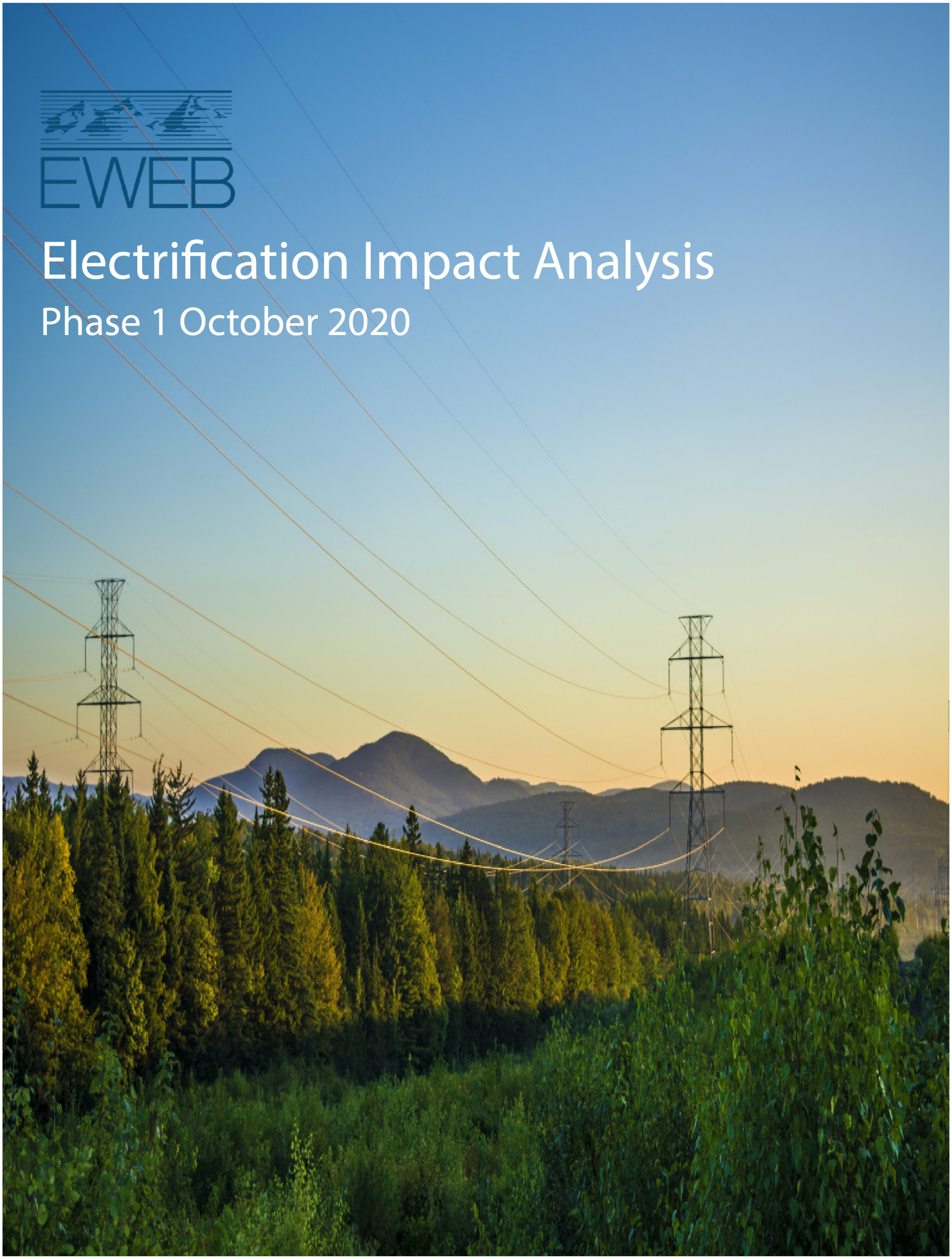
EWEB

Electrification Impact Analysis

Phase 1 October 2020



EWEB

Readers:

EWEB is pleased to present our first in-depth assessment of the potential impacts of economy-wide community electrification.

This report reflects the beginning of our ongoing analysis of evolving electricity consumption patterns that will help guide decisions and investments associated with electricity generation, delivery infrastructure, and customer programs. Our studies will not advocate a position, or fully align with other agency targets or assumptions, but will attempt to inform and prepare the utility for a range of different future conditions.

Consistent with the values of our customer-owners, over the next ten years EWEB will need to align our power portfolio with the evolving energy needs of our community. In preparation, we plan to model multiple scenarios, considering the potential effects of climate change, economics, technology, customer behavior, industry variations, and policy changes to gauge the impacts on EWEB and our customers.

As we move forward with additional analysis, we will work with partners across the region to further understand the assumptions and trends of all forms of energy, including the carbon intensity of both the electric and natural gas systems over time. We will further assess consumer and utility costs, climate-related impacts and uncertainties, the influence of customer programs, and other conditions effecting electricity consumption.

Thank you for your interest. More to come!

Frank Lawson

Eugene Water & Electric Board CEO & General Manager

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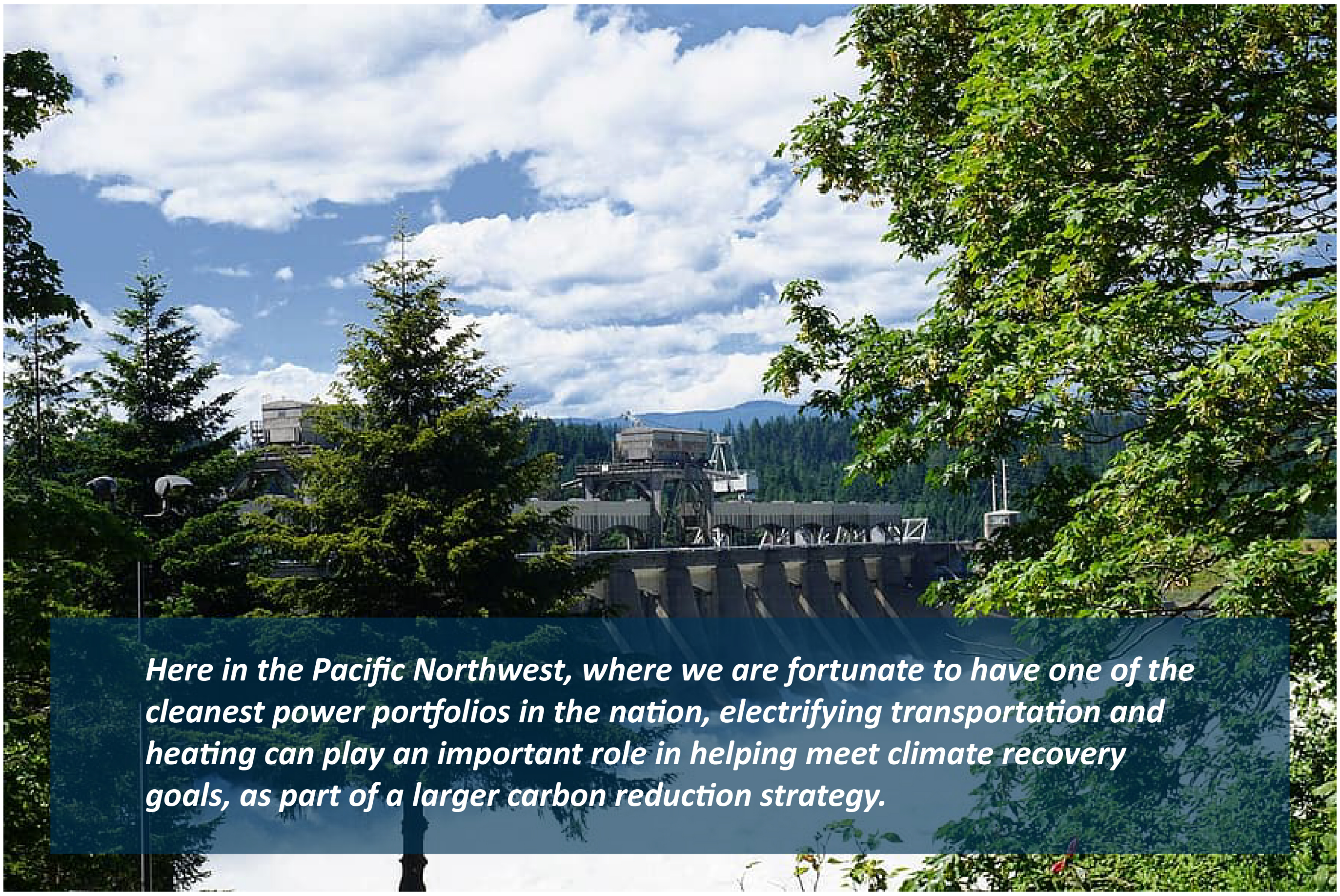
1 ABSTRACT

Electrification is a term for replacing direct fossil-based fuel use (e.g. natural gas, heating oil, gasoline) with electricity, which has environmental (GHG), economic (cost), and social (customer choice, resiliency) impacts.

Here in the Pacific Northwest, where we are fortunate to have one of the cleanest power portfolios in the nation, electrifying end-use technologies (like space heating, water heating and electric vehicles) presents the opportunity to reduce our community's carbon footprint. At the same time, the impacts of electrification could be far-reaching, significantly altering how much, when and where electricity is used across the region.

The goal of this study is to create a data-driven analysis of the impacts of electrification and to help the utility prepare for various electrification futures, including the policies and programs, resources, technology and infrastructure that will be needed to meet customers' changing energy needs over the next 30 years.

Understanding the impacts of electrification will be an ongoing process for the utility. Therefore, this analysis will be completed in phases, with Phase 1 focused on potential changes to electricity consumption patterns and environmental impacts from electrification of passenger vehicles, as well as residential and commercial water and space heating.



Here in the Pacific Northwest, where we are fortunate to have one of the cleanest power portfolios in the nation, electrifying transportation and heating can play an important role in helping meet climate recovery goals, as part of a larger carbon reduction strategy.

2 EXECUTIVE SUMMARY

Transitioning from fossil-based fuel use to electricity while continuing to “green” the electrical grid and pursuing energy efficiency are often cited as common pathways to reduce carbon emissions associated with climate change.

While electrification can play an important role in helping meet carbon reduction goals, it is just one part of a larger carbon reduction strategy. Studies consistently show that achieving economy-wide deep decarbonization[1] requires action on multiple fronts, including de-carbonizing fuels, energy efficiency, carbon mitigation/ sequestration and offsets, reducing non-combustion GHGs, and electrification using a cleaner grid. The electrification of transportation and building energy use are key components of the electrification pathway and could have far reaching impacts on EWEB and its customers.

The goal of this study is to quantify the potential impacts of electrification using data-driven analysis and to help the utility understand various electrification futures, including the policies and programs, resources, technology and infrastructure that may be needed to meet customers’ changing energy needs.

This study targets the transportation and building sectors which could experience electrification over the next 30 years. Phase I of the study’s scope focused on end-uses within these sectors that are the most relevant to a majority of EWEB’s customers.

Study Scope

	In-scope	**Out-of-scope**
Transportation sector	Passenger and light duty vehicles	Commercial freight vehicles Transit buses
Buildings sector	Residential & commercial space & water heating	Industrial process loads

Key Findings

Transportation

While passenger and light duty electric vehicle (EV) adoption is expected to increase, the rate and timing of adoption is uncertain. This study examines a range of EV market penetration rates from 3% on the low end to 100% of total vehicle stock by 2050.

The energy and peak impacts to EWEB due to EV adoption are dependent on the number of EVs adopted as well as the charging behavior of EV owners. In the study, we analyzed both unmanaged EV charging and managed charging to understand the potential impacts to the utility. Based on research, EWEB estimates that the peak of *unmanaged* EV charging would take place around 7PM when overall power consumption is highest and there is increased use of fossil-based fuel-burning generators on the grid. Further analysis of *managed* charging behavior found that shifting peak EV charging from 7 PM to 12AM (off-peak) moves the EV charging load away from EWEB’s existing system peak and results in lower energy costs and lower carbon emissions.

In all except the fastest modeled adoption rate, unmanaged EV charging load growth is linear. A high level of EV adoption could increase EWEB’s average system load up to 15% and increase peak demand up to 30%.

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[1] Deep decarbonization can have different definitions depending on the study, but typically means reducing 1990 GHG emission levels by at least 80% by 2050.

Assuming unmanaged charging behavior, the study also estimates that each new EV, on average, represents a 75% reduction (2.75 MTCO2e/vehicle) in annual carbon emissions compared to a new light-duty gasoline vehicle. Based on various potential EV adoption rates, this could reduce community carbon emissions annually in the range of 10,000 (low growth) to 100,000 MTCO2e (fastest growth) by 2030.

In order to calculate carbon emissions from unmanaged EV charging, EWEB multiplied hourly unmanaged charging behavior by the hourly NWPP grid carbon intensity. The analysis concluded that the average annual carbon intensity of unmanaged EV charging was 0.22 MTCO2e/MWh which is higher than the NWPP grid average annual carbon intensity (0.19 MTCO2e/MWh) because unmanaged EV charging takes place during peak electricity use. While EWEB's portfolio carbon intensity is lower than the NWPP, using regional carbon intensity assumptions acknowledges that future load growth may be met with market resources which are part of a larger, regional electric grid.

Managed charging could be used to reduce peak impacts as well as the carbon intensity of EV charging. Currently, EWEB offers incentives for Level 2 charger installation, specifically because this equipment can be programmed to charge at certain times. In addition, EWEB has started a public education campaign to encourage customers to shift discretionary energy use, like EV charging, to off-peak hours (10PM to 6AM).

Due to the limited penetration of EVs in our service territory, EWEB has not yet implemented an electric vehicle charging rate and/or load management program. However, EWEB is preparing for a future where such programs could be implemented.

Buildings

Of the many different end-uses within the residential and commercial sectors, this study focuses on space and water heating. These end-uses were chosen because improvements in heat pump technology offer competitive alternatives to traditional electric and natural gas equipment. In addition, the consumption patterns of these end-uses, particularly space heating, correlate to EWEB's existing system peaks, which could have environmental, economic, and social impacts for EWEB customers.

EWEB's existing system load is weather dependent primarily due to the amount of electric space heating load within our service territory today. To understand potential impacts to peak load under a range of weather conditions, EWEB analyzed peak energy use during average (1-in-2) weather as well as less frequent cold weather conditions (1-in-10).

Based on EWEB customer data and information from Northwest Natural Gas (NWNG), we estimate that approximately 25% of residences and 35% of commercial businesses in EWEB service territory use natural gas for space and water heating. Using this data, we estimated the impact to average load, peak load and carbon emissions that may occur due to converting existing natural gas space and water heating to electricity.

Similar to EV adoption, the potential impact of electrification of space and water heating has a wide range of uncertainty. To illustrate the potential impacts to the utility, we analyzed low, medium and high levels of conversion (10%, 50%, and 80%, respectively).

Converting 80% of existing *residential* natural gas space and water heating could increase EWEB's average system load up to 8% and increase 1-in-10 peak demand up to 17%. Conversion of 80% of *commercial* natural gas space and water heating could increase EWEB's average system load an additional 3% and increase 1-in-10 peak demand an additional 10%.

It should be noted that space and water heating equipment efficiency play an important role on the impacts to EWEB. Because electric heat pumps lose capacity to heat at very cold outside temperatures, many heat pumps are paired with a backup heat source, typically in the form of an electric resistance attachment to an air handler, or a gas furnace. Thus, the estimated energy use during EWEB's cold winter peaks is dependent on the amount of backup heat used during cold weather. To show a range of potential peak impacts based on installed heat pump performance, EWEB estimated peak impacts based on both optimal and sub-optimal heat pump installation. Optimal installation assumes that heat pumps would be installed to utilize little or no electric resistance back-up and perform well at low temperatures. Sub-optimal installation, where a heat pump relies on electric resistance heat more frequently, could increase the potential peak impacts.

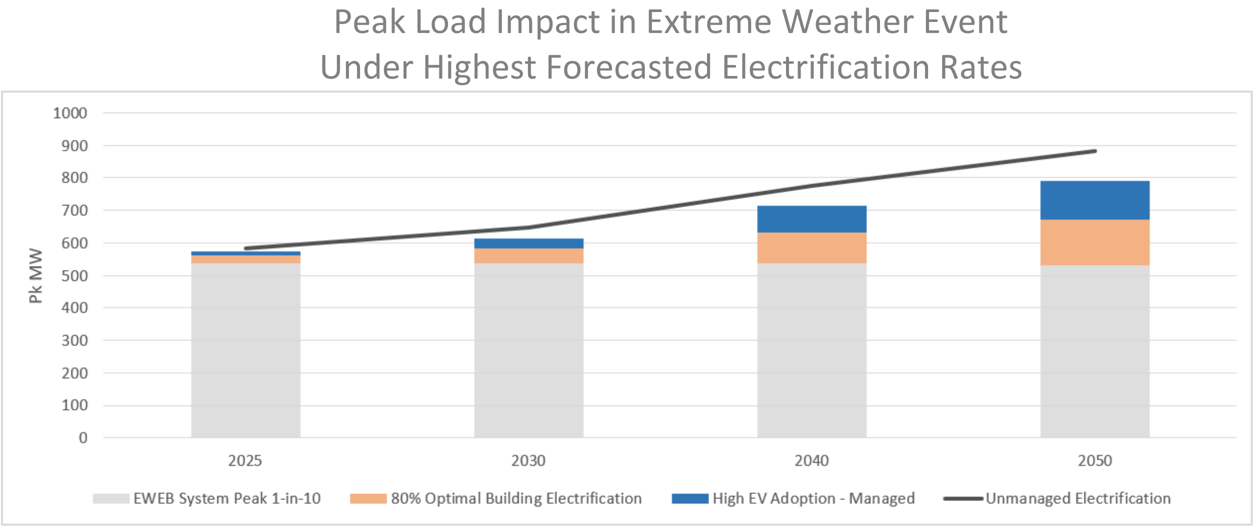
As was done with transportation electrification, EWEB staff used an hourly carbon emissions factor for the Northwest Power Pool (NWPP) to model the potential impact that electrification of space and water heating can have on GHGs. The study finds that conversion of gas space and water heating to electricity is likely to yield carbon savings, which are included in the cumulative summary below. However, it should be noted that expected, and yet uncertain, reductions in the carbon intensity of the electric grid and natural gas system over the next 30 years make anticipated carbon reductions due to conversion more uncertain. In addition, there is variation of the building stock (age, insulation, business-type, space heating requirements, etc.) within EWEB's service territory, which creates further uncertainty when estimating the potential community-wide carbon savings associated with natural gas conversions.

Cumulative Impacts of Electrifying Transportation and Buildings

Energy and Peak Impacts

Assuming high levels of electrification, EWEB could experience load growth of up to 64 aMW by 2050 (roughly 20% increase) and could add between 50-70% to peak load during colder, less frequent (1-in-10) weather events.

To present a range of potential peak impacts as a result of high electrification, EWEB assumed two different scenarios: managed and unmanaged electrification. In the chart below, the peak impacts of managed electrification are shown in the bar charts. Managed electrification assumes: (1) peak EV charging would be shifted from 7 PM to 12AM and, (2) optimal installation of new space and water heat pumps (i.e. units that require little or no electric resistance back-up and perform well at low temperatures). Unmanaged electrification assumes that 1) EV peak charging would remain at 7 PM and, 2) sub-optimal installation of new space and water heat pumps (i.e. heat pump relies on electric resistance heat more frequently during peak).



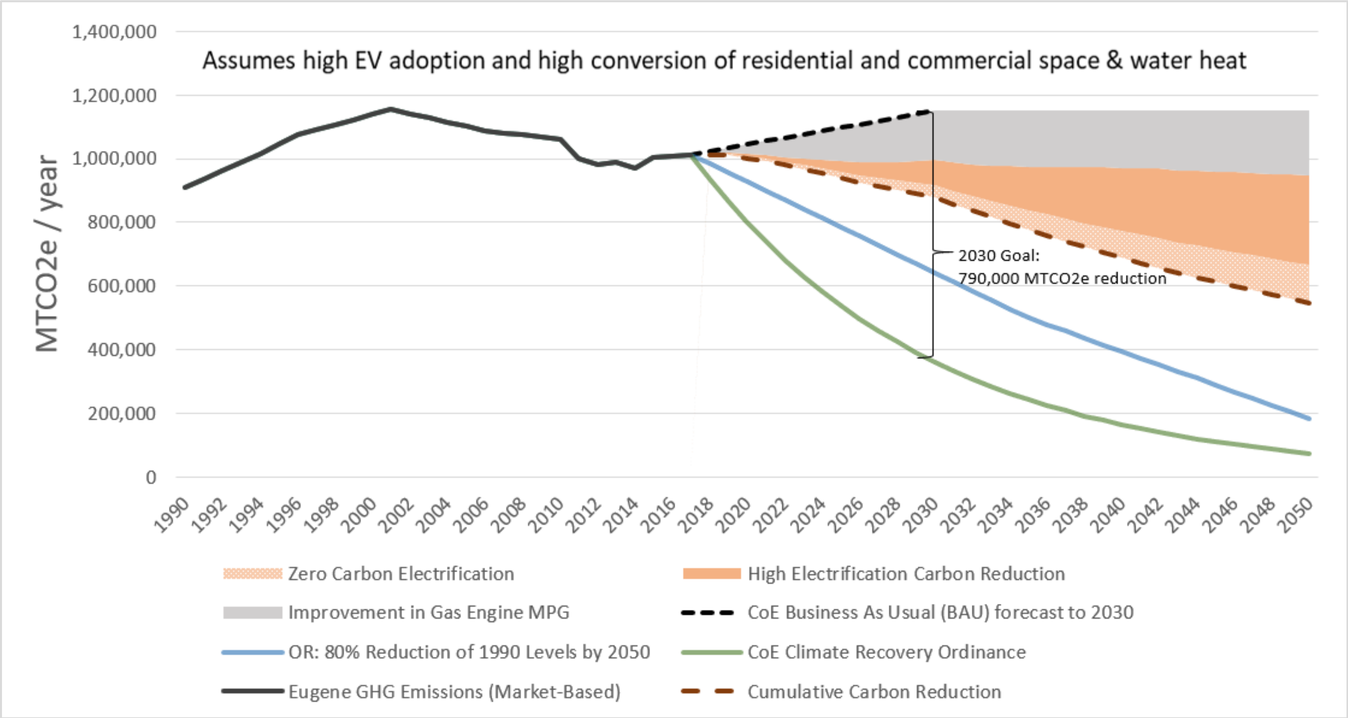
Carbon Reduction Impacts

In addition to the actions identified by the City of Eugene's Climate Action Plan (CAP) 2.0, electrification of light-duty vehicles and buildings can support community carbon reduction goals. As a result of high EV adoption and high conversion of residential and commercial space and water heating, electrification could reduce 109,000 MTCO2e annually by 2030 (approximately 14% of the City of Eugene's carbon reduction goal).

To help illustrate the benefits of other carbon reduction actions that are indirectly related to electrification, this study also modeled carbon savings due to improvements in internal combustion vehicle efficiency (MPG) over time, as well as the potential benefits of utilizing zero carbon electricity, to account for a continual "greening" of the grid.

Taken altogether, improvements in transportation fuel efficiency plus high levels of zero-carbon electrification could help meet as much as 34% of the City's carbon reduction goal by 2030. These total carbon savings alone could be more than 50% of the CAP 2.0 goal by 2050.

Eugene MTCO2e Reduction Goals



In addition to the electrification carbon reductions shown in the chart above, the City of Eugene and its community partners have identified 245,000 MTCO2e in carbon reduction commitments by 2030. The City of Eugene plans to continue to identify more actions to meet the 790,000 MTCO2e reduction goal through the process outlined in the CAP 2.0.

Summary

The pace of electrification is expected to be slow in the next decade, giving EWEB opportunity to respond and adapt to emergent trends.

On a forecasted, average energy basis, EWEB's power portfolio has enough surplus energy to meet our customers' electrification needs and we expect that the forecasted pacing and magnitude associated with all electrification scenarios can be managed with our existing portfolio. If needed, EWEB can purchase additional energy products from the wholesale energy market to supplement the portfolio, as new long-term resources are considered and developed as part of the broader Electricity Supply Planning process.

While electrification may require EWEB to purchase additional energy on the supply-side, Demand-side Management (DSM) can be a mitigation strategy for EWEB as well. DSM includes conservation programs to incent technologies that reduce overall energy consumption, as well as consumer education to voluntarily shift discretionary use to off-peak times.

For example, we estimate that EWEB customers could reduce the current peak load associated with electric resistance heating by at least one-third, by replacing existing low efficiency units with standard efficiency heat pumps. Other voluntary demand management programs can be a cost-effective mitigation strategy today. Examples include alerting customers when peak events are forecasted and requesting that they shift their peak energy use to the extent possible, or EWEB energy management personnel working with industrial customers to identify site-specific peak reduction solutions.

Rate design and electricity pricing will also play an important role in sending our customers effective price signals. While the northwest does not have strong peak market price signals today, that could change over time. Rates designed around peak price signals could influence customer consumption patterns and help mitigate peak impacts from electrification.

Phase 1 of this study presents a wide range of potential outcomes to the utility, which reflects the uncertainty surrounding influences of local and regional policy on electrification as well as consumer technology choices. Phase 1 focuses on the potential impacts of electrification without analyzing the costs to customers who choose to electrify. The cost/benefit of these individual customer choices play an important role in forecasting expected electrification levels over the next 30 years. Further, EWEB programs have the potential to influence those customer electrification choices (i.e. ‘smart’ electrification).

To build on the context and findings of Phase 1, the following topics can be explored in more detail in Phase 2 of the Electrification Impact Analysis:

- Changes to the carbon intensity of the NWPP and to the natural gas system over time
- Further understanding of consumer and EWEB costs associated with electrification, including resources, infrastructure, and individual customer upgrade costs
- Explore ‘smart’ or ‘beneficial’ building and transportation electrification programs and how EWEB programs can influence the rate and impacts of electrification
- Additional scenarios, such as rapid population growth and other climate-related uncertainties, including impacts on hydroelectric production
- Deeper dive into the capacity of our power supply and delivery (transmission and distribution) system, including transformer loading under different electrification scenarios
- Continued conversations with stakeholders to refine assumptions, modeling, and forecasted results
- Further analysis of potential peak energy savings and potential DSM/conservation programs

Phase 2 is scheduled to be completed in 2021.

3 ELECTRIFICATION IMPACT ANALYSIS SCOPE

Findings from the Electrification Impact Analysis are part of EWEB's broader and on-going Electricity Supply Planning (ESP) effort. Electricity Supply Planning includes a broad set of actions, such as evaluating power portfolio options, negotiating power purchase agreements, and developing customer products and services, all with the goal of continuing to serve our community over the long-term with clean, affordable, and reliable power. It is key to the success of EWEB's strategic priorities of facilitating more flexible and efficient energy consumption, synchronizing supply and demand, and creating a more resilient electric grid.

The Electrification Impact Analysis aims to answer five key questions:

1. How might state and local policies impact the rate of electrification in Eugene?
2. How could widespread electrification impact electricity consumption patterns and carbon emissions?
3. What impact would electrification have on EWEB's power system (generation, transmission, distribution, etc.)?
4. What role might energy efficiency and demand-side flexibility play in mitigating challenging outcomes of mass electrification?
5. What are potential costs, benefits and impacts of various electrification futures?

Phase 1 of the analysis discusses elements of the topics, providing context for further analysis in Phase 2.

The study uses a 30-year timeframe, with results summarized for present state, 2025, 2030, 2040 and 2050. This study targets two economic sectors with high potential for carbon reductions:

- Transportation, specifically passenger and light duty vehicles
- Building space and water heating in the residential and commercial sectors

End-use applications that are deemed less likely to transition to electricity for fuel, such as freight/heavy-duty vehicles and industrial loads, are outside the scope of the study. Industrial electrification is out of scope due to the complexity of converting existing gas industrial load which is often site-specific. Although some level of medium and heavy-duty transportation (including freight) electrification is likely over the study period, this is outside the scope of this analysis due to significant uncertainty regarding the extent of electrification in larger vehicles.

Study Scope		
	In-scope	**Out-of-scope**
Transportation sector	Passenger and light duty vehicles	Commercial freight vehicles Transit buses
Buildings sector	Residential & commercial space & water heating	Industrial process loads

3.1 KEY ASSUMPTIONS

As with any 30-year study, the electrification impact analysis is heavily reliant on a variety of assumptions to model the future.

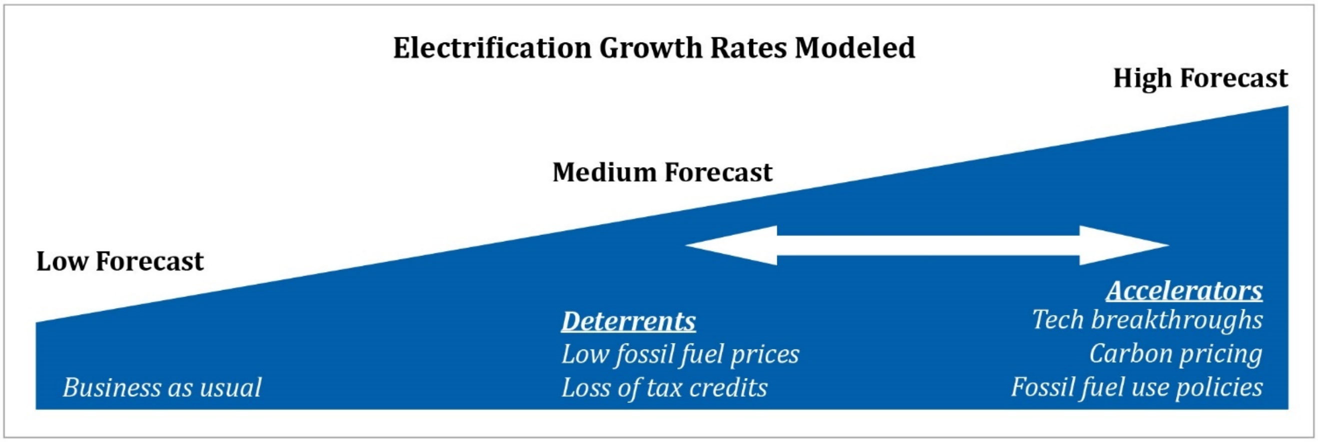
Adoption rates

While it is generally accepted that improved electric vehicle and heat pump performance combined with meaningful carbon reductions make electrification an essential strategy to meet future carbon reduction goals established by legislation, these technologies are emergent and do not currently have significant market share.

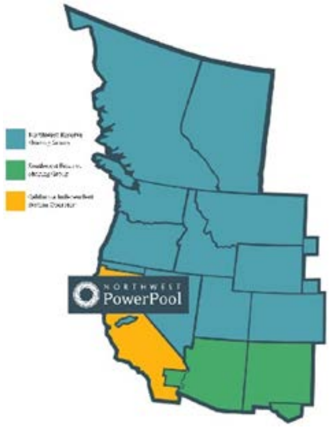
Additionally, past behavior may be a poor indicator of future adoption trends when it comes to building and transportation electrification. Extrapolating existing trends over a 30-year period is likely to yield results which underestimate the complexity of end-use electrification. The effect of legislative influence and evolving cost signals may cause the pace of electrification to fluctuate and even plateau over time. Simply put, the real impact of electrification is hard to predict over 30 years, as many variables make outcomes uncertain.

Phase 1 of this study addresses this uncertainty with multiple scenarios reflecting wide-ranging electrification growth rates.

