MEMORANDUM

EUGENE WATER & ELECTRIC BOARD

Rely on us.

TO:	Commissioners Schlossberg, Brown, Carlson, Barofsky and McRae
FROM:	Megan Capper, Energy Resources Manager
DATE:	December 7, 2021
SUBJECT:	Final Electrification Impact Analysis Reports (Phase 1 and Phase 2)
OBJECTIVE:	Information

Issue

EWEB has completed an analysis of the impacts of electrification, published in two phases (October 2020 and November 2021) that will used as planning criteria in EWEB's Integrated Resource Plan (IRP) scheduled for completion in early 2023. The reports from both phases of the study are attached or can be found online (http://www.eweb.org/about-us/electricity-supply-planning).

Background/Discussion

In early 2020, EWEB's management and Commissioners agreed to develop a better understanding of the impacts of electrification on EWEB's future planning efforts. Understanding the impacts and pace of electrification will inform future utility decisions related to integrated resource planning, including supply impacts, customer programs, infrastructure planning, and rate design. These analyses fulfill the 2021 EWEB Organizational Goal #5, approved by the Board in January 2021.

> *Continue electrification impact assessment, specifically analyzing the future decarbonizing trends of electricity and natural gas, and the division of costs/benefits between participants, utilities, and society at-large -- a.k.a. who benefits and who pays?*

Phase 1 of the Electrification Impact Analysis Report focused on potential changes to electricity consumption patterns and environmental impacts from electrification of passenger vehicles, as well as existing residential and small commercial water and space heating. While the Phase 1 study relied on assumed low, medium, or high levels of electrification, the adoption rate of electrification was uncertain because the analysis was done without considering costs.

Phase 2 seeks to build on the analysis and context established in Phase 1 by considering the economics of electrification from multiple perspectives, and therefore providing a better understanding of the likelihood of electrification and EWEB's opportunities to engage with customers and develop programs. This study utilizes benefit/cost analysis to understand the financial benefits of electrification and explores key variables which will influence customer choices over the next 20 years.

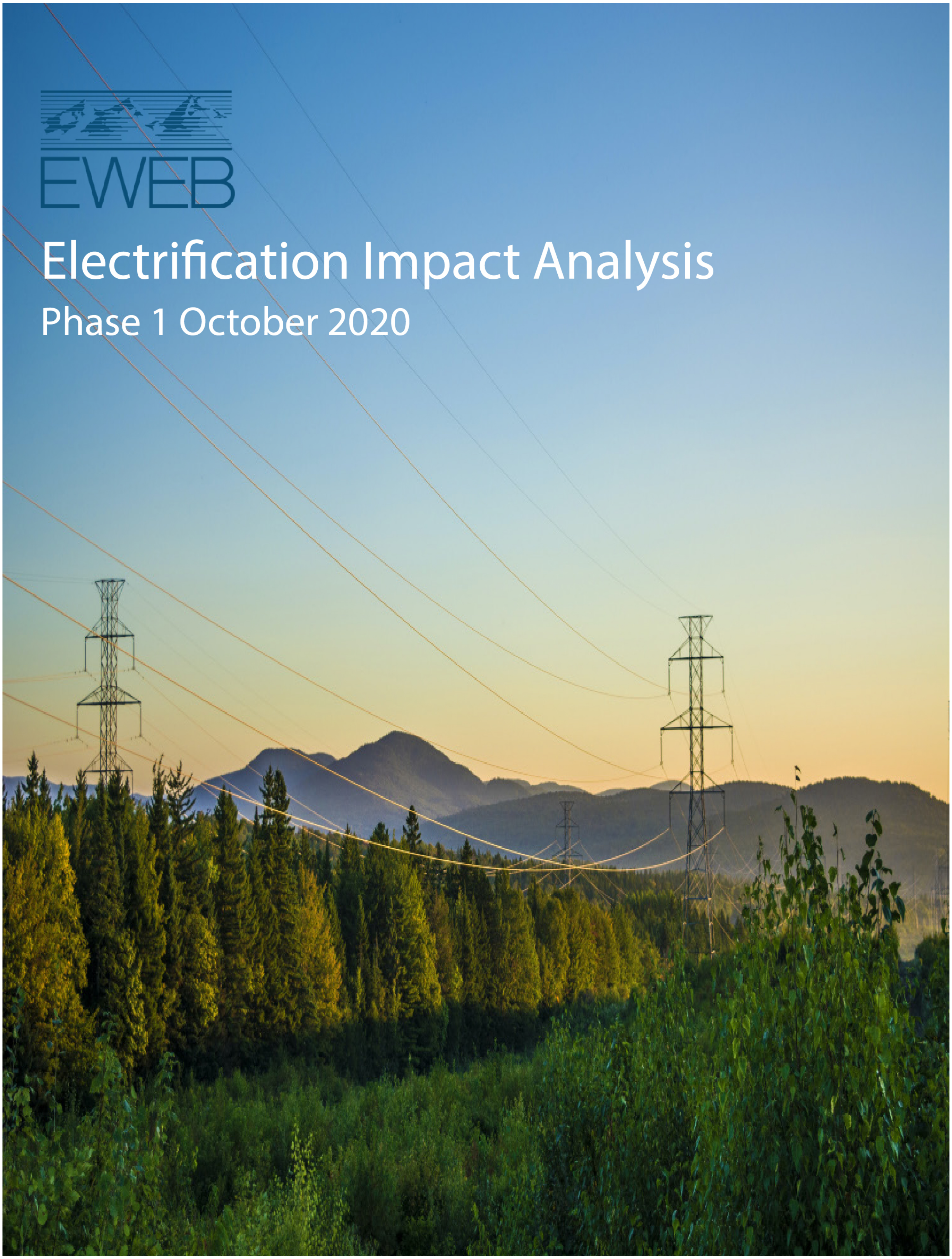
Requested Board Action

No Board Action required or requested

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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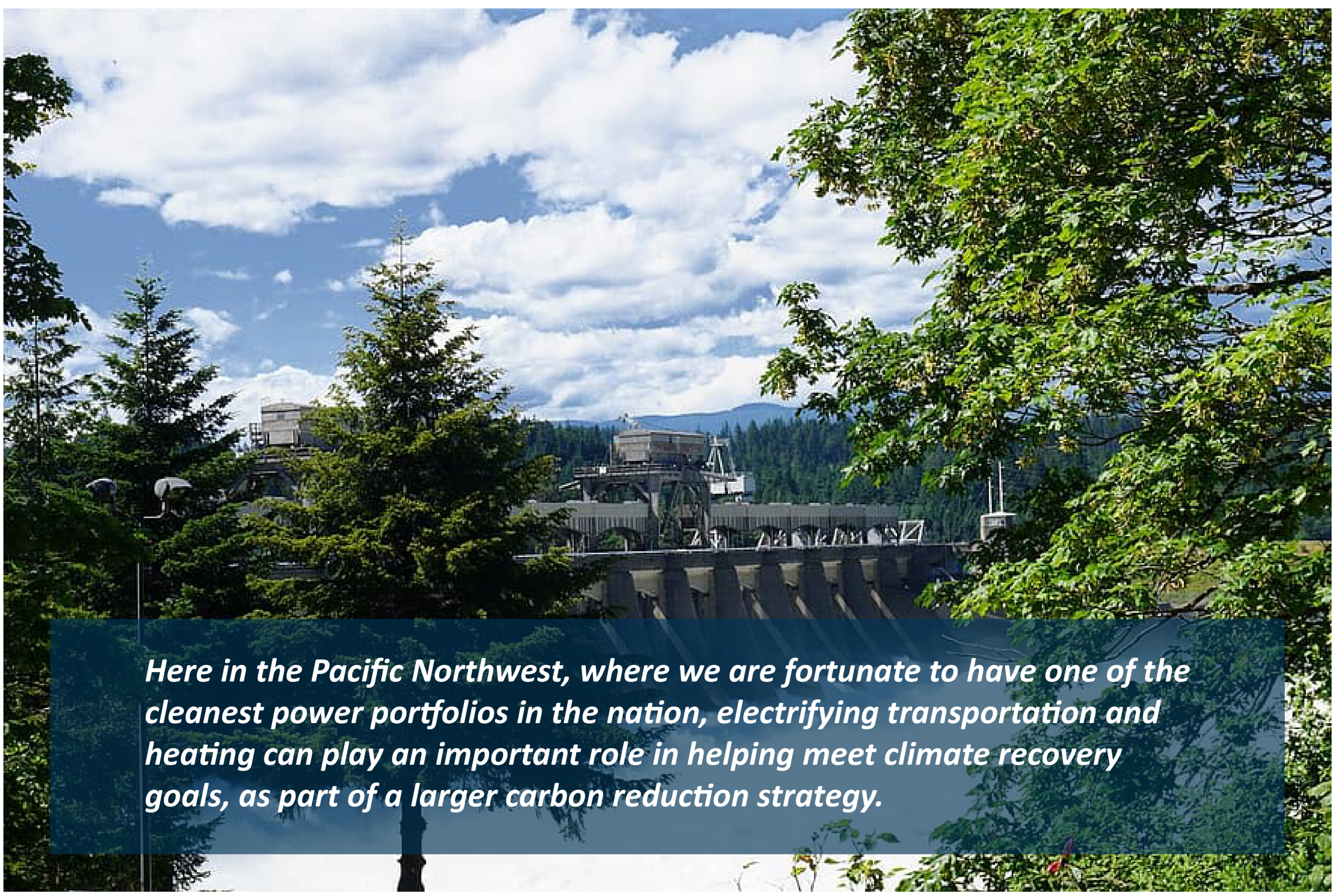
1 ABSTRACT

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.



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%.

[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.

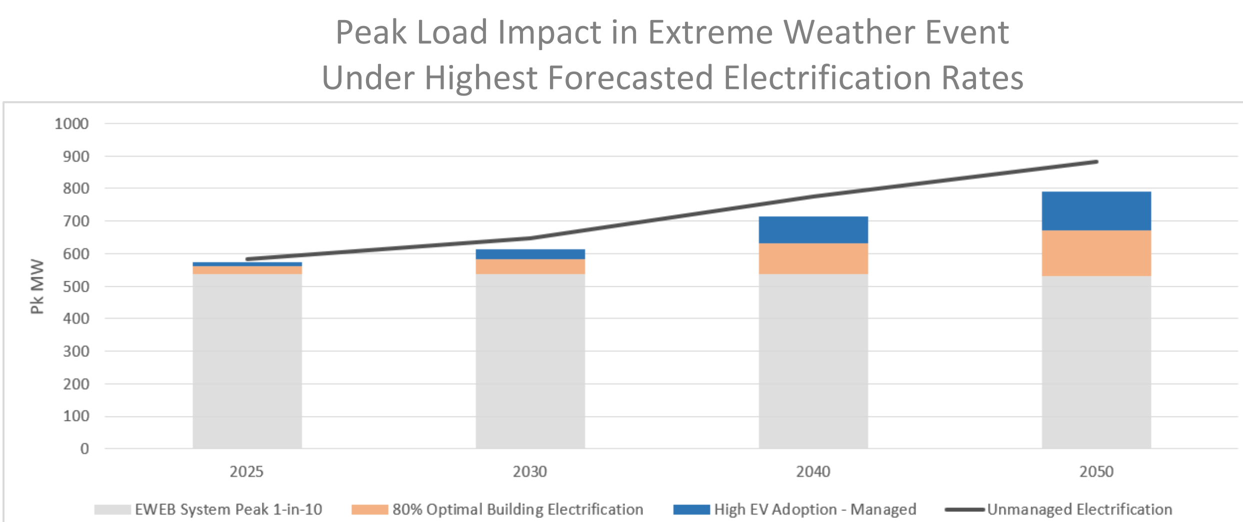
As was done with transportation electrification, EWEB staff used an hourly carbon emissions factor for the Northwest Power Pool (NWPP) to model the potential impact that electrification of space and water heating can have on GHGs. The study finds that conversion of gas space and water heating to electricity 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).



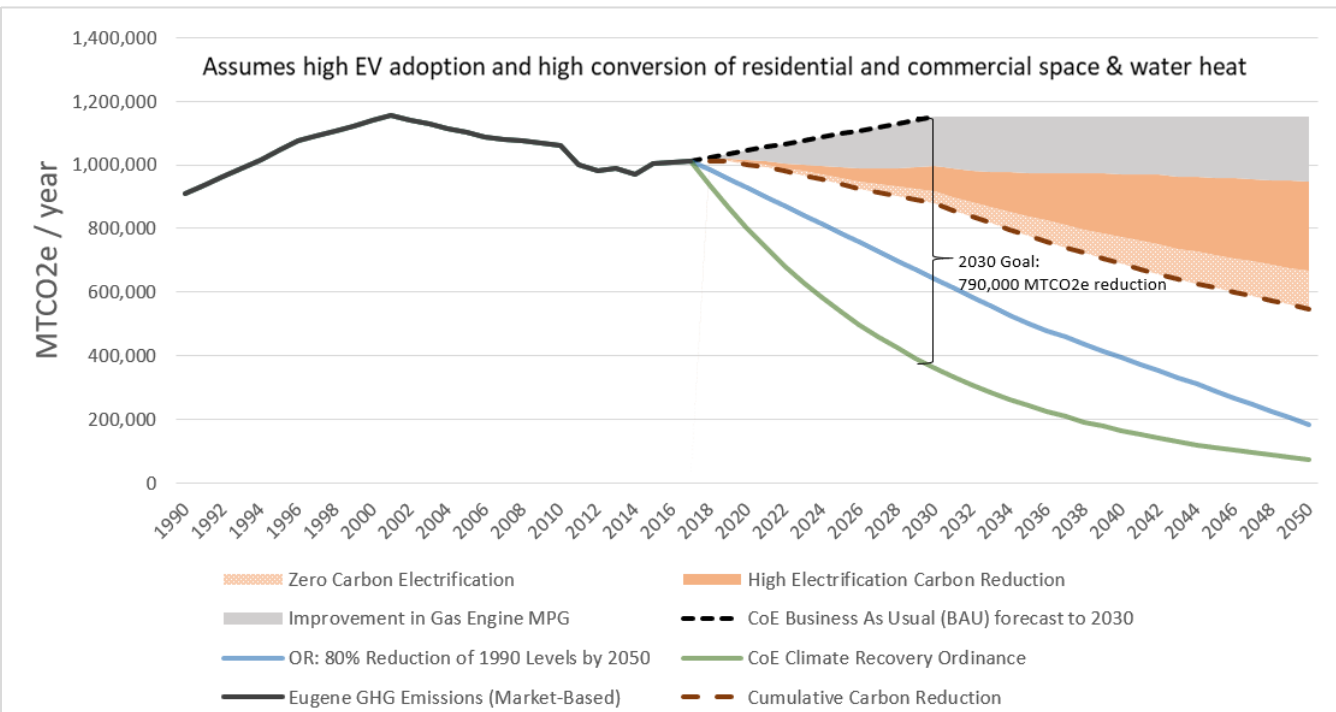
Carbon Reduction Impacts

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.

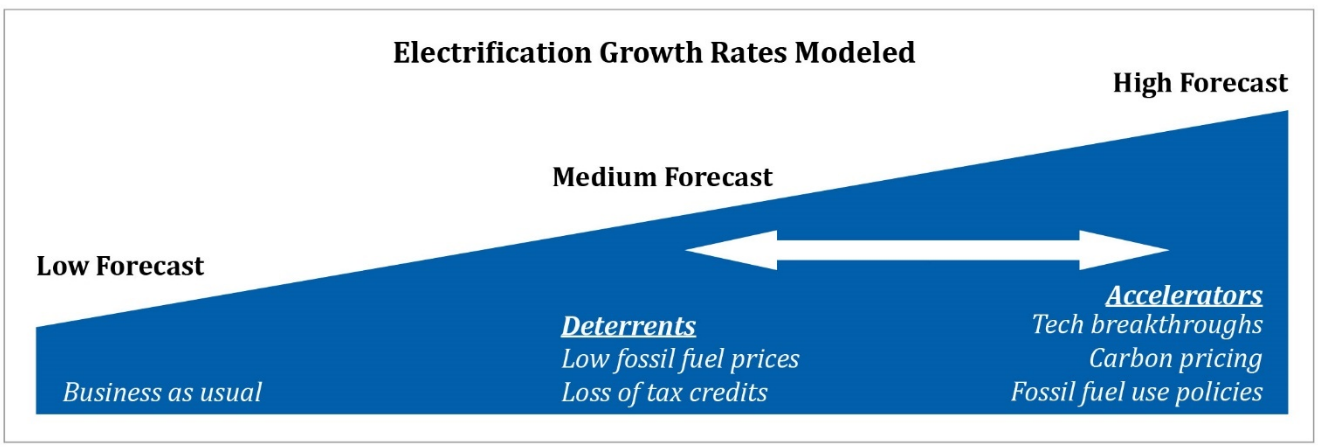
Adoption rates

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.

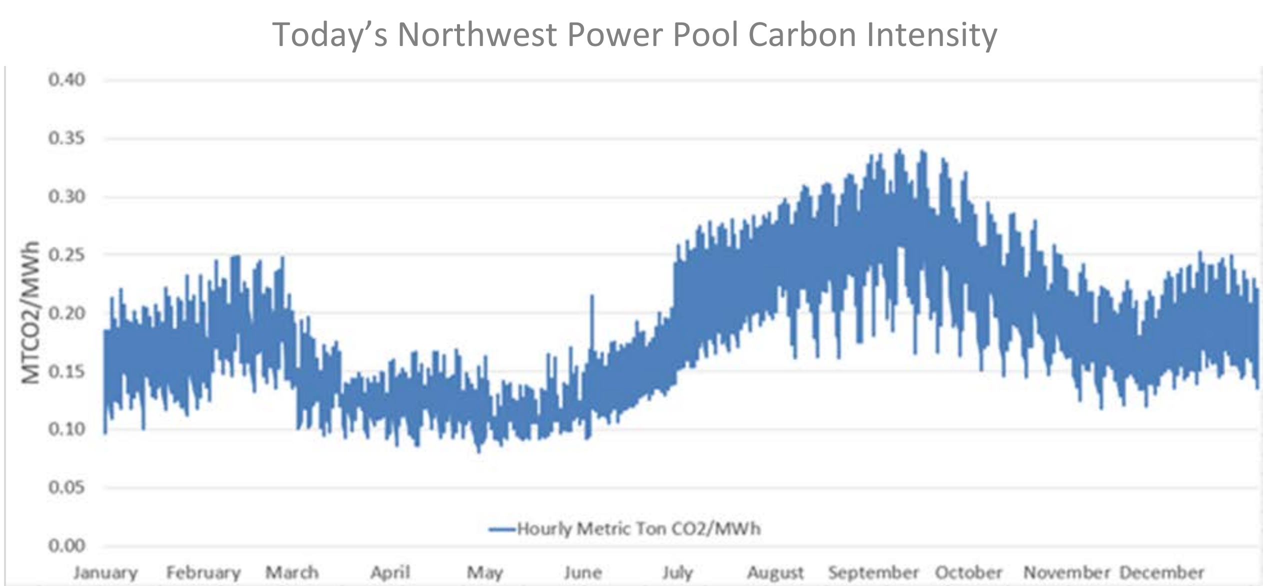


Figure A - The hourly carbon emission for the NWPP region based on Aurora modeling software. The areas used by EWEB for modeling the NWPP region may differ from the actual physical boundaries of the NWPP but is intended to illustrate the region's carbon intensity.

[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.

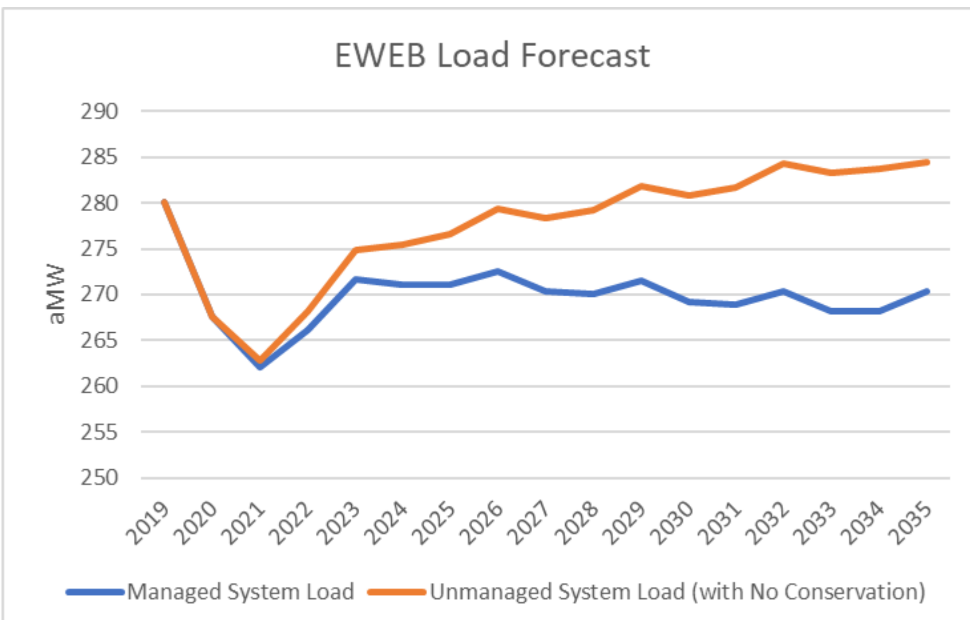


Figure B - Average load forecasts show little to no load growth (Managed System Load is net of conservation)

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.

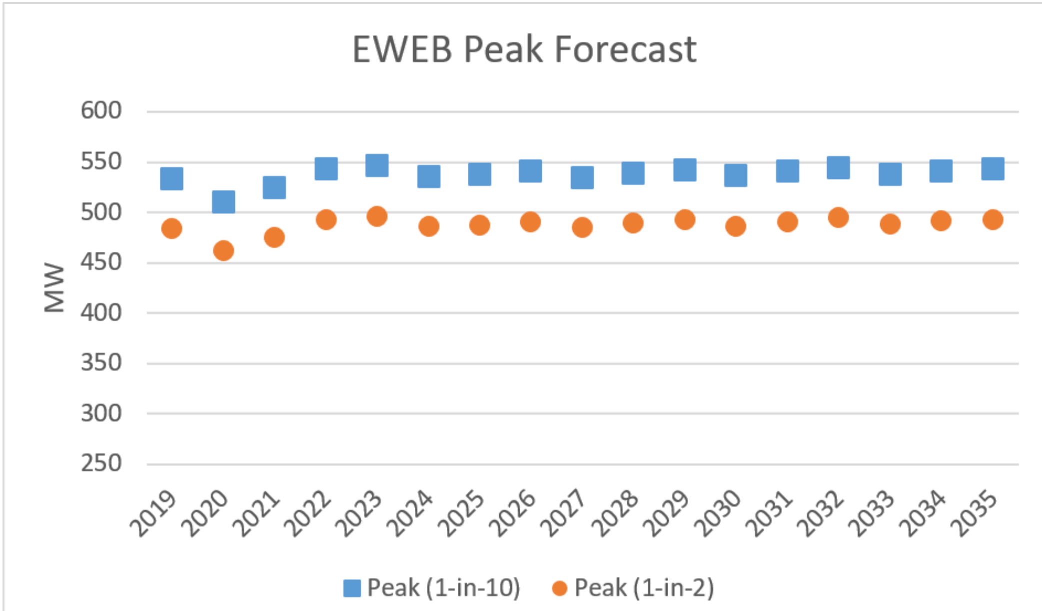


Figure C – EWEB's 1-in-10 peak load is roughly 10% greater than 1-in-2 peak.

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.

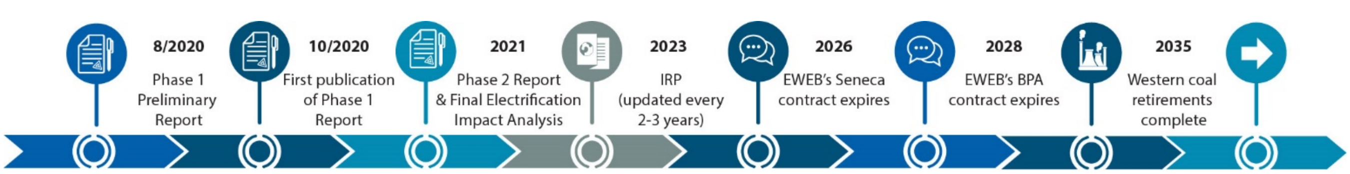
Mitigating peak demand can be a useful strategy to delay infrastructure investments due to capacity constraints, limit the need for new resource acquisitions, and reduce reliance on "peaker plants" which are more carbon-intensive energy resources in the market.

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.

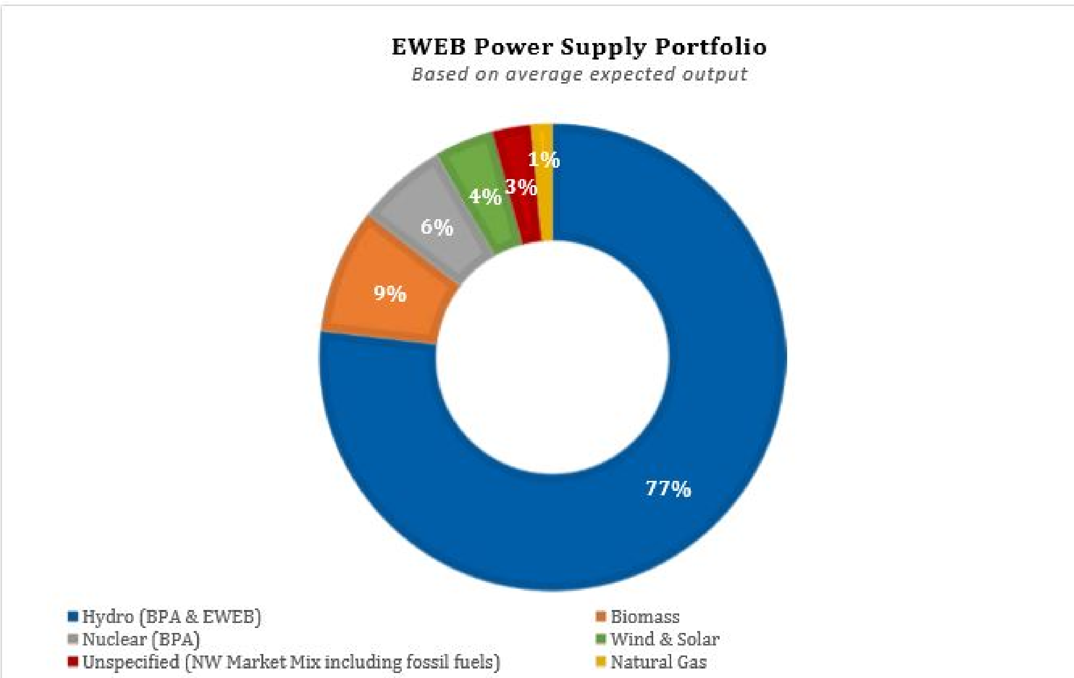


Figure D – Illustrates that only 4% of EWEB resources emit carbon.

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.

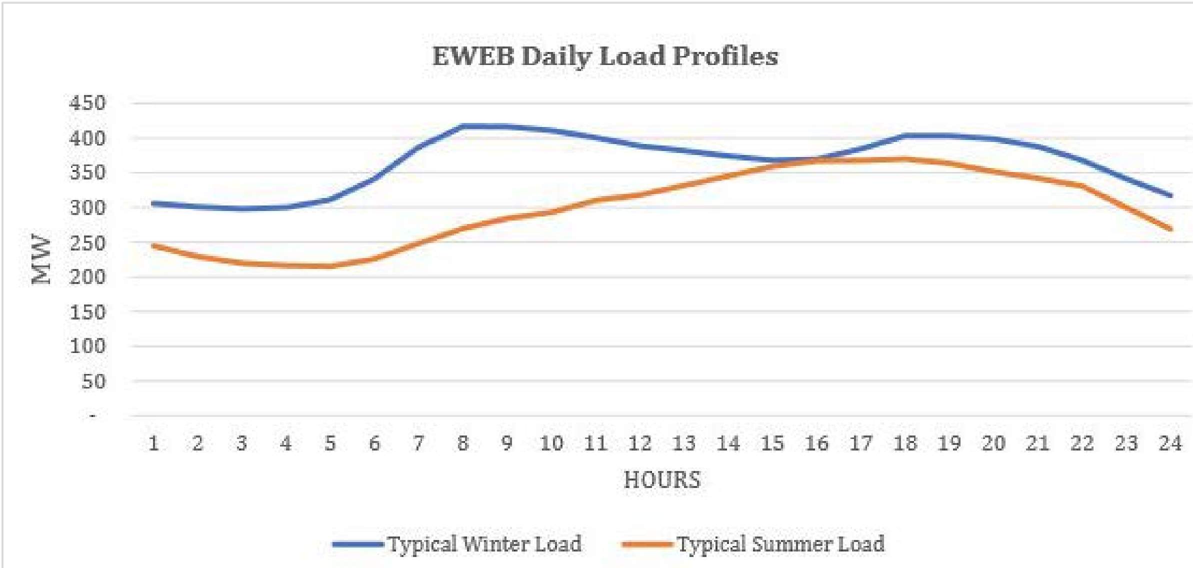


Figure E - Seasonally, Eugene's peak demand occurs in the winter months, when heaters are running continuously. On a daily basis, consumption typically peaks in the evening and winter mornings.

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.

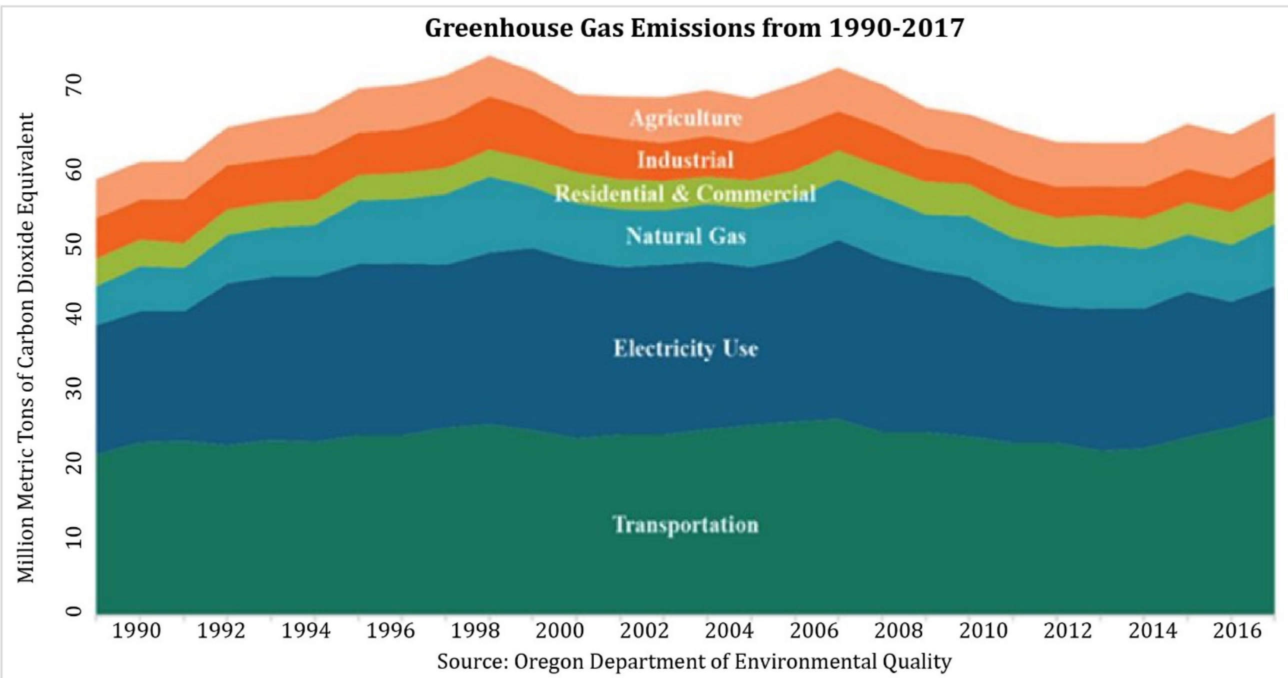


Figure F - State of Oregon's historical GHG emissions by sector

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

[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

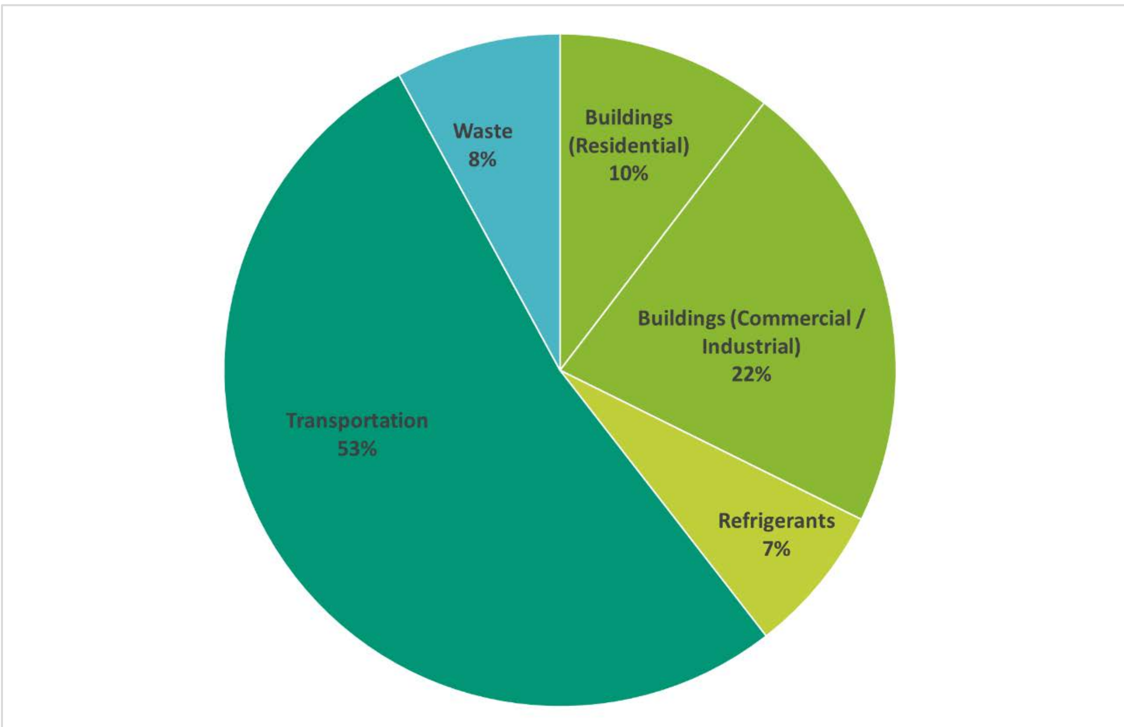


Figure G – Eugene's 2017 GHG emissions by sector

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.

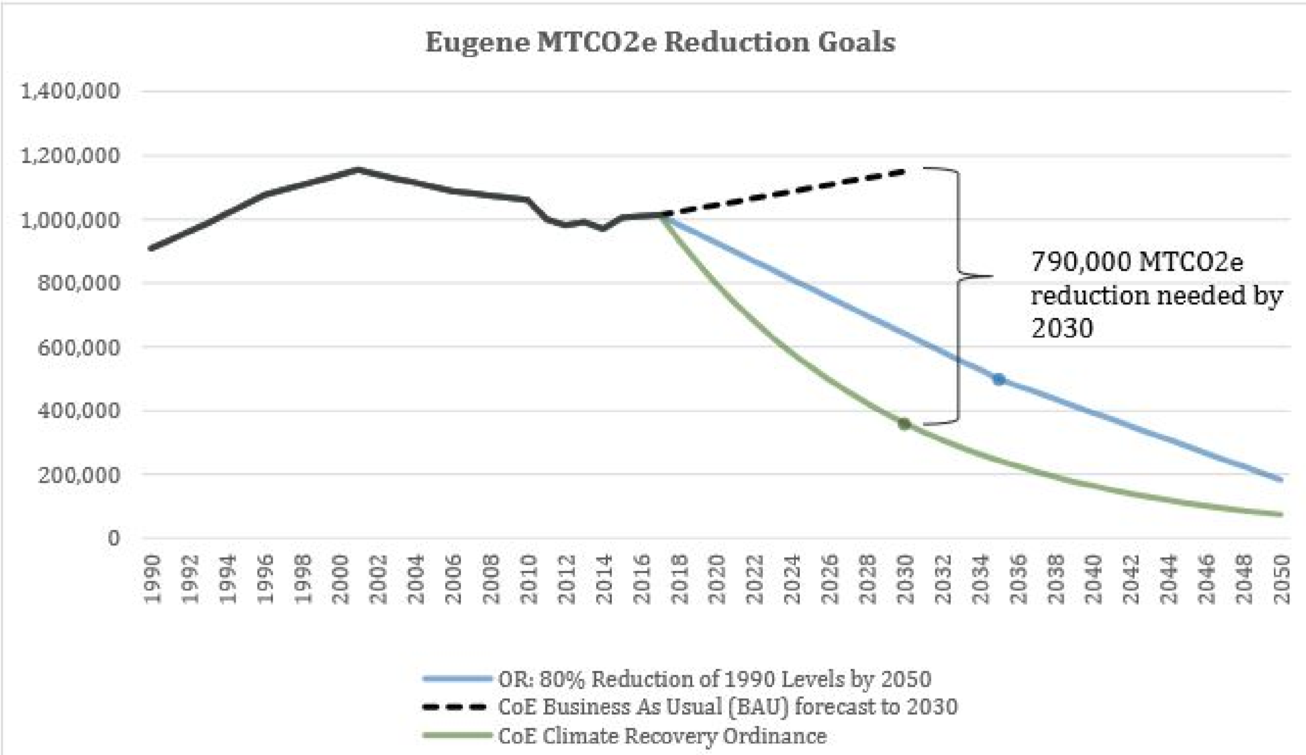


Figure H - City of Eugene CAP 2.0 esitmates that Eugene must reduce GHG emissions by 790,000 MTCO2e by 2030 in order to meet Eugene's Climate Recovery Ordinance. EWEB estimated local GHG emissions back to 1990 based on State of Oregon DEQ reporting.

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

[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

[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.

[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.

[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.

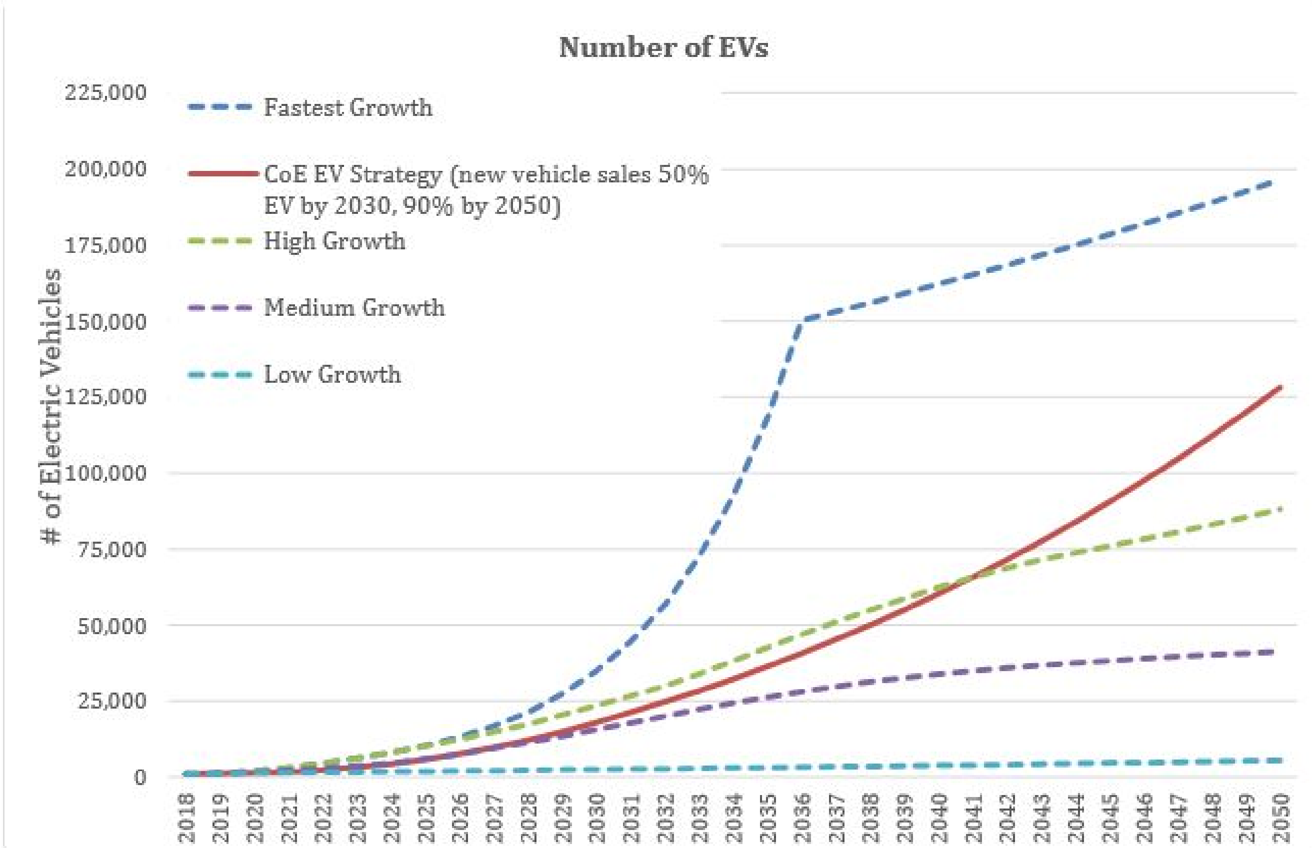
The low projection uses a slightly elevated adoption rate over the historical national trend through 2050. For the medium and high projection rates, we utilized data from E3 which has been acting as a strategic advisor for this study. The fastest projection builds on the high forecast rate and assumes 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.

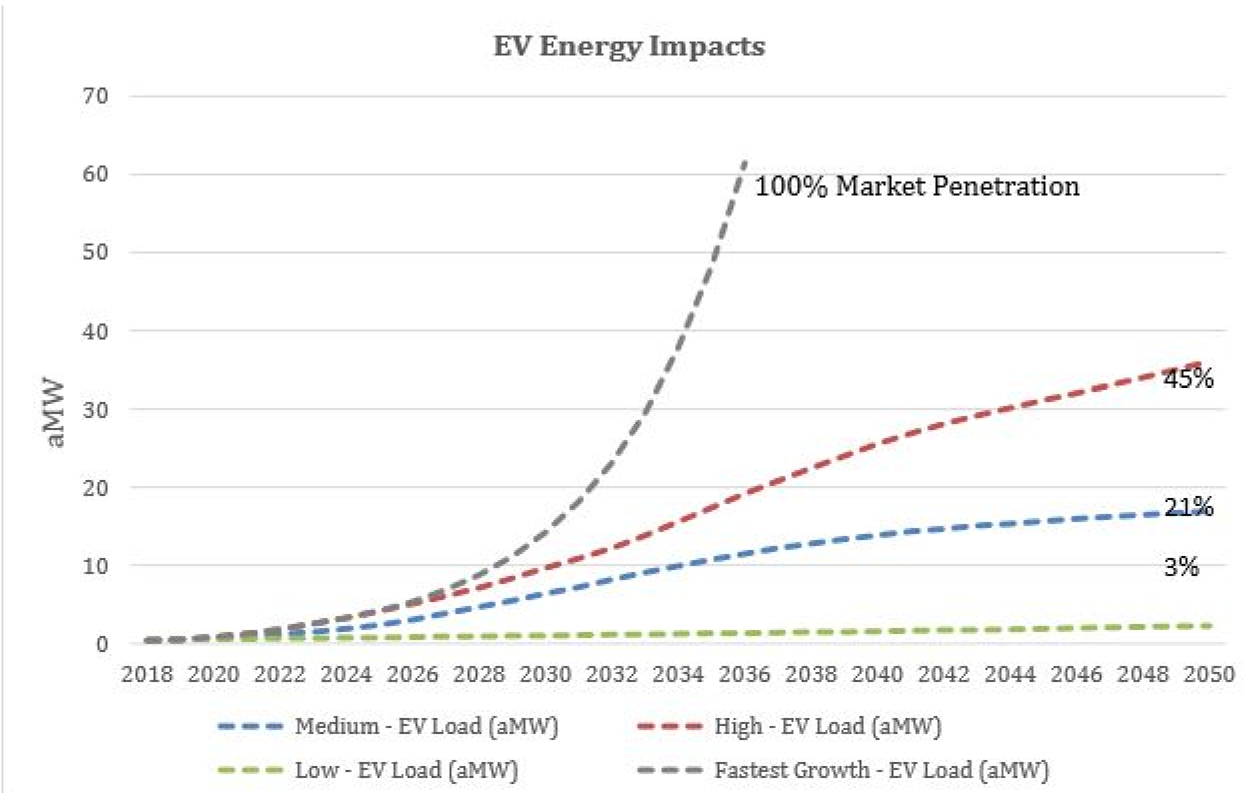

Figure J – A High EV adoption rate is estimated to represent 45% market penetration and approx. 36 aMW of load by 2050.

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).

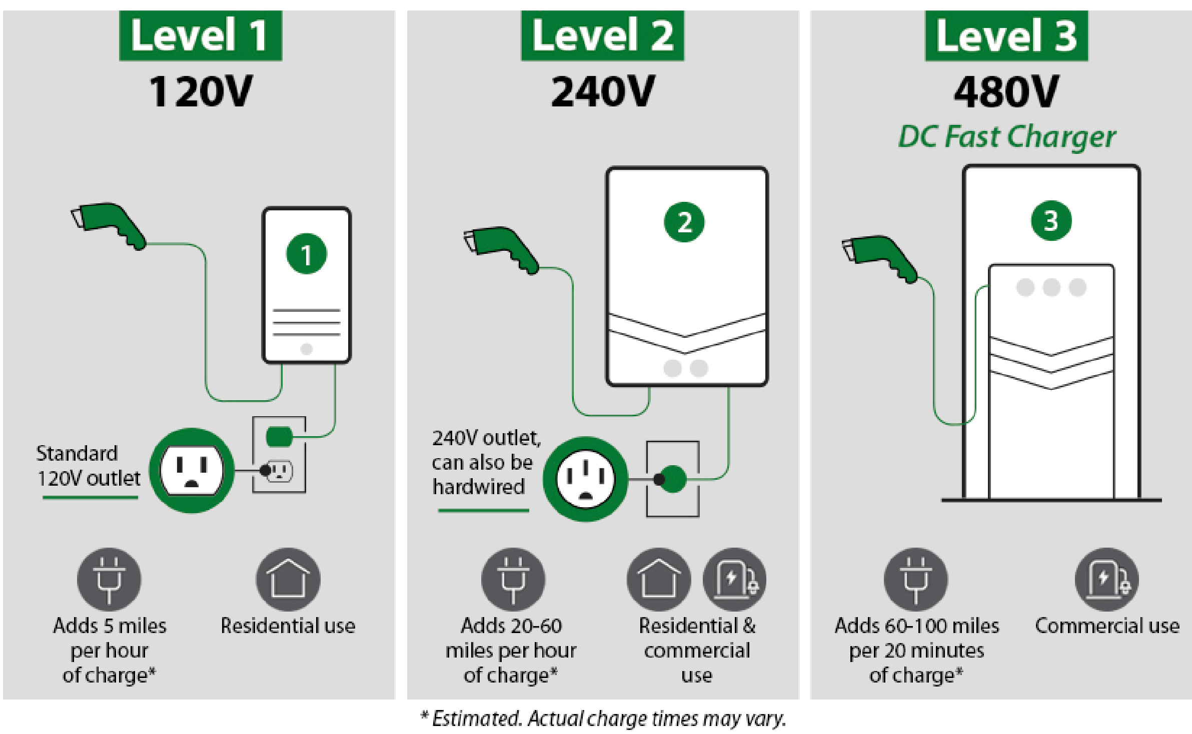

Figure K - Source: https://www.cenhud.com/my-energy/electric-vehicles/how-to-charge/

[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.

