FINAL

Building "Good Load" to Reduce Carbon Emissions:

Getting Northwest Utilities More Involved in Widespread Transportation Electrification

NW Energy Coalition
for a clean and affordable energy future

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About the Coalition

nwenergy.org

The NW Energy Coalition is an alliance of more than 100 environmental, civic, and human service organizations, progressive utilities, and businesses in Oregon, Washington, Idaho, Montana and British Columbia. We promote development of renewable energy and energy conservation, consumer protection, low-income energy assistance, and fish and wildlife restoration on the Columbia and Snake rivers.

The NW Energy Coalition and its members advocate a clean and affordable energy future for the region based on:

- Meeting all new energy demand with energy efficiency and new renewable resources.
- Full and fair accounting for the environmental effects of energy decisions.
- Protecting and restoring the fish and wildlife of the Columbia River Basin.
- Consumer and low-income protection.
- Informed public involvement in building a clean and affordable energy future.

About this paper and accompanying resolution

This staff workpaper is intended to provide background and analytical support for the "NW Energy Coalition Resolution on the Electrification of Transportation" adopted by the membership on December 4, 2015 (link). It is informed by the participation of a workgroup of Coalition members and friends that met several times in September and October 2015.

The issue is timely due to the very recent introduction of production-volume battery-electric cars, trucks and buses to the marketplace, which have connected the utility sector with the transportation sector in new ways. Northwest legislators and regulators have begun to turn their attention to the policy opportunities and challenges for utilities in this space. Also, transportation represents a large and rising fraction of the region's greenhouse gas emissions, and electrification is increasingly viewed as a key pathway for emissions reductions.

This paper necessarily draws from national studies that may not be completely applicable to northwest grid conditions; much additional, local applied work is needed. Future work of the Coalition may also address the potential for natural gas transportation applications to have similar environmental and cost benefits, particularly renewable natural gas applications from landfill methane and other biodigesters. Finally, members concerned with protection of fish species in northwest waterways have expressed interest in the potential water quality benefits of transportation electrification, which occur if less motor oil and airborne emissions products settle on roadways and get washed into water bodies. Other pollutants (such as tire particulates) are likely to be similar to conventional vehicles. Further research on this topic may be useful going forward.

Acknowledgements

Many thanks for workgroup participants and external reviewers for their helpful feedback and resources, including Karen Glitman of the Vermont Energy Investment Corporation, Jim Lazar of the Regulatory Assistance Project, Jim Francfort of Idaho National Lab, Max Baumhefner of the Natural Resources Defense Council, Eric Christiensen of Cairncross & Hempelmann and Tom Saxton of Plug In America. Thanks to NW Energy Coalition Executive Director Nancy Hirsh and Policy Director Wendy Gerlitz for their feedback and support in this work. Any remaining errors or omissions are attributable to the author.

Table of Contents

Executive Summary

Many of the earliest cars and trucks on U.S. roads ran on electricity, but petroleum fuel has dominated transportation for most of the 20th century. Within just the past five years, the re-introduction of production-volume battery-electric vehicles has connected the utility sector and the transportation sector in new ways. Opportunities for transportation electrification go beyond passenger vehicles and include city buses, short-haul trucks and vans, shore power for marine vessels, heavy rail, industrial equipment such as forklifts, plus lawn and garden equipment. The northwest, with its relatively clean and low-cost electricity grid, is uniquely positioned to leverage its electrical assets for transportation. The convergence of the two presents a new opportunity for electric utilities to build "good load" that can deliver a host of societal and utility benefits. These include:

Reduced Greenhouse Gas Emissions – Lifecycle analyses show that EVs have 40% lower emissions than conventional gas vehicles when powered by combined-cycle natural gas electricity, and up to 85% when powered by renewables. Further reductions are possible if the manufacturing phase is also powered with renewables, and northwest states have some of the best emissions performance in the country from electricity applied to transportation.

Improved Air Quality – EVs powered by wind, water, solar, and natural gas decrease air toxics emissions by 50% or more compared with conventional gasoline and diesel vehicles. Major air toxics include ozone, fine particulates ($PM_{2.5}$), and nitrogen oxides. These are typically non-point sources of human health impacts near highways and industrial facilities that disproportionately affect low-income populations.

Greater End-Use Energy Efficiency – An EV, powered by an electric motor, is about 60% efficient in translating stored electrical energy into forward motion on the wheels, which is three times as efficient as a car with an internal combustion engine and about twice as efficient as the best hybrid. As a result, EVs consume 70% to 80% less energy per mile traveled. The conservation potentials for this cross-fuel efficiency are easily as large as conservation potentials currently being sought in the electricity sector.

Low and Stable Operating Costs – Driving electric at average northwest utility prices is equivalent to paying $1.00 per gallon or less, and electricity prices have proven to be far less volatile than gasoline over the years. This can save drivers about $380 per year in fueling costs compared with a hybrid, and about $1,100 per year compared with an average gas car.

Greater Energy Security – Driving on domestically produced electricity reduces reliance on foreign oil and may reduce involvement in foreign conflicts.

State and Regional Economic Gains – Multiple macroeconomic studies show that money saved on fuel costs gets spent in other sectors of the local economy, producing far more jobs and economic activity than the petroleum sector, which is a relatively poor job creator.

Greater Utilization of the Electricity Grid – Electrical systems operate below maximum capacity for most of any year, so with optimal charging management, particularly in the overnight hours, more than two million vehicles could be electrified without adding new generation assets to the Northwest Power Pool. This has the benefit of spreading utilities' fixed costs over more units, putting downward pressure on rates.

Integration of Renewable Energy and Other Grid Services – Highly manageable transportation loads may also enable new kinds of grid services and help integrate variable renewable generation resources, particularly overnight when wind generation may exceed current demand.

Transportation electrification will eventually drive new costs for the electric utility sector if plug-in vehicle adoption reaches the truly broad scale needed to meet our emissions reduction targets. New generation assets will be needed to support high levels of adoption, and local distribution systems may require upgrades to accommodate high levels of simultaneous charging. In addition, regulators and policymakers are turning their attention to questions of who pays for charging infrastructure, which can be costly and represents a significant barrier to transportation electrification, particularly in hard-to-serve locations like apartments and condominiums and in low-income areas. Here, retrofits can often run $10,000 - $15,000 to supply power to parking spaces not originally designed for it, or much more if additional power supply to the site is required. Key questions of whether these costs are paid by through private funds, through utility investment, or through other general government funds, including carbon pricing program revenue (e.g. cap & trade), will need to be confronted in each jurisdiction.

Along the way, attention must be paid to questions of equity for low-income consumers, who have generally not been among the early adopters of battery electric vehicles but who could benefit substantially from low-cost transportation options and improved air quality. Additional questions of ratepayer equity on any utility infrastructure investments will need to be addressed.

In 2015, various states, including Washington, California, and Vermont, took legislative action to address transportation electrification, directing their utilities to pursue reductions in fossil fuel use via rate-funded investments in charging infrastructure, among other approaches.

For all these reasons, transportation electrification represents a major new opportunity for the utility sector and a challenge to make good policy. The members of the NW Energy Coalition will play a key role in achieving maximum benefits for the environment (reducing greenhouse gas and air toxics emissions as quickly as possible), for ratepayers (ensuring that all ratepayers benefit from electrification investments), and for low-income communities (providing affordable energy rates and equitable access to low-cost transportation options).

Policy Recommendations

To start seizing these opportunities, we recommend:

- Local, state, and federal programs to boost transportation electrification. This is to include charging infrastructure in multi-family and workplace settings, and public charging for "garage orphans" who lack off-street parking.

- Streamlined permitting procedures for charging installation and EV readiness in buildings through strong building codes.

- Clear legal authority for northwest utilities to participate in the transportation electrification.

- Utility investment in the transportation sector for home, apartment, condominium, workplace, industrial, public, and highway fast charge settings, with attention paid to consumer choice and competitive provision of charging station equipment.

- Policies to ensure low-income access and equity, so that ratepayer benefits are shared broadly. This may include income-targeted vehicle incentives from state and local programs, as well as minimum performance standards for utilities to reach low-income households with charging infrastructure.

- Utility policies and programs that minimize system costs, which may include time-of-use rates or other charge management programs that shift transportation loads to off-peak hours.

- Fair charges and rates for transportation uses that reflect utility system costs but do not present unnecessary hurdles or burdens on users.

- Guarantees that transportation electrification programs will be additional to existing investments in energy efficiency and renewable energy under current law.

- Exploration of potential business cases for utility system benefits from transportation loads, including demand management, vehicle to grid (V2G) integration for grid services, energy storage, and integration of variable renewable energy generation.

Introduction

The northwest, with some of the cheapest and cleanest electricity in the nation, is uniquely poised to leverage its electrical assets for use in transportation. The recent introduction of production-volume battery-electric cars, trucks and buses has connected the two sectors in new ways. Policymakers and regulators previously focused on reducing electrical loads through energy efficiency are beginning to turn their attention as well to the new "good load" opportunities and challenges that transportation electrification presents. As this paper will discuss, the list of potential societal benefits is long and includes lower emissions of greenhouse gases and other air toxics, lower fueling costs, greater (cross-fuel) energy efficiency, greater energy security, and improved regional economic performance. If properly managed, transportation electrification may also benefit electric utilities and their customers directly by utilizing existing grid assets more fully, putting downward pressure on rates. It may also prove useful in integrating variable renewable resources and providing opportunities for load management and other grid services. However, transportation electrification may also drive additional utility costs for generation and distribution when it reaches sufficient scale, and the utilities will need to explore load management policies to minimize those costs.

This paper describes the scope of transportation electrification that may be pursued, the benefits it may provide, and some of the potential costs and benefits to the electrical grid. It describes rate impact and social equity issues that will need to be confronted. And finally, it reports on transportation electrification policy steps taken in multiple states to establish a range of policy approaches that may be desirable in northwest states.

Potential Scope of Transportation Electrification

Since 2011, major automakers have begun selling production volumes of battery electric light-duty vehicles worldwide, but the potential for widespread transportation electrification goes beyond this one vehicle category. The California Electric Transportation Coalition (CalETC), a membership organization comprised of electric utilities there and some automakers, has commissioned studies of the following transportation uses and found large potential environmental benefits from electrification in reducing greenhouse gas (GHG) and other air toxics emissions:

- Forklifts
- Light duty passenger vehicles
- Medium-duty vehicles
- Light and heavy passenger rail
- High speed rail
- Shore power for marine vessels
- Heavy-duty vehicles
- Port cargo handling equipment
- Transport refrigeration units
- Airport ground support equipment
- Lawn & garden equipment
- Tow Tractors / Industrial Tugs
- Various others

Major Vehicle Categories

BEV – A battery electric vehicle (BEV), of which the Nissan Leaf is a typical example, uses energy stored in lithium-ion battery packs to power its electric motor. Mid-market BEVs today commonly have a battery capacity of 24-30 kWh, delivering a range of 80-110 miles on a charge. High-end offerings like the Tesla Model S feature larger battery packs (up to 85 kWh), which can provide more than 250 miles on a charge. Battery packs are expected to get cheaper, lighter, and more energy dense in the coming years as the technology changes and the manufacturing achieves greater scale.

PHEV – A plug-in hybrid electric vehicle (PHEV), of which the Chevrolet Volt is the most common example, utilizes both battery power charged from an external source and gasoline power in hybrid operation. Typically, the vehicle operates in battery-only mode until the 16.5 kWh capacity is exhausted – affording about 38 miles of electric range today (rising to 53 miles with the 2016 model). Then the vehicle switches into hybrid operation, where it achieves efficiency of 37 miles per gallon (rising to 42). Variations on the theme include the BMW i3 with the range extender gas engine, which in the U.S. market typically only acts when the battery capacity is exhausted. PHEV drivers typically get 70% to 80% or more of their total miles on electric power.

PEV or EV – Together, BEVs and PHEVs are often also referred to as plug-in electric vehicles (PEVs). This paper will use the term PEV or EV to mean any vehicle that is capable of being recharged by an external electricity source.

Battery-Electric Buses – Transit agencies like King County Metro in Washington are beginning to purchase and field test battery-electric buses from manufacturers such as Proterra (pictured) and BYD. These often cost more than a conventional diesel bus to purchase, but the lower operating cost economics of electricity may make them an attractive total cost proposition, as well as non-polluting. These buses can feature large batteries (150-350 kWh), and some are equipped with high-powered (500 kW) overhead re-charging stations, intended to return a bus to its route schedule in under 10 minutes. Both Proterra and BYD recently made the procurement list for the State of Washington, which allows transit agencies in Washington and Oregon to order these buses in bulk.

Medium Duty Short-Haul Vehicles – Major corporations are now testing medium-duty EV for short-haul uses, including those made by Smith Electric (pictured). These often feature battery packs ranging from 36-120 kWh and ranges of up to 100 miles, which vary widely with size and payload. Potential applications include delivery vans, passenger shuttle buses and school buses.

Forklifts & Other Industrial Equipment – Many major manufacturers, including Toyota (pictured) have full ranges of electric forklifts, which can reduce diesel emissions in industrial and workplace settings, particularly indoors. These often feature 40-50 kWh battery packs. Other non-road vehicles typically have speeds of 45 mph or less and are sometimes categorized as neighborhood electric vehicles (NEVs).

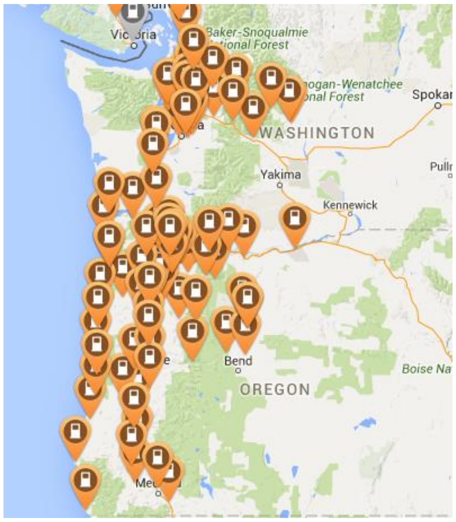
EV Charging Basics

Level 1 charging uses any grounded electrical outlet, typically at 120V / 12A drawing 1.4 kW of power. This is often the cheapest way to charge, as it may require no additional equipment and little impact on a home electrical supply. However, it is also the slowest, delivering just 3-4 miles of range for every hour plugged in. Level 1 is often most suitable for PHEVs, as their smaller battery packs can easily be charged in a home garage overnight or at work during an 8-hour day for a typical commute home, although some BEV drivers make do with Level 1 as well.

Level 2 charging uses a universal J1772 standard for all vehicle types on a 240V connection, like a home dryer plug. Installation typically requires new conduit and an outlet, and the additional load may also require upgrades to a home electrical panel if the service is already maxed out. Level 2 loads can vary widely from 15A (3.3 kW) to the more typical 30A (6.6 kW) up to a maximum of 80A (19.2 kW). This delivers 10, 20, or about 50 miles of range, respectively, per hour of charging. Level 2 is often most suitable for BEVs with their larger battery pack sizes, fully recharging a Nissan Leaf from empty in about 4 hours.

Quick Charging – High power DC (direct current) fast charging is by far the most costly to install and is typically only found on highway corridors for extended-range BEV trips. It requires a three-phase power connection at the site and delivers anywhere between 25 and 100 kW, with the goal of getting a vehicle 80% charged in under 30 minutes. Unfortunately, disparate standards fracture this market, with Tesla having a proprietary standard for its vehicles, a Japanese standard (CHAdeMo), and a U.S./European standard (called either CCS or SAE Combo) – all present on U.S. highways. Recent state and private installations in 2015 have featured dual port capability for both CCS and CHAdeMo.

Current Northwest PEV Market



Highway Fast Charge Network (PlugShare)

Washington and Oregon have some of the highest rates of EV adoption nationally, with about 20,000 registered between them. The category represented about 1.6% and 1.1% of new vehicle sales, respectively, in 2013. Washington incentivizes sales of both EVs and charging equipment with an exemption on state and local sales tax. Oregon is one of eight states with the zero-emission vehicle (ZEV) mandate, which requires automakers to manufacture and place in service a small but increasing percentage of ZEVs in those states.