High and medium forecasts are modeled to show the effects of electrification accelerators—such as carbon pricing and other policies around fossil-based fuel use—and deterrents—like low fossil-based fuel prices and the loss of tax credits. Low growth forecasts project business as usual with existing policies and present trends continuing into the future.



Carbon intensity of power



The extent to which electrifying the transportation and buildings sectors advances carbon reduction goals depends, in part, on the amount of fossil-based fuel used to generate the electricity.

While EWEB's power portfolio is made up of almost 90% carbon-free resources, with a lower annual average emissions rate than the region as a whole, we are part of an inter-connected grid with an active trading floor that is buying and selling power in response to hourly demand.

This electrification study recognizes that local electrification is likely to occur at the same time as regional electrification. **Therefore, this study utilizes an emissions factor for the Northwest Power Pool (NWPP) to account for EWEB's market trading activity within the interconnected region.** While EWEB's portfolio carbon intensity is lower than the NWPP, using regional carbon intensity assumptions acknowledges that future load growth may be met with market resources which are part of a larger, regional electric grid.

Average Annual MTCO2e/MWh	
EWEB[2]	.02
Northwest Power Pool (NWPP)[3]	.19
US Average	.45

The regional electric supply must continuously match demand instantaneously. This means that the carbon intensity of the NWPP fluctuates as various underlying resources generate in real time. Figure A below indicates that regional carbon emissions are strongly correlated to the availability of hydropower generation, which declines in the summer and fall.

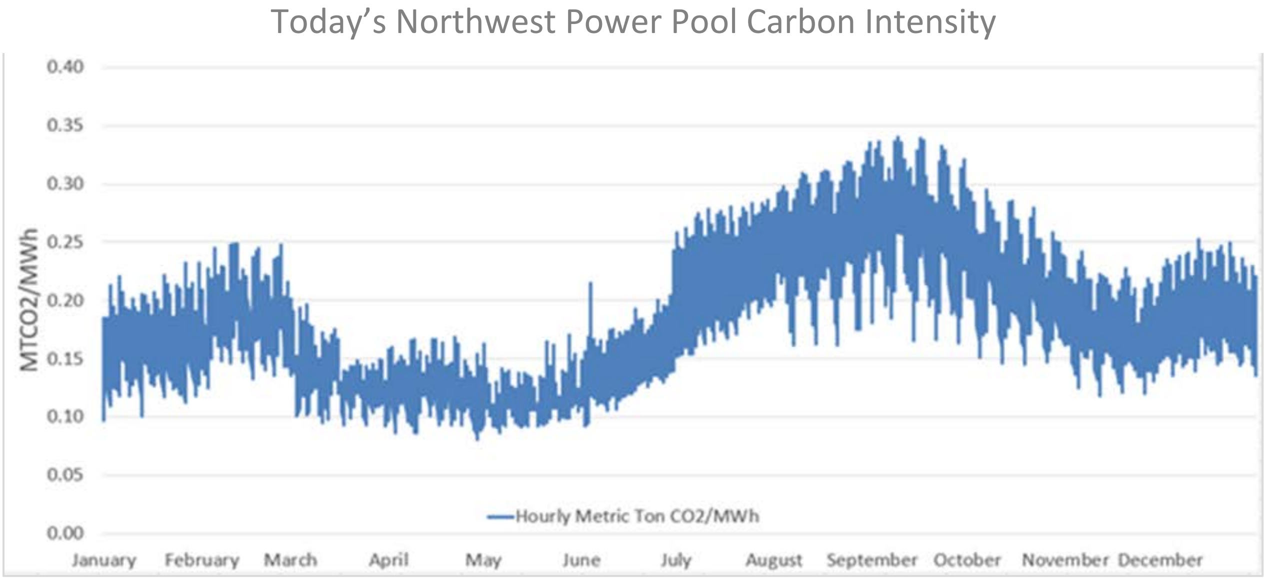


Figure A - The hourly carbon emission for the NWPP region based on Aurora modeling software. The areas used by EWEB for modeling the NWPP region may differ from the actual physical boundaries of the NWPP but is intended to illustrate the region's carbon intensity.

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[2] Per Oregon DEQ GHG Reporting 2018

[3] Average of hourly carbon emission for the NWPP region based on Aurora modeling software

To calculate the carbon intensity associated with a particular end-use (EV charging, for example), we analyzed hourly power consumption by end-use and multiplied it by the respective NWPP hourly carbon intensity. This hourly carbon calculation was done over the course of the entire year (8,760 hours) to factor in the seasonality of carbon emissions. This hourly methodology improves the accuracy of estimating carbon emissions attributable to each end-use.

Carbon intensity of the NWPP is expected to decline over time due to coal retirements and increased renewable generation. Phase 2 of the study will examine these changes to the electric grid further.

Load Forecasts

EWEB's recent update to the 2011 Integrated Energy Resource Plan shows that the utility continues to have adequate resources to meet customers' energy needs and can readily meet forecasted load growth with energy conservation.

Annual conservation targets are based on five-year average load forecasts, which continue to show little to no load growth. Economic impacts of COVID-19 are forecasted to result in load reductions of approximately 5% through 2021. A return to average load (270 aMW) is forecasted by 2023, with conservation maintaining minimal load growth throughout the current planning horizon.

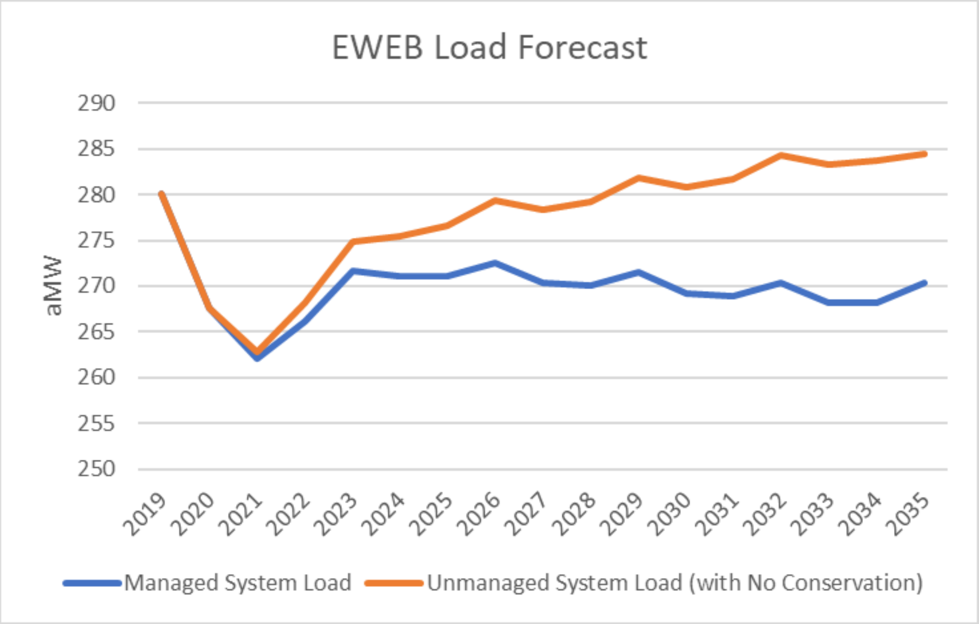

Figure B - Average load forecasts show little to no load growth (Managed System Load is net of conservation)

Peak load forecasts

We analyzed peak load under two different types of cold weather conditions. Average weather conditions, or 1-in-2 events, reflect temperature ranges that would be observed in an average weather year. Less common cold weather conditions, or 1-in-10 events, reflect more extreme temperature ranges that would be observed once every 10 years. Both weather conditions produce periods of peak consumption, but a 1-in-10 cold event produces higher peaks than a 1-in-2 events.

Figure C below illustrates the difference 1-in-2 and 1-in-10 weather events on forecasted peak load.

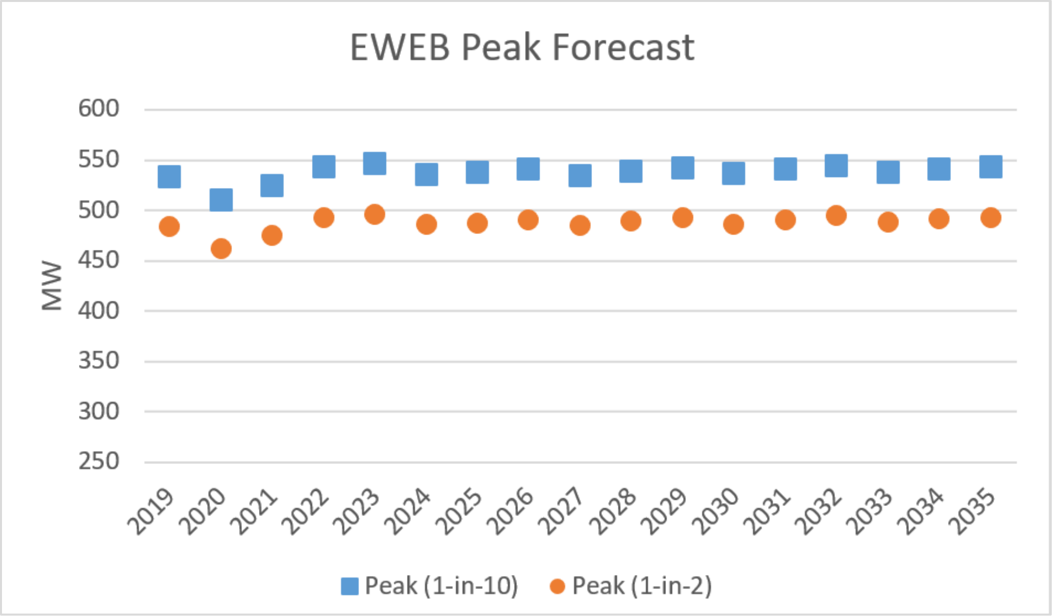

Figure C – EWEB's 1-in-10 peak load is roughly 10% greater than 1-in-2 peak.

Taken together, these forecasts indicate that EWEB's average load will remain around 270 aMW when managed with conservation programs, and typical (1-in-2) peak demand will hover near 500 MW.

Mitigating peak demand can be a useful strategy to delay infrastructure investments due to capacity constraints, limit the need for new resource acquisitions, and reduce reliance on "peaker plants" which are more carbon-intensive energy resources in the market.

The timing and size of electrification-based peak demand has both carbon and cost implications that require careful consideration. In addition, EWEB will be experiencing these peak impacts at the same time as other utilities in the Pacific Northwest. Therefore, this assessment must also consider a regional perspective when considering the impacts of electrification.

3.2 TIMELINE

Phase 1 of the study looks at both the overall energy and peak load impacts of different electrification scenarios using a regional framework. This is important given EWEB's reliance on market liquidity to meet peak load needs and to balance loads and resources. It is also timely given the pace of change to northwest power supplies as coal plants are retired.

It should be noted that while EWEB is monitoring the adequacy of power resources in the region closely, our involvement in the Northwest Power Pool (NWPP) Resource Adequacy Program is out of scope for this study.

Phase 2 will analyze cost impacts from widespread electrification and evaluate how EWEB programs could fit into local and regional carbon reduction policy goals. Phase 2 is an opportunity to model additional scenarios, such as rapid population growth and other climate-related uncertainties. The analysis will also take a deeper dive into the capacity of our power supply and delivery system.

The Electrification Impact Analysis is a precursor to the next Integrated Energy Resource Plan. As such it will assist the utility's planning efforts by modeling potential impacts to load (overall, peak and shape), our energy portfolio (resource mix, costs, carbon intensity, and compliance factors), and to our electric infrastructure. Ultimately, these planning efforts are aimed at optimizing our power resources, generating assets, infrastructure and customer products and services so that we continue to serve our community with clean, affordable and reliable power.

Phase 2 of the Electrification Study is scheduled to be completed in 2021, concluding with the Final Electrification Impact Analysis.

4 KEY CONTEXT: EWEB RESOURCE PORTFOLIO AND LOAD

HIGHLIGHT

A combination of ample, clean energy resources and a strong legacy of energy efficiency programs puts EWEB in a strong position to support electrification, both for our own customers and within the larger region.

Power Resource Portfolio

EWEB's energy portfolio is made up almost entirely of carbon-free resources. About 80% of our power comes from hydroelectric energy, while the remaining 20% comes from conventional and renewable resources. The majority of our energy is supplied through a contract with the Bonneville Power Administration (BPA); this contract is set to expire in 2028.

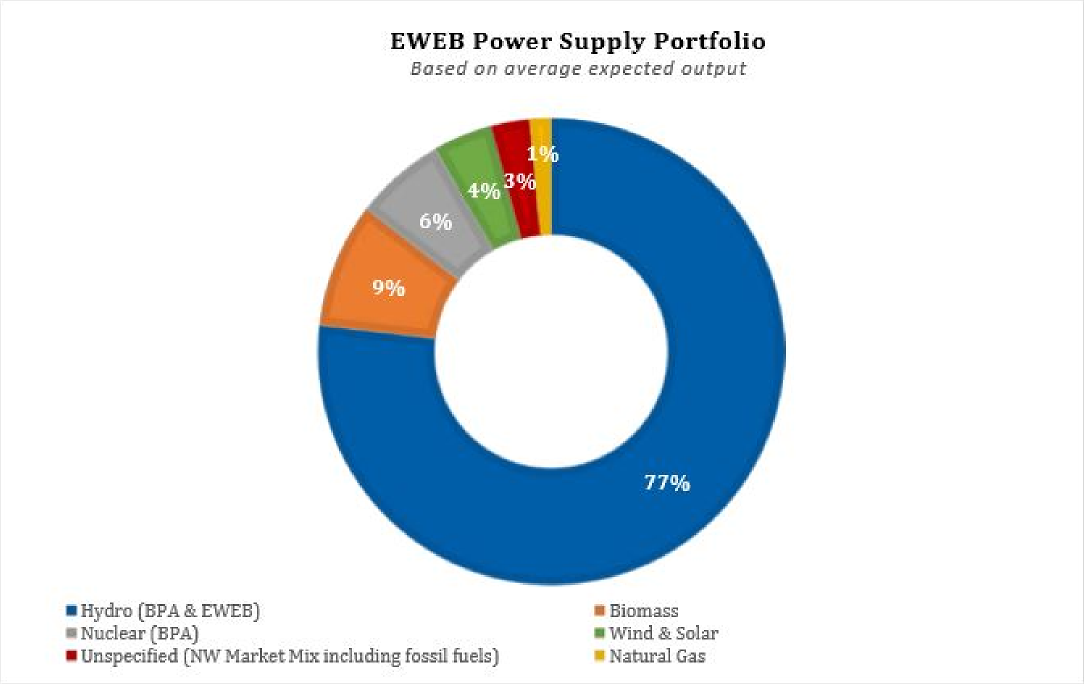

Figure D – Illustrates that only 4% of EWEB resources emit carbon.

System Load Shape & Peak Demand

When considering the impacts of electrification, it is critical to consider not just overall energy use, but also peak demand. Peak electricity is more expensive, affecting power supply, infrastructure costs, and ultimately customer bills.

Like most northwest utilities, EWEB currently experiences peak demand for power in the winter months, when space and water heating needs are highest, and when the availability of renewable resources like wind and solar are diminished. Winter peak is highly weather dependent and strongly correlated to space and, to a much lesser extent, water heating needs.

EWEB's daily load follows a fairly predictable diurnal pattern, with a morning peak demand during the coldest hours of the day, and smaller secondary peak in the late afternoon coinciding with customers' (especially residential) usage patterns.

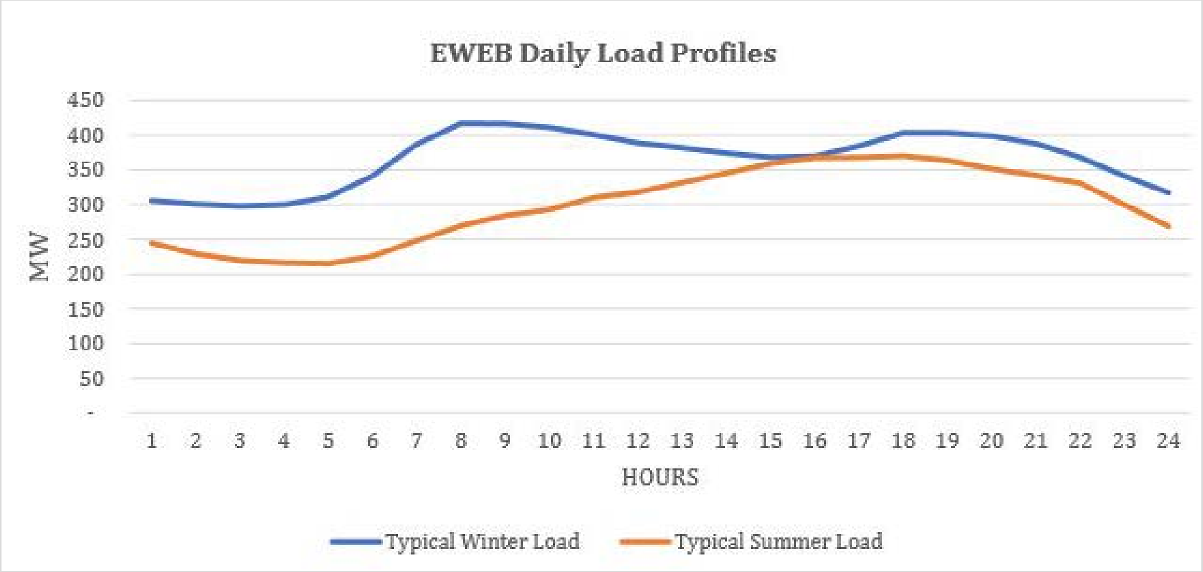

Figure E - Seasonally, Eugene's peak demand occurs in the winter months, when heaters are running continuously. On a daily basis, consumption typically peaks in the evening and winter mornings.

Conservation targets

EWEB's conservation targets are established annually based on load growth and collection of BPA conservation reimbursement.

Experience has shown that conservation programs are more efficiently delivered with relatively steady targets. EWEB plans to maintain the current level of energy savings to ensure the long-term stability of our program's administration.

While this amount of conservation exceeds our expected load growth in the near-term (due to decrease in load as a result of COVID-19), it reflects the maximum amount of conservation possible within budget, which is slightly higher than the reimbursement level from BPA. This level of activity meets the "natural demand" for our conservation programs, where customers and contractors bring projects to us, rather than EWEB stimulating new projects through outreach and advertising.

With this level of conservation and our current power contracts in place, EWEB typically has a surplus of energy resources available to serve our customers and sell on the wholesale market. The combination of ample, clean energy resources and a strong legacy of energy efficiency programs puts EWEB in a strong position to support electrification, both for our own customers and within the larger region.

5 KEY CONTEXT: GREENHOUSE GAS REDUCTION GOALS

HIGHLIGHTS

- Both state and local greenhouse gas inventories show the transportation sector as the largest contributor to greenhouse gas emissions.
- The City of Eugene's Climate Action Plan (2.0) forecasts that Eugene needs to reduce emissions by 790,000 MTCO2e by 2030 to meet climate goals. This translates to a 64% reduction in emissions from the 2017 baseline.

Transitioning from fossil-based fuel use to electricity while continuing to 'green' the electrical grid and pursuing energy efficiency are often cited as common pathways to reducing carbon emissions associated with climate change. Electrification of transportation and building energy use are key components of this over-arching strategy and are impactful to EWEB.

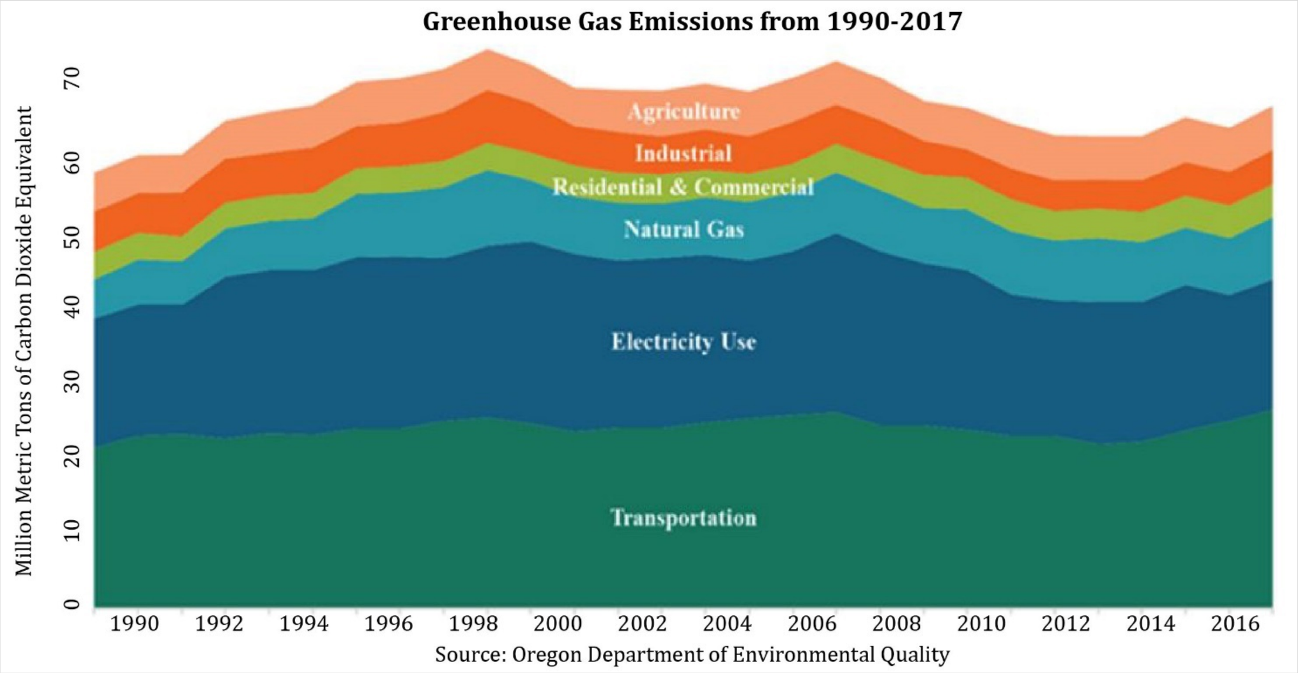

Figure F - State of Oregon's historical GHG emissions by sector

Both state and local greenhouse gas inventories show the transportation sector as the largest contributor to greenhouse gas emissions. As the graph above indicates, electricity is a major source of Oregon's GHG emissions as well, despite the predominance of hydroelectricity in the Northwest. According to the Oregon Department of Environmental Quality (DEQ), about 75% of the greenhouse gas emissions associated with the generation of electricity comes from power imported from other states[4].

In March 2020, Governor Kate Brown signed an executive order that sets out statewide emission reduction goals that call for Oregon to reduce its emissions at least 45% below 1995 levels by 2035, and at least 80% below 1990

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[4] "Program Options to Cap and Reduce Greenhouse Gas Emissions Final Report," Oregon DEQ, June 2020.

levels by 2050. Further, it directs the DEQ to establish programs to reduce emissions from three key sectors: large stationary sources, transportation fuels, and all other liquid and gaseous fuels, including natural gas.

Locally, the City of Eugene has recently released its Climate Action Plan 2.0 (CAP 2.0) which establishes science-based emission reduction goals by highest impact sectors in our community: transportation fuels, energy use in buildings and fugitive emissions (e.g. landfill waste, refrigerant leakage).

According to the City's 2017 greenhouse gas inventory, 53% of emissions are from transportation fuels, while 32% are from the electricity and natural gas used to heat and cool buildings.

City of Eugene CAP 2.0 GHG Emissions by Sector Using Market-Based Emissions Methodology

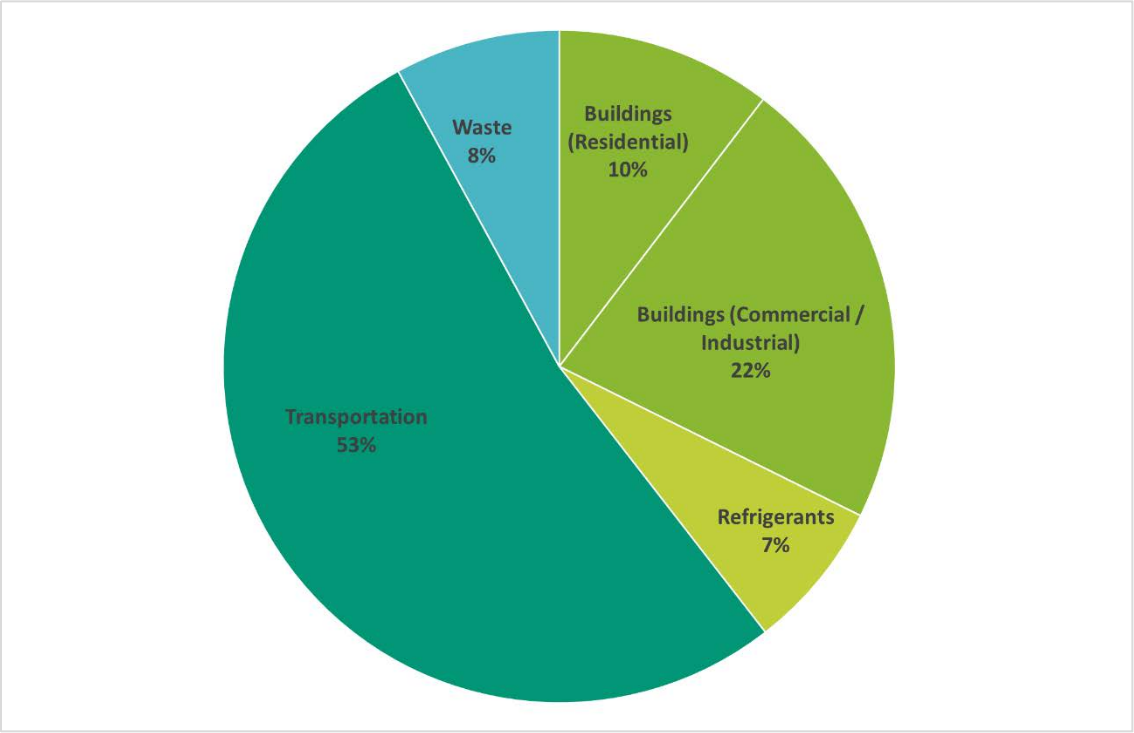

Figure G – Eugene's 2017 GHG emissions by sector

According to the CAP 2.0, 85% of local greenhouse gas emissions are from fossil-based fuel use. Therefore, meeting the CAP 2.0 goal will require bold policy and state legislative action to support the community in using less fossil-based fuel-based energy for transportation and in buildings.

The primary goal of the CAP 2.0 is to meet the carbon reduction goals established by Eugene's Climate Recovery Ordinance (CRO). The latest version of the CAP 2.0 forecasts that Eugene needs to reduce emissions by 790,000 MTCO2e by 2030 to meet those goals. This translates to a 64% reduction in emissions from the 2017 baseline.

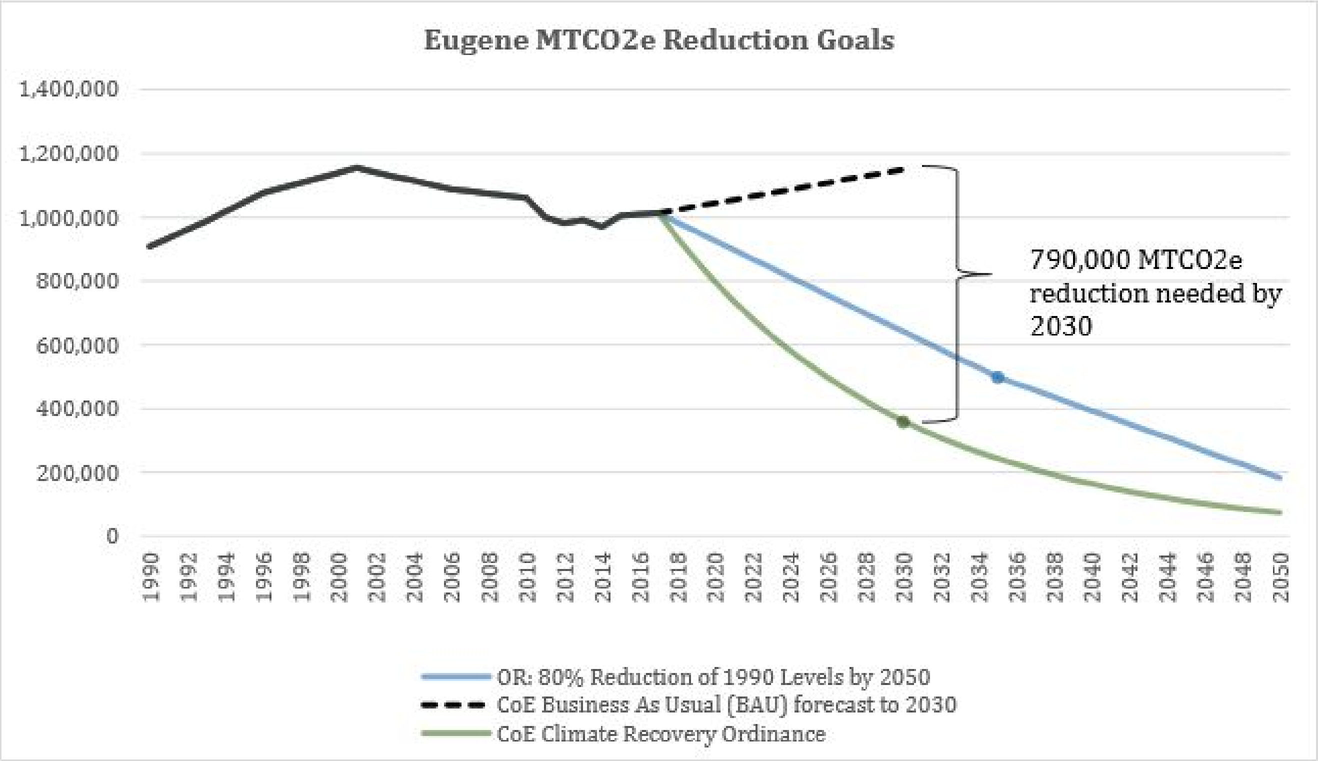

Figure H - City of Eugene CAP 2.0 esitmates that Eugene must reduce GHG emissions by 790,000 MTCO2e by 2030 in order to meet Eugene's Climate Recovery Ordinance. EWEB estimated local GHG emissions back to 1990 based on State of Oregon DEQ reporting.

6 KEY CONTEXT: REGIONAL AND LOCAL POLICIES

HIGHLIGHTS

- State and local policies can have a significant impact on the extent of electrification within EWEB's service territory.
- There are numerous policy options already in place and new legislation under consideration.
- While none of these policy actions on their own appear to have a noticeable impact on the pace of electrification in Eugene, collectively these policy actions do influence the market and reduce GHG emissions.

In the absence of federal action addressing climate change, state and local governments have passed legislation and adopted policies to establish carbon reduction goals. Different pathways exist to achieve these policy goals, but there are several common strategies to achieve deep de-carbonization. In the energy sector, these pathways include: 1) improvements in energy efficiency and reductions in per capita electricity use, 2) a significant decrease in the carbon intensity of electricity generation, and 3) electrification of transportation and buildings.

Overall, climate change policies that focus on carbon reduction tend to have an accelerating effect on the pace of electrification because this strategy crosses over multiple deep decarbonization strategies.