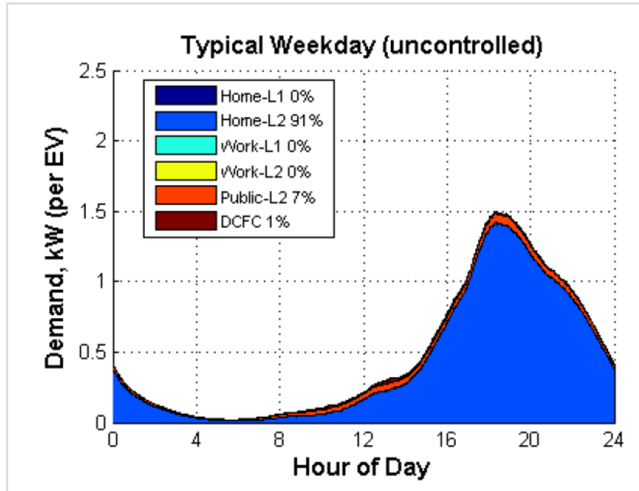

Figure L – NREL study shows energy impacts of uncontrolled EV charging behavior.

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 rates projections based on unmanaged/uncontrolled charging behavior.

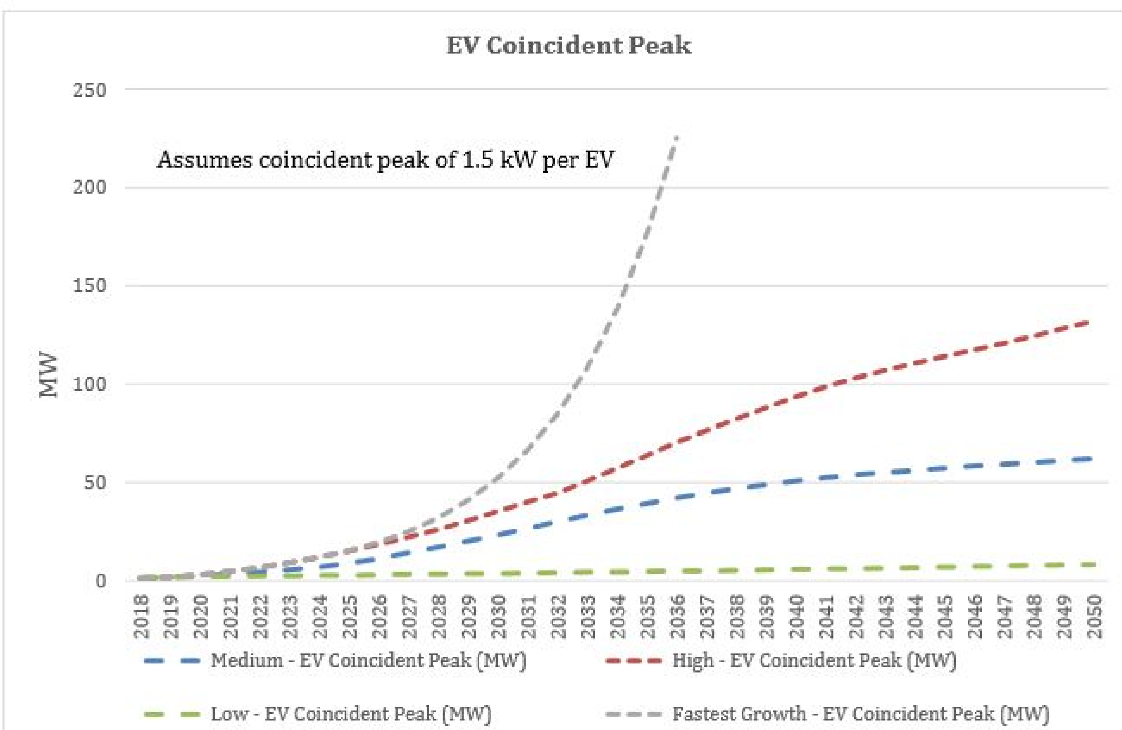

Figure M – Coincident peak load impacts based on various adoption rates of EV's over time.

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.

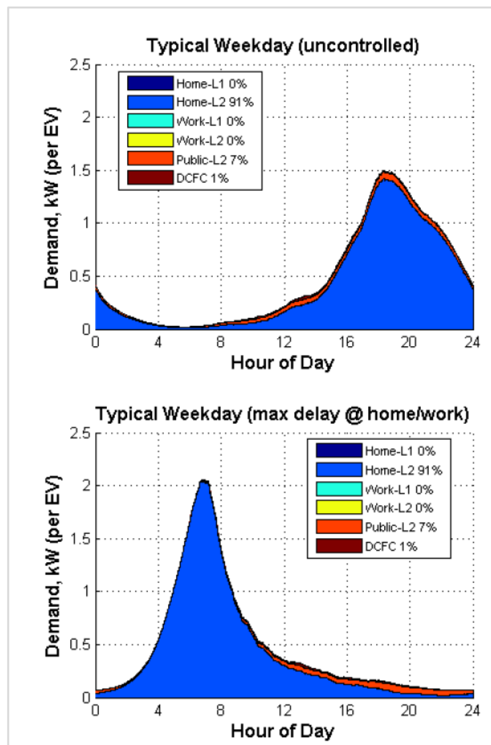

Figure N – Comparison of uncontrolled and controlled EV charging behavior shows that the timing and load shape of energy consumption can be changed.

[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 CO_2e 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 CO_2e 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.

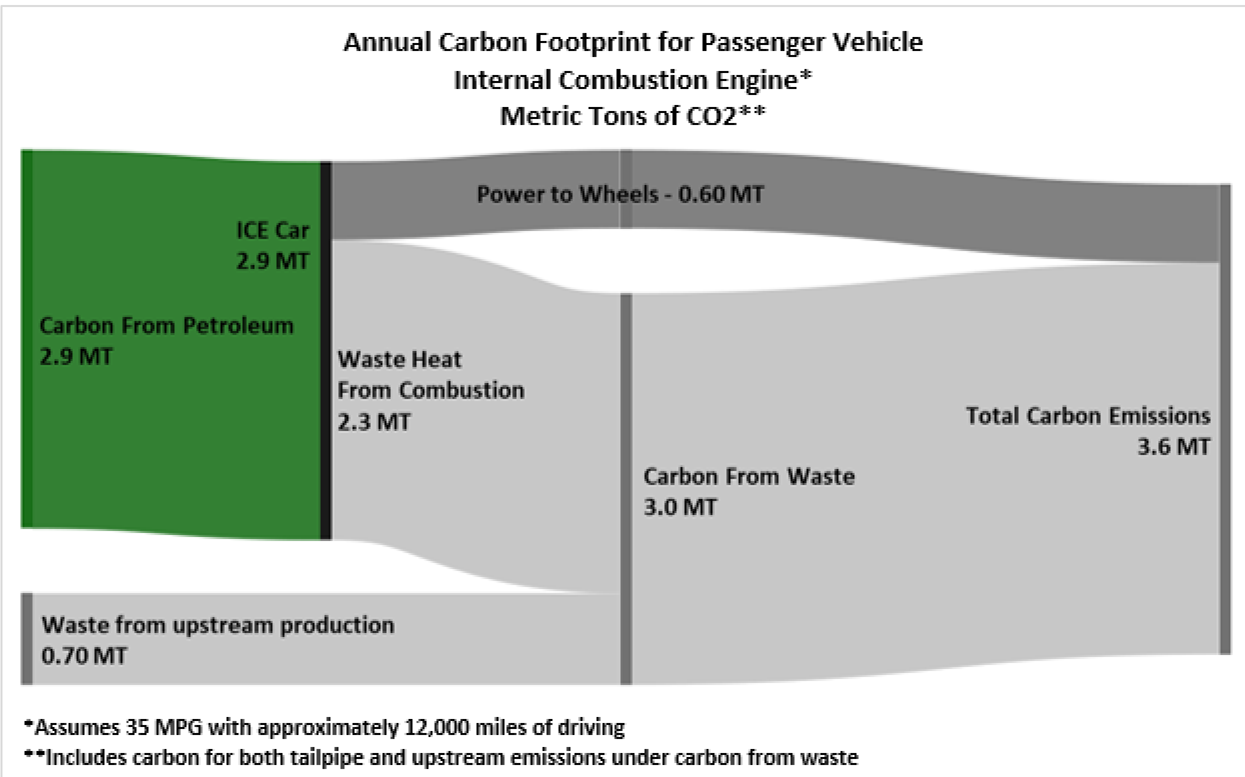

Figure O – Sankey chart illustrates the source of carbon emissions associated with an internal combustion engine.

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).

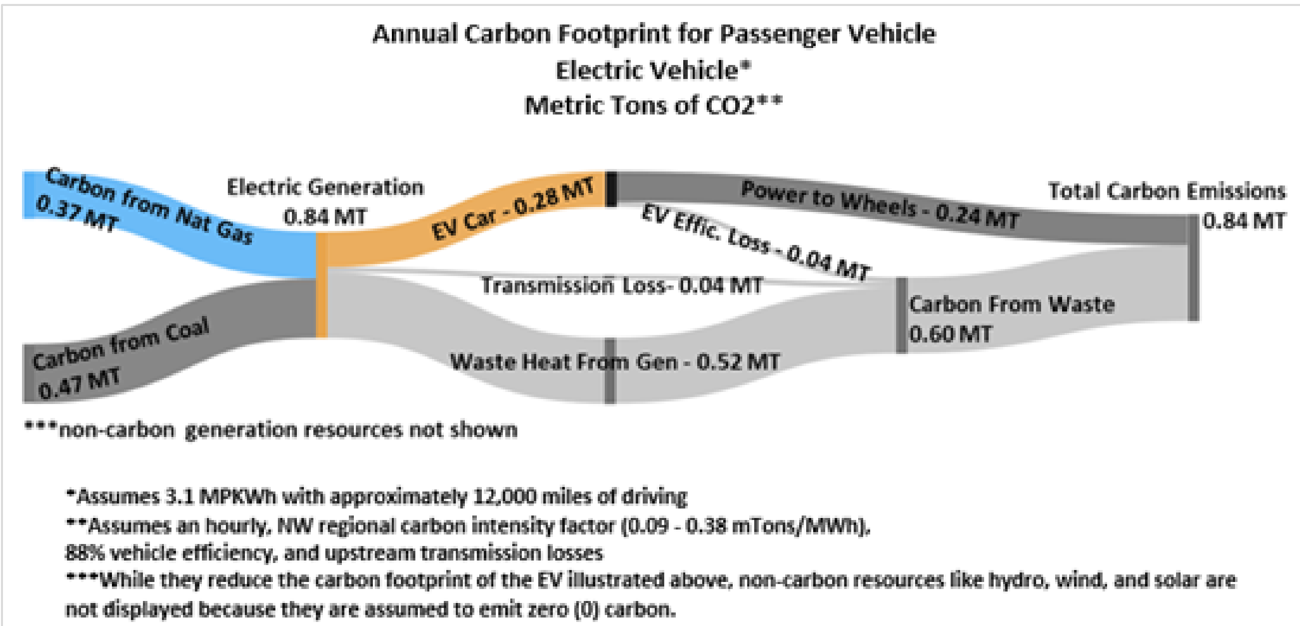


Figure P – Sankey chart illustrates the source of carbon emissions associated with EV charged with electricity.

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.

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

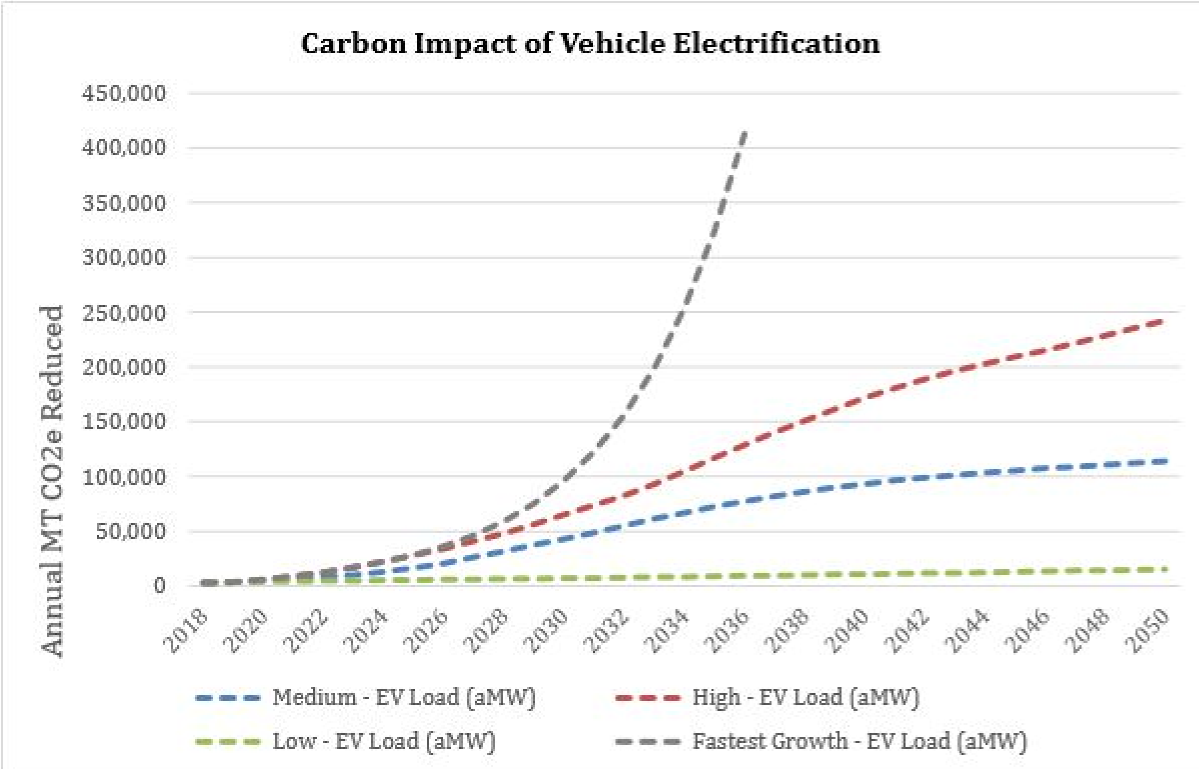


Figure Q – Annual Carbon savings as a result of EV adoption are quite meaningful over time.

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.

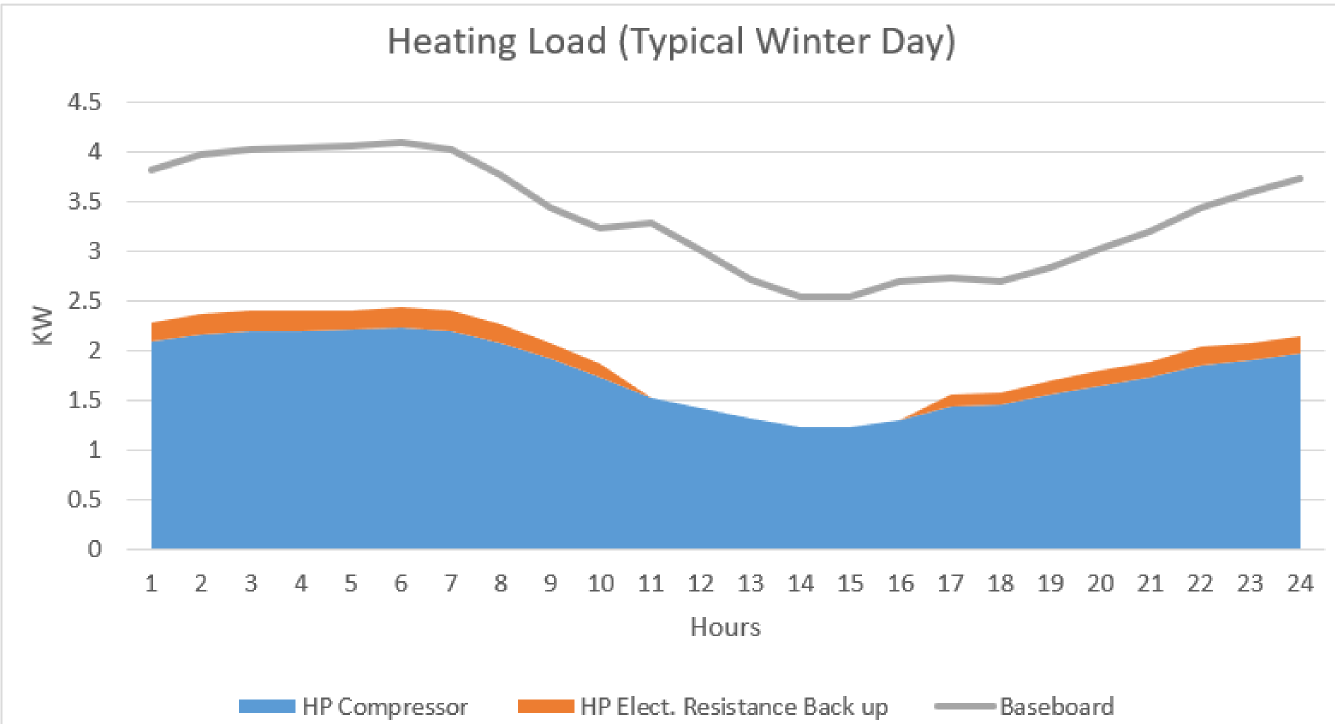


Figure R – Modeled energy use of a heat pump (HP) system compared to baseboard heating.

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.

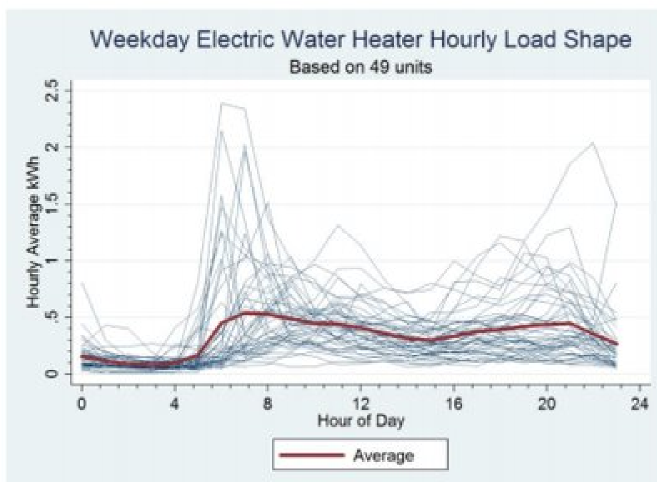


Figure S – Source: NEEA RSBA metered data study

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.

[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).

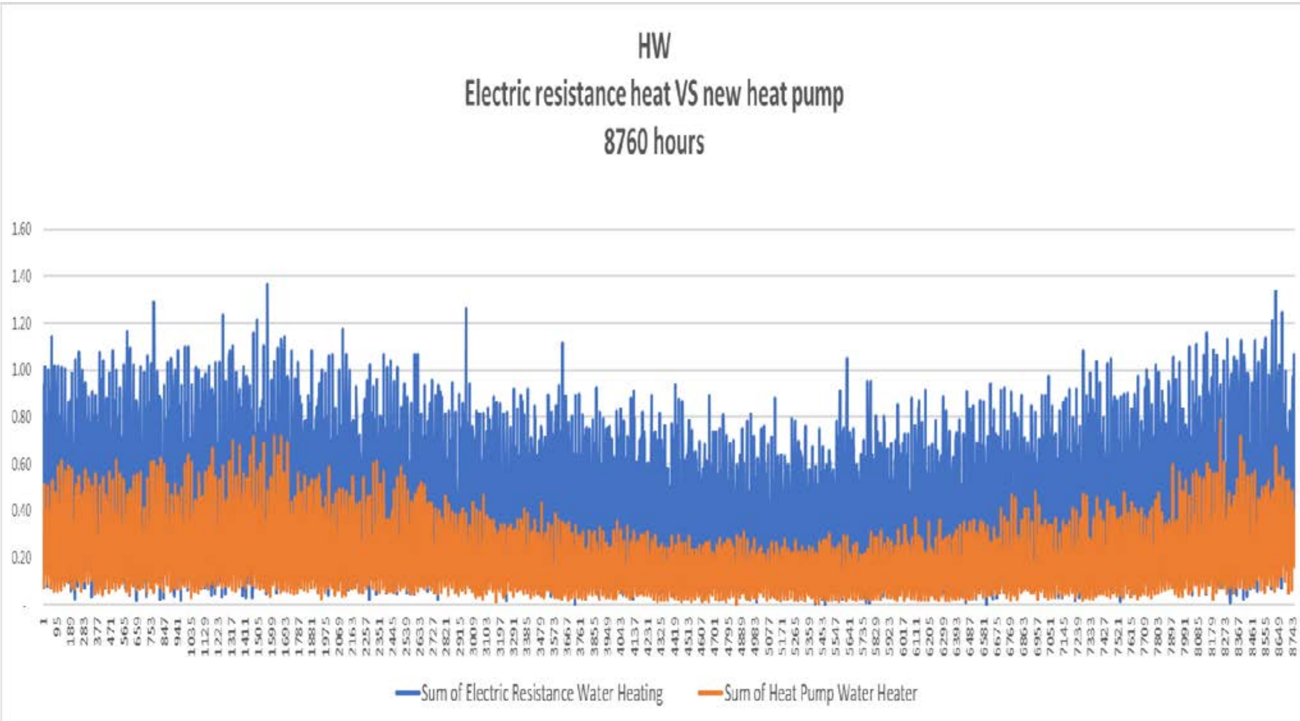


Figure T - Source: Cadmus consulting (RSBA derived)

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.)

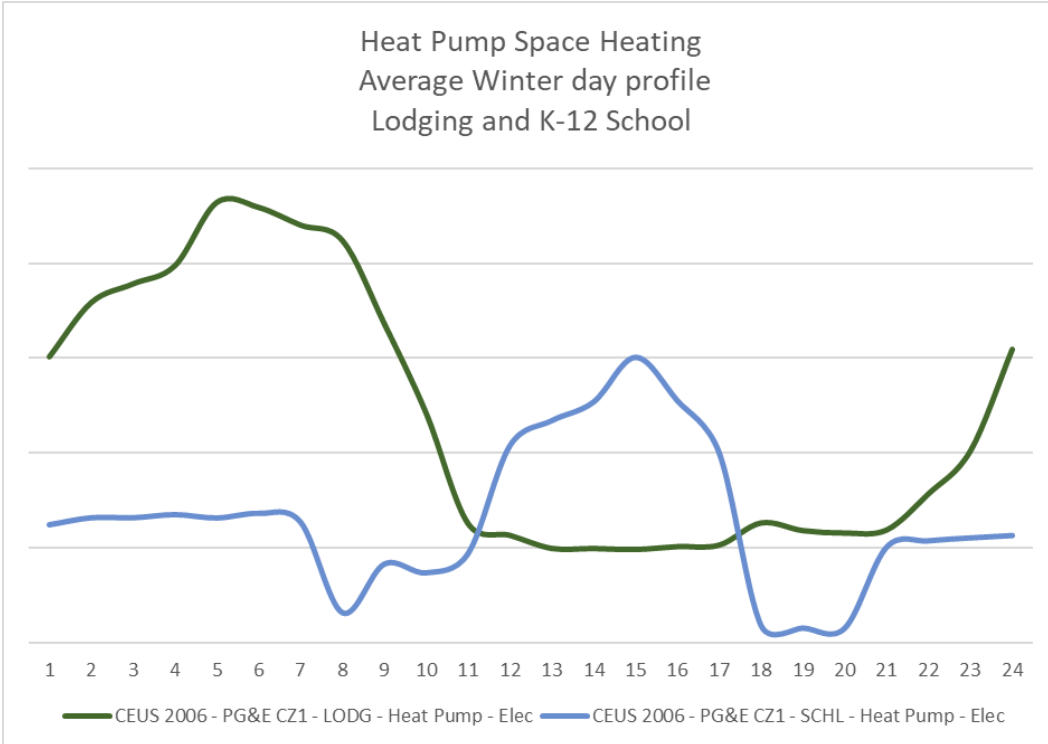


Figure U - Average winter day space heating load shape difference for lodging and K-12 school (heat pump technology)

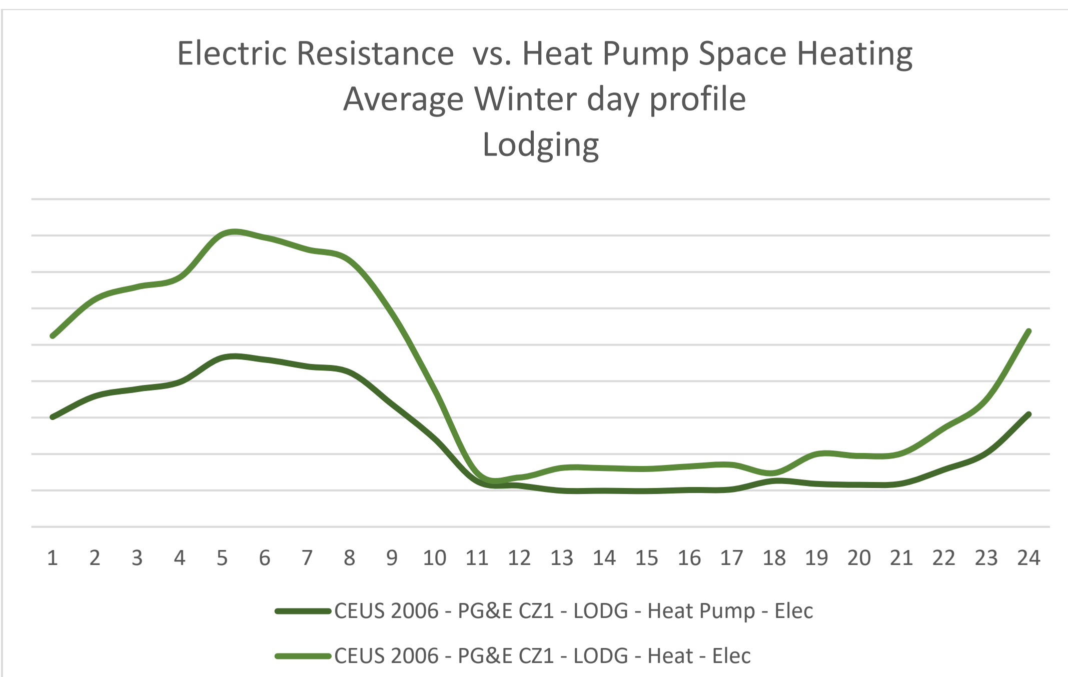


Figure V - Within the same industry, the space heating load shape varies by technology.

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.

[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%

[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.

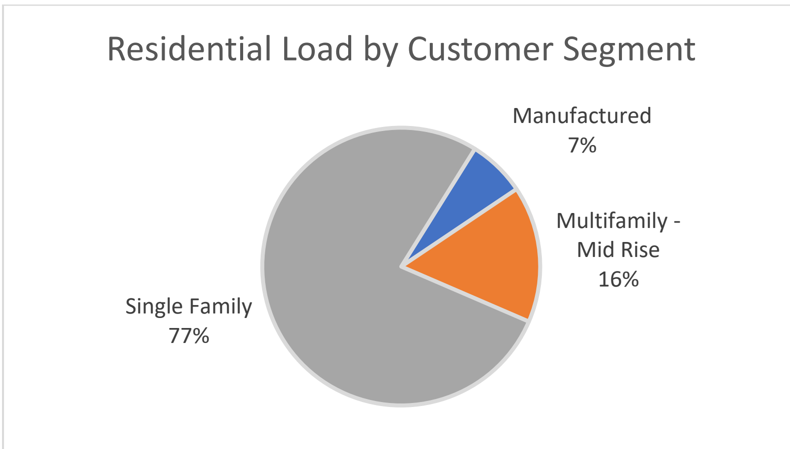


Figure X – Single family homes represent the vast majority of residential building stock at 77%.

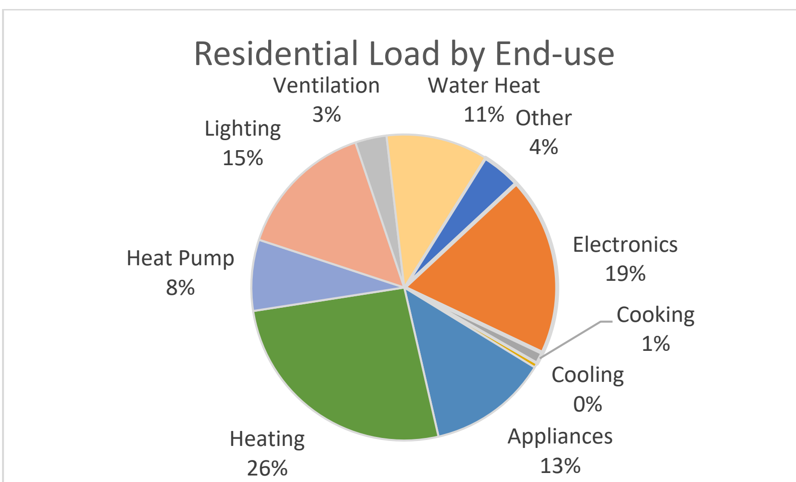


Figure Y– Space heating accounts for about 34% of EWEB's total residential load, while water heating adds another 11%[28].

[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.

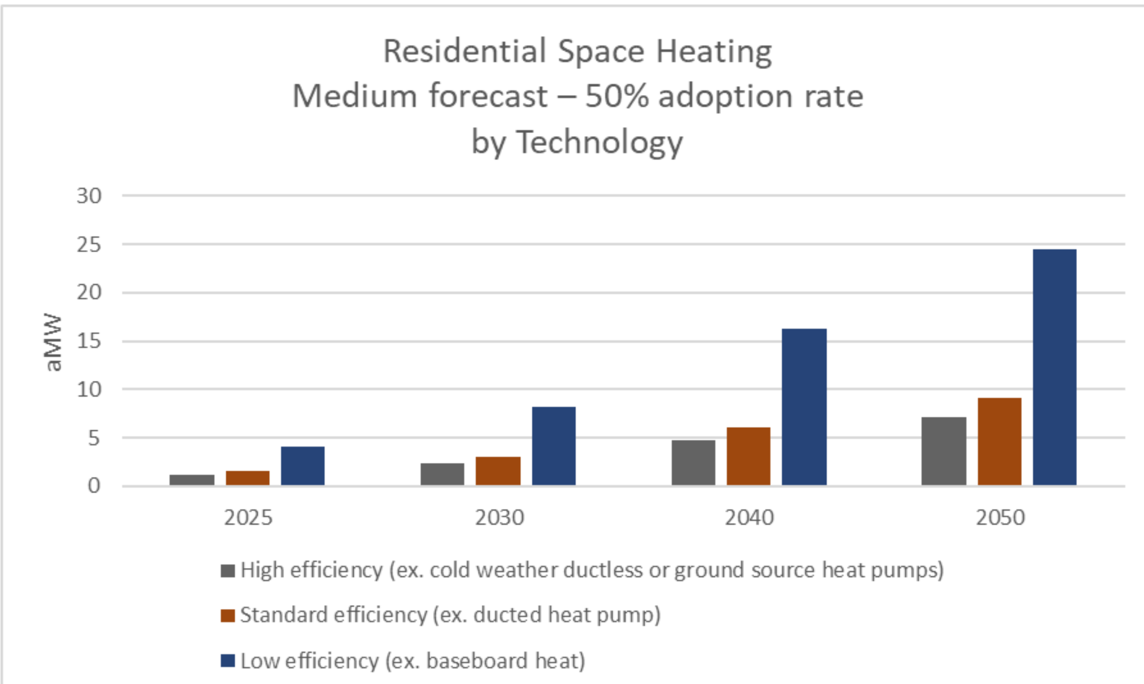


Figure Z – Space heating load is higher compared to water heating,
and the efficiency of electrified heating equipment is important.

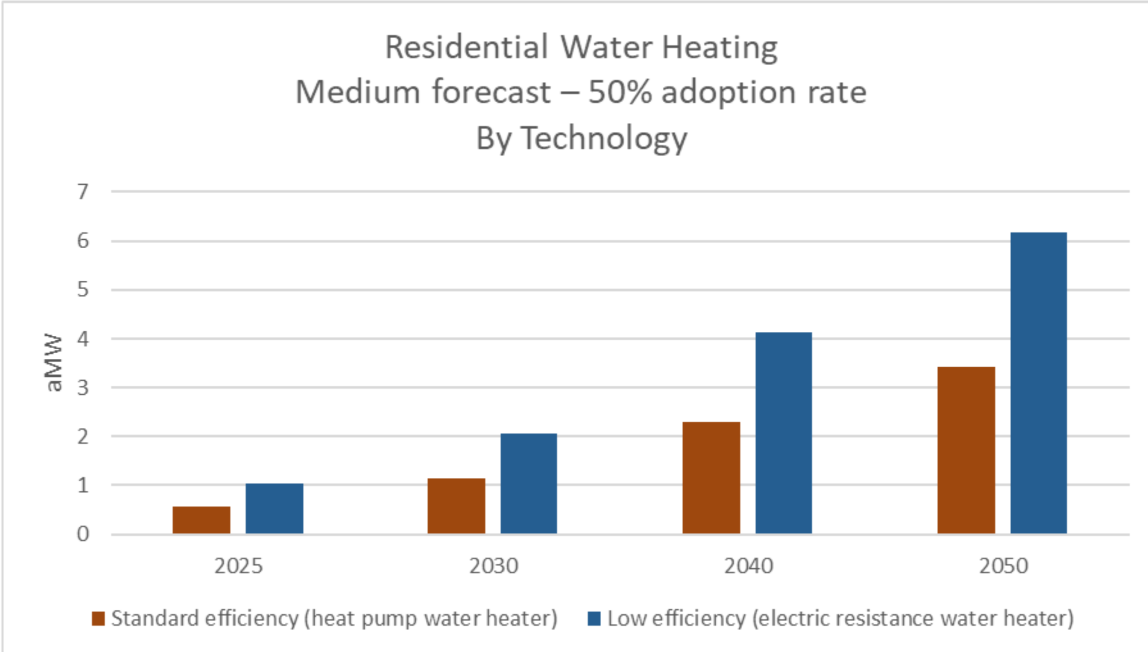


Figure AA – Water heating load as a result of electrification is less impactful to EWEB.

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.

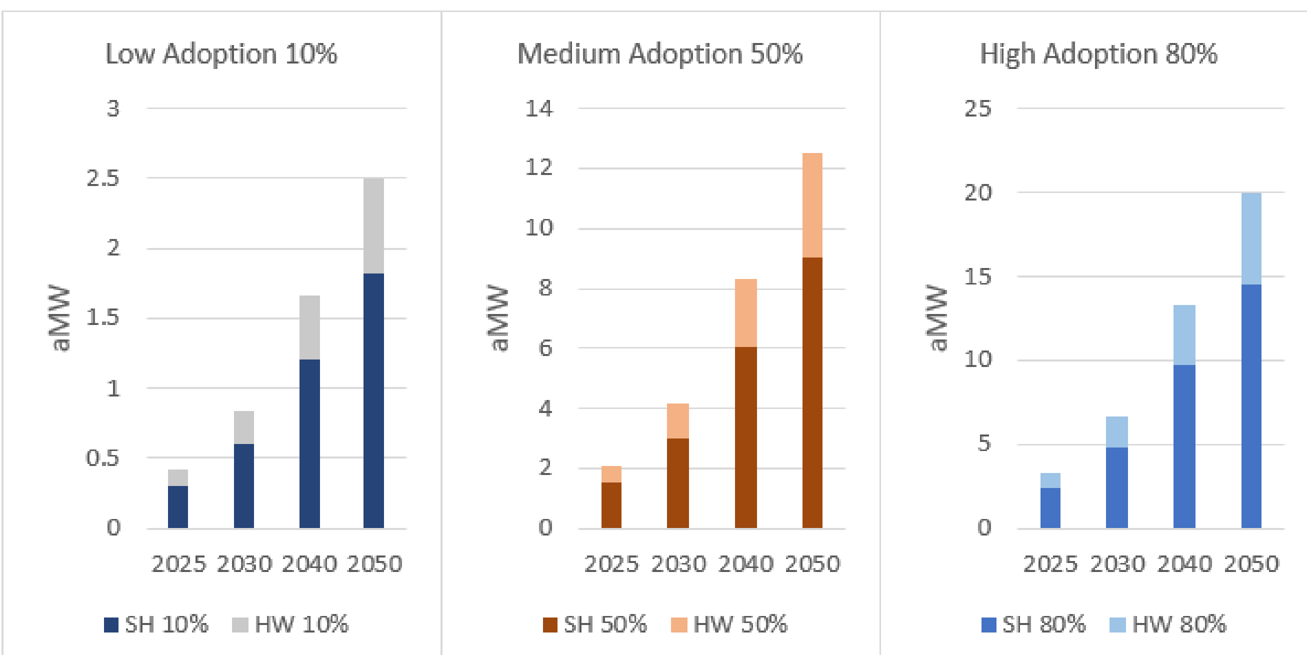


Figure BB – The energy impacts of space and water heating increase proportionally as conversion rates increase.

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).

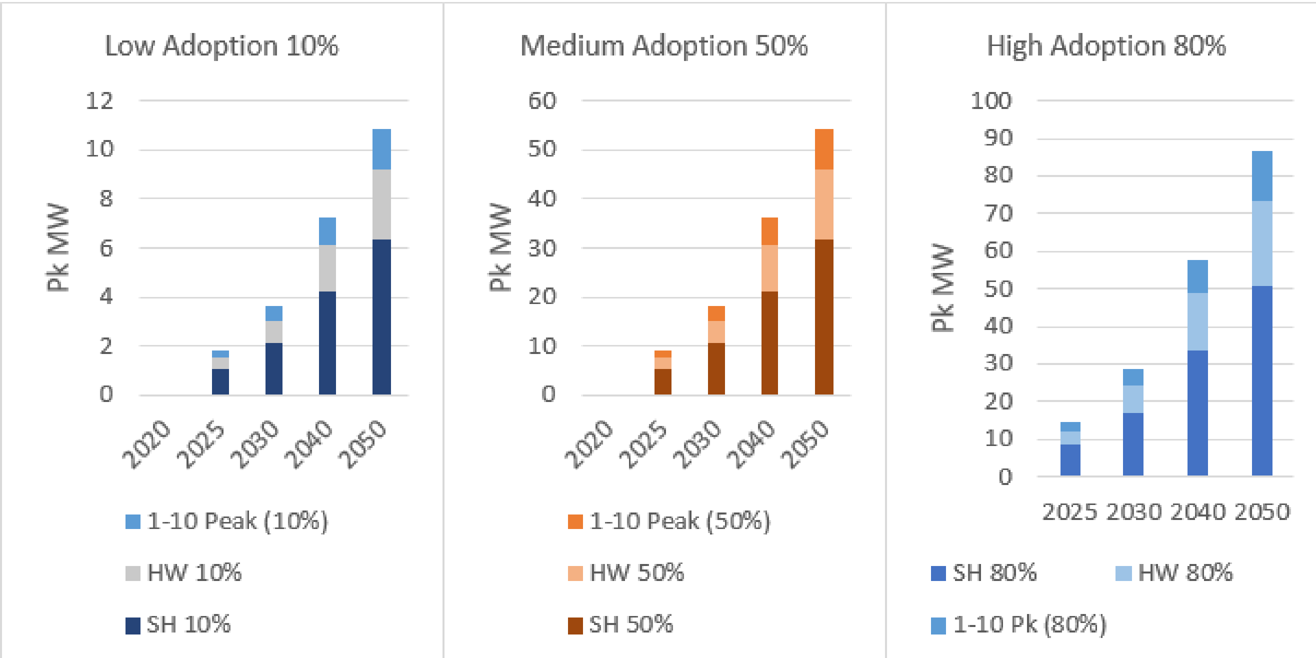


Figure CC– Peak impacts to the utility are dependent on the amount of space and water heating electrification which occurs over time but are also increased by colder than average weather (1-in-10).

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.

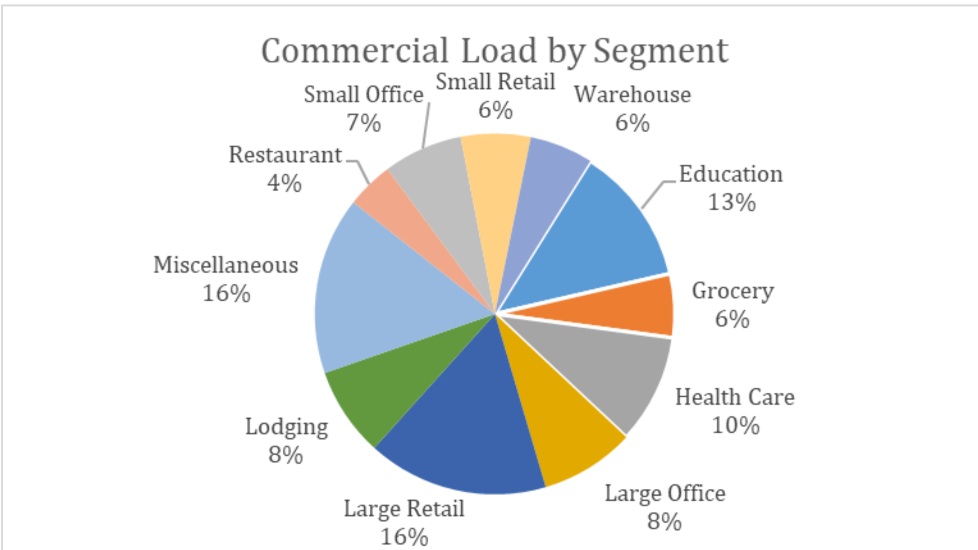


Figure DD– The commercial sector is much more diverse than the residential sector in terms of building stock and the activity that takes place within the building.

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%.

[29] Chart represents electric load only.

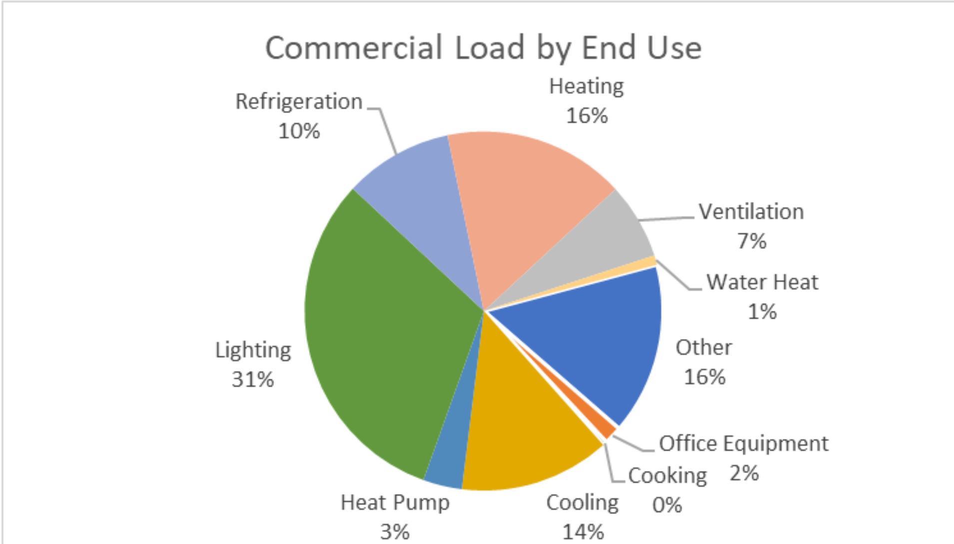


Figure EE– Lighting is a much higher electricity use the commercial sector compared to residential, and thus the proportion of space and water heating electricity use is smaller by comparison.

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.

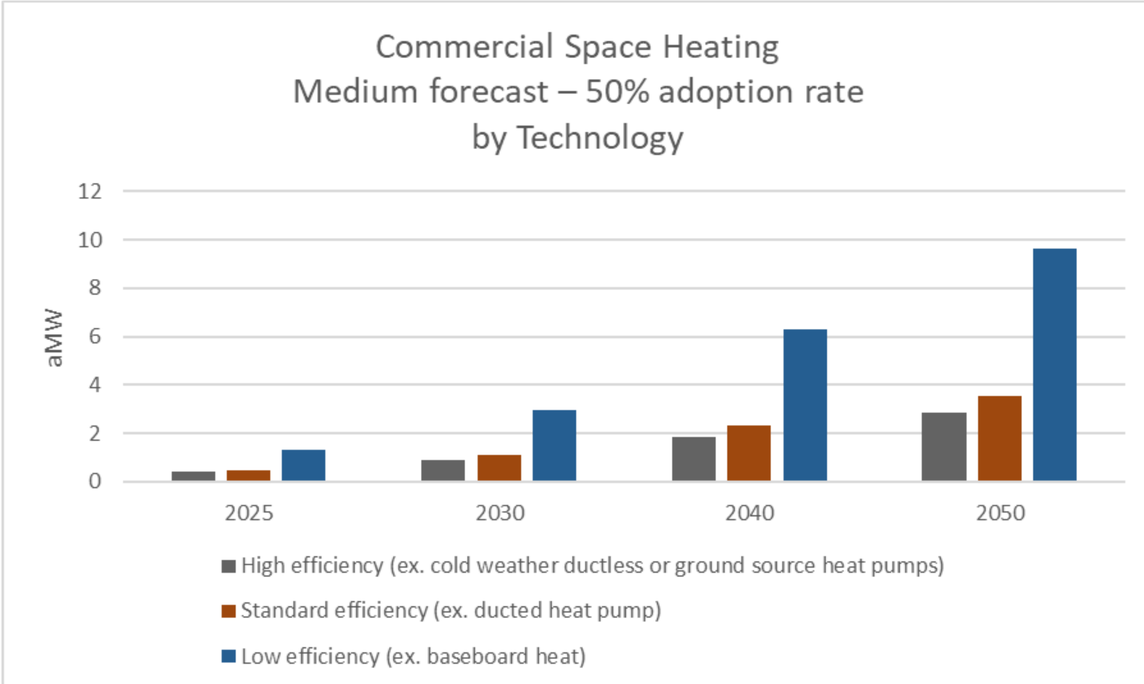


Figure FF – Commercial space heating load is higher compared to water heating, and the efficiency of electrified heating equipment is important.

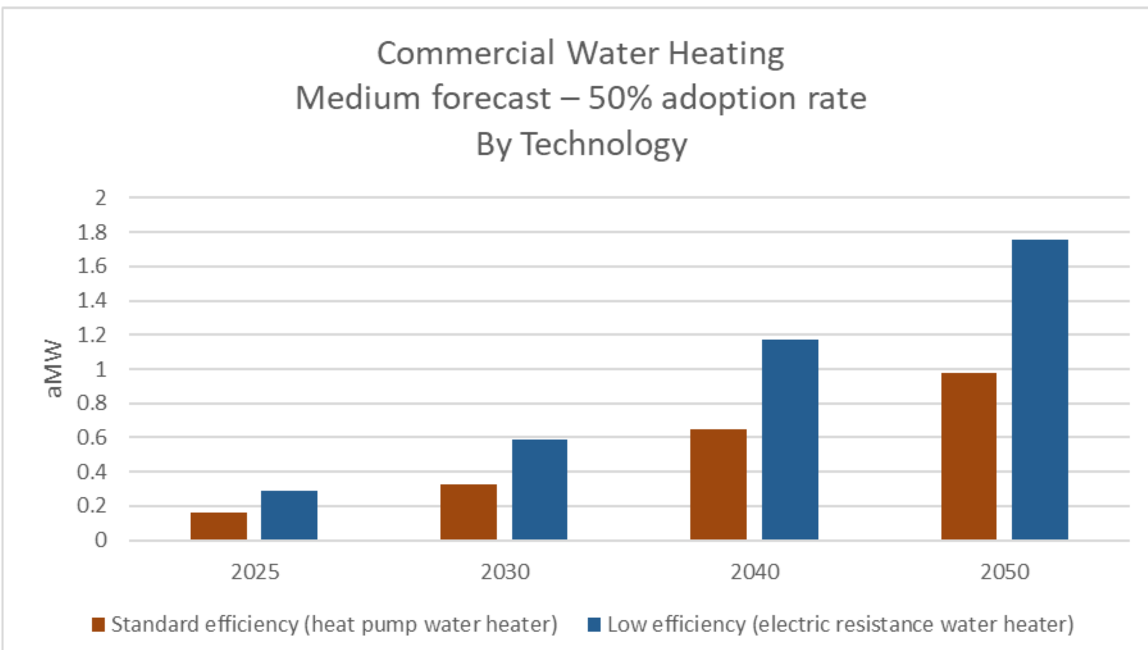


Figure GG – Commercial water heating load as a result of electrification is less impactful to EWEB.