Both states have worked to craft a highway charging network to facilitate extended range trips. Washington has about 40 fast chargers along the I-5 corridor and across two mountain passes to Wenatchee and Roslyn. Oregon has more than 50 fast chargers along I-5, the Oregon coast, and east to Mt. Hood, Arlington, and Redmond. Some of these stations were built using federal stimulus funding, some with state funding, and some were built by automakers at dealerships that sell EVs. The network remains skeletal at this time, typically with just one fast-charge plug per station. This means that drivers must wait to charge if multiple vehicles show up at once, and an outage on a single piece of charging equipment can make extended EV trips prohibitively long or even impossible for a whole section of a state.

Regarding Other Transportation Reform Efforts

Some may see transportation electrification as being in conflict with other reform efforts aimed at promoting walking, biking, and transit as better alternatives to single-occupancy vehicles. These reforms also reduce greenhouse gas emissions and improve air quality. They can have additional benefits on land use, traffic congestion, time loss, etc. This paper views all these efforts as complimentary. It takes no particular position on the proper mix of each transportation mode; rather, whatever mix of vehicles vs. biking, walking, and rail transit is desired, it seeks to decarbonize *all* of the vehicles (cars, trucks, transit buses, and trains) in the system.

Societal Benefit #1 – Reductions in Greenhouse Gas Emissions

Transportation comprises a large fraction of Washington and Oregon's carbon emissions – around 40-47% vs. 27% nationally, and this share will grow, as planned and future coal retirements take effect. This suggests that the transportation sector will be a central element in those states' efforts to meet their emissions reduction goals.

Table 1 – Greenhouse Gas Emissions by Sector as a Share of the Total Emissions Profile

State	Annual Transportation Greenhouse Gas Emissions (MMT CO_2e)	Transportation as a Share of Total Emissions (Gross)
Washington	49	47%
Oregon	24	39%
Idaho	11	28%
Montana	9	23%
U.S.	1,810	27%

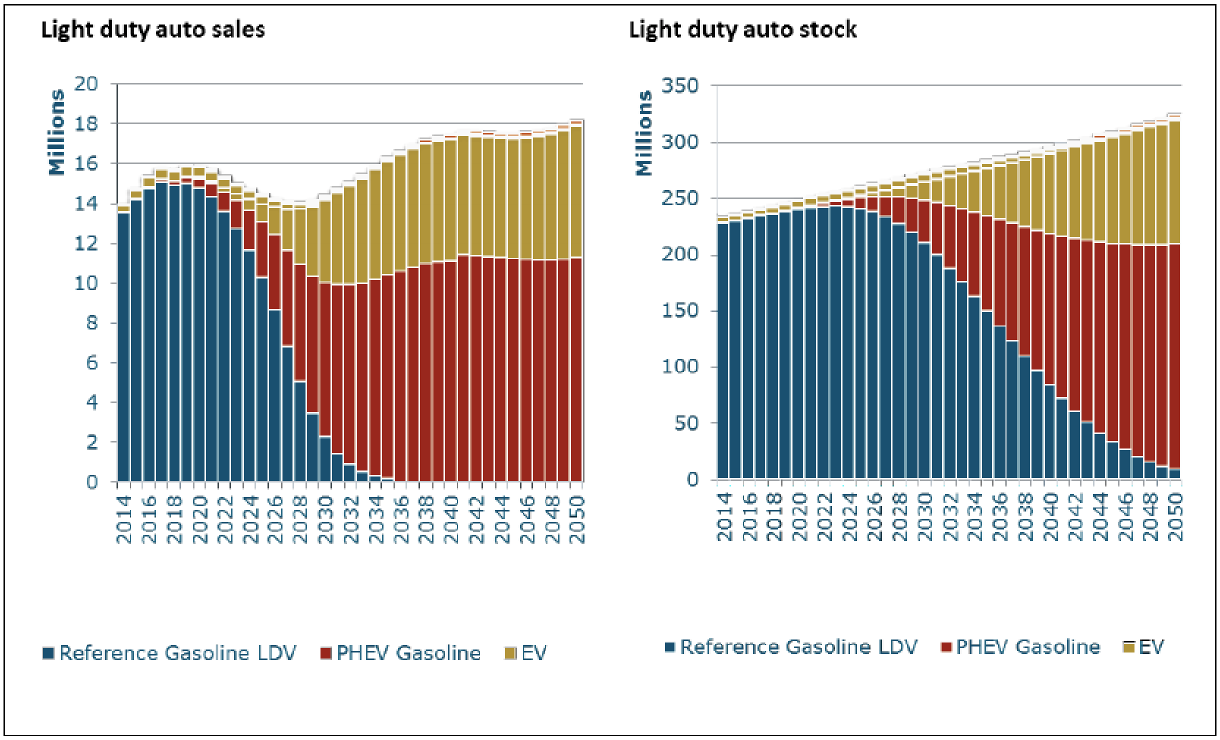
SOURCE: State and EPA greenhouse gas inventories, various years.

National research finds that widespread transportation electrification will be required to decarbonize the U.S. economy and achieve the kinds of deep emissions reductions that the Intergovernmental Panel on Climate Change (IPCC) says will be required to keep the planet below a 2°C warming threshold. The U.S. 2050 Report that maps out viable pathways to meet those emissions targets concludes the following:

> "Deep decarbonization requires three fundamental changes in the U.S. energy system:
>
> (1) highly efficient end use of energy in buildings, transportation, and industry;
> (2) decarbonization of electricity and other fuels; and
> (3) fuel switching of end uses to electricity and other low-carbon supplies."

The report calls on the transportation sector to achieve very aggressive plug-in vehicle targets, with sales of light-duty vehicles rising to 100% plug-in hybrids or full battery electrics by 2035, shown in Figure 1 below, in order to convert the total vehicle stock by 2050. Adoption rates are projected to be somewhat modest for the next five years, requiring very sharp acceleration after that.

Figure 1 – Sales and Stock Pathways to Meet 2050 Emissions Targets

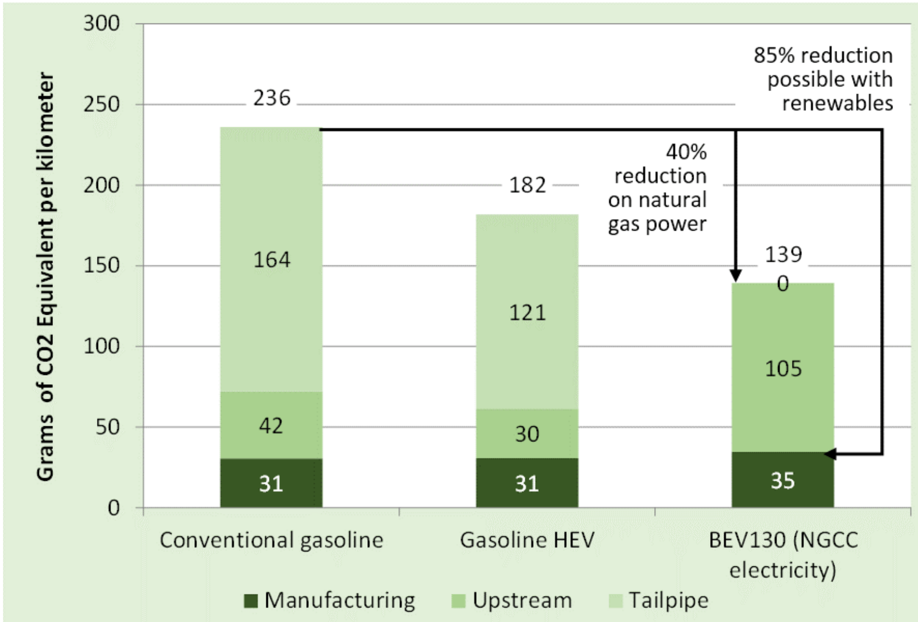


SOURCE: U.S. 2050 Report: Pathways to Deep Decarbonization, 2014

Lifecycle Emissions Analysis

EVs have no tailpipe emissions, but their overall greenhouse gas reduction potential depends entirely on the grid that they plug in to, how they are manufactured, and how their end-of-life recycling and reuse is managed. Most of any vehicle's carbon footprint is in the phase that burns fuel, as shown below in Figure 2 from the Carnegie Mellon University energy group. It may be surprising to many that vehicle manufacturing adds a relatively small share to the total emissions, about 13% in the case of a conventional gas car. The CMU team found that battery electric cars reduce lifecycle emissions per kilometer by about 40% compared with a conventional gas car when the EV is powered by combined-cycle natural gas electricity (139 gCO_2e/km vs. 236). Using their data, it's easy to see that the reduction would be 85% if the upstream emissions were also eliminated by powering the vehicle on renewables, such as hydropower, wind, geothermal, or solar (35 gCO_2e/km vs. 236). Still further reductions are possible if the manufacturing sector also migrates to renewable energy.

Figure 2 – Lifecycle Emissions of Conventional Gas Cars, Hybrids, and a 130 mile range Battery Electric Vehicle Powered by Combined-Cycle Natural Gas Power

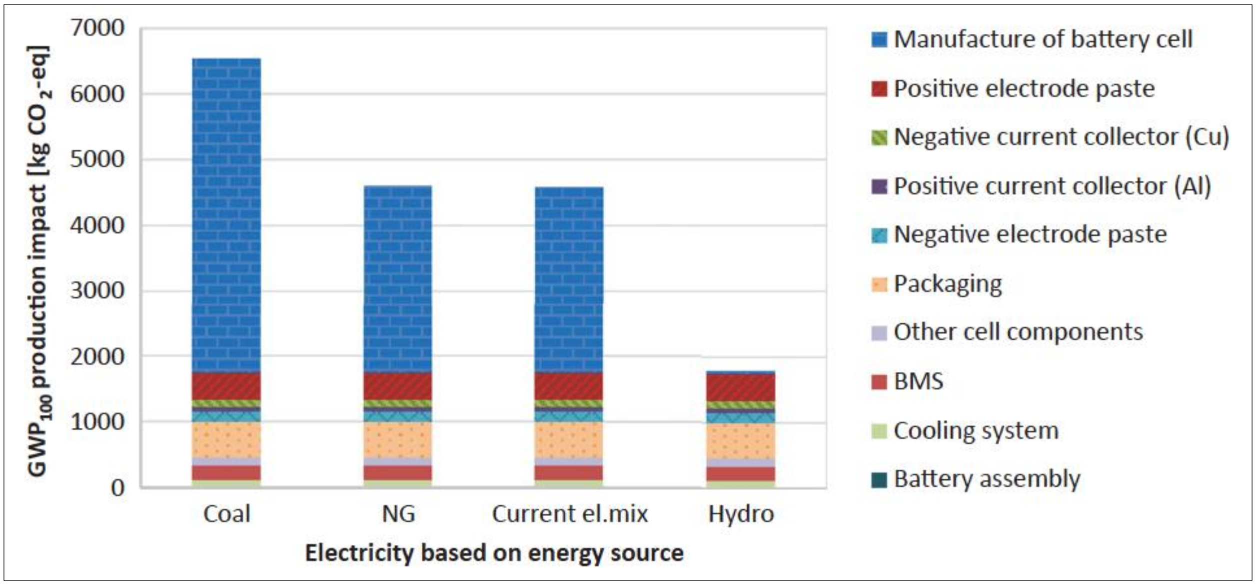


SOURCE: Excerpted from Tong et al 2015 data table.

On Battery Manufacturing Emissions

EVs tend to have somewhat higher manufacturing emissions than conventional gas cars due to the additional requirement of making the lithium-ion batteries. The size of this impact, too, depends on where the manufacturers get their energy. A research team from the University of Norway recently found that making a 26 kWh battery pack produces about 4.6 metric tons of carbon dioxide equivalents on Europe's current electricity mix. For comparison, this is about the same emissions as one year's worth (12,000 miles) of gasoline use in an average gas car. The battery manufacturing emissions fall to about 1.8 metric tons if the factory gets its power from renewables. It should be noted that Tesla Motors and Panasonic are covering their battery "gigafactory" roof – currently under construction outside Reno, Nevada – with acres of solar panels, so it's reasonable to expect that production impacts will fall as manufacturers themselves adopt renewable energy. Similarly, BMW located its carbon fiber manufacturing at Moses Lake, Washington for the i3 car, which uses hydropower, giving that vehicle not only very good efficiency due to the lightweight construction but also low manufacturing emissions.

Figure 3 – Lithium-Ion Battery Production Emissions Using Various Energy Sources



SOURCE: Ager-Wick Ellingsen et al, 2013

National Emissions Reduction Potentials from Transportation Electrification

The Electric Power Research Institute and the Natural Resources Defense Council recently projected that widespread transportation electrification can reduce transportation sector emissions by 52% in 2050, or 60% if less carbon-intensive generation resources are chosen. Current fuel efficiency standards are expected to drive a 24% reduction over the same period, with the difference driven by electrification. To achieve this, about 60% of all personal and commercial (short-haul) vehicles on the road would need to be electrified. It's also important to note that the study's base case assumes that combined-cycle natural gas will the dominant source for new generation to meet these transportation needs, with lesser contributions from wind and solar. A harder push for renewables could deepen these emissions reductions even further.

Exceptional Northwest Regional Promise for Decarbonization

The carbon intensity of the electricity grid varies widely from grid region to grid region. The northwest, and Washington and Oregon in particular, are uniquely positioned to lower greenhouse gas emissions in the transportation sector through electrification.

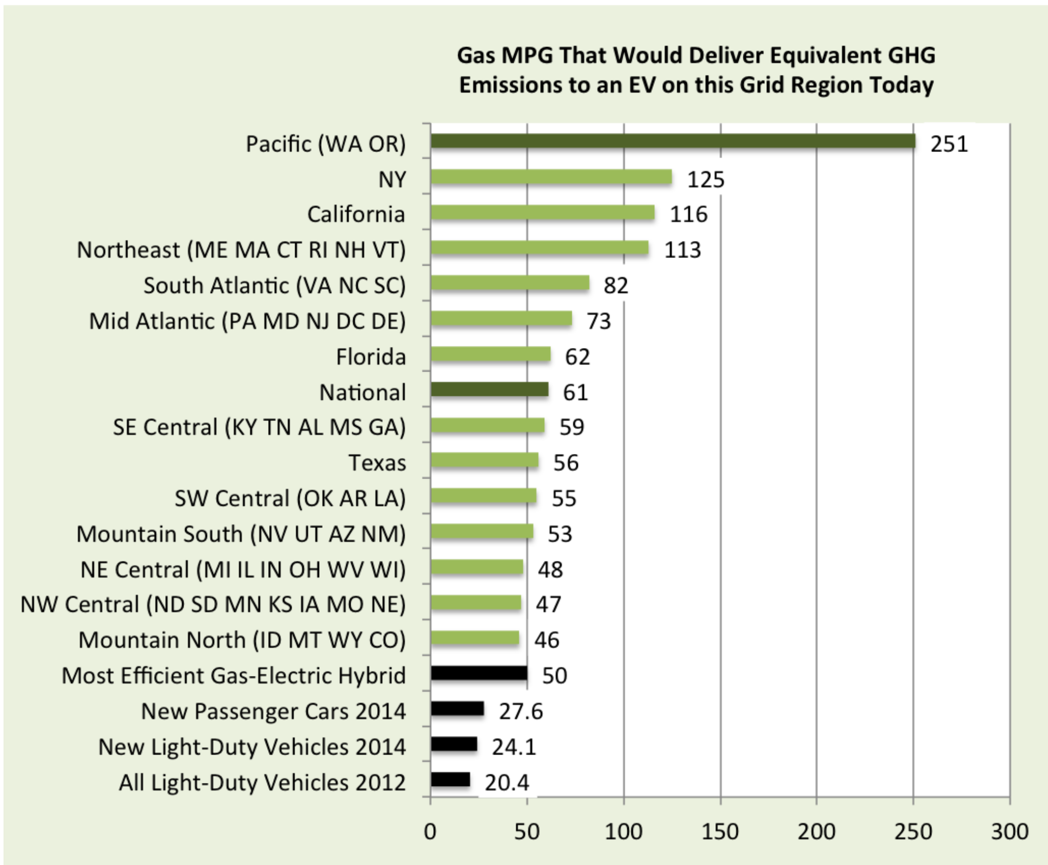
Study #1 – EPRI/NRDC – Their 2015 report also calculated the relative emissions performance of plug-in vehicles in grid regions across the country. Figure 4, which is adapted from their results table, provides several takeaways:

- EVs beat conventional gas cars on emissions performance today in every grid region studied.
- In Washington and Oregon, EVs beat the best hybrids by a factor of 5 and conventional cars by a factor of 9 or 10.
- On a national basis, EVs beat the best hybrids (61 MPG equivalent vs. 50 MPG), but hybrids beat EVs slightly in several of the more coal-dependent regions of the central U.S. From an emissions

standpoint, one might be indifferent between an EV and a high-performance hybrid in those regions.