Policies influencing the pace of electrification can be categorized into two broad types: mandates or market-based solutions.

Mandates tend to be more traditional policy approaches where regulators set specific targets or goals and mandate specific technologies or solutions to achieve these goals. Market-based policies do not identify specific technologies or solutions, but rather create incentives or deterrents to influence business decisions and consumer behaviors to reach the given policy goal.

Each policy approach can have beneficial outcomes (reducing carbon emissions) as well as unintended consequences (impacting equity, increasing costs, decreasing market competitiveness, etc.)[5].

A synopsis of key policies and programs that could further advance electrification is below:

Oregon Renewable Portfolio Standards (RPS)

In 2007, Oregon enacted Senate Bill 838, the Oregon Renewable Energy Act (Act) which established Renewable Portfolio Standards (RPS) for all Oregon electric utilities. RPS legislation requires electricity generation to increasingly come from renewable resources, thereby reducing utilities' reliance on fossil-based fuels, while supporting other goals like improved air quality. This policy took the mandate approach by defining which types of renewable generation are considered "qualifying electricity" like wind power. RPS legislation is credited with helping "clean up the grid" by incentivizing the development of new renewable resources like wind and solar and contributing to early retirements of coal-fired power plants. However, those incentives contributed to lower wholesale power prices, which had unfavorable financial impacts on utilities like EWEB that sell surplus power into the wholesale markets. While this policy does not have a direct impact on the pace of electrification, it will

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[5] https://www.epa.gov/environmental-economics/economic-incentives

reduce the carbon intensity of the electric system over time. And should EWEB need to acquire new power resources in the future, the legislation will influence the utility's choices for supplementing its portfolio.

Clean Fuels Program

The Oregon Clean Fuels Program (CFP), managed through the Department of Environmental Quality (DEQ), is a market-based program aimed at reducing GHGs in the transportation sector. The legislation requires that oil companies reduce the carbon intensity of the transportation fuels used in Oregon, specifically gasoline and diesel, by 10% over ten years, beginning in 2016. Modeled after the California Low Carbon Fuel Standards, Oregon's program uses market credits and deficits to determine compliance, with the value of the credits increasing over time as the carbon-intensity for fuel is reduced. The program allows utilities to generate credits by aggregating the number of EVs registered in their service territory as well as any utility-owned charging stations. These credits can then be sold in the market to fuel providers that need them for program compliance.

EWEB has been participating in the Clean Fuels Program since 2017 and earning credits that generate revenue for the utility. Clean Fuel Credits help support electric vehicle programs, including education and outreach efforts like Ride and Drive events and rebates for residential and public Level 2 EV charging equipment. The credits are also included in the budgeting process for EWEB's smart electrification program, which rewards conversion to highly efficient electric technologies in buildings. Currently, the CFP and the revenue from the sale of credits is scheduled to sunset in 2025, but program extension to 2030 is likely.

Phaseout of gas-powered vehicles

In September 2020, California Governor Gavin Newsom signed an executive order directing state regulators to require all new cars and passenger trucks sold in California be zero-emission vehicles by 2035. This order would implement the phaseout of new gas-powered cars and light trucks over the next 15 years and the governor hopes this will help spur greater innovation for zero-emission vehicles. While this mandate is agnostic to the type of transportation technology, it is expected to increase adoption of EVs. Locally, EWEB customers would indirectly benefit from any innovations or cost reductions which come about as EVs achieve economies of scale. Overall, the mandate is expected to increase the EV offerings from automakers over time, which is expected to increase EV adoption locally.

Carbon Pricing

EWEB has taken an active role advocating for carbon pricing as the least-cost approach to achieving Oregon's GHG reduction goals. As a general policy position, the Board supports carbon pricing policies, such as a cap and trade approach, that are direct, economy-wide, market-based and technology neutral. This policy position has been reinforced by multiple analyses demonstrating that a state carbon cap and trade[6] program can reduce GHG emissions in the energy sector by Oregon's GHG target – a reduction of 80% from 1990 levels by 2050 – at the least cost to Oregonians and Oregon businesses. Any market-based policy placing a cost on carbon is expected to increase the pace of electrification by making carbon emitting end-uses less cost competitive. However, the Oregon legislature was unsuccessful in passing carbon-pricing legislation in 2019 and there is much uncertainty about the political viability of another attempt in the 2021 session.

Executive Order No. 20-04

Less than a week after the 2020 legislature adjourned without passing carbon cap-and-trade legislation, Governor Brown issued Executive Order No. 20-04 (EO 20-04), which is aimed at creating a GHG program that

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[6] Cap and trade is a regulatory system designed to incentivize entities to reduce their carbon emissions. The cap puts a firm limit on emissions. The trade creates an exchange value for entities that reduce emissions below their permitted emissions cap.

exercises executive authority to the fullest extent permitted by existing legislation. EO 20-04 issues several directives to accomplish these statewide carbon reduction goals and take effect by the beginning of 2022, including:

- Carbon polluters in the industrial, transportation and natural gas sectors would have emissions capped and reduced over time by the state's Environmental Quality Commission (EQC) and Department of Environmental Quality (DEQ).
- Directs DEQ to amend the existing Clean Fuels Program (CFP) standards and schedule a phase-in implementation to reduce emissions "per unit of fuel energy" to 20% below 2015 levels by 2030, and 25% by 2035.
- Directs the DEQ and EQC to pursue methods to accelerate the generation of Clean Fuels Credits.
- Directs state agencies to alter building codes to prioritize energy efficiency.
- Provisions for updated state energy efficiency standards for appliances and directives for reducing food waste.
- A plan to swap out the state's existing automobile fleet with zero-emissions vehicles and add charging stations at state buildings, a statewide analysis of what infrastructure Oregon needs to expand use of EVs, mandatory evaluation of GHG impacts in state planning of transportation projects.

All these directives are expected to increase the pace of electrification, especially in the transportation sector.

Local Natural Gas Moratoriums

In 2019, Berkeley, CA became the first city in the U.S. to ban natural gas hookups in new single-family homes, town homes and small apartment buildings. This approach has caught the attention of other municipalities struggling to reach their carbon reduction goals, but few have followed Berkeley's lead. Rather than a mandated approach, some jurisdictions are looking to more restrictive building codes to reduce energy use in buildings in a more fuel-neutral way. For example, Governor Brown's recent executive order includes prioritizing energy efficiency in building codes as well as establishing an aggressive timeline to achieve net-zero energy ready buildings[7].

Collective Policy Impacts

State and local policies can have a significant impact on the extent of electrification within EWEB's service territory. There are numerous policy options already in place and new legislation under consideration. While none of these policy actions on their own appear to have a noticeable impact on the pace of electrification in Eugene, collectively these policy actions do influence the market and reduce GHG emissions (for example, automakers increasing their lineup of electric vehicles).

As noted earlier, electrification is just one pathway to deep decarbonization. New and existing policies will need to create stronger economic signals, or establish mandates, to meaningfully accelerate the transition to electric technologies.

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[7] Zero energy-ready buildings are so energy efficient that a renewable energy system could offset all of its annual energy consumption, U.S. Department of Energy.

7 ELECTRIFICATION OF PASSENGER AND LIGHT DUTY VEHICLES

HIGHLIGHTS

- EV adoption is expected to increase, but the rate and timing of adoption is uncertain.
- In all except the fastest modeled adoption rate, load growth is gradual and results in less than a 15% increase to EWEB's overall average load and less than 30% increase in peak demand.
- Customer programs to shift the timing of EV charging behavior is a promising strategy to mitigate the potential negative cost and carbon impacts of peak demand from EVs.
- EV adoption has the potential to reduce community carbon emissions annually in the range of 10,000 (low growth) to 100,000 MTCO2e (fastest growth) by 2030.

The low carbon emissions from the Pacific Northwest electric grid make EV carbon emissions much lower than gas powered vehicles. According to a 2020 report [8], EVs powered by grid-average electricity in the Pacific Northwest are estimated to generate an equivalent amount of carbon as a gasoline car that gets 96 mpg. Given the sizeable contribution the transportation sector has on greenhouse gas emissions, increased adoption of EVs is a cornerstone to a meaningful carbon reduction strategy for Eugene.

The market and policy landscape for transportation electrification is changing rapidly, and these shifts have implications for utilities and the climate. For EWEB, transportation electrification has impacts not only for load, but also for infrastructure planning and development of customer programs.

Phase 1 of this study focuses on light duty vehicles recognizing their potential growth in market share as battery technology and cost-competitiveness improves, and as customer acceptance gains traction. Some levels of medium and heavy-duty transportation (freight) electrification is likely over the study period. However, this is outside the scope of this analysis due to significant uncertainty regarding the extent of electrification in larger vehicles.

7.1 EV ADOPTION RATES

Several studies predict that EVs will reach cost-parity with conventional gas-powered cars in the next few years, which is considered a key "tipping point" in EV adoption.

To model the impacts of electrification of light duty vehicles in EWEB's service territory, EWEB identified a range of future EV adoption rates.

Based on Oregon vehicle registration data, there were 1,041 and 1,328 registered EVs in EWEB's service territory in 2018 and 2019, respectively. This represents a year-over-year growth rate of 28%.

Still, local historical data on EV adoption rates is limited, and there is great uncertainty in the levels of market penetration that can be expected over the next 30 years.

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[8] Electric Vehicle Costs and Benefits for BPA Full Requirements Customers, Bonneville Environmental Foundation, April 2020

To model a range of potential EV adoption rates in our area, we reviewed national studies from organizations like the Electric Power Research Institute and Energy and Environmental Economics, Inc. ("E3"), and ultimately developed four projections reflecting low, medium and high and fastest growth forecasts.

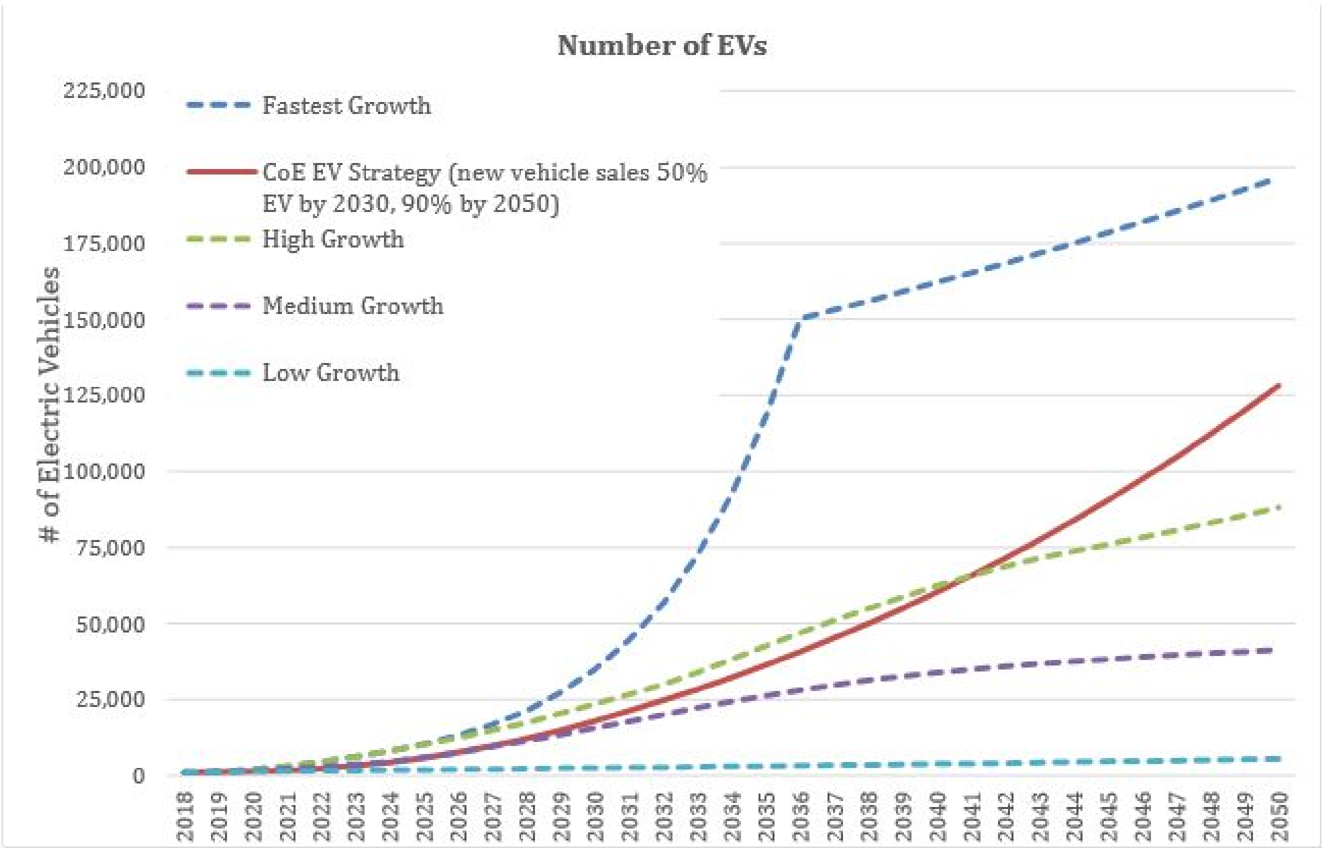
The low projection uses a slightly elevated adoption rate over the historical national trend through 2050. For the medium and high projection rates, we utilized data from E3 which has been acting as a strategic advisor for this study. The fastest projection builds on the high forecast rate and assumes Eugene's 28% year-over-year growth rate in 2019 will continue until 100% market penetration is reached in 2036.

The City of Eugene is in the process of developing an Electric Vehicle Strategy with the goal of 50% EVs by 2030 and 90% EVs by 2050. Assuming the typical light-duty vehicle has a useful life of more than 10 years, conversion of the existing stock of vehicles over time may be slow. Therefore, we interpreted the City's adoption strategy as a percentage of new sales rather than as a percentage of total vehicles on the road (i.e. stock). EWEB's estimated City EV strategy adoption is included as a separate EV growth rate, for additional context.

The table below translates these projections into a percentage of total vehicles stock in 2050.

Estimated EV Percent of Total Vehicle Stock by 2050	
Low adoption (business as usual)	3%
Medium adoption	21%
High adoption	45%
Estimated City EV Strategy	65%
Fastest EV adoption*	100%

The wide range of potential EV penetration rates is due to the significant uncertainty regarding consumer behavior. While price parity with conventional gas-powered vehicles is one economic driver of EV adoption, so too are fuel prices, tax incentives and even marketing by automakers. We will continue to monitor local EV data in order to refine these projections over time.



**The fastest growth rate is included for reference and continues to increase past 2036 as all new vehicles sold (2% growth annually) are EVs*

Figure I – The current number of EV's in EWEB's territory is low but growing, and future adoption rates of EV's have a wide band of uncertainty.

7.2 LOAD IMPACTS OF EV ADOPTION

As more EVs enter EWEB's service territory, impacts to the utility's load from charging these vehicles will grow over time.

To calculate these impacts, we need to determine the energy used per EV. This requires two main assumptions:

1) Average number of miles driven: Based on national data for light-duty vehicles, the average travel distance is approximately 31.5 miles per day[9].

2) Average amount of energy used per vehicle mile driven: Energy consumption per mile driven varies depending on the make and model of each EV. EWEB reviewed the MPGe of various EVs currently available today and calculated an average power consumption of 0.31 kWh per mile. This yields an average energy consumption of 9.85 kWh/day[10] for each EV in EWEB's service territory.

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[9] "Highway Statistics 2018", Federal Highway Administration, 2020.

[10] Derived by multiplying miles driven per day by kWhs consumed per mile, 31.5 miles per day x 0.3125 kWhs per mile = 9.85 kWh consumed per EV per day

This daily consumption can be annualized and scaled based on the amount of EVs adopted over the next 30 years to forecast the energy impacts of EV adoption.

In Figure J below, the energy impacts from the various EV adoption rate scenarios are shown over time in average megawatts (aMW). The market penetration rates are shown as percentages.

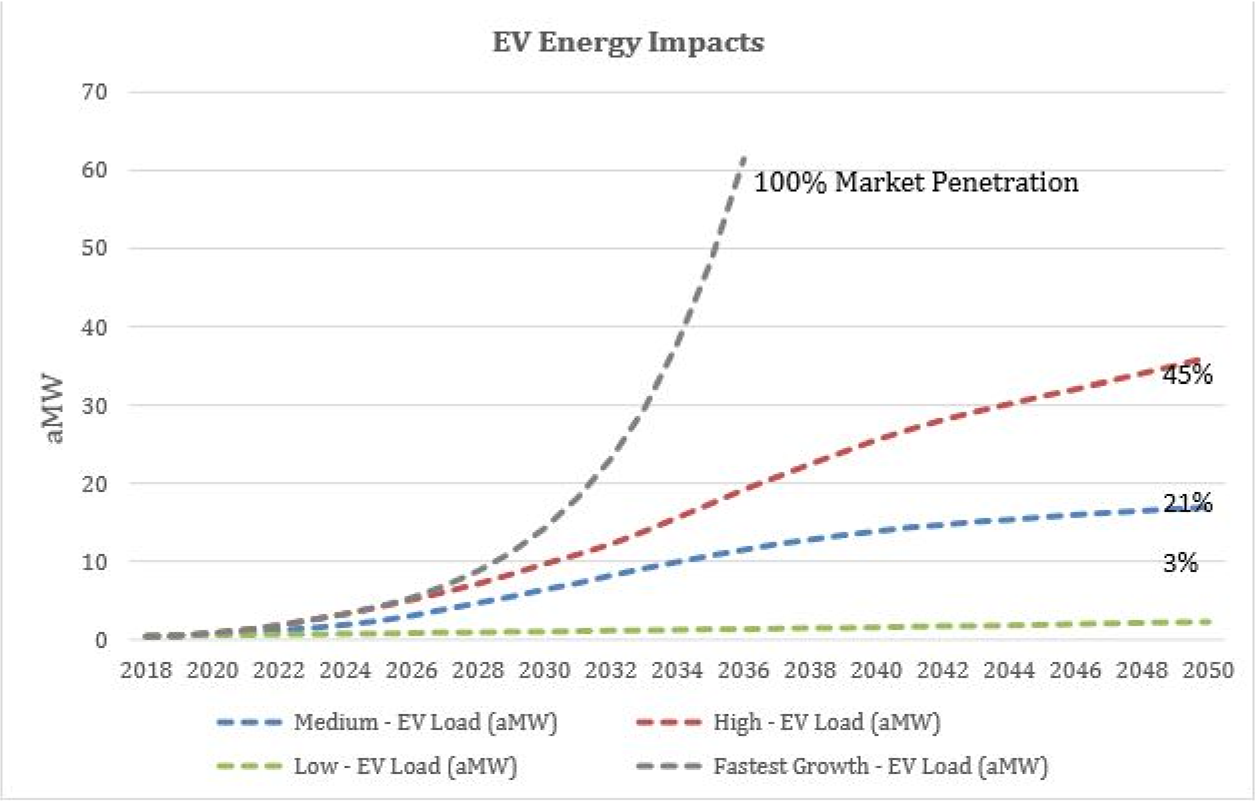


Figure J – A High EV adoption rate is estimated to represent 45% market penetration and approx. 36 aMW of load by 2050.

Recall that EWEB’s overall average load is 270 aMW. **In all except the fastest adoption rate, load growth is gradual and results in less than a 15% increase to EWEB’s overall average load by 2050.**

It should be noted that EV efficiency is expected to improve over time, which would change this average energy consumption. EV efficiency improvements are not modeled in Phase 1 of EWEB’s study.

This analysis is helpful in forecasting long-term energy demand trends, but it does not reflect the full impact of EVs on the electric utility. The following sections discuss the impact of transportation electrification on peak demand.

7.3 PEAK IMPACTS OF EV ADOPTION

A key question this study strives to answer is to what extent EV charging behavior will alter EWEB's existing peak demand. This requires estimating the coincident peak demand, which refers to the collective power consumption of the fleet of EV equipment over a 24-hour period.

Modeling Approach

For EVs, coincident peak demand is dependent on the type of charging infrastructure and the individual EV driver's charging habits (e.g. at home, at work).

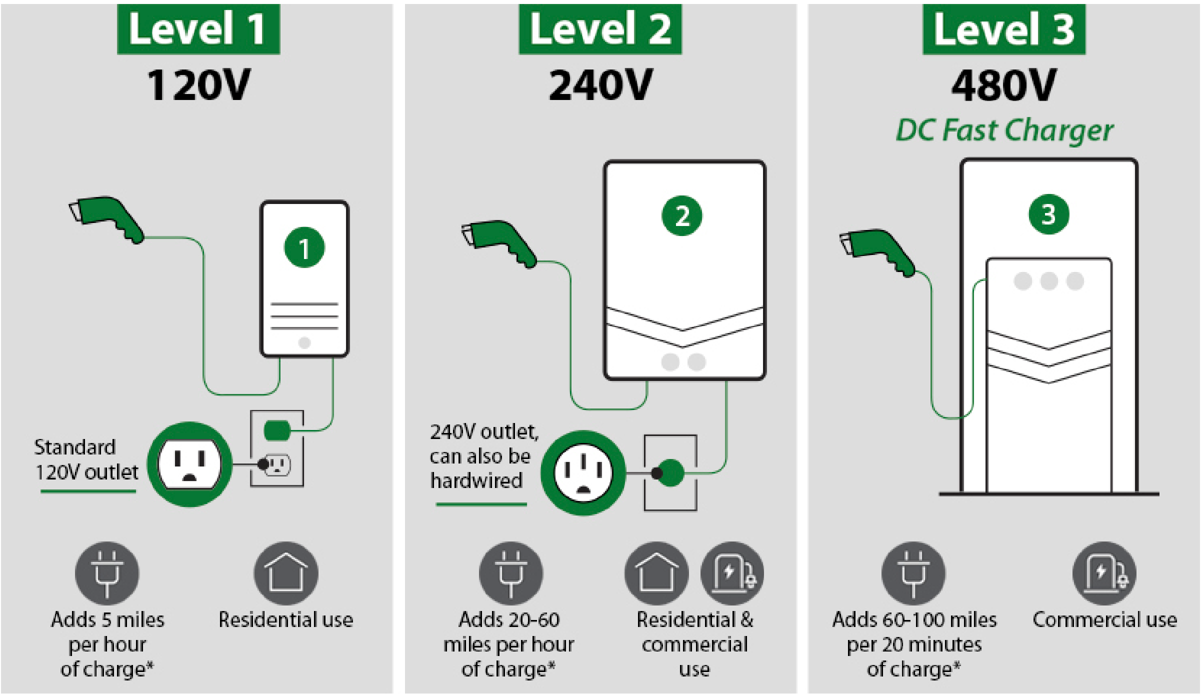
Research shows that for a majority of early EV adopters, charging most commonly occurs at home. In a survey of over 2,800 electric vehicle drivers funded by the California Air Resources Board, 83% utilize home charging, while 11% rely mostly on non-residential charging[11].

Type of charging infrastructure used (level 1, level 2 or DC fast chargers)

Regarding the type of charging equipment used at home, the California Air Resources Board study found that the majority used Level 1 while the remainder had Level 2 charging equipment.

For the purposes of this study, EWEB analyzes Level 2 charging only as a more conservative measure of potential impacts to utility infrastructure and peak load.

The graphic below illustrates the various levels of electric vehicle supply equipment (EVSE).



** Estimated. Actual charge times may vary.*

Figure K - Source: https://www.cenhud.com/my-energy/electric-vehicles/how-to-charge/

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[11] Quantifying the electric vehicle charging infrastructure gap across U.S. markets https://theicct.org/publications/charging-gap-US

Timing of charging

The National Renewable Energy Lab (NREL) modeled the charging behavior of 100,000 EV users to better understand the impacts of EV charging over the course of a 24-hour period (Team, 2019). The aggregate charging demand profiles generated by NREL's modeling shows strong correlation to an 8AM – 5PM workday, with most drivers charging when they get home from work (Figure L).

This study shows that the coincident demand reaches a 1.5 kW peak around 7PM when the majority of those 100,000 EVs are charging simultaneously.

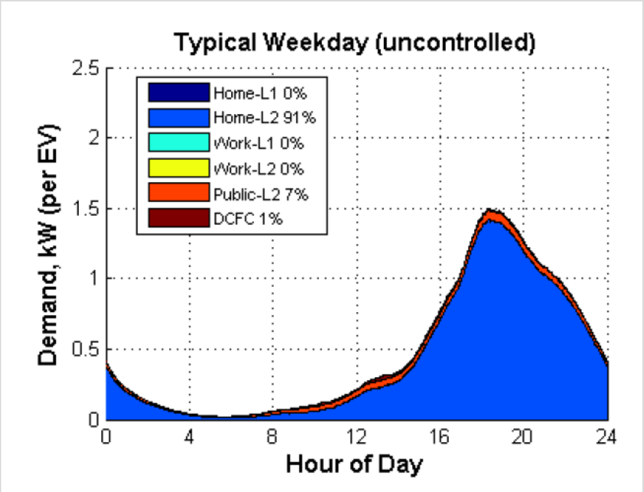

Figure L – NREL study shows energy impacts of uncontrolled EV charging behavior.

EV Peak Analysis Results

Based on the NREL data, as well as coincident EV demand information provided in industry trainings, it appears that 1.5 kW coincident demand per EV is reasonable. Using this assumption, we can now model the coincident demand of EVs over time depending on different adoption rate projections based on unmanaged/uncontrolled charging behavior.

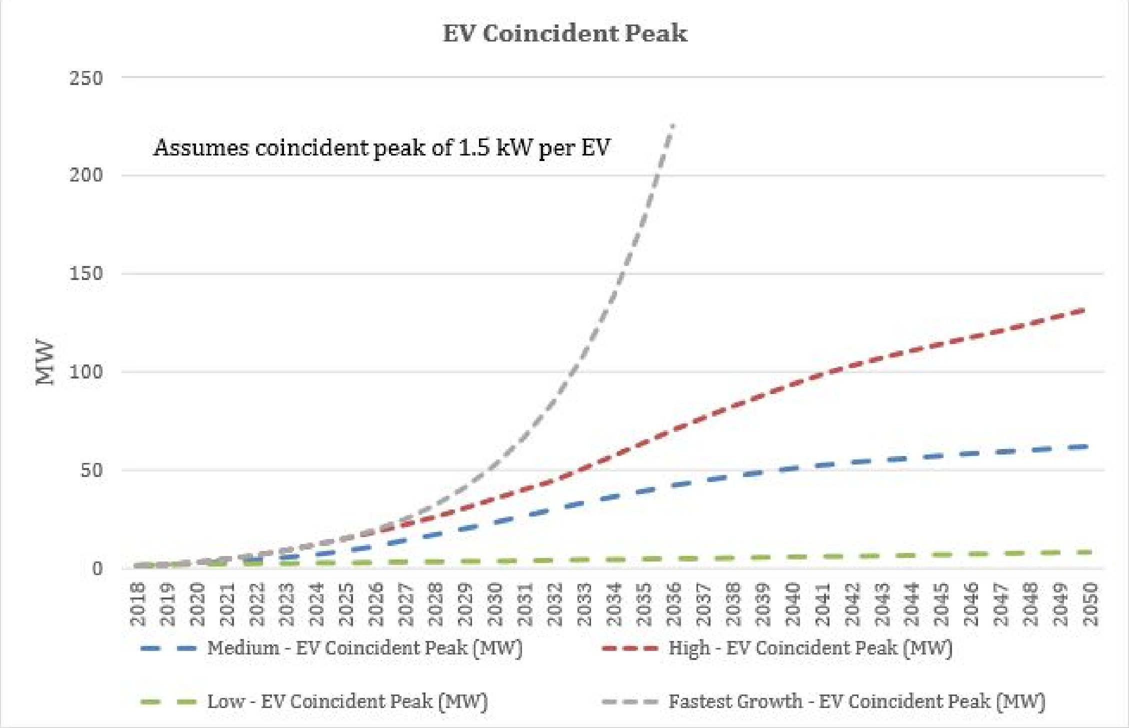

Figure M – Coincident peak load impacts based on various adoption rates of EV's over time.

Recall that EWEB's typical peak is around 500 MW. **The study shows that without mitigation measures, in all except the fastest adoption rate, peak demand increases by less than 30% by 2050, with that demand accumulating gradually over time.** The fastest adoption rate creates a dramatic and sizeable peak demand starting in 2028.

7.4 MITIGATING PEAK DEMAND

Mitigating peak demand can be a useful strategy to delay infrastructure investments due to capacity constraints, limit the need for new resource acquisitions, and reduce reliance on "peaker plants" which are more carbon intensive energy resources in the market.

In the same NREL study, researchers shifted the aggregate charging demand profiles of 100,000 EVs on a typical weekday by controlling charge times (Figure N). Per the study: "Uncontrolled charging represents the case where EVs charge immediately at full power once connected and continue until completely charged. Maximum delay represents the case where demand is shifted into the latest period that ensures the EV receives a complete charge before departure. These two cases represent both ends of the spectrum of vehicle charging."

In the NREL study, the weekday uncontrolled charging creates an evening charging peak of approximately 150 MW from 6 to 10 PM, whereas the maximum delay creates an early morning charging peak of approximately 205 MW from 6 to 10 AM. These aggregate peaks translate to 1.5 kW-per vehicle and 2 kW-per vehicle, respectively[12].

It should be noted that for EWEB, delaying EV peak charging to 7AM (as in this NREL study) is not the ideal delay, but rather shifting to midnight, when EWEB's load is lowest, would minimize impacts to the utility. See Mitigation Strategies section for illustration of managed EV charging compared to EWEB system load.

Customer interventions to shift the timing of EV charging behavior is a promising strategy to mitigate the potential negative cost and carbon impacts of peak demand from EVs.

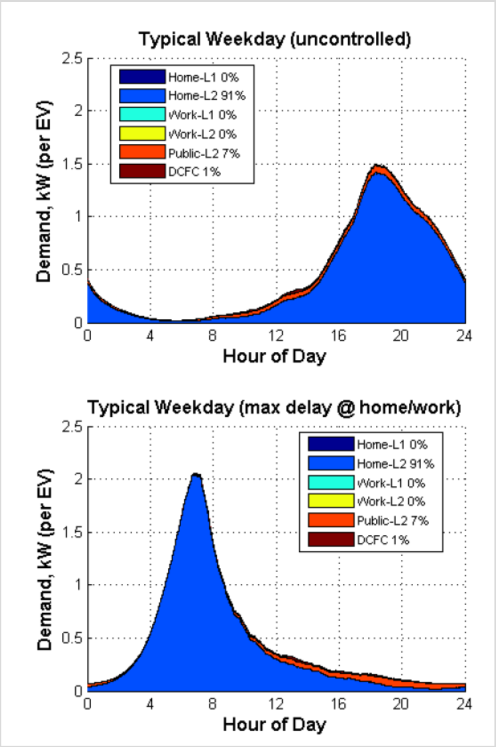

Figure N – Comparison of uncontrolled and controlled EV charging behavior shows that the timing and load shape of energy consumption can be changed.

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[12] Grid Integration Tech Team and Integrated Systems Analysis Tech Team- Summary Report on EVs at Scale and the U.S. Electric Power System – 2019, p. 7

Due to the limited penetration of EVs in our service territory, EWEB has not yet implemented an electric vehicle charging rate and/or load management program. However, EWEB is preparing for a future where such programs could be implemented.

Currently, EWEB offers incentives for Level 2 charger installation, specifically because this equipment can be programmed to charge at certain times. EWEB also has started a public education campaign to encourage customers to shift discretionary energy use, like EV charging, to off-peak hours (10PM to 6AM).