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.

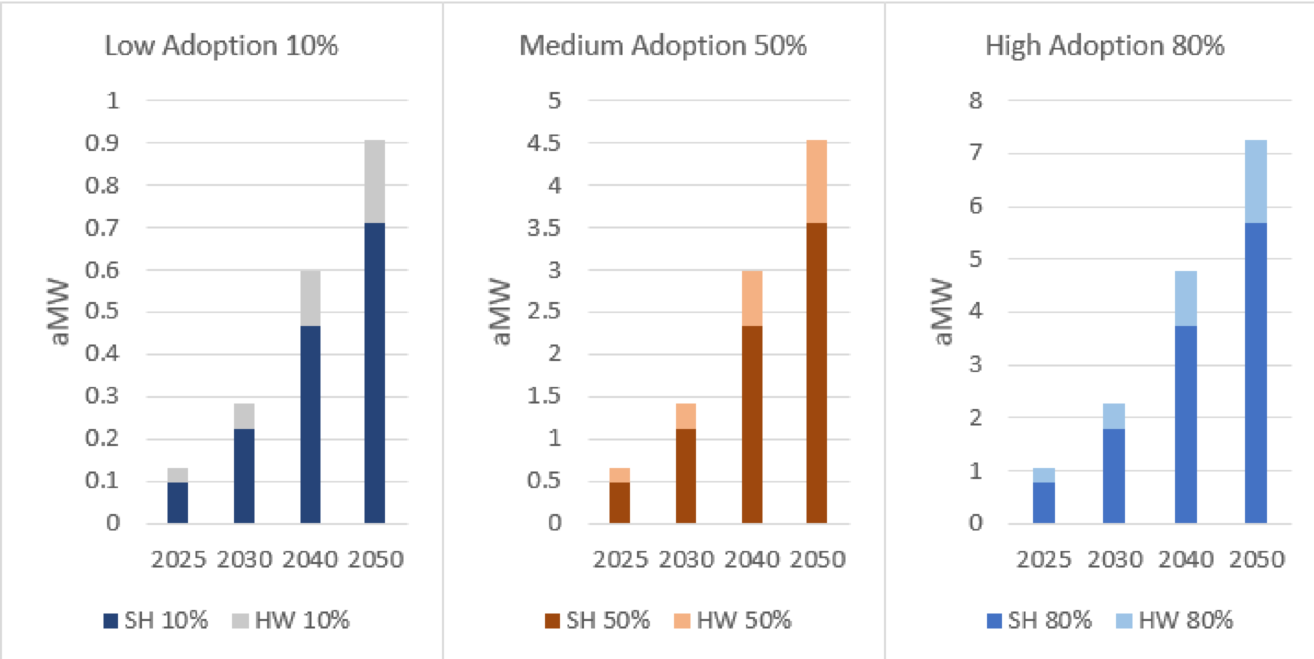


Figure HH– The energy impacts of commercial space and water heating increase proportionally as conversion rates increase.

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).

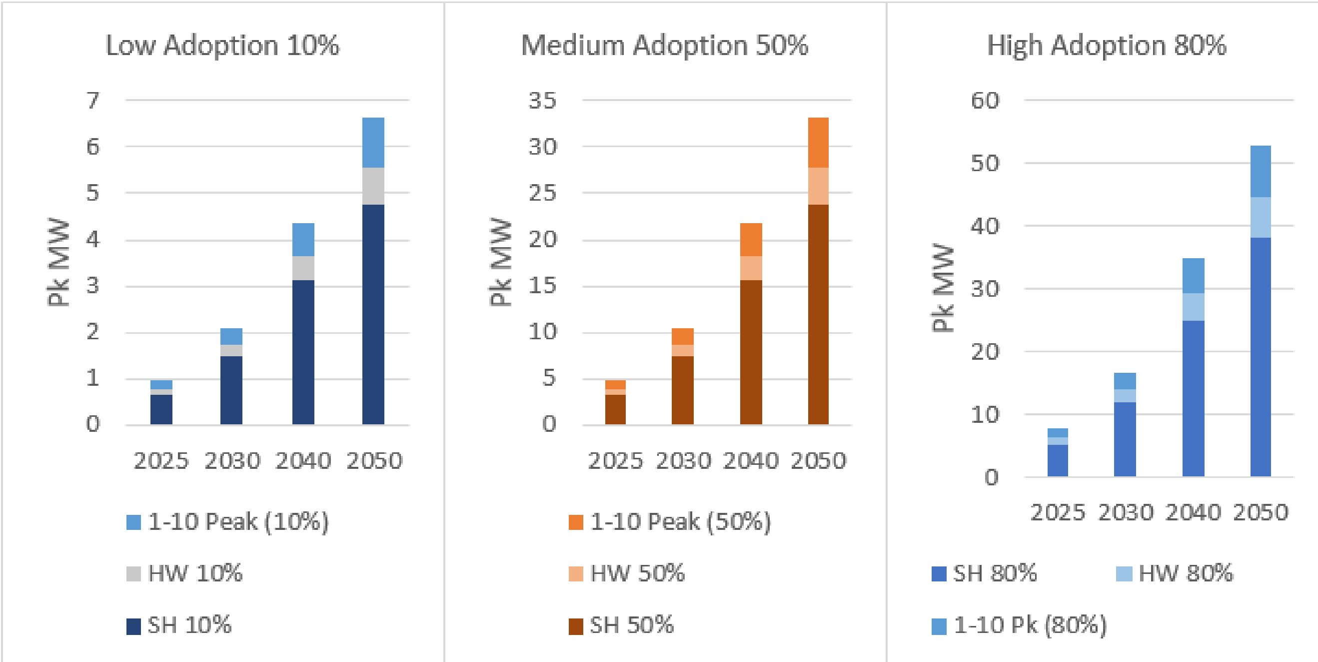


Figure II– Peak impacts to the utility are dependent on the amount of commercial space and water heating electrification which occurs over time but are also increased by colder than average weather (1-in-10).

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

[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].

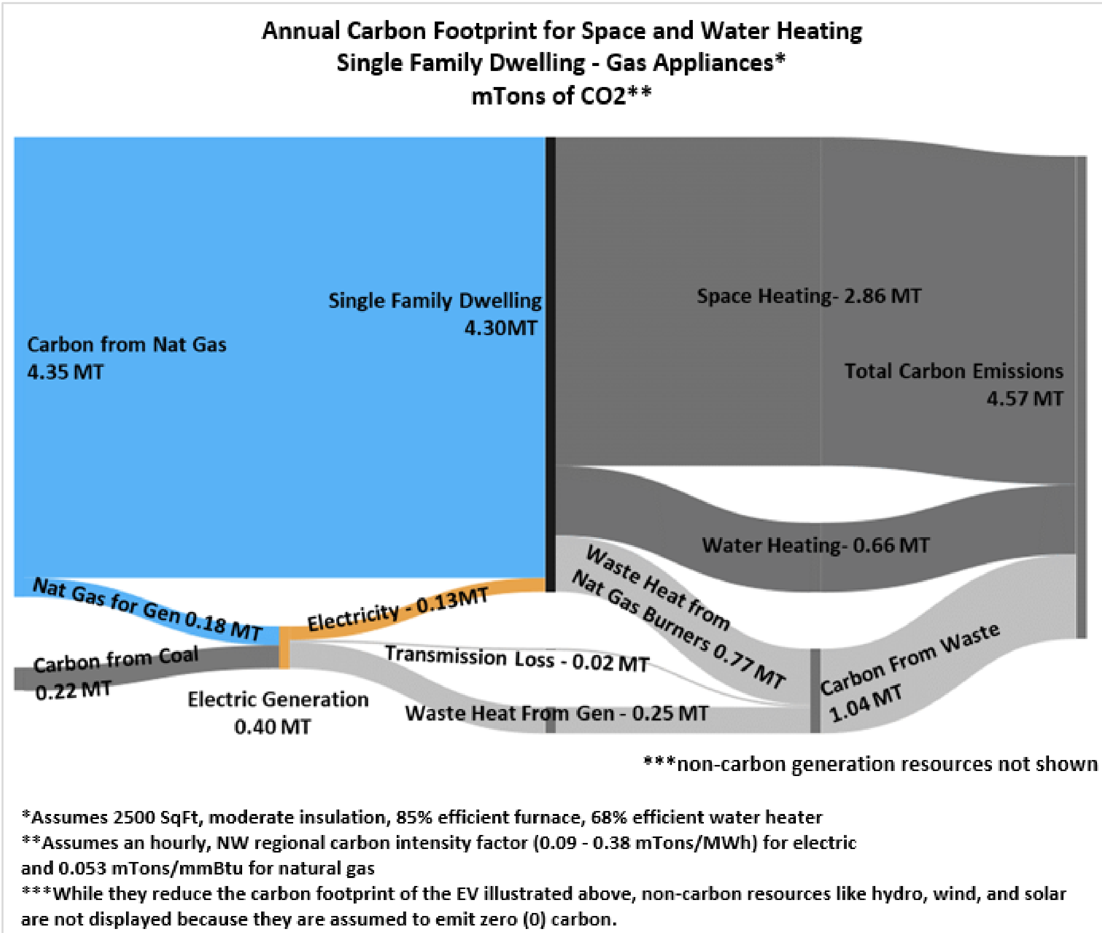


Figure JJ – Modeled Natural Gas energy use emits more carbon compared to a home heated with efficient electric appliances (like a heat pump).

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

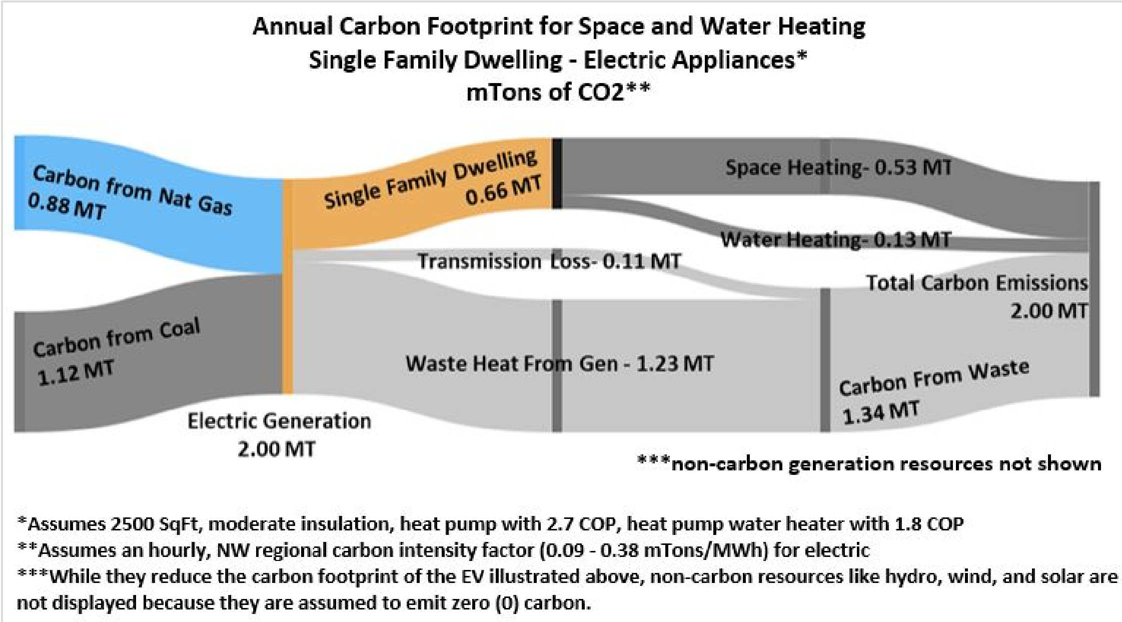


Figure KK – The majority of energy from electricity is carbon-free. However, electricity generated with natural gas and coal must be considered in the carbon footprint.

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.

[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.

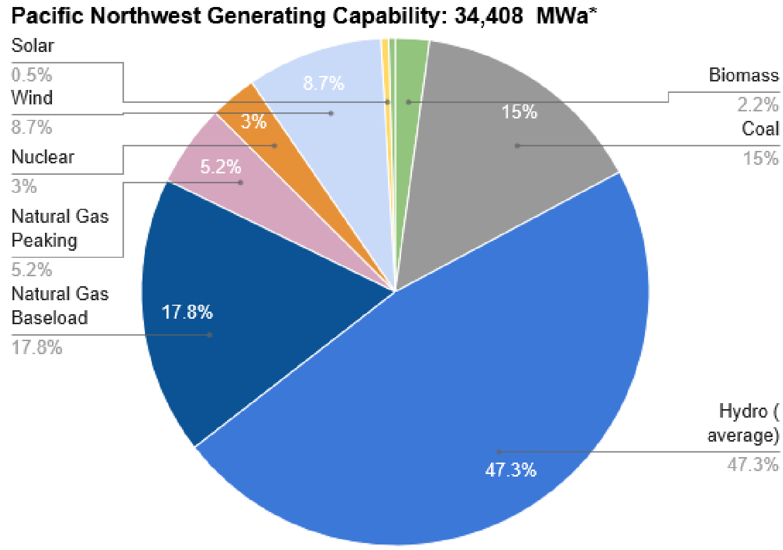


Figure LL – The Pacific Northwest's generating capacity is primarily comprised of carbon-free resources like hydro and wind.

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

[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.

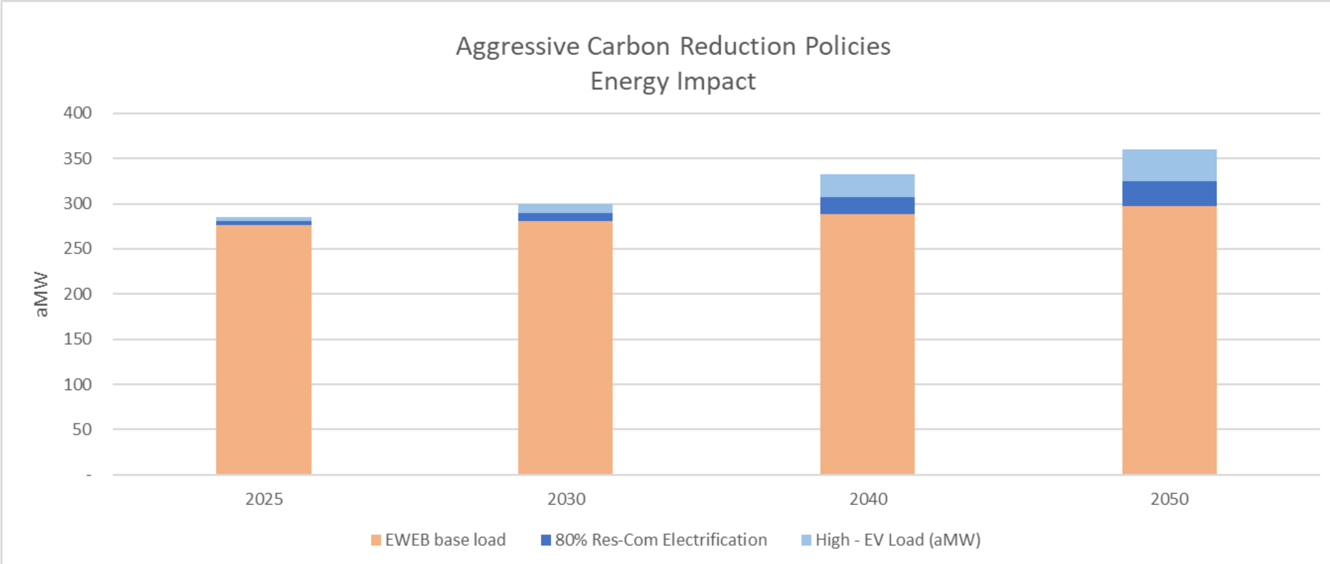


Figure MM – High levels of electrification lead to approximately 20% increase in average load by 2050.

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.

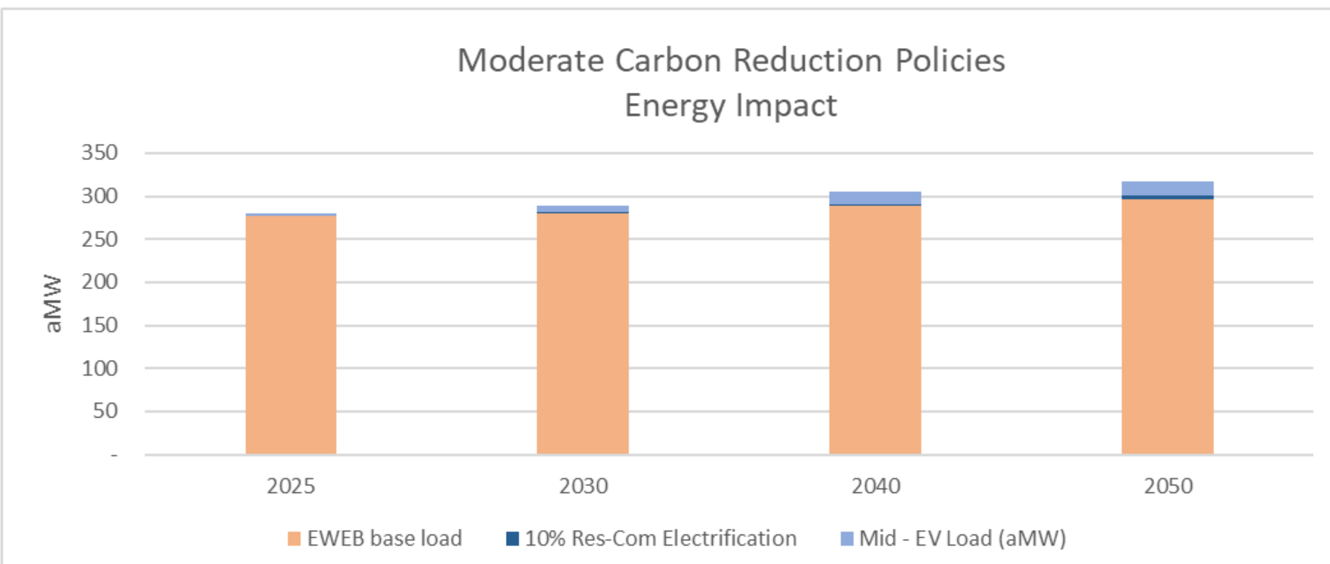


Figure NN – Absent aggressive carbon reduction policy, conversion of space and water heating end-uses is expected to remain sluggish and the average energy impacts lessen to an increase of 7%.

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.

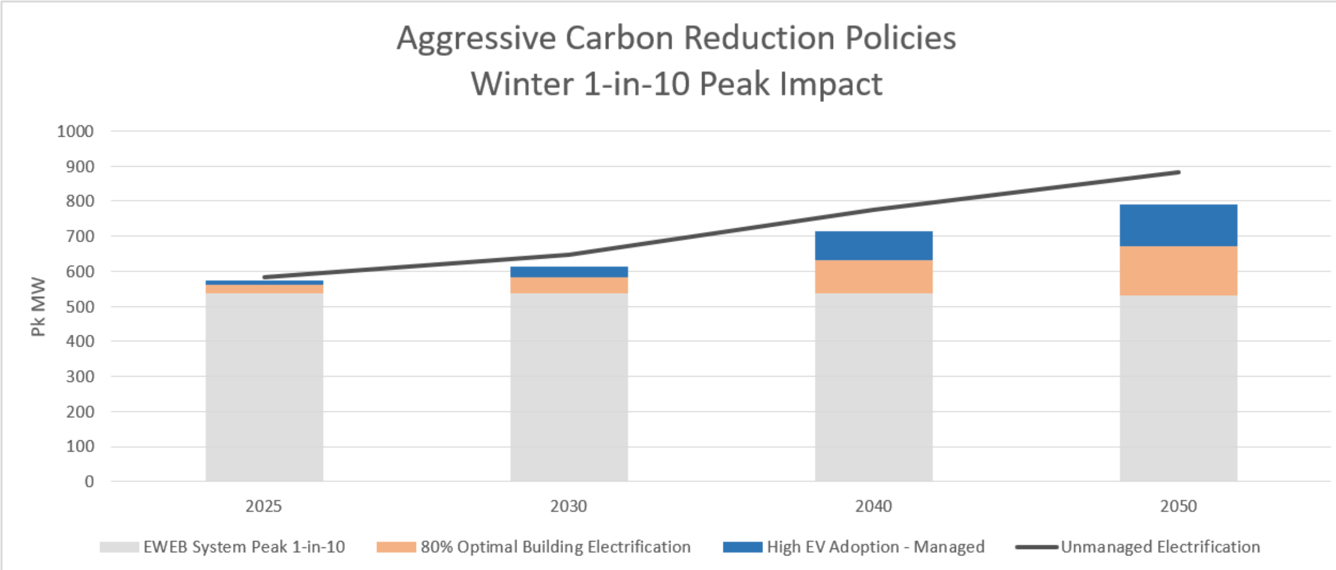


Figure OO – High levels of electrification could add between 49-66% to EWEB's existing 1-in-10 peak

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.

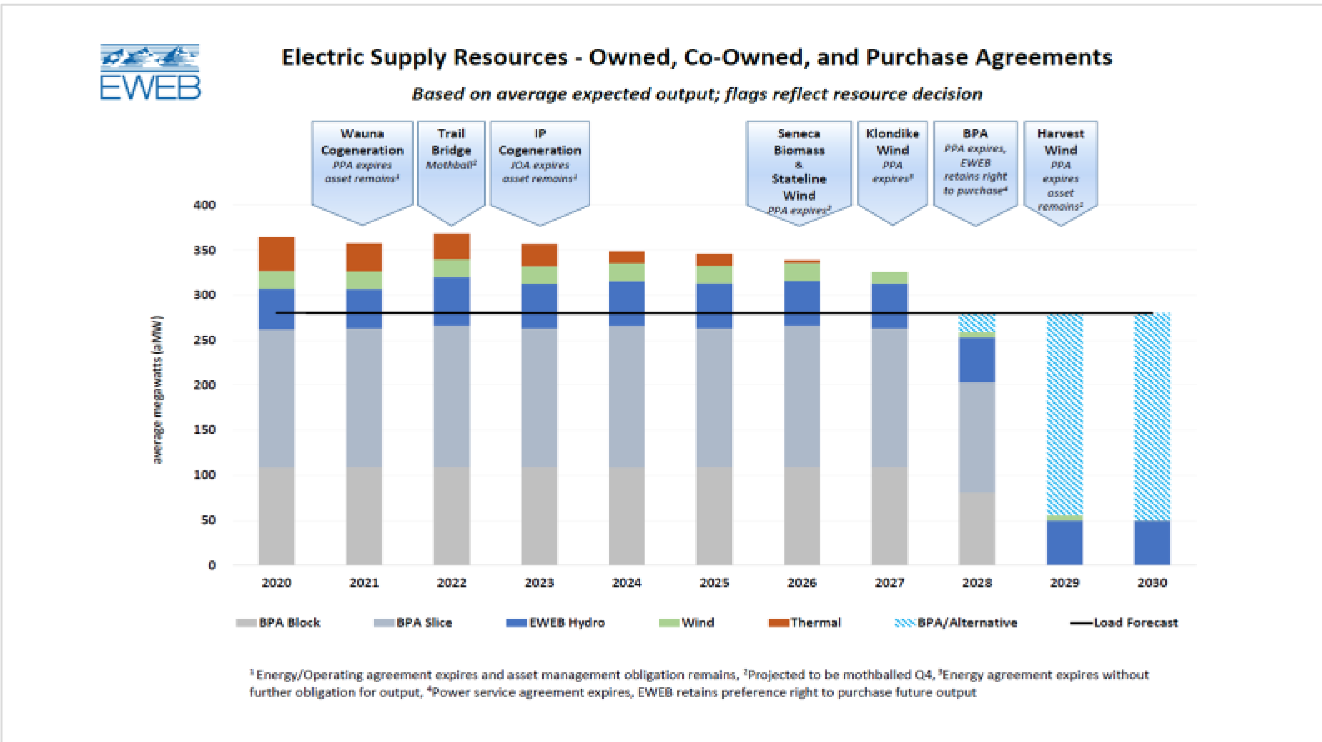


Figure PP – EWEB has major energy supply decisions to make over the next decade.

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

[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.

[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.

[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.

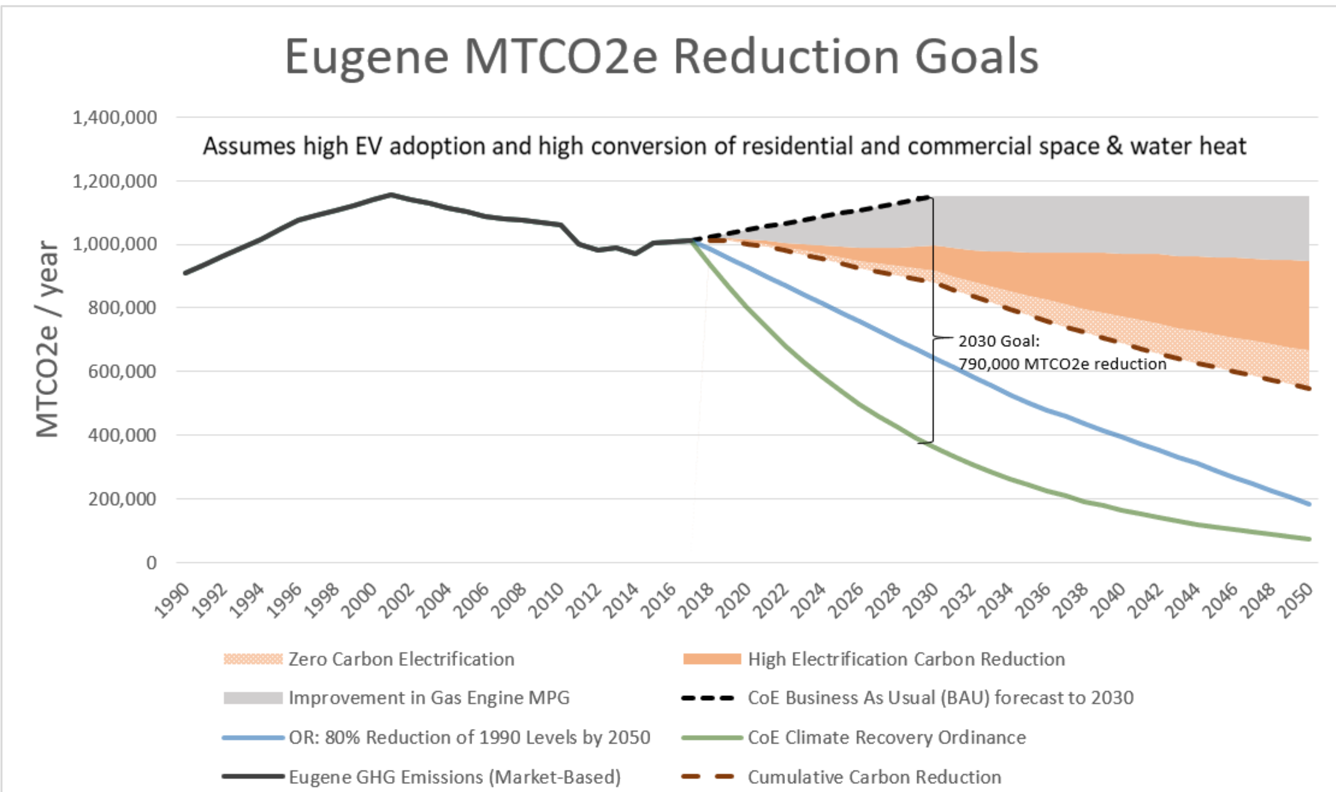


Figure QQ - Eugene's historical and projected GHG using the market-based carbon accounting method based on EWEB's DEQ GHG reporting. Carbon savings associated with electrification of the transportation and building sector are displayed in gray and orange to provide context on the amount of carbon reduction 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.

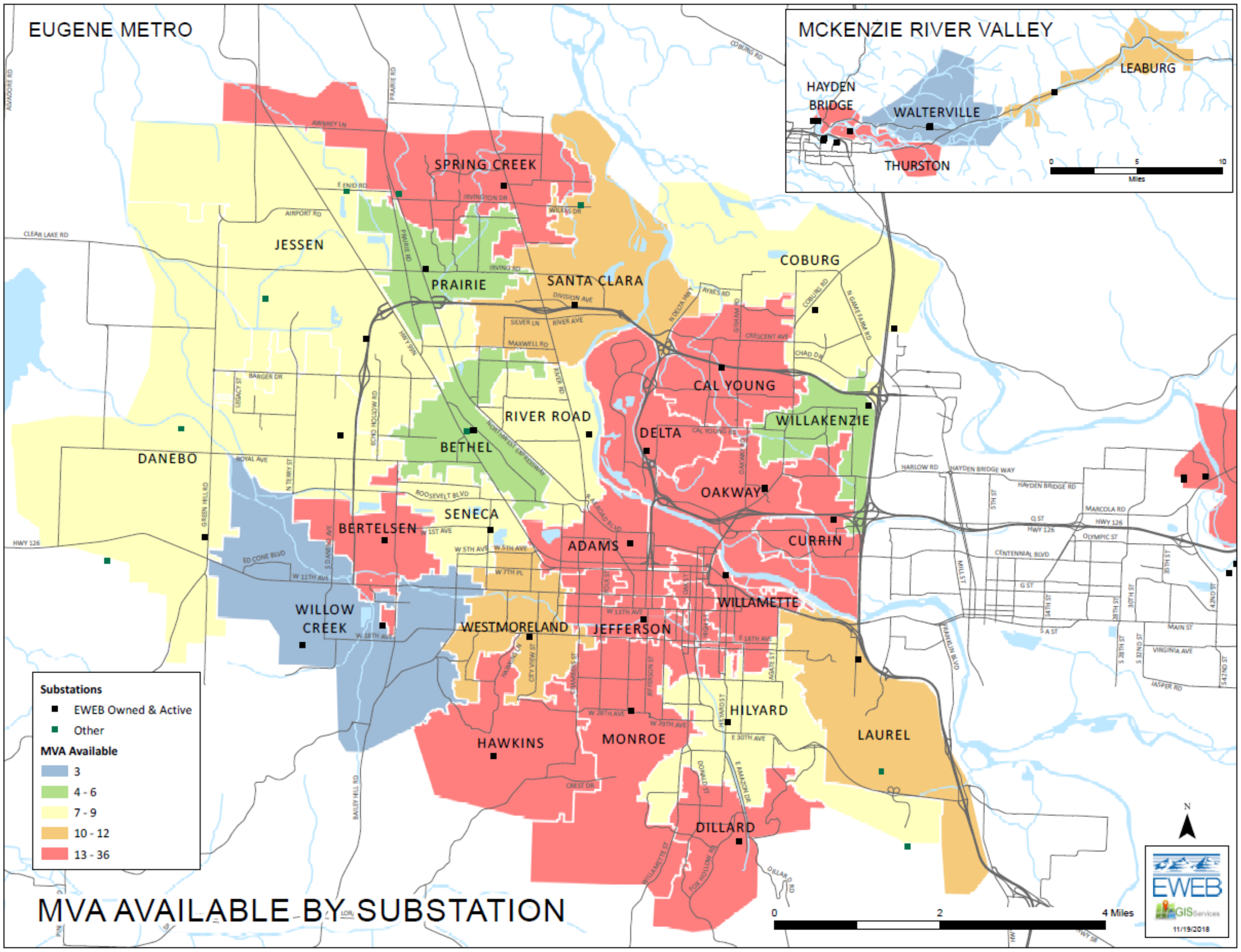


Figure RR – This map illustrates which areas within EWEB's service territory have much more available capacity (red) compared to those that are near capacity (blue) at the substation level.

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%.

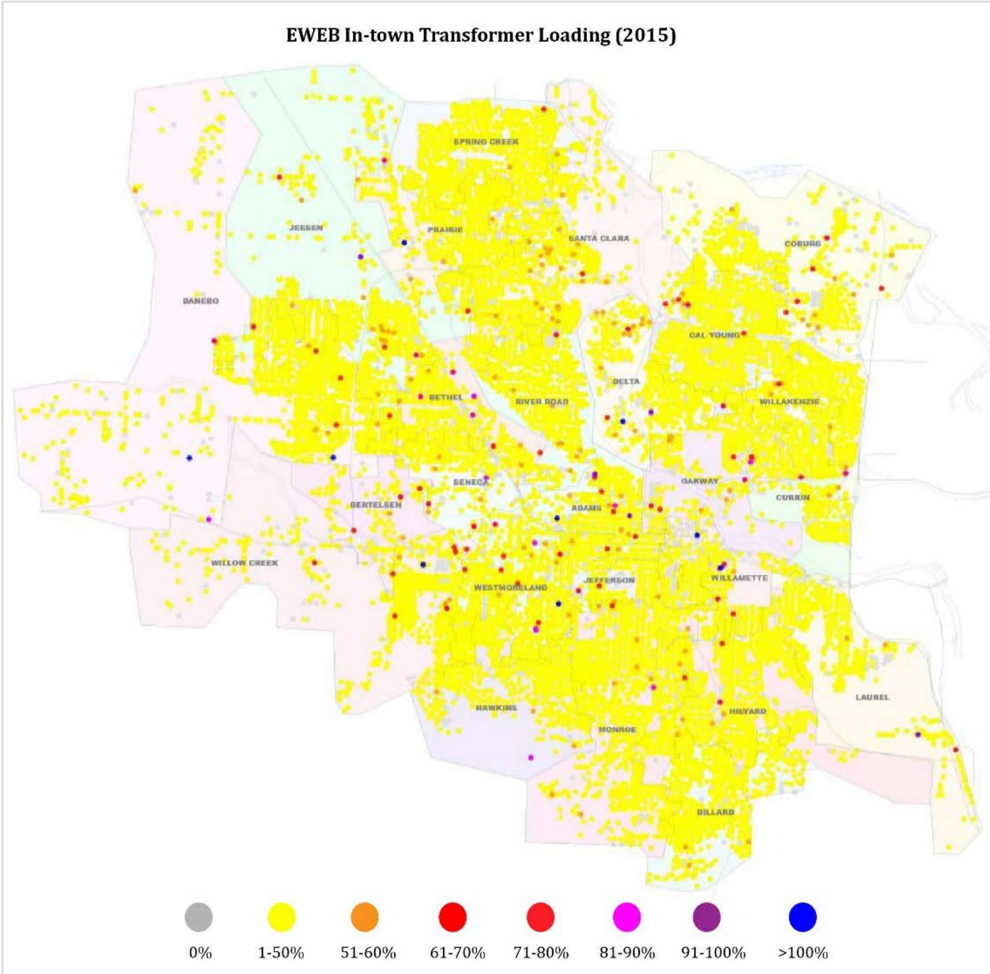


Figure SS - Most distribution transformers (over 80%) were loaded at 50% or less in 2015.

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.

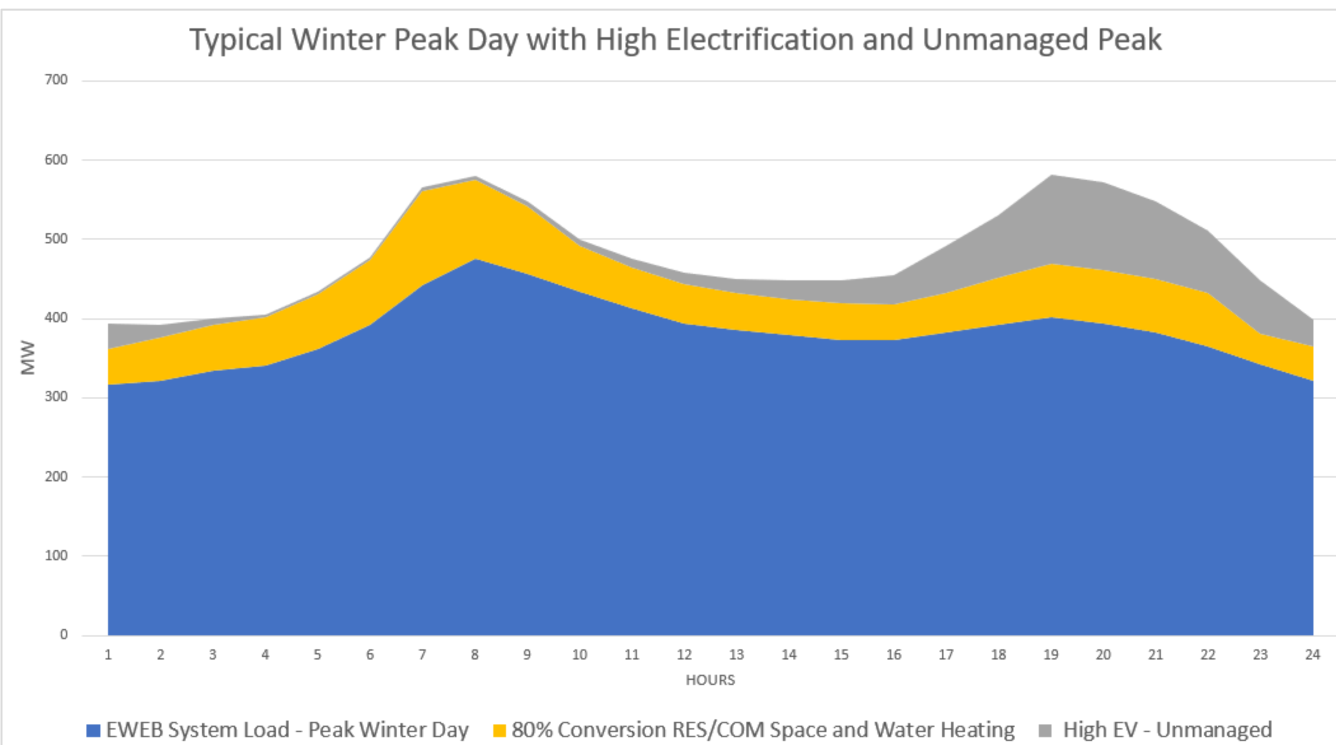


Figure TT- Electrification of space and water heating accentuates the morning peak, while the additional load associated with EV charging creates a second evening peak.

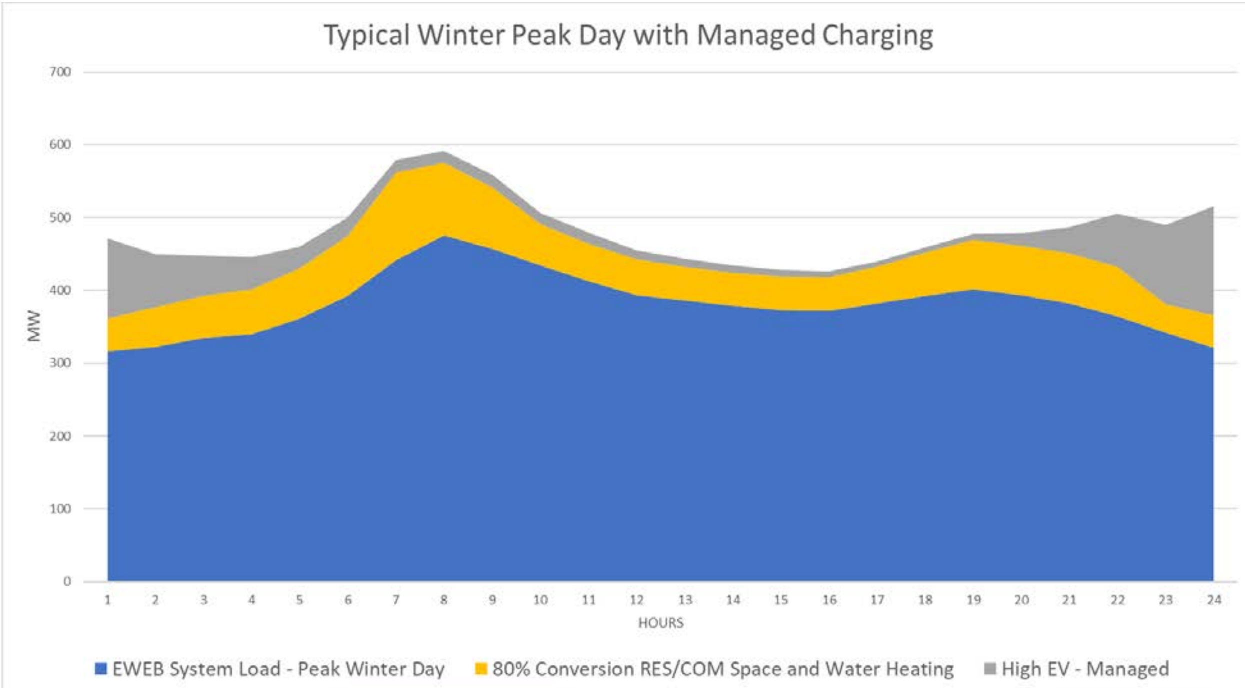
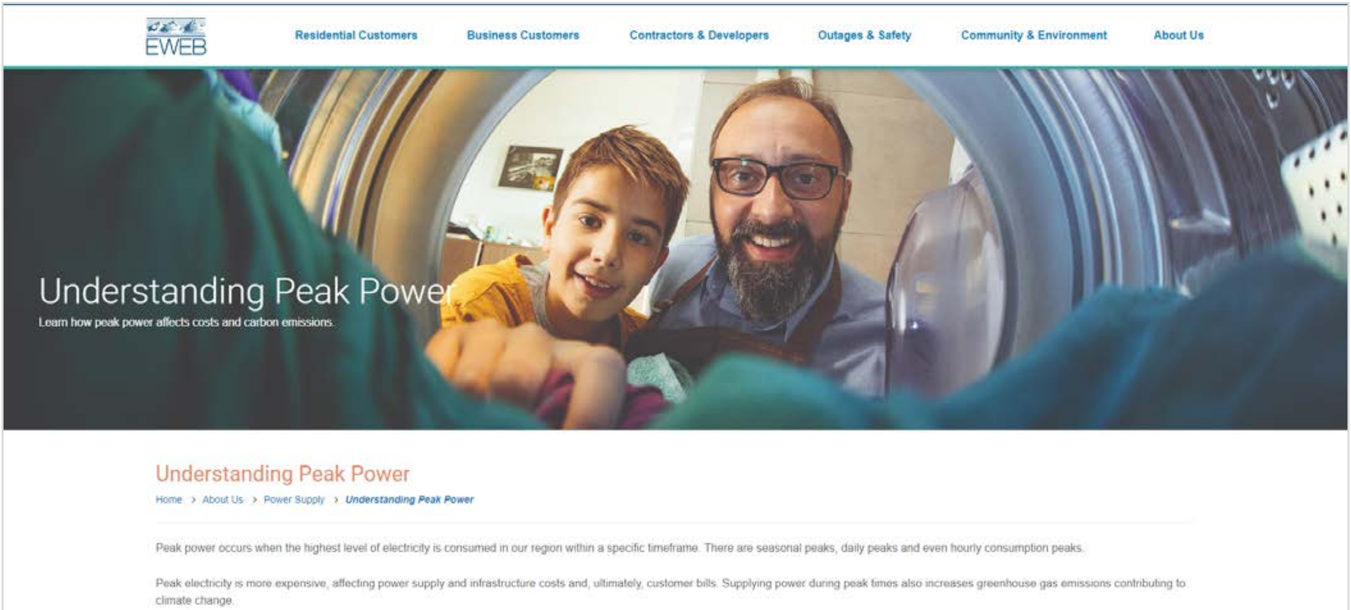


Figure UU- Shifting peak EV charging from 7 PM to 12AM (off-peak) moves the EV charging load away from EWEB's system peak and results in lower energy costs and much lower carbon emissions.

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.



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.

[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.

[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

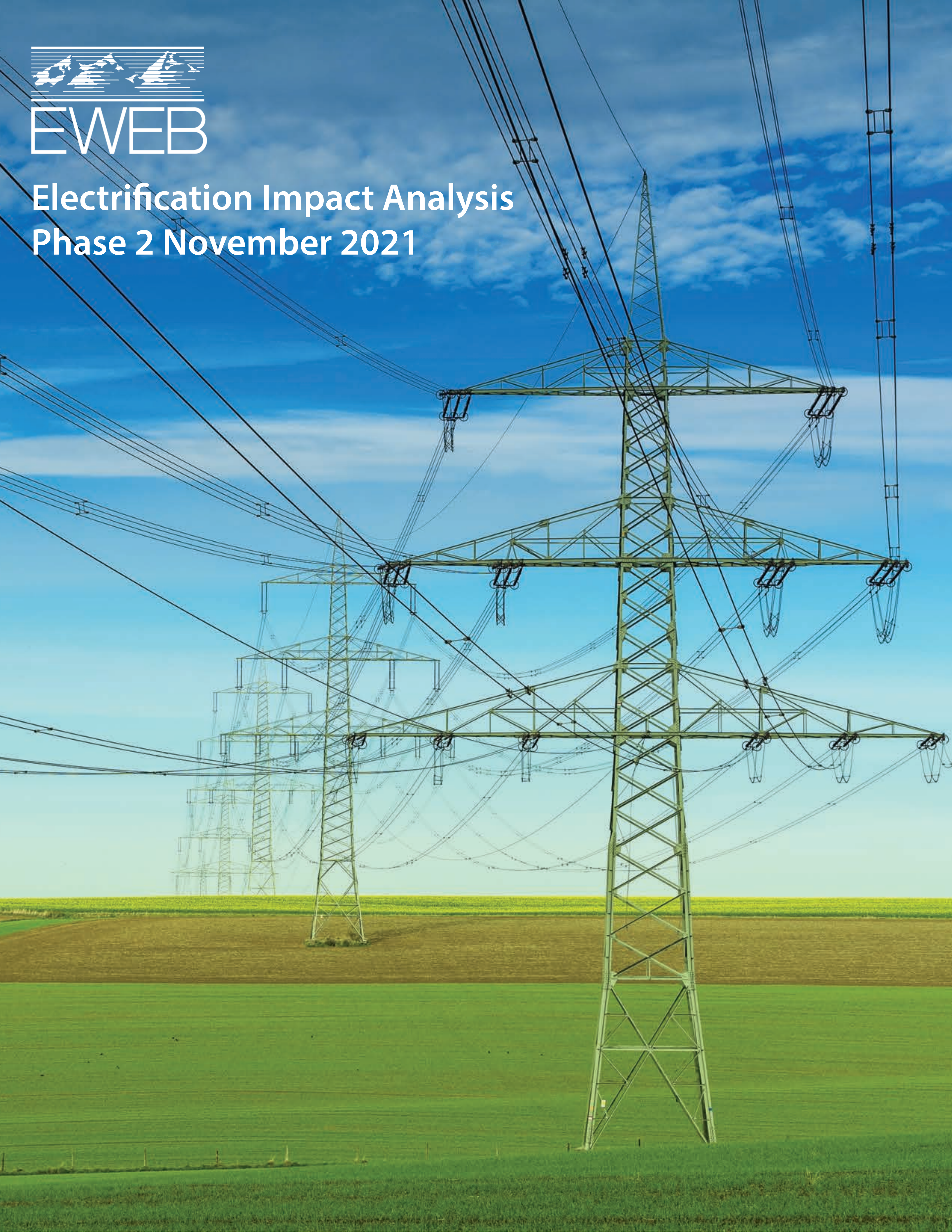
Interval Metering	Interval metering data is a series of measurements of energy consumption, taken at pre-defined intervals, typically sub-hourly. In end-use studies, energy consumption is measured in 15-minute or 1-minute granularity.
Light-duty Vehicles	Light-duty refers to gross vehicle weight rating 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.

[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.

EWEB

Electrification Impact Analysis
Phase 2 November 2021



EWEB

Readers:

In early 2020, EWEB's management and Commissioners agreed to develop a better understanding of the impacts of electrification on EWEB's future planning efforts. I am pleased to present our second analysis of the potential impacts of electrification, this time including economic factors affecting decisions to convert to electricity.

EWEB's first report, published in November 2020, focused on the potential impacts of electrification without analyzing the costs to customers choosing to electrify. The attached second report seeks to build on that initial analysis and context by considering the economics of electrification from multiple perspectives.