It is also important to remember that these comparisons are reflective of today's electricity grid. Retirements of coal plants – both those already scheduled and those that will be driven by the EPA's Clean Power Plan – will improve emissions performance as the national and northwest grids get cleaner.

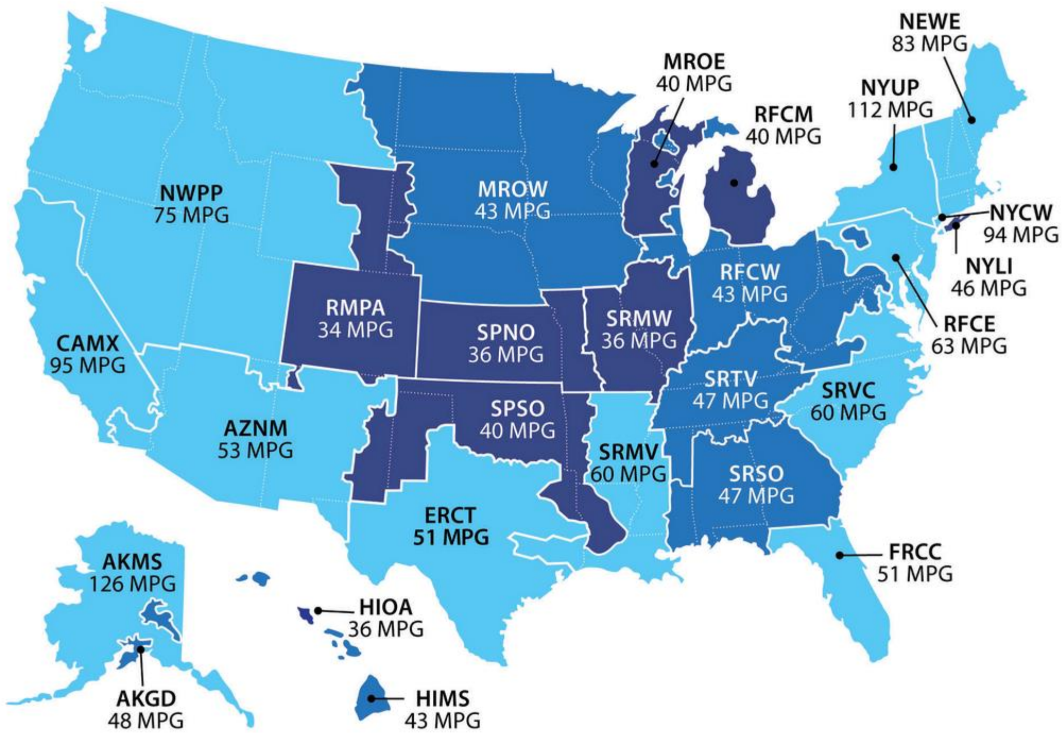
Figure 4 – Equivalent Emissions Performance of EVs, Hybrids, and Gas Cars on U.S. Grid Regions



SOURCE: Adapted from EPRI/NRDC

Study #2 – Union of Concerned Scientists, State of Charge – Though they used different geographic groupings, the Union of Concerned Scientists came to similar conclusions in their "State of Charge" study. EVs beat the average gasoline vehicle nationwide and beat hybrids in all but the most coal-dependent parts of the country.

Figure 5 – Gas Mileage Required to Generate Equivalent Lifecycle Emissions Performance as an EV on Each Grid Region



SOURCE: Union of Concerned Scientists, 2014 Update

The Union of Concerned Scientists also evaluated EV emissions by electricity fuel source using a method that includes the lifecycle emissions embedded in the making of various types of energy, including wind and solar. The results are shown in the table below and indicates a pattern similar to the map above: fossil–powered EVs are roughly comparable to efficient gas cars or hybrids, while renewable powered EVs are orders of magnitude better.

Generation Source	Well-to-Wheels Emissions-Equivalent MPG
Coal	30
Oil	32
Natural Gas	54
Solar	500
Nuclear	2,000
Wind	3,900
Hydro	3,800
Geothermal	7,600

SOURCE: Union of Concerned Scientists, 2012

Societal Benefit #2 – Improved Air Quality

With no tailpipe emissions, widespread electrified transportation can improve local air quality as well, with benefits to human health, particularly for lower-income populations who live near industrial areas or freeways with heavy exposure. Gasoline and diesel vehicles emit a host of toxic compounds regulated by the Environmental Protection Agency (EPA), which include many known carcinogens and causes of respiratory ailments, such as:

- Benzene
- Formaldehyde
- Acetaldehyde
- Acrolein
- Ozone (O_3)
- Naphthalene
- 1,3-Butadiene
- Fine particulates ($PM_{2.5}$)
- Carbon Monoxide
- Sulfur Dioxide
- Volatile Organic Compounds (VOCs)
- Nitrogen Oxides (NO_X)
- Polycyclic aromatic hydrocarbons (PAH)

Depending on the electricity generation source, there may be countervailing emissions at the point of generation, but these emissions are often easier to control as a large point source.

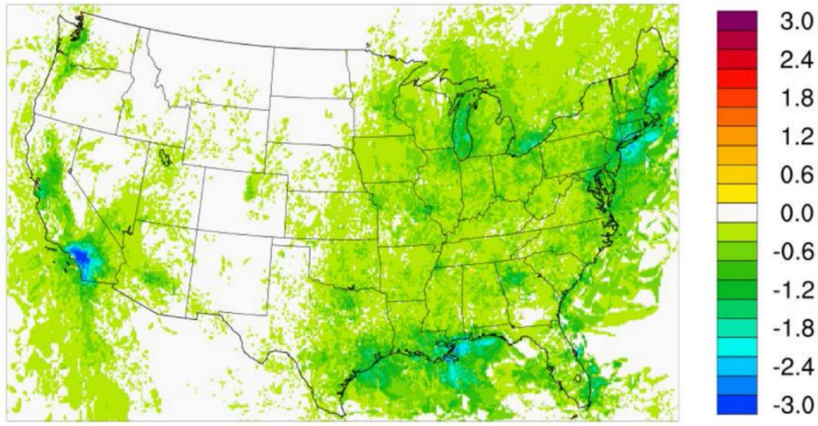
Agencies responsible for meeting the region's federal air quality standards are now turning to transportation electrification as a key strategy. For example, Western Washington Clean Cities, a U.S. Dept. of Energy program hosted by the Puget Sound Clean Air Agency, is working with employers to promote fleet electrification, in part to make sure that ozone and other pollutant limits do not exceed federal standards. In 2010, the agency concluded that "mobile sources (car, trucks, ships, etc.) contribute most to health risk from air toxics" for the Seattle-Tacoma area. Certain Tacoma neighborhoods face the highest overall health risk. Diesel particulates are responsible for 70 percent of the cancer risk from air toxics in Seattle's Beacon Hill and Duwamish neighborhoods.

- Tessum *et al* modeled vehicle and electricity impacts in an impressive national spatial model that assessed the location of emissions and population, the transport of pollutants and their chemical lifecycles, with a particular emphasis on fine particulates and ozone. The study found that (even after taking battery and manufacturing impacts into account) EVs powered by clean energy sources reduced air quality-related health impacts and mortalities by 50% in the case of a vehicle powered by natural gas electricity; and 70% for vehicles powered by renewables (wind, water and solar). It should be noted that the same study found problematic increases in air quality impacts for EVs powered by coal, but the northwest, with its preponderance of zero- to low-emission generation sources should be in a favorable position to reap the air quality benefits described above.

- The California Electric Transportation Coalition (CalETC) modeled air quality impacts for transportation electrification in that state, including passenger vehicles and other industrial uses such as forklifts, shore power, etc. Their "aggressive adoption" scenario found that by 2030, transportation electrification could reduce emissions of particulates by 1.3 tons per day and reduce emissions of nitrogen oxides and reactive organic compounds by 72 tons per day. These reductions may prove highly valuable, as health studies tend to put the highest externality price on particulates, often in the hundreds of thousands or millions of dollars per ton.

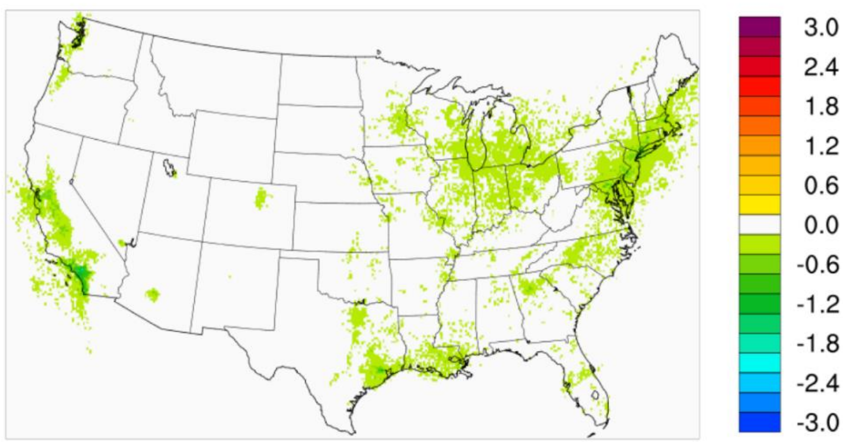
- EPRI/NRDC (see Figure 6, Figure 7, and Figure 8 below) also modeled air quality impacts to vehicle electrification in a recently released study, though their electrification scenario for air quality was different from their scenario for greenhouse gases. The air quality work looked at moderate electrification by 2030 totaling 17% of light-duty vehicles, 8% of heavy-duty vehicles, and varying amounts of non-road equipment, including lawnmowers, forklifts, shore power, and airport ground equipment. The study estimated the net change in emissions from burning petroleum fuels vs. providing electric power for various pollutants. They found that, nationally, electrification can reduce NOx by 3%, VOCs by 4%, SOx by 0.5% and $PM_{2.5}$ by 1.1%. In some cases, non-road electrification had the largest benefits.

Figure 6 – Net Decreases in Max Ozone Concentrations from Transportation Electrification



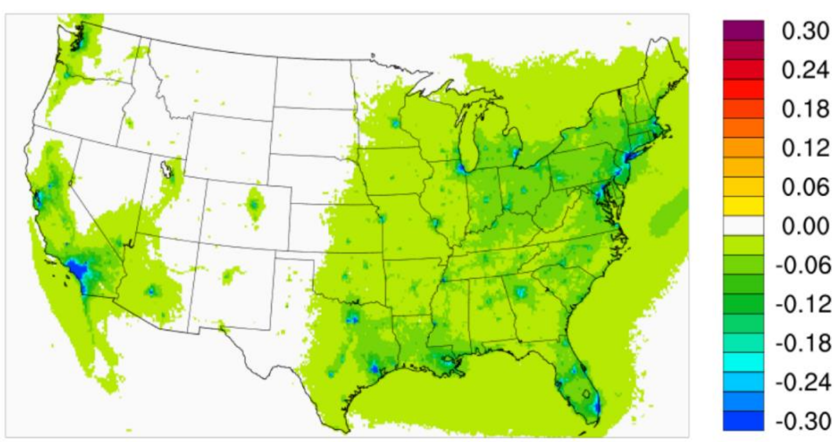
SOURCE: EPRI/NRDC 2015. Units in parts per billion.

Figure 7 – Net Decreases in Max Concentration of Fine Particulates ($PM_{2.5}$) from Transportation Electrification



SOURCE: EPRI/NRDC 2015. Units in micrograms per cubic meter.

Figure 8 – Net Decreases in Nitrogen Deposits from Transportation Electrification



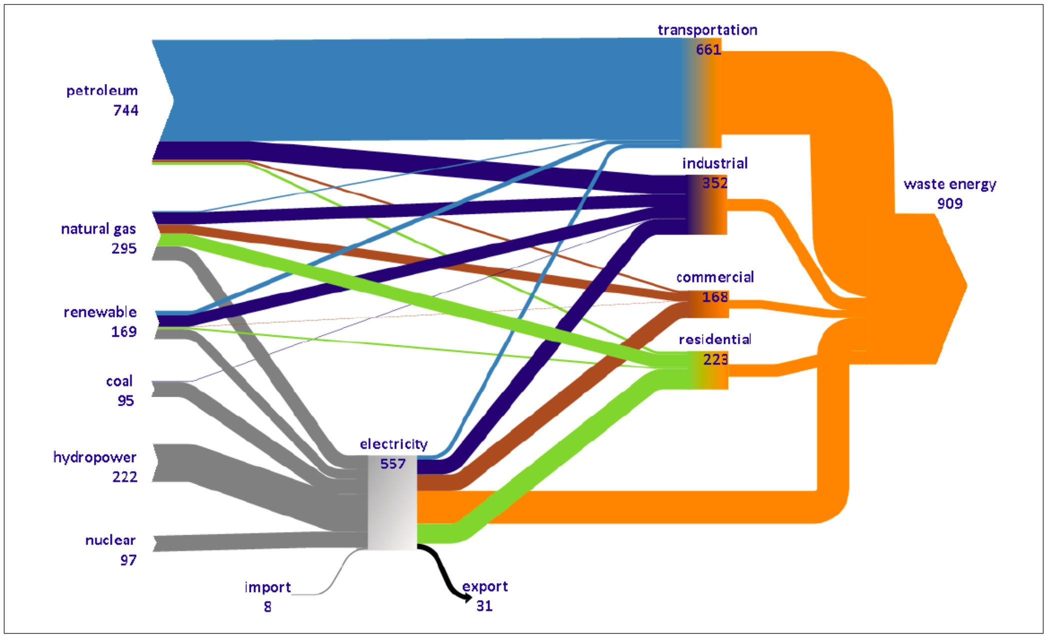
SOURCE: EPRI/NRDC 2015. Units in kilograms of nitrogen per hectare per year.

Societal Benefit #3 – Greater End-Use Energy Efficiency

The transportation sector is currently the most wasteful sector of our economy, and electrification offers an opportunity to improve that. Transportation is wasteful because, despite more than 100 years of research and development, the internal combustion engine (ICE) is still only 20% to 25% efficient in translating the energy content of gasoline into forward motion on the wheels. A typical ICE car loses up to 80% of that energy content as waste heat. By contrast, an EV powered by an electric motor is about 60% efficient in translating the energy content of the battery into forward motion on the wheels, a three-fold increase.[1] Consequently, EVs can be thought of as just another energy-efficient appliance, like an LED bulb or a heat pump that does the same job as a prior technology but using less energy.

The graphic below, from the Washington Department of Commerce's 2013 energy report, shows how energy is generated, used, and wasted in the state. Transportation "deliver[s] only 26 percent of the primary energy as useful energy services, and losing the remainder as waste heat."

Figure 9 – Energy Production, Use, and Waste in the Washington Economy in trillions of BTUs



SOURCE: WA Department of Commerce Energy Report, 2013

Until recently, the electricity sector and the transportation sector were in separate silos and not connected on the above map. EVs have linked them functionally, but they remain largely separated in policy. Northwest electric utilities have a variety of energy efficiency programs targeting industrial, commercial, and residential sectors, as well as the efficiency of electricity generation itself. These are mandated under laws like the federal Northwest Power Act of 1980 and Washington's Energy Independence Act (I-937). However, utility programs targeting transportation are just getting started.

