSE: Puget Sound Energy, *Charging Ahead (But Faster)*, 17 December 2014, archived at http://web.archive.org/web/20150407002739/http://pse.com:80/aboutpse/PseNewsroom/NewsReleases/Pages/PSE-Launches-New-Rebate-Program-for-Purchase-of-Level-2-Electric-Vehicle-Chargers.aspx; Avista, *Electric Transportation*, accessed 9 November 2017, archived at http://web.archive.org/web/20171109165435/https://www.myavista.com/about-us/energy-innovations/electric-transportation.

85 See note 11.

86 Ibid.

86 See note 83.

88 Ibid.

89 Ibid.

90 See note 16.

91 See Methodology.

92 See note 17.

93 Ibid.

94 See note 18.

95 Details on small building characteristics available through the Department of Energy's State and Local Energy Data site available at https://widgets.nrel.gov/mea/commre/assets/building_stock_characterization.docx (untitled Word document).

96 National Renewable Energy Laboratory, *Renewable Electricity Futures Study*, 2012, available at https://www.nrel.gov/analysis/re-futures.html.

97 See note 6.

98 Studies detailing high or 100 percent renewable energy scenarios include:

- Christian Breyer et al., "On the role of solar photovoltaics in global energy transition scenarios," *Progress in Photovoltaics Research and Applications*, DOI: 10.1002/pip.2885, May 2017.
- Cory Budischak, "Cost-minimized Combinations of Wind Power, Solar Power and Electrochemical Storage, Powering the Grid up to 99.9% of the Time," *Journal of Power Sources*, 225: 60-74, 1 March 2013.
- M.M. Hand et al., National Renewable Energy Laboratory, *Renewable Electricity Futures Study*, December 2012.
- Mark Jacobson et al., "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-sector Energy Roadmaps for the 50 United States," *Energy & Environmental Science* 2015 8:2093, DOI: 10.1039/C5EE01283J, 27 May 2015.
- Alexander MacDonald et al., "Future Cost-Competitive Electricity Systems and Their Impact on U.S. CO2 Emissions," *Nature Climate Change*, DOI: 10.1038/nclimate2921, 25 January 2016.
- James H. Williams et al., Energy and Environmental Economics, *Pathways to Deep Decarbonization in the United States*, 16 November 2015.

99 See note 20.

100 See note 21.

101 For one explanation of how V2G charging might take place, see: Zoheb Devar, Cleantech Rising, *How Electric Vehicles Can Drive Renewable Energy Forward*, 20 June 2017, archived at http://web.archive.org/web/20170621214513/https://medium.com/cleantech-rising/how-electric-vehicles-can-drive-renewable-energy-forward-485b8e792db6.

102 "How Parked Electric Cars Are Earning Money in Denmark," *Time*, 15 August 2017, archived at

http://web.archive.org/web/20171019155947/http://time.com/4901153/diplo-interview/.

103 Michael Genseal and Scott Kenner, Department of Defense, *Plug-in Electric Vehicle-Vehicle to Grid (PEV–V2G) LAAFB Technical Update*, December 2015, archived at http://web.archive.org/web/20170215075717/http://www.energy.ca.gov/research/notices/2015-12-14_workshop/presentations/13__CTC_Los_Angeles_Air_Force_Base__Genseal_Kenner.pdf.

104 Enel, *Nissan and Enel Launch Groundbreaking Vehicle-To-Grid Project in the UK* (Press Release), 10 May 2016, archived at http://web.archive.org/web/20170228191102/https://www.enel.com/en/media/press/d201605-nissan-and-enel-launch-groundbreaking-vehicle-to-grid-project-in-the-uk.html.

105 Washington net electricity generation by source for 2016 data from U.S. Energy Information Administration, *Electricity Data Browser*, accessed at https://www.eia.gov/electricity/data/browser/ on 12 October 2017.

106 Ibid.

107 See note 5.

108 U.S. Energy Information Administration, *Table E13. Transportation Sector Energy Expenditure Estimates, 2015*, archived at http://web.archive.org/web/20171019155850/https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_ex_tra.html.

109 See note 23.

110 See note 24.

111 Travis Hoium, "Investing in EV Infrastructure: Where the Money Is Going," *The Motley Fool,* 15 March 2017.

113 M. Pedden, National Renewable Energy Laboratory, *Analysis: Economic Impacts of Wind Applications in Rural Communities*, January 2006, archived at http://web.archive.org/web/20170216160708/http://www.nrel.gov/docs/fy06osti/39099.pdf.

114 Rachel Alexander, "Dayton Lost Its Asparagus Business to the 'War on Drugs' but Residents Persevered," *The Spokesman-Review*, 21 May 2017.

115 See note 26.

116 Existing hydroelectric resources generally do not count toward the goal. More information on the current standards available at: NC Clean Energy Technology Center, *DSIRE – Washington Renewable Energy Standard*, archived at web.archive.org/web/20170703064720/http://programs.dsireusa.org/system/program/detail/2350.