In both studies, the analysis of the transportation sector focuses on light-duty vehicle electrification, while the building sector analysis focuses on the electrification of space and water heating technologies for existing residential and small commercial buildings.

These reports reflect our ongoing assessment of evolving electricity consumption patterns that will help guide decisions and investments associated with electricity generation, delivery infrastructure, utility rate design, and customer program development. These studies do not advocate a position, or necessarily fully align with other agency targets or assumptions but attempt to inform and prepare EWEB for a range of different future conditions.

Prior to 2028, EWEB will need to reassemble an electric supply portfolio for the long-term economic, environmental, and social benefit of our community. These electricity supply decisions can be improved by effectively aligning time-of-use consumption, distributed generation, demand response, and efficiency programs with the increasingly dynamic future of clean energy resources and evolving storage technologies.

Consistent with the values of our customer-owners, EWEB will need to align our electricity supply portfolio with the evolving energy needs of our community, considering the potential effects of climate change, economics, technology, customer behavior, industry variations, and policy changes. All of these factors, including the likelihood, degree, and pace of electrification, will be used as planning criteria in EWEB's Integrated Resource Plan (IRP), scheduled to begin in early 2022 for completion in early 2023.

Thank you for your interest.

Frank Lawson
Eugene Water & Electric Board
CEO & General Manager

CONTENTS

1 ABSTRACT

In early 2020, EWEB's management and Commissioners agreed to develop a better understanding of the impacts of electrification on EWEB's future planning efforts. The likelihood, degree, and pace of Electrification, or the conversion of fuel-based consumption to electricity, will be used as planning criteria in EWEB's Integrated (Electricity) Resource Plan, scheduled for completion in early 2023.

Phase 1 of the Electrification Impact Analysis Report focused on potential changes to electricity consumption patterns and environmental impacts from electrification of passenger vehicles, as well as residential and small commercial water and space heating. While the Phase 1 study relied on assumed low, medium, or high levels of electrification, the adoption rate of electrification was uncertain because the analysis was done without considering costs. Phase 2 seeks to build on the analysis and context established in Phase 1 by considering the economics of electrification from multiple perspectives, and therefore providing a better understanding of the likelihood of electrification and EWEB's opportunities to engage with customers and develop programs. This study utilizes benefit/cost analysis to understand the financial benefits of electrification and explores key variables which will influence customer choices over the next 20 years.

2 EXECUTIVE SUMMARY

In early 2020, EWEB initiated a study of the impacts of widespread electrification in our community to understand various electrification scenarios and assess potential impacts to power supply, demand, local infrastructure, and community greenhouse gas (GHG) emissions.

Phase 1 of the study, completed in Oct. 2020, focused on potential changes to demand and consumption patterns, generation needs, and environmental impacts from electrification of small vehicles, water and space heating. Phase 2 of the Electrification Impact Analysis Report seeks to build on the analysis and context presented in Phase 1 by considering the economics of electrification.

For Phase 2, EWEB analyzed economic value from the perspective of the Customer/Participant, EWEB Ratepayers, and Society as a whole.

Like Phase 1, analysis of the transportation sector focuses on light-duty vehicle electrification. The building sector analysis focuses on space and water heating technologies for existing buildings using natural gas which can be electrified using heat pumps.

To perform this economic analysis, EWEB worked with Energy and Environmental Economics (E3). Using this financial analysis, EWEB can better understand customer choices, key variables impacting the likelihood of transportation and building electrification and impacts under a Base Case (expected future) and Aggressive Carbon Reduction (ACR) scenario.

This analysis can help EWEB refine forecasting of future electricity demand, inform Integrated Resource Planning efforts, and highlight opportunities to engage with customers around the topics of power supply, carbon reductions, consumer behaviors, and electrification impacts.

2.1 ELECTRIC AND NATURAL GAS SUPPLY DECARBONIZATION

Both the electricity and natural gas sector are anticipated to decarbonize over the next 30 years due to regulatory influences, coal plant retirements, buildout of renewable resources (primarily wind and solar), the increasing use of Renewable Natural Gas (RNG) and the potential of methanized hydrogen. The costs to decarbonize electricity and natural gas can, in turn, impact consumer prices and thus influence the pace of electrification.

Whereas the rate impact in the electric sector is expected to be moderate, increasing RNG content will put strong upward rate pressure on natural gas providers. In The Challenge of Retail Gas in California's Low Carbon Future study by E3[1], the analysis indicated that California electric rates could increase 20-40% by 2050, depending on the scenario, where natural gas rates could increase by 300% over the same period.

In EWEB's Phase 2 study, the increasing use of RNG and resulting upward costs of natural gas improve the financial benefits of electrification of space and water heating improve over time.

[1] "*The Challenge of Retail Gas in California's Low Carbon Future*", authored by E3 and University of California, Irvine, Advanced Power and Energy Program Engineering Laboratory Facility for the California Energy Commission, April 2020, CEC-500-2019-055-F.

2.2 Key Findings

2.2.1 Transportation

Electrification of light-duty vehicles creates value (marginal benefit/marginal cost) from all perspectives (Customer/Participant, EWEB Ratepayer, Society) in both the Base Case and ACR scenario, indicating electrification is likely and beneficial.

While federal and state incentives help provide benefits to EV purchases today, the benefits of owning an EV are expected to dramatically improve by 2030, even as incentives expire or are eliminated.

Economic analysis indicates that EV adoption will rapidly increase after 2030, with nearly 85% of all vehicles on the road being electric by 2040. Based on the benefits to customers, the phase 2 economic analysis shows an accelerated adoption of EV's greater than the "high adoption" assumption modeled in the phase 1 study.

EVs provide benefits for owners, ratepayers, and society:

- All battery electric vehicles, regardless of size or vehicle type, are expected to become cheaper than conventional cars before 2030.
- EWEB ratepayers benefit through the increased sales of electricity realized by EV charging, the proceeds of which could be used to cover the fixed costs of the utility, reduce rates, pay for distribution infrastructure investments, or fund additional incentives for EV adoption.
- By 2040, Eugene's total carbon emissions could be reduced by 38% due to EV adoption.

Phase 2 of the study estimates a lower coincident peak of EV charging (1 kW per EV) compared to Phase 1 of the study due to increased levels of off-peak workplace and public charging in the future. The electric peak impact, while still significant, can be mitigated with managed or diversified charging behavior.

EWEB can encourage diversified charging behavior by increasing the availability of public and workplace charging infrastructure and utilizing dynamic energy price signals (like time-of-use rates) to encourage vehicle charging to shift to non-peak times. In the near term, EWEB's engagement and collaboration with electric vehicle owners and the City of Eugene to shift charging times to non-peak hours of the day when carbon benefits are highest, and costs are lowest, will be beneficial to the impact and rate of electrification.

2.2.2 Buildings

The benefit/cost analysis of electrification of space and water heating is influenced by multiple factors, primarily building type and technology choices.

Water Heating

Even without incentives, water heating electrification has economic benefits for all three electrification perspectives by 2030. The aggregate carbon reduction benefits are small compared to other end-uses, due to relatively low energy consumption of water heaters, but so is the electric system peak impact.

For Single Family Dwellings (SFD), electrification of water heating is expected to have financial benefits in 2030 as heat pump water heaters become more cost competitive with natural gas water heaters over time.

Space Heating

The economics and impacts of space heating electrification is more complex and uncertain. Removing other variables (mandates, incentives, equity, personal choice), substantial single-family dwelling electrification of space heating is unlikely under the Base Case scenario given lack of economic benefit created for the Customer/Participant.

From this value perspective, for a residential property, electrifying with standard performance heat pump or dual-fuel heat pump technology creates the most economic value for both the participant and society. However, the standard heat pump has the most electric system peak impact, which may be more difficult to mitigate given its correlation to EWEB's existing system peaks.

For both scenarios studied, multifamily dwellings (MFD) have lower energy consumption than SFD, which makes it more difficult for the Customer/Participant to recover the upfront costs of electrifying through annual energy savings. All the space heating electrification measures studied were a net cost to the Customer/Participant, making electrification of MFD space heating unlikely.

Small office electrification was also found to be unlikely due to EWEB's commercial rate structure which includes a demand charge on peak energy use. This demand pricing signal may currently be acting as a deterrent to electrification for commercial customers.

2.2.3 Cumulative Impacts of Electrifying Transportation and Buildings

Overall, the study finds that the pace of customer-driven electrification, if based on economic value alone, will be slow in the next decade with EV adoption appearing to be the most likely and impactful form of electrification based on the large conversion potential (number of cars).

The following tables and charts summarize the cumulative electrification findings and highlight the differences between the Base Case and the Aggressive Carbon Reduction (ACR) scenarios. The cumulative energy impacts are relative to EWEB's existing system loads and existing peak demand periods. The percentage increase is based on EWEB's existing system average load of 270 aMW and a 1-in-10 peak of 510 MW, which is a common planning standard for electric utilities.

2040 - Base Case

Electrification Measure	% Electrified	Average Energy Increase (aMW)	% Increase	1-in-10 Peak Increase (MW)	% Increase
Electric Vehicle - Managed	85%	57	21%	77	15%
Electric Vehicle - Unmanaged	85%	57	21%	131	26%
Heat Pump Water Heater	50%	1	0.3%	1.5	0.3%
Standard Performance Heat Pump	< 2%	Without significant incentives or mandates, impactful space heating electrification is unlikely if driven by participant economics (consumer choice).			
Cold Climate Heat Pump	< 2%				
Dual Fuel Heat Pump	< 2%				

2040 - Aggressive Carbon Reduction

Electrification Measure	% Electrified	Average Energy Increase (aMW)	% Increase	1-in-10 Peak Increase (MW)	% Increase
Electric Vehicle - Managed	95%	63	24%	85	17%
Electric Vehicle - Unmanaged	95%	63	24%	145	28%
Heat Pump Water Heater	85%	2	1%	3	1%
Standard Performance Heat Pump*	50%	8	3%	33-61	6-12%
Cold Climate Heat Pump*	50%	4	2%	17-31	3-6%
Dual Fuel Heat Pump*	50%	6	2%	Minimal	Minimal

*Space heating energy impacts shown assume 100% of space heating electrifcation assuming a single technology to illustrate that space heating technology choice matters. In reality, customers will choose a mix of the 3 different space heating technologies. Peak impacts are presented in ranges due to uncertainty regarding coincident load of units. Utilizing AMI data in the future, EWEB could better estimate the coincident load of these space heating technologies.

As mentioned in Phase 1, electrification is just one of the pillars of decarbonization. Although separate from the benefits of electrification, staff provided an estimate of the potential carbon reduction benefits of RNG based on the Eugene Climate Action Plan's 2017 carbon inventory for additional context.

Annual Carbon Reductions	2040					
	Base Case			Aggressive Carbon Reduction Scenario		
Carbon Reduction Measures	% Electrified	MTCO2e Reduced	% Carbon Reduction	% Electrified	MTCO2e Reduced	% Carbon Reduction
Vehicle Electrification	85%	(390,000)	-38%	95%	(432,000)	-43%
Water Heating Electrification	50%	(5,700)	-1%	85%	(6,500)	-1%
Space Heating Electrification	0%	-	0%	50%	(16,000)	-2%
Residential RNG Benefits*		(19,600)	-2%		(45,100)	-4%
Commercial & Industrial RNG Benefits*		(45,300)	-4%		(104,400)	-10%
Total Annual Carbon Reductions		(460,600)	-45%		(604,000)	-60%
Total 2017 Carbon Emissions (City of Eugene CAP 2.0)		1,013,600	100%		1,013,600	100%

*The Base Case assumes a blend of 23% RNG by 2040 and the Aggressive Carbon Reduction scenario assumes a blend of 53% RNG by 2040. The estimated carbon reduction benefits of increased carbon-free RNG are shown in addition to the benefits of building electrification for context.

2.3 EWEB's Electrification Opportunities

Electrification measures can be most beneficial when they reduce carbon emissions while maintaining reliability and affordability.

Measures that add to existing system peaks may create reliability risks because they could, (1) increase utilization (reduce available capacity) of EWEB's existing local distribution network, and (2) increase reliance on the regional electric grid, where decarbonization efforts are impacting the availability of existing transmission and generation capacity. To manage the reliability risk, additional distribution, transmission, and generation assets potentially need to be procured at a cost to EWEB, which represents a risk to future customer affordability.

Economics are another factor influencing the benefits of various electrification measures. Technologies that do not produce economic benefits show lower likelihood of consumer-driven adoption and may require more resources to influence customer choices. Therefore, maintaining affordable/competitive electricity rates will have a favorable impact on electrification.

To the extent that electrification provides financial benefits to participants, EWEB programs will need to consider access to these benefits and equity among customers. Exclusion of multifamily housing incentives, for example, may inadvertently exclude low and moderate income (LMI) communities from the benefits.

The Electrification Scorecard below was developed by staff to provide high level context for the different electrification measures studied in Phase 2.

Electrification Scorecard	Carbon Reduced	Base Case 2030			1-in-10 Peak Adder	Peak Management Potential	EWEB Engagement Opportunities
		EWEB Participant	EWEB Ratepayer	Society			
Electric Vehicle							Encourage managed charging to avoid peak, increase public and workplace charging opportunities.
Heat Pump Water Heater							Consider existing energy efficiency incentive program's influence on electrification of water heating.
SFD - Standard Heat Pump							Participant benefits are neutral, making electrification unlikely. Possible incentive opportunity.
SFD - Cold Climate Heat Pump							Participant benefits are lacking, making electrification unlikely. Possible incentive opportunity.
SFD - Dual Fuel Heat Pump							Participant benefits are neutral, making electrification unlikely. Possible incentive opportunity.
Multi-Family Dwelling Space Heat							Participant benefits are lacking, making electrification unlikely. Possible incentive opportunity.
Small Office Space Heat							Participant benefits are lacking, making electrification unlikely. Consider rate design changes for commercial electrificaiton.

Electrification Scorecard	Carbon Reduced	Aggressive Carbon Reduction 2030			1-in-10 Peak Adder	Peak Management Potential	EWEB Engagement Opportunities
		EWEB Participant	EWEB Ratepayer	Society			
Electric Vehicle							Encourage managed charging to avoid peak, increase public and workplace charging opportunities.
Heat Pump Water Heater							Consider existing energy efficiency incentive program's influence on electrification of water heating.
SFD - Standard Heat Pump							Influence customer space heating technology choices to mitigate peak impacts.
SFD - Cold Climate Heat Pump							Influence customer space heating technology choices to mitigate peak impacts.
SFD - Dual Fuel Heat Pump							Influence customer space heating technology choices to mitigate peak impacts.
Multi-Family Dwelling Space Heat							Participant benefits are lacking, making electrification unlikely. Possible incentive opportunity.
Small Office Space Heat							Participant benefits are lacking, making electrification unlikely. Consider rate design changes for commercial electrificaiton.

3 PHASE 2 ELECTRIFICATION IMPACT ANALYSIS SCOPE

Phase 2 of the electrification study seeks to build on the analysis and context presented in Phase 1 by considering the financial costs and benefits of electrification. Similar to Phase 1, analysis of the transportation sector focuses on light-duty vehicle electrification. The building sector analysis focuses on space and water heating technologies for existing buildings using natural gas which can be electrified with heat pumps. To perform this economic analysis, EWEB worked with Energy and Environmental Economics (E3) to develop in-house tools for modeling benefits and costs of electrifying.

Consumer choices are influenced by forces largely beyond the control of EWEB, such as state or federal tax policies and technological innovation. EWEB programs and pricing can influence consumer technology decisions. This analysis lays out a framework that may inform potential EWEB programs by end-use. For example, incentive levels that leave the utility/customers indifferent (held harmless) while providing financial benefit to program participants can help drive consumer adoption. For some end uses, educational campaigns without additional incentives may influence customer choices where the value proposition is already clear. This analytical framework can indicate how potential incentives could change over time, as economics change. This is intended to be information only and not a recommendation or call to action. It should be emphasized that this economic analysis is foundational and informs other work streams such as future integrated resource plans.

3.1 OUTSIDE OF SCOPE

Non-economic decision making is outside the scope of this study. Consumer choice has multiple drivers, like convenience or aesthetics, but economics are nearly always a primary consideration. Thus, economics is the basis of our quantitative analysis. While we do not disregard qualitative impacts to customer choice (e.g. customer desire for carbon reduction), these factors can be difficult to model and often require alternate forms of analytical methods.

Carbon emissions associated with upstream production of energy are outside the scope of this study. These upstream emissions do have impacts on the climate (like methane gas leaks from natural gas production and distribution[2] or the lifecycle of solar panel manufacturing and disposal). Other organizations like the National Renewable Energy Laboratory (NREL) have done studies on life cycle carbon emissions across electricity generation technologies which readers may find helpful[3]. For the purposes of economic analysis, staff focused on the carbon emissions with the direct use of electricity or fossil-based fuels for the specific end-uses analyzed.

For the transportation sector, this study focuses on electrification of light-duty vehicles only. According to the City of Eugene's 2017 Greenhouse Gas Inventory[4], approximately 33% of the transportation sector emissions come from diesel and the remaining come from gasoline. Diesel is more commonly used in mid-size pickups (over 6,500 lbs) and freight trucking. Reduction of emissions of this portion of the transportation sector is outside of this study's scope.

For the building sector, the space and water heating equipment for the residential sector overlaps with the small office segment of commercial sector. Hence, our study of the economics of electrification can be more broadly

[2] Northwest Power and Conservation Council has published staff recommendations for upstream methane emission assumptions related to the 2021 Power Plan here: https://www.nwcouncil.org/energy/energy-advisory-committees/natural-gas-advisory-committee

[3] https://www.nrel.gov/analysis/life-cycle-assessment.html

[4] City of Eugene Climate Action Plan 2.0 – Appendix 6 2017 GHG Inventory.

applied to small offices or other commercial properties with energy equipment similar to residential homes. Space and water heating end-uses for larger commercial and industrial segments represent a smaller proportion of total energy consumption (estimated to be 33% and 7% for commercial and industrial[5], respectively). Electrification of space and water heating end-uses for large commercial and industrial segments is more complex and site-specific and is outside the scope of this economic analysis.

4 KEY CONTEXT: ROLE OF ECONOMICS IN ELECTRIFICATION

HIGHLIGHTS

- While some consumers will choose to electrify for environmentally altruistic reasons, significant electrification will either be driven by policy mandate or economic benefit to the consumer.
- For Phase 2 of the electrification study, EWEB used benefit-cost modeling for targeted electrification measures to better understand the economic value from the perspective of the consumer (participant), EWEB ratepayers, and society as a whole.
- Understanding and aligning the economic interests of participants, ratepayers, and society can inform future electrification programs, utility rate designs, and financial incentives.
- Maintaining affordable electric rates is crucial to preserving the economic benefits and offsetting the upfront cost of electrification investment.

Phase 2 of the electrification study utilizes benefit-cost analysis to better understand the customers' financial considerations when choosing to electrify. The benefit-cost analysis considers the total lifecycle of targeted electrification measures, and then presents those findings on a discounted cash flow basis. Since most customers do not consider discounted cash flows when making purchasing decisions, EWEB also translates discounted cashflows into simple payback periods (upfront costs divided by annual savings) to better estimate the likelihood a consumer may choose to electrify. These are standard tools for estimating consumer adoption of new technologies. **While some consumers will choose to electrify regardless of financial impact, it is likely that widespread electrification will only occur if there is either: 1) a financial benefit to the consumer to voluntarily choose to electrify, or 2) a policy driven mandate that requires consumer electrification.**

The cost-effectiveness of electrifying can differ depending on one's frame of reference. The consumer or "participant" is the EWEB customer who chooses to electrify, and ultimately determine which transportation, space, and/or water heating technology will be implemented. However, those participant choices have specific impacts on EWEB ratepayers and society in general. Thus, the benefit-cost analysis is presented from multiple perspectives:

- **EWEB Participant:** Do benefits outweigh costs for an EWEB customer adopting a new technology?
- **EWEB Ratepayer:** Do benefits outweigh costs for a nonparticipant EWEB ratepayer?
- **Society:** Do benefits outweigh costs for a resident of the community?

Analyzing benefits and costs from multiple perspectives helps the utility understand to what extent value can be exchanged between EWEB ratepayers and participants. For example, EWEB's level 2 charger rebate is an exchange of value from EWEB ratepayers who fund the incentive to participants who receive the rebate. The participant clearly benefits in the form of a financial rebate. Value is also passed along to EWEB ratepayers in the form of additional revenue collected from the electric vehicle charging over time, and society will benefit from the emissions reductions associated with the electric vehicle. But does the benefit to society outweigh the

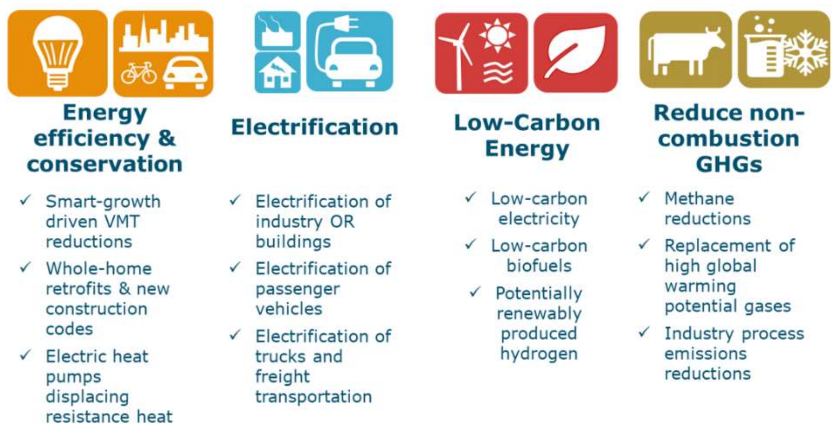
[5] Per CADMUS end-use model

incremental cost to the participant to purchase the technology? Is there a way to compensate the participant for the benefit created for society? EWEB has significant influence over the exchange of value between ratepayers and program participants (through electric rates and incentives). By quantifying the benefits from multiple perspectives, EWEB can understand the financial benefits of electrification for ratepayers while being mindful of costs to participants and ratepayers. This information can inform future electrification programs, rate design, and electrification incentives.

The goal of the Society perspective is to provide context for the participant who pays for the upfront equipment costs, the supply chain that provides energy to the equipment and the benefit of avoided emissions (based on the assumed social cost of carbon). It can be useful to understand the efficiency of electrification for society to get the benefits of reduced carbon emissions. If the society perspective is a net cost for an electrification measure, it indicates that the financial investment of electrification is greater than the financial benefit of carbon reduction. This is not meant to imply that carbon reduction is not valuable, but instead to distinguish the financial efficiency of the identified electrification opportunities.

4.1 AFFORDABILITY

As discussed in Phase 1 of EWEB's electrification study, electrification is just one pillar of a larger decarbonization strategy[6]. The greening of the electric grid plays an important role in decarbonization as well, and the Northwest electric sector is legislated to become cleaner. However, it is possible that increasing electric rates could become a deterrent to electrification. To date, encouraging building and transportation electrification as a critical pillar of successful, economy-wide decarbonization has focused on incentives rather than legislative mandate. Absent such mandates to electrify, an attractive economic proposition is necessary to induce businesses and individuals to choose electrified technology over a fossil fuel-based alternative on a widespread basis. This includes ensuring that electricity remains competitively priced.



4.2 ENVIRONMENTAL IMPACTS AND EQUITY

As identified in the City of Eugene CAP 2.0, national research and local experience show that the impacts of climate change tend to disproportionately impact marginalized communities, including indigenous peoples, communities of color, low and moderate income (LMI) communities, the elderly, and people experiencing disabilities. As we explore potentials for electrification and who is impacted by such decisions, we must consider how electrification might address or exacerbate social disparities. For example, Seattle City Light (SCL) City Light actively engaged with communities most impacted by environmental inequities and racial, social and economic burdens to prioritize transportation electrification investments. As a result of this engagement, SCL placed higher prioritization on electrification of public assets (like public transit, commercial, non-profit & government

[6] https://www.ethree.com/wp-content/uploads/2018/11/E3_Pacific_Northwest_Pathways_to_2050.pdf

fleets) before personal mobility electrification (cars, bikes, scooters, etc.). A key factor for this priority was to direct the environmental benefits of electrification (reduced air and noise pollution) to where the impacts are greatest. As EWEB works to engage customers around electrification, it will be important to consider the impacts on LMI populations as well as those experiencing racial and environmental inequities. EWEB will need to think about how to ensure the environmental benefits of electrification flow to marginalized communities while at the same time, avoiding program costs that could impact affordability of electricity for our LMI customers.

5 Key Context: Emergent Trends in Electrification

HIGHLIGHTS

- State and federal policies are encouraging increased EV adoption and reduction in the use of carbon emitting fuels.
- Vehicle manufacturers are offering more electric vehicles and committing to increase electric vehicles' percent of new car sales.

5.1 Regulatory Trends

Over the last several months, political support for decarbonization has increased, especially in the west. As a result, several new regulatory policies and related efforts have been introduced or passed since Phase 1 of EWEB's electrification study, all of which seem to be accelerators of carbon reduction and electrification. For example:

- In September of 2020, Governor Newsom of California signed Executive Order N-79-20 which aims to phase out the sale of gasoline-powered vehicles by 2035.
- In May of 2021, Oregon passed SB 333, a bill that directs state agencies to study the potential of, and benefits to Oregon from renewable hydrogen. Additionally, the Oregon legislature passed HB 2021, a 100% clean energy standard which would require Oregon's largest investor-owned utilities to reduce greenhouse gas emissions by 100 percent, below baseline levels, by 2040. Interim goals are 80 percent emissions reduction by 2030 and 90 percent reduction by 2035. Finally, as proposed HB 2021 would include a new gas generation siting ban in Oregon.
- Also in May of 2021, Washington's legislature passed a ban on the sale of gasoline-powered vehicles starting in 2030. The bill was subsequently vetoed by Governor Inslee because the legislation was tied to a separate road usage fee change[7].
- Nationally, the Biden administration has been working to advance the adoption of electric vehicles (EVs) and deploy additional charging infrastructure across the country[8].
- Some cities are updating building codes to reduce greenhouse gas emissions and, in some cases, restricting the use of natural gas. For example, in February 2021, Seattle updated commercial and large multifamily building codes to eliminate gas from most water heating and space heating systems.

[7] https://www.seattletimes.com/seattle-news/politics/inslee-vetoes-2030-target-for-electric-cars-set-by-washington-legislature/

[8] https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-biden-administration-advances-electric-vehicle-charging-infrastructure/

- Seattle's code changes apply to new construction and major renovations, or when space and water heating systems are being replaced[9].

5.2 VEHICLE MANUFACTURER TRENDS

The electric vehicle market continues to see a rapid evolution as more Original Equipment Manufacturers (OEMs) are committing to increased or even 100% electric offerings within the next 15 years. According to the International Energy Agency, 18 of the 20 largest OEMs, which combined accounted for almost 90% of all worldwide new car registrations in 2020, have announced intentions to increase the number of available models and boost production of electric light-duty vehicles (LDVs)[10]. In addition, the OEMs are beginning to expand their EV lineup into larger vehicles like SUVs and Crossovers. A prominent example of this expanded offering is the Ford F150 Lightning, which is an electric version of the bestselling pickup truck in the U.S. It should be noted that these commitments by OEMs have not yet been realized and that EV sales accounted for only 1-3% of new car sales in 2020.

Below is a summary of vehicle makers' EV offerings and commitments:

Original equipment manufacturer	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BMW Group			25		15-25%					10
BAIC Group	2				1.3					50%
Changan Automobile (Group)					33					
Daimler		10			25%					50%
Dongfeng Motor Co	1	30%	1		1				1	1
FAW					40%					60%
Ford		40				100%*				
GM Group			22		30	1				1
Honda										40%T
Hyundai-Kia					1					
					29					
Mazda		1								5%
Renault-Nissan		20								
		20%								
Maruti Suzuki	1									1.5
SAIC					30%					30
Stellantis					38%*					70%*
					31%**					35%**
Toyota Group	1				15					>1
Volkswagen					20%					70%*
			1		3				26	50%**
					75					
Volvo (Geely Group)	1	1	1	1	50%					100%*

% of sales electric
Annual sales (million)
New EV models (number)
Cumulative sales (million)

* European market only
** Chinese and US markets only
T Includes both EVs and FCEVs

11

In 2020, 559 new electric vehicles were registered within EWEB's service territory. This represents a 42% increase in the number of EVs in 2019. While we do not have exact data regarding total car sales within the service territory, this is estimated to be less than 5% of the new vehicles sold in 2020.

[9] https://www.seattle.gov/environment/climate-change/buildings-and-energy/seattle-energy-code
[10] IEA (2021), Global EV Outlook 2021, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2021
[11] https://www.iea.org/reports/global-ev-outlook-2021/trends-and-developments-in-electric-vehicle-markets

6 KEY CONTEXT: ELECTRIC AND NATURAL GAS SUPPLY DECARBONIZATION

HIGHLIGHTS

- Increasing the blend of Renewable Natural Gas (RNG) is a likely pathway to decarbonizing the natural gas sector.
- The supply of RNG sources is limited and much more expensive compared to fossil fuel natural gas. Thus, increasing RNG content will put strong upward rate pressure on natural gas providers.
- The electricity supply in the Pacific Northwest already has low carbon content and the upward rate pressure from continued decarbonization is expected to be lower compared to natural gas.

6.1 RENEWABLE NATURAL GAS (RNG) IN NATURAL GAS SUPPLY

To meet decarbonization goals, existing fossil-based natural gas will need to reduce its associated carbon emissions. The carbon reduction benefits of building electrification are relative to the carbon content of direct use natural gas. An increase in RNG would reduce the comparative carbon reduction benefits of electrification, however there would also be financial impacts to increasing the blend of RNG in the natural gas supply. This section highlights findings from "The Challenge of Retail Gas in California's Low Carbon Future," authored by E3 and University of California, Irvine[12]. It should be noted that the study's results are based on total US supply and are not specific to the northwest. However, given common industry and western energy market trends, the results of this study could be considered indicative for the northwest region.

To meet the deep decarbonization climate goal of 80% reduction by 2050[13], the carbon content of fossil-based natural gas will need to be proportionally reduced by 80%. To achieve this goal, natural gas use will have to be significantly reduced and/or replaced with RNG.

RNG is broadly defined as:

1. **Biomethane** – produced from anaerobic digestion of biomass waste or gasification of biomass waste
2. **Hydrogen gas** – sometimes called "green hydrogen" which is carbon neutral. This could be produced from electrolysis using renewable electricity which might otherwise be wasted.
3. **Methane** – produced synthetically from climate neutral sources of carbon and hydrogen

[12] "*The Challenge of Retail Gas in California's Low Carbon Future*," authored by E3 and University of California, Irvine., Advanced Power and Energy Program Engineering Laboratory Facility for the California Energy Commission, April 2020, CEC-500-2019-055-F.

[13] Deep decarbonization can have different definitions depending on the study, but typically means reducing 1990 GHG emission levels by at least 80% by 2050. This metric is a common multi-sector goal used in the US.

Figure A - Categories of Renewable Natural Gas that could be use within existing distribution infrastructure

Waste biogas	Gasification of biomass	Hydrogen	Synthetic Natural Gas
Sources: Municipal waste, manure	**Sources:** Agriculture and forest residues	**Sources:** Electrolysis + zero-carbon electricity, or steam methane reformation with carbon capture and sequestration*	**Sources:** Renewable hydrogen + CO2 from biowaste (bi-product of biofuel production) or direct air capture
Constraints: Very limited supply	**Constraints:** Limited supply and competing uses for biofuels	**Constraints:** Limited pipeline blends (7% by energy, 20% by volume) without costly infrastructure upgrades**	**Constraints:** Limited commercialization, low round-trip efficiency

***This analysis did not model SMR + CCS for hydrogen production.**
****This analysis did not evaluate conversion of the gas system to 100 percent hydrogen, which would require replacement of end-use devices and gas pipeline upgrades.**

Source: E3

6.2 RNG SUPPLY CURVE

All RNG sources can be scaled to increase volumetric production, however, all sources are far more expensive compared to existing fossil fuel natural gas. Further, the least expensive source (biomethane) is limited in availability, so the model assumes that more expensive RNG sources will be required. The graph below shows two anticipated supply curves (cost vs. volume) for four RNG technologies.

Figure B - California Renewable Natural Gas Technical Potential Supply Curve in 2050, assuming all biomass is directed to Renewable Natural Gas[14]

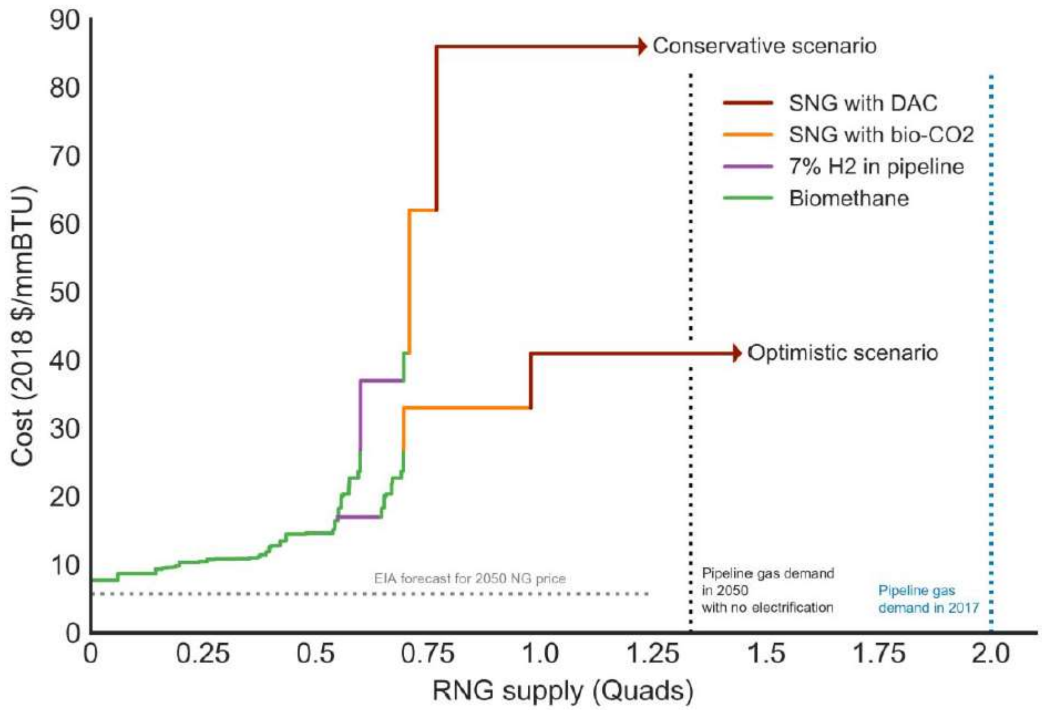


Figure B, above, illustrates the limited supply of renewable natural gas and the increasing cost of supplying greater quantities of RNG. In the optimistic scenario, synthetic natural gas with direct air capture technology (labeled SNG with DAC above) at $41/MMBtu would be the marginal resource to fully decarbonize the gas system in 2050. This optimistic scenario is approximatly 8 times greater than the estimated cost of fossil fuel natural gas in 2050 (shown as a blue dotted line). The conservative RNC supply scenario shows that by 2050 the marginal cost of RNG will be approximately 18x higher than the cost of fossil fuel natural gas.

6.3 Economic Impacts for Natural Gas Providers

It is anticipated that higher levels of RNG in the natural gas system will increase retail natural gas rates. Higher retail rates provide an economic response to reduce consumption, resulting in lower volume sales for the gas provider. Customer classes (industrial, commercial or residential) are impacted differently due to cost causation principles incorporated in rate designs. The residential customer class requires significant distribution piping systems to serve relatively small individual loads compared to large commercial and industrial loads that tend to be centralized (lower distribution costs) with large loads (higher consumption costs).

In "The Challenge of Retail Gas in California's Low Carbon Future" study [15], the key impacts of decarbonization for natural gas providers are:

1. Assumed higher commodity prices in the future as higher levels of RNG are needed and the low-cost sources of RNG are depleted.

[14] Pipeline gas demand in 2017 was 2 quadrillion BTU (quads), including electricity generation. This demand could decline to 1.3 quads in a scenario with high energy efficiency and renewable electricity generation by 2050. CEC-500-2019-055-F.
[15] https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-055-F.pdf

2. Substantial rate increases compared to today (300% by 2050) due to higher supply costs and lost customer sales (assuming high building electrification future). It is anticipated that the residential segment could see increases of 600% by 2050 compared to today due to high distribution costs, whereas industrial and transportation segments are not as greatly impacted.
3. Anticipated lower volume sales because of increased natural gas rates

Figure C below illustrates how natural gas retail rates could increase dramatically. Both internal and external factors combine to create a cycle of upward rate pressure. Overtime, a growing pool of natural gas system costs are spread over a declining customer base, which in turn increases costs to these customers.

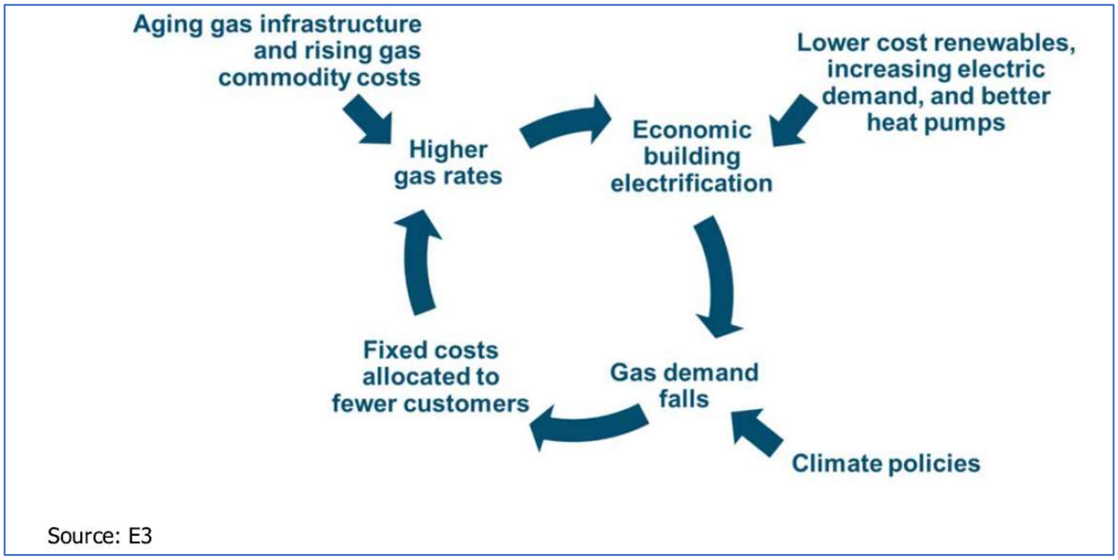
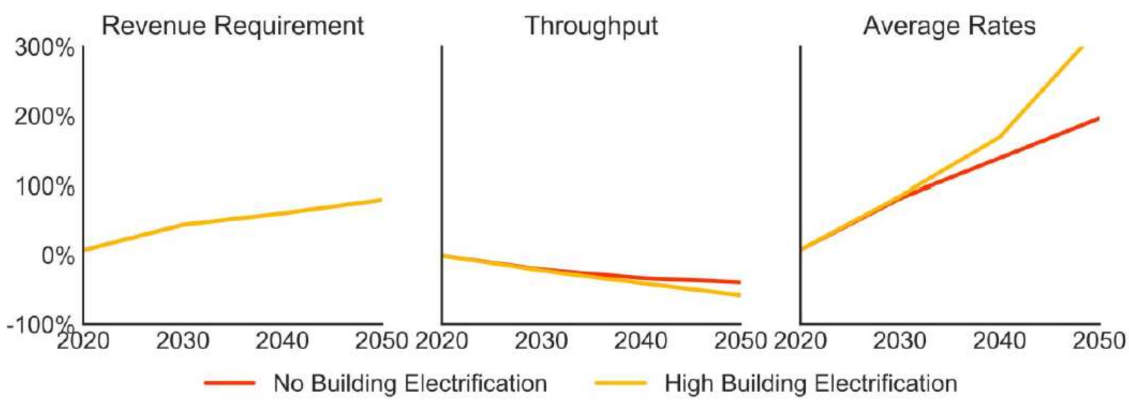
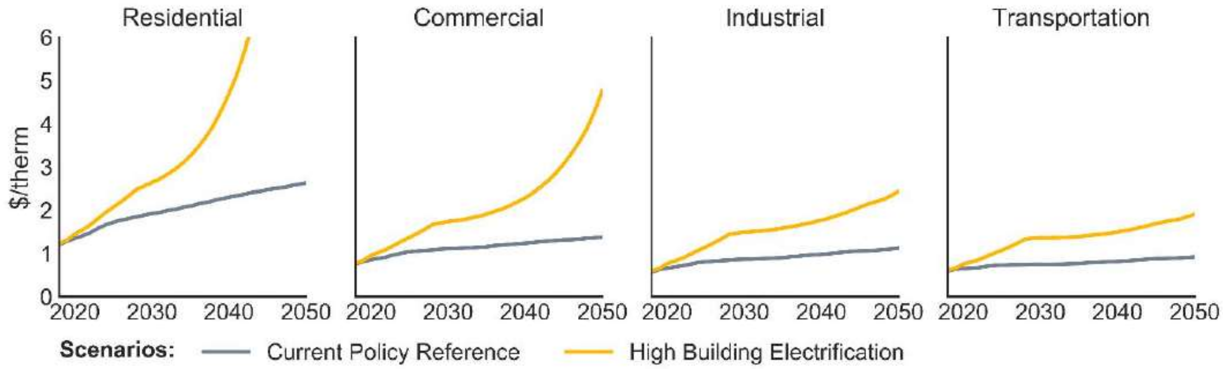


Figure D - Percentage Increase Relative to 2019 in Gas Sector Revenue Requirement, Throughput (retail gas consumption), and Average Rates. Assuming a high building electrification future (lower gas consumption) and increasing costs, average natural gas rates are forecasted to increase by 300%.



Source: E3

The Residential sector is expected to bear a higher burden relative to the other sectors as shown in Figure E, below.



Source: E3

6.4 Economic Impacts for Electricity Providers

Decarbonization of the electricity sector is expected to result in less upward rate pressure than the natural gas sector, especially in areas that already have a high concentration of carbon-free energy sources like the Pacific Northwest (PNW). As discussed in Phase 1 of the study, the Pacific Northwest (PNW) electric grid carbon intensity (CI) is much less than national average. The PNW generation portfolio is about 50% hydro and was an early adopter in wind generation making approximately 65% of electricity generation in the region[16] carbon free (EWEB's power portfolio is approximately 90% carbon-free).

Figure F - Existing PNW generating capacity[17] (MW)

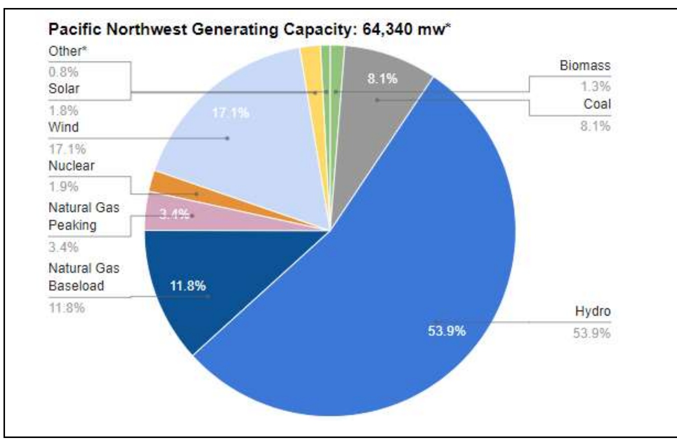
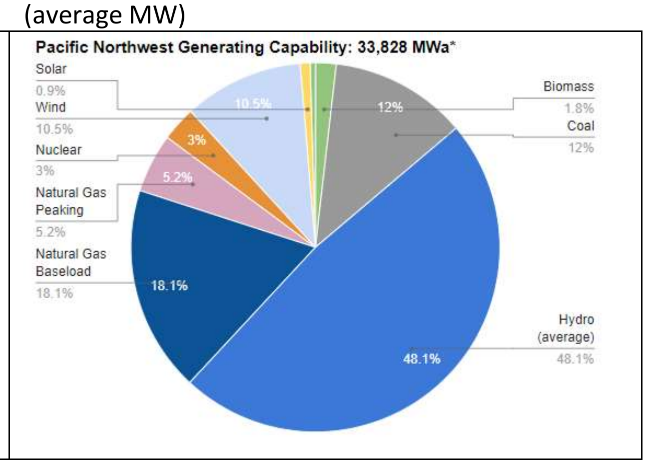


Figure G - Existing PNW generating capability[18] (average MW)



[16] https://www.nwcouncil.org/2021powerplan_defining-region

[17] Figures F - I (4 Figures total) Northwest Power and Conservation Council https://www.nwcouncil.org/2021-power-plan-technical-information-and-data

[18] The installed nameplate capacity of the system describes the manufacturer rated output of the generator. While a useful parameter, generators rarely run at full output at all times. Rather, by defining the average resource capability, we are describing the typical expected output that the generator could produce. This takes into account realistic discounts such as an estimated annual capacity factor for variable energy resources, forced outage rates for fossil fueled resources, and scheduled maintenance for nuclear resources (among other examples).

Going forward, coal generation is being retired from the system (Figure H) and new natural gas plant builds are expected to be limited. According to the Northwest Power and Conservation Council, most new generator additions (Figure I) are anticipated to be renewable, utilizing sources of energy like wind and solar to create electricity.

Figure H - Generation capacity additions and retirements

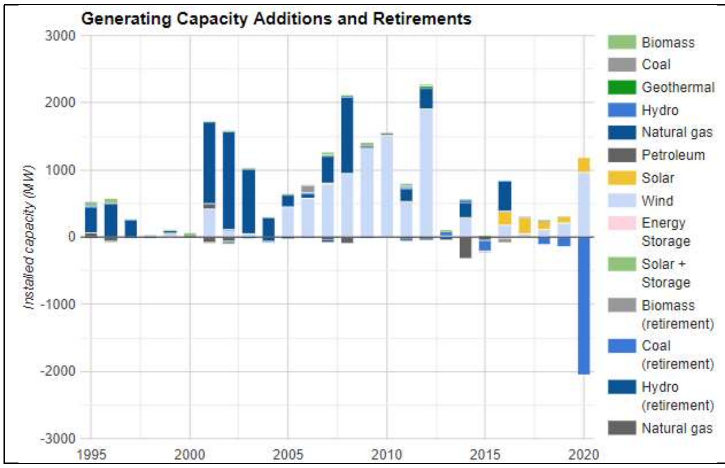
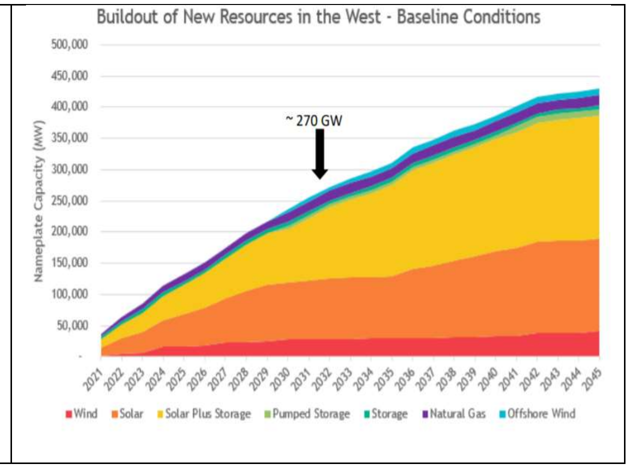
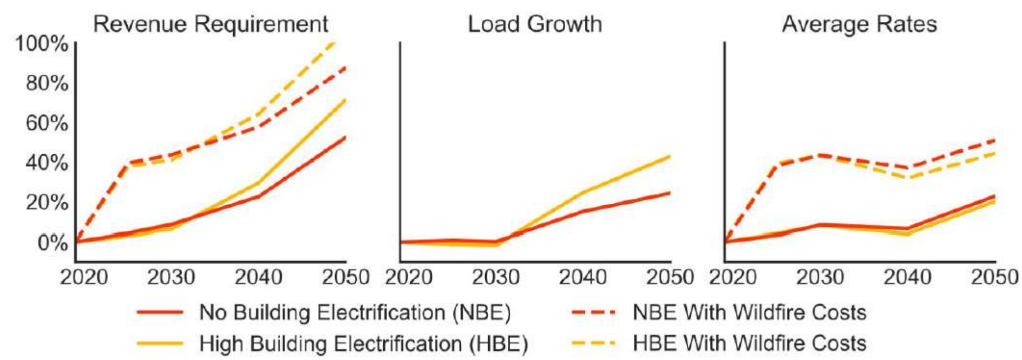


Figure I - Buildout of new resources in the west



The carbon intensity of the electricity sector is expected to decline over time and the rate impact is expected to be moderate. For example, per E3's analysis, California electric rates could increase 20 - 40% by 2050, depending on the scenario, where natural gas rates could increase by 300%.