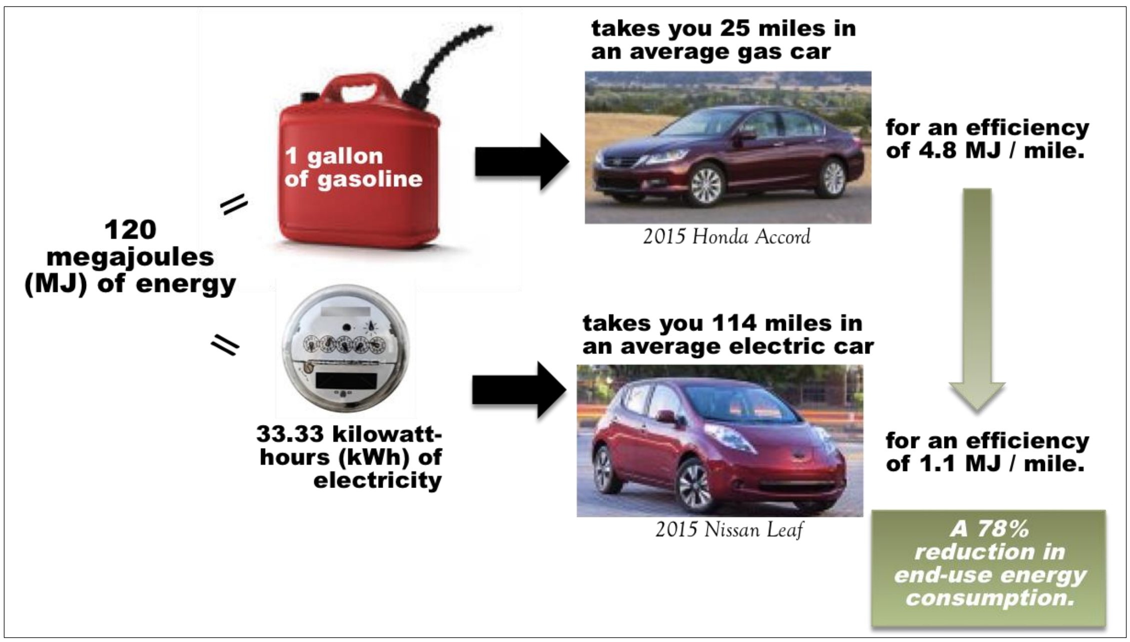
[1] Gasoline does succeed, however, in being far more energy dense by weight and by volume than today's generation of lithium-ion batteries, which accounts for EVs' shorter ranges.

Cross-Fuel Efficiency Defined

Our energy use takes multiple forms – gasoline, natural gas, electricity, biomass, etc. – but all can be rendered into equivalent units based on their energy content, which is based on the fuel's ability to do work. Multiple units of measurement are possible here – BTUs, therms, calories, etc. The IPCC uses Joules and so will this paper. The IPCC estimates that the global human population consumes about 500 exajoules (EJ, 10^{18}) of energy annually from all sources.

In considering cross-fuel efficiency, it's important to understand a key equivalence between the fuel sources. A gallon of gasoline contains 120 million joules (mega, MJ, 10^{6}) of energy. This can take an average car 25 miles. That same energy content in the form of electricity would equal 33.33 kilowatt-hours (kWh). Due to the greater efficiency of the electric motor, this can take a typical EV 114 miles. This means that EVs reduce the amount of energy consumed per mile by 78%, from 4.8 megajoules per mile to 1.1 on "wall-to-wheels" basis.[2] Applied broadly across the transportation sector, this represents a major conservation opportunity.

Figure 10 – Efficiency Equivalence Between the Internal Combustion Engine and the Electric Motor

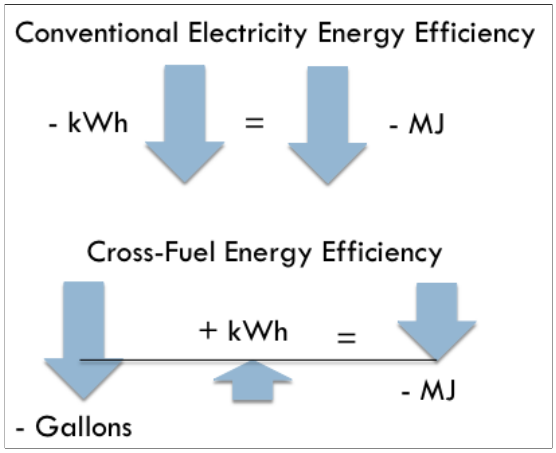


SOURCE: NWEC illustration based on EPA fuel economy ratings.

This cross-fuel efficiency presents a new pattern for the electric utilities and for policy, as shown in Figure 3. Traditional conservation programs reduce kWh and MJ on a one-to-one basis. Cross-fuel efficiency, on the other hand, reduces energy in the form of gallons, while increasing use in the forms of kWh, for the net reduction in MJ described above.

[2] Other styles of analysis not shown here include "well-to-wheels" analysis across the full lifecycle of each fueling chain.

Figure 11 – Patterns of Traditional Energy Efficiency vs. Cross-Fuel Efficiency

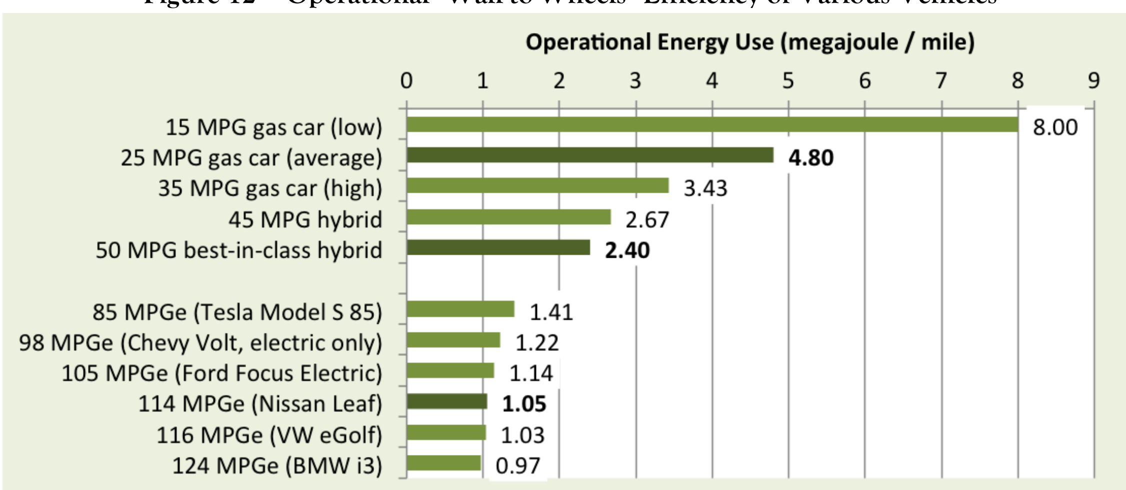


SOURCE: NWEC Illustration

Efficiency of EVs vs. Gasoline Cars and Hybrids

The relative efficiency of various vehicles can be seen in Figure 4. Even the heaviest and least efficient EV uses less total energy per mile than the best-in-class hybrid.

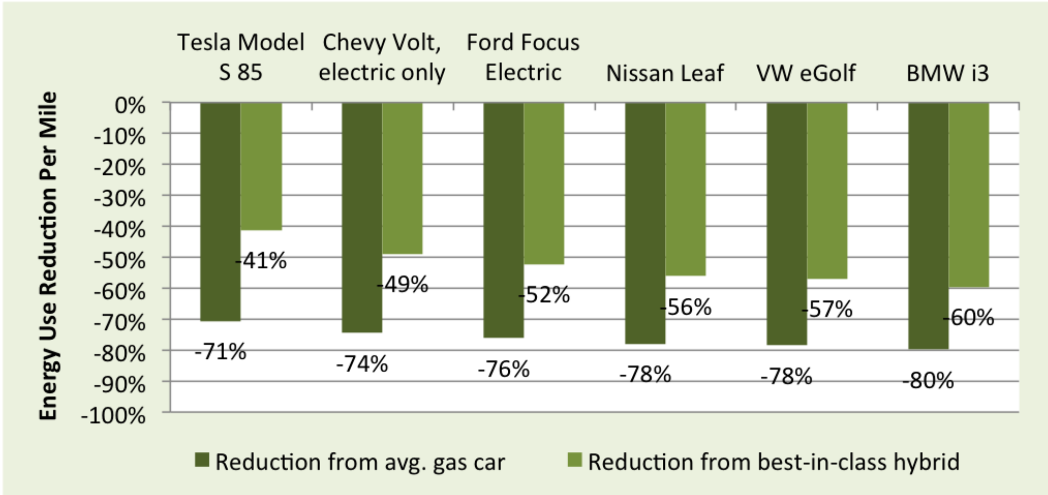
Figure 12 – Operational "Wall-to-Wheels" Efficiency of Various Vehicles



SOURCE: NWEC calculations based on EPA fuel economy ratings. Includes all charging losses.

We have seen similar gains with appliance efficiency standards promulgated by the Department of Energy. For example, current model refrigerators use one-third of the energy that refrigerators used a generation ago, and clothes washers have seen a 70% reduction in energy use. By the same token, EVs represent a 70%-80% decrease in energy use compared to the average gas vehicle for the same task. And they represent a 40% - 60% reduction in energy use compared with the best available hybrid, the Toyota Prius C.

Figure 13 – Energy End-Use Reduction Per Mile, Various EVs vs. Average Gas Car or Best-in-Class Hybrid (Toyota Prius C)



SOURCE: NWEC calculations based on EPA fuel economy ratings.

It should be noted that the above analysis is limited to the *operation* phase of these vehicles. Lifecycle analyses tend to show that *producing* an EV requires more energy than producing a gas car, largely due to the increased requirements for battery manufacturing. However, these analyses show that EVs still achieve lower total lifecycle energy per mile driven and (in clean grid regions) lower total emissions than gas-powered vehicles and high-efficiency hybrids (see greenhouse gas section for more on lifecycle impacts).

Well-to-wheels comparisons – The above statistics show end-use energy efficiency gains only. Several commenters have said that EVs should be evaluated with an eye to upstream efficiency losses as well, which include the efficiency of the electricity generation as well as transmission and distribution losses. On the gasoline side, a full pathway analysis would similarly account for the energy used in extraction, refining and transport of the fuel, which can add almost 20% to the total energy cost of a gallon of gasoline. Oak Ridge National Labs looked at a full pathway analysis of energy efficiency with particular attention to natural gas.

Figure 14 –Well-to-Wheels Energy Use of Conventional Gas Car vs. Hybrids vs. EVs

	Approximate Well-To-Wheels Energy Use (MJ/mi)	Reduction from Avg. Gas Car	Reducton from Avg. Hybrid
Average Gas Car (26 mpg)	5.6		
Average Hybrid (36.4 mpg)	4.0	-29%	
EV (99 MPGe) on US Grid Mix	3.1	-44%	-22%
EV on Coal Power	3.9	-31%	-4%
EV on High-Efficiency Natural Gas Generation	2.8	-50%	-30%
EV on 50% Renewables	2.4	-57%	-40%

SOURCE: Adapted from Oak Ridge National Lab, Curran et al. 2014.

They found that EVs powered by the national grid mix reduce well-to-wheels energy use by about 44% compared with an average gas car and by 22% compared with an average hybrid. On a grid mix with high renewables, the gains are stronger – EVs use about 57% less energy than a conventional gas car and about 40% less than an average hybrid. The study did not model hydropower efficiency specifically, but that should show even better performance in the northwest given the high efficiency of hydropower generation. It also should be noted that these comparisons assumed the 99 MPGe efficiency of the 2012 Nissan Leaf. The EPA rates subsequent models about 15% better at 114 MPGe, which would improve the performance reported above.

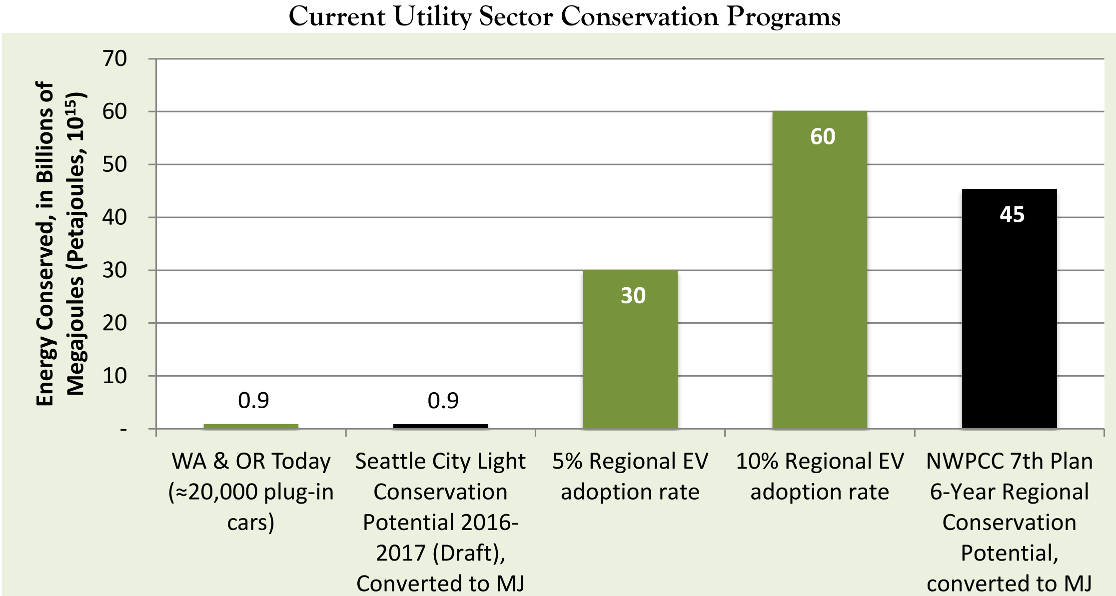
Comparison to Existing Utility Conservation Programs

Conservation potentials from transportation electrification look to be of a similar order of magnitude to the utility conservation programs supported by the NW Energy Coalition and its members.

On an individual car basis, a gas car at average efficiency (25 mpg) driving 12,000 miles in a year would consume 480 gallons of gasoline, or about 57,600 MJ. An EV doing the same drive would consume 3,500 kWh, or about 12,600 MJ. The switch to an EV saves almost 45,000 MJ.

Figure 6 shows this calculation scaled up to the region. The approximately 20,000 plug-in vehicles on Washington and Oregon roads today conserve about 1 billion MJ annually compared to the average gas cars they replaced. This is about the size of a large utility conservation program, such as Seattle City Light's, whose current draft conservation potential assessment is also projecting about 1 billion MJ of conservation (27 average megawatts, aMW) over the next two years. Scaling these figures up, if the northwest region were to achieve a 5% EV adoption rate (around 670,000 vehicles) in the coming years, this would conserve 30 billion MJ annually. A 10% rate would double all those figures. These totals are in the same ballpark as the Power Council's 7th Plan conservation potentials, which are calling for 1,440 aMW of cost-effective conservation over the next six years, about 45 billion MJ.

Figure 15 – Relative Conservation Potentials (in Joules) From EVs and Current Utility Sector Conservation Programs



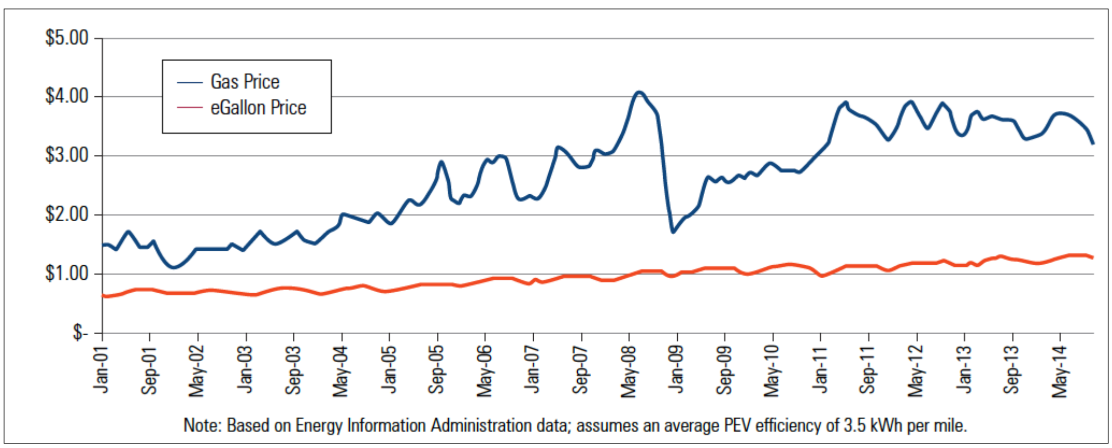
SOURCE: NWEC calculation. Represents the difference in joules consumed by an average gas car at 25 mpg for 12,000 miles vs. an EV at 114 MPGe.