117 State Zero-Emission Vehicle Programs, *Memorandum of Understanding,* 24 October 2013, archived at http://web.archive.org/web/20171013215941/http://www.nescaum.org/documents/zev-mou-8-governors-signed-20131024.pdf.

118 Lingzhi Jin and Peter Slowik, The International Council on Clean Transportation, *Literature Review of Electric Vehicle Consumer Awareness and Outreach Activities*, 21 March 2017.

119 See note 27.

120 SolSmart, *Designees*, 13 August 2017, archived at http://web.archive.org/web/20170813045726/http://www.gosparc.org/solsmart-designees.

121 New York City Mayor's Office, *Leading the Charge: Mayor Announces Fast-Charging EV Hubs in All 5 Boroughs* (press release), 20 September 2017, archived at http://web.archive.org/web/20170922030416/http://www1.nyc.gov/office-of-the-mayor/news/600-17/leading-charge-mayor-fast-charging-ev-hubs-all-5-boroughs.

122 SF Environment, *San Francisco Green Building Code*, accessed 27 September 2017, archived at http://web.archive.org/web/20170927015131/https://sfenvironment.org/green-building-ordinance-sf-building-code.

123 City of Seattle, *2017 Drive Clean Seattle*, June 2017, archived at web.archive.org/web/20171031212016/http://www.seattle.gov/Documents/Departments/OSE/Reports/Drive%20Clean%20Seattle%202017%20Report.pdf.

124 Salt Lake City Mayor's Office, *Mayor Biskupski Announces New Solar Installations Completed on Seven Government Facilities* (press release), 14 September 2017, archived at http://web.archive.org/web/20171020160529/http://www.slcmayor.com/pressreleases/2017/9/14/mayor-biskupski-announces-

new-solar-installations-completed-on-seven-government-facilities.

125 Gil Tal and Michael Nicholas, "Exploring the Impact of the Federal Tax Credit on the Plug-In Vehicle Market," *Journal of the Transportation Research Board*, Volume 2572, DOI: 10.3141/2572-11, 2016.

126 City of Riverside, *Alternative Fuel Vehicle Rebate Program*, archived at http://web.archive.org/web/20161126192930/http://riversideca.gov:80/publicworks/air/alternativefuel.asp.

127 Sierra Club, *Is Your City #ReadyFor100?*, archived at http://web.archive.org/web/20171014003217/http://www.sierraclub.org/ready-for-100/cities-ready-for-100.

128 U.S. Conference of Mayors, *2017 Adopted Resolutions*, accessed at http://legacy.usmayors.org/resolutions/85th_Conference/proposedcommittee.asp?committee=Energy on 15 October 2017; more than 250 cities: Robert Walton, "US Mayors Pass Resolution to Target 100% Renewable Energy by 2035," *Utility Dive,* 27 June 2017*,* archived at http://web.archive.org/web/20170915111522/http://www.utilitydive.com/news/us-mayors-pass-resolution-to-target-100-renewable-energy-by-2035/445894/.

129 Sierra Club, *Edmonds Becomes First Washington City to Commit to 100 Percent Clean Energy (press release),* 29 June 2017, archived at web.archive.org/web/20170709102455/http://content.sierraclub.org/press-releases/2017/06/edmonds-becomes-first-washington-city-commit-100-percent-clean-energy.

130 Cambridge Econometrics, *2040 Government Ban Positive: But Significant Challenges Remain*, 27 July 2017, archived at web.archive.org/web/20170914081739/https://www.camecon.com/news/2040vehicleban/; National Grid, *Future Energy Scenarios*, July 2017, archived at http://web.archive.org/web/20171101193025/http://fes.nationalgrid.com/media/1253/final-fes-2017-updated-interactive-pdf-44-amended.pdf.

131 U.S. Department of Energy, *All-Electric Vehicles*, accessed 26 September 2017, archived at http://web.archive.org/web/20170925150437/http://fueleconomy.gov/feg/evtech.shtml.

132 Debbie Sniderman, The American Society of Mechanical Engineers, *Using Waste Engine Heat in Automobile Engines*, June 2012, archived at http://web.archive.org/web/20150617112234/https://www.asme.org/engineering-topics/articles/automotive/using-waste-engine-heat-in-automobile-engines.

133 U.S. Energy Information Administration, *Sales of Distillate Fuel Oil by End Use*, 12 May 2016, available at https://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm.

134 Available at https://www.eia.gov/state/seds/sep_use/notes/use_b.pdf.

135 Washington 2016 electricity retail sales available at Energy Information Administration, *Electricity Data Browser*, accessed at https://www.eia.gov/electricity/data/browser/#/topic/

136 Share of Global Warming Emissions from Driving: See note X; Share of Estimated Electrified Vehicle Fleet Demand That Could be Met by Small Rooftop Solar: See note X; Number of Charging Stations as of September 2017: See note 24.