Figure J – Percentage Increase in Electric Sector Revenue Requirement, On-Grid Loads and Average Rates

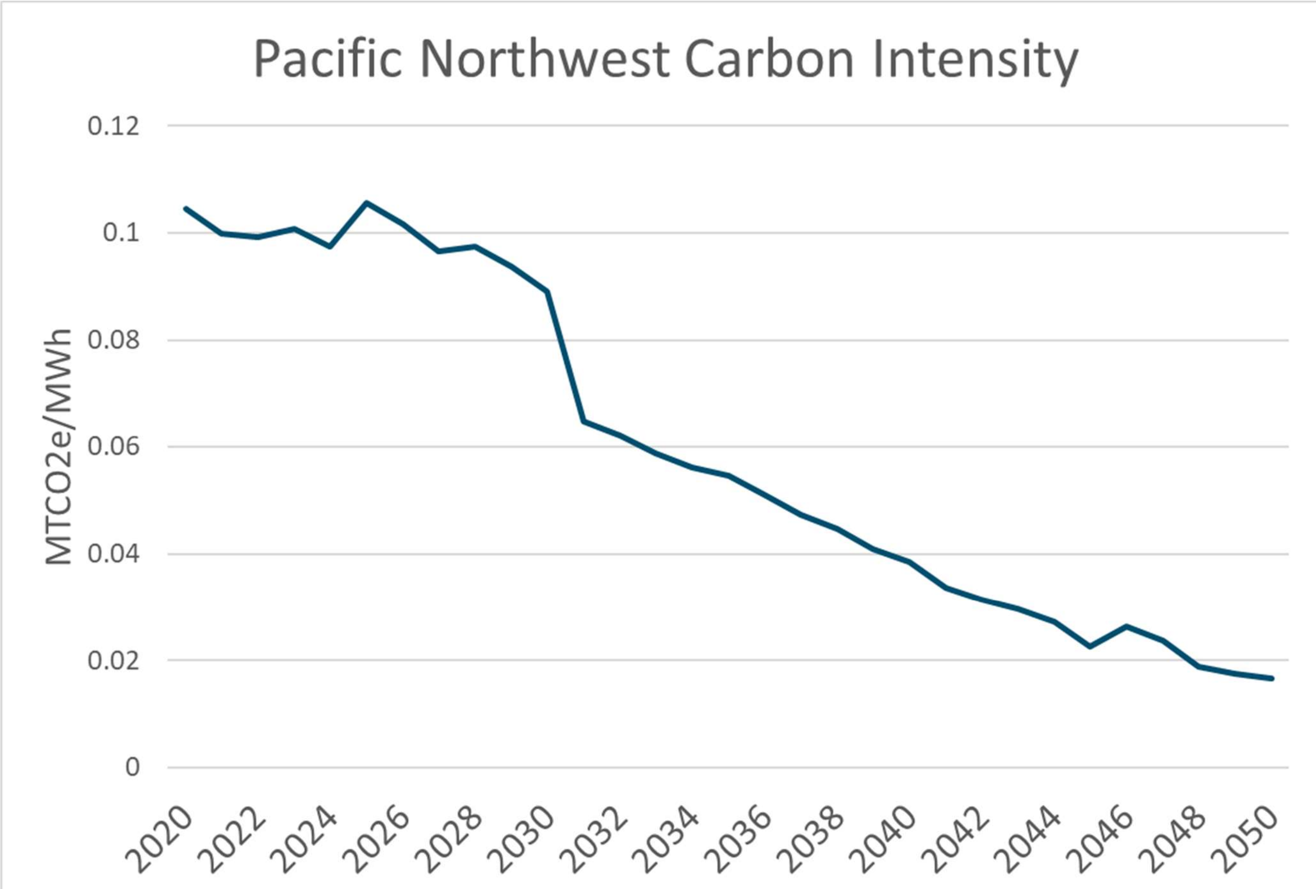


Source: E3

6.4.1 Declining Electric Grid Carbon Intensity

The modeling work performed in Phase 2 of the study utilized E3's modeling of the PNW, which has a lower carbon intensity than the NWPP footprint modeled in Phase 1 of the study. The PNW footprint is smaller and excludes some of the coal generation found in the larger NWPP region. However, the decarbonization trends in both the NWPP and PNW regions are similar, as both anticipate that as coal generation retires, it will be replaced by renewable electric resources. This is driven by legislative influences as well as the declining cost of solar and wind generation.

Figure K below shows the modeled PNW Carbon Intensity declining over time.



6.4.2 Electricity Supply Challenges

This transition to higher levels of renewables in combination with retirement of coal and other dispatchable resources creates new challenges for the electricity sector. The high build-out of solar generation is expected to present intra-day net load ramping challenges similar to those seen in California that will be increasingly difficult to manage. Dispatchable resources like hydro and natural gas will be important to integrate increased renewable, variable generation. Climate change is presenting new operational challenges to utilities with more volatility in customer demand as well as infrastructure challenges due to extreme weather and fire risks. In addition, adding new electrification load will put strain on existing generation, transmission and distribution assets. Significant electrification would impact the timing and amount of peak energy use in the region. The Northwest Power Pool (NWPP) is currently engaged in creating a resource adequacy program to help address these concerns. In addition, there has been increased regional discussion of market formation[19] in the West which some believe will be able to help the region better address these new reliability and resource adequacy challenges. However, these solutions will have financial impacts on the electricity supply and could be a threat to any economic benefits of electrification.

[19] https://www.energy.gov/eere/articles/new-doe-report-shows-how-continued-western-state-collaboration-can-support-affordable

7 Base Case Assumptions & Sensitivities

The next sections of the report present the economic analyses for electrification of light duty transportation and residential/small commercial buildings. These analyses rely on a number of assumptions for the base case (or expected 20-year future scenario). The purpose of this section is to define the key assumptions used throughout the study. Note that some assumptions are discussed in greater detail in the Modeling Sensitivities and Financial Impacts (Section 10).

7.1 General Assumptions

- **Inflation** is assumed to be 2% throughout the study period.
- All perspectives assumed a **discount rate** of 5%. In some benefit/cost analysis, participants are assumed to have higher discount rates compared to ratepayers and participants due to higher borrowing costs. However, for the purpose of this benefit/cost analysis and simplicity staff have chosen to use the same discount rate for all perspectives.
- **Transmission & distribution losses** are assumed to be 7%.
- No electrical **panel upgrade costs** were assumed for the Base Case and Aggressive Carbon Reduction (ACR) scenario. However, this was tested as a sensitivity assuming average panel upgrades would cost $2,000 for any electrification measure.
- The study excludes the influence of existing **EWEB incentives** in the benefit/cost analysis. However, Federal and State tax incentives for EV adoption were included.

Electricity Rate Increases

For the EWEB participant perspective, EWEB's electricity rates are assumed to increase 3% on average throughout the study period in the base case. For the ACR scenario, a 6% annual rate increase was assumed to reflect increased electricity supply costs.

Electricity Supply Costs – Energy

The EWEB ratepayer perspective assumes that load growth due to electrification will be met with market rate energy. Regional energy markets are assumed to continue to reduce carbon content to very low (but non-zero) levels by 2050. **Marginal energy costs** are modeled in Aurora[20] on an hourly basis. Modeled marginal energy costs range between $15-$33/MWh on average. However, peak pricing can be much higher than average., The maximum marginal energy price modeled in a single hour was $311/MWh. Staff modeled a 100% increase in the assumed hourly energy costs as a sensitivity for the EWEB Ratepayer perspective.

Electricity Supply Costs – Other

EWEB's existing **Generation Capacity** is assumed to be $16 per kW-year in the base case based on premiums paid for market energy purchases. The high generating capacity cost sensitivity assumes a $90 per kW-year cost, which is roughly the cost of a natural gas combustion turbine generator's capacity.

- **Transmission Capacity** is assumed to cost $24 per kW-year based on BPA's existing network transmission tariffs.

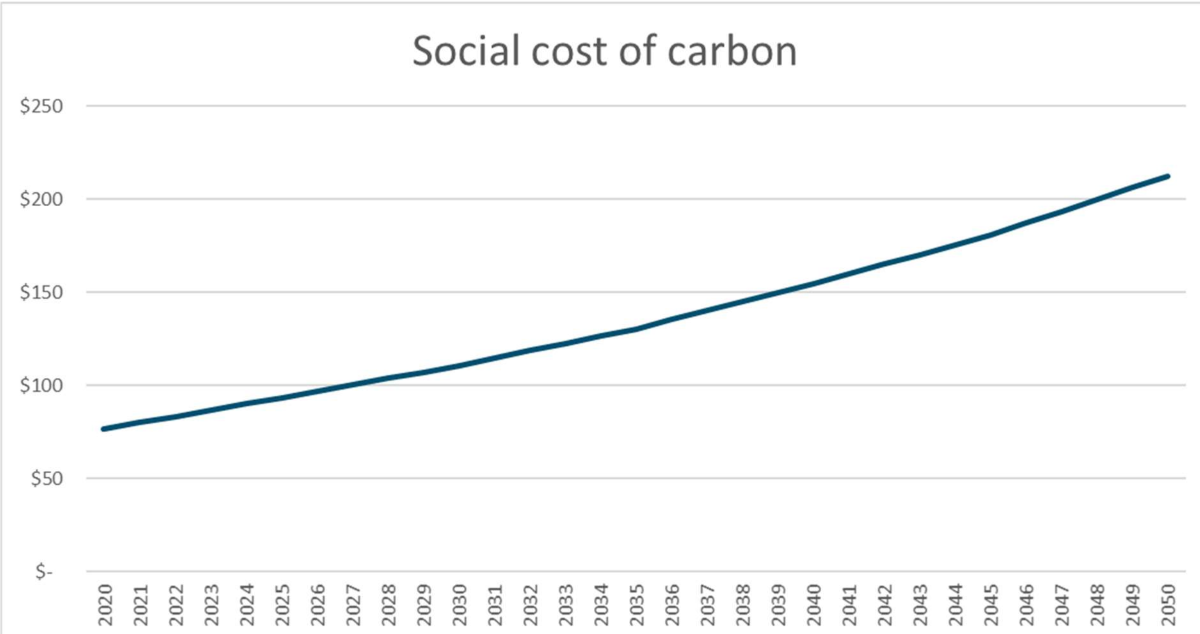
[20] Aurora is electric modeling forecasting and analysis software.

- **Distribution Capacity** is assumed to be $25 per kW-year based on marginal cost estimates for EWEB's existing distribution infrastructure (substations, poles, wires, etc.) and is an average across the system. This system wide average is to recognize that some portions of EWEB's existing system have capacity for growth with no costs, whereas other neighborhoods will require capacity upgrades.

Carbon Emissions Factors

- **Gasoline CO2** = .0087 metric tonne per gallon (Raw Data from GREET 2018)
- **Natural Gas CO2** = 0.005307 metric tonne per therm (Combustion emissions only. Including upstream methane emissions would increase this factor.)

Social cost of carbon based on values for Washington's Clean Energy Transformation Act (CETA)[21]



7.2 Transportation Electrification – Key Assumptions

- Vehicle lifetime is assumed to be 12 years[22]
- Conventional gas vehicles are expected to improve in efficiency over time. EV costs and carbon are calculated relative to the purchase of a new conventional gas vehicle. Conventional gas vehicles are assumed to have 34 MPG in 2021 and improve steadily to 49 MPG by 2040. EV efficiency may improve over time, but that remains uncertain. Therefore, the assumed efficiency of EVs (.31 miles/kWh) is held constant over time.
- Future gasoline prices were derived from the 2021 Energy Information Administration Annual Energy Outlook (EIA AEO) Pacific region forecasts. The base case assumes mid-level of gasoline price increases over time, which is approximately 4% on average.
- Home and Workplace Charging efficiency (Level 1 & 2) = 90%

[21] https://www.utc.wa.gov/regulated-industries/utilities/energy/conservation-and-renewable-energy-overview/clean-energy-implementation/social-cost-carbon

[22] https://ihsmarkit.com/research-analysis/average-age-of-cars-and-light-trucks-in-the-us-rises.html

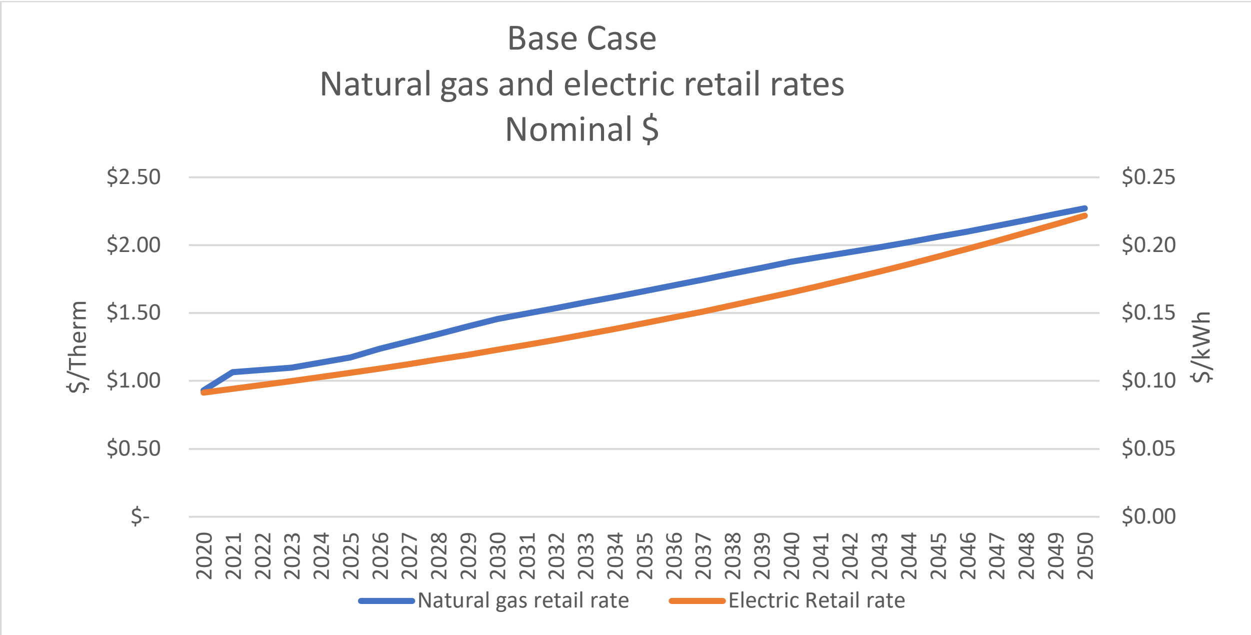
- Home Charging Access: 34% Level 1, 40% Level 2, 26% no home charging access.
- DC Fast Charging Efficiency: 85%

7.3 Building Electrification – Key Assumptions

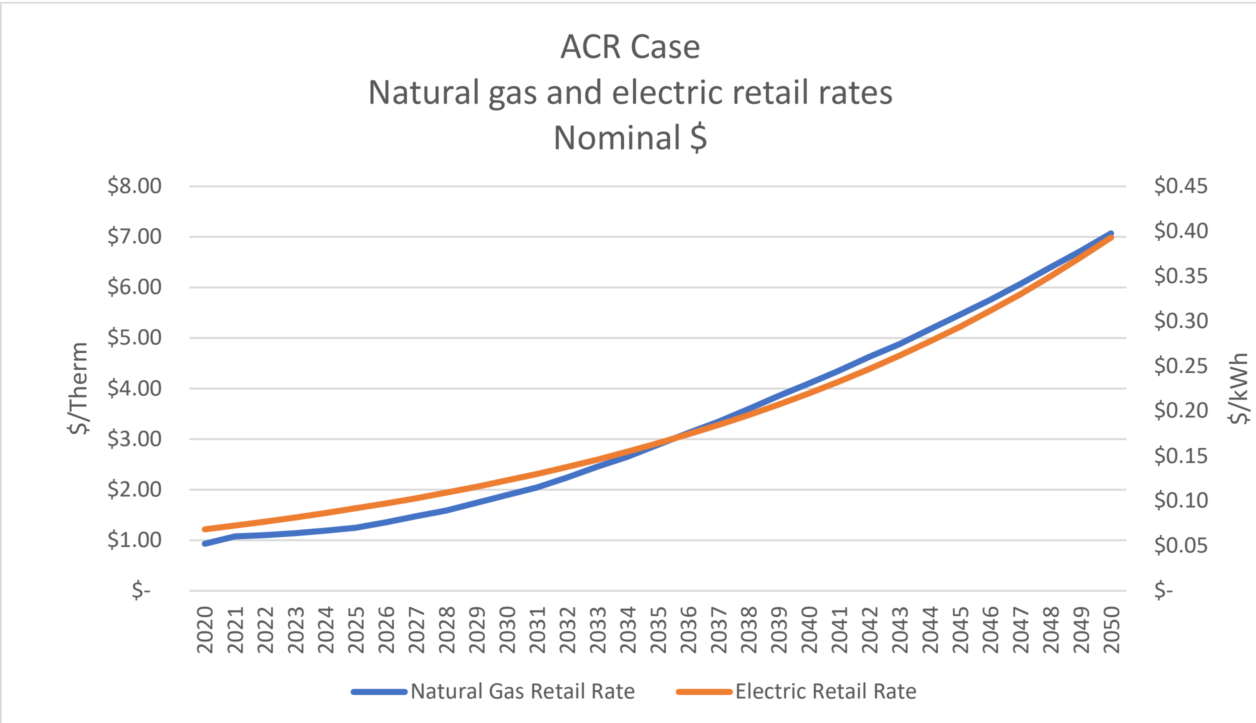
- Water heater lifetime: 10 years. Space Heater (heat pump/furnace) lifetime: 16 years.
- Single family dwelling (SFD) is assumed to be a 2,500 square foot (sq ft), 2-story detached home. Multi-family (residential) is assumed to be a 3-story, residential building containing 24 units with 1,400 sq ft. of space per unit. Small office (commercial) is assumed to be a 5,500 sq ft single story building, with average occupancy of about 28 people.
- The study assumed a 4.5-ton heat pump for SFD and 2.5-ton heat pump for MFD. Small office heat pump cost was assumed to be equivalent to 5 heating/cooling zones, each with a 3-ton heat pump unit (15 tons total). All Water heating units are assumed to be 3 tons.
- This study focuses on retrofit of existing natural gas buildings. New devices are installed at existing device end-of-life.
- For both HVAC and water heating, the model compares "like-for-like" replacement with a gas appliance. Heat pump HVAC unit is assumed to replace both gas furnace and air conditioner. Because spaces heated with natural gas utilize ducting, only ducted heat pumps were studied. However, ductless systems or "mini splits" offer a similar electrification opportunity as the ducted, cold-climate heat pumps studied.
- By default, the model assumes that the existing air conditioning (AC) is not fully depreciated at furnace expiration in the retrofit. Thus, only 50% of a new AC cost is considered "avoided" in the electrification process.
- Equipment and installation costs are based on cost estimates from the environmental and engineering firm AECOM and benchmarked against data from the Energy Trust of Oregon.
- Hourly labor rate for HVAC / water heater installation in Eugene based on data from the Bureau of Labor Statistics.
- In the Base Case, Renewable natural gas blend is assumed to be 15% RNG by 2030 and 30% by 2050, based on Oregon Senate Bill 98. Under the "high" RNG blending sensitivity analysis, it is assumed that the percent of RNG in the natural gas system will increase from 3% today at a consistent rate until it reaches 80% RNG by 2050.
- Retail rates for natural gas will be impacted by the RNG assumptions as well as commidity price forecasts. See the Independent Variables and Scenario Definition section for further details on RNG blening, RNG prices and natural gas commodity pricing.
- Natural Gas Delivery rates are assumed to increase at 2% annually in the Base Case, which is roughly the rate of inflation.
- From the participant perspective, "Avoided Gas Bills" is the avoided costs of natrual gas for the customer including the delivery charges to the customer. The society perspective looks at "Avoided Gas Supply Costs" which is the avoided natural gas commodity costs avoided by the natural gas utility. Because this study is focused on electrification of existing natural gas customers, the natural gas delivery

infrastructure is already built and considered unavoidable in this study. This may be a conservative assumption over time, should Northwest Natural be able to avoid repairs and maintenance costs due to electrification. These delivery infrastructure cost would be fully avoidable in new buildings, which would increase the societal benefits of going "all electric" in new buildings. However, new building electrification is outside the scope of this Phase 2 analysis.

- The overall impact of these assumptions is that natural gas prices (rates) and electric prices were estimated to annually escalate at similar rates in the Base Case (approximately 3-4% per year).



- In the ACR scenario, natural gas prices (rates) were estimated to annually escalate at slightly higher pace compared to electric prices (6.6% for natural gas and 6% for electric, annually).



8 Transportation Electrification Base Case Findings

HIGHLIGHTS

- While federal and state incentives help provide benefits to EV purchases today, the benefits of owning an EV are expected to dramatically improve by 2030, even as incentives go away.
- EVs provide benefits for owners, ratepayers, and society.
- Economic analysis indicates that EV adoption will rapidly increase after 2030, with nearly 85% of all vehicles on the road being electric by 2040.
- Phase 2 of the study estimates a lower coincident peak of EV charging (1 kW per EV) compared to Phase 1 of the study due to increased levels of off-peak workplace and public charging in the future.
- By 2040, Eugene's total carbon emissions could be reduced by 38% due to EV adoption.

In Phase 2 of this study, the benefits and costs of purchasing an electric vehicle (EV) were quantified and analyzed from EWEB participant, EWEB ratepayer, and society perspectives. This analysis was performed over a 20-year future time horizon to understand how the economic value of purchasing an electric vehicle is expected to change over time. As the cost of battery technology and the efficiency of EV manufacturing improves, the purchase price of an EV is expected to decrease over time.

Figure L – Vehicle purchase prices over time as forecasted by the ICCT

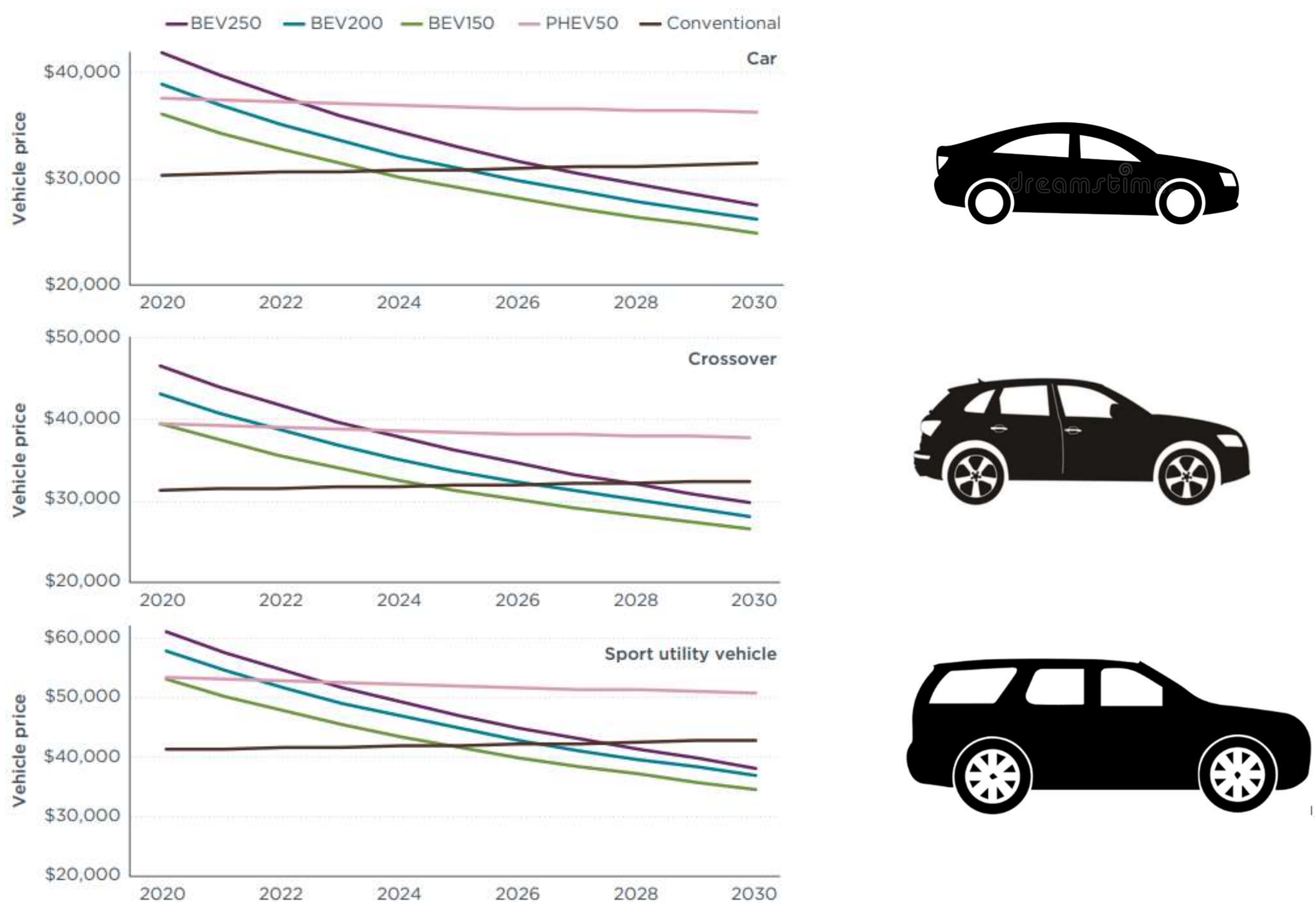
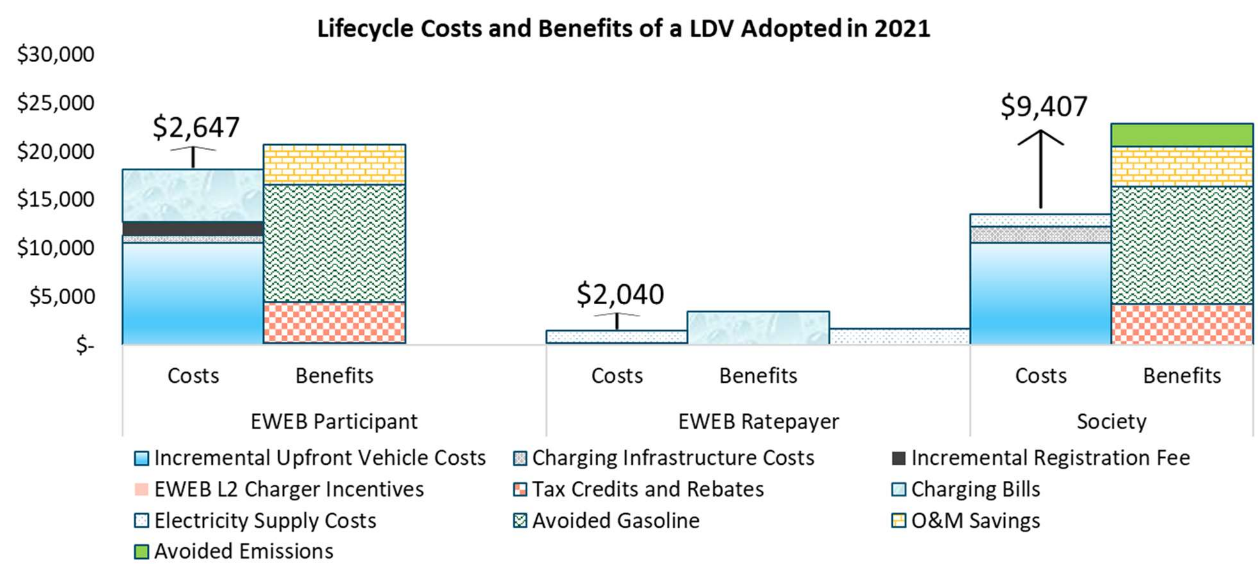


Figure L, above[23], from the International Council on Clean Transportation (ICCT), compares the forecasted purchase price of EVs, at various battery sizes[24], with the forecasted price of conventional gas vehicles. As shown in Figure L, all battery electric vehicles, regardless of size or vehicle type, are expected to become cheaper than conventional cars before 2030. Declining purchase price projections is a key component of the benefit-cost analysis and one of the largest drivers of forecasted EV adoption. Figure L shows that unlike EVs, PHEVs are not anticipated to reach cost parity with conventional vehicles, primarily due to their smaller battery sizes and need for both electric and combustion engine components. While pricing forecasts vary, with some studies showing faster or slower cost reductions compared to the ICCT trajectory, this electrification analysis assumes that projected cost reductions are achievable at the pace shown in the ICCT study.

Incentives play an important role address current price disparities between EVs and conventional vehicles. Federal tax credits (up to $7,500) are available for certain models of electric vehicles, but the number of qualifying vehicles is currently limited to 200,000 per manufacturer. For example, EVs made by Tesla no longer qualify for federal tax credits because Tesla vehicle sales have surpassed this cap. The Oregon Clean Vehicle Rebate Program offers a cash rebate for Oregon drivers who purchase or lease an EV and is set to run through January 2, 2024. The standard $2,500 rebate is limited to vehicles with a battery capacity of 10 kWh or more. A $1,500 rebate is offered for vehicles with a battery capacity less than 10 kWh. In all cases a vehicle must have an MSRP less than $50,000 to qualify. Oregon also offers the Charge Ahead rebate, which is an additional rebate (up to $2,500) that participants can receive based on income qualifications. EWEB offers incentives (up to $500) for Level 2 charger installation. Due to the uncertainty of future incentives, EWEB's benefit-cost analysis included only the incentive programs available today. Given incentive program limitations, it is assumed that only a portion of current incentives would be applicable to the average EV purchase (accounting for some vehicles not qualifying).

A discounted cash flow of costs and benefits for an EV adopted in 2021 under base case conditions is presented in Figure M, below, from the perspective of the EWEB participant, EWEB ratepayer and society.

Figure M - Benefit/cost Analysis of a Light Duty Vehicle adopted in 2021



[23] From Update on electric vehicle costs in the United States through 2030 https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf

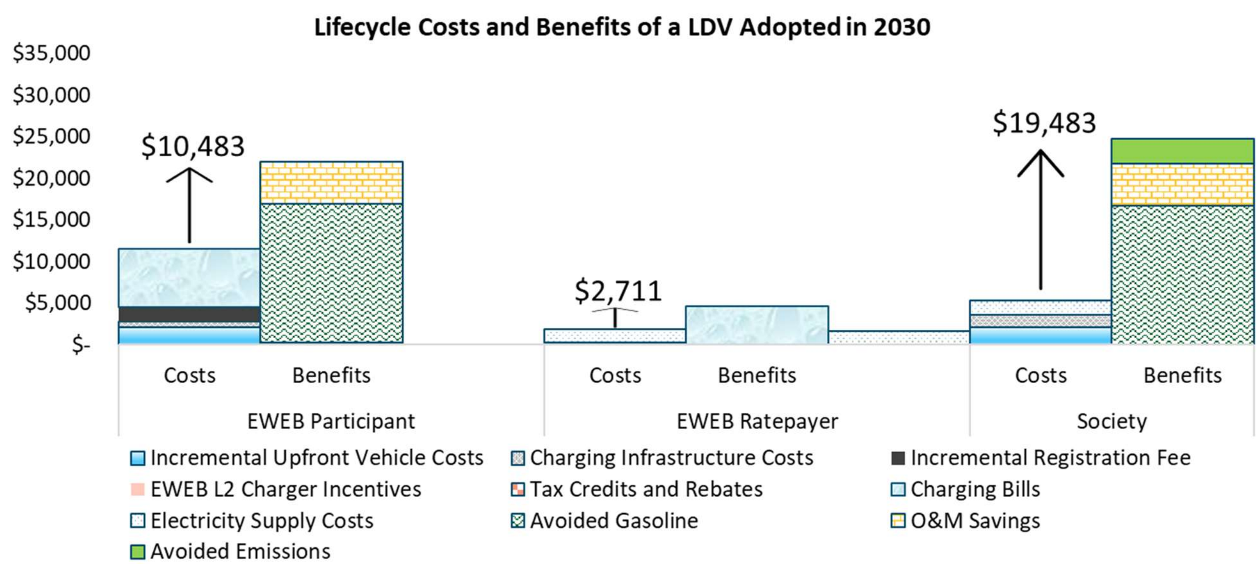
[24] The series names in the chart correspond with the potential vehicle range based on battery size. For example, BEV150 is a Battery Electric Vehicle with an assumed range of 150 miles. PHEV50 is a plug-in hybrid with 50 miles of range.

The base case assumes moderate increases in both gasoline and EWEB electricity rates over time (3-4% on average). Overall, the purchase of an EV presents a benefit to the EWEB participant, EWEB ratepayer and society on a net present value (NPV) basis.

In 2021, Federal tax credits and Oregon rebates are one of the primary reasons that there is a net present benefit to the EWEB participant. Without these incentives, purchasing an EV would become a net cost to the EWEB participant. From the EWEB ratepayer perspective, the adoption of an electric vehicle presents more than twice the net benefit received by the EWEB participant. The EWEB ratepayer benefit is primarily realized through the increased sales of electricity to the EWEB participant, the proceeds of which could be used to cover the fixed costs of the utility, reduce rates, pay for distribution infrastructure investments, or fund additional incentives for EV adoption. The society perspective shows the benefits from the other two perspectives and adds an additional benefit of $2,300 for carbon reduction. The NPV of carbon reduction is estimated using the social cost of carbon[25] multiplied by the annual emission savings over the vehicle life. Annual emissions savings are calculated by subtracting the carbon emissions associated with EV charging (based on a future year's electric grid carbon intensity) compared to a new gasoline vehicle's efficiency (MPG efficiency is assumed to improve over time in the study period).

By 2030, the net benefit of purchasing an EV is expected to gradually increase for the EWEB participant, EWEB ratepayers, and society. This increase is primarily driven by the projected declines in EV purchase price. These calculations assume that State and Federal incentives phase out before 2030. In Figure N, below, the benefit-cost calculations are shown for purchasing an EV in 2030.

Figure N - Benefit/cost Analysis of a Light Duty Vehicle adopted in 2030

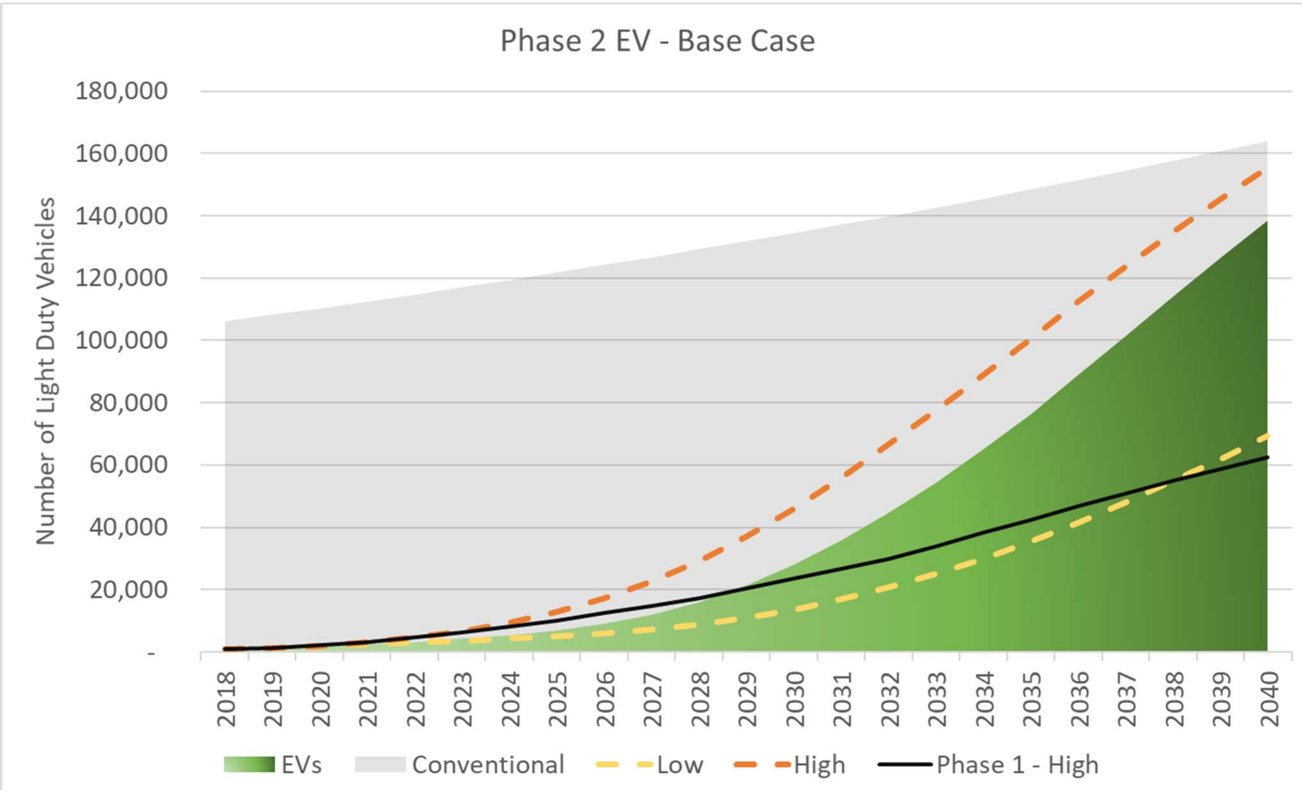


The incremental upfront costs for purchasing an EV are expected to decline from $10,500 in 2021 to approximately $2,000 in 2030. This forecasted decline in upfront costs, combined with projected annual

[25] To estimate the value of emissions reductions, the model used the social cost of carbon as adopted in the Washington Clean Energy Transformation Act and adjusted for an assumed inflation rate of 2%. The resulting social cost of carbon forecasted prices from $80/MTCO2e in 2021 to $155/MTCO2e in 2040. https://www.utc.wa.gov/regulated-industries/utilities/energy/conservation-and-renewable-energy-overview/clean-energy-implementation/social-cost-carbon

savings[26] leads to a steady improvement in the simple payback period for EVs (declining from 6 years simple payback in 2021 to only 2 years in 2030). Based on this improved simple payback period, the pace of EV adoption is expected to rapidly increase as the EV market matures[27]. Assuming the cost reductions projected are realized, this leads to much higher estimated EV adoption compared to Phase 1 of the electrification study published last year.

Figure O – Adoption forecast for EVs over time



The updated EV adoption forecast, shown in Figure O above, is represented by the green shaded area. To illustrate how sensitive the pace of EV adoption can be to forecast inputs, high and low trend lines were added in orange and yellow, respectively. The high trend line assumes the EV market matures two years faster than the base case, and the simple payback period of purchasing an EV improves over time. The low adoption trend line assumes a market maturing two years slower than base case and that the simple payback period in 2021 remains constant for the next 20 years. These adoption trends consider the economic benefits of EV adoption but are not adjusted for legislative influences which can accelerate or delay adoption of EVs.

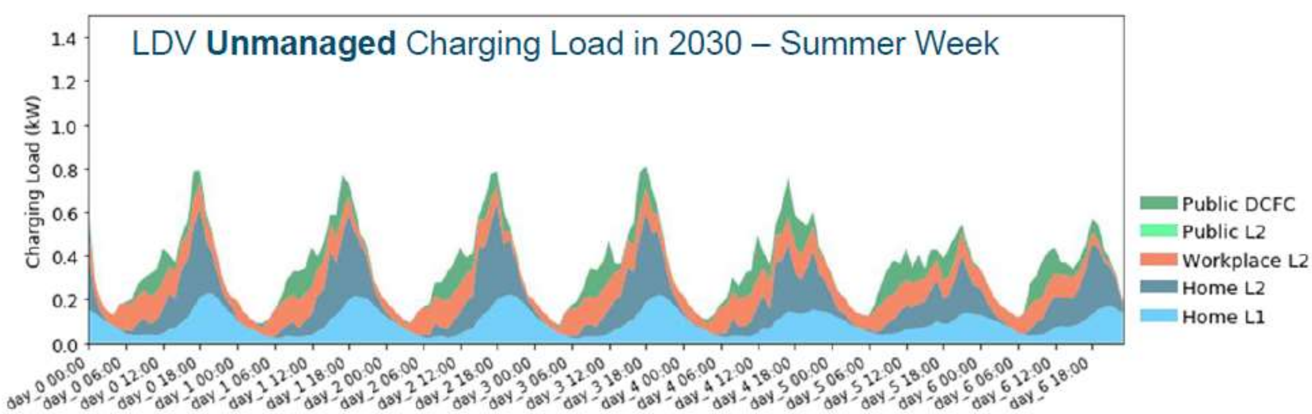
In the base case scenario, EWEB's adoption model estimates that in 2021 approximately 60% of customers would purchase an EV based on the simple payback analysis under "mature market" conditions. However, EVs only account for 2-3% of new car sales today, which implies that the market maturity for EV's remains a major constraint to EV adoption. Examples that the EV market still needs time to mature include lack of broad EV offerings (crossovers, SUVs, and pickups), battery range anxiety, low dealer EV inventory, and lack of customer awareness of the financial benefits of EVs in general. As EV availability and marketing improve, the market will mature to the point where there are fewer barriers for potential EV customers. At this time, many of the large

[26] Annual savings associated with EV ownership come primarily from fuel savings (electricity fueling costs lower than gasoline costs) and reduced operations and maintenance costs.
[27] See Vehicle Manufacturer Trends section for further discussion of market maturity.

vehicle manufacturers are committing to increased or even 100% electric offerings within the next 15 years, which indicates that the market will continue to mature over time.

8.1 Energy Impacts of EV Adoption

EWEB worked with E3[28] to incorporate more advanced modeling of charging behavior into Phase 2 of the electrification analysis. The model assumed drivers would choose the least cost charging options available to them, while also considering driving patterns, availability of home and workplace charging, and a forecasted mix of battery sizes. Utilizing these variables, E3 simulated a variety of charging profiles in the year 2030 (halfway through the study period) and scaled the load to a single vehicle. The chart below represents the unmanaged charging load at the scale of a single light-duty vehicle (LDV), but with the collective profile and mix of charging locations across an entire population of drivers.

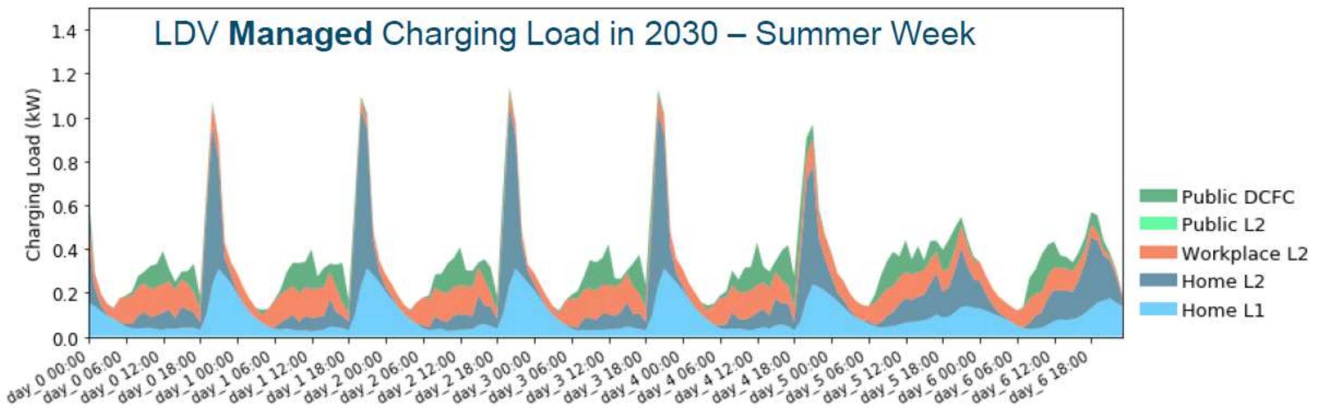


In Phase 1 of the electrification study, staff utilized a 2018 NREL charging behavior simulation to estimate the load shape of EV charging. The NREL study estimated that a single EV would add approximately 1.5 kW to system peak. However, E3's modeled results (above) estimate a lower peak EV load of less than 1 kW per EV. The difference between the studies is driven by E3's assumption of higher levels of workplace and public charging in the middle of the day. E3's model confirms that home charging remains the largest contributor to peak EV load, but the peak impact can be lessened through increased day-time workplace and public charging. This modeling is believed to be more representative of the charging behavior in 2030 as it reflects the reality that some EV drivers will not have access to home charging, or that people who do have home charging will still choose workplace and public charging based on the location of their vehicle throughout the day.

E3 simulated "managed" EV charging behavior to show the potential benefits of shifting EV charging away from EWEB's existing system peaks. This load profile assumes drivers would choose to optimize (find the cheapest solution) for charging their EV given a time of use (TOU)[29] rate. This load profile assumes that even though a customer's electric energy usage has shifted, they're still able to charge enough to complete their trips. Further, the E3 load profile assumes that after a high TOU rate period, customers will stagger vehicle charging start times to avoid a spike in consumption at exactly 10PM each night. As vehicle electrification increases, EWEB may want to develop programs to encourage this staggered charging behavior under a TOU rate structure.

[28] Energy + Environmental Economics - https://www.ethree.com/

[29] Time of use rates are rate structures which incent a customer to change their electric usage patterns, because they typically charge higher prices for consumption during peak periods.



It should be noted that the non-coincident load impact of managed charging is 1.3 kW per EV, which is higher than the unmanaged impact of 1 kW per EV. This is because managed vehicles are intentionally delaying their charging start times until non-peaking periods, to mitigate the impact to EWEB's existing system peak load. In other words, managed vehicle charging load is concentrating in off-peak periods to better utilize existing system infrastructure (a benefit to EWEB ratepayers), whereas unmanaged charging adds to EWEB's existing system peaks. Adding to EWEB's existing peaks will increase the potential need for future transmission and distribution system upgrades (a cost to EWEB rate payers.) Even with a well-managed program, it is assumed that some EV charging will occur during EWEB's peak load periods, which is why managed charging behavior still adds to EWEB's existing system peaks. From a high level, unmanaged charging is approximately double the peak impact of managed charging.

The table below shows the total forecasted change in average energy and peak load (comparing unmanaged and managed charging behavior) given the adoption ranges presented above. The percentage increase shown is based on EWEB's current system average load of 270 MW and a 1-in-10 peak of 510 MW.

2030	Low	Base Case	High	% Increase
Average	6 aMW	12 aMW	19 aMW	2-7%
Unmanaged Peak	13 MW	27 MW	43 MW	3-8%
Managed Peak	7 MW	15 MW	24 MW	2-5%

2040	Low	Base Case	High	% Increase
Average	29 aMW	57 aMW	64 aMW	11-24%
Unmanaged Peak	68 MW	131 MW	147 MW	14-29%
Managed Peak	40 MW	77 MW	86 MW	8-17%

Under a high EV adoption scenario, the Phase 2 peak energy impacts are 18% higher than estimates provided in Phase 1 high scenario and these impacts happen 10 years sooner (by 2040). This is due to increased levels of anticipated EV adoption, which is partially offset by the lower peak impact, per EV, derived from E3's advanced charging behavior model. Managed charging behavior significantly lowers the overall peak impact to the utility but requires coordination and greater diversification of charging locations to achieve. EWEB will need to work with customers in the coming years to know when and where to charge to avoid system peaks. Location diversity can be achieved through expanded investments in public and workplace charging infrastructure.