Societal Benefit #4 – Low and Stable Operating Costs

EVs often cost about $10,000-$12,000 more than their conventional gas counterparts, though that difference is expected to decrease over time as battery manufacturing costs decrease and efficiencies of scale are achieved. Current incentives can help consumers bridge that upfront hurdle, including as the $7,500 federal income tax credit and Washington's sales tax exemption, which can be worth up to $3,500 on the sale of an EV (less on a lease). Economic studies suggest that upfront costs loom large with consumers, who tend to heavily discount future operational savings and focus more intently on the purchase price. For example, one study estimated that consumers in the mid-2000s implicitly discounted future gas savings by 15% annually when deciding between a hybrid or conventional gas vehicle purchase. In addition, low income can be a significant barrier to financing and acquiring an efficient vehicle.

Much as it was with hybrids, if consumers can get over the upfront cost hurdle of EVs, the vehicles offer clear operational cost savings and a good total cost of ownership proposition. Figure 16 shows that the price of electricity has been consistently lower and more stable than gasoline. The Department of Energy's "eGallon" methodology implicitly includes the greater efficiency of the electric motor.

Figure 16 – Relative Price of Gasoline and Electricity for Transportation 2001-2014



SOURCE: EIA data shown in Collaborative Efficiency / NRCEA report.

Though gas prices have fallen recently, the northwest region shows some of the biggest gas/electricity price difference in the country, as summarized by Table 2 below.

Table 2 – Savings per Gallon/eGallon of Fuel Used in the Northwest Region

	WA	OR	ID	MT	Nation
Gasoline Price	$3.02	$3.01	$2.73	$2.73	$2.78
eGallon Price	$0.86	$1.04	$0.95	$1.05	$1.22
Savings	$2.16	$1.97	$1.78	$1.68	$1.56

SOURCE: Department of Energy website http://energy.gov/maps/egallon

These savings can amount to over $1,100 per vehicle annually compared to an average gas car, or up to $380 per vehicle compared to a hybrid.

Table 3 – Fuel Cost Savings Gas Cars vs. EVs at Washington and Oregon Average Gas and Electricity Price

		Cost / mi	Annual Fuel Cost (12,000 mi)	Annual Fuel Cost Savings vs. Avg. Gas Car	in %	Annual Fuel Cost Savings. Vs Best-in-Class Hybrid	in %
Gas Cars	15 MPG gas car (low)	$ 0.20	$ 2,412				
	25 MPG gas car (average)	**$ 0.12**	**$ 1,447**				
	35 MPG gas car (high)	$ 0.09	$ 1,034				
	45 MPG hybrid	$ 0.07	$ 804				
	50 MPG best-in-class hybrid	**$ 0.06**	**$ 724**	$ (724)	-50%		
EVs	85 MPGe (Tesla Model S 85)	$ 0.04	$ 463	$ (984)	-68%	$ (260)	-36%
	98 MPGe (Chevy Volt, electric only)	$ 0.03	$ 402	$ (1,045)	-72%	$ (322)	-44%
	105 MPGe (Ford Focus Electric)	$ 0.03	$ 375	$ (1,072)	-74%	$ (348)	-48%
	114 MPGe (Nissan Leaf)	$ 0.03	**$ 346**	**$ (1,102)**	-76%	**$ (378)**	-52%
	116 MPGe (VW eGolf)	$ 0.03	$ 340	$ (1,108)	-77%	$ (384)	-53%
	124 MPGe (BMW i3)	$ 0.03	$ 318	$ (1,129)	-78%	$ (406)	-56%

SOURCE: NWEC calculation. Assumes $0.10 per kWh and $3.02 per gallon bi-state average costs.

Maintenance costs for electric motors also run cheaper than gasoline cars, with fewer moving parts and no oil changes required.

Societal Benefit #5 – Greater Energy Security

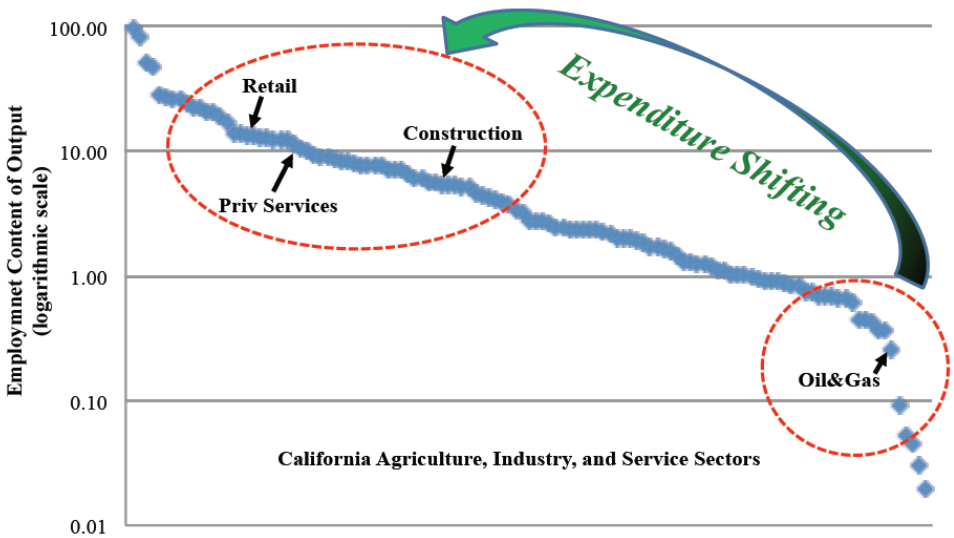
The reliance of U.S. transportation on foreign produced oil is a concern to many Americans. Historically, the country has been the target of oil embargos and other price manipulation from the OPEC oil cartel. Control of the oil supply has also been a major factor driving U.S. involvement in Middle East wars, imposing great expense in both money and lives from military activity. A greater reliance on domestically produced energy for transportation may help shield the country from these market pressures and reduce the need to get involved in foreign conflicts. Research suggests that these concerns are a motivating factor for green vehicle adoption among military-connected and/or more politically conservative citizens. One study on hybrid vehicle adoption rates in the mid-2000s found that greater levels of military service were associated with an 11% higher rate of hybrid vehicle adoption, even after controlling for other factors (such as gasoline price, state purchase incentives, and environmental concern) in a multivariate statistical model. And anecdotally, at least one Washington Republican State Representative (and retired Air Force Lt. Col.) is fond of telling audiences that driving his Nissan Leaf is "the most patriotic thing I do all day."

Societal Benefit #6 – State & Regional Economic Gains

Several macroeconomic studies of EVs have shown gains to state and regional economies due to reduced fuel costs. Fuel cost savings allows drivers to retain more of their disposable income and spend it on other goods and services in the economy, which the analysis shows are often much better producers of jobs and economic activity than the petroleum sector.

CalETC hired economists at Berkeley who calculated that EV deployment in California would boost the Gross State Product (GSP) from between $5 billion to $8 billion by 2030, and create net new job growth of 50,000 to 100,000 jobs. This is partly due to greater state income from the federal EV income tax credit, and partly due to the fuel cost savings. The economists estimate that each $1 spent on other goods and services in the local economy creates 16 times as many jobs and economic activity as the same dollar spent on petroleum sector, which is one of the weakest employment-generating sectors in the entire economy.

Figure 17 – Employment Intensity by Sector



SOURCE: CalETC / Roland-Holst / Berkeley 2012

The Keybridge Economic Group applied similar macroeconomic analysis to Washington and Oregon during the 2015 Legislative sessions. They found that:

- In Oregon, introduction of a state vehicle purchase incentive would add nearly 2,600 EVs to the road annually and improve state GDP by $83 million over the following 16 years. This figure is net of the government's cost of providing the rebates and is due largely to fuel savings that get spent in job-producing sectors of the local economy, as well as the income boost to state residents when they receive federal income tax credits for EV purchases.

- In Washington, the analysis was similar. Renewing the Washington's sales tax exemption on EV purchases and leases is associated with an additional 2,100 EV sales annually, which is expected to boost state GDP by $68 million over 16 years (net of government incentive costs) for the same reasons.

Utility Benefits – Introduction

To date, very little applied research has been conducted mapping the potential benefits and impacts of transportation electrification to northwest-specific utilities and grid conditions. What follows is a set of preliminary thoughts and reports from research on national grid norms or from California. The results here may depend on a variety of factors, including whether the utility's generation is hydro-dominant or more of a mixed portfolio, whether the utility has balanced generation resources or is long on power and selling substantially into wholesale markets, whether a short-run marginal or a long-run view is taken, and whether we look at small-scale deployments (thousands of vehicles) or much larger scales (millions) over time. Much additional work is required to get a sense of the net effects on utility systems and ratepayers in each of these cases.

Increased Utilization of the Existing Electricity Grid

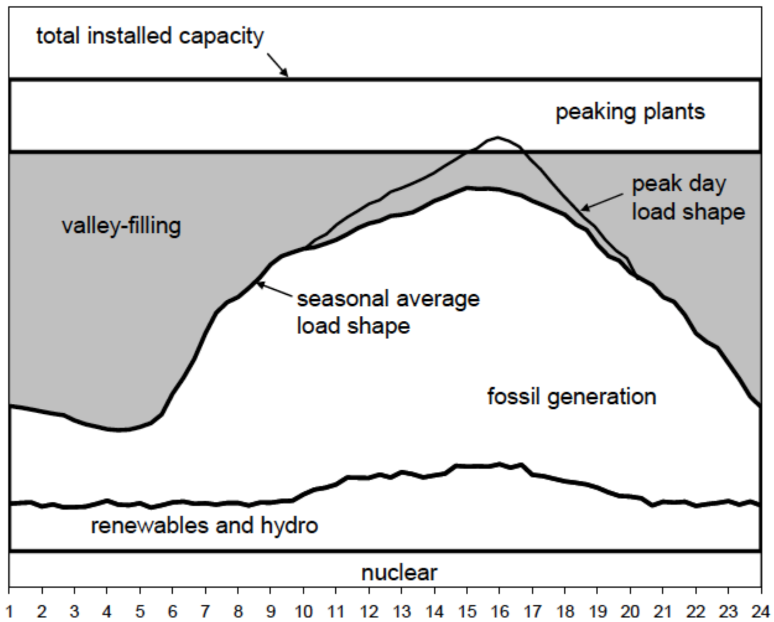
Many northwest utilities are facing relatively flat load forecasts with less than 1% annual load growth, and some are actually seeing declines. This is largely due to the tremendous success the region has had in improving energy efficiency. Better federal and state building codes and equipment standards are driving U.S. consumers toward electric appliances that consume half or less of the energy that older appliances did, with prominent examples including LED light bulbs, new refrigerators, and microwaves. As a result, many utility load forecasts are growing hardly at all, even as population increases, and the 7th Plan from the Northwest Power and Conservation Council is showing that future gains in conservation can supply virtually all of the new needs for the next decade.

Electrifying transportation provides an opportunity to utilize existing utility assets to a greater degree and provide utilities with "good load" opportunities that reduce environmental impacts, lower transportation costs, and create some potential downward pressures on rates, to the extent that the additional sales help spread their fixed costs over more units.

Filling in the Valley

Electrical grids are sized to meet peak demands and may only operate near full capacity for a small number of hours in a year. This leaves many existing generation, distribution and transmission assets underutilized for much of each day and much of the year.

Figure 18 – Peak and Excess Capacity for a Stylized Electrical Grid[3]



SOURCE: PNNL Kinter-Meyer et al, 2007

Since most vehicles sit parked for much of the day and often all night, drivers have many choices for when and how quickly they charge. This provides an opportunity to shape charging loads around excess grid capacity. A typical Level 1 (1.4 kW) charge rate provides about 4 miles of range per hour of charge. A typical Level 2 (6.6 kW) charge rate can provide about 20 miles per hour plugged in. So an average daily commute drive of 30 miles would require 7.5 hours or 1.5 hours of charging, respectively. If a vehicle sits idle for 8 hours during a workday or 10-12 hours overnight in a home garage, this allows considerable flexibility in both the power level and timing of vehicle charging.

The Pacific Northwest National Lab (see Figure 18 above) examined excess capacity in 2007, using a dispatch model that excluded peaking plants. Their analysis asked the question of what share of light-duty vehicles could be powered by electricity for a 33-mile daily drive without causing a single dollar to be invested in new generation assets. PNNL found that if the grid "valleys" were optimally filled in with charge management programs:

- Nationally, 73% of the light-duty vehicle fleet could be converted to plug-in hybrids without adding any generation capacity, and
- In the Northwest Power Pool[4] region, 18% of the light-duty fleet (2.8 million vehicles) could be converted with no additional generation.

These figures are probably best considered upper bounds, as optimal valley filling is almost certainly not practical. However, these upper bounds are at least two orders of magnitude larger than the current rate of

[3] This generation mix is obviously not reflective of the northwest, which also runs much closer to peak capacity than the national average view shown here.
[4] Which includes Washington, Oregon, Idaho, Montana, Wyoming, Utah. The study did not analyze for British Columbia and Alberta.

plug-in vehicle adoption in the northwest (approximately 20,000), so considerable headroom should exist for transportation electrification.

Previous analyses have shown that shifting load to the nighttime in the northwest may have the effect of dispatching more coal-fired power. So it's possible that valley filling and time-of-use rates could impair the average environmental performance. These analyses, however, were conducted before the deployment of large scale wind resources in the region, so they would need to be revisited to determine current performance. Moreover, this concern may also abate as coal-fired resources are retired.

Integrating Renewable Energy

A second potential grid benefit may come in better matching variable renewable generation resources to demand. Again, given the large flexibility of vehicle charging times, charge management programs or price signals (such as time-of-use rates) can match vehicle charging to overnight periods when wind generation may exceed demand or to mid-day periods where solar does.

In the northwest, it appears that integration with overnight wind generation is likely to be the dominant factor. Under some conditions, when the hydro system is running at high capacity and the wind is blowing during periods of low overnight demand, the spot price of power can go negative and wind curtailments may be ordered. EV charging could soak up some of that excess generation. In the sunnier, most easterly sections of northwest states, integrating with solar may play a bigger role, depending on future adoption rates. Time-varying rate schedules can be developed for use to address night or day excess generation. However, since vehicles are likely to be at work during the solar generation peak, this form of renewables integration will likely require deployment of large amounts of workplace charging infrastructure (and to a lesser extent public place charging).

Other Potential Grid Benefits (V2G)

Various models for vehicle-to-grid integration have been proposed by the Regulatory Assistance Project and others, and many are undergoing pilot testing. The vision for this often involves a high degree of automation, where the user can set parameters on a smartphone, such as "have my vehicle 80% charged by 6 a.m." for a morning commute, or "have it fully charged by 5 p.m." for an evening commute. The utility then manages the power flow within that constraint to optimize for cost or grid benefits. It remains unclear, however, which of these models might provide a compelling enough business case to warrant widespread implementation.

- **V2H** – Using vehicle batteries as a home power backup in case of a power outage is often called vehicle-to-home (V2H). Some manufacturers (Nissan) are currently selling V2H functionality in limited areas. This may have some value as a backup system, but since outages are rare, this value is unlikely to be very large.

- **V2O** –Vehicle batteries may also be used to supply power to other locations (V2O), such as worksites. An example of this is the Via Motors' PHEV truck, which has two-way flow capabilities to power tools or other equipment at a worksite.