Implementation of advanced metering technology will enable the utility to adopt time of use pricing and other pricing programs to encourage EV owners to shift charging to off-peak times. Further analysis of the potential impacts of managed EV charging behavior is recommended to help inform EWEB's future program offerings.

7.5 EVS AND CARBON REDUCTION

As State and local greenhouse gas inventories show, transportation-related emissions are a major component of our community's carbon footprint. This study aims to improve our understanding of the role electrification of transportation plays in the context of a northwest grid. This regional perspective captures the impacts of transitioning from fossil-based fuels to electricity in the context of a shared and integrated power grid, including overall energy and peak demand impacts.

Modeling Approach

To model the carbon impacts from EVs, EWEB first calculated the carbon intensity associated with vehicle charging. We then used national data on average miles driven to calculate the carbon emitted by an average EV in EWEB's service territory, compared to emissions from a typical internal combustion engine vehicle.

To determine the carbon intensity of EV charging, we analyzed typical weekday and weekend, uncontrolled hourly charging patterns. As stated in the peak impact section above, most of the uncontrolled EV charging takes place around 7PM, a time of high power consumption across the grid.

Using these hourly charging patterns, we multiplied the power consumed by the hourly NWPP carbon intensity for that hour. Analyzing the hourly data over the course of a year, we concluded that the average annual carbon intensity of uncontrolled EV charging was 0.22 MT CO2e per MWh.

It should be noted that this EV charging carbon intensity is higher than the average carbon intensity of the NWPP because the uncontrolled charging is taking place when overall power consumption is highest and there is increased use of fossil-based fuel-burning generators on the grid. However, shifting this charging to off-peak periods can reduce the carbon emissions associated with EV charging. See the Cumulative Carbon Reduction section for further analysis on the potential benefits of zero-carbon electrification.

Using the daily vehicle miles traveled figure of 31.5 miles/day, and carbon intensity stated above, an EV in EWEB's service territory is expected to produce approximately 0.84 MT CO2e per year. This represents about a 75% reduction in carbon emitted when compared to a standard light-duty gasoline vehicle that meets current fuel economy standards of 35 MPG.

It should be noted that carbon reduction estimates are dependent on the assumed efficiency of the gas combustion engine. See the Cumulative Carbon Reduction section for further analysis on the carbon reduction potential of legislated improvements in gas engine efficiency over time.

The annual carbon footprint of a typical passenger car compared to an EV are illustrated in the following charts. They start on the left-hand side at the source. As you work your way right on the chart, you see how the fuel sources are converted to either the desired end-use (power to wheels) or into unused "waste" GHGs, generally from heat lost during energy consumption/transformation. Keep in mind these charts reflect GHG emissions and not explicitly energy usage[13]. Further, these charts account for upstream electric transmission energy losses, and emissions from fuel production and transportation.

An average light-duty gasoline vehicle uses roughly 20%[14] of its energy to move the car forward; the rest is lost as waste heat at the tailpipe due to various internal combustion engine inefficiencies. In addition to tailpipe emissions, there are upstream emissions associated with the production and transportation of gasoline[15], which is estimated to increase vehicle carbon emissions by another 20-25%. In total, a typical gas-powered vehicle will produce approximately 3.6 MT CO2e per year, the majority of which is associated with losses from waste energy. GHG emissions associated with gasoline vehicles can be reduced with higher vehicle efficiencies and/or less GHG intensive fuels.

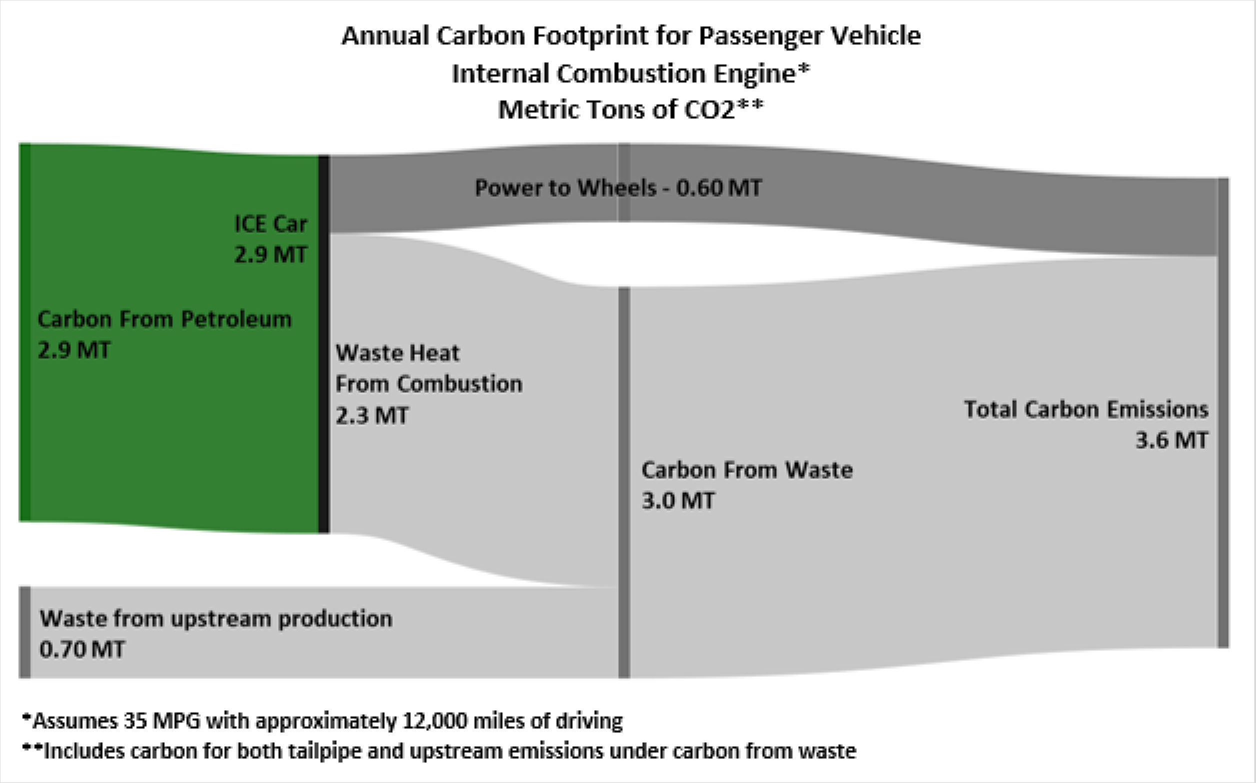

Figure O – Sankey chart illustrates the source of carbon emissions associated with an internal combustion engine.

By contrast, roughly 88%[16] of the GHGs created by energy that goes into an EV is used to move the car forward, after accounting for regenerative braking. The waste in an EV is due to drivetrain and battery inefficiency. EVs also need to account for upstream waste associated with electric generation, transmission and distribution[17], which accounts for nearly 67% of the carbon created by the energy used to power an EV.

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[13] Energy usage and carbon creation can differ with energy resource mix and vehicle type

[14] https://fueleconomy.gov/feg/atv.shtml

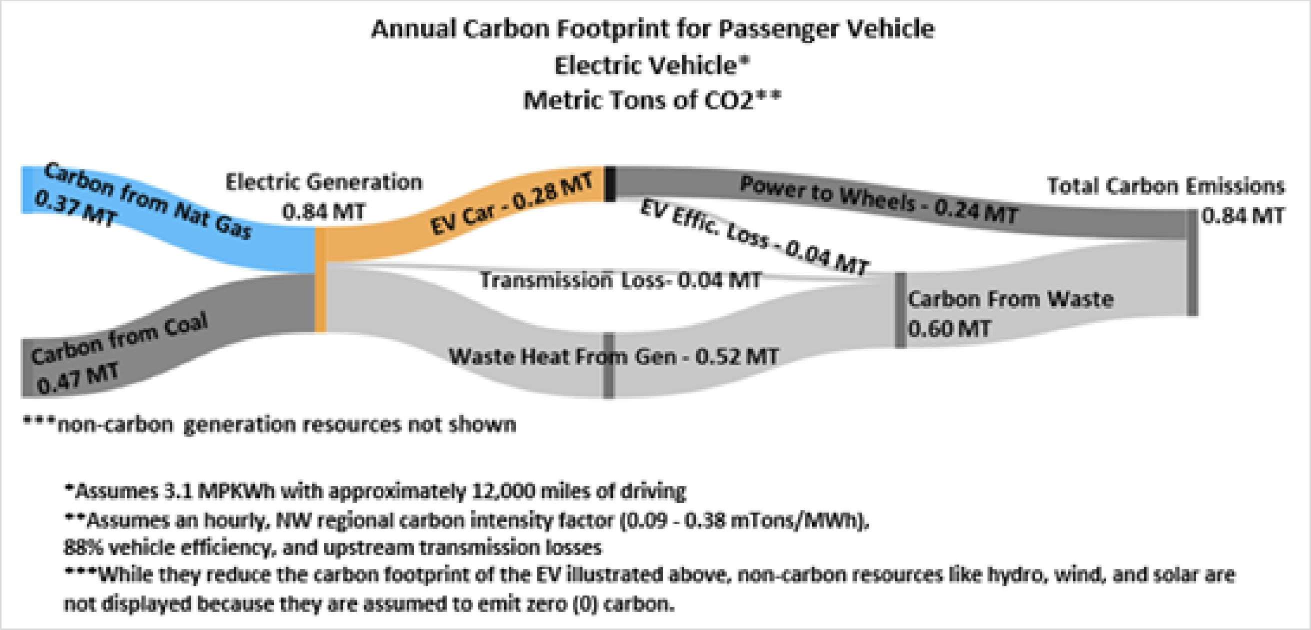
[15] https://fueleconomy.gov/feg/label/learn-more-gasoline-label.shtml & https://fueleconomy.gov/feg/climate.shtml

[16] https://fueleconomy.gov/feg/atv-ev.shtml

[17] We assumed thermal generation efficiency to be 35% and losses from transmission and distribution to be ~6%

In total, 29% of the carbon created by an EV comes from energy that is used to move the car forward, while the remaining 71% is lost as waste heat energy. However, because most of the energy produced in the Northwest comes from carbon free resources[18] that don't emit a large portion of their energy/carbon as waste heat, the example EV is expected to produce a total of 0.84 MT CO2e annually.

Carbon associated with EVs can be reduced by increasing the efficiencies of thermal generators and using less carbon intense fuels (natural gas and renewable generators vs coal).


Annual Carbon Footprint for Passenger Vehicle
Electric Vehicle*
Metric Tons of CO2**

***non-carbon generation resources not shown

*Assumes 3.1 MPKWh with approximately 12,000 miles of driving
**Assumes an hourly, NW regional carbon intensity factor (0.09 - 0.38 mTons/MWh), 88% vehicle efficiency, and upstream transmission losses
***While they reduce the carbon footprint of the EV illustrated above, non-carbon resources like hydro, wind, and solar are not displayed because they are assumed to emit zero (0) carbon.

Figure P – Sankey chart illustrates the source of carbon emissions associated with EV charged with electricity.

Analysis Results

Using these assumptions, each new EV that replaces an internal combustion engine in EWEB's service territory translates into a 2.75 MT reduction in annual GHG emissions.

Note that the actual GHG benefit of any EV will be influenced by numerous factors, including travel patterns, specific vehicle efficiencies and the carbon intensity of fuels used. This estimated carbon savings can be applied to different forecasted adoption rates to show potential community-wide impact, as illustrated in the chart below.

In the medium case (21% adoption rate) EVs would annually reduce 43,000 MT CO2e by 2030, with a wide range of possible carbon benefits depending on actual adoption rates by 2050.

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[18] https://www.nwcouncil.org/energy/energy-topics/power-supply

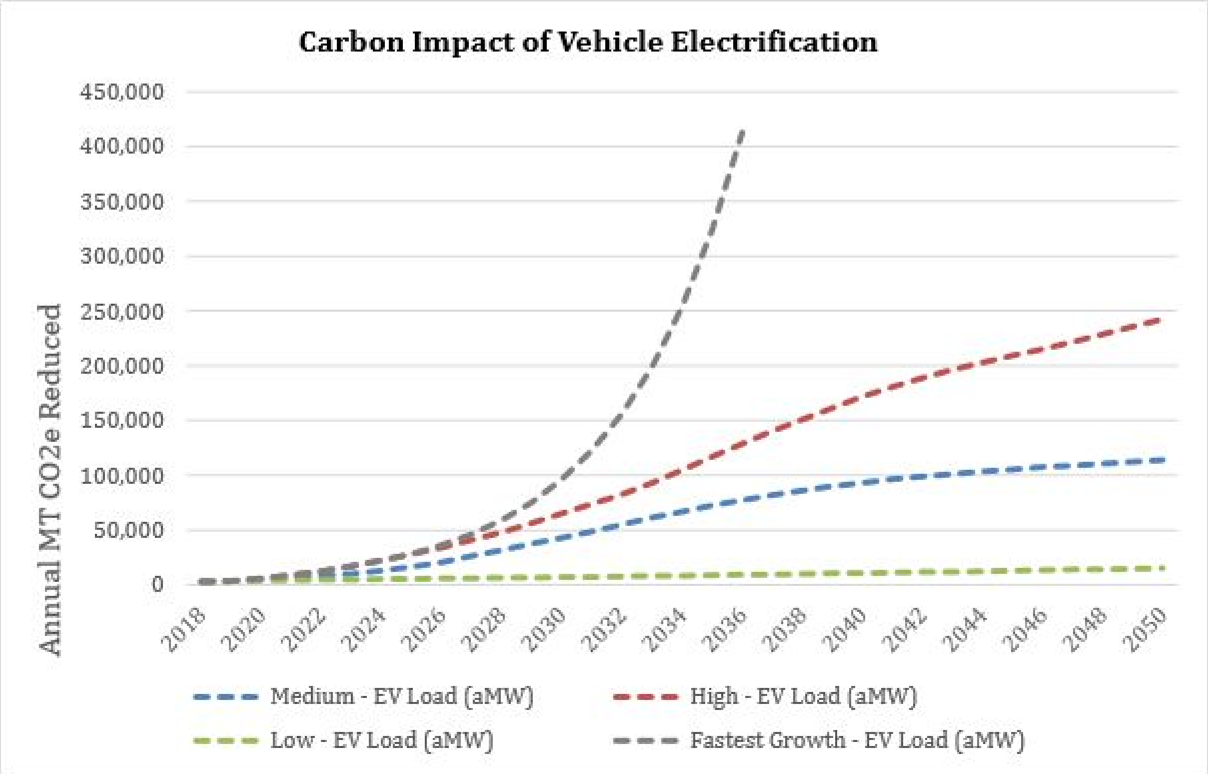

Figure Q – Annual Carbon savings as a result of EV adoption are quite meaningful over time.

To see these reductions within the context of the State and Eugene's climate goals, see the "Cumulative Carbon Reduction" section of the study.

8 ELECTRIFICATION OF BUILDINGS

8.1 EWEB CUSTOMER SEGMENTATION & SCOPE

For modeling purposes, the EWEB customer base is represented by three sectors: Residential, Commercial, and Industrial. This study focuses on residential and commercial customer sectors only. Industrial loads make up about 22% of EWEB's average load and are not included in this study.

In the sections below, the impacts of electrifying space and water heating are presented separately for the residential and commercial sector. This is due to the differences in customer demographics, and the space and water heating energy needs unique to each sector.

Residential customer segmentation is based on building type: single family, multi-family and manufactured homes. Commercial segmentation is based on business type: Education, Grocery, Health Care, Office, Restaurant, Warehouse, etc.

Of the many different end-uses within the residential and commercial sectors, the electrification study focuses on space and water heating because:

1. Improvements in heat pump technology have created a variety of high-efficiency, cost-competitive alternatives to traditional electric and natural gas heating equipment. For example, heat pumps rated for cold weather down to five degrees Fahrenheit are now available on the market, as are heat pumps for water heaters. These types of technology are gaining customer acceptance for both space and water heating end-uses.

2. These end-use load shapes correlate closely to EWEB's existing system peaks. Unmanaged growth due to electrification in this sector is expected to add to existing system peak loads.

To quantify electrification impacts from these end-uses, we need to first understand our customers' current technology choices across segments. Primarily, we need to understand how much of each end-use energy demand is being met with electricity compared to natural gas, and to a lesser extent, propane, wood, and other fuel sources. Using end-use modeling tools, regional survey data, and information from Northwest Natural Gas (NWNG), EWEB analyzed the potential impacts of electrifying existing natural gas end-uses in EWEB's service territory. The results of this analysis are found in the Residential and Commercial Sector sections below.

NWNG also studied the potential impacts of electrification in our community, and found potential challenges to fuel-switching, especially during very cold periods when EWEB is experiencing peak electricity use. Their findings indicate that serving this additional load with electricity rather than direct-use natural gas may have unintended consequences such as an increased need for natural gas-fired generation in the region to maintain reliability, which may increase carbon emissions and costs to customers. Further, NWNG's study indicates that peak natural gas consumption in our community is substantial, and that conversion of natural gas end-uses to electricity could significantly increase EWEB's peak load.

EWEB and NWNG have been working together to better understand the differences in our respective study assumptions. Some of these differences are due to system planning standards (i.e. for natural gas utilities a 1-in-100 peak is a planning standard, while for electric utilities 1-in-10 peak is most common for stress-testing purposes). Other differences are due to the assumed performance of heat pumps during peak cold weather events. As such, there are still differences in what our respective organizations expect would be the impact of electrification of space and water heating in our community.

We believe that the estimated electrification impacts to the utility presented in this study are reasonable. However, as our analysis continues into Phase 2 it is likely that assumptions, modeling, and forecasted results will continue to be refined through continued conversations with NWNG.

8.2 METHODOLOGY AND KEY ASSUMPTIONS

We estimated the average energy required to meet the end-use of space and water heating in therms in order to convert all non-electric heating systems (natural gas, propane, wood). This estimate of energy required was based on high-level Eugene customer data provided by NWNG in 2019. While the analysis assumes conversion of all non-electric heating, it should be noted that only 2-3% of customers use wood or propane for home heating, with the remaining customers being served by NWNG.

In addition, we assumed that the historical growth rate of new NWNG customers would steadily decline to zero over the next 30 years due to electrification.

After estimating the end-use energy required, we calculated the amount of electricity needed to meet today's space and water heating demand, assuming various levels of heat pump technology efficiency. The different efficiency assumptions provided a range of electric energy that would be required on an annual basis.

Key assumptions for non-electric heating systems:

1. Average natural gas furnace efficiency is 85%
2. Average residential natural gas customers use the equivalent of 568 therms for space heating and 160 therms for water heating annually
3. Average commercial natural gas customers use the equivalent of 2,308 therms for space heating and 293 therms for water heating annually
4. Any wood or propane heating end-uses have the same energy use as natural gas
5. Estimated NWNG annual growth rate of 1.6% (2020)
6. NWNG growth rate steadily declines to zero between 2020 and 2050

Heat Pump Efficiency Assumptions - Coefficient of Performance (COP):

1. Low efficiency - COP = 1.0; Electric resistance heating (baseboard/furnace/water heater)
2. High efficiency - COP = 3.4; Variable speed HP (Cold Weather Heat Pump)
3. Standard efficiency - COP = 2.7; ASHP (Air Source Heat Pump)
4. Standard efficiency - COP = 1.8 HPWH (Heat Pump Water Heater)

Heat pump efficiency (COP) is indicative of systems that are typically installed today, however, there are much higher performing systems currently available in the market, and performance is likely to improve over time.

Heat Pump Technology

A heat pump is a device that transfers heat energy from a source of heat to what is called a thermal reservoir. Heat pumps move thermal energy in the opposite direction of spontaneous heat transfer, by absorbing heat from a cold space and releasing it to a warmer one. A heat pump uses external power to accomplish the work of transferring energy from the heat source to the heat sink. The most common design of a heat pump involves four main components – a condenser, an expansion valve, an evaporator and a compressor. The heat transfer medium circulated through these components is called refrigerant.

Because heat pumps lose capacity to heat at very cold outside temperatures, many heat pumps are paired with a backup heat source, typically in the form of an electric resistance attachment to an air handler or a gas furnace.

Figure R below shows the reduction in both hourly energy consumption and daily peak, which can be achieved by a heat pump on a typical winter's day, when compared to electric baseboard heat.

In short, the electric consumption is nearly cut in half, even during the nighttime hours when the electric resistance backup turns on to support the need for heat. These energy savings are realized through the heat transfer process described above.

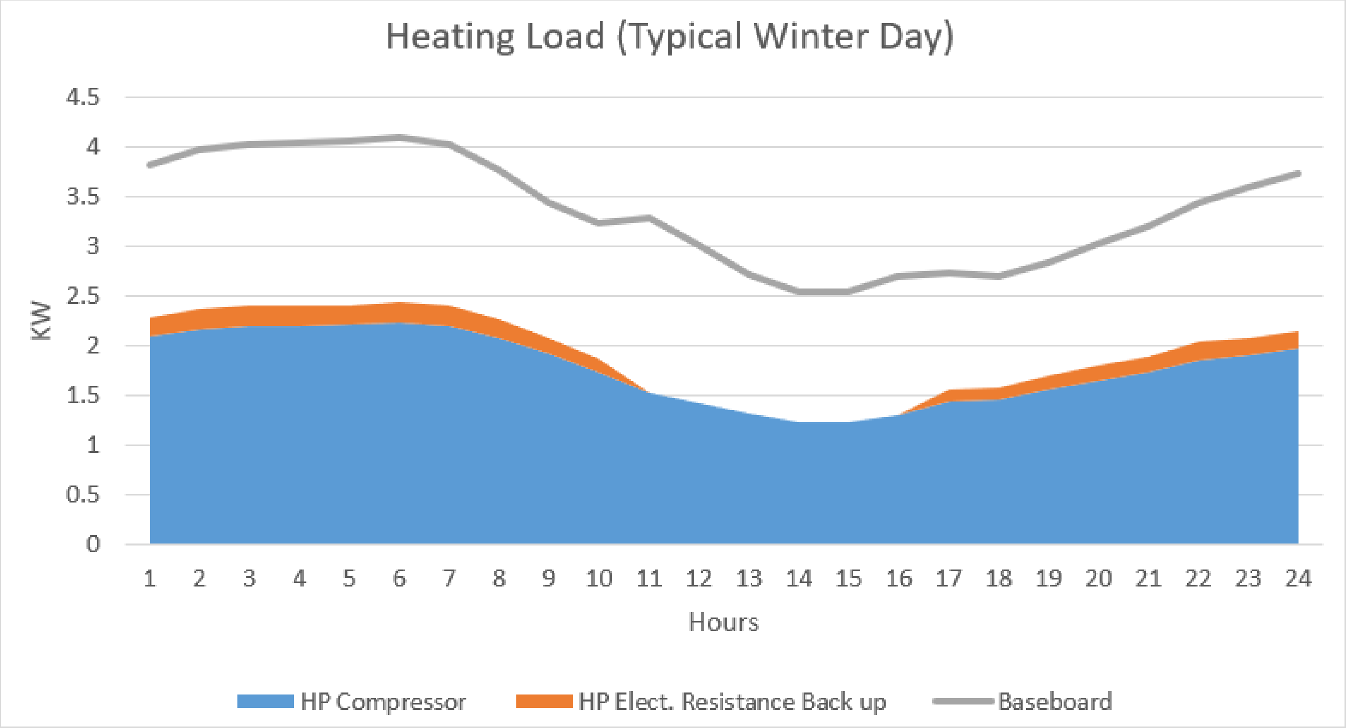

Figure R – Modeled energy use of a heat pump (HP) system compared to baseboard heating.

Typical Peak (1-in-2 average weather peak)

After establishing average energy impacts from electrification, we estimated peak impacts by analyzing the hourly load shapes of space and water heating end-uses**.**

Hourly load shapes for a particular end-use (like residential heat pumps) have a peak hour, or maximum value, of electricity consumption which can be used to scale average energy use. These end-use load shapes were analyzed separately for the residential and commercial sectors.

It should be noted that hourly end-use load shapes used in this study represent collective load shapes of multiple units to represent the coincident load on an hourly basis.

Using the hourly load shapes discussed in greater detail below, we calculated a "Peak to Average Ratio" which represents the relationship between the maximum hour value compared to the average hourly value for a particular end-use technology over the course of a year. This Peak to Average Ratio can then be used to estimate the peak impacts to the utility based on the average energy impacts of electrification by multiplying the average energy by the Peak to Average Ratio.

End-use aMW x Peak to Average Ratio = End-use Peak MW

The table below represents the Peak to Average ratios for 1-in-2 winter temperatures for sample technologies used in this study. These ratios cannot be compared without the underlying average energy profiles for each technology. For example, baseboard heating has a lower Peak to Average Ratio than heat pumps, but heat pumps have a much lower average energy profile (as illustrated in Figure R above).

End-Use Technology	**Peak to Average Ratio**
Residential Baseboard Heat	3.1
Residential Forced Air Furnace	3.4
Residential Heat Pump	3.5
Res/Com Heat Pump Water Heater	4.1
Res/Com Electric Resistance Water Heating	3.1
Commercial Electric resistance Heating[19]	5.1
Commercial Heat Pump[20]	6.7
Weighted (Res/Com) sectors	4.3

Residential Space and Water Heating Load Shapes

Load shapes are derived from interval metering of end-uses. Interval metering data is a series of measurements of energy consumption, taken at pre-defined intervals, typically sub-hourly. In end-use studies, energy consumption is measured in 15-minute or 1-minute granularity.

Publicly available interval meter data from the PNW region is used in this study. For the residential sector, much of the data is from the Residential Building Stock Assessment (RBSA) conducted in 2016-17[21]. It includes a representative sample of single-family, multi-family and manufactured homes gathered across the Northwest region. Whenever possible, data was collected in a similar manner as the 2011 – 2012 RBSA assessment to ensure continuity and comparability between the studies.

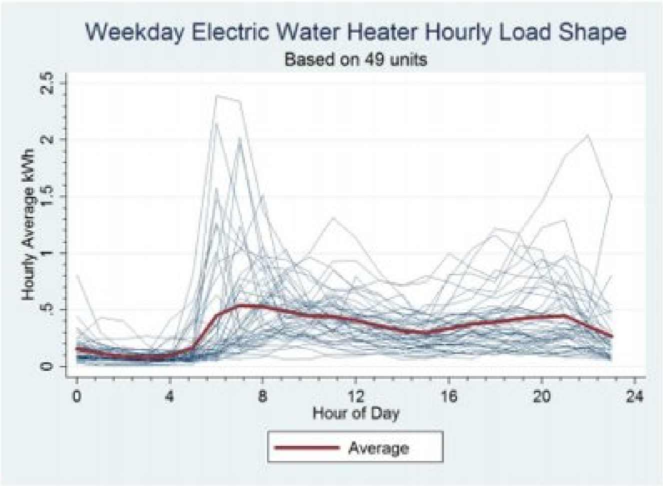

Figure S – Source: NEEA RSBA metered data study

The example in Figure S shows how meter data from multiple units of the same technology can be used to create an average load shape. The example is a summary of metered electricity use for 49 different water heaters over a 24-hour period.

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[19] Commercial heating values are averaged across 11 categories. See Commercial Sector section for sector categories

[20] Each market segment (lodging, office, restaurant, etc.) has a unique load shape. The peak to average of 6.7 is an aggregated value.

[21] https://neea.org/data/residential-building-stock-assessment

Figure T shows how hourly load shapes are also seasonal and that the amount of energy used is dependent on the type of technology. In the chart below, the hourly water heating electricity use declines in the summer months as less energy is needed to heat water in the summer months. The difference between the orange and blue areas illustrates that on average, heat pump water heaters use less electricity compared to electric resistance water heaters (even during cold months).

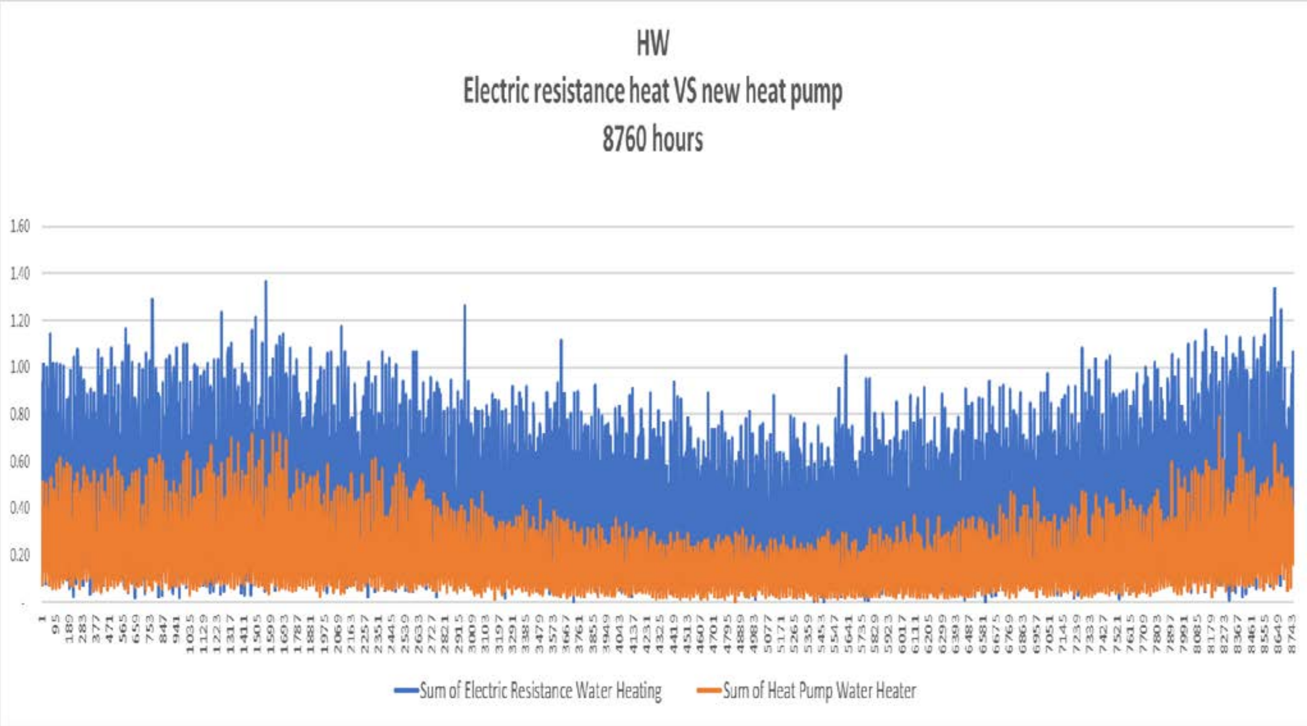

Figure T - Source: Cadmus consulting (RSBA derived)

Commercial Space and Water Heating Load Shapes

Commercial load shapes utilize data from a 2006 California Commercial End-Use Survey (CEUS). A stratified random sample of 2,790 commercial facilities was collected from the service areas of Pacific Gas & Electric (PG&E) and San Diego Gas & Electric. EWEB uses Zone 1 (Northern CA - CZ1) data because of similar heating and cooling degree days (HDD – CDD) compared to Eugene.

Individual end-use units exhibit large differences in load shapes due to size, insulation levels, location, etc. It is the aggregate average load shape that drives the high-level electric system response.