Currently, EWEB offers residential and commercial charging station incentives as well as education materials and workshops about the importance of charging during off-peak times[30]. New EWEB programs are being rolled out that support investments in EWEB-owned charging infrastructure (including DC Fast Charging), expanded EVSE

[30] http://www.eweb.org/residential-customers/going-green/electric-vehicles/ev-incentives

Infrastructure rebates (like multi-family EVSE), and electric mobility rebates (including e-bikes). In addition, staff are developing programs to expand access to EV technology through an affordable housing EV sharing pilot and electric mobility community grants.

8.2 EVs and Carbon Reduction

The City of Eugene's Climate Action Plan 2.0 estimated that annual carbon emissions from the transportation sector were 532,000 MTCO2e in 2017 (over 50% of total emissions[31]). Adjusting for the improved efficiency of gas engines over time, as well as the continued decline in carbon emissions from the regional electric grid, it is estimated that EV adoption could reduce transportation sector emissions by 14% by 2030. If the rapid transition to EVs continues after 2030, the annual transportation sector emissions could be reduced by 73% by 2040. Under base case conditions, these carbon reductions could happen nearly a decade earlier than was shown in Phase 1 of the electrification study.

	2030	**2040**
Number of EVs – Base Case	28,000	130,000
Estimated Annual Carbon Savings	(74,000 MTCO2e)	(390,000 MTCO2e)
% Carbon Reduction - Transportation Sector	14%	73%
% Carbon Reduction – Total Emissions[32]	7%	38%

9 Building Electrification Base Case Findings

HIGHLIGHTS

- Heat pump equipment for space and water heating has a higher upfront cost when compared to natural gas equipment.
- Economic analysis indicates minimal space heating electrification and moderate levels of water heater electrification by 2040.
- Base Case building electrification is estimated to increase average and peak energy use by less than 1% by 2040. Of the technologies studied, cold climate heat pumps have greatest carbon reduction potential, but have the lowest likelihood of adoption due to high upfront costs.

9.1 Background

Electrification of buildings is a key component to a comprehensive de-carbonization strategy. Removing or replacing the usage of fossil-based fuel (primarily natural gas) for space and water heating eliminates most of the greenhouse gases directly emitted by buildings. During Phase 1 of the electrification study, staff examined the impacts from three electrification scenarios that were based on fixed adoption percentages (10%, 50%, and 80% unitary adoption rates). This was an effective means to understand a wide range of potential impacts for energy, demand, and carbon reduction caused by switching from fossil-based fuels to electric end uses. While insightful, the Phase 1 analysis lacked economic grounding and wasn't helpful in understanding the likelihood of building electrification. In the absence of a legislated mandate to fuel switch, interest in building electrification

[31] Transportation is 53% of emissions using market-based accounting method for 2017. City of Eugene Climate Action Plan 2.0 - https://www.eugene-or.gov/4284/Climate-Action-Plan-20
[32] Total City of Eugene Cap 2.0 Market-based emissions in 2017 was 1,013,600 MTCO2e

will likely be governed by financial constraints. As such, the Phase 2 analysis examines adoption rates of various space and water heating technologies based on the economics of consumer choice.

The economics of building electrification were analyzed using three different assumed building types: single family dwellings (SFD), Multifamily Dwellings (MFD) and Small Office. The Small Office economic analysis is a small subset of the total commercial sector (about 7%), whereas SFD and MFD buildings are considered residential sector. It is estimated that there are approximately 16,300 SFDs and 3,900 multi-family units served by natural gas today (electrification opportunities). Electrifying SFDs is relatively simple, as natural gas space and water heating systems can generally be replaced with like-for-like electric equipment choices (like ducted heat pumps and heat pump water heaters).

The path to commercial electrification is more complex than the residential segment because commercial end use of natural gas is generally more varied. Only small office buildings share similar equipment replacement options like those found in the residential sector. As such, commercial segment electrification will require a broader range of equipment to be studied, with unique economic factors, which are beyond the scope of this phase of the study. As such, only the Small Office segment of the commercial sector will be analyzed in this economic analysis.

For space heating, customers have multiple electric technology options to consider when replacing existing natural gas technology. In addition, many homes with natural gas heating have separate air conditioning units (cooling load for EWEB today). As such, both space heating and space cooling needs were considered in the analysis.

The space and water heating technology options considered in this study include:

Space Heating Equipment	Modeled Efficiency (Single-family)	2021 installed cost[33] (Single-family)
Gas Furnace	80 AFUE	$4,800
Split Air Conditioner	10.8 EER, 2-speed	$6,100
Ducted Standard performance heat pump	12.5 EER (cooling), 8.5 HSPF (heating), 2-speed, 32° shut-off	$9,800
Ducted Cold Climate Heat Pump	13 EER (cooling), 10.5 HSPF (heating), variable, 5° shut-off	$16,400
Dual-fuel Heap Pump	Standard HP + Gas Furnace	$11,000

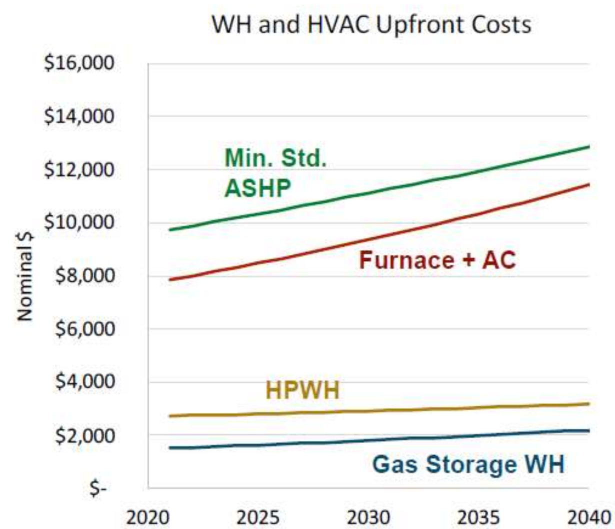
[33] Equipment and installation costs are based on cost estimates from AECOM and benchmarked against data from the Energy Trust of Oregon. The study assumed a 4.5-ton heat pump for SFD and 2.5-ton heat pump for MFD. Small Office heat pump cost was assumed to be equivalent to 5 heating/cooling zones, each with a 3-ton heat pump unit (15 tons total). All Water heating units are assumed to be 3 tons.

It should be noted that during this phase of the study, staff did not analyze the potential use of ductless heat pumps or "mini-splits" as a replacement technology for natural gas heating. While ductless heat pumps will likely be installed in specific electrification applications, it is more likely that a customer will choose to swap out their ducted natural gas furnace with another ducted electric or dual fuel solution. The same inverter-driven, variable speed compressor technology used in mini-split systems is used in cold climate heat pump technology and is included in this analysis. Customers choosing to electrify with ductless systems may have similar characteristics to the cold climate heat pumps modeled in this study. If a customer's needs can be met with a more affordable ductless system, then electrification may be more financially beneficial for that customer.

Water Heating Equipment	Modeled Efficiency (Single-family)	2021 installed cost[34] (Single-family)
Gas Storage[35]	0.6 Uniform Energy Factor (UEF)	$1,500
Heat Pump Storage	3.5 Energy Factor (EF)	$2,700

9.2 Upfront Equipment Cost over Time

Standard air-source heat pumps have matured over the last few decades with proven reliability and efficiency standards. It is anticipated that over time, there will be only slight improvements in the cost competitiveness of heat pump equipment due to improvements in the technological learning curve or efficiencies gained through additional production scaling efforts. Equipment cost are roughly 50% of the total upfront cost of new space and water heating installations. The remaining upfront cost includes things like dealer markup, installation/ fabrication labor, electric labor, other parts and materials, and administrative overhead. Because the equipment itself is approximately half of the total cost, the anticipated cost improvements over time are muted. Unlike EV's, where the technology is still in early development, electric choices in space and water heating are more mature and unlikely to become cheaper than their gas counterparts.



In the chart to the right, minimum standard air source heat pump (ASHP) prices increase at a slower pace relative to gas furnace combined with air conditioning. Heat pump water heaters (HPWH) are also projected to remain more expensive than a gas storage water heater.

[34] Equipment and installation costs are based on cost estimates from AECOM and benchmarked against data from the Energy Trust of Oregon.

[35] Gas storage water heaters utilize a tank to hold the heated water. This technology is much less expensive than on-demand (tankless gas water heaters).

9.3 Other Economic Influences

9.3.1 Air Conditioning Unit Depreciation

This study assumes that existing natural gas customers have heating and cooling energy use and that the air conditioning (AC) unit is only 50% depreciated at furnace end-of-life. For example, the combined cost of an air conditioner ($6,100) and gas furnace ($4,800) in 2021 is $10,900 whereas a standard performance heat pump is assumed to cost $9,800 (an upfront savings of $1,100). However, because this study focuses on the retrofit of existing natural gas buildings, it is assumed that only 50% of the air conditioner cost can be avoided ($3,050) when electrifying, which makes an electric heat pump have a higher upfront cost relative to a gas furnace and AC unit combined. However, some customers do not currently have air conditioning. Thus, customers who are looking to replace their furnace, are looking to purchase an AC unit for the first time, or their existing AC units are at end of life will likely see greater value if they choose to electrify with a heat pump instead.

9.3.2 Rebates and Incentives

The benefit/cost analysis performed in the study does not include the influence of incentives or rebates. For residential customers, EWEB offers energy efficiency upgrade rebates for ductless ($800) and ducted ($1,000) heat pumps. These HVAC rebates are also available to natural gas customers looking to electrify. Commercial EWEB customers can also qualify for $350 per ton heat pump rebates if they are electrifying[36]. Northwest Natural offers new and existing natural gas customers incentives towards natural gas appliances, but they are subject to certain eligibility requirements[37]. EWEB currently offers an $800 incentive for heat pump water heaters and Northwest Natural offers a $500 rebate for natural gas water heaters[38]. These incentives can play an important role in the benefit/cost analysis for customers, but the qualification process can make it difficult to model across a larger population of customers. Further, these incentives can serve as a tool for utilities to influence customer choice as well as address inequity. For example, it is common to offer higher incentives to LMI customers. Incentive programs and rebates will be important tools that can change the baseline economics studied in this report and can be used to influence the pace and likelihood of electrification.

9.4 Base Case – Building Electrification

9.4.1 Benefit-Cost Analysis – Residential SFD

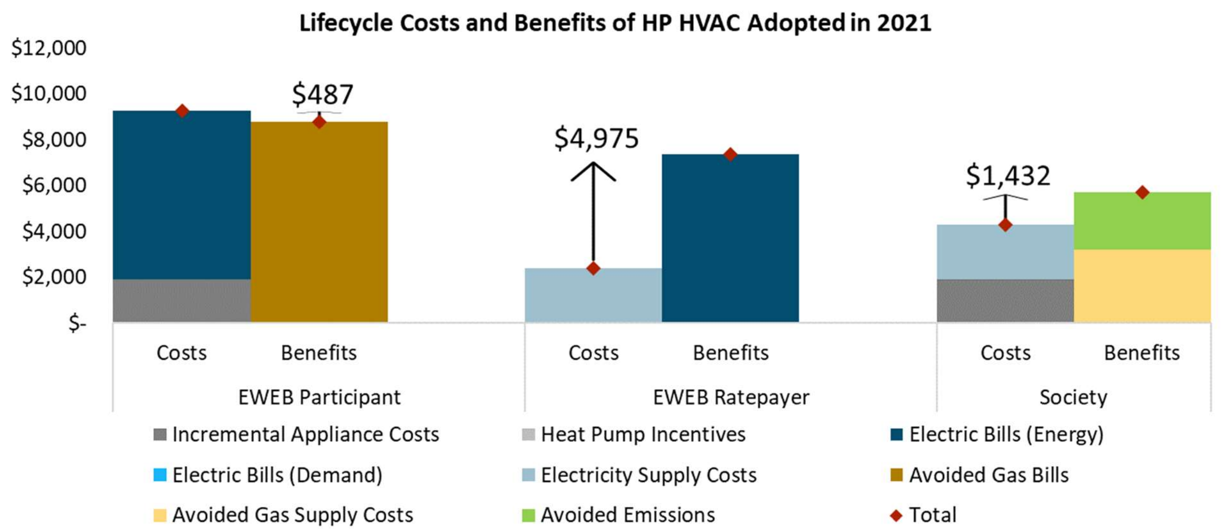
For the base case, electrification has a positive benefit from the EWEB ratepayer perspective, but the benefits for the participant and society are neutral to slightly negative. The table below summarizes the Benefit-Cost Ratio of an electrification measure by stakeholder group in both 2021 and 2030. A Benefit-Cost Ratio represents the Benefits divided by the Costs. A ratio greater than 1 indicates that benefits outweigh costs, which results in a positive economic outcome from the perspective studied. The results are presented in a heat map showing green with the highest net benefits and red with no net benefit (i.e., net cost). The society perspective is often a net cost because EWEB participants who choose these electric technologies are experiencing net costs which outweigh the monetized carbon reduction benefits.

[36] http://www.eweb.org/business-customers/rebates-loans-and-conservation/hvac-systems-rebates
[37] https://www.nwnatural.com/ways-to-save/rebates-offers
[38] https://www.nwnatural.com/ways-to-save/rebates-offers/water-heater-offer

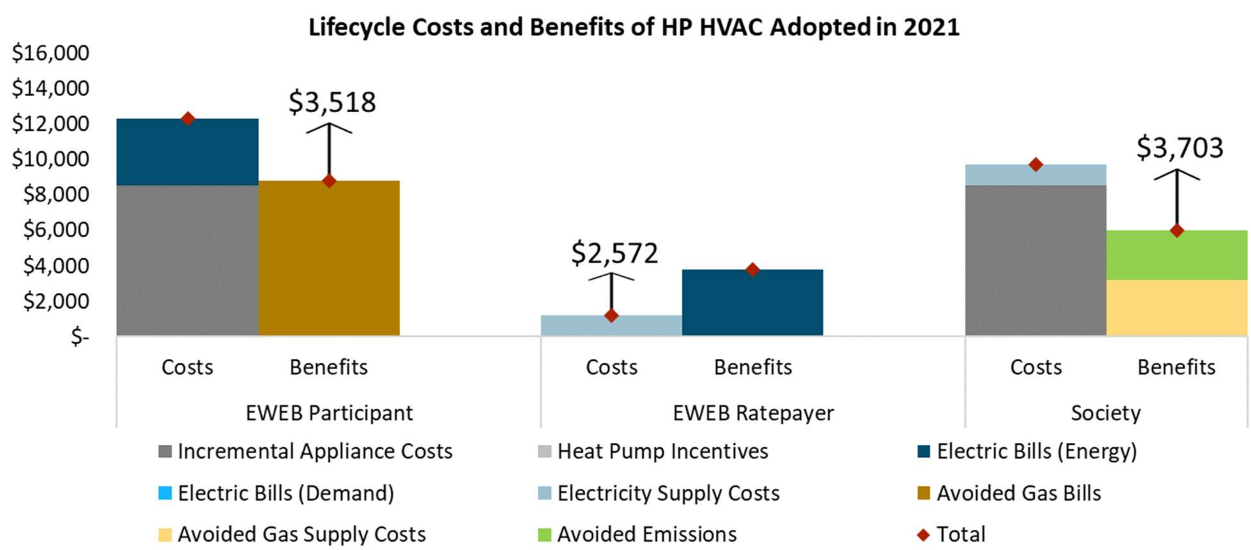
	Residential SFD Benefit-Cost Ratio (without EWEB incentives)					
	2021			2030		
Technology:	EWEB Participant	EWEB Ratepayer	Society	EWEB Participant	EWEB Ratepayer	Society
Standard HP	0.9	3.1	1.3	1.0	3.1	1.6
Cold Climate HP	0.7	3.1	0.6	0.8	3.2	0.8
Dual Fuel	0.9	3.7	1.1	1.0	3.8	1.5
Heat pump WH	0.8	2.8	0.7	1.1	2.7	1.0

For context, the benefit/cost Calculations (which are the underlying analysis for the benefit/cost Ratios) for 2021 are shown below. Note all perspectives assume a discount rate of 5%.

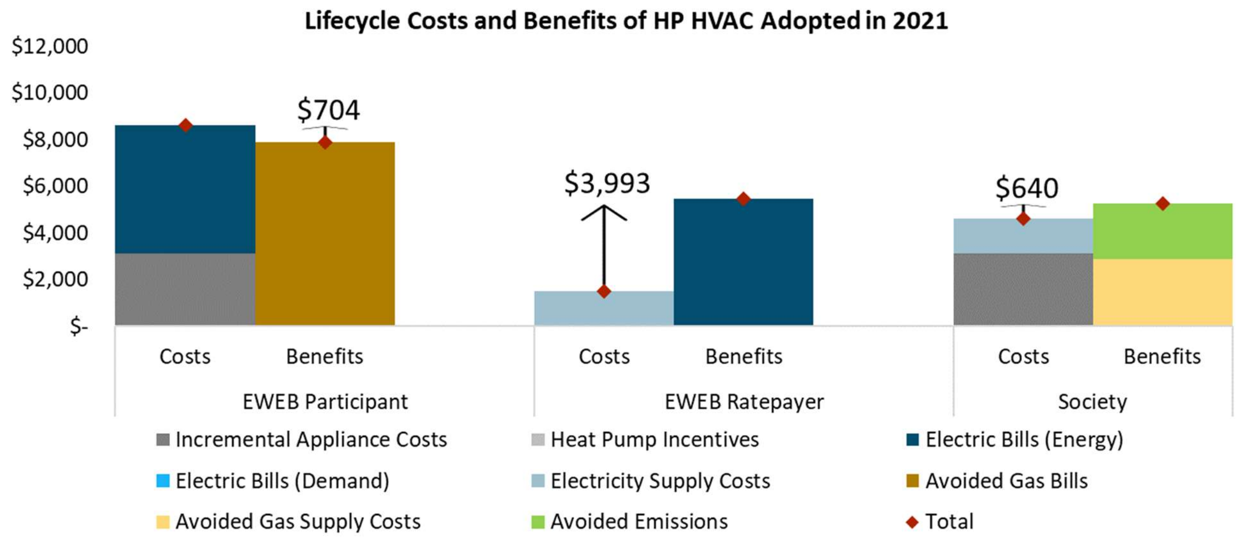
SFD – Standard Performance Heat Pump 2021



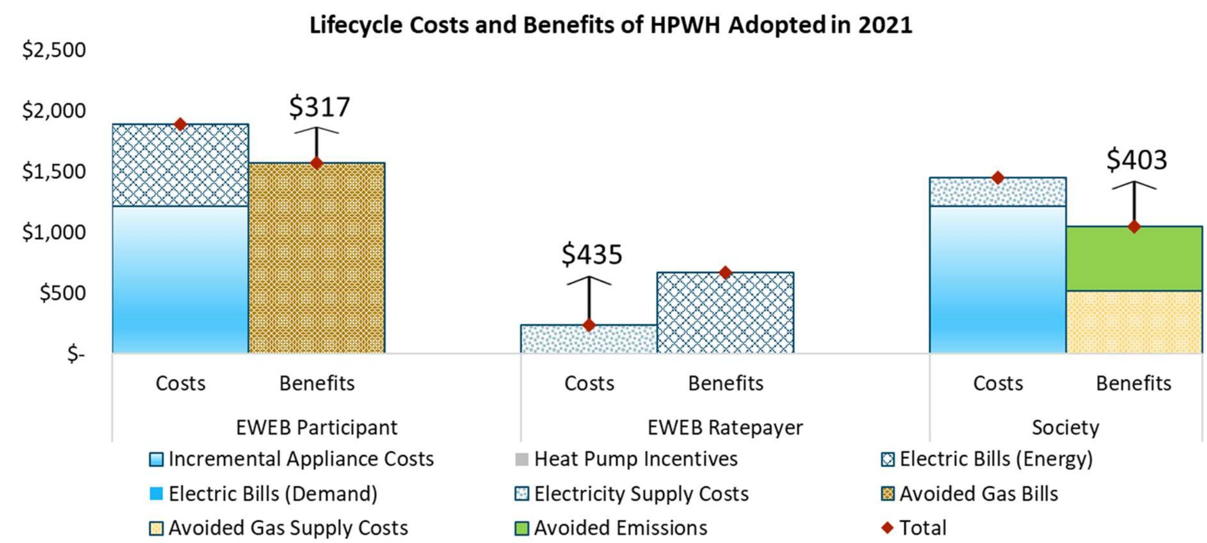
SFD – Cold Climate Heat Pump 2021



SFD – Dual Fuel Heat Pump 2021



SFD – Heat Pump Water Heater (HPWH) 2021



9.4.2 Impact of EWEB's Residential incentives[39]

Incentives can be an important influence over the economics of electrification. Below is a table illustrating benefit-cost ratios including EWEB energy efficiency incentives.

Heat pump water heaters currently have an $800 incentive from EWEB which represents a net benefit to the EWEB participant, but a net cost to the EWEB ratepayer. A $317 heat pump water incentive would represent a breakeven point between EWEB ratepayers and the EWEB participant perspective (i.e., both perspectives would have a benefit-cost ratio of 1).

EWEB currently offers a $1,000 energy efficiency incentive for residential ducted heat pumps that meet higher energy efficiency standards. The modeled standard heat pump does not qualify for the incentive, but the cold

[39] Information regarding EWEB residential incentives and program eligibility can be found at: http://www.eweb.org/residential-customers/rebates-loans-and-conservation

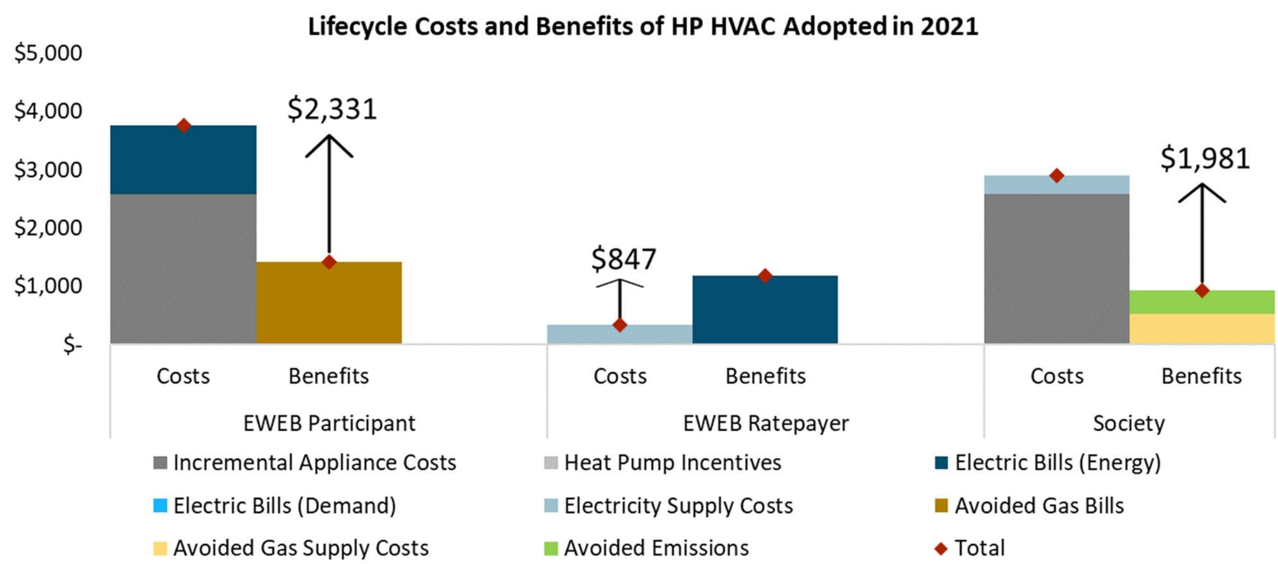
climate heat pump modeled in this study would qualify. While the incentive improves the benefit-cost ratio, it does not bring the cold climate heat pumps benefit-cost ratio above 1. There is no breakeven point at which both the EWEB participant and the EWEB ratepayer can have a benefit-cost ratio of at least 1 for cold climate heat pumps as studied.

	Benefit-Cost Ratio (with EWEB incentives[40])					
	2021			2030		
Technology:	EWEB Participant	EWEB Ratepayer	Society	EWEB Participant	EWEB Ratepayer	Society
Standard HP	0.9	3.1	1.3	1.0	3.1	1.6
Cold Climate HP	0.8	1.7	0.6	0.9	1.9	0.8
Dual Fuel	0.9	3.7	1.1	1.0	3.8	1.5
Heat pump WH	1.3	0.6	0.7	1.5	0.8	1.0

9.4.3 Benefit-Cost Analysis – Residential Multifamily Dwelling (MFD)

MFD have lower energy consumption than SFD, which makes it more difficult for MFD to recover the upfront costs of electrifying through annual energy savings. All the space heating electrification measures studied were a net cost to the participant, making electrification unlikely.

The benefit/cost Analysis below is for MFD electrification with a Standard Performance Heat Pump.



[40] Note EWEB incentives are influenced by BPA energy efficiency programs as well as other factors.

The heat map below summarizes the benefit/cost Ratios for all measures studied for Multifamily Dwellings.

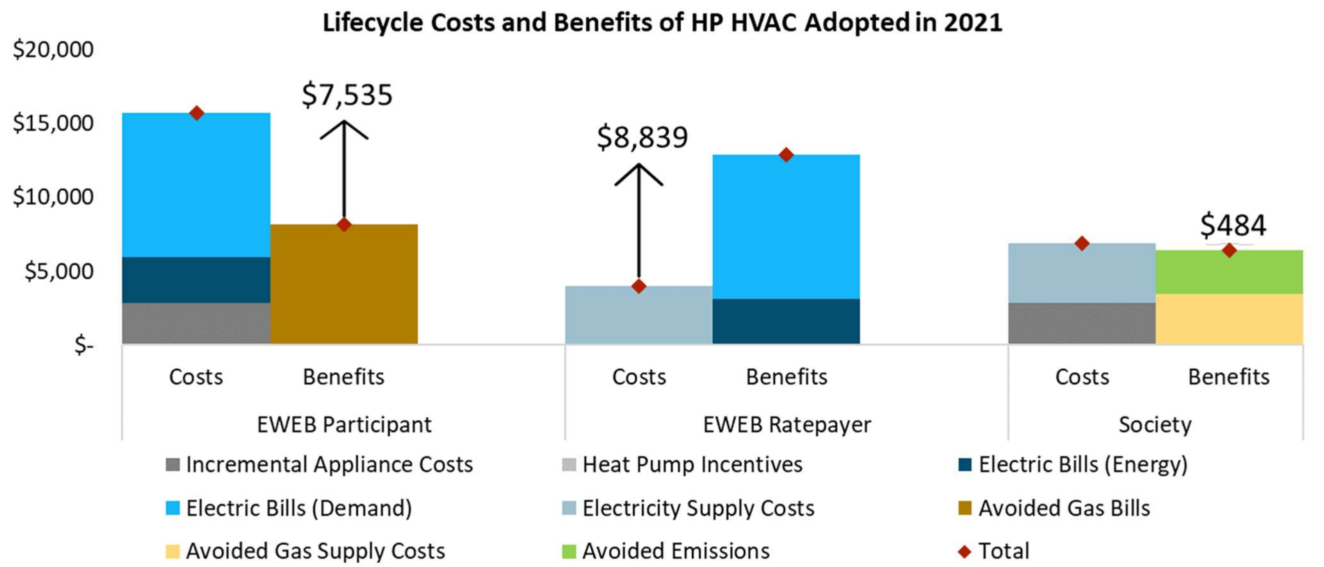
	Residential MFD Benefit-Cost Ratio (without EWEB incentives)					
	2021			2030		
Technology:	EWEB Participant	EWEB Ratepayer	Society	EWEB Participant	EWEB Ratepayer	Society
Standard HP	0.4	3.5	0.3	0.5	3.6	0.4
Cold Climate HP	0.2	2.5	0.1	0.2	2.5	0.1
Dual Fuel	0.3	3.7	0.2	0.4	3.8	0.3
Heat pump WH	0.8	2.8	0.7	1.1	2.7	1.0

Again, the key reason for the lack of participant benefit is the comparably smaller energy use of MFD compared to SFD. This makes it more difficult for MFD annual energy savings to offset the upfront costs of electrifying.

9.4.4 Benefit-Cost Analysis – Small Office (Commercial)

Small Office properties can utilize similar space and water heating technology to the residential heat pump technology included in this study. The commercial segment has different electric rates than residential customers and has a demand Charge[41] which is designed to send a peak pricing signal to commercial customers. Unfortunately, electrification is likely to add to the Small Office's existing peak load which would increase the electricity costs for that customer. While this rate design may send useful signals to commercial customers to reduce their peak energy use, it may also be a deterrent to commercial electrification. EWEB may consider alternative rate designs to encourage electrification in this sector.

The benefit/cost Analysis below is for a Standard Performance Heat Pump electrification for a Small Office property.



Note the large demand charges that commercial customers would receive over the heat pump lifetime because of electrification.

[41] EWEB's Small General Service (Commercial) Demand Charge is for peak kilowatt usage during the billing period. It is set on the highest consumption of power required in any 15-minute period during the billing period. http://www.eweb.org/business-customers/commercial-pricing

The heat map below summarizes the benefit/cost Ratios for all measures studied for Small Office buildings.

	Small Office Benefit-Cost Ratio (without EWEB incentives)					
	2021			2030		
Technology:	EWEB Participant	EWEB Ratepayer	Society	EWEB Participant	EWEB Ratepayer	Society
Standard HP	0.5	3.2	0.9	0.6	3.2	1.3
Cold Climate HP	0.3	3.0	0.3	0.4	3.1	0.4
Dual Fuel	0.7	2.6	0.9	0.8	2.7	1.3
Heat pump WH	0.2	1.9	0.1	0.2	1.8	0.2

Dual Fuel Heat Pumps (DFHP) would be much more beneficial for customers wanting to avoid the higher demand charges for peak energy use. However, the Phase 2 economic analysis indicates that even DFHP electrification has a benefit/cost ratio below 1. For Dual Fuel HP, there is a small breakeven point where both Ratepayers and Participants can be beneficiaries through an incentive. For Small offices, the incremental cost of a DFHP is approximately $4,000 greater than a comparable natural gas system in 2021. If there was a $4,000 incentive to offset this upfront cost, both the Participant and Ratepayer Benefit/Cost Ratio would be slightly above 1. Standard Performance Heat Pumps do have a breakeven point with an $7,500 incentive, but this incentive is much larger than the upfront equipment cost of $2,900.

9.4.5 Simple Payback Analysis

Simple payback is a leading indicator of consumer adoption. An example of a simple payback calculation for a residential water heater adopted in 2021 is shown in Figure P, below.

Figure P – Simple payback period calculation for SFD heat pump water heater in 2021

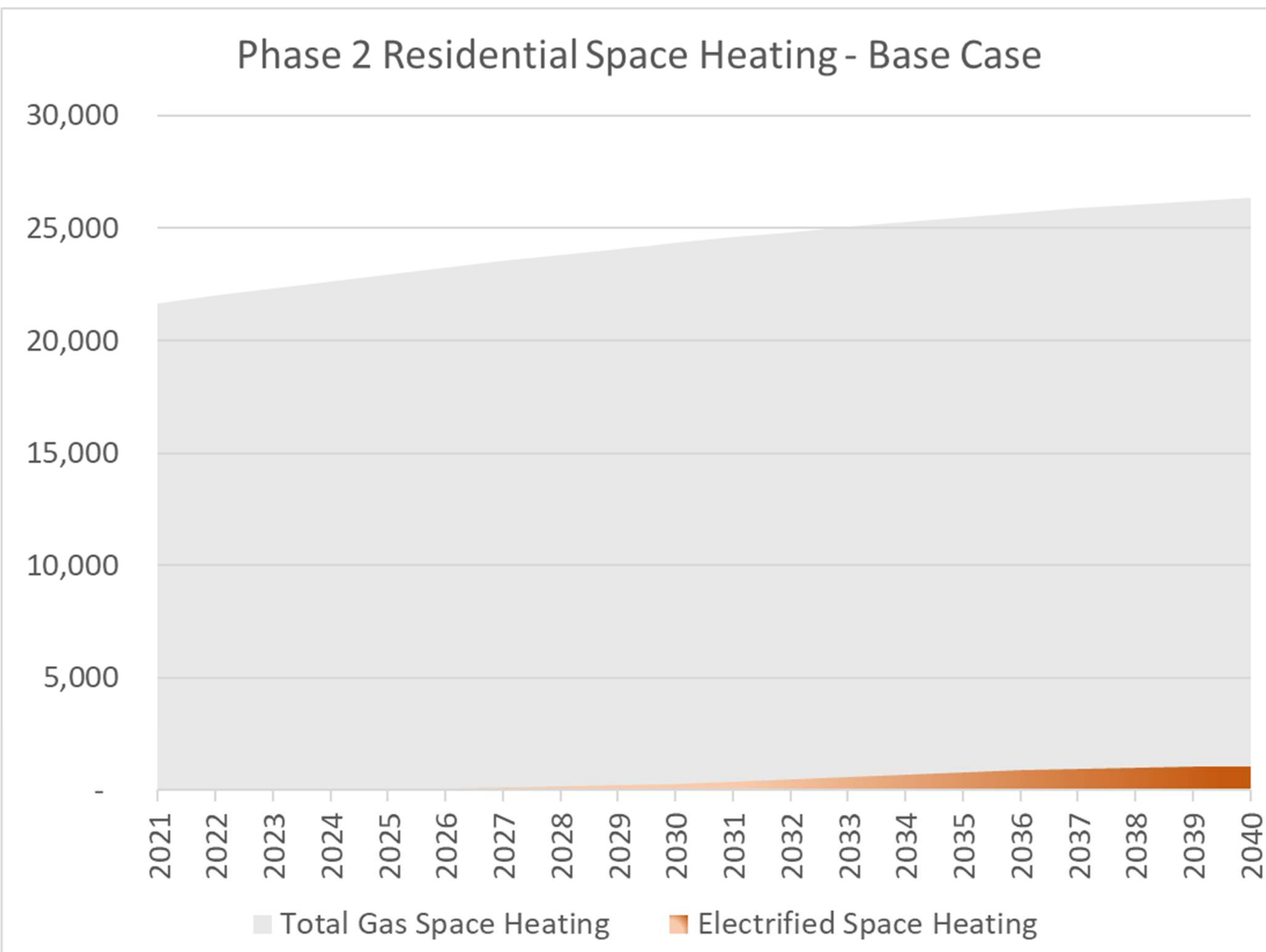
Residential Heat Pump Water Heater		
Total Costs		
Incremental Upfront Water Heater Costs	$ 1,215	
Utility Incentive	$ -	
Total	**$ 1,215**	
Total Opearting Cost Savings		
Avoided Gas Bills	$ 1,969	
Increased Electricity Bills	$ (842)	
Annual Average	**$ 113**	
Simple Payback Period	11	*Years*

The table below shows the simple payback periods (in years) for SFD space and water heating electrification technologies.

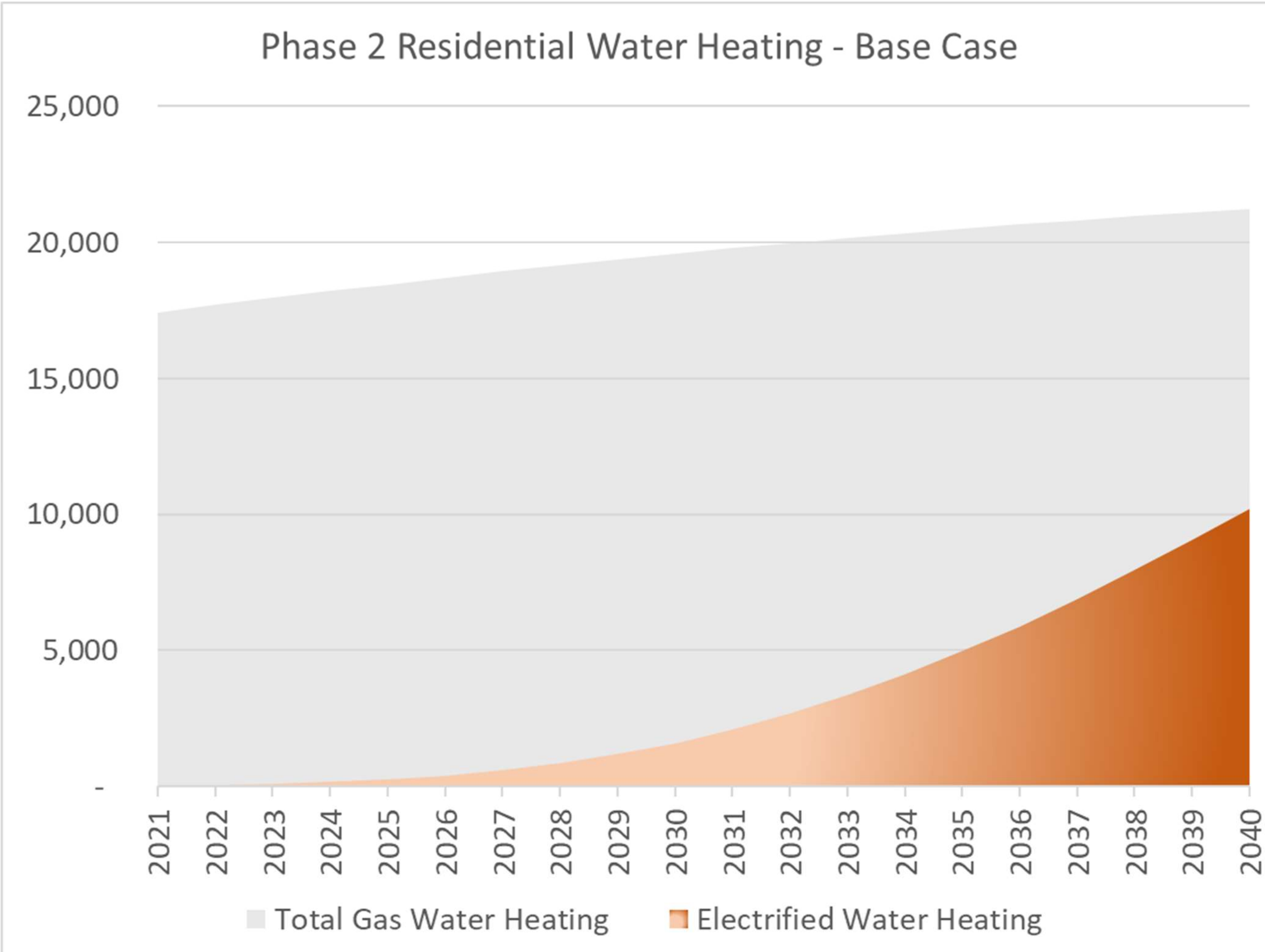
		Simple Payback		Simple Payback (with incentive)	
		2021	2030	2021	2030
Technology:	Assumed useful life	Base Case		Base Case	
Standard HP	16	14	11	Does not qualify	
Cold Climate HP	16	19	16	16	14
Dual Fuel	16	14	11	Does not qualify	
Heat pump WH	10	11	7	4	2

9.4.6 Adoption modeling based on simple payback

The life expectancy for a HVAC heat pump is assumed to be 16 years on average. In the base case, the simple payback analysis indicates that the initial heat pump investment will generally take more than 10 years to pay off for the customer. Using adoption modeling based on simple payback, these long simple payback periods significantly reduce the estimated number of customers who will choose to electrify. Therefore, there is very little electrification of space heating anticipated by 2040 under base case assumptions.



The life expectancy for a heat pump water heater is 10 years. Based on simple payback, the base case (without incentives) indicates by 2040, we would expect about 11,000 gas water heaters to convert to heat pump water heaters (roughly 50%). This is primarily driven by the improvements in the cost competitiveness of heat pump water heaters compared to natural gas water heaters over time.



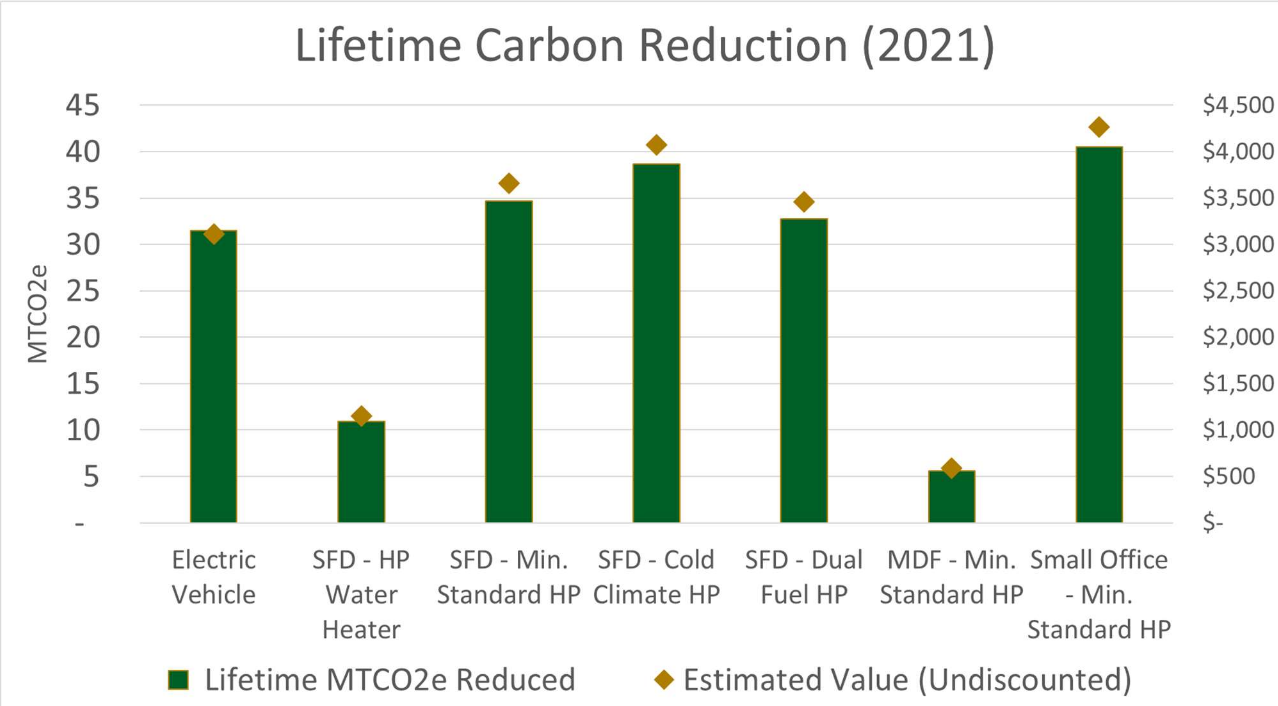
The adoption forecasts in the Base Case for space and water heating would have minimal levels of energy impact to the utility. Space heating electrification is unlikely and water heating is a relatively small energy use.

Base Case building electrification is estimated to be less than a 1% increase in average and peak energy use by 2040.

9.5 Base Case - Carbon Savings

Under Base Case assumptions, all the electrification measures studied can reduce carbon emissions over the equipment lifetime. For Space heating, technology choice can play a role in the total carbon savings associated with electrification. Figure Q below illustrates the lifetime carbon emissions that could be avoided by each electrification measure if it were adopted in 2021. This assumes the average carbon intensity for market rate electricity used to serve electrification load.

Figure Q



Electric vehicles are assumed to have a useful life of 12 years and space & water heating equipment are assumed to have useful lives of 16 years. Given the long useful life, the carbon reduction potential for EVs and space heating equipment is meaningful. Water heating and multifamily dwelling space heating represent the least carbon savings opportunities due to low amounts of energy use over the equipment life. Conversely, the carbon reductions for Small Office electrification are greater due to higher space heating energy use (compared to SFD space heating).

10 Modeling Sensitivities and Financial Impacts

HIGHLIGHTS

- Electricity prices (rates) are an important variable in the value of electrification. The value of electrifying is maintained so long as electricity rates can increase at a slower pace than fossil-fuel based energy sources.
- Increased blending of RNG is expected to increase natural gas prices, making electrification more appealing for participants.
- Ratepayer benefits of electrification would be reduced by increases in electricity supply costs or generation capacity costs.
- Electric panel upgrade costs can be a deterrent for electrification by adding an average upfront cost of $2,000 in addition to any other upfront costs to electrify.

Many assumptions were used in the modeling of base case results. The purpose of this section is to provide context regarding the sensitivities studied and the relative impact of these variables.

10.1 Independent Variables and Scenario Definition

The following table outlines major variables (sensitivities) and scenarios (groups of sensitivities) analyzed by staff. The sensitivities are also grouped to show whether they impact all electrification measures or a subset, like the building or transportation sectors, exclusively. The two scenarios include a "Base Case" (expected future) scenario, and an Aggressive Carbon Reduction (ACR) Scenario. The ACR scenario considers a future where both electric and fossil fuel energy sources are influenced by policies which prioritize carbon emission reductions and is based on trends and technology that exists today.

	Tested Sensitivity			Scenarios	
	Sensitivity 1	Sensitivity 2	Sensitivity 3	Base	Aggressive Carbon Reduction
All Measures					
Annual Electric Rate Increase	1.00%	3.00%	6.00%	3.00%	6.00%
Electric Supply Cost	Low	High		Low	Low
Rate Structure	Existing Flat	TOU		Existing Flat	TOU
Generation Capacity Cost	Low	High		Low	High
Panel Upgrade	No	Yes		No	No
Space and Water Heating					
Natural Gas Commodity Price	Low	Med	High	Med	High
RNG Percent Blend	Low	High		Low	High
RNG Commodity Price	Average	Marginal		Average	Marginal
Heat Pump Cost Reduction*	Low	High		Low	High
Electric Vehicles					
Gasoline Price	Low	Med	High	Med	High
Managed EV Charging	No	Yes		No	Yes

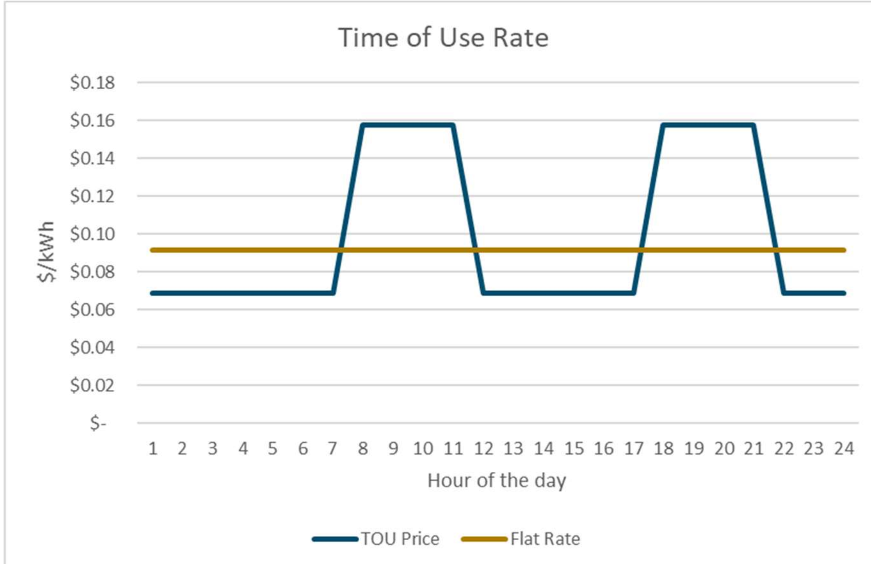
*Reductions in cold climate heat pump manufacturing cost, given increased production maturity

10.1.1 Sensitivity Definitions:

- **Annual Electric Rate Increase:** The relative increase in EWEB's annual electric rates over time. Higher electric prices reduce the economic benefit of electrification to the participant but increases the benefit to ratepayers.

- **Electric Supply Cost:** The assumed marginal cost of electric energy to EWEB. As this cost increases, the benefit to the EWEB Ratepayer diminishes. The low sensitivity is based on an Aurora modeled forecast of spot market values. The high sensitivity assumes the same Aurora modeled forecast for market energy but increased by 100%.

- **Rate Structure:** The design of electric rates, or how EWEB recovers costs, can influence the economic benefit of electrification to the participant. This analysis compared EWEB's current, "flat" rate structure to a Time of Use (TOU) rate structure. TOU rate structures incent the participant to shift consumption behavior by shaping the cost of energy throughout a 24-hour period.