- **V1G** – Models that control the one-way flow of power to serve utility needs are often labeled "V1G". This may involve real-time pricing or time-of-use rates to match the load to intermittent generation or otherwise reduce the likelihood that transportation loads will exceed capacity limits. Other V1G applications include varying transportation loads to maintain power quality or provide ancillary grid services, such as frequency regulation, which involves balancing overall grid supply and demand on small time scales (seconds). Such models would require a high degree of automation and the presence of an entity that can aggregate small 3 and 6 kW vehicle loads into the MW ranges that are necessary for grid services. It remains to be seen whether such aggregation is logistically feasible and whether the cost of the automation can be low enough to make aggregated transportation loads a competitive supplier of these grid services.

- **V2G** – Models involving two-way flow of power from vehicles to the grid are often labeled "V2G". This may allow for bulk storage of energy to be used by the utility for peak demand needs, or additional grid services such as two way (up and down) frequency regulation. Again, it remains to be seen whether the costs will allow transportation to be a competitive supplier of these services. Few current plug-in vehicles are equipped for two-way power flow.[5] Even if manufacturers were to embrace the model, the cost to utilities may prove prohibitive. Each charge-discharge cycle on a battery degrades it slightly, so the utility would need to compensate the vehicle owner for the depreciation of their private battery asset. This cost has been estimated as high as $0.20 - $0.40 / kWh, which may well be more than the value of the service being provided. And while battery costs will decline with further increases in scale of battery manufacturing, it seems likely that stationary storage (that is owned and operated by a utility or a grid services company) will pencil out before mobile storage does. Stationary storage would also appear poised to avoid the logistical hurdles and additional cost of aggregating hundreds of individual vehicles out in the world.

Potential Downward Pressure on Rates

Adding transportation uses to the electrical grid will drive additional energy sales for northwest utilities, which could amount to $300-$500 per vehicle in gross revenue annually, as shown in Table 4 below. To get a sense of the scale, at typical efficiency and driving patterns, it would take between 2,000 and 3,700 EVs to add one average megawatt (aMW) of load to the grid. This suggests that the approximately 7,000 EVs registered in King County, Washington currently are adding between 2-3 aMW today.

Table 4 – Annual Incremental Energy Sales and Gross Revenue Per Vehicle

Annual Miles	8,000	10,000	12,000	15,000
Incremental kWh Sold	2,400	3,000	3,600	4,500
Incremental Annual Utility Revenue Per Vehicle	$287	$359	$431	$539

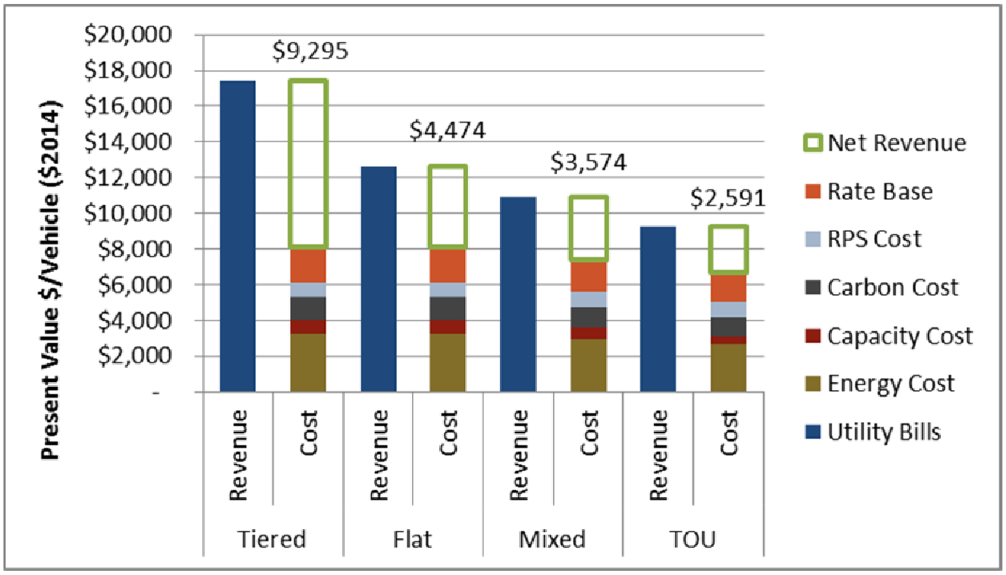
SOURCE: NWEC Calculation.

Assumes Nissan Leaf Efficiency and Seattle City Light's Tier 2 Residential rate of 11.97 cents / kWh

Taking a short-run marginal cost view, this additional load and revenue can put downward pressure on rates, since utility rates typically exceed short-run marginal costs. CalETC has estimated the present value of this net new revenue over the lifetime of the EV at between $2600 and $9300, using California rates. The wide variation reflects the different rate structures that may apply, with both costs and benefits being minimized for time-of-use rates. Whether these short-run effects continue in the long run and at large scale remains a subject for further study and will depend primarily on whether revenues grow faster than costs.

[5] The Via Motors truck and BYD bus are two examples of vehicles that do have two way power.

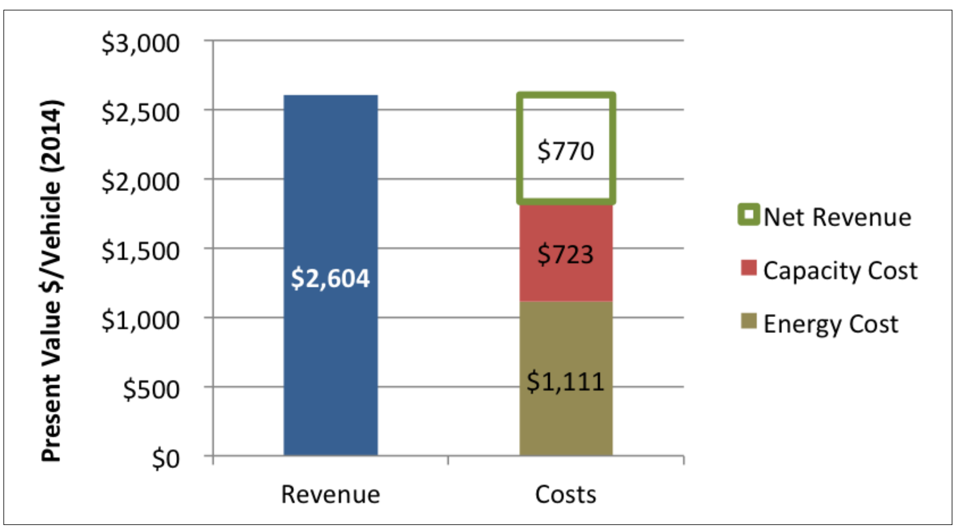
Figure 19 – Ratepayer Costs and Benefits in Several California Rate Scenarios in Present Value per Vehicle



SOURCE: E3/CalETC phase 2

Northwest utility rates are considerably lower than California's, and the net revenue figure here is also lower. Puget Sound Energy calculated it at $770 over the lifetime of an EV as part of the rate docket for their home charging rebate program. It's noteworthy that PSE's analysis assumed a relatively low annual electric utilization (2,400 kWh, equivalent to about 8,000 miles) than the California study as well.

Figure 20 – Ratepayer Costs and Net Lifetime Revenue Per EV



Adapted from Puget Sound Energy Workpaper, 2014

This net revenue headroom also suggests that utilities could provide some programmatic support in rates for vehicle incentives or charging infrastructure without adversely impacting other ratepayers. The size of that headroom and potential for "win-win" space where all ratepayers benefit is likely to be a key factor in regulators' review of the ratepayer interest in any utility spending on electrification.

Electricity Conservation Through Efficiency of Charging

In addition to the cross-fuel efficiency gains described above, there may be opportunities for smaller gains in the arena of traditional electricity conservation through the use of efficient charging modes and equipment. Vehicle battery charging is typically 80% to 90% efficient, with the remainder lost as waste heat during the process.[6] According to published benchmark testing, charging efficiency can vary with many factors, such as ambient air temperature and the power level, with higher power rates (3.3 kW and 6.6 kW) being more efficient than lower power charging (1.4 kW). The efficiency can also vary during the course of the charging event: the charger draws maximum amperage (and is therefore more efficient) on an empty battery and less amperage on relatively full battery, and the power rate drops somewhat steadily over the course of the charge event. This falloff is particularly evident with DC quick charging – the first 80% charge may take 30 minutes or less, but the remaining 20% at steeply falling power levels often requires an additional 30 minutes.[7]

Table 5 (below) shows the conservation potential from higher efficiency charging. Boosting charge rates from Level 1 to Level 2 could increase efficiency up to 2.7%, conserving around 100 kWh per vehicle per year. Though not huge, this conservation potential could be worth $100-$200 per vehicle over its life and may be policy relevant in that it supports traditional conservation. This efficiency gain was considered by the Washington Utilities & Transportation Commission during the review of Puget Sound Energy's $500 Level 2 charging station rebate program docket, forming part of the rationale for commissioning the study of charging behavior, which is currently underway. Boosting charge rates to higher powers may also help shape loads in ways that better map to lower-cost generation opportunities.

Table 5 – Rough Conservation Potential from Optimal Charging

	Level 1 "Wall-to-Tank" Charging Efficiency	Level 2 "Wall-to-Tank" Charging Efficiency	Difference	Annual kWh / Vehicle Conserved at Higher Power Rate	Value Over 15-Year Vehicle Life @ SCL Tier 2 Residential Rate $0.1197 / kWh	# of EVs Charging at Higher Efficiency Needed to Conserve 1 aMW
INL Volt Test	88.8%	90.8%	2.0%	74	$134	117,720
VEIC/FleetCarma (Volt)	83.7%	86.4%	2.7%	112	$201	78,209
Average	86.3%	88.6%	2.4%	92	$166	94,953

SOURCE: NWEC calculation from INL and VEIC testing data.
Assumes 12,000 miles/year and 4 miles/kWh "tank-to-wheels" efficiency.

[6] Note: those charging losses are included in the above cross-fuel calculations. EPA's efficiency factors for each vehicle are a "wall-to-wheels" measurement that most closely approximates the customer's electrical usage and billing.
[7] In recent weeks, Nissan has teased significant improvements in the impedance of its next-generation battery packs, enabling DC charging at higher power levels for longer periods, so this falloff may become less of a factor in the future.

Potential Utility Costs Associated with Transportation Electrification

Other sections of this paper have discussed how EVs can provide additional revenue to utilities and better utilize existing grid assets, putting potential downward pressure on rates. However, transportation electrification will also drive some costs. Available research suggests that the system impacts are likely to be quite modest for some time. The cost of charging infrastructure appears to be the dominant factor, and determining who pays these infrastructure costs and how they are financed is likely to be a key question for utilities and policymakers.

Generation Costs

Transportation electrification is unlikely to drive new generation asset needs in the northwest for the short to medium term. For example, at 22,000 EVs registered in the four-state region, even if each consumes 3,600 kWh per year, this load represents just 0.04% of the 177 million MWH of energy sold in the region in 2014. As shown in Table 6 below, it would take nearly 500,000 vehicles to be a 1% load issue for the utilities. Utilities report that EVs do not yet rate on their load forecasts or integrated resource plans in a measurable way. And as previously reported, PNNL estimated that the northwest could electrify 18% of the light duty fleet without adding a single generation asset, if that charging occurs off peak. Peak capacity is likely to be the first area that would see new capital costs, so it may be cost effective to invest in charge management programs or time-of-use rates to move transportation loads to the off-peak to the greatest extent possible.

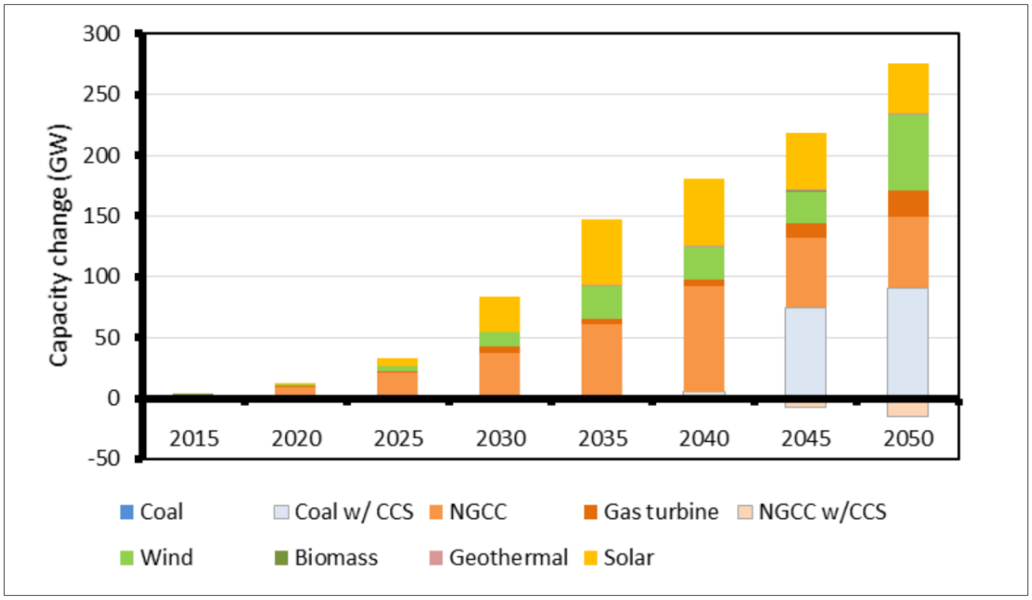
Table 6 – Rough Market Sizing of EVs at Different Adoption Rates

		Approximate Current EV Registrations			
# of Vehicles	**10,000**	**22,000**	**100,000**	**1,000,000**	**10,000,000**
MWH / Year	36,000	79,200	360,000	3,600,000	36,000,000
in aMW	4	9	41	411	4,110
% of 2014 Regional Electricity Sales	0.02%	0.04%	0.2%	2%	20%
% of Regional Vehicle Registrations	0.07%	0.2%	0.7%	7%	74%

SOURCE: NWEC Calculation Based on EIA Sales Data for MT, ID, WA & OR 2014

In the longer term, aggressive electrification scenarios will require additional generation assets for peak and base load charging. EPRI/NRDC are forecasting that transportation electrification by 2030 may require a 5% increase in load (around 65-85 GW of additional capacity nationally depending on the scenario) as shown in Figure 21 below. By 2050, they are forecasting a need for a 13% increase (around 225-275 GW). They modeled different generation mixes for that capacity, primarily featuring natural gas combined cycle.

Figure 21 – National Capacity Changes Resulting from Transportation Electrification (Lower GHG Scenario)[8]



SOURCE: EPRI/NRDC 2015

This scenario is consistent with PEVs rising to about 45% of new vehicle sales by 2030 and 60% by 2050, as well as heavy electrification of industrial equipment and other non-road equipment.

Distribution Costs

Adding new EV loads in homes and apartments may also require upgrades to neighborhood distribution transformers and secondary side service as the local load could exceed the transformer capacity. This may particularly occur if EVs cluster in certain neighborhoods. Reports from California suggest that these costs will be relatively small, however, totaling less than 1% of the utilities' annual capital budgets, and even this expense would be partially or completely offset by the incremental revenue from EV charging.

The Sacramento Municipal Utility District published a study of EV transformer upgrade costs where they modeled the need for upgrades given likely patterns of clustering (i.e. if EVs cluster the same way hybrids did in the past decade). SMUD's engineers estimate that transformer and side service upgrades each cost $5,000 - $8,000 with hardware and labor. The potential system cost varied widely with the power rate used by the vehicles. Hundreds of EVs at Level 1 (1.4 kW) could get added to a neighborhood without triggering an upgrade, whereas just 4 vehicles at the maximum Level 2 standard (19.2 kW, 80A) would be likely to trigger one.

[8] Reproduction of this chart does not constitute an endorsement of the particular natural gas generation mix shown; nor is it a comment on the viability of carbon capture and storage technologies.