This study utilizes averaged metered data to represent proto-typical aggregated load shapes. Both carbon accounting and electric system peak impacts are directly correlated to aggregated end-use load shapes.

Peak loads for any given aggregation of end-uses vary by time of day and season. Additionally, there are differences in timing between end-uses as a function of customer segment as demonstrated in Figures U and V. The same heat pump will have a unique shape due to the application of use/schedule (home, office, school, etc.)

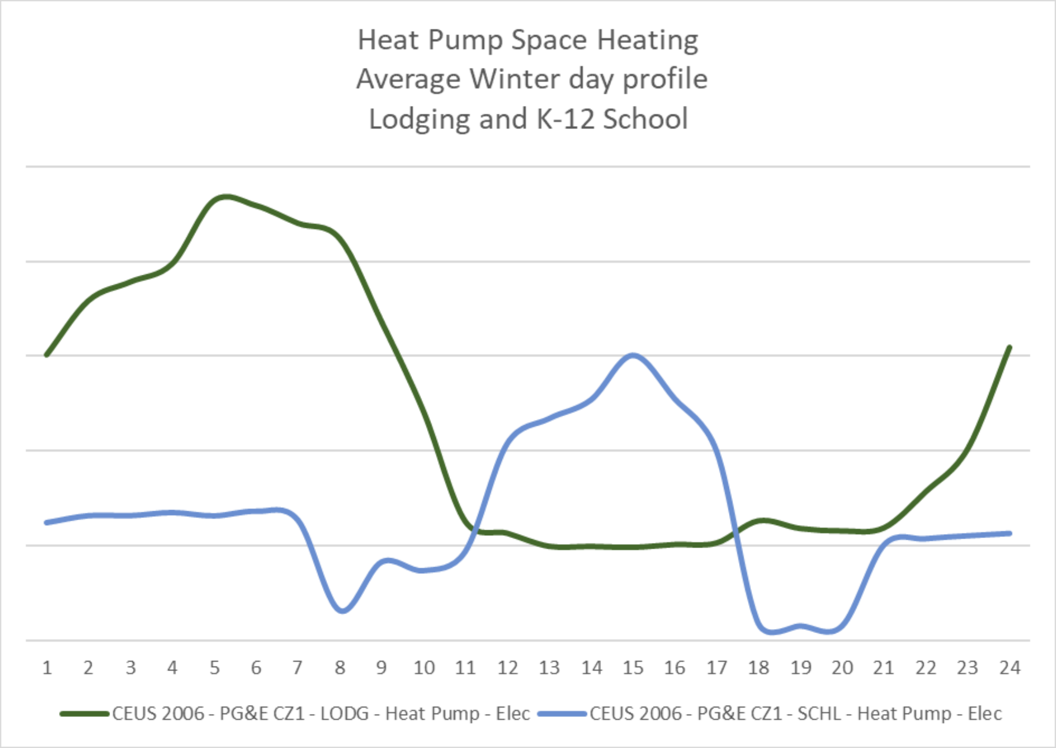

Figure U - Average winter day space heating load shape difference for lodging and K-12 school (heat pump technology)

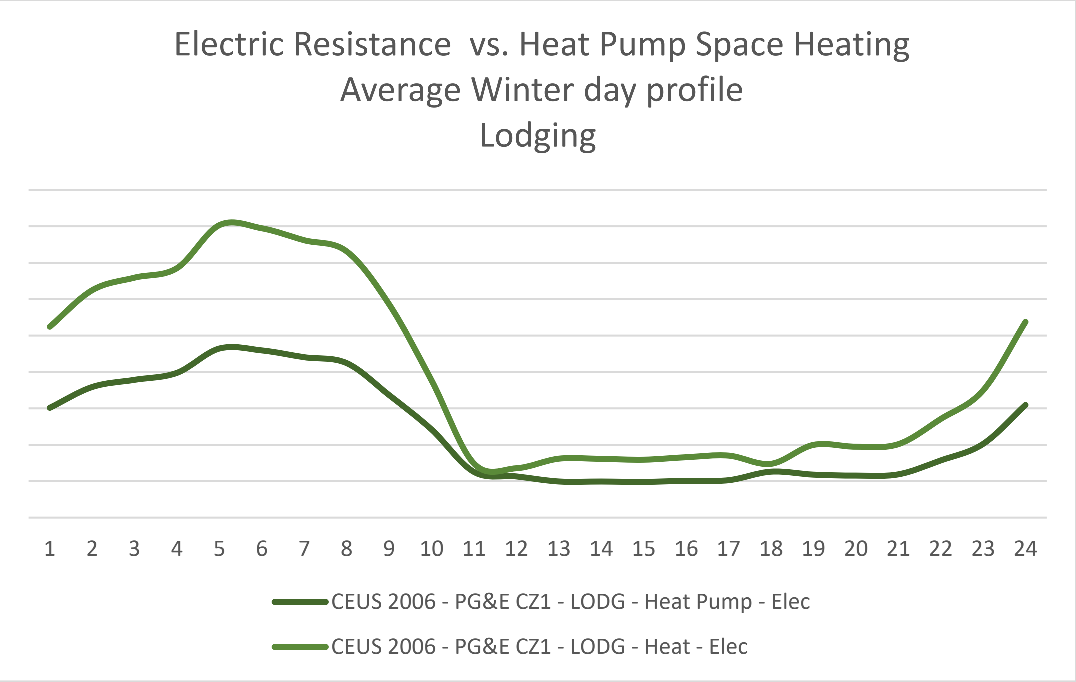

Figure V - Within the same industry, the space heating load shape varies by technology.

Design Peak (1-in-10, extreme weather peak)

This study analyzes peak impacts under two weather scenarios, average and extreme weather. Peaks are measured as a single (1) hour maximum load in MWs.

System peaks are driven by weather. Average weather (1-in-2-year event) is simply expected seasonal temperatures based on historical records (typically greater than 30 years). Though temperatures will deviate in any given year, averages are a useful metric for planning purposes.

More extreme weather (1-in-10-year event) is another important utility design condition. For a winter peaking utility like EWEB, these are colder than average temperatures that can be expected to occur about once every 10 years.

For example, there is about a 50 MW system load increase in 1-in-10 weather conditions. The increase in system load is due to the aggregate end-use loads that use more energy in lower temperatures.

Peak contribution to EWEB system Load by weather scenario:

Weather Condition	RES/COM Total Peak Hour (MW)[22]	Temperature (Fahrenheit)	Incremental Peak Hour MW[23]
1 in 2	427	17	0
1 in 5	462	10	35
1 in 10	477	6	50
1 in 100	545	-11	118

Design Peak Adder

In order to estimate the difference between 1-in-2 peak and 1-in-10 peak impacts from electrification, EWEB estimated a design peak adder which could be used to convert 1-in-2 peak impacts into 1-in-10 peak impacts.

We assumed that space heating and water heating is responsible for EWEB's existing system peaks because industrial and non-heating loads are not weather dependent. Therefore, any incremental increase in residential and commercial load is due to weather-dependent space and water heating. **The result of this analysis determined that 1-in-2 peak space and water heating electrification results could be increased by 18% to yield a 1-in-10 peak impact.**

The assumptions and calculations for the Design Peak Adder are detailed below.

EWEB utilizes an end-use model to estimate the portions of EWEB's system load attributable to space and water heating on an average basis (aMW). The table below shows EWEB's total aMW end-use load for space and water heating by sector, which can then be multiplied by the Peak to Average System Ratio, weighted by sector, to calculate the peak space and water heating load on EWEB's system today.

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[22] Represents Residential and Commercial Peak Hour Load and excludes Industrial Peak Load. Source is EWEB's existing load forecasting model

[23] Incremental load for various weather events provided by EWEB's existing load forecasting model

End-use CADMUS[24] Model	EWEB System aMW			Peak to Average System ratio (weighted Res/Com)	Estimated Res/Com Space and Water Heating Peak Load
End-Use Description	Res	Com	Total		
Space Heating	28.2	14.5	42.7		
Space Heating - Heat Pumps	5.7	3.1	8.8		
Water Heating	11.3	0.8	12.1		
Total	45.2	18.4	**63.6**	**4.3**	**274**[25]

After estimating that 274 MW of EWEB's existing peak is attributable to Residential and Commercial space and water heating peak load, we analyzed peak increases compared to different weather conditions.

For example, during 1-in-10 weather conditions, system load increased by about 50 MW, an increase of 18% above the 1-in-2 peak space and water heating load of 274 MW. The impact of a 1-in-10 whether event, as well as other weather events, are illustrated in the table below.

Weather Condition	RES/COM Space and Water Heating Peak Hour (MW)	Temperature (Fahrenheit)	Incremental Peak Hour MW[26]	Incremental Peak % compared to 1-in-2[27]
1 in 2	274	17	0	0%
1 in 5		10	35	13%
1 in 10		6	50	**18%**
1 in 100		-11	118	43%

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[24] EWEB hired CADMUS consulting to assist in developing an end-use modeling tool which can be used to analyze EWEB's system load based on the various end-use electricity consumption which takes place "behind the meter". This model allows EWEB to better understand how customer's technology choices and behaviors collectively influence EWEB's system load.

[25] 63.6 aMW x 4.31 Peak MW/aMW = 274 Peak MW

[26] Incremental load for various weather events provided by EWEB's existing load forecasting model

[27] Incremental peak compared to 1-in-2 is calculated by dividing incremental peak by 274.

8.1 RESIDENTIAL SECTOR

HIGHLIGHTS

- Approximately 72% of the residential space and water heating units in EWEB service territory use electricity.
- Assuming high levels of conversions from gas to electric, EWEB's average annual load could increase by up to 8% due to residential building electrification by 2050.
- The peak impact of electrification of residential space and water heating could increase EWEB's 1-in-10 peak load up to 17% by 2050.

Energy used by EWEB's residential customers can be classified based on building type: single family, multi-family and manufactured homes. How energy is used within these residences can be further broken into ten basic end-uses.

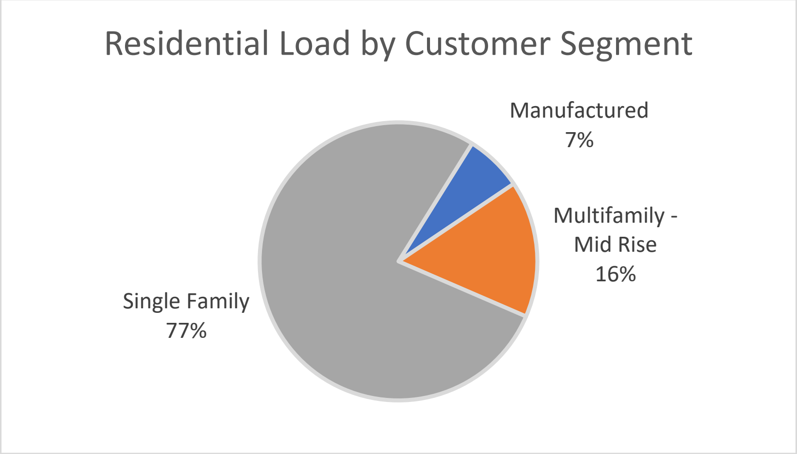

Figure X – Single family homes represent the vast majority of residential building stock at 77%.

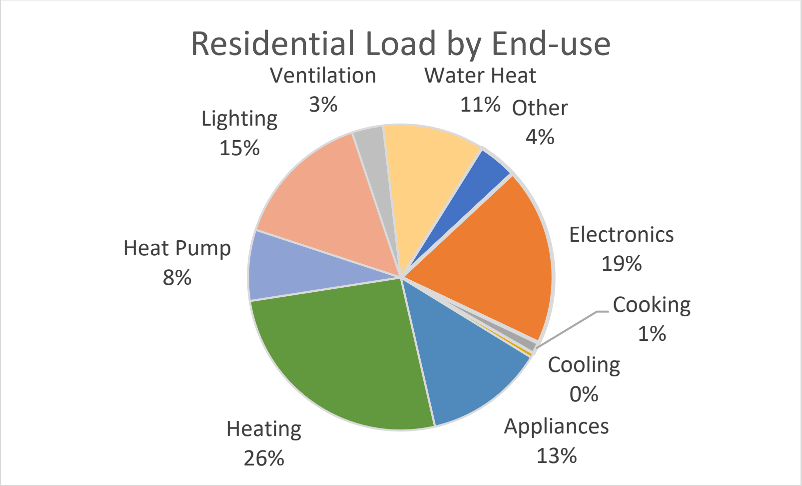

Figure Y– Space heating accounts for about 34% of EWEB's total residential load, while water heating adds another 11%[28].

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[28] Chart represents electric load only.

Residential Space Heating Stock

Based on EWEB customer data and information from Northwest Natural Gas (NWNG), out of more than 83,000 heating units in EWEB service territory, approximately 72% use electricity. The remainder are served by NWNG, with 2-3% of customers using wood or propane for home heating.

Our end-use model starts with regional data, both hourly metered data and data collected from regional surveys. The regional data was then adjusted to reflect our current understanding of usage in EWEB's service territory. The table below reflects the most current dataset and breaks out electric space heating by both residential housing and appliance type.

Estimated Electric Space Heat in EWEB Service Territory		
Segment	**Heating Type**	**Quantity**
Manufactured	Furnace – Standard	823
Manufactured	Heat Pump – Federal Standard 2015	823
Manufactured	Baseboard Zonal Heating – Standard	1,330
Multifamily – Mid Rise	Baseboard Zonal Heating – Standard	23,107
Single Family	Furnace – Standard	9,246
Single Family	Heat Pump – Federal Standard 2015	9,246
Single Family	Baseboard Zonal Heating – Standard	14,936
Total		**59,511**

The remainder of the non-electric heating units (23,622) are served by NWNG with about 2-3% using wood heat or propane. The results of this study focus on the incremental electric load that would result under differing electrification scenarios (10%, 50%, and 80% conversion rates) and technologies (various heat pump efficiencies).

Residential Water Heating Stock

There are an estimated 81,000 residential water heaters in EWEB's service territory, and about 50 of those are solar assisted. Of those 81,000, there are just under 20,000 water heaters that use natural gas and, to a lesser extent, propane. This indicates that, like space heating statistics, about 75% of EWEB residential customers have electric water heaters.

Until recently, electric resistance technology was standard for water heating. However, Heat Pump Water Heaters, which offer much higher efficiency ratings, are now common in the marketplace.

Current market penetration rates of this technology are low, but manufacturer rebates, combined with EWEB incentives, can encourage more rapid adoption of this newer technology. As of June 30, 2020, EWEB has processed 228 incentives for heat pump water heaters during 2020, a large uptick over last year, which is largely driven by a manufacturer promotion.

8.1.1 Energy Impact

As the previous data demonstrates, residential customers are predominantly reliant on electricity for space and water heating in EWEB's service territory. To determine how moving more customers to electric technologies impacts EWEB load, we need to consider two main variables: (1) the conversion rate from non-electric to electric heating, and (2) the efficiency of that technology.

The key assumptions for the forecasts and energy efficiency levels modeled are as follows:

Forecast Conversion Rates
Low – 10%
Medium – 50%
High – 80%

Technology Efficiency Ratings
Low efficiency (ex. baseboard heat, electric resistance water heater)
Standard efficiency (ex. ducted heat pump, heat pump water heater)
High efficiency (ex. cold weather ductless or ground source heat pumps)

The impacts to EWEB's load are shown in Figures Z and AA, first assuming a 50% adoption rate for each technology efficiency rating. As Figure Z illustrates, technology choices matter when looking at load impact. It should be noted that the energy impacts of electrifying water heating are much less impactful than space heating due to the different amount of energy required for each end-use.

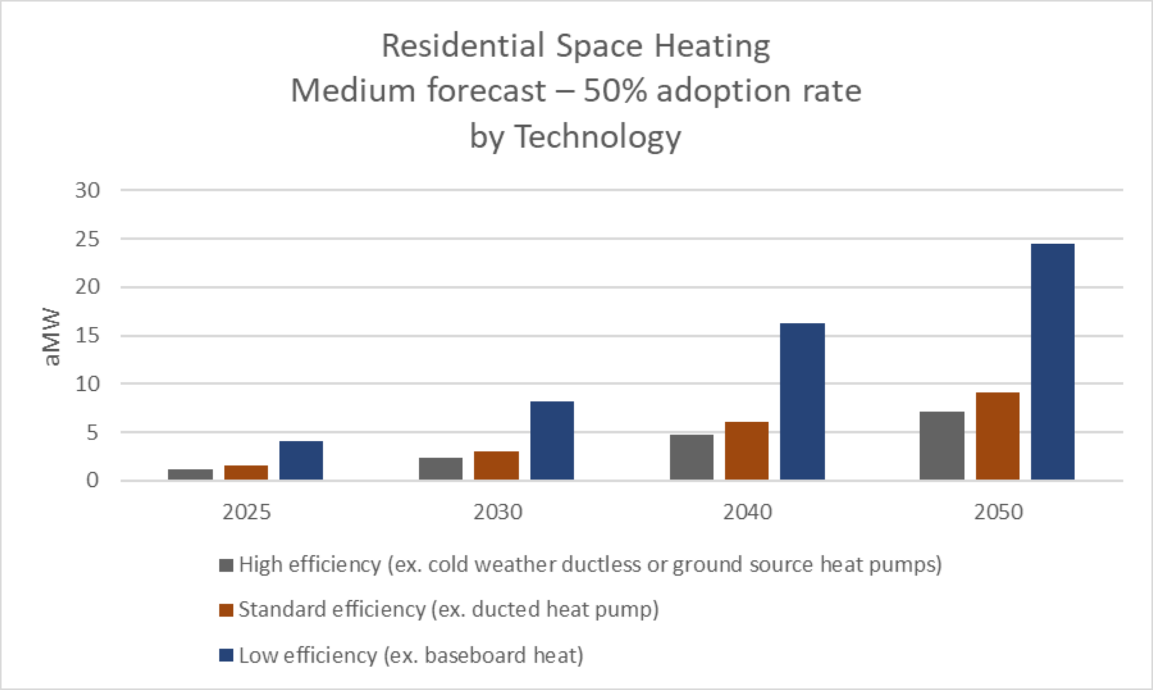

Figure Z – Space heating load is higher compared to water heating, and the efficiency of electrified heating equipment is important.

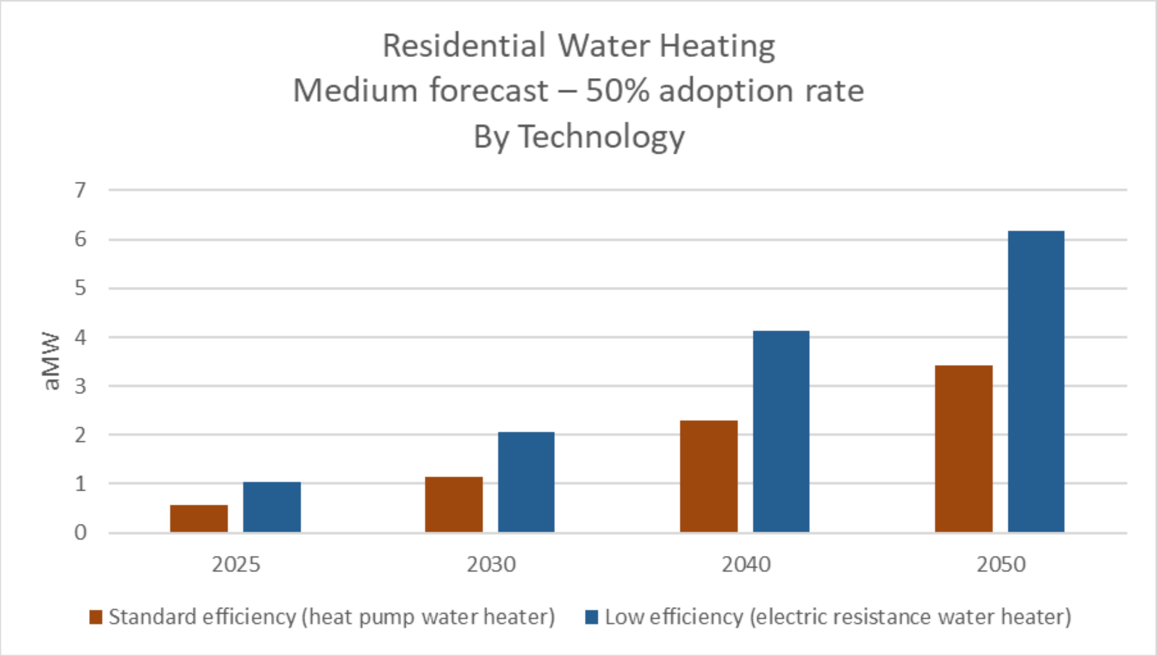

Figure AA – Water heating load as a result of electrification is less impactful to EWEB.

While a low-efficiency, space heating case is illustrated, it is unlikely that customers will opt to switch out their natural gas heating equipment for low efficiency baseboard technology. Therefore, Figure BB projects energy impacts over all three load forecasts, assuming the customer adopts electric heating equipment with more contemporary efficiency ratings.

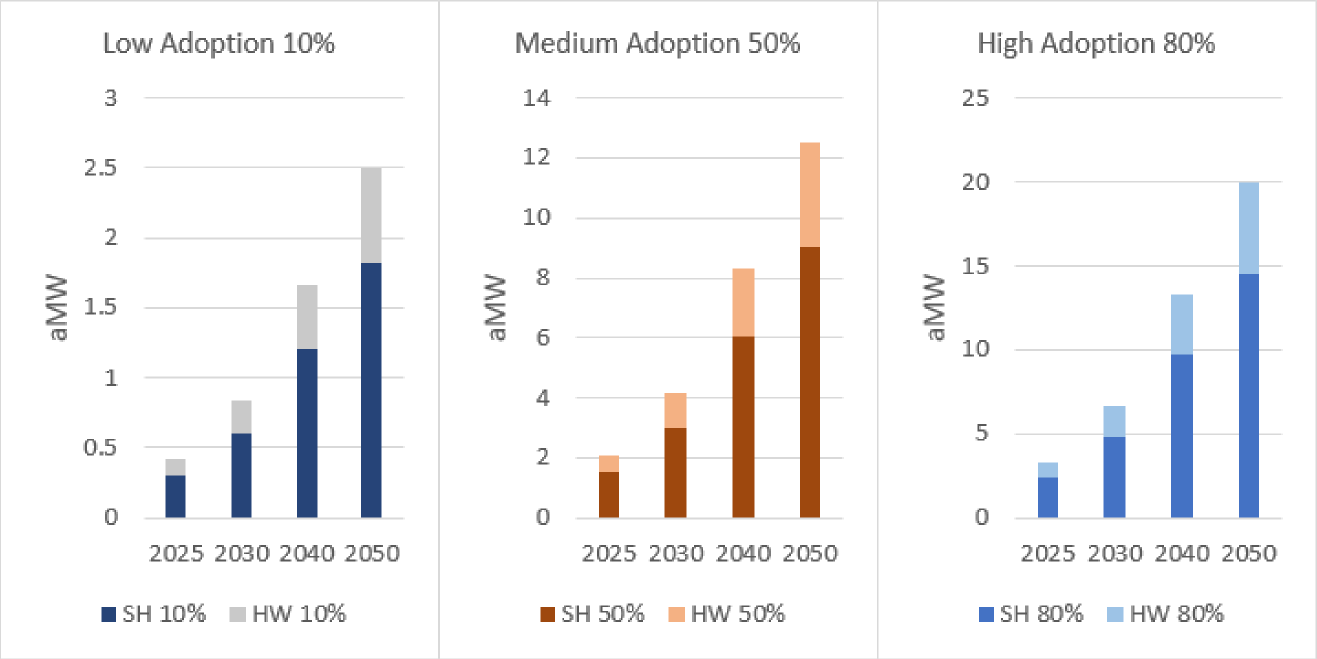

Figure BB – The energy impacts of space and water heating increase proportionally as conversion rates increase.

By 2050, EWEB's average annual energy may increase between 1% and 8% due to electrification of residential space and water heating. Improved space and water heating technology would further reduce that growth. See Cumulative Impacts of Electrification section for further discussion.

8.1.2 Peak Impact

Incremental Peak impacts due to conversion of residential space and water heating loads under average and 1-in-10 weather conditions are expected to add to EWEB's existing peak. Assuming 80% conversion, electrifying is estimated to increase 1-in-10 system peaks by approximately 90 MW (or 17% increase compared to EWEB's current 1-in-10 peak).

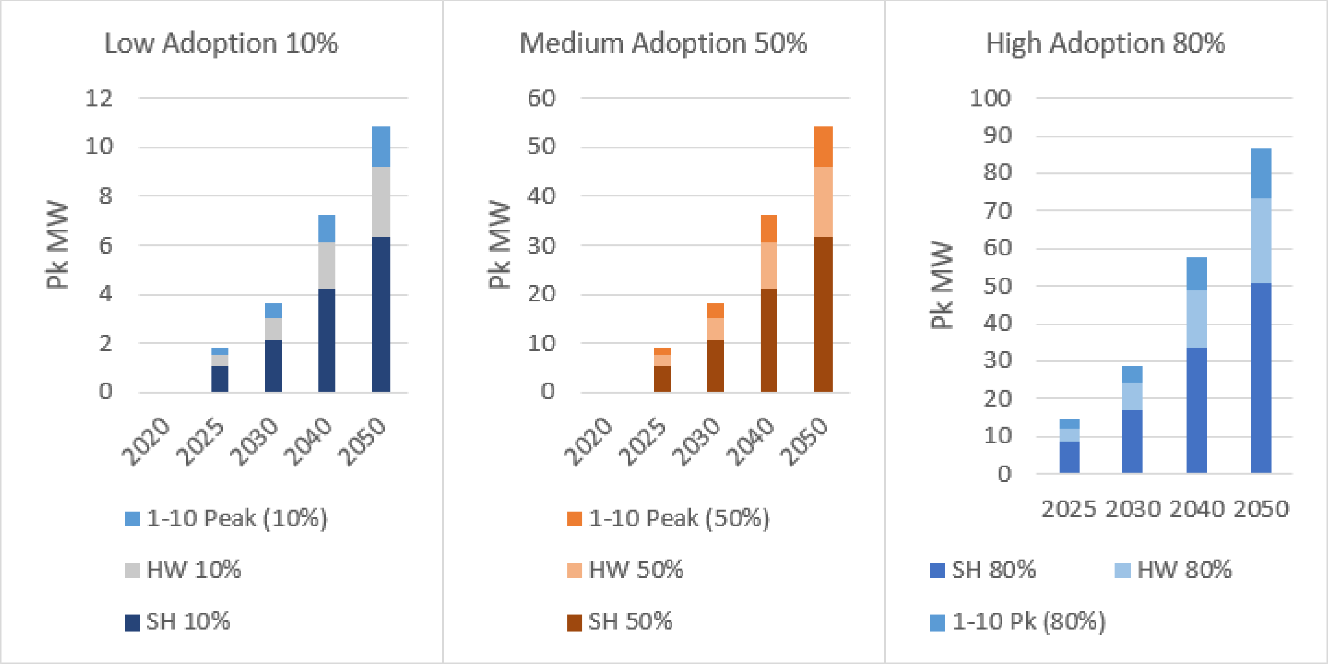

Figure CC– Peak impacts to the utility are dependent on the amount of space and water heating electrification which occurs over time but are also increased by colder than average weather (1-in-10).

While the average energy impacts of space and water heating conversion are lower, the peak impacts to EWEB could be larger. However, it should also be noted that these projections do not take into account efficiency gains (i.e. energy reductions) as customers with electric space and water heating upgrade their existing equipment over time. See the Mitigation Strategies for more discussion on this topic.

8.2 COMMERCIAL SECTOR

HIGHLIGHTS

- Approximately 65% of the commercial space and water heating units in EWEB service territory use electricity.
- Assuming high levels of conversions from gas to electric, EWEB's average annual load could increase by up to 3% due to commercial building electrification by 2050.
- The peak impact of electrification of commercial space and water heating could increase EWEB's 1-in-10 peak load up to 10% by 2050.

EWEB's commercial sector is segmented into 11 categories (business types) and represents a much more diverse building stock compared to the residential sector.

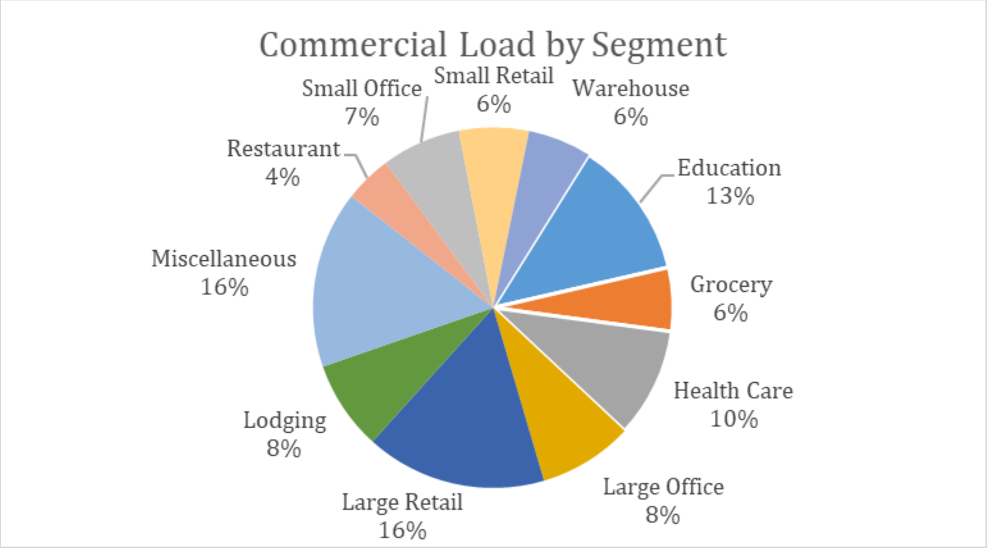

Figure DD– The commercial sector is much more diverse than the residential sector in terms of building stock and the activity that takes place within the building.

How energy is used within these businesses can be further broken into nine basic end-uses. As Figure EE[29] shows, space heating accounts for about 19% of EWEB's total commercial load, while water heating represents only 1%.

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[29] Chart represents electric load only.

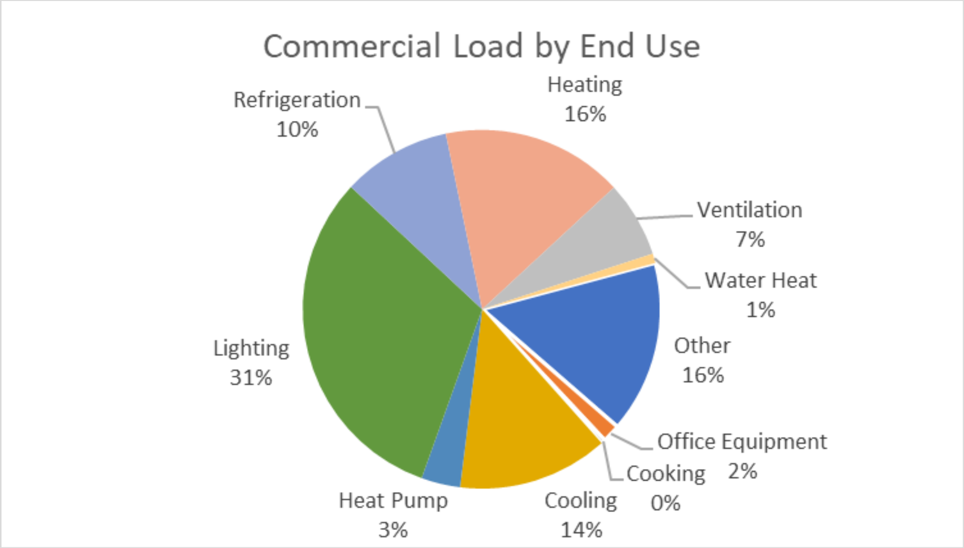

Figure EE– Lighting is a much higher electricity use the commercial sector compared to residential, and thus the proportion of space and water heating electricity use is smaller by comparison.