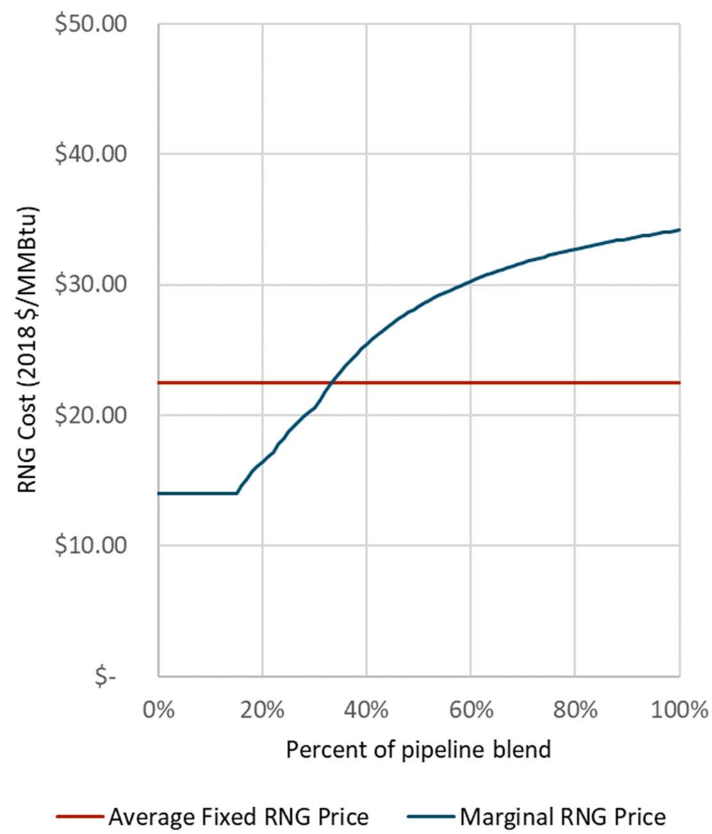
- **Generation Capacity Cost:** The incremental cost of generation used to serve EWEB's capacity needs. What EWEB pays for capacity in the future is unknown, but it will have an impact on EWEB's ability to promote electrification in the future. Higher capacity costs reduce the value of electrification to ratepayers. Today, EWEB's capacity cost are low (assumed to be $16 per kW-year based on market pricing), but it is thought that EWEB's capacity costs could be higher in the future. For this analysis, high capacity costs are assumed to be $90 per kW-year (roughly equivalent to natural gas generator capacity on standby).

- **Panel Upgrade:** Panel upgrade costs increase the upfront cost of electrification over time. A panel upgrade will likely be required in older/smaller homes where the existing electric service was sized to meet the basic space and water heating needs of the time (estimated to be about 12% of all housing units in Eugene). Staff assumed that a panel upgrade would average $2,000 and that it would impact the upfront cost of electrification. A panel upgrade will reduce the economic benefit of electrification to the participant.

- **Natural Gas Commodity Price:** The relative increase in natural gas commodity prices over time. This sensitivity directly impacts the cost of natural gas purchased by the participant. Higher natural gas prices increase the value of electrification to the participant over time.

- **Renewable Natural Gas Percent Blend:** The percent of RNG required for natural gas end use. As natural gas utilities look to decarbonize (either voluntarily or due to carbon reduction policies), they'll likely need to introduce greater amounts of non-fossil based (renewable or synthetic) natural gas into their pipelines. It is assumed that RNG will be more expensive than conventional sources of natural gas, especially as required volumes increase, given limitations in RNG supply. Higher percentages of RNG improve the value of electrification over time due to increased natural gas supply costs.

- **Renewable Natural Gas Commodity Price:** RNG costs significantly more than fossil fuel natural gas, which improves the value of electrification over time. The model has two options: Average or Marginal RNG Price. Average assumes a $22.50 fixed cost for RNG throughout the study. Marginal assumes a supply curve of RNG costs that the availability of lower cost RNG will be depleted over time and that supplying greater quantities of RNG will become more expensive over time. The chart to the right illustrates the difference between average and marginal price assumptions.



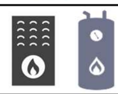
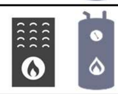
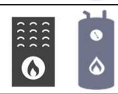
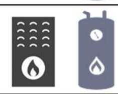
- **Heat Pump Cost Reduction:** The degree to which manufacturing of heat pump technology improves with maturity (efficiencies of scale). This variable impacts cold climate heat pumps only, as it is assumed that traditional heat pumps are a fully matured technology. This reduces the upfront cost of electrification for the participant for cold climate heat pumps.

- **Gasoline Price:** The relative increase in gasoline prices over time. This measure only impacts vehicle electrification. Higher gasoline prices increase the value of electrification over time.

- **Managed EV Charging:** The existence of utility programs designed to proactively shift vehicle charging away from traditional energy peaks. Load management programs (like managed EV charging) may help to avoid or delay distribution system upgrades.

It should be noted that direct incentives from EWEB ratepayers to participant to electrify were not measured as an explicit variable for this analysis.

The following table illustrates how each variable can impact benefit/cost analysis, for participants and EWEB ratepayers, and can be either an accelerant or deterrent to electrification:

Tested Sensitivity	Impacted Measure	Participant BCA Impact	EWEB Ratepayer BCA Impact	Accelerator/Deterrent
Increasing Annual Electric Rates		↓	↑	Deterrent
Increasing Electric Supply Costs			↓	Deterrent for utility
TOU Rates Implemented		↓	↑	Deterrent (vs today's flat rate structure)
Increasing Generation Capacity Cost			↓	Deterrent for utility
Panel Upgrade Needed		↓		Deterrent
Increasing Natural Gas Commodity Prices		↑		Accelerator
Increasing RNG Percent Blend		↑		Accelerator
Increasing RNG Commodity Prices		↑		Accelerator
Future Heat Pump Cost Reductions*		↑		Accelerator
Increasing Gasoline Prices		↑		Accelerator
Managed EV Charging Implemented			↑	Accelerator for utility

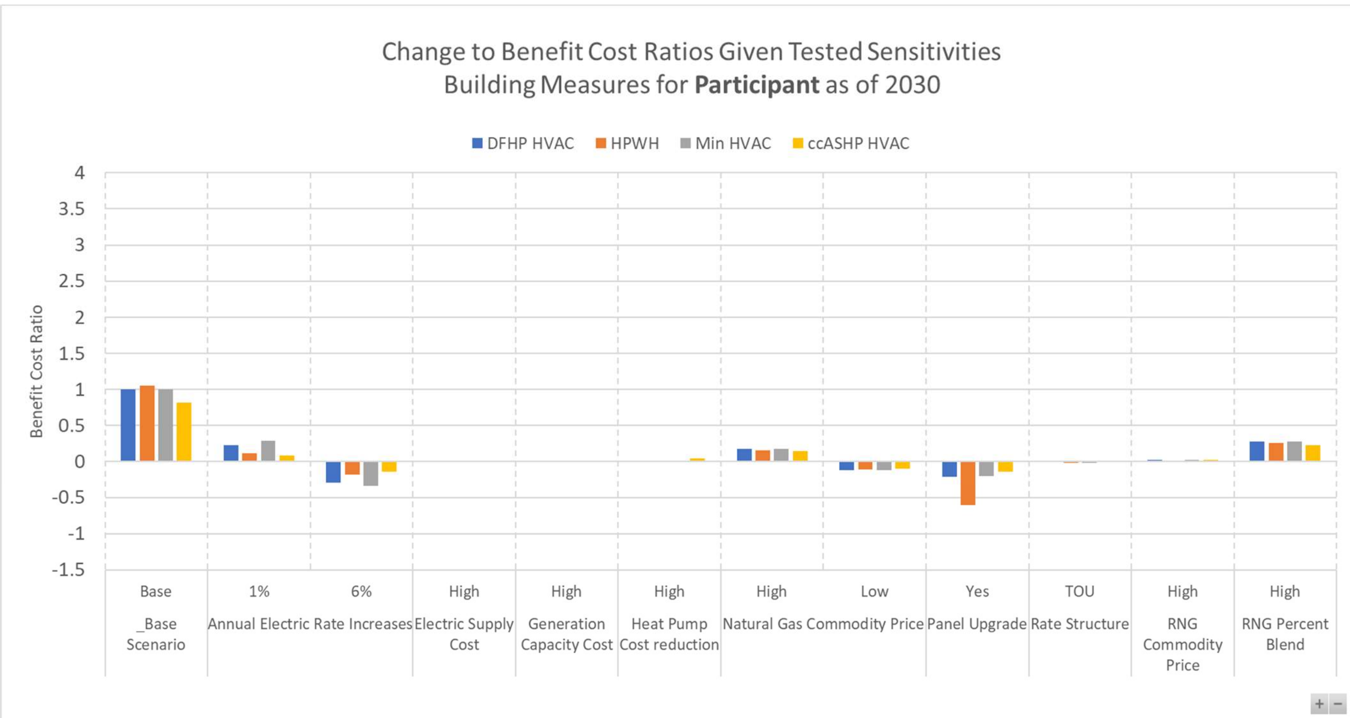
Note that some variables only impact the participant or ratepayer perspective. If the field is blank, it indicates that the variable does not have a direct financial impact from that perspective.

10.2 Benefit/Cost Ratio Sensitivities to Independent Variables

10.2.1 Building Electrification Findings

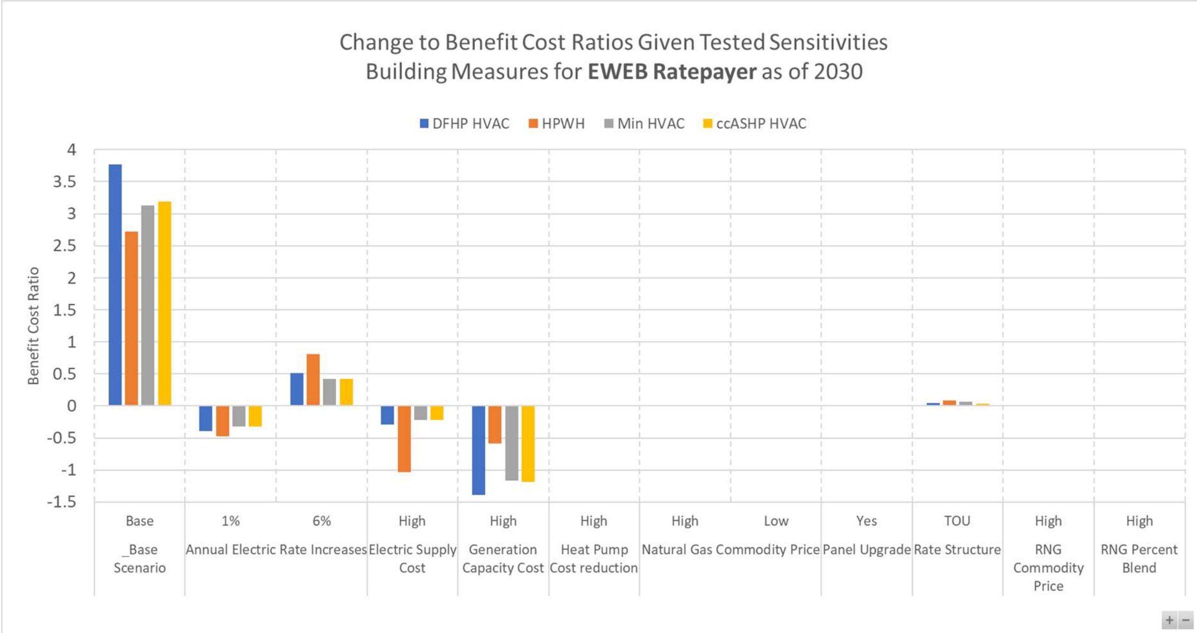
For Single-family Participants by 2030

- The base scenario shows that most space and water heating measures have a benefit/cost ratio (BCR) of ~1.0, except for cold climate heat pumps. This implies that most HVAC measures should be close to economic breakeven over the life of the measure, though only by a slim margin. Cold climate heat pumps do not break even economically, and as such, are less likely to be adopted by the participant.
- Most of the sensitivities that impact the BCR generally pertain to the ongoing cost of operation; the cost of electricity (annual rate increase, TOU rate structure) or the avoided cost of natural gas (natural gas commodity price, RNG blend, RNG Price) being the largest two contributing factors.
- Another large factor is whether a panel upgrade is required. A panel upgrade reduces the BCR for all measures, but especially heat pump water heating.



For EWEB Ratepayers, given electrification of single-family homes by 2030

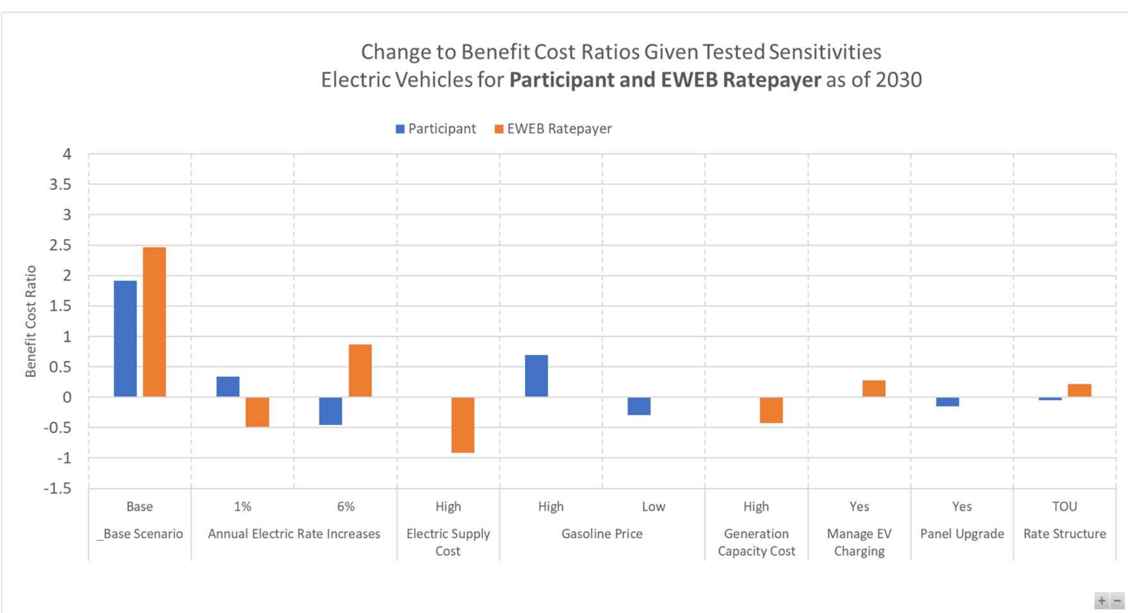
- The base scenario shows that all space and water heating measures benefit EWEB ratepayers by a large margin. BCR ratios range from ~2.7-3.7 with heat pump water heating being the least beneficial, and dual fuel heat pumps being the most beneficial to EWEB ratepayers.
- EWEB ratepayer BCRs are generally impacted by electric rates (annual electric rate increases, TOU) and the assumed cost of energy (electric supply and generation capacity). It should be noted that even under an adverse scenario (low electric rates, and high electric supply and generation capacity costs) EWEB ratepayers may still see a benefit to electrification.



10.2.2 Electric Vehicle Findings

For Participants and EWEB Ratepayers by 2030

- The base scenario shows that, by 2030, BCRs for the participant and EWEB ratepayers exceed 1.0, by a large margin.
- Much like building electrification, the major influencing factors can be generally categorized as ongoing costs like electricity (annual electric rates, TOU), and the avoided cost of gasoline.
- For the participant, panel upgrades can still influence the ratio, but to a lesser extent, compared to building electrification, given the relative cost of a panel upgrade compared to the lifetime savings achieved from electric vehicle conversion.
- For the EWEB ratepayer, electric supply and generation capacity cost are a large factor, but their impact appears to be offset from the benefits that can be achieved through managed EV charging programs.



10.2.3 Additional variable findings

All Sensitivities
When reviewing these sensitivity charts, it's important to remember that the benefit/cost value is a normalized ratio and not an explicit measurement of nominal dollar value. Further, the sensitivity deltas shown above are supposed to illustrate how a variable may impact a specific measure alone. While there are trends across measure types, the magnitude of impact is not directly comparable across measures. A seemingly large shift for one measure compared to another indicates overall sensitivity, but it doesn't lend itself to understanding the gross dollar impact to the participant or the EWEB ratepayer.

Electric Rate Increases and Structure
Increasing electric rates over time is an overall deterrent to electrification for all measures studied. The benefits of electrification are built on the assumption that electric rates will increase at a slower pace than fossil-fuel based energy sources like gasoline and natural gas. Maintaining affordable electric rates will be key to incentivizing electrification. From the EWEB ratepayer perspective, minimizing rate increases (from electric supply and generation capacity) will be important to maintaining benefits for electrification participants.

From a financial perspective, TOU rates studied were not as impactful as other variables, but they can be helpful by sending consumers price signals regarding the timing of electricity consumption. This impact of TOU on electrification and consumption will likely grow with the overall value of capacity. From the EWEB ratepayer perspective, the increased revenue from customers unable to avoid TOU rates would be used to offset the higher costs incurred to serve customers who consume energy during those peak periods. If done correctly, time-based rate structures like TOU (examples include critical peak pricing, peak time rebates, real time pricing) can send price signals to help participants and ratepayers save money. This is often seen as a cost-effective mitigation tool that utilities can use to reduce peak energy use, but typically requires advanced metering infrastructure to implement.

Electric Supply Costs and Generation Capacity Costs
These costs are born directly by the utility as load from electrification increases. The impact of electricity supply costs (energy or capacity) on the benefit of electrification are a function of both the diurnal (daily) and seasonal load shape of a specific measure.

Space heating measures tend to have larger incremental usage in winter, and early spring periods[42] where energy is forecasted to be cheaper. As such, changes in energy supply costs are not very impactful to the EWEB ratepayer. However, because of the variability (i.e. "peakiness") of the space heating loads, generation capacity costs tend to be high, so shifts in generation capacity cost can have a larger impact.

Water heating and EV load shapes are less peaky and generally maintain the same level of consumption throughout the year (limited seasonality). As such, EWEB ratepayers will see a larger reduction in benefit from shifts in energy supply costs when compared to shifts in generation capacity cost.

Panel Upgrade
Panel upgrade costs can easily surpass $2,000. This can be a major deterrent to electrification[43].

[42] This study assumes that natural gas customers who convert to electric space heating already have air conditioning load in the summer. As such, the incremental impact on space heating in the summer is very small.
[43] https://www.utilitydive.com/news/residential-electric-panels-represent-a-nearly-100b-roadblock-to-full-el/605829/?

Though not addressed in this study, we assume that homes built prior to 1950 will most likely require panel upgrades to accommodate EV charging. This represents about 12% of all housing units in Eugene. Building codes can be used to address panel sizing to help ensure panel sizes are ready for future electrification. Heat pump water heaters appear to be more sensitive to panel upgrade costs, but this is generally a function of the overall cost of the measure itself. For more expensive measures, like purchasing an EV or a new space heating system, the impact of a panel upgrade is more diffuse. It should be noted that all future electrification can be facilitated with a single panel upgrade. If a participant needs to upgrade to support EV charging, it may make sense to ensure that their panel can also facilitate all other electric end uses at that time.

Natural Gas and Gasoline Cost

These are costs that are avoided by the participant when they electrify. As the price disparity between gas and electricity grow, the benefit to the participant will increase.

Increases in natural gas commodity costs are expected to grow from both increases in demand and efforts to decarbonize with RNG. The influence of RNG will likely be predicated on how much voluntary or mandated RNG is blended into natural gas pipelines. Higher levels of RNG appear to have a significant cost impact and will likely be a key driver for the disparity between natural gas and electric rates. See discussion of the impacts of decarbonization in the gas sector in Section 6 - Key Context: Electric and natural gas supply decarbonization.

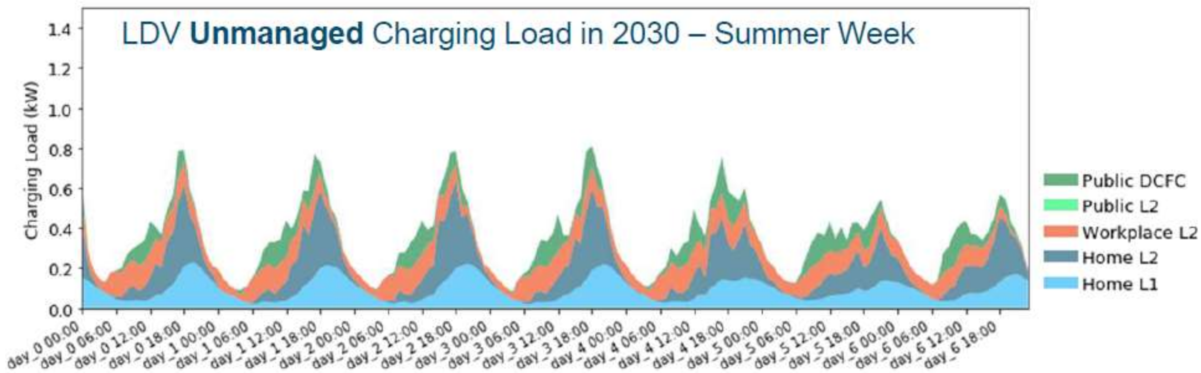
Gasoline prices are also expected to grow both from general supply and demand dynamics, but also due to cost adders like carbon credits mandated by Oregon's clean fuels program.

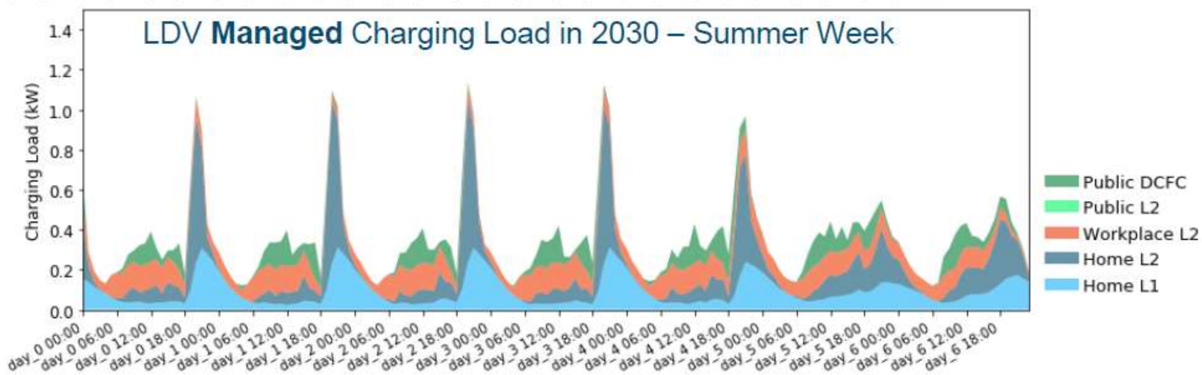
Heat Pump Cost Reductions (Cold Climate Heat Pumps only)

This study only looked at ducted cold climate heat pump systems, which are relatively new. This inverter driven, variable speed technology was already common in mini-split ductless systems and is expected to become more common for ducted heat pumps as well. While maturation in manufacturing practices can reduce the total installation cost of these types of systems, the overall impact of this sensitivity appears to be limited.

Managed EV Charging

E3 modeled both managed and unmanaged charging behavior based on driving behavior. To determine the likely location of EV charging, they analyzed the amount of time that a driver spends at home, the workplace or driving between locations. In the unmanaged charging scenario, it is assumed drivers would distinguish among charging locations based on cost but would charge with no attention paid to peak and off-peak time of use rates. For managed charging, they assumed they would optimize charging behaviors against TOU rates and assumed cascading charging to limit all drivers charging exactly at the transition between peak and off-peak hours (i.e., not all EVs would immediately charge at 10PM, but rather vehicles would stagger off-peak charging behavior in some way).





It should be noted that managed charging behavior does increase the peak EV load, but the impacts are not as meaningful because the peak is shifted away from EWEB's system peak hours. Looking at the chart, one can see an approximate 0.8 kW per EV peak around 6PM in the unmanaged charging behavior compared to a peak of 1.3 kW around 11PM for managed charging. It should also be noted that the managed peak is primarily controlled by Level 2 home charging habits.

The time of use variable indicates only a minor net cost to the participant (assuming they modify their charging behavior to the best of their ability) and provide a net benefit from the ratepayer perspective. Utilizing Time of Use rates and helping incentivize managed charging behavior are actions focused on a sub-set of customers who have more discretion regarding the timing of their charging behavior. EWEB currently has incentives for Level 2 chargers and encourages customers with Level 2 charging at home to schedule charging during off-peak periods. For EV adoption, time of use and managed charging variables are not financially impactful and are not expected to influence EV adoption. However, both variables are important for EWEB to consider in order to influence discretionary charging behavior and help mitigate increased costs to ratepayers.

11 Aggressive Carbon Reduction Scenario

HIGHLIGHTS

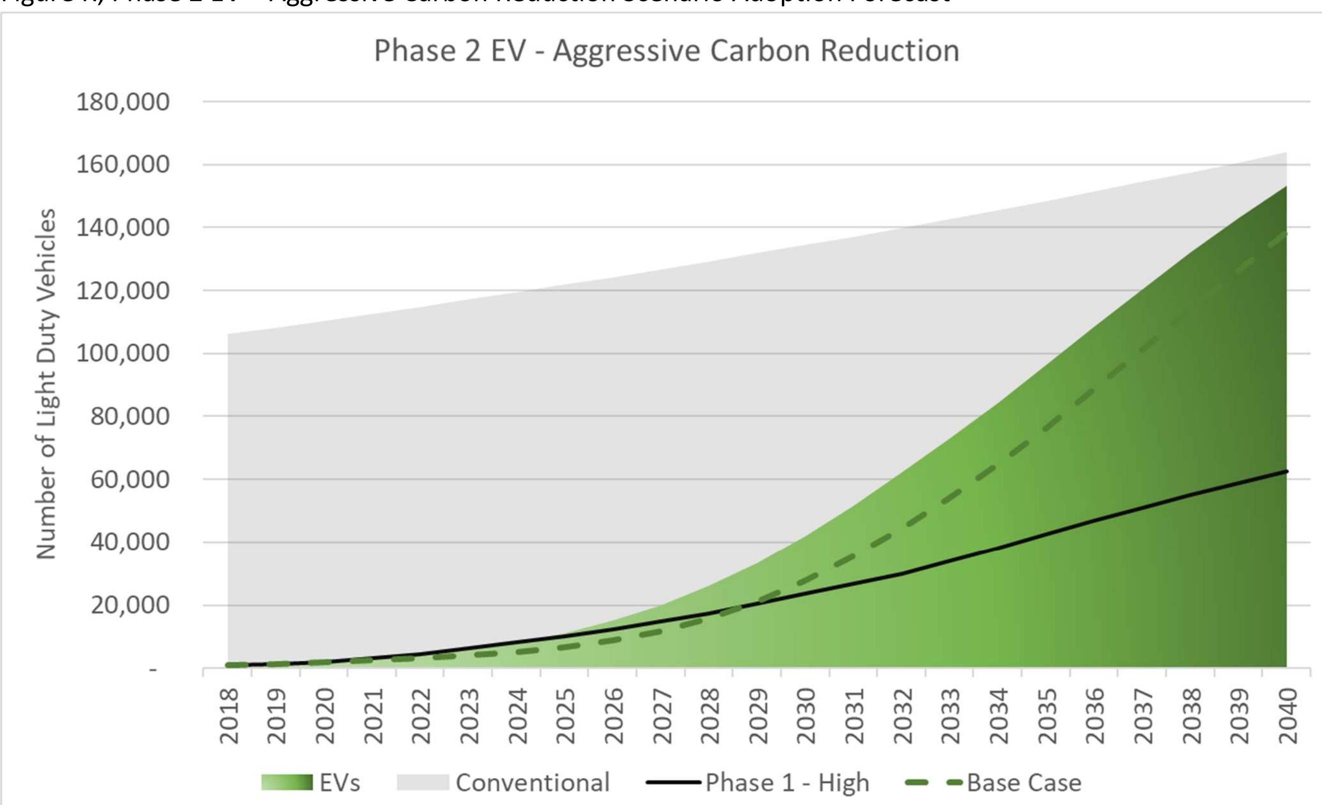
- Under the ACR scenario, there is a significant increase in space and water heating electrification compared to base case leading to meaningful carbon reductions (particularly from space heating).
- EWEB could see an increase of 3-12% to existing 1-in-10 peak energy use compared to the Base Case due to increased space heating loads in the ACR scenario.
- Slight increase in EV adoption by 2040 is driven by the assumption that the market maturing at a faster pace.
- Increased RNG leads to higher natural gas pricing compared to electricity costs.

As discussed in section 10.1 Independent Variables & Scenario Definition, the ACR scenario considers a future where both electric and fossil fuel energy sources are influenced by policies which prioritize carbon emission reductions and is based on trends and technology that exists today. In this scenario, it is likely that the pace of electrification would be faster than base case assumptions.

11.1 Aggressive Carbon Reduction Scenario – Transportation Sector

EV adoption was already anticipated to be high in the future under base case assumptions. The ACR scenario simply accelerates the pace of electrification, leading to approximately 95% of all light duty vehicles being electrified by 2040 (up from 85% in the base case).

Figure R, Phase 2 EV – Aggressive Carbon Reduction Scenario Adoption Forecast



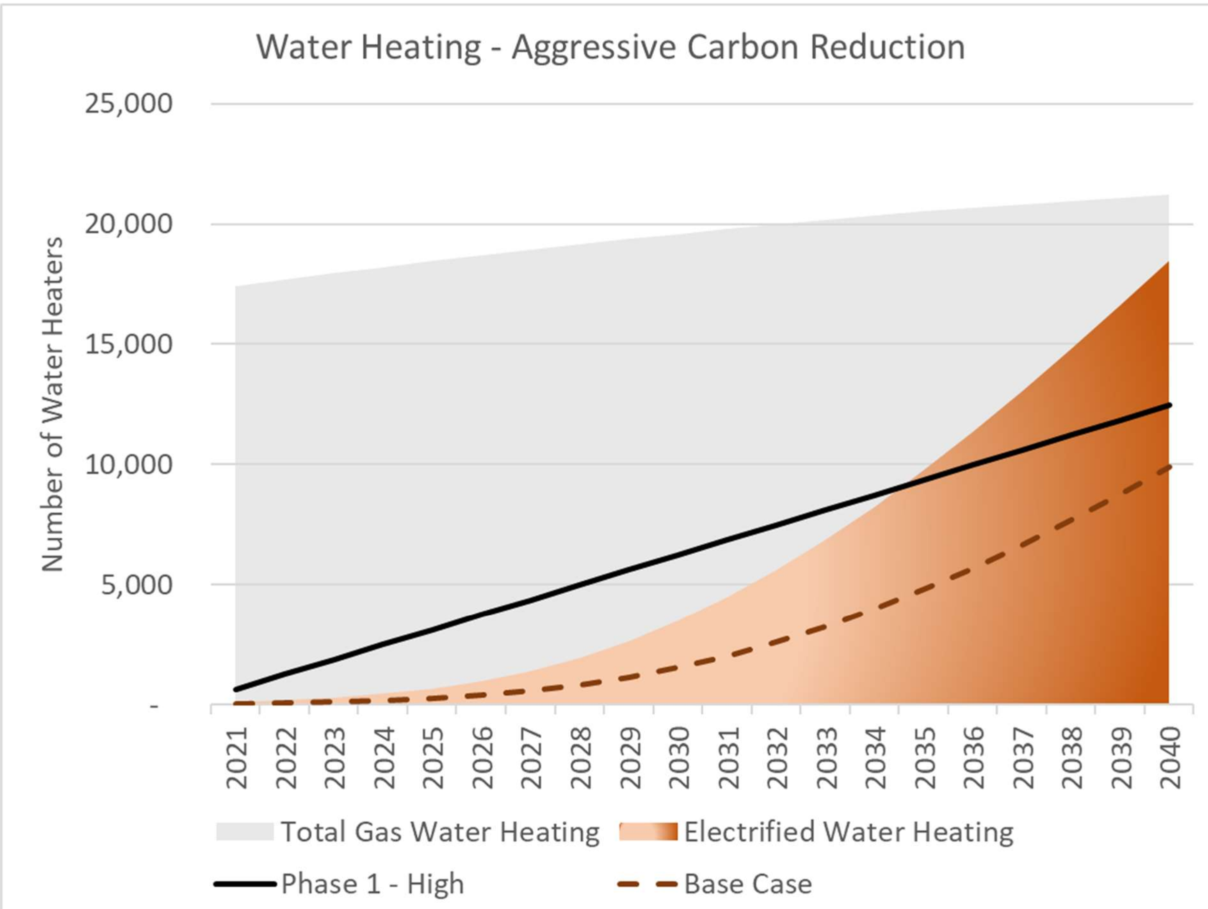
Overall, this slight increase in vehicle electrification by 2040 is expected to be 2% higher than the average and peak energy estimates in the Base Case. See the Cumulative Energy Impacts (Section 12) for a table showing the differences.

11.2 Aggressive Carbon Reduction Scenario – Building Sector

11.2.1 ACR Water Heating Energy & Carbon Impacts

Water heating electrification is anticipated to be much higher under the ACR scenario with approximately 85% of existing natural gas water heating electrified by 2040.

Figure S, Phase 2 Existing Natural Water Heating Units Electrified – Aggressive Carbon Reduction



Water Heating represents a relatively small use of energy and only a portion of EWEB customers use natural gas for water heating today. Even high levels of electrification by 2040 are estimated to have small impacts on both average and peak energy use.

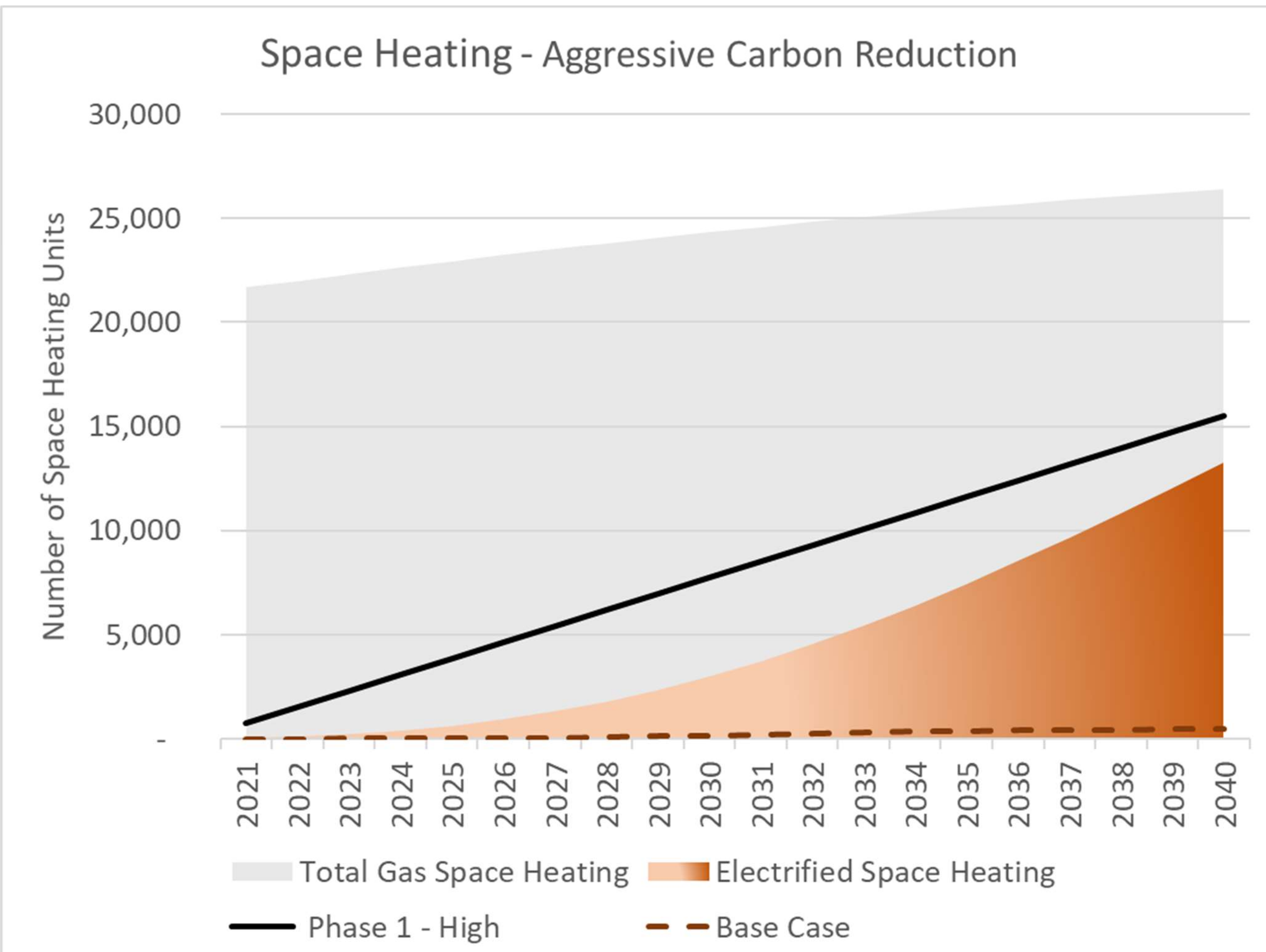
2040	Base Case	ACR Scenario	% Increase
Average	1 aMW	2 aMW	0.3-1%
Peak	1.5 MW	3 MW	0.3-1%

This study sought to quantify the relative carbon emission reduction benefits of electrification. Carbon savings from higher percentages of RNG are outside the scope of this study. The annual reductions shown in the table below are only related to electrification and any savings associated with increased RNG use would be in addition to the MTCO2e reductions as a result of electrification.

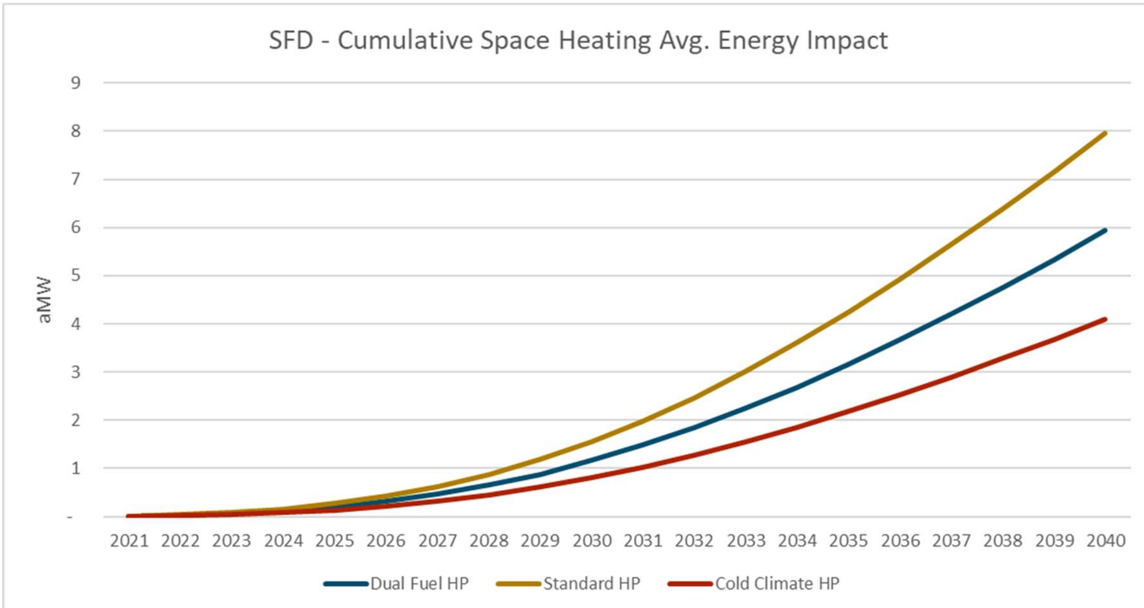
Water Heating Annual Carbon Reductions	2040	
	Base Case	ACR Scenario
Electrification	5,700 MTCO2e	6,500 MTCO2e
RNG Blend	23%	53%

11.2.2 ACR Space Heating Energy & Carbon Impacts

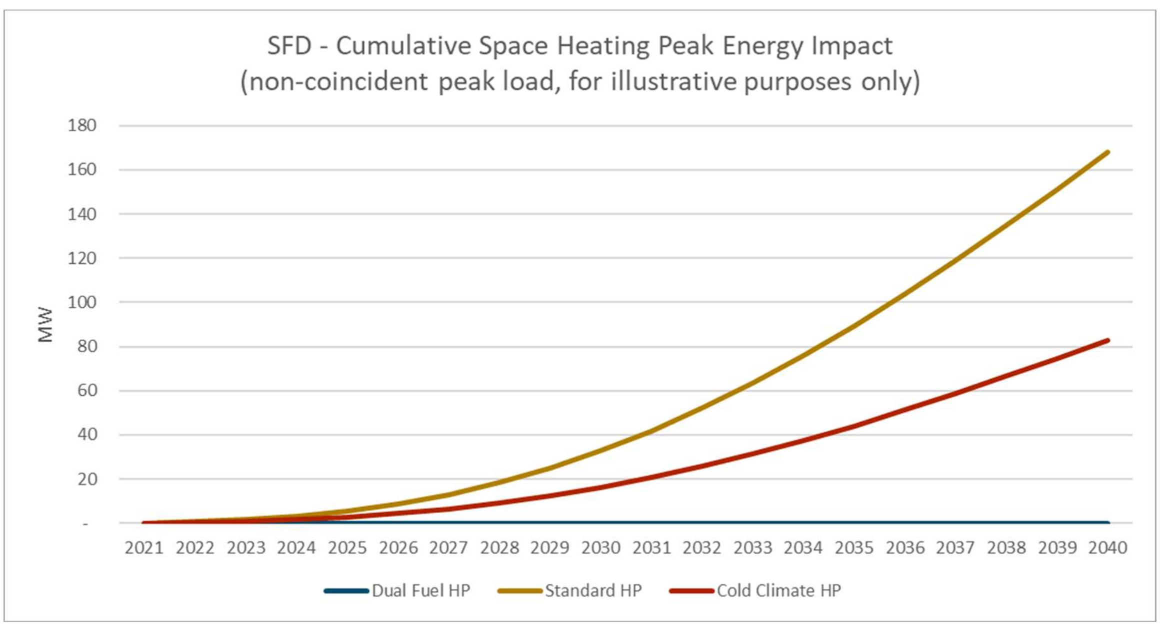
Under base case assumptions, space heating electrification is very unlikely due to lack of participant benefits. In the ACR scenario, the high costs of blending RNG is anticipated to increase natural gas rates and improve the benefits of electrification. The chart below shows the number of space heating units currently served by natural gas (which is a sub-set of all space heating units in EWEB's service territory). By 2040, approximately 50% of existing natural gas space heating units could be electrified.



For space heating electrification, the choice of technology has a strong influence over the average and peak energy impacts to the utility. To illustrate the impacts, the charts below show the energy impacts assuming 100% of the units electrified chose the same space heating technology. The results are shown based on single family dwelling (SFD) energy use.



The peak impacts of these technology choices are significant, as cold climate heat pumps are able to utilize the compressor at very low temperatures and reduce reliance on backup electric heat. Dual fuel heat pumps are assumed to switch over to natural gas below 32 degrees Fahrenheit, meaning they would add only a minimal amount to EWEB's existing peak load. For context, EWEB's existing 1-in-10 peak system load is 510 MW.



The chart above shows the non-coincident peak load of electrifying space heating units. The coincident peak impacts are anticipated to be much lower, as equipment diversity and customer behavior reduce the system peak impacts the utility would see as a result of electrification. It should also be noted that different customers will choose different space heating technologies, so the impacts are further diversified by different equipment types.

Under base case assumptions, carbon reduction for space heating is expected to be minimal because electrification is unlikely. However, the higher space heating adoption in the ACR scenario does show meaningful carbon reduction as a result of electrification. The amount of carbon reduction is influenced by space heating technology choice, hence a range of potential MTCO2e in carbon reduction is shown.

Space Heating Annual Carbon Reductions	2040	
	Base Case	ACR Scenario
Electrification	Minimal	14-16,000 MTCO2e
RNG Blend	23%	53%

12 Cumulative Energy Impacts & Electrification Opportunities

This study focuses on light-duty vehicle electrification in the transportation sector. The building sector analysis focuses on space and water heating technologies for existing buildings in EWEB's service territory using natural gas which can be electrified. It should be noted that this economic analysis focused primarily on the residential sector and only looked at the possible electrification of small office buildings in the commercial sector. The likelihood of larger commercial building electrification is more difficult to estimate due to the wide range of HVAC types that serve these customer's space heating needs. Industrial uses of natural gas are significant but encompasses many unique applications requiring a case-by-case analysis. In this study, the economic analysis is helpful for assessing the likelihood of electrification if left to consumers (participants) to choose as well as the anticipated impacts on energy consumption and related carbon emissions reduction. The following tables and charts summarize the cumulative electrification findings and highlight the differences between the Base Case and the Aggressive Carbon Reduction (ACR) scenarios.

12.1 Cumulative Energy Impacts

The cumulative energy impacts are relative to EWEB's existing system loads and existing peak demand periods. The percentage increase is based on EWEB's existing system average load of 270 aMW and a 1-in-10 peak of 510 MW, which is a common planning standard for electric utilities.

2040 - Base Case					
Electrification Measure	% Electrified	Average Energy Increase (aMW)	% Increase	1-in-10 Peak Increase (MW)	% Increase
Electric Vehicle - Managed	85%	57	21%	77	15%
Electric Vehicle - Unmanaged	85%	57	21%	131	26%
Heat Pump Water Heater	50%	1	0.3%	1.5	0.3%
Standard Performance Heat Pump	< 2%	Without significant incentives or mandates, impactful space heating electrification is unlikely if driven by participant economics (consumer choice).			
Cold Climate Heat Pump	< 2%				
Dual Fuel Heat Pump	< 2%				

2040 - Aggressive Carbon Reduction					
Electrification Measure	% Electrified	Average Energy Increase (aMW)	% Increase	1-in-10 Peak Increase (MW)	% Increase
Electric Vehicle - Managed	95%	63	24%	85	17%
Electric Vehicle - Unmanaged	95%	63	24%	145	28%
Heat Pump Water Heater	85%	2	1%	3	1%
Standard Performance Heat Pump*	50%	8	3%	33-61	6-12%
Cold Climate Heat Pump*	50%	4	2%	17-31	3-6%
Dual Fuel Heat Pump*	50%	6	2%	Minimal	Minimal

*Space heating energy impacts shown assume 100% of space heating electrifcation assuming a single technology to illustrate that space heating technology choice matters. In reality, customers will choose a mix of the 3 different space heating technologies. Peak impacts are presented in ranges due to uncertainty regarding coincident load of units. Utilizing AMI data in the future, EWEB could better estimate the coincident load of these space heating technologies.

Consumer-driven electrification of light-duty vehicles and water heating are likely in the next 20 years and should be included in EWEB's load forecasting going forward. Between the two scenarios studied, consumer-driven space heating electrification remains the most uncertain. In the ACR scenario, higher levels of building electrification (50% of the installed base as shown above) will have varying levels of energy impacts depending on the space heating technology that customers choose. Cold climate heat pumps provide the greatest carbon benefit but are the highest priced option for consumers. For transportation electrification, the greatest peak mitigation comes from developing programs to manage charging behavior. This could complement EWEB's existing and future energy efficiency programs which are designed to reduce peak energy use. The goal for all peak mitigation efforts would be to shift customer consumption away from, if not reduce, EWEB's existing system peaks using the least cost interventions. EWEB's Customer Solutions and Energy Management staff are well positioned to help develop both electrification and energy efficiency programs to actively manage the impacts of customer choices.

12.2 Cumulative Carbon Impacts

The table below shows carbon reduction by measure under the two scenarios studied. Again, the study considers the likelihood of electrification based on economic analysis and consumer choices and is only for specific measures within scope. As mentioned in Phase 1, electrification is just one of the pillars of decarbonization. Although separate from the benefits of electrification, staff provided an estimate of the potential carbon reduction benefits of RNG based on the Eugene Climate Action Plan's 2017 carbon inventory for additional context. In the Base Case, RNG blend is assumed to be 15% RNG by 2030, 23% by 2040 and 30% by 2050, based on Oregon Senate Bill 98. Under the high RNG blending sensitivity in the ACR Scenario, it is assumed that the % of RNG in the natural gas system will increase from 3% today at a consistent rate until it reaches 53% by 2040 and 80% by 2050.