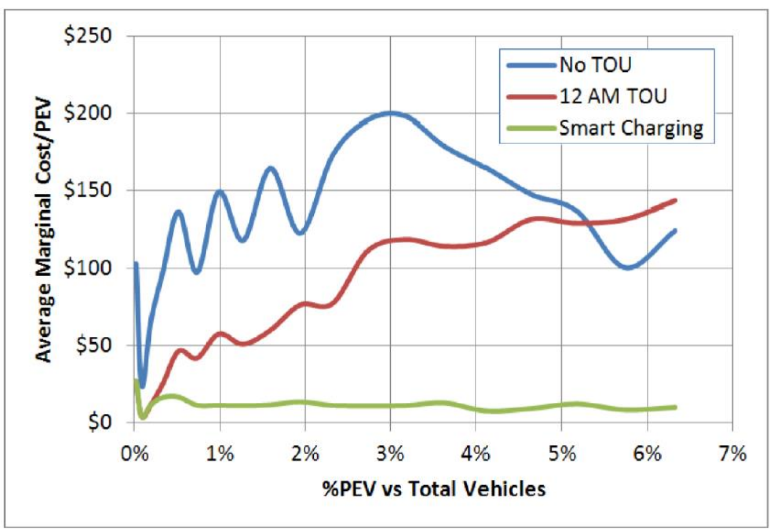
Table 7 – Sacramento Study of Distribution Upgrade Costs

Charge Rate		# of EVs charging on the same node before an upgrade is required
Level 1	1.4 kW	250
Level 2 Low	3.3 kW	38
	6.6 kW	12
Level 2 High	9.6 kW	7
	19.2 kW	4

SOURCE: Adapted from Boyce presentation to EV & the Grid Summit, 2015

SMUD's simulation found (see Figure 22 below) that distribution upgrade costs were likely to run to $100 - $200 per EV on average if no charge management strategies were employed, but these costs could be reduced to less than $100 per vehicle with time-of-use rates. They could be reduced still further with "smart charging" programs that manage the power level and timing of charging. The study did not attempt to perform a cost-benefit comparison between the two charge management strategies to see whether time of use or smart charging provided the better overall value. Total infrastructure costs were estimated to run $1-$2 million per year for the utility without any load management effort, which is less than 1% of that utility's $265 million annual capital budget. CalETC examined the situation for SMUD and the state's investor-owned utilities using their grid system data and potential clustering patterns and found similar results.

Figure 22 – Distribution Upgrade Costs Per Vehicle



SOURCE: Berkheimer et al SAE Paper, 2014

Charging Infrastructure Costs

The "last mile" problem of getting charging to the vehicles where they park is likely to be the single biggest cost driver for transportation electrification. Costs for charging infrastructure vary widely depending on how many stations are installed at a time and on the site conditions. Studies of charging station business models show relatively poor prospects for public charging to succeed as a stand-alone endeavor, given the infrastructure costs. Typically, some form of government subsidy and leveraging of other benefits (such as retail sales at the charging location while the customer fills up) are required to make it economically viable.

- Level 1 (120V) charging is the cheapest to install and may be the most cost-effective forms of charging for many applications. It's free if electrical service is already included in a home garage by code. It also has the drawback of being quite slow and requiring long dwell times to enable typical daily commutes.

- Level 2 (240V) stations have a wide range of costs per station depending on the site conditions. In a typical single-family home installation, the station can cost $500 and the installation $500-$750 if extra electrical capacity is available and considerably more if new service is required. Level 2 charging in apartment and condominium retrofits can often cost $10,000 - $20,000, and potentially far more if additional electrical service is required to the site.

- DC quick charge stations are by far the most expensive to install and depending on site conditions may require $80,000 to $100,000.

One key way to minimize charging infrastructure costs is through codes and standards that require buildings to be "EV ready" with panel capacity and conduit in place at the time of construction. This minimizes significant retrofit costs, which can involve disturbing and repairing pavement or sidewalks to set up the stations as well as running hundreds of feet of conduit, if electrical supply is located in places far from parking area. The California Air Resources Board has estimated that its EV readiness codes avoid $3750 - $6975 in retrofit costs per parking space. California codes currently require 3% or 6% of parking spaces be EV ready in apartment, condo, and other commercial buildings. A similar proposal was recently approved by the Washington Building Code Council, requiring EV readiness in 5% of parking spaces for new construction.

Who Pays and How?

How to finance these charging infrastructure costs and what mix of tax dollars, private funds, and utility rates is appropriate remain open questions and a very active policy discussion. In single-family homes, it's often the private end-user who pays. The federal government stepped in with stimulus funding to provide Level 2 stations and installation credits to homeowners for the EV Project, in exchange for data. One-time federal dollars built a network of highway quick charge stations, with very mixed results that included a terminated Department of Energy contract, lack of station upkeep, and a company bankruptcy. State governments often provide incentives: in Washington, EV charging equipment and installation costs are exempt from state and local sales tax, and the 2015 transportation budget provided $1 million for additional highway fast-charge stations. Other private funders, such as NRG eVgo are using mixes of litigation settlement funds and shareholder funds to build fast charge networks as well. California is devoting carbon market cap-and-trade revenue to vehicle incentives and other transportation electrification initiatives, such as car sharing, with a specific focus on low-income access. And as described in the next sections, utility funds are increasingly on tap for charging infrastructure, either in the form of rebates or utility-owned and installed charging infrastructure. This requires regulators to consider ratepayer interest, rate impacts, and balance the social and environmental benefits.

Low-Income Equity Issues and Approaches

Surveys and vehicle registration data show that the early adopters of battery electric passenger vehicles skew significantly to upper income and college- or graduate-educated consumers. This is expected to change as EVs achieve more widespread adoption, as more used EVs come up for sale, and as battery and vehicle prices decline with greater scale of manufacturing. The early phase of the EV rollout is not unlike the early days of hybrid vehicles, such as the Toyota Prius, in the mid-2000s, which were often derided as "eco-yuppie" cars for their higher initial price tag. These same hybrid cars now present such a good total cost proposition that they are often the vehicles of choice for many cab and Uber drivers.

Low-income consumers face numerous barriers to adopting transportation electrification:

- Vehicle acquisition costs typically run $10,000 (or more) higher than an equivalent gasoline car. In addition, since the vehicles are new, the opportunity to purchase cheaper, used EVs are still rare, though growing rapidly. Economic studies show that these initial costs loom large in consumers' eyes, and that they apply very high discount rates (15% or more) to the future fuel savings they will receive. The implicit discount rate to low-income consumers is likely to be among the highest. Leasing options, which can run just $200-$300 per month on some models and allow consumers to save about $100 per month on fueling, may help bridge this gap.

- Charging infrastructure barriers are highest in apartments and condominiums, which may face $10,000 - $15,000 in upfront retrofit costs to get the power supply out to parking garages and surface lots that were not designed for it. This barrier is likely to affect low-income consumers disproportionately, as they are often renters. Indeed, most EV adoption to date is found in owner occupied single-family homes that have off-street parking, which makes home charging set up cheaper and easier.

- Awareness and education barriers are also likely to impact low-income communities disproportionately. Consumers are typically interested in making changes when they see examples of them in their neighborhoods. Also, going electric involves learning a new vocabulary around charging rates, battery pack capacity, and vehicle model type. Current range constraints also require a much greater degree of trip planning and researching charging locations, forcing the consumer to engage in a fair amount of mental math to make sure that trips are feasible. Not all consumers are willing to plan this much around their vehicles and trips.

California appears to have done the most to address equity concerns with transportation electrification. The state is using its cap and trade revenue to implement a "cash for clunkers" style program that targets low-income families in areas with poor air quality and provides up to $12,000 for a ZEV purchase (described more fully in Appendix 1). In addition, the state has implemented electric car-sharing programs in low-income areas, intended as a supplement to transit options. The state recently capped its general EV purchase exemption by income, excluding those with very high incomes. And finally, in the utility space (also described in Appendix 1), the three California utility dockets for utility-provided charging infrastructure all feature a minimum 10% service to disadvantaged communities.

Conclusion and Recommendations

A variety of policy and market changes will be needed to make transportation electrification a reality in the northwest and reap the benefits described above. The policy resolution drafted by the Transportation Electrification workgroup convened for this process calls for the following policy actions (abridged – see the resolution for full text):

- Local, state, and federal programs to boost transportation electrification. This is to include charging infrastructure in multi-family and workplace settings, and public charging for "garage orphans" who lack off-street parking.
- Streamlined permitting procedures for charging installation and EV readiness in buildings through strong building codes.
- Clear legal authority for northwest utilities to participate in the transportation electrification.
- Utility investment in the transportation sector for home, apartment, condominium, workplace, industrial, public, and highway fast charge settings, with attention paid to consumer choice and competitive provision of charging station equipment.
- Policies to ensure low-income access and equity, so that ratepayer benefits are shared broadly. This may include income-targeted vehicle incentives from state and local programs, as well as minimum performance standards for utilities to reach low-income households with charging infrastructure.
- Utility policies and programs that minimize system costs, which may include time-of-use rates or other charge management programs that shift transportation loads to off-peak hours.
- Fair charges and rates for transportation uses that reflect utility system costs but do not present unnecessary hurdles or burdens on users.
- Guarantees that transportation electrification programs will be additional to existing investments in energy efficiency and renewable energy under current law.
- Exploration of potential business cases for utility system benefits from transportation loads, including demand management, vehicle to grid (V2G) integration for grid services, energy storage, and integration of variable renewable energy generation.

Appendix 1 – State Activity and Potential Utility-Transportation Policy Models

Multiple states enacted legislation around EV-utility policy in 2015. Below is a summary of recent laws enacted. These descriptions are not an endorsement of any particular policy by the NW Energy Coalition or its members, but they may present elements of models that could be applied in northwest states.

Washington

HB 1853 – This May, Washington enacted HB 1853, which allows the state's investor-owned utilities to install vehicle charging infrastructure behind the customer meter and treat it as a capital asset in rates. To qualify, the infrastructure must be deployed in locations where the vehicle is expected to park for more than two hours, which suggests residential and workplace applications primarily. Among the bills findings statements: "The legislature finds that utilities, who are traditionally responsible for understanding and engineering the electrical grid for safety and reliability, must be fully empowered and incentivized to be engaged in electrification of our transportation system . . . [and] intends to provide a clear policy directive and financial incentive to utilities for electric vehicle infrastructure build-out."

The bill's sponsor, Rep. Chad Magendanz (R-Issaquah) has stated publicly that he was interested in having the utilities reach apartments and condominiums, which have proven hard to serve, given retrofit costs of supplying additional electric service to existing parking structures. Under HB 1853, the utilities may earn up to a 2% bonus incentive rate of return, a rate that was previously applied to some efficiency programs. The rate impact is capped at 0.25%, though the legislation does not specify whether this is gross capital cost or a net impact after considering incremental energy sales revenues to EVs. The legislation also directs the Utilities and Transportation Commission to regulate potential competitive issues around the selection of charging station hardware and network vendors, which has proven to be a divisive issue in California. Avista, Puget Sound Energy (PSE) and PacifiCorp are the three utilities which may potentially utilize this new authority, but as of this writing, none has yet proposed a program. The state's many consumer-owned utilities, chartered under different sections of Washington law, were not included in the new HB 1853 authority but may offer a bill in 2016.

Other vehicle incentive policy – Also in 2015, Washington extended its sales tax exemption for alternative fueled vehicles for 4 more years (2019), which can be worth up to 9.8%, depending on the local tax rate. Eligibility is newly capped at vehicles priced at $35,000 or less and expanded to plug-in hybrids with 30 miles of electric range or more. The session's transportation package also raised the annual registration fee on EVs from $100 to $150 (starting in 2016) and devoted $1 million of the incremental revenue to highway fast-charging projects. Previous highway quick charge efforts in Washington used all federal funding.

California

Perhaps no state in the country is altering policy and practice more to facilitate transportation electrification than California, which has seen activity on multiple fronts this year.

SB 350 – In October, California enacted SB 350, which, in addition to raising the renewable portfolio standard to 50% and calling for the doubling of building energy efficiency, put the utilities squarely into the business of electrifying the transportation sector. "It is the policy of the state and the intent of the Legislature to encourage transportation electrification." The law directs utilities to plan for transportation electrification in their IRPs. Further, it requires utility and air quality regulators to accept applications by electric utilities for programs and investments that encourage electrification of vehicles, vessels, trains, boats and other equipment. It also directs regulators to approve those applications and allow cost recovery if they satisfy ratepayer interest tests. The law goes on to define the ratepayer interest quite broadly, reflecting many of the values articulated in this work paper, including:

"(a) Safer, more reliable, or less costly gas or electrical service . . . including electrical service that is safer, more reliable, or less costly due to either improved use of the electric system or improved integration of renewable energy generation.

(b) Any one of the following:

(1) Improvement in energy efficiency of travel.
(2) Reduction of health and environmental impacts from air pollution.
(3) Reduction of greenhouse gas emissions related to electricity and natural gas production and use.
(4) Increased use of alternative fuels.
(5) Creating high-quality jobs or other economic benefits, including in disadvantaged communities . . ."

Charging Infrastructure Dockets – Even before SB 350 passed, California's investor-owned utilities had collectively proposed spending $1.1 billion for rate-based EV charging infrastructure to help the state reach its air quality and carbon mitigation goals. This will involve upgrading and retrofitting power supply (make ready) in homes, apartments, and business for both workplace and general public settings. It will also involve either direct provision of EV charging stations or rebates for customers to select and install their own choice of station. The utilities will be required to provide a share of this service to disadvantaged communities. The three IOU proposals are summarized in Table 9 below.

Cap & Trade Revenue Programs – Finally, California provides a range of rebates for clean vehicles out of its carbon cap and trade program revenue, including some rebates that are targeted by income and air quality problems. These provide rebates – "cash for clunkers" – of up to $12,000 toward the purchase of a new or $9,500 on a used zero-emission vehicle for low income buyers who turn in a higher polluting gas car. Lesser rebates are available for higher-income populations and for either plug-in hybrid cars or conventional hybrids. The state is also facilitating electric vehicle car share services in low-income neighborhoods as a supplement to public transit options.

Table 8 – CA Low-Income Vehicle Incentives in Poor Air Quality Areas

Income	Hybrid ≥ 20 MPG	Hybrid ≥ 35 MPG	Plug-in Hybrid	EV
Low Income ≤ 225% of federal poverty level	$6,500	$7,000	$9,500 + $1,500*	$9,500 + $2,500*
Moderate Income 226%-300% of federal poverty level		$5,000	$7,500 + $1,500*	$7,500 + $2,500*
Above Moderate Income 301% - $400% of federal poverty level			$5,500 + $1,500*	$5,500 + $2,500*
* if new				

SOURCE: California Air Resources Board

Table 9 – Recent EV Charging Infrastructure Dockets at the California Public Utilities Commission

<table>
<tr><th>Utility</th><th>Proposed Charging Infrastructure Investment</th><th>Model Major Features</th><th>Other features in common</th><th>Status of Docket</th></tr>
<tr><td>Pacific Gas & Electric</td><td>$551 million capital
$103 million O&M over 5 years</td><td>Utility installs make-ready and charging stations.

Utility owns stations with 3rd party operation contract, which resells power at approved time-of-use rates.</td><td rowspan="3">Targeting multifamily dwellings, workplace and retail / public locations.

All dockets and/or settlement agreements feature a minimum 10% set aside for installations in disadvantaged communities.</td><td>Awaiting PUC hearing.</td></tr>
<tr><td>Southern California Edison</td><td>$335 million over 5 years</td><td>Make ready and “stub” for 30,000 charging stations.

Rebate to customer for charging station, up to 100% for multi-family sites and disadvantaged communities.

Customer owns and operates stations with choice of provider.</td><td>Settlement agreement between utility, consumer advocates, social justice advocates, EV charging equipment companies, labor unions, and environmental organizations in PUC review.</td></tr>
<tr><td>San Diego Gas & Electric</td><td>$58 million capital
$44 million O&M over life of project</td><td>5,500 charging stations at multiunit dwellings and workplace.

Stations are utility owned and operated. Site host retains choice of provider.