Commercial Space and Water Heating Stock

EWEB estimates that out of about 8,700 commercial customers within its service territory, the electric share is approximately 65% the existing space and water heating stock.

8.2.1 Energy Impact

Similar to residential, estimating the energy impacts from conversion of commercial gas customers to electricity has two main variables: (1) the conversion rate to electric heating, and (2) the efficiency of that technology.

The key assumptions for the forecasts and energy efficiency levels modeled are as follows:

Forecast Conversion Rates
Low – 10%
Medium – 50%
High – 80%

Technology Efficiency Ratings
Low efficiency (ex. baseboard heat, electric resistance water heater)
Standard efficiency (ex. ducted heat pump, heat pump water heater)
High efficiency (ex. cold weather ductless or ground source heat pumps)

The impacts to EWEB's load are shown in Figures FF-GG, first assuming a 50% adoption rate for each technology efficiency rating. As this chart illustrates, technology choices matter when looking at load impact. It should be noted that the energy impacts of electrifying water heating are much less impactful than space heating due to the different amount of energy required for each end-use.

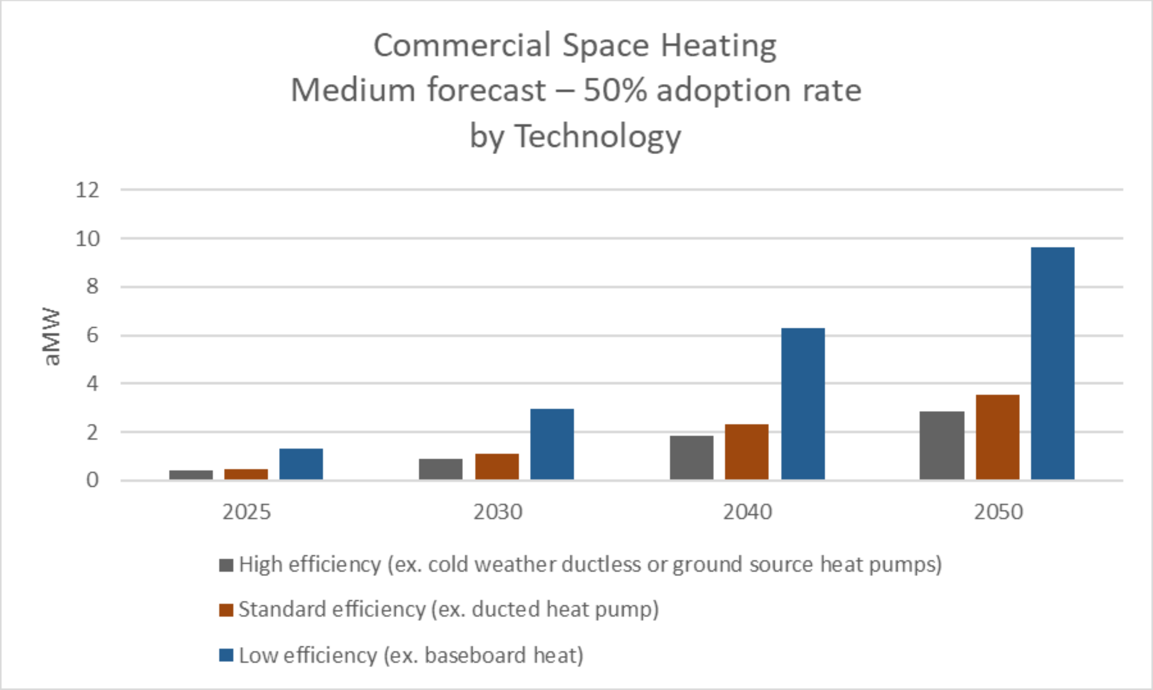

Figure FF – Commercial space heating load is higher compared to water heating, and the efficiency of electrified heating equipment is important.

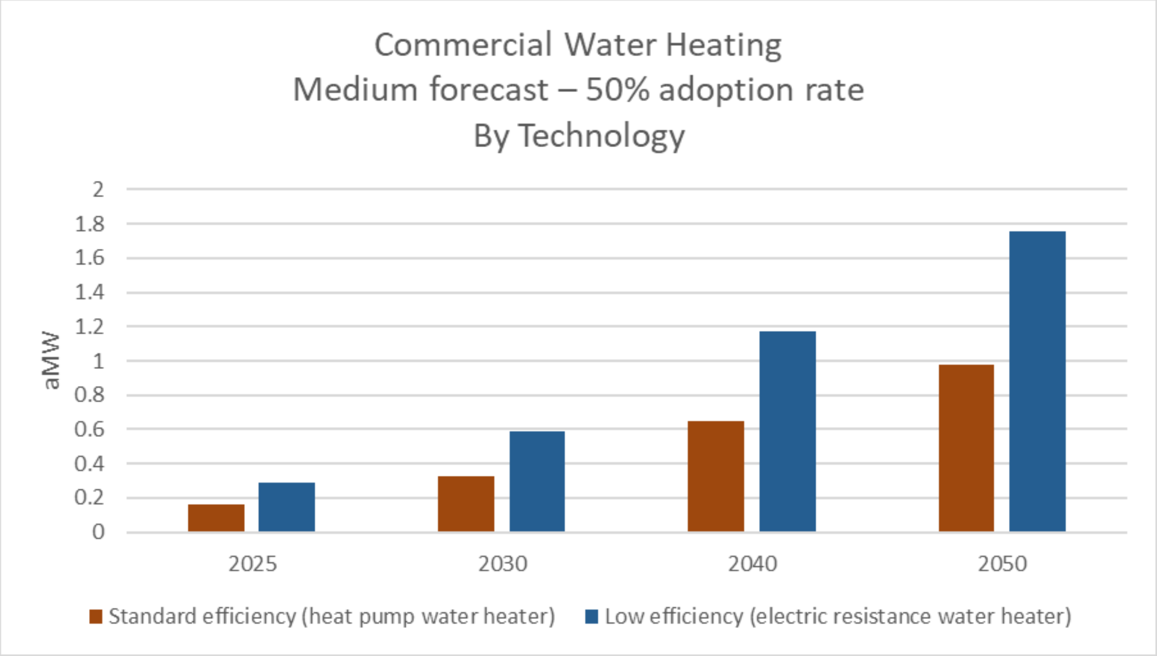

Figure GG – Commercial water heating load as a result of electrification is less impactful to EWEB.

While a low-efficiency, space heating case is illustrated, it is unlikely that customers will opt to switch out their natural gas heating equipment for low efficiency baseboard technology. Therefore, Figure HH projects energy impacts over all three load forecasts assuming the customer adopts electric heating equipment with more contemporary efficiency ratings.

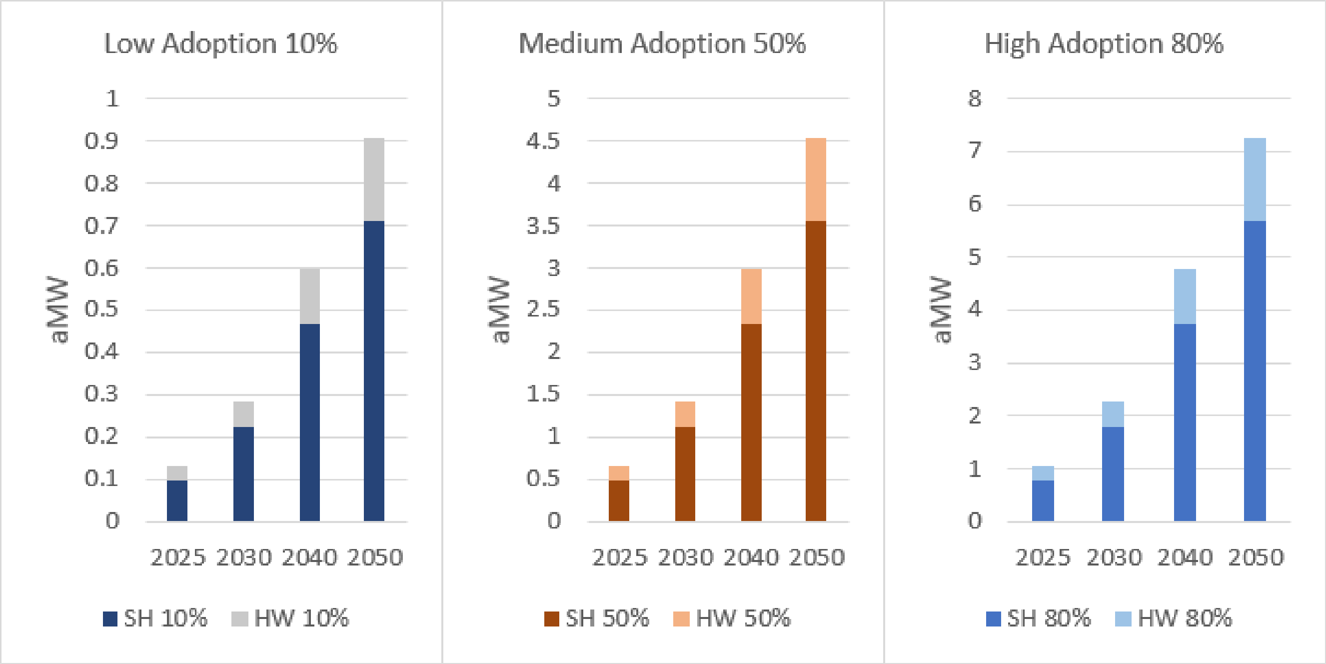

Figure HH– The energy impacts of commercial space and water heating increase proportionally as conversion rates increase.

By 2050, EWEB's average annual energy may increase between 0.3% and 3% due to electrification of commercial space and water heating. Improved space and water heating technology would further reduce that growth. See Cumulative Impacts of Electrification section for further discussion.

8.2.2 Peak Impact

Incremental Peak impacts due to conversion of commercial space and water heating loads under average and 1-in-10 weather conditions are expected to add to EWEB's existing peak. Assuming 80% adoption, electrifying these loads are estimated to increase 1-in-10 system peaks by approximately 50 MW (roughly 10% increase compared to EWEB's current 1-in-10 peak).

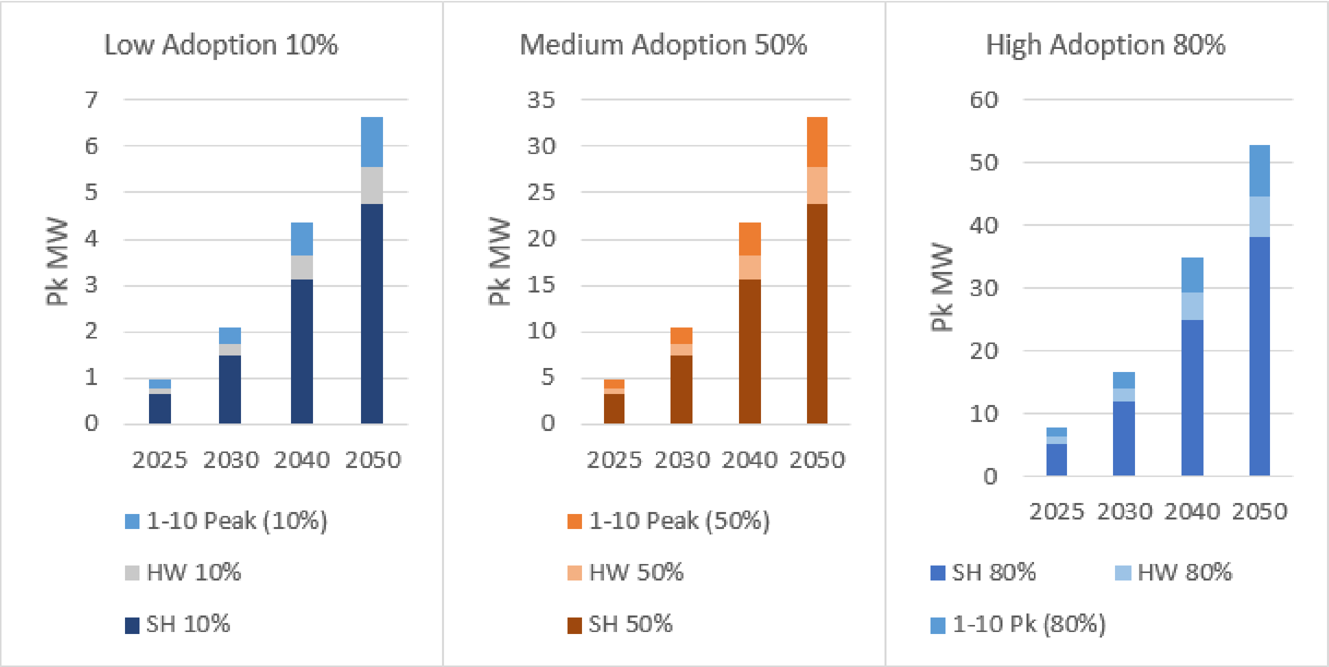

Figure II– Peak impacts to the utility are dependent on the amount of commercial space and water heating electrification which occurs over time but are also increased by colder than average weather (1-in-10).

Similar to residential peak impacts, the average energy impacts of commercial space and water heating conversion are small on an annual basis. However, these peak impacts to EWEB could be more meaningful because space and water heating adds to EWEB's existing system peak. See section 10.1.2 for further discussion of the cumulative peak impacts of building electrification.

It should also be noted that these projections do not take into account efficiency gains (i.e. energy reductions) as customers with electric space and water heating upgrade their existing equipment over time. See the Mitigation Strategies for more discussion on this topic.

8.3 BUILDINGS AND CARBON REDUCTION

Key Context

- A gas home, with standard equipment and other assumptions as stated, creates 4.57 MT CO2e/year. An electric home with high efficiency equipment only produces 2.00 MT CO2e.
- The carbon savings achieved by the electric house are due to the relatively low carbon intensity of northwest power and standard heat pump technology, which reduces the amount of electricity needed to serve the same load by approximately two-thirds.
- These results are indicative of change that can occur, but results may vary given the specific needs of the home.
- Finally, the technology/fuel landscape is changing for a variety of reasons. As such, the most efficient/cost effective way to minimize carbon may look different in the future. EWEB will explore this further in Phase 2.

To illustrate the potential carbon saving associated with electrifying a gas-served single-family dwelling in EWEB's service territory, we used a DOE-2[30] building energy analysis tool to model the hourly consumption of electricity and natural gas in a "typical single family dwelling" (home) that has both space and water heating needs. The model assumes a typical home is 2,500 square feet in size, with a moderate level of insulation. This is based on EWEB's understanding that homes using natural gas tend to be larger and newer than the average single-family dwelling in EWEB's service territory. The model also assumes a typical (1-in-2) weather year.

We modeled two equipment variations: a home that uses gas appliances, and a home that uses electricity for space and water heating. For both equipment variations we chose to model consumption in hourly granularity with typical seasonal weather patterns, for an entire calendar year.

The natural gas home was modeled with an 85% efficient furnace, without electric heat pump, and a 68% efficient water heater. This is standard equipment that can be found in the market today and it likely reflects equipment installed in many of the homes of EWEB customers. The natural gas home uses a small amount of electricity to run furnace fans.

The electric home was modeled with a standard efficiency (COP of 2.7) heat pump and a standard efficiency (COP of 1.8) heat pump water heater. The energy consumed by both modeled homes was converted to carbon emissions by multiplying against the hourly carbon intensity (CI)[31] of the modeled energy type.

With the assumptions stated above, an electrified home in EWEB's service territory is expected to emit approximately 2.00 MT CO2e per year. This is approximately a 56% reduction in carbon when compared to a home that primarily uses natural gas to heat space and water.

The charts below illustrate how carbon is emitted by each modeled home. They start on the left-hand side at the fuel source. As you work your way right on the chart, you see how the fuel sources are converted to either the desired end-use (space and water heating) or into unused "waste" carbon, generally from heat lost during

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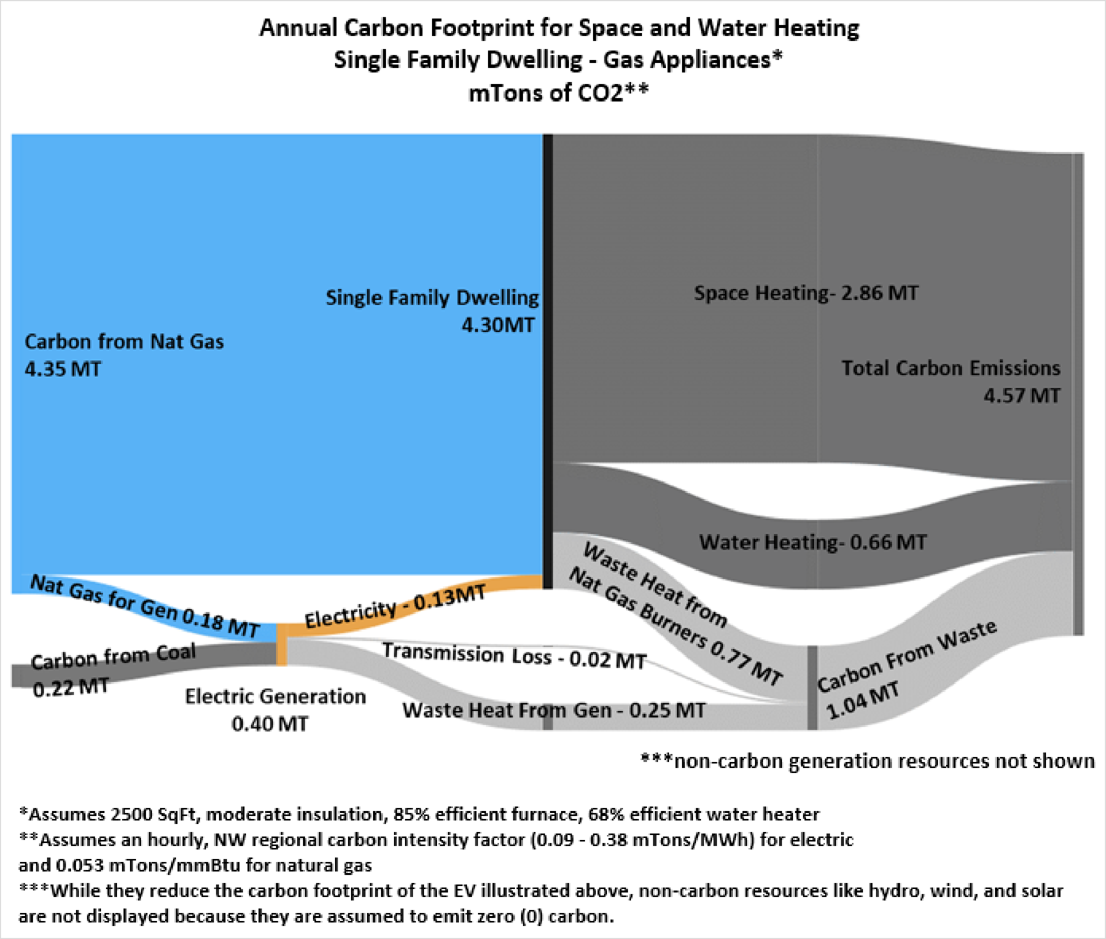
[30] http://www.doe2.com/

[31] Natural gas is assumed to have an average carbon intensity of 0.053 mTons/mmBtu across all hours. Electricity is assumed to have a CI that varies each hour within a range of 0.09 to 0.38 mTons/MWh. This aligns with the CI of the Northwest Power Pool.

energy consumption/transformation. Keep in mind these charts reflect carbon creation and not explicitly energy usage[32].


Annual Carbon Footprint for Space and Water Heating
Single Family Dwelling - Gas Appliances*
mTons of CO2**

***non-carbon generation resources not shown

*Assumes 2500 SqFt, moderate insulation, 85% efficient furnace, 68% efficient water heater
**Assumes an hourly, NW regional carbon intensity factor (0.09 - 0.38 mTons/MWh) for electric and 0.053 mTons/mmBtu for natural gas
***While they reduce the carbon footprint of the EV illustrated above, non-carbon resources like hydro, wind, and solar are not displayed because they are assumed to emit zero (0) carbon.

Figure JJ – Modeled Natural Gas energy use emits more carbon compared to a home heated with efficient electric appliances (like a heat pump).

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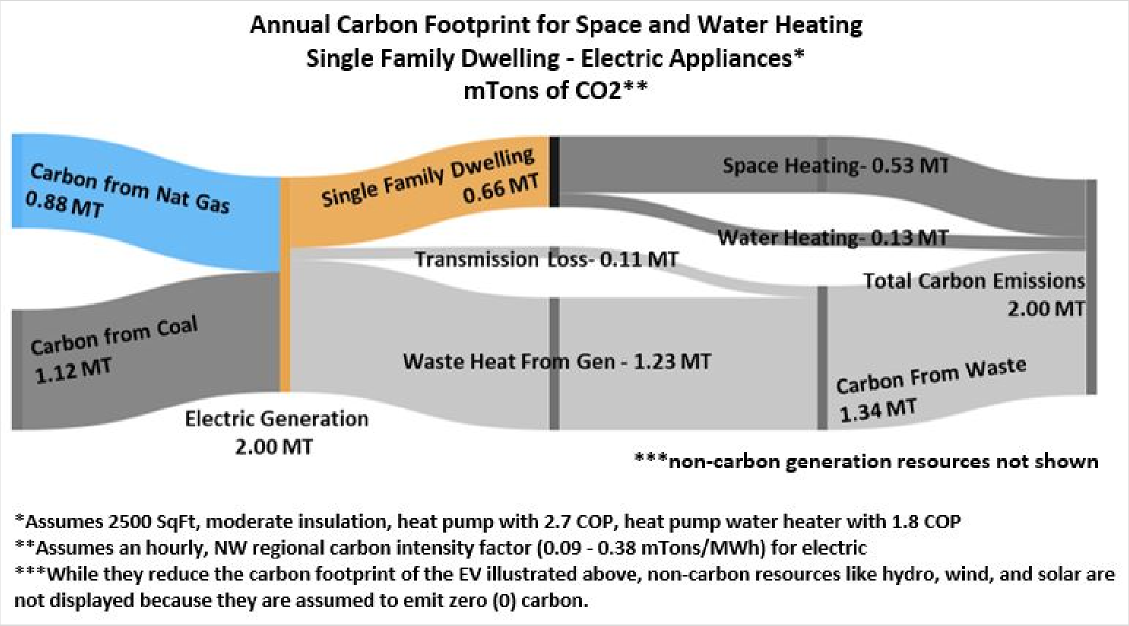
[32] Energy usage and carbon creation can differ with energy resource mix and heating equipment choice



*Assumes 2500 SqFt, moderate insulation, heat pump with 2.7 COP, heat pump water heater with 1.8 COP
**Assumes an hourly, NW regional carbon intensity factor (0.09 - 0.38 mTons/MWh) for electric
***While they reduce the carbon footprint of the EV illustrated above, non-carbon resources like hydro, wind, and solar are not displayed because they are assumed to emit zero (0) carbon.

Figure KK – The majority of energy from electricity is carbon-free. However, electricity generated with natural gas and coal must be considered in the carbon footprint.

In terms of space and water heating, 77% of the GHG emissions created by the modeled home with gas appliances can be attributed to these end-uses. The remaining 23% is accounted for as waste, primarily from heat ventilated to atmosphere while burning natural gas.

This relatively low amount of waste can be attributed to the direct use of natural gas in the home and the efficiencies of the equipment used. More efficient equipment could reduce the waste stream down to near zero but would have no impact on the carbon emissions from the gas used to heat space and water. Without additional changes to the home's insulation, or the carbon intensity of the fuel source, the gas home would struggle to reduce its carbon emissions below 3.52 MT CO2e

By contrast, 33% of GHG emissions created by a modeled home with efficient electric appliances can be attributed to space and water heating end-uses. This is because most of the emissions can be accounted for as waste heat lost, vented to atmosphere, by generators[33] that burn coal and natural gas to create electricity.

However, despite the relative percentage of waste emissions which can be attributed to space and water heating end-uses, when compared to a gas home, the electric home generates substantially less (56% less) total emissions. The overall reduction in emissions produced by the electric home with electric appliances, can be attributed to two major factors: 1) the carbon intensity of electricity in the northwest and 2) the relative efficiency of the equipment installed.

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[33] Thermal electric generator efficiencies range from 32 – 60% efficient depending on configuration. The flow diagrams in this scion assume an average 35% efficiency for all thermal generators.

According to the Northwest Power and Conservation Council[34] carbon emitting resources like coal and natural gas account for only 38% of the electricity generated in the northwest[35]. The rest comes from zero carbon or carbon neutral resources like hydro, wind, nuclear, biomass and solar. As such, the carbon intensity of direct use natural gas is similar to delivered energy, after accounting for thermal heat and line losses[36]. The two modeled homes would have more comparable carbon footprints, if not for the efficient heat pump utilized by the electric home.

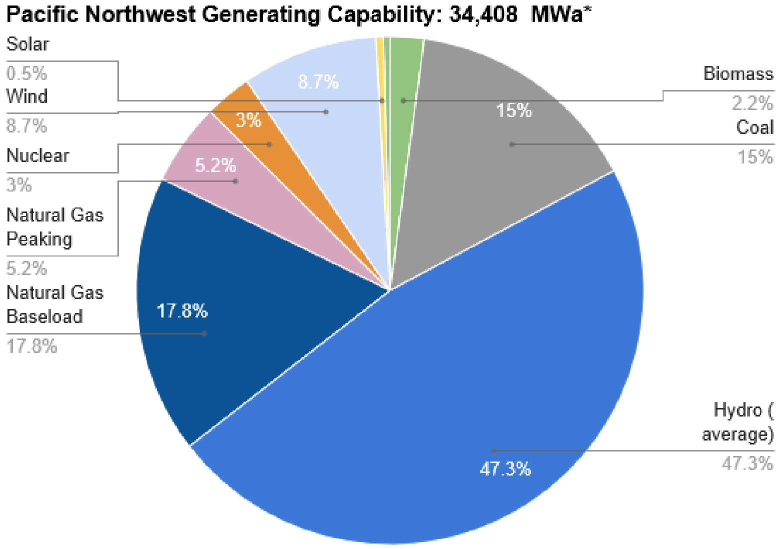

Figure LL – The Pacific Northwest's generating capacity is primarily comprised of carbon-free resources like hydro and wind.

Heat pump technology uses compressed gas to concentrate and move heat that is already present in the atmosphere. Generally speaking, it is a more efficient way to heat a building, because it takes less energy to move heat than to create it by burning natural gas or heating an element. Since heat energy captured from the atmosphere produces zero incremental carbon, the electric home is able to realize the same level of space and water heating at a fraction of the total carbon created by the natural gas home. This is an example of the amount of carbon that can be saved by electrification, but there are many variables to consider.

First, the carbon intensity of fuel used to heat homes and create electricity is changing. It is generally accepted that in the next few years the Northwest carbon intensity will shrink as coal plants retire and more renewable and natural gas generation is brought online to meet the needs of the system. New natural gas generation could be engineered to have higher efficiencies to reduce waste heat and carbon creation. At the same time there are efforts to reduce the carbon intensity of natural gas fuel by creating new sources of renewable methane for both electric generation and direct consumer use.

Second, home appliance technology continues to make efficiency gains. Newer cold weather heat pumps are beginning to see COPs over 4.0. These units can operate well below freezing temperatures and are fairly ideal for a moderate climate like EWEB's service territory. Further they add much needed cooling capability to homes, which cannot be attained with a standard furnace, alone. It should be noted that furnace technology continues to improve as well. There are many furnaces on the market that can achieve 90 and 95% efficiency ratings.

It's possible that the ideal solution for carbon reduction is to combine both heat pump and furnace technology into a dual fuel system. With a dual fuel system, the heat pump would provide low carbon heating the vast majority of the time. However, when temperatures get cold, effective heat pump efficiencies drop, and electricity is being generated at peak carbon intensity, there may be short periods of time where heating homes

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[34] https://www.nwcouncil.org/energy/energy-topics/power-supply

[35] This reflects the Northwest Resource mix today. OR Coal to Clean and WA CETA legislation, as well as Pacific Corps' plans to retire substantial shares of its coal generators will very likely reduce this value in the near future.

[36] Direct use natural gas CI is 0.21 MT/MWhe, after accounting for 85% furnace efficiency. Delivered electricity has a CI of 0.21 MT/MWh after accounting for 5.56% line losses.

with natural gas makes more sense. In addition to carbon reduction, dual fuel systems may support other system needs like grid resiliency and transmission/distribution management.

There is no universal solution that meets the needs of all customers, but there are a lot of options that could be considered, given a specific application. During Phase 2 of this study, EWEB will look further into feasibility and cost efficacy of various types of potential heating solutions.

9 CUMULATIVE IMPACTS FROM ELECTRIFICATION OF TRANSPORTATION AND BUILDINGS

HIGHLIGHTS

- Based on available market share, EVs represent more of an electrification opportunity compared to buildings.
- Under the highest forecasted electrification rates, EWEB could experience load growth of 64 aMW (roughly 20%) by 2050.
- There remains a wide range of uncertainty in EV adoption rates and potential peak impacts.

9.1 CUMULATIVE LOAD IMPACTS

Because space and water heating systems in EWEB's service territory are already predominantly electric, the market share for conversion is relatively small. Alternatively, with EVs making up just a few percent of new vehicle sales, the transportation sector represents a larger, emergent electrification opportunity.

Previously we have discussed both energy (aMW) and peak demand (MW) at the sector level (light duty vehicles, residential and commercial space and water heating end-use). In each section, we have illustrated the impacts of different levels of electrification (low, medium and high).

In this section, we will illustrate the potential impacts to the utility on a cumulative basis for the residential, commercial and transportation sectors.

As noted earlier in the study, climate change policies that focus on carbon reduction tend to have an accelerating effect on the pace of electrification. In the charts below the cumulative impacts of electrification are shown assuming varying levels of carbon reduction policy achievement. The scenarios below assume no specific details to the policy, but rather illustrate the range of carbon reduction that may come as a result of such policies.

Aggressive carbon reduction policies could take many forms, but the intent is to align with something close to 80% carbon reduction by 2050, or the City of Eugene Climate Action Plan.

Moderate carbon reduction policies describe a set of policies that fall short of the aggressive policies, yet still provide moderate reductions in carbon and moderate amounts of electrification.

Energy Impact

Figure MM shows the cumulative electrification that may come about as a result of aggressive carbon reduction policy achievement. This represents high levels of electrification of the end-uses and sectors within the scope of this study (80% conversion of residential and commercial space and water heating and high EV adoption). It is also assumed that space and water heating end-uses are electrified with standard-efficiency equipment.