Annual Carbon Reductions	2040					
	Base Case			Aggressive Carbon Reduction Scenario		
Carbon Reduction Measures	% Electrified	MTCO2e Reduced	% Carbon Reduction	% Electrified	MTCO2e Reduced	% Carbon Reduction
Vehicle Electrification	85%	(390,000)	-38%	95%	(432,000)	-43%
Water Heating Electrification	50%	(5,700)	-1%	85%	(6,500)	-1%
Space Heating Electrification	0%	-	0%	50%	(16,000)	-2%
Residential RNG Benefits*		(19,600)	-2%		(45,100)	-4%
Commercial & Industrial RNG Benefits*		(45,300)	-4%		(104,400)	-10%
Total Annual Carbon Reductions		(460,600)	-45%		(604,000)	-60%
Total 2017 Carbon Emissions (City of Eugene CAP 2.0)		1,013,600	100%		1,013,600	100%

*The Base Case assumes a blend of 23% RNG by 2040 and the Aggressive Carbon Reduction scenario assumes a blend of 53% RNG by 2040. The estimated carbon reduction benefits of increased carbon-free RNG are shown in addition to the benefits of building electrification for context.

12.3 Electrification Opportunities

As EWEB considers how to engage with customers on electrification, the utility should be looking for electrification measures that are both impactful and sustainable. Technologies that show lower likelihood of consumer-driven adoption may require more resources to influence customer choices. In addition, EWEB should consider the benefits of reduced carbon emissions while maintaining reliability and affordability. Adding to existing system peaks may increase reliability risks because it could both increase utilization (reduce available capacity) of EWEB's existing local distribution network, as well as increase reliance on the regional electric grid, where decarbonization efforts are impacting the availability of existing transmission and generation capacity. To manage the reliability risk, additional distribution, transmission, and generation assets potentially need to be procured at a cost to EWEB, which represents a risk to future customer affordability.

The Electrification Scorecard below was developed to provide a high-level comparison for the different electrification measures studied in Phase 2. Leaves are used to highlight the relative benefits of total lifetime carbon reduction, with more leaves indicating higher benefits. For each of the benefit/cost analysis perspectives, the measure was assigned green to show a net benefit, yellow to show neutrality, or red to indicate a net cost as of 2030. The benefit/cost Analysis is based on adoption in a single year, so 2030 BCA results are shown below to illustrate economic benefits in the mid-point of the study period. Lightning bolts illustrate the 1-in-10 peak impacts for each measure while the band-aids symbolize the potential for the utility to influence customer behavior to manage peak impacts. For example, electric vehicles have three band aids because managed charging behavior represents a meaningful opportunity for the utility to reduce incremental peak impacts. Space heating has less opportunity to shift energy because peaks are typically caused by weather conditions, but some space heating technology choices have lower peak impacts compared to the standard performance heat pump. Therefore, EWEB's Peak Management Potential has more to do with influencing customer space heating technology choices, than shifting the timing of customer consumption. In the EWEB Engagement Opportunities column, staff highlighted actions that EWEB could consider when evaluating electrification.

Electrification Scorecard	Carbon Reduced	Base Case 2030			1-in-10 Peak Adder	Peak Management Potential	EWEB Engagement Opportunities
		EWEB Participant	EWEB Ratepayer	Society			
Electric Vehicle							Encourage managed charging to avoid peak, increase public and workplace charging opportunties
Heat Pump Water Heater							Consider existing energy efficiency incentive program's influence on electrification of water heating
SFD - Standard Heat Pump							Participant benefits are neutral, making electrification unlikely. Possible incentive opportunity.
SFD - Cold Climate Heat Pump							Participant benefits are lacking, making electrification unlikely. Possible incentive opportunity.
SFD - Dual Fuel Heat Pump							Participant benefits are neutral, making electrification unlikely. Possible incentive opportunity.
Multi-Family Dwelling Space Heat							Participant benefits are lacking, making electrification unlikely. Possible incentive opportunity.
Small Office Space Heat							Participant benefits are lacking, making electrification unlikely. Consider rate design changes for commercial electrificaiton.

Electrification Scorecard	Carbon Reduced	Aggressive Carbon Reduction 2030			1-in-10 Peak Adder	Peak Management Potential	EWEB Engagement Opportunities
		EWEB Participant	EWEB Ratepayer	Society			
Electric Vehicle							Encourage managed charging to avoid peak, increase public and workplace charging opportunties
Heat Pump Water Heater							Consider existing energy efficiency incentive program's influence on electrification of water heating
SFD - Standard Heat Pump							Influence customer space heating technology choices to mitigate peak impacts.
SFD - Cold Climate Heat Pump							Influence customer space heating technology choices to mitigate peak impacts.
SFD - Dual Fuel Heat Pump							Influence customer space heating technology choices to mitigate peak impacts.
Multi-Family Dwelling Space Heat							Participant benefits are lacking, making electrification unlikely. Possible incentive opportunity.
Small Office Space Heat							Participant benefits are lacking, making electrification unlikely. Consider rate design changes for commercial electrificaiton.

Electrification of light-duty vehicles and water heating creates value (marginal benefit/marginal cost) from all perspectives (participant, EWEB ratepayer, society) in both the Base Case and ACR scenario, indicating electrification is likely and beneficial. In the case of light-duty vehicles, carbon reduction is substantial and the electric peak impact, while significant, can be mitigated with managed or diversified charging behavior. EWEB can encourage this diversified charging behavior by increasing the availability of public and workplace charging infrastructure and utilizing dynamic energy price signals (like Time-of-use rates) to encourage vehicle charging to shift to non-peak times. EWEB will need to actively manage the peak energy impacts to the utility to maintain both ratepayer and participant value over time.

Even without incentives, water heating electrification has economic benefits for all three electrification perspectives by 2030. The aggregate carbon reduction benefits are small compared to other end-uses, due to relatively low energy consumption of water heaters, but so is the electric system peak impact. EWEB's existing heat pump water heater incentive is helping to encourage electrification today. Given the ability to leverage an existing incentive program, and the low energy and peak impacts, electrification of water heating should be sustainable.

The economics and impacts of space heating electrification is more complex and uncertain. Removing other variables (mandates, incentives, equity, personal choice), substantial single-family dwelling electrification of space heating is unlikely under the Base Case scenario given lack of economic benefit created for the decision-making participant. From this value perspective, for a residential property, electrifying with standard performance heat pump or dual-fuel heat pump technology creates the most economic value for both the participant and society, but the standard heat pump has the most electric system peak impact, which may be more difficult to mitigate given its correlation to EWEB's existing system peaks.

The type of space heating technology (minimum standard, cold climate or dual fuel) chosen by a customer is a key variable in this study. The results of technology choice have been presented to illustrate their potential energy impacts. Standard performance heat pumps may offer the lowest upfront costs to consumers, but they have the most impact on system energy peak, as they rely on less efficient backup electric resistance heaters during low temperature conditions. Cold climate heat pumps (CCHP) can offer meaningful carbon reduction benefits over their lifetime, but high upfront costs remain a barrier. Today EWEB provides incentives customers to consider more cost-effective CCHP technologies like ductless heat pumps, or "mini splits", that can operate efficiently at low temperature, but this solution may not be as cost-effective for larger natural gas heated homes. Partial electrification with dual-fuel heat pump technology showed economic value from all perspectives (participant, ratepayer, society with upfront costs between standard heat pumps and cold climate heat pumps. Dual-fuel heat pump systems have the lowest peak electricity impact, while providing carbon emissions savings from increased electricity usage. While dual-fuel systems rely on natural gas backup heating during low temperature periods, this technology could allow customers who do not wish to discontinue their use of natural gas entirely an opportunity to decarbonize. However, the carbon emissions benefit of partial electrification using dual fuel heat pump technology is less certain and will depend on the carbon intensity of both the electric and gas grids under peak conditions over time, and the frequency of the circumstances requiring gas backup/peaking in this region.

Substantial multi-family space heating electrification is economically challenging in both scenarios, barring other variables, due to comparably lower energy needs and less opportunity to recover upfront costs with monthly savings. Small commercial/office electrification is also challenging due to increased demand charges to the commercial customer, indicating that the demand charge component of the electric rate structure may be acting as a deterrent to commercial electrification. To the extent that electrification provides financial benefits to participants, EWEB programs will need to consider access to these benefits and equity among customers. Exclusion of multifamily housing incentives, for example, may inadvertently exclude low and moderate income (LMI) communities from the benefits.

12.4 Conclusions

Overall, the study finds that the pace of customer-driven electrification, if based on economic value alone, will be slow in the next decade with EV adoption appearing to be the most likely and impactful form of electrification based on the large conversion potential (number of cars). In the near term, EWEB's engagement and collaboration with electric vehicle owners and the City of Eugene to shift charging times to non-peak hours of the day when carbon benefits are highest, and costs are lowest, will be beneficial to the impact and rate of electrification.

Space heating electrification creates the most tradeoffs between conversion options, including standard heat pump, cold climate heat pump, and dual fuel heat pump (partial electrification) technologies. Cold climate heat pumps (that operate at low temperatures) provide the most carbon emissions reduction but are the most expensive option. Standard heat pumps are the cheapest but provide less carbon benefit because of their reliance on more carbon-intensive peak electricity that will need to be managed. The carbon emissions benefit of partial electrification using dual fuel heat pump technology is less certain and will depend on the carbon intensity of both the electric and gas grids under peak conditions over time, and the frequency of the circumstances requiring gas backup/peaking in this region.

13 DISTRIBUTION GRID VISIBILITY

HIGHLIGHTS

- Phase 1 of the electrification study indicated that EWEB's electric system has the capacity and flexibility to manage low-to-moderate electrification levels in the near term, but such capacity varied within the service territory.
- Phase 2 of the study highlights the need for more granular distribution system planning.
- Advanced Metering Infrastructure (AMI) offers an opportunity to measure load at the individual transformer level, specifically via the Harris SmartWorks Compass Meter Data Management (MDM) application.
- Transformer health can be monitored using existing information technology, but further modernization may require additional investment.
- Knowing transformer capacity utilization can help manage future load growth (EV, Batteries, DR, EE, PV, DER), which is becoming a standard industry practice.

Significant electrification of the transportation and building sectors can create challenges for utility distribution systems. As discussed in Phase 1, EWEB's distribution system appears to have sufficient capacity to accommodate a low-to-moderate increase in load from electrification, but the amount of available capacity varies by area within EWEB's service territory. As customers electrify, they will likely do so unevenly across EWEB's system, with load growth clustering in neighborhoods and other smaller areas based on consumer choices. As such, having a high degree of grid visibility will become an increasingly important planning tool. Ongoing in-depth analysis of the distribution system will highlight the potential opportunities EWEB has to manage the impacts of electrification.

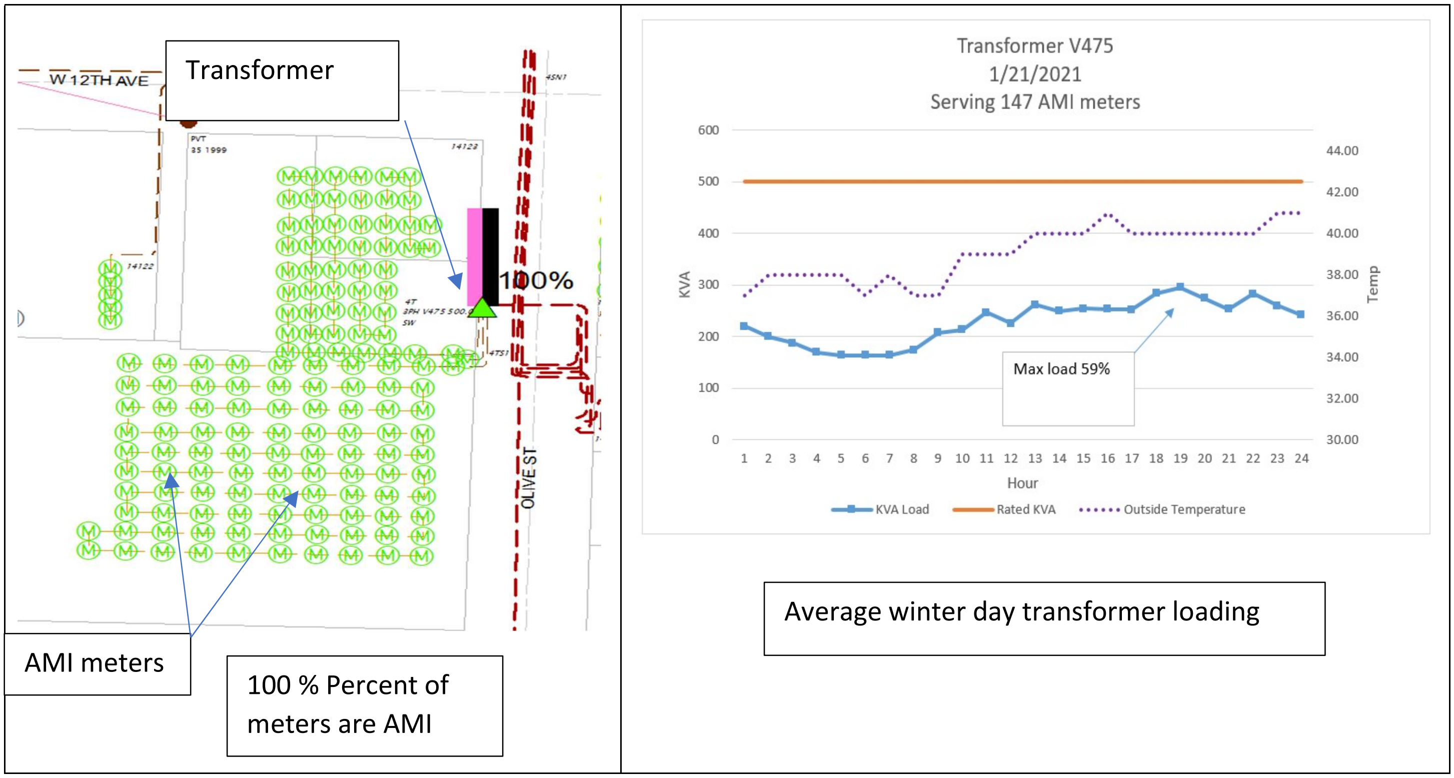
Since transformers are a high-cost component of EWEB's distribution system, monitoring transformer capacity can help manage or mitigate the impacts of load growth. Developing distribution system awareness can enhance system planning efforts by proactively identifying system constraints, voltage issues, or overloaded transformers before failure occurs. Targeted distribution system upgrades (rather than running equipment to failure) may help reduce the number and overall cost of unplanned outages to EWEB and its customers.

Currently, EWEB has over 18,000 units in its transformer fleet. As such, it is not cost effective to set up individual meters for each transformer. However, one of the major benefits of advanced metering infrastructure (AMI) is the visibility it can provide into the capacity utilization of distribution transformers. By integrating the relational information from GIS[44] and meter information from MDM[45], it becomes possible to group together AMI meters

[44] Geographical Information System (GIS) is mapping software used to visually represent, map, and analyze information about equipment used by utilities.
[45] Meter Data Management (MDM) is software used to track consumption data gathered from customer meters.

to create "virtually metered" transformers. This enables a comprehensive mapping of each transformer to the load it serves. By comparing the sum of all metered consumption associated with a transformer with the equipment's capacity rating, staff can derive its real capacity utilization factor, in hourly granularity.

Below is an example of how a virtual transformer can be metered. This 500 KVA[46] transformer (green triangle, pictured below on the left) from the GIS system serves an apartment complex of nearly 150 residential AMI meters (green M symbol).



Each connected meter (child) is assigned to its virtual transformer (parent). Hourly load data from each of the individual meters is summed for each hour and the maximum hourly load can be compared to the transformer's capacity rating, as illustrated in the image on the right.

EWEB is in mid-stream deployment of AMI and expects to have most electric meters changed in the next few years. Additionally, other necessary back-office systems, such as the SmartWorks Compass Meter Data Management (MDM) system will need to be configured for additional functionality to support emergent areas of operational work. Included in these back-office tools are a variety of reports and metrics that measure transformer capacity utilization, voltage, coincident peak, weather correlation, and other elements which aid in distribution system visibility. After the build out of this required foundational work, it may be possible to have hourly capacity utilization metrics for EWEB's entire transformer fleet.

These technology improvements can help EWEB monitor transformer loading (heat/stress) under more extreme weather conditions in both winter and summer periods. Additionally, the same data sets would allow EWEB to better understand coincident peak consumption by customer class (e.g., residential, commercial). When combined with additional customer information, the data could be further broken out by customer segment (single family, multi-family, office, retail, box store, restaurant, motel, etc.). Developing a detailed understanding

[46] Kilovolt-Amperes (KVA) are a measure of a transformers apparent size (capacity).

of customers' energy usage is becoming a standard industry practice, as these insights are instrumental for electricity supply planning, customer program development, and rate design. However, it should be noted that this modernization effort may require additional investment in data integration and analytical tools.

Energy Use Analysis with Advanced Metering

Beyond determining transformer loading with virtual meters, this data can be useful for understanding and measuring the energy use impacts of electrification. Below are some example statistics for the 150-unit apartment complex with electric heating and cooling discussed on the previous page. The statistics shown are for an average (1-in-2) winter day and a rare (1-in-1,000) summer day (June 2021 Heat Dome). Note these statistics are representative of a single day and are not representative of annual energy use

Electric only customers (air-source heat pump heating and cooling) - Virtual Meter (VM)

Residential apartments	Meter Count	Non-coincident Peak (kW)	Coincident Peak (kW)	Peak Diversity Factor	% of rated Transformer Capacity
Average Winter day	150	534	280	52%	59%
Heat Dome peak day	150	611	379	62%	80%

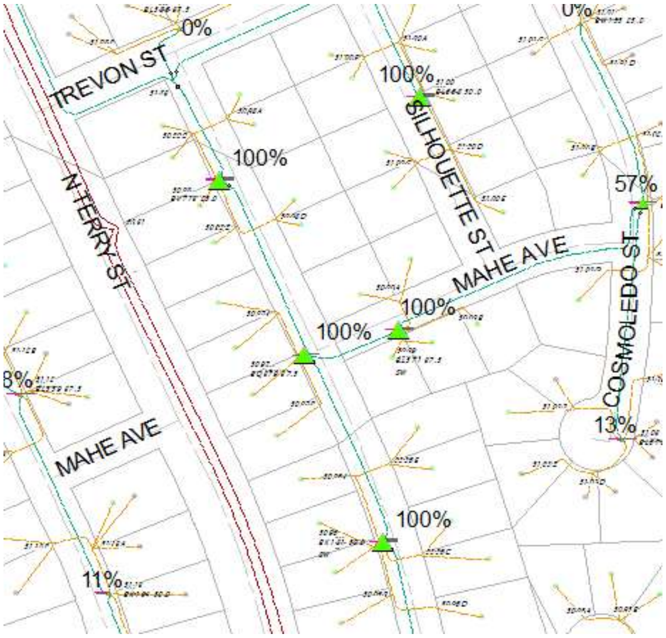
Many electrification studies assume that once a single home's peak is known, you can simply add up the number of homes to find the total peak. This is known as non-coincident peak and assumes that each home peaks at exactly the same time which overestimates actual system. Metered data (like the virtual meter from above) shows that the actual peak (coincident peak), for an average winter day, is much less (only 52%) than the non-coincident peak load. Understanding the coincident peak load can be helpful in system planning for estimating the impacts of many customers choosing to electrify. Additionally, the statistics for these 2 virtual meter examples represent the total energy from the whole dwelling and not just a single end-use, such as a heating, hot water, or cooling system.

Below are some example statistics for a group of single-family dwellings which have gas space heating and electric cooling Note these statistics are representative of a single day and are not representative of annual energy use.

NWNG customers (gas heating and electric cooling)- Virtual Meter (VM)

Residential single family dwellings	Meter Count	Non-coincident Peak (kW)	Coincident Peak (kW)	Peak Diversity Factor	% of rated Transformer Capacity
Average Winter day	34	82	48	58%	25%
Heat Dome peak day	34	181	132	73%	69%

Below is a GIS representation of the NWNG heated homes that were gathered to create a virtual meter for analysis.



Unfortunately, this early EWEB advanced metering data is limited. What is missing from this analysis is a collection of electric-only SFD statistics to compare to the statistics for SFD with natural gas. This could be useful when trying to estimate the impacts of electrification on SFDs. After AMI is fully deployed and analytical tools are developed, along with customer segmentation information, it may be possible to better understand and predict customer driven load profiles and their cumulative impacts on EWEB's distribution system. This type of data can inform our end-use models and energy resource needs in the upcoming IRP.

Grid Visibility and Modernization

Electric utility customers expect affordable, clean, and reliable power. As the distribution network becomes more dynamic, its complexity increases, and the volume of data that utilities need to understand and integrate change will continue to multiply. Historically, the Supervisory Control and Data Acquisition (SCADA) system delivered monitoring and control while the Outage Management System (OMS) assisted in power restoration. But these systems do not provide utilities with the ability to proactively monitor the health of our evolving grid. Ultimately, additional systems, like CIS[47], GIS, MDM, EMS[48], and outside data sources, like natural gas availability databases, need to be integrated to provide sufficient grid visibility to better manage customers' changing energy needs.

An integrated approach is often referred to as an Advanced Distribution Management Solution (ADMS). Ultimately, providing dispatchers and distribution system planners with location specific, real-time data and advanced analytics will benefit both the utility and their customers. ADMS takes a bottom-up distribution system planning approach, allowing for location specific solutions, in areas with the greatest need. Though this type of planning may not be a requirement for EWEB today, a growing number of utilities are implementing these tools. For example, Portland General Electric is developing grid visibility tools to help plan for future DER[49], DR[50], as well as providing customers with local grid information. This level of detail enables a collaborative partnership between the utility and its customers to develop and manage change in the most cost-effective manner.

[47] Customer Information Systems (CIS) track general customer account information.
[48] Energy Management Systems (EMS) track customer conservation information.
[49] Distributed Energy Resource (DER) are small scale generators that are located close to where energy is consumed.
[50] Demand Response (DR) is a programmatic change in customer consumption to better match power supply.

14 Appendix A: 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.
Annualized Fuel Utilization Efficiency (AFUE)	Annualized Fuel Utilization Efficiency (AFUE) Furnaces are rated by the Annual Fuel Utilization Efficiency (AFUE) ratio, which is the percent of heat produced for every dollar of fuel consumed. Any furnace with an efficiency of 90% or higher is considered high efficiency.
Benefit/Cost Ratio (BCR)	A ratio used to summarize a benefit-cost analysis to determine if a proposed project's benefits outweigh the costs. If the BCR is greater than one, the net present value of taking action is expected to be positive. If the BCR is less than one, the costs outweigh the benefits.
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.
Capacity Utilization	Capacity utilization measures the maximum rate of potential output used over a set period of time.
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.
Capacity	The maximum output or electrical rating, commonly expressed in megawatts (MW).
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.
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.
Coincident Demand	The sum of two or more demands that occur in the same time interval[51].
Cold Climate Heat Technology	The most efficient type of air source heat pump designed for cold climates using variable speed drive compressor technology.
Commodity	An economic good that can be bought and sold and interchangeable with other goods of the same type.
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.
Cost-parity	Same price for product that is equivalent in value.
Critical Peak Pricing	Critical Peak pricing is a price-responsive mechanism designed to incentivize customers to reduce or shift electricity usage during a critical event.

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

Demand	The rate at which energy is being used by the customer.
Demand Response (DR)	Demand response is a measure to reduce or shift electricity usage during peak periods or as a response to supply constraints.
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 Air Capture	A technology to capture CO2 from the atmosphere.
Direct Load Control (DLC)	The consumer load that can be interrupted at the time of peak load by direct control of the utility[52].
Discounted Cash Flow	A method to estimate the present value of an investment based on the expected future cash flows.
Discount Rate	The interest rate used to determine the present value of future cash flows.
Dispatchable	The operating control of an integrated electric system involving operations such as the assignment of load to specific generating stations and other sources of supply to effect the most economical supply as the total or the significant area loads rise or fall[53].
Distributed Energy Resources (DER)	DER refers to systems that generate electricity at or near the load it is intended to serve and connected to the distribution system.
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.
Distribution Capacity	The installed capacity and capable load of individual circuits within the distribution asset system.
Diurnal	Diurnal variation refers to daily fluctuations.
Duct System	A system of tubes and pipes used for heating, ventilation, and air conditioning
Electric Panel	The electric service panel or circuit breaker box connects the main power line and distributes electrical currents to circuits within a home or building.
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. • 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[54]. • 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.

[52] https://www.eia.gov/tools/glossary
[53] https://www.eia.gov/tools/glossary
[54] https://www.energy.gov/eere/electricvehicles/charging-home

	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.
End Use	The use of energy for a specific purpose where electricity is converted into useful work. Examples include transportation, heating or cooling.
Energy Efficiency (EE)	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.
Energy Efficiency Ratio (EER)	The Energy Efficiency Ratio (EER) of an HVAC cooling device is the ratio of output cooling energy (in BTU) to input electrical energy (in watts) at a given operating point.
Energy Factor (EF)	The energy factor (EF) indicates a water heater's overall energy efficiency based on the amount of hot water produced per unit of fuel consumed over a typical day.
Fossil Fuel	An energy source formed in the Earth's crust from decayed organic material. The common fossil fuels are petroleum, coal, and natural gas[55].
Generation	The process of producing electricity from water, wind, solar, fossil-based fuels, and other sources.
Generation Capacity	The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load[56]
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[57].
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[58].
Heating seasonal performance factor (HSPF)	Heating seasonal performance factor (HSPF) is a term used in the heating and cooling industry. HSPF is specifically used to measure the efficiency of air source heat pumps. HSPF is defined as the ratio of heat output (measured in BTUs) over the heating season to electricity used (measured in watt-hours).
HVAC	HVAC is an acronym for heating, ventilation, and air conditioning.
Incremental Cost	See Marginal Cost
Inflation	The growth rate of a price index. Inflation occurs when the purchasing power of your dollars decreases due to rising prices.

55 https://www.eia.gov/tools/glossary
56 https://www.eia.gov/tools/glossary
57 https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
58 https://www.eia.gov/tools/glossary

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.
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.
Intra-day Net Load Ramping	Net load ramping occurs within the day when renewable generation decreases at the same time load rises.
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[59]. Interval metering of end-uses is one method used to develop a load shape.
Marginal Cost	The change in cost associated with a unit change in quantity supplied or produced[60].
Marginalized Communities	Communities that experience discrimination and exclusion from social, economic, and/or cultural life.
Market-based pricing	Prices of electric power or other forms of energy determined in an open market system of supply and demand under which prices are set solely by agreement as to what buyers will pay and sellers will accept. Such prices could recover less or more than full costs, depending upon what the buyers and sellers see as their relevant opportunities and risks[61].
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.
Mini-Split Ductless System	A ductless heating and cooling system for use in smaller spaces or individual rooms. Mini-split systems have two main components: an outdoor compressor/condenser and an indoor air-handling unit(s).
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[62].
MSRP	MSRP is the acronym for manufacturer's suggested retail price.
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
Nominal Dollar	Nominal or current dollars have not been adjusted for inflation.

59 https://www.eia.gov/tools/glossary
60 https://www.eia.gov/tools/glossary
61 https://www.eia.gov/tools/glossary
62 https://www.epa.gov/fueleconomy/text-version-electric-vehicle-label

Noncoincident Demand	Sum of two or more demands on individual systems that do not occur in the same demand interval[63].
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.
Peak Diversity Factor	Peak Diversity Factor is the ratio of coincident peak demand to the non-coincident peak demand over a given period of time. This ratio illustrates the relationship between the peak electricity use of a population relative to the sum of all individual peak electricity use within the population. A high peak diversity factor (100%) indicates that the individual units within the population peak simultaneously, whereas a low peak diversity factor illustrates that individual units within the population peak at different times.
Peak Time Rebate	A pricing mechanism designed to incentivize reducing energy during peak time events by offering a rebate.
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.
Photovoltaic (PV)	PV is the process of converting sunlight into electrical energy using semiconducting materials.
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)[64].
PUC	Public Utility Commission
Quad	Quadrillion Btu 10^{15} Btu. The quantity 1,000,000,000,000,000(10 to the 15th power).[65]
Qualitative	Qualitative data is descriptive, conceptual, and is non-numerical.
Quantitative	Quantitative data is anything that can be counted, measured, or quantified using a numerical value.
Real-time	Actual time of occurrence.
Real-time Pricing	Real-time Pricing is designed to charge each kWh delivered based on fluctuating wholesale prices or production costs.
Renewable Natural Gas (RNG)	RNG is derived from the decomposition of organic waste and has lower carbon emissions than conventional natural gas.
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.
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.

[63] https://www.eia.gov/tools/glossary
[64] https://www.eia.gov/tools/glossary
[65] https://www.eia.gov/tools/glossary

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.
Social Cost of Carbon	The estimated economic damage in dollars from emitting one ton of carbon dioxide.
Therms	A measurement of heat energy in natural gas. One unit of heat is equal to 100,000 British thermal units (BTU).
Time of Use (TOU) Rate	Time of use rates are rate structures which incent a customer to change their electric usage patterns, because they typically charge higher prices for consumption during peak periods.
Total Lifecycle	Lifecycle of a targeted measure refers to the expected life from the time the product is introduced in the market until it's removed.
Transformer	An electrical device for changing the voltage of alternating current[66].
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.
Transmission Capacity	The maximum line and associated equipment available to move or transfer bulk energy across a transmission system.
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.
Uniform Energy Factor (UEF)	A water heater's UEF rating is a measure of its energy efficiency, with higher numbers denoting more efficient units. The UEF calculation is based off how much energy the water heater uses and how much energy is used to power the water heater itself.
Upstream Emissions	Upstream typically refers to accounting for the all the emissions associated with extracting and processing resources used to create energy.
Variable Generation	Variable generation is produced using renewable resources (e.g., solar, wind, or run-of-river hydro) that is intermittently available.
Voltage	The difference in electrical potential between any two conductors or between a conductor and ground. It is a measure of the electric energy per electron that electrons can acquire and/or give up as they move between the two conductors.[67].
Wholesale Market	The market for buying and selling of electricity before it is sold to the end-user.

[66] https://www.eia.gov/tools/glossary
[67] https://www.eia.gov/tools/glossary

15 Appendix B: 2021 EWEB Residential Energy Program Summary

Program	Rebates Available	Loan Limit (0% interest)	Program Requirements
Ducted Heat Pump	$1,000 Income eligible: $3,800 for owner occupied or $1,000 for rentals	$12,000 for site-built homes, $7,000 for manufactured	• Air-source heat pumps only. • For income eligible amount, home must have electric heat. • Learn more at **bit.ly/EWEBductedhp**
Ductless Heat Pump	$800 Income eligible: $3,800 for owner occupied or $1,000 for rentals	$4,000, plus $1,500 per additional head, up to $10,000	• For buildings with more than 4 units (side-by-side condos/townhouses, or apartments) check with EWEB for eligibility. • Homes with existing operable ducted heat pumps are not eligible to participate. • If there is a pre-existing ductless heat pump, it must be removed. • For income eligible amount, home must have existing electric heat. • Learn more at **bit.ly/EWEBdhp**
Insulation & Air Sealing	$0.80/sf of insulation, up to 50% of eligible cost, plus $0.10/sf for air sealing Income eligible: 100% of eligible insulation cost, plus $0.10/sf for air sealing	$4,000 plus $1,000 for air sealing	• Home must have electric heat and be poorly insulated. • For income eligible, a minimum of 2 bids are required. • Air sealing limited to being an additional component of an attic and/or underfloor crawlspace insulation project in single-family homes. • Learn more at **eweb.org/weatherize**
Windows	$4.00/sf of glass Income eligible: $20/sf for owner occupied or $10/sf of glass for rentals	$4,000 for U-factor ≤ 0.25 or $6,000 for U-factor ≤ 0.22 Multifamily: $3,500 + $500/unit up to $20,000	• Home must have electric heat and existing single pane or double pane metal windows. • Unless otherwise specified, must have U-factor ≤ 0.22. • For income eligible, the home must have electric heat and existing single pane windows. Windows with U-factor ≤ 0.30 are allowed for owner-occupied. • Learn more at **eweb.org/weatherize**
New Construction	$1,000 heat pump, ducted or ductless $800 heat pump water heater NEEM-certified manufactured homes: $1,200 for v1.1 or $1,400 for v2.0	N/A	• EWEB encourages homes to be built with efficient low-carbon electric heating and water heating systems. • Rebates for multifamily, affordable housing and custom projects are available but not listed here, contact us for details. • Learn more at **bit.ly/EWEBnewconst**
Solar Electric Net Metering	$0.40/AC output watt up to $2,500	N/A	• Site must have at least an 85% total solar resource fraction to receive rebate. • 25 kW max. Direct generation option available in lieu of net meter. • Learn more at **eweb.org/solar**
Level 2 EV Charger	$500	N/A	• Charger must be Level 2 (240V, 30 Amp minimum power output capacity), equipped with the SAE J1772 standard or Tesla connector plug, installed in compliance with applicable codes. Learn more at **eweb.org/ev**

Program	Rebates Available	Loan Limit (0% interest)	Program Requirements
Heat Pump Water Heater	$800 Income eligible: $1,700 for owner occupied, $1,000 for rental	$2500	• Must be Tier 3 and on a qualified products list, with at least a 40-gallon tank. • For income eligible amount, home must have electric water heat. • Learn more at **bit.ly/EWEBhpwh**
Toilets	$50 for 1.28 gpf toilets, or $100 for 1.0 gpf toilets	N/A	• New toilet must be WaterSense and use either 1.28 gallons per flush or 1.0 gallons per flush or less. • New toilets must replace an existing toilet using 1.6 gallons per flush or more. • Rebate is paid via bill credit. Learn more at **eweb.org/waterconservation**
Hand Valve	Free valve (or $75 bill credit) and $75 bill credit for installation	N/A	• Shut-off valve to be installed on customer side of water meter by a plumber. Valves may be provided by plumber or EWEB. • Learn more at **eweb.org/waterconservation**
Water Service Line Replacement	N/A	$5,000	• Replacement of a leaking water service line between the meter and the house only. Must be done by a qualifying plumber. • Learn more at **eweb.org/leakassistance**
Leak Repair Assistance	100% of eligible costs, income eligible only	N/A	• Applies to minor plumbing repair and/or service line replacement.
Septic	$250 to inspect and pump out septic system	$10,000 for repair or replacement of septic system	• Property must be within the McKenzie River Pure Water Partners Boundary. • Learn more at **eweb.org/septic**
EWEB Greenpower	N/A	N/A	• Support clean energy & encourage renewable energy projects in our community by assigning 100% of your electricity to Greenpower or choosing blocks of Greenpower for as little as $1.50 per month. • Learn more at **eweb.org/greenpower**
Efficiency Education Program	FREE	N/A	• Income qualified customers receive a free kit with energy and water-saving products and basic emergency preparedness supplies. We visit your home and evaluate it, looking for opportunities to reduce your monthly bill, improve your home comfort and lower your carbon footprint. Contact us for details.
Home Energy Score	FREE	N/A	• Focused on rental properties, either tenants or rental owners can apply and receive an energy report with recommendations. Tenants can choose to have recommendations sent to landlord. Learn more at **eweb.org/rentals**
Electric Service Upgrade	N/A	$20,000	• Property must be in EWEB electric service territory. Examples include electric panel or meter base replacement, underground service work, or new services. • Learn more at **eweb.org/service-upgrade**
Backup Generator	N/A	$2,000 $4,000 with well for domestic water	• Installation must include a transfer switch and be permitted. Applicant must be an EWEB electric customer and be the owner of the property. • Learn more at **eweb.org/generatorloan**

1. Unless otherwise noted, customer is eligible for a loan OR rebate, not both, unless income eligible. Loans and rebates are capped at project cost, including installation.
2. An application submitted by the homeowner is required. Apply online for most programs at **https://secure.eweb.org/ProgramApp.aspx**.
3. Program restrictions may apply. Rebate and loan amounts are subject to change at any time, please contact EWEB at **541-685-7088**, or visit our web site, for the most current program information.
4. Loan funding may be used to cover costs of labor from participating contractors. See lists of contractors online at **eweb.org/contractorlist**.
5. Information about all of EWEB's rebate and loan offerings can be found at **http://www.eweb.org/saveenergy**.
6. To qualify for the limited-income funding, households must meet income guidelines, which can be found at **bit.ly/EWEBLI**.
7. Aggregate loan limit is $20,000 per customer. The term for an EWEB loan is 48 months when borrowing under $5,000, or 60 months when borrowing $5,000 or more.
8. Homes with gas, oil, wood, or propane heat can qualify for non-income eligible rebates for Ducted of Ductless Heat Pump programs.

16 Appendix C: EWEB Business Commercial Programs, Rebates, and Loans - Program Summary

<table>
<tr><th>Commercial Lighting</th><th>Rebates Available</th><th>EWEB Code</th><th>Program Requirements</th></tr>
<tr><td rowspan="7">Lighting Rebates</td><td>$2 per LED tube</td><td rowspan="7">N/A</td><td rowspan="7">• Actual rebate is determined by EWEB's lighting calculator.
See EWEB Lighting Rebates for complete list of rebates
• An increase or decrease in the number of fixtures may be allowed.
• Installed LED products must be listed by DLC or ENERGY STAR.
• Rebates not to exceed 50% of the project cost. For new construction projects, rebates not to exceed 50% of the incremental cost for the LED package.
• Rebates over $2,500 need EWEB pre-approval.
• Additional rebates available for networked lighting controls.
• All lamps, ballasts, and fixtures must be disposed of according to law
• Learn more at http://bit.ly/EWEBclt</td></tr>
<tr><td>$2-5 per small screw-in LED</td></tr>
<tr><td>$20-200 per General Indoor/Outdoor LED fixture</td></tr>
<tr><td>$30-500 per LED fixture replacing HIDs or High Bay</td></tr>
<tr><td>$30 – 500 LED Exterior</td></tr>
<tr><td>$20 per LED exit sign</td></tr>
<tr><td>$10-40 per lighting controls such as occupancy sensors</td></tr>
<tr><th>Commercial HVAC</th><th>Rebates Available</th><th>EWEB Code</th><th>Program Requirements</th></tr>
<tr><td rowspan="3">Ductless Heat Pumps</td><td>**$1,300 per ton – existing electric heat</td><td>DHP-30</td><td rowspan="3">• System must replace an existing zonal or forced-air electric resistance or gas system.
• Systems with no ductwork must have a minimum HSPF of 11. Systems with any mix of ductwork must have a minimum HSPF of 10.
• Learn more at http://bit.ly/EWEBchvac</td></tr>
<tr><td>$350 per ton – existing non-electric heat</td><td>DHP-40</td></tr>
<tr><td>$300 per ton – existing DHP upgrade or new construction</td><td>DHP-50</td></tr>
<tr><td>Variable Refrigerant Flow (VRF)</td><td>**$1,300 per ton of cooling capacity, retrofit</td><td>VRF-110</td><td>• Replacing existing electric resistance heat for retrofit. If replacing existing gas heat, see Custom Projects.
• Installed system must have an AHRI certificate showing it meets minimum efficiency requirements. Requirements vary with system capacity, see website for details.</td></tr>
<tr><td rowspan="3">Packaged Heat Pumps</td><td>$1,000 per ton – existing resistance heat</td><td>HP-100</td><td rowspan="6">• Air-source heat pumps only. Ground-source heat pumps do not qualify.
• Split systems have an indoor air handler and a separate outdoor compressor. A packaged system has the heating and cooling equipment in a single package, often located on the roof.
• Installed system must have an AHRI certificate showing it meets minimum efficiency requirements. Requirements vary with system capacity, see website for details.
• Learn more at http://bit.ly/EWEBchvac</td></tr>
<tr><td>$350 per ton – existing non-electric heat</td><td>HP-110</td></tr>
<tr><td>$150 per ton – existing heat pump upgrade or new construction</td><td>HP-140</td></tr>
<tr><td rowspan="3">Split System Heat Pumps</td><td>$1,000 per ton – existing resistance heat</td><td>HP-120</td></tr>
<tr><td>$350 per ton – existing non-electric heat</td><td>HP-130</td></tr>
<tr><td>$150 per ton – existing heat pump upgrade or new construction</td><td>HP-150</td></tr>
</table>

Commercial HVAC (Cont.)	Rebates Available	EWEB Code	Program Requirements
Packaged Terminal Heat Pump (PTHP)	$600 per unit – replacing PTAC or zonal electric resistance heat	PTHP-100	• Retrofit of existing installations and new equipment are both eligible. • Only lodging facilities (hotel, motel, B&B, dormitory, or shelter) or residential care buildings (nursing homes, retirement homes, and assisted living facilities) are allowed.
	$100 per unit – new construction	PTHP-110	
Variable Frequency Drives (VFD)	$300 per fan motor horsepower – electric or gas heat	VFD-100	• Retrofits only. Must be installed on a single-speed air handling unit fan. • Any existing AHU throttling or bypass devices must be removed or permanently disabled.
Connected Thermostats	$350 per thermostat – electric heat	CT-100	• For retrofits only. Heating system can be electric or gas. • Not available for lodging, 24/7 occupancy, or semi-conditioned spaces. • A building is eligible to receive payment for more than one thermostat. • Product must be on qualified list. Learn more at http://bit.ly/EWEBchvac
	$350 per thermostat – gas heat	CT-110	
Advanced Rooftop Unit Controls (ARC)	**$200 per ton – Lite: VFD or controller for multispeed fan operation	ARCL-1	• Existing rooftop units must be unitary systems (split-systems are not eligible), have a cooling capacity of at least 5 tons, and use constant speed supply fans (RTUs with variable speed fans are not eligible). • RTU heating fuel type may be electric or gas. • Installed controls must be on a qualified products list. • Learn more at http://bit.ly/EWEBchvac
	**$300 per ton – Full: VFD or controller for multispeed fan operation, plus digital economizer control and demand control ventilation with CO2 sensor	ARCF-11	
Commercial Weatherization	**Rebates Available**	**EWEB Code**	**Program Requirements**
Windows	$4 per square foot of glass – electric air source heat pump	WIN-100	• Retrofits only. Pre-existing windows must be single pane, single pane with storms, or double pane metal. • Installed windows must have a U-factor of 0.22 or less. Patio doors must have a U-factor of 0.25 or less.
	$4 per square foot of glass – electric forced air furnace or zonal heat	WIN-110	
Insulation	$0.80 per square foot, up to 50% of cost – electric heat – attic or roof insulation	INSA-100	• Retrofits only. Pre-existing insulation must be between R-0 and R-5.
	$0.80 per square foot, up to 50% of cost – electric heat – wall insulation	INSW-110	
Process and Manufacturing	**Rebates Available**	**EWEB Code**	**Program Requirements**
Small Compressed Air Systems	$0.18 per annual kWh saved, up to a maximum of 70% of project cost	AIR-100	• VFDs applied to a single air compressor or installation of cycling refrigerated air dryers of 75 horsepower or less. Incentives for air compressors over 75 hp, and for other compressed air savings measures, are available through EWEB's custom incentive program. • Each VFD compressor must be submitted as an individual project (i.e. compressors may not be combined or divided).
High Frequency Battery Charger	$0.18 per annual kWh saved, up to a maximum of 70% of project cost	HFBATT-100	• New construction projects are not eligible. • This measure applies to the replacement of existing ferroresonant or silicon-controlled rectifier (SCR) chargers ONLY. • Installation of a new, high-frequency inverter-based battery charger, with rated input power of more than 2 kW and that uses 10W or less of standby power. • Power conversion efficiency no less than 89%.

Welder Upgrade	$0.18 per annual kWh saved, up to a maximum of 70% of project cost	WELD-100	• New construction projects are not eligible. • Installed inverter-based welder must be rated for a minimum of 200 amps.
Block heaters	$200 – for generators under 3 kW	GBH-100	• Retrofit of existing installations and new equipment are both eligible. • The generator or engine must be stationary and fixed. • Installed generator engine block heater must be forced-circulation heaters. • A Project Information Form is required.
	$1,500 – for generators 3 kW and greater	GBH-110	
New Construction & Custom	**Rebates Available**	**EWEB Code**	**Program Requirements**
Commissioning (RCx)	$0.07 per kWh of first year savings $0.03 per kWh of second year savings $0.03 per kWh of third year savings	N/A	• Savings are determined using billing data from year prior to commissioning work, and weather-adjusted billing data from subsequent years.
Custom Projects	$0.18 per annual kWh of saved, or custom	N/A	• Custom projects typically require a measurement and verification plan before project begins. • Partial payment is generally processed upon project completion, with remaining payment being processed after measurement and verification plan is met.
New Construction Projects	$0.18 per annual kWh of saved, or custom	N/A	• For efficient electric HVAC systems. • Additional rebates for qualifying affordable housing new construction are available. Contact EWEB for details.

Commercial Food Services	**Rebates Available**	**EWEB Code**	**Program Requirements**
Commercial Food Services Rebates	$500 per combination oven – 5 to 15 pans	FS-414	• Installed product must be electric and meet ENERGY STAR v2.2 requirements. • Learn more at http://bit.ly/EWEBcfs
	$500 per combination oven – 16 to 20 pans	FS-415	
	$400 per full size convection oven	FS-412	
	$200 per half size convection oven	FS-413	
	$250 per commercial fryer	FS-405	• Installed product must be electric and meet ENERGY STAR v3.0 requirements. • Learn more at http://bit.ly/EWEBcfs
	$250 per insulated holding cabinets, half size	FS-406	• Installed product must be electric and meet ENERGY STAR v2.0 requirements. • Learn more at http://bit.ly/EWEBcfs
	$500 per insulated holding cabinets, full size	FS-407	
	$1,000 per insulated holding cabinets, double	FS-408	
	$500 per steam cooker, 6-pan capacity	FS-603	• Installed product must be electric and meet ENERGY STAR v1.2 • Learn more at http://bit.ly/EWEBcfs
Demand-Controlled Kitchen Ventilation	$200 per horsepower - single control sensor	FS-450	• Controls must reduce fan speed during times of low demand and must be applied to both primary ventilation and make-up air units in a kitchen. • Controls can be applied to either new or modified existing exhaust hoods. • Learn more at http://bit.ly/EWEBcfs
	$400 per horsepower - multiple control sensors	FS-455	

Commercial Refrigeration	Rebates Available	EWEB Code	Program Requirements
Reach-in Case Anti-Sweat Heater Controls	$40 per linear foot - medium temp (1° F - 35° F)	RF-162	• Controls must reduce run-time of the anti-sweat heaters in the door rail, glass and/or frame by at least 50%. • This rebate does not apply to existing doors already equipped with low/no anti-sweat heat. • Learn more at http://bit.ly/EWEBcref
	$40 per linear foot - low temp (below 0° F)	RF-161	
Strip curtains	$9 per square foot – Cooler, grocery	SC-100	• Applies to retrofits only. • Must install strip curtains or swinging doors at least 0.06 inches thick. • Learn more at http://bit.ly/EWEBcref
	$9 per square foot – Freezer, grocery	SC-110	
	$9 per square foot – Freezer, convenience store	SC-120	
	$9 per square foot – Freezer, restaurant	SC-130	
Efficient Fan Motors for Coolers	$140 per motor – walk-in – 23 watts or less	RF-080	• Existing equipment must be standard efficiency shaded pole fan motors in a refrigerated display case, walk-in cooler or freezer. • Walk-in cooler or freezer fans must have a diameter of at least 10 inches. • Installed motors must be electronically commutated motors (ECMs). • Learn more at http://bit.ly/EWEBcref
	$140 per motor – walk-in – greater than 23 watts	RF-081	
	$55 per motor – display case	RF-172	

Rebates cannot exceed 100% of program cost.

* An application must be submitted by the property owner or owner's representative. Low-interest loans may also be available, upon approved credit.

** Promotional Incentive. Project application must be approved by September 30, 2021.

*** Program restrictions may apply. Rebate and loan amounts are subject to change at any time.

Please contact EWEB at 541-685-7088 for the most current program information.