Smartphone based real-time pricing and charge management services.</td><td>Settlement agreement between utility, consumer advocates, social justice advocates, EV charging equipment companies, labor unions, and environmental organizations in PUC review.</td></tr>
</table>

SOURCE: Docket Files and CalETC / E3 Summaries

Vermont

Act 56 – In June, Vermont enacted Act 56, which, in addition to setting a renewable energy standard of 75% by 2032 (and a 10% distributed generation standard within that total), created a new distribution utility requirement to engage in “energy transformation” programs using rate dollars. Energy transformation is defined as reducing fossil fuel use by utility customers, and the utilities have a wide menu of possible approaches, including charging and electric vehicle incentives, home weatherization, high-efficiency heating systems and support for wider efforts involving biofuels and transportation demand strategies. The utilities are directed to seek out the lowest lifecycle costs, including environmental costs, for the program approaches. They may also increase electricity sales, though regulators are directed to monitor that effect, and utilities are directed to employ "best practices" to minimize additional burdens to the electric system. Vermont regulators are expected to review the programs for equity issues within rate classes, by income, and by service territories. Program effort is sized by a formula that attempts to relate the energy content of the avoided fossil fuel consumption to the utility's electricity sales in MWH. As a result, utilities must achieve avoided net lifecycle fossil fuel energy consumption equaling 2% of the utility's annual retail sales in 2017, rising to 12% by 2032. An alternative compliance mechanism allows the utilities to buy compliance with programs run by the Vermont Clean Energy Development Fund for a maximum price of $0.06 / kWh-equivalent of avoided fossil fuel energy. (So, if applied to 2% of the utility's retail sales, this presumably represents a maximum of $0.0012 / kWh of total rate impact in 2017). Vermont advocates expect the utilities will be able to achieve compliance for less than this maximum price, however. Regulators are directed to provide exemptions if the law results in "significant" rate impacts.

Appendix 2 – Current Utility Approaches to Transportation Electrification

State law and utility interest in transportation electrification vary widely, it's perhaps not surprising that electric utilities nationally have a wide array of different approaches. At the high end, some utilities are proposing to own and operate their own utility-branded public charging infrastructure, while at the low end, some utilities have no particular EV programs or merely offer information on vehicle and charging station installation to their customers. Many utilities also combine the programs in Table 10 below with efforts to electrify their own vehicle fleets for their internal emissions reductions goals.

Table 10 – Examples of Different Utility Approaches to Transportation Electrification

Utility Approach	Example Utilities
Information only.	• Seattle City Light EV information page with guides to charging basics and charging station permitting and installation. Staff support for answering customer questions.
Customer incentive (rebates), either through an ongoing program or a time-limited data collection project.	• Puget Sound Energy (pilot program). $500 rebate for installation of home EV charging station. Requires participation in study on charging habits. Limited to 5,000 customers and ends in November 2016. • Alabama Power (limited program). $750 vehicle purchase rebate. • Central Maine Power $5,000 vehicle purchase rebate + $2,500 charging station rebate for non-profits. Requires data study participation.
Utility-owned and operated charging infrastructure, financed either by rate funds or shareholder funds.	• Kansas City Power & Light network of utility-branded public charging network of 1,000 Level 2 charging stations. *(Note: It's unclear whether regulators in that state will allow this project to be funded via rates or require that investor funds be used).* • Portland General Electric installation of Electric Avenue DC fast charging (recently moved to PGE headquarters). Shareholder funds were used for the project. • San Diego Gas & Electric and Pacific Gas & Electric (proposed) $750 million charging station infrastructure program, primarily in multifamily and workplace uses.

SOURCE: RAP/VEIC Summary + Individual Utility Websites

References by Section First Cited

Introduction

California Transportation Electrification Assessment, Phase 1 Final Report, September 2014. Available at: http://www.caletc.com/wp-content/uploads/2014/09/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf

Nissan Leaf Price & Specs, available at: http://www.nissanusa.com/electric-cars/leaf/versions-specs/version.s.html

Tesla Model S Price & Specs, available at: http://www.teslamotors.com/models

Chevy Volt Driver Statistics, available at: http://www.greencarreports.com/news/1088628_chevy-volt-owners-drive-more-electric-miles-than-nissan-leaf-drivers-why

Proterra Electric Specs, available at: http://www.proterra.com/product-tech/product-portfolio/#catalyst

BYD Electric Bus Specs, available at: http://www.byd.com/na/ebus/ebus.html

Smith Electric Truck Specs, available at: http://www.smithelectric.com/smith-vehicles/

Toyota Electric Forklift Specs, available at: http://www.toyotaforklift.com/forklifts/large-electric-forklift

Washington & Oregon EV sales 2013, available at: http://insideevs.com/top-10-and-bottom-10-us-states-for-ev-market-share-in-2013/

PlugShare charging station maps, available at http://www.plugshare.com/

Societal Benefit #1 – Reductions in Greenhouse Gas Emissions

Center for Climate Strategies. “Washington State Greenhouse Gas Inventory and Reference Case Projections, 1990-2020.” December 2007. Available at http://www.ecy.wa.gov/climatechange/docs/WA_GHGInventoryReferenceCaseProjections_1990-2020.pdf

Oregon Greenhouse Gas Emission Data 1990-2012. Available at http://www.oregon.gov/deq/AQ/Pages/Greenhouse-Gas-Inventory-Report.aspx

Center for Climate Strategies. “Idaho Greenhouse Gas Inventory and Reference Case Projections 1990-2020.” Spring 2008. Available at http://www.deq.idaho.gov/media/345475-ghg_inventory_idaho_sp08.pdf

Center for Climate Strategies. “Montana Greenhouse Gas Inventory and Reference Case Projections 1990-2020”. September 2007. Available at http://www.deq.mt.gov/ClimateChange/Data/pdfs/GreenhouseGasInventory.pdf

U.S. Environmental Protection Agency. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013.” April 15, 2015. Available at http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html

Williams, J.H., B. Haley, F. Kahrl, J. Moore, A.D. Jones, M.S. Torn, H. McJeon (2014). “Pathways to deep decarbonization in the United States.” Energy & Environmental Economics. Available at http://unsdsn.org/wp-content/uploads/2014/09/US-Deep-Decarbonization-Report.pdf

Tong, Fan, Jaramillo, Paulina, and Azevado, Ines. “Comparison of Life Cycle Greenhouse Gases from Natural Gas Pathways for Light-Duty Vehicles” May 2015. Energy & Fuels. Available at http://pubs.acs.org/doi/pdf/10.1021/acs.energyfuels.5b01063

Ager-Wick Ellingsen, Linda et al. “Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack.” February 2014. Journal of Industrial Ecology. Available at http://bilavgifter.org/files/2015/02/Hammer-jiec12072-ea.pdf

EPRI/NRDC. “Environmental Assessment of a Full Electric Transportation Portfolio.” September 2015. Available at http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=3002006881

Union of Concerned Scientists. “State of Charge.” 2012. Available at http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf and 2014 Update available at http://blog.ucsusa.org/how-do-electric-cars-compare-with-gas-cars-656?_ga=1.264126476.1860893792.1445636430

Societal Benefit #2 – Improved Air Quality

Automotive air toxics data, available at http://www.epa.gov/otaq/toxics.htm, http://www.ecy.wa.gov/programs/air/cars/automotive_pages.htm, and http://www.bcairquality.ca/topics/vehicle-pollutants.html

Western Washington Clean Cities electrification program description available at http://wwcleancities.org/alt-fuels-and-vehicles/

Western Washington Clean Cities. "2010 Study of Air Toxics in Tacoma and Seattle." February 2011. Available at http://wwwdev.pscleanair.org/library/Documents/TacomaExSummary2010air_toxics_study.pdf

Tessum, Christopher et al. "Life cycle air quality impacts of conventional and alternative light-duty transportation in the United States" University of Minnesota. 2014. Available at: http://www.pnas.org/content/111/52/18490

EPRI/NRDC. "Environmental Assessment of a Full Electric Transportation Portfolio." September 2015. Volume 3. Available at http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?productId=000000003002006876

Societal Benefit #3 – Greater End-Use Energy Efficiency

WA Department of Commerce. 2013 Biennial Energy Report. Available at http://www.commerce.wa.gov/Documents/2013-biennial-energy-report.pdf

International Panel on Climate Change. "Renewable Energy Sources and Climate Change Mitigation." 2012 Special Report. Available at http://srren.ipcc-wg3.de/report

U.S. Department of Energy and Environmental Protection Agency fuel efficiency ratings for EVs, available at http://www.fueleconomy.gov/feg/evsbs.shtml and PHEVs, available at http://www.fueleconomy.gov/feg/phevsbs.shtml

NW Power & Conservation Council 7th Plan Preview, available at http://www.bpa.gov/EE/Utility/toolkit/Documents/6Goingon7-7thPlanSummary-BrownBag-ForWebsite.pdf

Forward, Evan, Glitman, Karen, and Roberts, David. "An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency." Efficiency Vermont. 2013. Available at http://www.veic.org/documents/default-source/resources/reports/an-assessment-of-level-1-and-level-2-electric-vehicle-charging-efficiency.pdf

Carson, Richard. "Advanced Vehicle Testing Activity Benchmark Testing of the Chevrolet Volt". Idaho National Lab. April 2012. Available at http://avt.inl.gov/pdf/phev/EfficiencyResultsChevroletVoltOnBoardCharger.pdf

Curran, Scott et al. Oak Ridge National Laboratory. "Well-to-wheel analysis of direct and indirect use of natural gas in passenger vehicles". Energy. August 2014. Available at http://www.sciencedirect.com/science/article/pii/S0360544214008573

Societal Benefit #4 – Low and Stable Operation Costs

Collaborative Efficiency for National Rural Electric Cooperative Association. "PEV Mechanics and Market Trends" Vol. 1. April 2015. Available at http://www.nreca.coop/wp-content/uploads/2015/06/EV-Mechanics-and-Market-Trends.pdf

U.S. Department of Energy, "eGallon Calculator". Available at http://energy.gov/articles/egallon-how-much-cheaper-it-drive-electricity

Average WA and OR electricity prices taken from U.S. Energy Information Administration data, available at http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a. Average gasoline prices taken in from http://www.washingtongasprices.com/Prices_Nationally.aspx

Societal Benefit #5 – Greater Energy Security

Gallagher, K.S., and Muehlegger, E. "Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology," Journal of Environmental Economics and Management. (2010). Available at http://www.sciencedirect.com/science/article/pii/S0095069610000768

Societal Benefit #6 – State & Regional Economic Gains

Roland-Holst, David. "Plug-in Electric Vehicle Deployment in California: An Economic Assessment."

September 2012. Available at http://are.berkeley.edu/~dwrh/CERES_Web/Docs/ETC_PEV_RH_Final120920.pdf

Keybridge Economic Group. "Impact of Eliminating the Alternative-Fuel Vehicle Tax Exemption on the Washington State Economy." March 3, 2015. Available at http://www.secureenergy.org/sites/default/files/SAFE_EC_Study_WA_Report_Final_0.pdf

Keybridge Economic Group. "Impact of Introducing an Electric Vehicle Rebate on the Oregon State Economy." April 2, 2015. Available at http://www.secureenergy.org/sites/default/files/Oregon_EV_Tax_Rebate_Study_FINAL.pdf

Utility Benefits – Increased Utilization of Existing Electricity Grid

Michael Kinter-Meyer, et al. "Impacts Assessment of Plug-In Hybrid Vehicle on Electric Utilities and Regional U.S. Power Grids. Part 1: Technical Analysis." 2007. Pacific Northwest National Lab. Available at http://www.ferc.gov/about/com-mem/5-24-07-technical-analy-wellinghoff.pdf

Keay-Bright, Sarah, and Allen, Riley. "Policy Brief: EU Power Policies for PEVs". June 2013. The Regulatory Assistance Project. Available at http://www.raponline.org/document/download/id/6620

Keay-Bright, Sarah. "EU power sector market rules and policies to accelerate vehicle take-up while ensuring power system reliability." December 2014. The Regulatory Assistance Project. Available at http://www.raponline.org/document/download/id/7441

Lazar, Jim, Joyce John, and Baldwin, Xavier. "Plug-in Hybrid Vehicles, Wind Power, and the Smart Grid." January 2008. Available at http://www.raponline.org/docs/RAP_Lazar_PHEV-WindAndSmartGrid_2007_12_31.pdf

Cutter, Eric. "Vehicle Grid Integration." 2015. Presentation to EV Roadmap. Available at https://www.dropbox.com/s/oiezw5dqowyrgah/EricCutter%20%281%29.pdf?dl=0

Collins, Watson. "EVs and the Grid Summit: Grid Service Applications and V2G.: Eversource Energy. Presentation available at https://www.dropbox.com/s/3zrdr9atrm3d44n/Watson%20Collins.pdf?dl=0

Saxton, Tom. "EV Battery Amortization and V2G Pricing." 2015. Plug in America. Presentation to EV & The Grid Summit. Available at http://images.pluginamerica.org/battery-surveys/V2G-Owner-Costs.pdf

Puget Sound Energy EV Rate Impact Workpaper, available at https://www.dropbox.com/s/oixivuutdych1ne/PSE%20EV%20Incentive%20Workpaper%20-%2018%20March%202014.xlsx?dl=0

Nissan Next-Generation Battery Pack Improvements, discussed at https://transportevolved.com/2015/11/10/confirmed-longer-range-2016-nissan-leaf-charges-faster-than-its-predecessor/

Potential Utility Costs Associated with Transportation

Boyce, Bill. "EV Charging Impacts and Mitigation Options." 2015. Sacramento Municipal Utility District Presentation available https://www.dropbox.com/s/9zin9zyrwhda63x/Bill%20Boyce%20-%20Sacramento%20Municipal%20Utility.pdf?dl=0. Associated research article available at http://papers.sae.org/2014-01-0344/

California Transportation Electrification Assessment, Phase 2: Grid Impacts, October 2014. Available at http://www.caletc.com/wp-content/uploads/2014/10/CalETC_TEA_Phase_2_Final_10-23-14.pdf

Center for Climate & Energy Solutions. "Business Models for Financially Sustainable EV Charging Networks." 2015. Report to the Washington Legislature's Joint Transportation Committee. Available at http://www.c2es.org/docUploads/business-models-ev-charging-infrastructure-03-15.pdf

WA EV readiness code proposal, available at https://fortress.wa.gov/ga/apps/sbcc/File.ashx?cid=4850

California Air Resources Board EV Code Study. 2015. Available at http://www.documents.dgs.ca.gov/bsc/2015TriCycle/CAC/GREEN/Exhibit-B-CARB-Cost-Analysis-and-Technical-Report.pdf

Appendix 1 – State Activity and Potential Utility-Transportation Policy Models

Washington's HB 1853 available at http://app.leg.wa.gov/billinfo/summary.aspx?bill=1853&year=2015

WA PEV incentive and highway charging station policy, Sections 203, 403, 404, 408, and 409. Available at http://app.leg.wa.gov/billinfo/summary.aspx?bill=5987&year=2015

California's SB 350, available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350

California Public Utility Commission EV dockets and rulemaking, available at http://www.cpuc.ca.gov/PUC/energy/altvehicles/

California Clean Vehicle Rebate program, available at https://energycenter.org/clean-vehicle-rebate-project

California's low-income clean vehicle subsidy program, available at http://www.arb.ca.gov/newsrel/efmp_plus_up.pdf

Vermont Act 56 (2015), available at http://legislature.vermont.gov/bill/status/2016/h.40

E3/CalETC Summaries of EV-Utility Dockets, available at https://www.dropbox.com/s/fsu9lthtp2zq2b8/E3-CalETC%20Summaries%20of%20CA%20EV%20Dockets.zip?dl=0

Appendix 2 –- Current Utility Posture on Transportation Electrification

Seattle City Light EV education web page, available at http://www.seattle.gov/light/electricVehicles/

Puget Sound Energy EV rebate web page, available at http://pse.com/savingsandenergycenter/AlternativeFuelVehicles/Pages/Electric-vehicles.aspx?utm_source=shorturl&utm_medium=webpage&utm_campaign=electricvehicles&WT.mc_id=1069

Georgia Power EV charging installation rebate programs available at http://www.georgiapower.com/about-energy/electric-vehicles/home.cshtml

Central Main Power vehicle rebate program for non-profits http://www.cmpco.com/electricvehicles/grant_program_details.html

Kansas City Power & Light Clean Charge network. Information available at http://www.kcpl.com/CleanCharge

Portland General Electric EV education web page, available at http://www.pge.com/en/myhome/saveenergymoney/pev/index.page

Tables and Figures