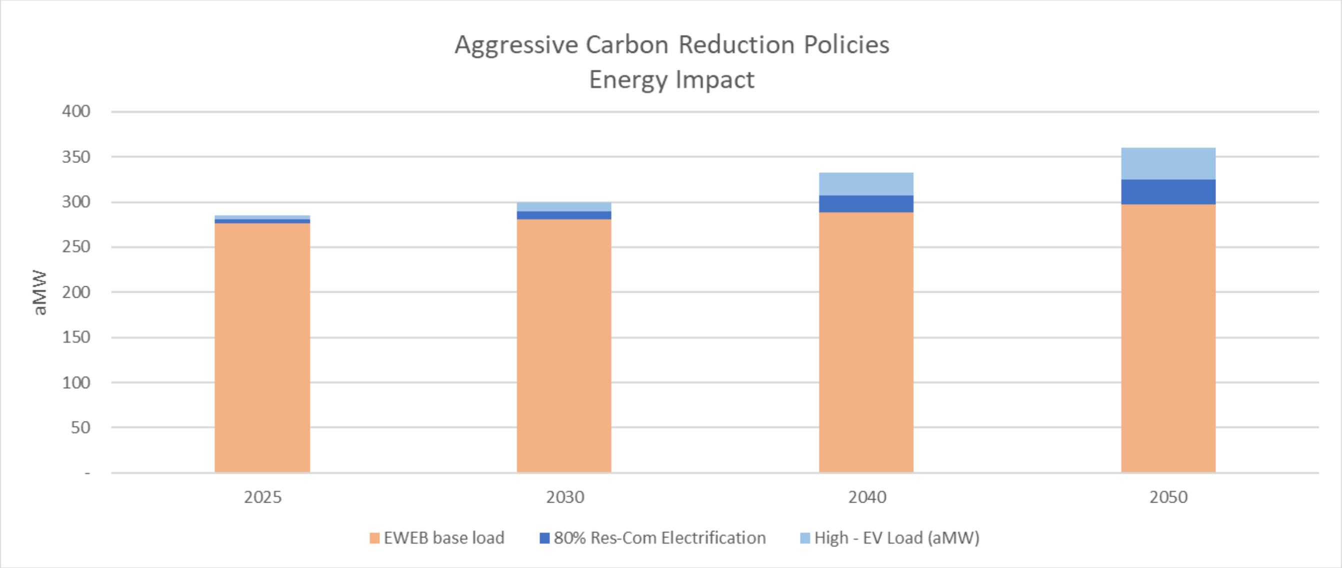


Figure MM – High levels of electrification lead to approximately 20% increase in average load by 2050.

Figure NN below shows the cumulative electrification that may come about as a result of moderate carbon reduction policy achievement. This represents moderate levels of electrification of the end-uses and sectors within the scope of this study (10% conversion of residential and commercial space and water heating and medium EV adoption). It is assumed that space and water heating end-uses are electrified with standard-efficiency equipment and that low levels of conversion (only 10%) will occur with only moderate carbon reduction policies.

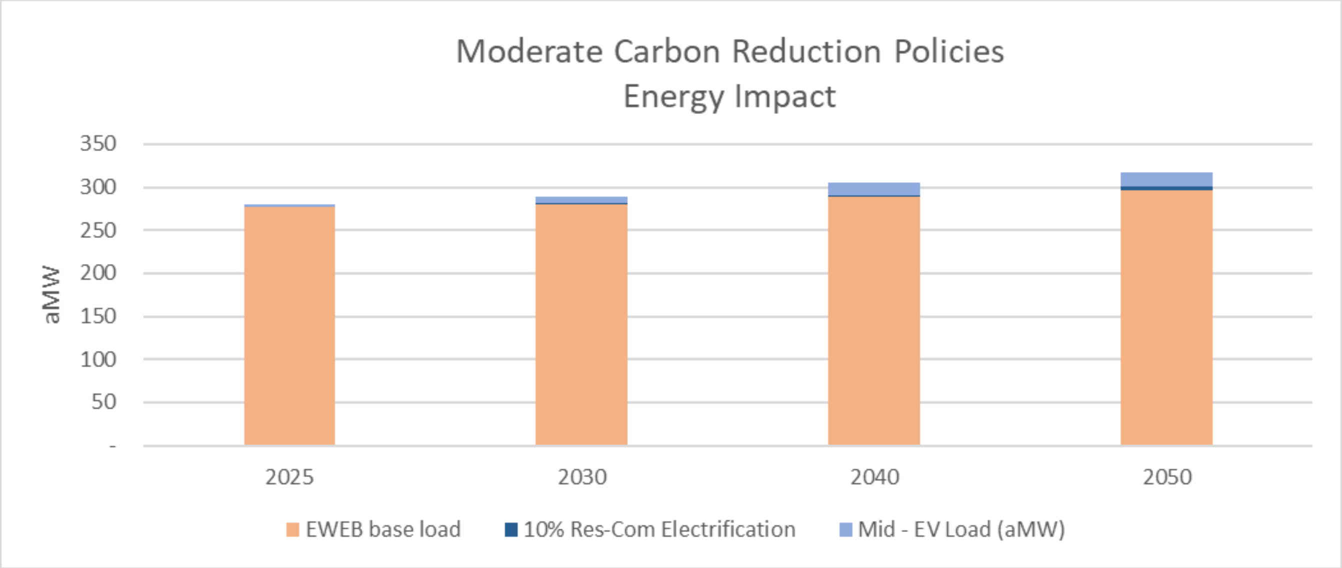


Figure NN – Absent aggressive carbon reduction policy, conversion of space and water heating end-uses is expected to remain sluggish and the average energy impacts lessen to an increase of 7%.

Peak Energy Impact

As mentioned throughout the study, electrification of transportation and buildings is expected to add to EWEB's existing system peaks. The timing of electricity consumption as well as the efficiency of the electrified technology are important variables to consider when looking out 30 years. This is especially true for space and water heating, as these end-use load shapes correlate closely to EWEB's existing system peaks (i.e. EWEB's winter peak is weather dependent and caused by space and water heating load). EVs can also contribute to system peaks depending on the time of charging.

In order to illustrate the potential peak impacts to the utility as a result of electrification, only the aggressive carbon reduction policy scenario is presented in the cumulative peak impacts chart. To show a range of potential peak impacts based on installed heat pump performance, EWEB estimated peak impacts based on both optimal and sub-optimal heat pump installation.

Optimal Heat Pump Installation

Because heat pumps lose capacity to heat at very cold outside temperatures, many heat pumps are paired with a backup heat source, typically in the form of an electric resistance attachment to an air handler or a gas furnace. To show a range of potential peak impacts from heat pumps, EWEB estimated the peak energy impacts of heat pumps that require little or no electric resistance back-up and perform well at low temperatures (optimal installation). To meet the building's heating loads at very low temperatures, it is assumed that optimally installed heat pumps would be sized appropriately to avoid utilizing backup heating.

In practice, this means that the heat pumps could be oversized by about 25-50% to ensure sufficient heating capacity at very low temperatures. Existing practice already includes oversized HVAC units by 25% or more, with contractors generally using a rule-of-thumb based on dwelling square footage to minimize customer comfort complaints. Optimal system sizing education or training could be a component of EWEB's HVAC electrification strategy. However, oversizing compared to today's standard practice translates to additional incremental cost to the customer, which would decrease adoption. Phase 2 of EWEB's electrification study can take a deeper dive into costs and benefits of optimal heat pump installation.

Sub-Optimal Installation

It is important to acknowledge optimized heat pump installation to reduce backup heating at cold temperatures would be new to the industry and some level of sub-optimal installation is likely without strong economic signals and managed installation programs. EWEB would likely need to influence new technology installations through strong performance specifications and/or oversight to achieve optimal outcomes.

Sub-optimal installation means that heat pump efficiency would reduce the COP during peak due to increased reliance on electric resistance backup, thus increasing the energy used by the HVAC system. The potential result of sub-optimal installation is an increase in peak and average energy impacts compared to optimal installation.

Figure OO shows EWEB's existing 1-in-10 peak as the base, with incremental peak from high electrification in the building and transportation sector. The blue and orange represent optimal installation of heat pump technology and managed EV charging. The line above the bars represents the potential peak impacts as a result of sub-optimal installation of electrified heat pumps and unmanaged EV charging.

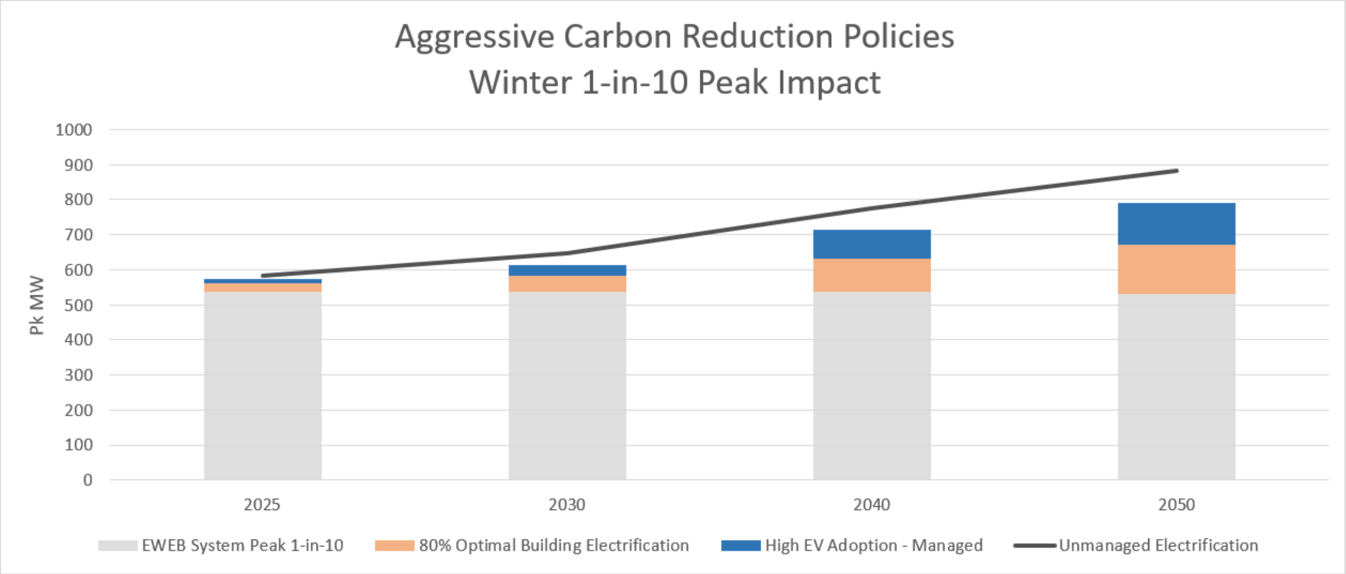


Figure OO – High levels of electrification could add between 49-66% to EWEB's existing 1-in-10 peak

While these peak impacts could be large over time, EWEB has the opportunity to manage EV charging and optimize heat pump installation to help mitigate the impact.

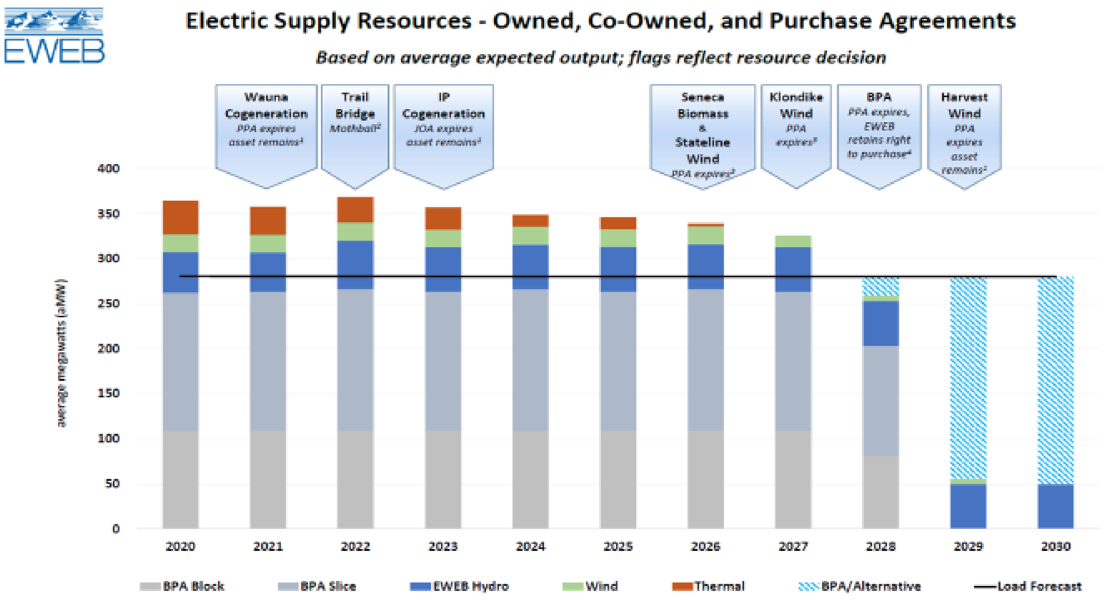
Given that the pace of electrification is expected to be slow in the near-term, EWEB will have the opportunity to respond and adapt to emergent trends and technologies. In addition, there are many additional steps that the utility can take to mitigate peak impacts which are discussed in the Mitigation Strategies section.

9.2 CUMULATIVE PORTFOLIO IMPACTS

The most significant issues facing EWEB in the next decade involve the sustained delivery of safe, reliable, affordable, and environmentally responsible services in the midst of a changing climate, new technology, developing markets, political and regulatory uncertainty.

Electrification planning is key to the success of EWEB's strategic priorities of facilitating more flexible and efficient energy consumption, effectively synchronizing generation resources with future customer-preferred consumption and creating a more resilient electric grid.

Figure PP below reflects the annual expected energy from EWEB's portfolio, available to serve load for the next ten years. It shows the important supply decisions, including the renewal, replacement, or retirement of major electric generating resource contracts, which EWEB will need to make before 2030[37]. These decisions are worth billions and will be made in the context of a changing climate, new technology, developing markets, and evolving customer expectations.



[1] Energy/Operating agreement expires and asset management obligation remains, [2] Projected to be mothballed Q4, [3] Energy agreement expires without further obligation for output, [4] Power service agreement expires, EWEB retains preference right to purchase future output

Figure PP – EWEB has major energy supply decisions to make over the next decade.

On a forecasted average energy basis, EWEB has enough surplus energy to meet our customers' electrification needs, for at least the next five years. If needed, EWEB can purchase additional energy products from the wholesale energy market to supplement the portfolio, as new long-term resources are considered and developed.

We expect that the forecasted pacing and magnitude associated with all electrification scenarios will be manageable with timely adjustments to our trade strategy. These adjustments will reflect the insights shared between staff and management at EWEB's monthly Risk Management Committee (RMC) meetings. This active

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[37] This chart reflects forecasted load, before electrification, and current resource mix. Both load and resources are subject to revision, given changes in customer demand (e.g. electrification/new large customers) and resource evaluation (e.g. ongoing review of projects located on the lower McKenzie River.)

portfolio strategy, which reflects current business practices, is in alignment with EWEB's Power Risk Management Procedures and Board Strategic Direction Policy 8 (SD8).

Balancing near term changes to load with the wholesale market is complementary to EWEB's long-term resource strategy, as it can take years to contract for, or develop, a new generation resource. The successful implementation of the next IRP will include analysis that considers all benefits and costs using a Triple Bottom Line (TBL)[38] framework for a comprehensive assessment of social, environmental and financial implications.

Power supply decisions will also reflect EWEB's commitment to equitable and affordable rates and incorporate the potential future cost of greenhouse gas emissions. Such an effort requires analysis and collaborative stakeholder engagement in order to ensure that EWEB acquires an optimal set of resources to meet the future needs of our customers, including internal, external, and regional representation. Once a prospective contract or resource is identified, securing firm transmission for delivery to load presents an additional challenge, given existing regional transmission constraints and the difficulty associated with siting, permitting, and constructing new transmission lines.

EWEB will also need to continue monitoring its Oregon Renewable Portfolio Standards (RPS)[39] obligation. Under current assumptions, the surplus of Renewable Energy Credits (RECs) and existing portfolio of non-fossil qualifying electricity is forecasted to meet compliance for at least the next five years. Per EWEB's Power Risk Management procedures, a REC strategy is developed and approved annually and includes forecasted assumptions for load, resources, and any updates or changes to state policy. This annual work will ensure all electrification efforts is included to meet the state RPS mandate.

In part, EWEB's future customer needs will be a function of emergent policy actions on the environment, and regional resource adequacy. We expect the Northwest energy resource landscape to look different after the current BPA contract ends in 2028. As such, EWEB staff and executive management are actively engaged with other Northwest utilities and stakeholder organizations to advocate for, and to help influence, a coordinated approach in developing an acceptable set of future regulatory, resource, and market solutions.

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[38] TBL is an approach to decision evaluation that takes into account more than just financial costs and benefits.

[39] Oregon's RPS establishes standards for electric utilities, requiring that a percentage of their annual retail sales must come from qualifying renewable resources.

9.3 CUMULATIVE CARBON IMPACTS

HIGHLIGHTS

- EVs present a meaningful carbon reduction opportunity in EWEB's service territory
- Conversion of gas space and water heating to electricity does yield carbon savings but is more difficult to estimate due to expected and yet uncertain reductions in the carbon intensity of both the electric grid and natural gas system over the next 30 years.
- Improvement in fuel efficiency and high levels of zero-carbon electrification could help meet as much as 34% of Eugene's 2030 GHG reduction goal

Key Context Regarding Phase 1 Cumulative Carbon Results

1. Phase 1 of this analysis uses the current NWPP electricity carbon intensity for the entire 30-year timeframe. However, we know that the NWPP resource mix will change as coal plants retire, resulting in lower grid-related emissions in the future. Changes to the carbon intensity of the NWPP and to the natural gas system over time will be considered in Phase 2 of our Electrification Impact Analysis.

2. Electrification can play an important role in helping meet the carbon reduction goals, but electrification is just one part of a larger carbon reduction strategy.

3. The CAP 2.0 was created by the City of Eugene and identifies a series of planned actions that will reduce our community's carbon footprint. Policymakers and the community continue to look for additional actions which can help meet the City's 2030 carbon reduction goals.

4. There remains a wide range of uncertainty in adoption rates and potential peak impacts of electrification.

Electrification of light-duty vehicles and space and water heating can support meaningful contributions towards community carbon reduction goals. The size and speed at which these benefits can be achieved is a timely question, particularly considering the targets set forth in the City of Eugene CAP 2.0 report.

However, it should be noted that electrification is just part of meeting carbon reduction goals. Decarbonization studies consistently state that achieving economy-wide deep decarbonization requires action on multiple fronts.

For example, E3's "four pillars" of deep decarbonization[40], all of which are available in the Pacific Northwest, are: 1) high levels of energy efficiency in buildings; 2) high levels of low-carbon energy (i.e., renewables, low-carbon electricity and sustainable, carbon-neutral biofuels); 3) nearly complete electrification of the transportation sector; and 4) reductions in non-combustion GHG emissions.

In Phase 1 of the electrification analysis, we analyzed potential carbon reductions specifically due to the electrification pillar.

Forecasting carbon reduction in the transportation sector involves two key reductions in carbon emissions from transportation: (1) the improvement of internal combustion efficiency over time, and (2) increased adoption of electric vehicles over time.

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[40] https://www.ethree.com/e3-analyzes-building-decarbonization-in-the-pacific-northwest/

The National Highway Traffic Safety Administration (NHTSA) Corporate Average Fuel Economy (CAFE) standards regulate how far vehicles must travel on a gallon of fuel. The purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and light trucks over time. The chart below illustrates the potential carbon reductions as a result of the improved fuel economy/MPG standards (gray) in addition to the benefits of electrification. It should be noted that carbon reduction due to MPG improvements appears relatively flat due to decreased adoption of gas vehicles and increased adoption of EVs as a result of electrification.

Although the majority of the carbon reductions are associated with the transportation sector, electrification of space and water heating in EWEB's service territory is expected to reduce carbon emissions as well. However, the impacts to carbon emissions from conversion of natural gas space and water heating to electric is more complex due to the impacts to peak electricity use. Both the electric grid and the natural gas system's carbon intensity are expected to improve over the next 30 years. Thus, electrification of space and water heating end-uses across the Pacific Northwest may not provide the same levels of carbon reduction by comparison over time. Further analysis of the carbon emissions impacts due to electrification of space and water heating is recommended for further study in Phase 2.

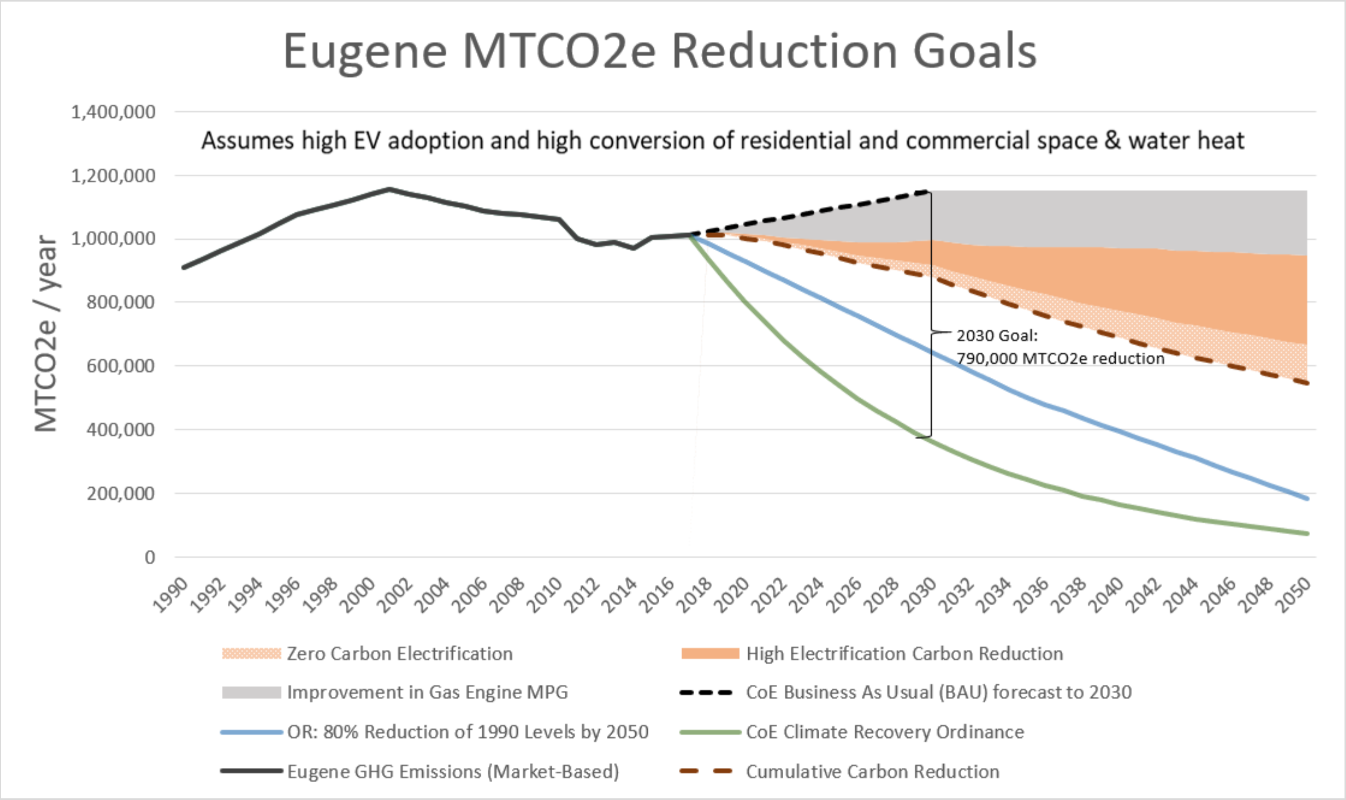


Figure QQ - Eugene's historical and projected GHG using the market-based carbon accounting method based on EWEB's DEQ GHG reporting. Carbon savings associated with electrification of the transportation and building sector are displayed in gray and orange to provide context on the amount of carbon reduction that could be possible with high levels of electrification by 2050 (80% conversion of existing residential and commercial space & water heating and 45% market penetration of EVs).

The carbon reduction associated with high electrification is shown using today's NWPP carbon intensity (orange) as calculated elsewhere in the study. However, the electric grid carbon intensity is expected to decline over the study period due to coal plant retirements and increased adoption of renewable resources. The reductions attributed to zero carbon electrification (textured orange) has been added to illustrate the potential benefits of utilizing zero carbon electricity rather than today's low carbon intensity NWPP grid.

Electrification can play an important role in helping meet Eugene's carbon reduction goals. As shown in Figure QQ, improvement of fuel efficiency and high levels of zero-carbon electrification could help meet as much as 34% of the City's 2030 carbon reduction goal. With continued high levels of electrification over the next 30 years, that could be over 50% by 2050.

As noted earlier, electrification is just part of the pathway to deep decarbonization. In addition to the electrification carbon reductions shown in in the chart above, the City of Eugene and its community partners have identified 245,000 MTCO2e in carbon reduction commitments by 2030. The City of Eugene plans to continue identify more actions to meet the 790,000 MTCO2e reduction goal through the process outlined in the CAP 2.0.

9.4 CUMULATIVE INFRASTRUCTURE IMPACTS

HIGHLIGHTS

- Early assessments indicate that EWEB's electric system has the capacity and flexibility to manage low-to-moderate electrification levels.
- EWEB has multiple options to address future capacity constraints, adapting as the load changes, regardless of the underlying causes for load change.

As Eugene's population and industry makeup has fluctuated over the decades, EWEB has both anticipated and reacted to our obligation to serve. Almost two-thirds of EWEB's present-day transmission lines and substations were constructed during Eugene's explosive growth in the 1960s and 1970s.

From 1955 - 1980, load was growing at an average rate of over 19 MW per year. The growth was extremely predictable, creating a planning environment that supported adding capacity. However, this abruptly changed in 1980 when our community entered a deep economic recession and load growth dropped to less than 1 MW/year.

EWEB continues to experience minimal load growth due to a combination of factors including changes to the make-up of our local economy, increased energy efficiency and the penetration of natural gas in new residential and commercial development.

As a result of these two dramatically different growth periods, the EWEB electric system is diverse in its build-out over time. In the south and northeast areas of Eugene, the system has capacity to handle additional load, while large swaths of the western portions of our service territory are more limited in terms of available capacity.

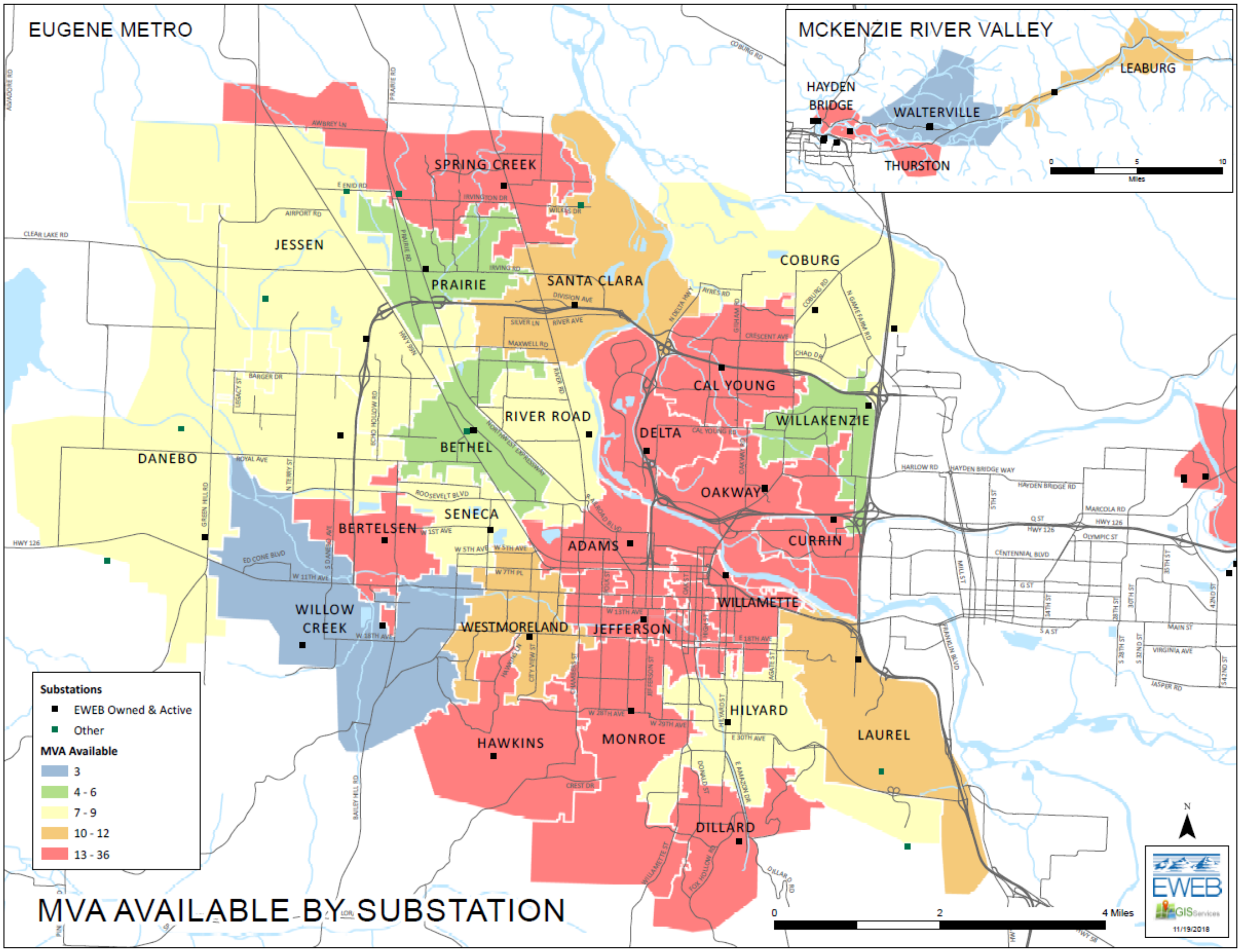


Figure RR – This map illustrates which areas within EWEB's service territory have much more available capacity (red) compared to those that are near capacity (blue) at the substation level.

One option to address capacity constraints is to build new substations, and EWEB has purchased two properties in West Eugene for this purpose. But this is an expensive solution, especially if predicted load growth does not occur in that area of our system.

Another option is to reconfigure the transmission system to move existing load from one substation to a nearby underserved substation to free up capacity where new growth is anticipated. This more cost-effective solution to adapt the system's existing assets was just completed in the industrial area near the Eugene airport, readying the Jessen substation for future growth. Such opportunities exist elsewhere in our system.

The impacts of electrification on infrastructure at the neighborhood, or distribution level, requires specific analysis. When new load is requested, or when load changes, the affected distribution assets are reevaluated according to current EWEB standards. Additionally, an ongoing inspection program, based on compliance obligations, is employed to systematically review the distribution system.

Each year, about ten percent of EWEB's distribution system is evaluated for compliance upgrades the following year; the resulting work includes conductor, transformer, pole, and other modifications required to meet clearance and other standards (NESC, PUC). Due to this ongoing work, the distribution system has regular and recurring opportunities to adapt as the load changes, regardless of the underlying causes for load change.

A review of transformer loading in 2015 showed that less than 1% of EWEB's approximately 15,000 transformers were loaded over 90%.

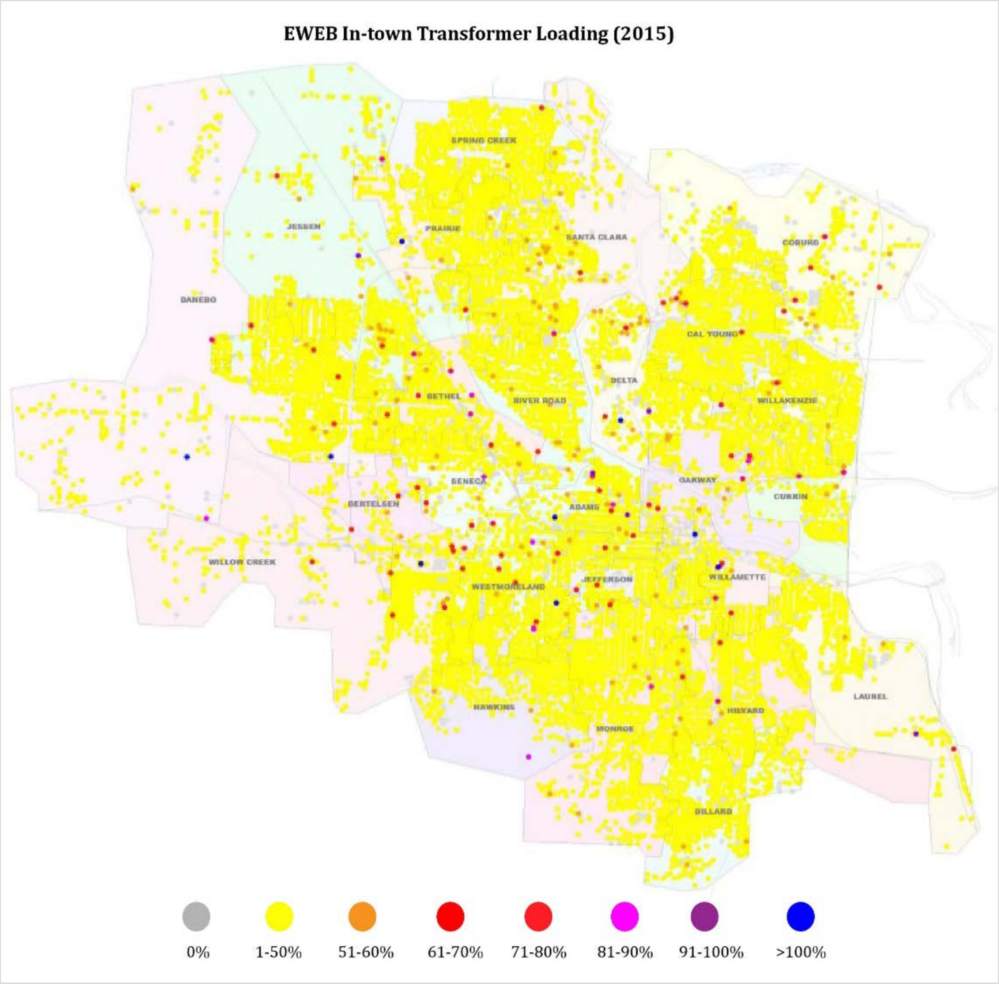


Figure SS - Most distribution transformers (over 80%) were loaded at 50% or less in 2015.

Taken together, our early assessment of infrastructure at the substation and neighborhood level indicates that the electric system has the capacity and flexibility to manage low-to-moderate electrification levels. A more in - depth assessment of the impacts to the transmission and distribution system, including transformer loading from different electrification scenarios, is planned for Phase 2 of this study.

10 MITIGATION STRATEGIES

Daily energy consumption patterns collectively create periods of high electricity use, called peak demand or peak load. Under certain load/resource conditions, it can be difficult for generators and transmission operators to meet all energy needs and maintain system reliability. There is concern that absent intervention measures, increased electrification can add to these peak periods and exacerbate issues related to system reliability. However, the size and timing of these peaks can be managed with customer intervention strategies, or demand side management (DSM).

DSM aims to delay, or altogether avoid, acquisition of new power supplies. This is accomplished by shifting energy consumption to reduce peak demand patterns and to optimize generation and transmission assets.

Demand-side management includes conservation programs to incent technologies that reduce overall energy consumption, as well as consumer education to voluntarily shift discretionary use to off peak times.

The most effective DSM programs leverage advanced rate design, often referred to as “time-of-use” programs, which can include sending dynamic pricing signals to customers. These price signals are intended to incent customers to reduce consumption when power supplies are scarce, or the transmission system approaches its peak carrying capacity. With this sort of rate design, customers benefit financially by reducing consumption during periods of high-priced energy.

Demand Side Management Programs

Energy efficiency is by far the most common and largest DSM strategy that EWEB utilizes today with programs available across all customer segments, including site-specific industrial projects which can deliver larger savings. Common programs include incentives for new heat pumps, insulation improvements, and commercial lighting upgrades. BPA estimates the energy savings related to each measure and provides financial reimbursement for measures implemented. EWEB provides additional financial support for efficiency projects supporting limited income customers.

Conservation and Efficiency

Currently, EWEB offsets 100% of new load growth with conservation and pursues the maximum amount of conservation possible within budget, which is slightly higher than the reimbursement level from BPA. As the chart below demonstrates, EWEB efficiency programs are effective in not only reducing overall energy consumption but also peak demand. In fact, while some measures are more effective than others in managing peak demand, in aggregate, EWEB conservation programs have two to three times the impact on peak load than average energy.

	EWEB Load Reductions from Conservation Programs					
	2017		2018		2019	
	aMW	Peak MW	aMW	Peak MW	aMW	Peak MW
Residential	0.47	1	0.4	1.5	0.3	1
Non-Residential	0.52	1.6	1.11	2	0.95	1.2
Total	0.99	2.6	1.51	3.5	1.25	2.2

With EWEB's deep experience in delivering conservation programs, the infrastructure and expertise are in place to ramp up programs that deliver greater peak reductions, whether through enhanced marketing or more attractive incentives.

Based on preliminary analysis, it is estimated that we could reduce the current peak load associated with electric resistance heating by at least one-third, by replacing existing equipment with standard efficiency heat pumps. The use of efficient dual fuel heat pumps in EWEB's service territory could also help mitigate the peak electric use by utilizing natural gas during periods of extreme cold and peak electric use. Programs could also be refined to target particular market segments or geographic areas to address constraints in our distribution system. Further analysis of potential peak energy savings and potential conservation programs should be considered for Phase 2 of this study.

Load Shifting

DSM programs can also be designed to encourage consumers to modify their level and pattern of electricity usage for their existing equipment. Because most EV users have the flexibility to charge their vehicles overnight, shifting charging behavior to later in the evening is particularly promising. Similar to delayed start times that can be set for appliances like dish washers and clothes dryers, EVs allow customers to 'set and forget' the timing for when charging starts for more consistent and predictable results. Such delays of discretionary consumption to off-peak time periods can mitigate impacts to EWEB's system peaks.

To illustrate the potential impact of EV load shifting on peak demand, we've modeled EWEB load on a typical peak winter day, with high incremental electrification load. This high electrification example assumes: (1) 80% conversion of space and water heating in both residential and commercial sectors using standard efficiency equipment, and (2) high EV adoption rates with unmanaged charging behavior.

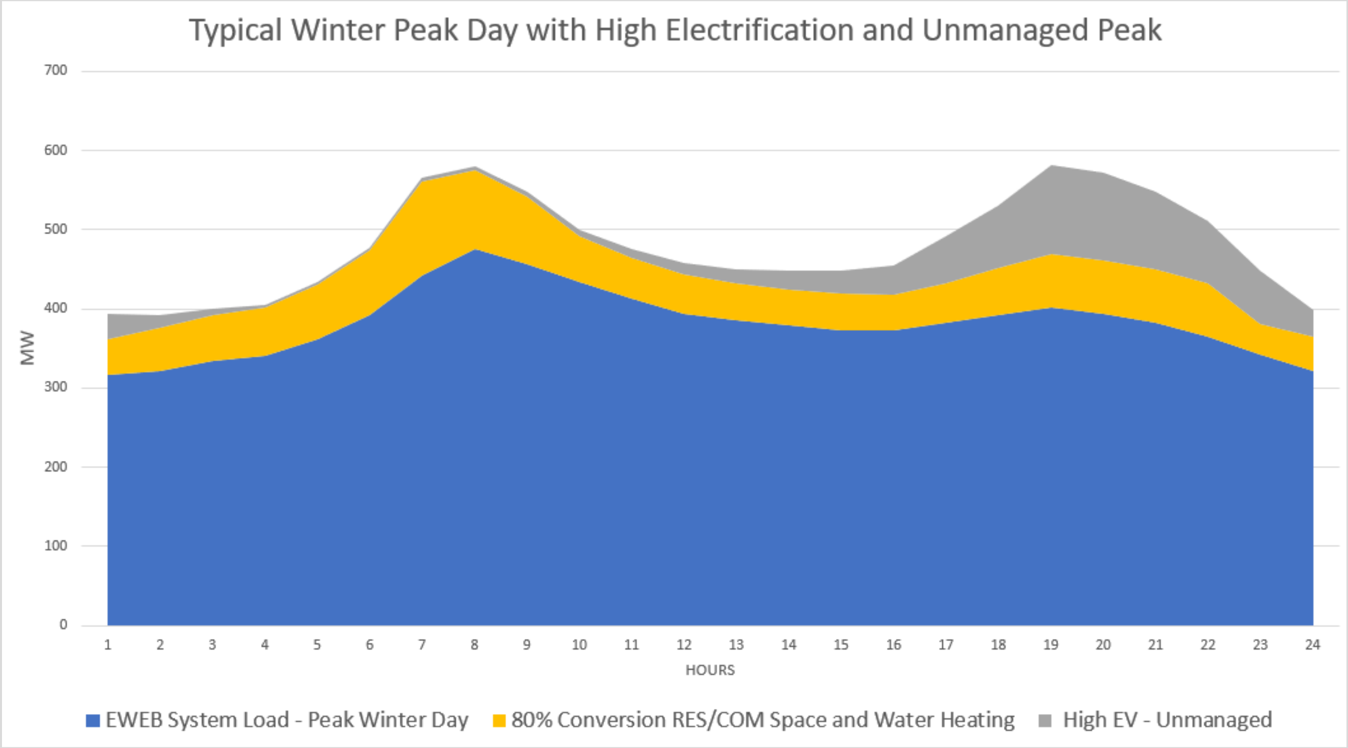


Figure TT- Electrification of space and water heating accentuates the morning peak, while the additional load associated with EV charging creates a second evening peak.

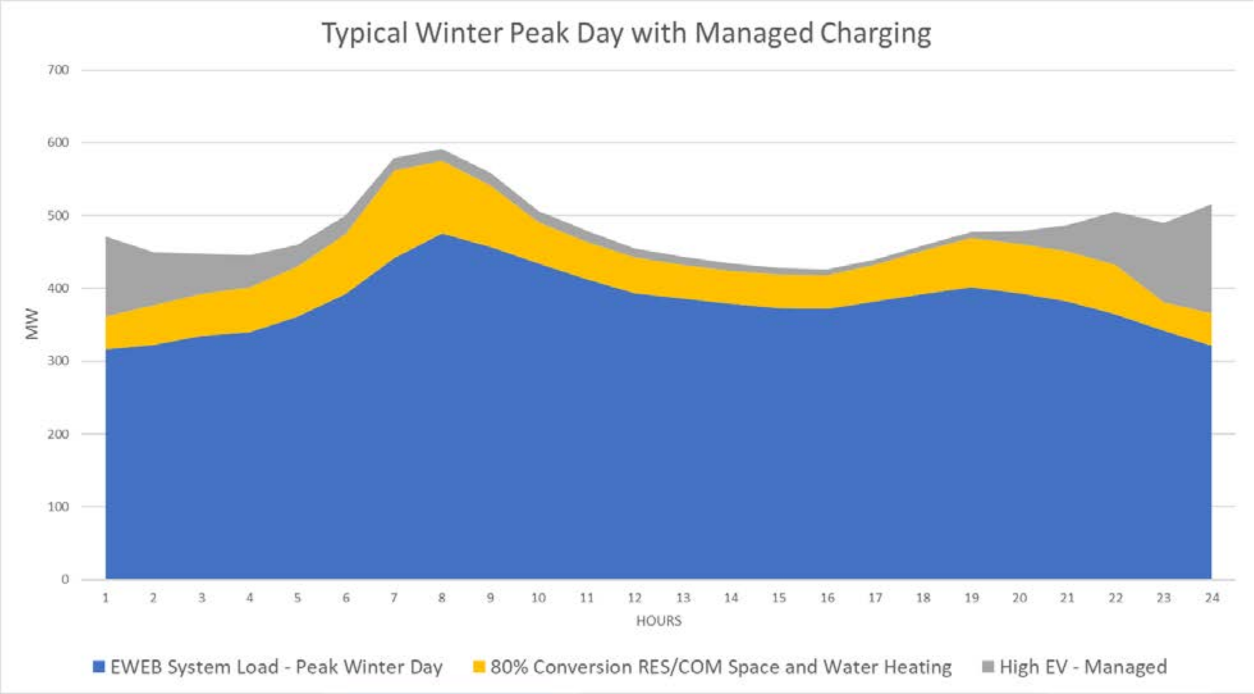
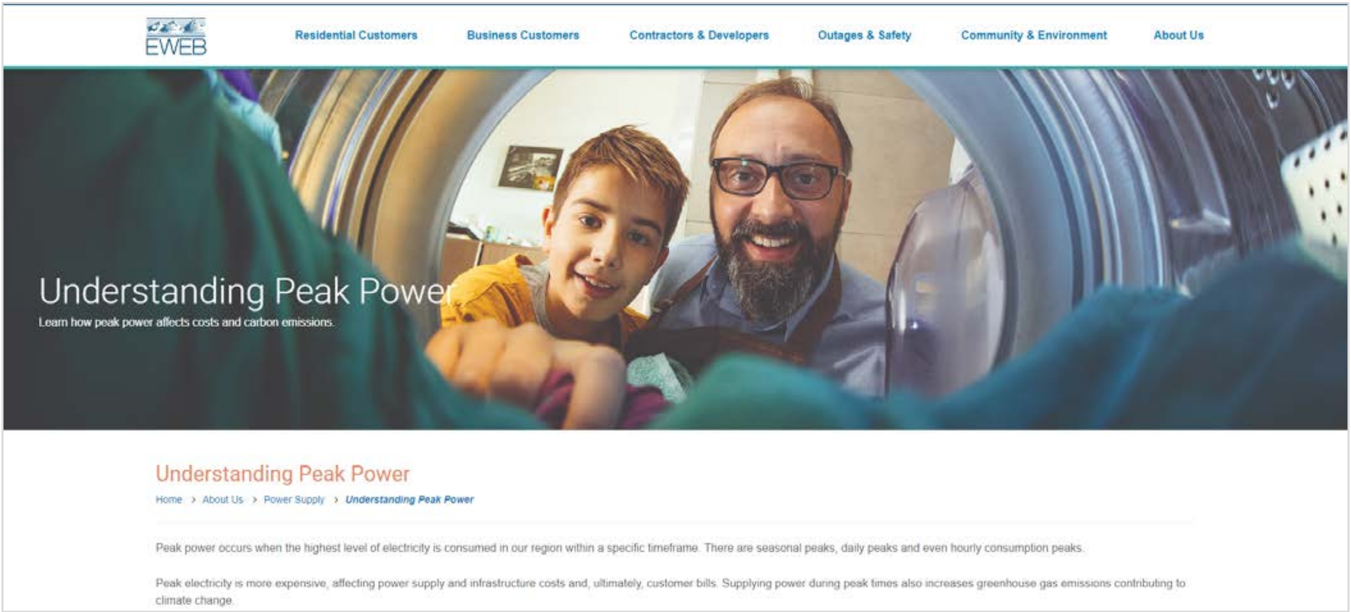


Figure UU- Shifting peak EV charging from 7 PM to 12AM (off-peak) moves the EV charging load away from EWEB's system peak and results in lower energy costs and much lower carbon emissions.

While EWEB does not have a formal program incenting off-peak charging, the utility has begun a consumer education campaign to raise awareness of the benefits of shifting consumption to off-peak hours.



Understanding Peak Power

Learn how peak power affects costs and carbon emissions.

Understanding Peak Power

Peak power occurs when the highest level of electricity is consumed in our region within a specific timeframe. There are seasonal peaks, daily peaks and even hourly consumption peaks.

Peak electricity is more expensive, affecting power supply and infrastructure costs and, ultimately, customer bills. Supplying power during peak times also increases greenhouse gas emissions contributing to climate change.

The utility is also about midway through installation of advanced electric meters throughout the customer base. ‘Smart meter’ technology is part of the technology infrastructure needed to establish time-of-use pricing programs, such as discounted pricing for off-peak EV charging.

Direct Load Control

Another approach involves Direct Load Control (DLC), where power to a load or appliance can be turned on or off in response to signals from the utility. This strategy can work well with end-uses that can tolerate short periods of reduced or no power. Water heaters, for example, can be super-heated during off-peak times and then turned off entirely for a few hours in the early morning without impact to the customer experience. The reverse can work for cold-storage units without impact to product. EWEB has explored both types of DLC as proof of concept pilot programs.

Each pilot project successfully shifted demand, but the metering and communication infrastructure costs necessary for broader adoption made the programs cost prohibitive. Technology advancement will facilitate utility engagement with “smart” electric appliances and control systems, which have been steadily gaining market share. Such devices (as part of the “internet of things”) may provide greater opportunities for cost-effective demand response programs in the future.

Energy Storage and Battery Technology

The northwest has traditionally relied on hydroelectric dams to store and release water to meet peak load, and resource needs in the region. In this way, hydro dams act as a battery which can quickly ramp up to meet cold winter peak demand, or ramp down to effectively store surplus energy, which helps integrate variable resources like wind and solar. However, the existing hydro system is approaching its limit to serve incremental load, or to integrate new renewable resources. Building additional hydro generation is costly and difficult and new hydro storage sites are almost non-existent. Further, changes in hydro system operation to promote ecological sustainability may reduce some of the current hydro systems capability in the future.

To meet more sustainable energy requirements, the northwest will need to consider other storage technologies including utility, commercial, and residential scale batteries. Such future applications could include pairing batteries with new renewable resources to reduce integration burden, placing batteries in substations for added grid reliability, and charging/discharging EVs throughout the day to manage energy oversupply.

With improvements in battery technology and manufacturing, the cost of large-scale battery storage has greatly improved over the last decade. Battery storage is currently most effective where there are short durations of energy needs (2-4 hours) and impactful pricing signals to shift energy use. Current battery storage may not be the best solution for addressing resource adequacy issues, which may require 3-5 days of energy storage during periods of increased load and decreased renewable generation.

Pumped hydro storage and renewable hydrogen generation are examples of technology which could store energy for longer periods of time. The Pacific Northwest currently lacks strong peak price signals, making battery and energy storage less cost effective than developing new generating resources which can be used to meet peak demand over extended periods of time.

Pricing and Rate Design

Rate design can play an important role in helping customers shift their energy use to off-peak periods. There are two types of potential solutions: time-based rates or demand charge rates.

Time-based rates can vary by season and/or time of day to more accurately reflect the varying cost of power. Time-based rates offer more accurate price signals to customers, better reflecting the marginal/opportunity cost of generating electricity.

Time-based structures can be used to encourage load shifting to off-peak times, or to discourage demand when energy supplies and/or transmission is constrained. Depending on the goals, pricing programs can target a customer class or market segment such as grocery stores, or an end-use such as EVs.

Demand charges are a common rate-making tool to recover the infrastructure costs necessary for the utility to be ready to meet customers' highest demand on any given moment. Utilities apply demand charges based on the maximum amount of power that a customer used in any interval (typically 15 minutes) during the billing cycle. Customers may respond by changing their consumption patterns to reduce peak demand, flattening their load profile.

EWEB currently has a demand charge for general service customers, but not for residential customers because it's difficult for residential customers to change consumption patterns based on their monthly bill's demand charge absent better information about when the peak occurs. Customer access to more granular energy consumption data available through smart meter technology may make the demand charge price signal more effective in changing behavior.

While technology is one obstacle to broad implementation of some DSM programs, the absence of market-based price signals is another barrier. Today, peak period power costs are largely dictated by transmission needs as well as the real and potential costs of energy consumed during periods of peak demand. By participating in energy markets, the utility's trading floor actively balances the portfolio, while reducing financial risk to our customers.

Since electrification will likely increase peak load when market prices are generally higher and more volatile, there is a corresponding increase in exposure to financial risk. Adoption of time-based pricing has the potential to help the utility reduce exposure to market risk, but current northwest energy-only markets generally lack the strength to drive a price signal strong enough to encourage behavior modification.

EWEB's current pilot time of use pricing for medium and large commercial customers offers a 27% price reduction for off-peak demand charges and 11-21% reduction for off-peak energy use. However, analysis of EWEB's pilot commercial TOU rate indicates that the difference between on-peak and off-peak pricing was largely insufficient to change their consumption patterns. Time-based pricing is generally more successful in areas like California, where energy prices are higher, and capacity and carbon markets exist. Until these conditions are met in the northwest, time-based pricing may not currently be the most effective tool for mitigating incremental peak.

The mitigation strategies most likely to help smooth or shift the electrification peak will be dependent on program costs and benefits to EWEB.

Currently, EWEB offers incentives for Level 2 charger installation, specifically because this equipment can help customers shift charging to off-peak periods. Incentives like this, along with public education campaigns to encourage customers to shift discretionary energy use to off-peak hours, do not have high costs and are further incentivized by revenue from the Oregon Clean Fuels Credit program.

Other voluntary demand management programs can be a cost-effective mitigation strategy today. Examples include alerting customers when peak events are forecasted and requesting that they shift their peak energy use to the extent possible, or EWEB energy management personnel working with industrial customers to identify site-specific peak reduction solutions. Costs and benefits of programs relevant to electrification will be further analyzed in Phase 2 of the study.

11 ELECTRIFICATION STUDY GLOSSARY

aMW	Average megawatt is calculated by totaling the annual power consumed in a year (in this case megawatts or MW) and dividing that total annual consumption by the number of hours in given year (typically 8,760 during non-leap years). In Electricity Supply Planning, the average megawatt can provide useful context for understanding the average energy required to meet demand on an annualized basis.
Advanced Metering Infrastructure (AMI)	Advanced metering infrastructure (AMI) is an integrated system of meters, communications networks, and data management systems that enables two-way communications between utilities and customer meters.
Balancing	Balancing or matching load with resources to meet demand. Commonly referred to as load/resource balance.
BTU and BTUH	British Thermal Unit (BTU) is a measure of heat energy. BTUH is British Thermal Unit per hour. One BTU is the amount of energy needed to raise 1 pound of water by one degree Fahrenheit.
Coincident Demand	The sum of two or more demands that occur in the same time interval[41].
Carbon	Short for Carbon Dioxide, a greenhouse gas produced by burning fossil-based fuels and other sources.
Carbon Intensity	The amount of carbon emitted per unit of energy consumed.
Climate Change	The rise in average surface temperatures on Earth due primarily to the human use of fossil-based fuels, which releases carbon dioxide and other greenhouse gases into the air.
Cost-parity	Same price for product that is equivalent in value.
Coefficient of Performance (COP)	An efficiency ratio that measures useful heating or cooling provided relative to the work required. In electric heat pumps, this is the relationship between the energy that is delivered from the heat pump as cooling or heat (BTUh is converted to equivalent power kW), and the power (kW) that is supplied to the compressor.
Controlled Charging	Controlled or managed EV charging enables the utility and customer to align charging behavior that will potentially mitigate higher costs and carbon impacts during peak demand hours.
Demand	The rate at which energy is being used by the customer.
Demand Side Management (DSM)	An action to effectively reduce or modify the demand for energy. DSM is often used to reduce load during peak demand and/or in times of supply constraint.
Direct Load Control (DLC)	The consumer load that can be interrupted at the time of peak load by direct control of the utility[42].
Distribution Assets	The portion of the electric system's poles, transformers, and other equipment dedicated to delivering electricity at the required voltage for the end-user.
Diurnal	Diurnal variation refers to daily fluctuations.
Electric Vehicle (EV)	A vehicle that derives all or part of its power from electricity supplied by the electric grid. Primary EV options include battery, plug-in hybrid, or fuel cell. • Battery Electric Vehicles (BEV) typically do not have an internal combustible engine (ICE) or fuel tank and rely solely on its battery charged by electricity to operate the vehicle. Typical driving ranges are considerably less when compared to other vehicle options but newer models coming out with advanced battery technology support higher ranges.

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[41] https://www.eia.gov/tools/glossary

[42] https://www.eia.gov/tools/glossary

	• Plug-in Hybrid Electric Vehicles (PHEV) are powered by an on-board battery and gasoline with the ability to operate solely on its battery, ICE, or a combination of both. When the battery is fully charged and gasoline tank full, the PHEV driving range is comparable to a conventional ICE vehicle. • Fuel Cell Electric Vehicles (FCEV) run on compressed liquid hydrogen. Combining hydrogen with oxygen generates the electrical energy that either flows to the motor or to the battery to store until it's needed. FCEVs have a driving range comparable to a conventional ICE vehicle.
Electric Vehicle (EV) Charging Stations	EV charging stations typically fall under three primary categories: Level 1, Level 2, and Level 3 also referred to as DC Fast Chargers[43]. • Level 1: Provides charging through a 120 V AC plug and does not require installation of additional charging equipment. Can deliver 2 to 5 miles of range per hour of charging. Most often used in homes, but sometimes used at workplaces. • Level 2: Provides charging through a 240 V (for residential) or 208 V (for commercial) plug and requires installation of additional charging equipment. Can deliver 10 to 20 miles of range per hour of charging. Used in homes, workplaces, and for public charging. • DC Fast Charge: Provides charging through 480 V AC input and requires highly specialized, high-powered equipment as well as special equipment in the vehicle itself. (Plug-in hybrid electric vehicles typically do not have fast charging capabilities.) Can deliver 60 to 80 miles of range in 20 minutes of charging. Used most often in public charging stations, especially along heavy traffic corridors.
Energy Efficiency	Refers to programs that are aimed at reducing the amount energy used in homes and other buildings. Examples include high-efficiency appliances, lighting, and heating systems.
Generation	The process of producing electricity from water, wind, solar, fossil-based fuels and other sources.
Green	Green or clean electricity produced with little-to-no environmental impact or contributes to global warming caused by greenhouse gas emissions.
Greenhouse Gas (GHG) Emissions	GHG emissions are gases, such as carbon dioxide, that trap heat in the atmosphere. The largest source of GHG emissions from human activities in the U.S. is from burning fossil-based fuels for electricity, heat, and transportation[44].
Grid	The electricity grid, or grid, refers to the system that moves electricity from its source through transformers, transmission lines, and distribution lines to deliver the product to its end-user, the consumer.
Heat Pump	Heating and/or cooling equipment that, during the heating season, draws heat into a building from outside and, during the cooling season, ejects heat from the building to the outside. Heat pumps are vapor-compression refrigeration systems whose indoor/outdoor coils are used reversibly as condensers or evaporators, depending on the need for heating or cooling[45].
Integrated Resource Plan (IRP)	An IRP is a plan that outlines how a utility will meet its future electricity needs over a long-term planning horizon.

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[43] https://www.energy.gov/eere/electricvehicles/charging-home

[44] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[45] https://www.eia.gov/tools/glossary

Interval Metering	Interval metering data is a series of measurements of energy consumption, taken at pre-defined intervals, typically sub-hourly. In end-use studies, energy consumption is measured in 15-minute or 1-minute granularity.
Light-duty Vehicles	Light-duty refers to gross vehicle weight rating and includes passenger cars, SUVs, trucks, and vans that weigh up to 10,000 pounds.
Line-loss	The amount of electricity lost during the transmission and distribution phases as it travels across the grid.
Load	The amount of electricity on the grid at any given time, as it makes its journey from the power source to all the homes, businesses.
Load Shape	A method of describing peak load demand and the relationship of power supplied to the time of occurrence[46]. Interval metering of end-uses is one method used to develop a load shape.
Market Liquidity	Market liquidity refers to the extent a market, such as the wholesale electricity market or real estate market, allows assets to be bought and sold with price transparency.
Megawatt (MW)	The standard term of measurement for bulk electricity. One megawatt is 1 million watts. One million watts delivered continuously 24 hours a day for a year (8,760 hours) is called an average megawatt.
MPGe	Miles per gallon of gasoline-equivalent. Think of this as being similar to MPG, but instead of presenting miles per gallon of the vehicle's fuel type, it represents the number of miles the vehicle can go using a quantity of fuel with the same energy content as a gallon of gasoline. This allows a reasonable comparison between vehicles using different fuels[47].
MTCO2e	Metric tons of carbon dioxide equivalent is a unit of measurement. The unit "CO2e" represents an amount of a GHG whose atmospheric impact has been standardized to that of one unit mass of carbon dioxide (CO2), based on the global warming potential (GWP) based on the global warming potential (GWP) of the gas.
NESC	National Electric Safety Code
Noncoincident Demand	Sum of two or more demands on individual systems that do not occur in the same demand interval[48].
1-in-2 or 1-in-10	A statistical measure used for risk analysis. The probability or chance of something occurring one year such as a one-hour peak in year 2, 1-in-2 year, is 1 / 2 or 50%. A 1-in-10 year has 1/10 or 10% chance of occurring in any one year.
Peak Demand	The largest instance of power usage in a given time frame.
Peaker Plant	Peaker plant, also known as a peaking power plant or simply peaker, is a power plant that generally runs during times when demand for electricity is high or at its peak time. Peaker plants are typically gas turbines that burn natural gas.
Power	The rate of producing, transferring, or using energy, most commonly associated with electricity. Power is measured in watts and often expressed in kilowatts (kW) or megawatts (MW)[49.]
PUC	Public Utility Commission
Real-time	Actual time of occurrence.
Residential Building Stock Assessment (RBSA)	An assessment developed to capture the residential building sector that considers building practices, fuel choices, and diversity of climate across the region.

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[46] https://www.eia.gov/tools/glossary

[47] https://www.epa.gov/fueleconomy/text-version-electric-vehicle-label

[48] https://www.eia.gov/tools/glossary

[49] https://www.eia.gov/tools/glossary

Resource Adequacy	Ensuring there are sufficient generating resources when and where they are needed to serve the demands of electrical load in “real time” (i.e., instantaneously). An adequate physical generating capacity dedicated to serving all load requirements to meet peak demand and planning and operating reserves, at or deliverable to locations and at all times.
Resource Portfolio	All of the sources of electricity provided by the utility.
Scenario	A projection or forecast that provides a framework to explore plausible outcomes. Scenario analysis is the process of analyzing plausible outcomes and typically includes base-case, expected-case, and worst-case scenario analysis.
Sector	Group of major energy consumers developed to analyze energy use. Commonly referred to as residential, commercial, industrial, and transportation sectors.
Segment	Customer segmentation or segment means separating the diverse population of end-use customers in groups based on similarities in customer needs and preferences.
Sensitivity	Sensitivity analysis is a method to determine how changes in methods, models, values of variable or assumptions may lead to different interpretations or conclusions by assessing the impact, effect or influence of key assumptions or variable.
Therms	A measurement of heat energy in natural gas. One unit of heat is equal to 100,000 British thermal units (BTU).
Transmission	An interconnected group of lines and associated equipment for the movement or transfer of bulk energy products from where they are generated to distribution lines that carry the electricity to consumers.
Uncontrolled Charging	Uncontrolled charging allows for charging at any time of time without restraints including differences in price to charge. Also known as unmanaged charging.
Wholesale Market	The market for buying and selling of electricity before it is sold to the end-user.