MEMORANDUM

EUGENE WATER & ELECTRIC BOARD

Rely on us.

TO:	Commissioners Schlossberg, Brown, Carlson, Barofsky and McRae
FROM:	Megan Capper, Energy Resources Manager
DATE:	August 3, 2021
SUBJECT:	Preliminary Results from Phase 2 of the Electrification Impact Analysis Report
OBJECTIVE:	Board Feedback & Guidance

Issue

This is a meeting to share preliminary results from Phase 2 of the Electrification Impact Analysis Report for Board discussion. This analysis is part of the 2021 EWEB organizational goal #5 approved by the Board in January 2021, which states:

> *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?*

Background

EWEB's strategic plan includes a statement that we value our *"role in reducing the greenhouse gases (GHGs) contributing to Climate Change"*. Supporting the strategy and values, EWEB's Climate Change Policy (SD15) "*directs the General Manager to assist customers with their carbon reductions through technical assistance and resources that support energy efficiency, alternative fuels, electric and water conservation, and smart electrification"*.

In March 2020, EWEB management and the Board of Commissioners determined that understanding the impacts of electrification will be the focus of the utility's near-term power supply planning work. This targeted analysis is intended to address the growing interest in our community to transition from fossil-based fuels to electricity to address climate change. It will help the utility quantify the potential impacts of electrification at scale and inform integrated resource planning for the future.

Phase 1, presented at the November 2020 Board meeting, focused on the potential impacts of electrification without analyzing the costs to society, utilities, or the customers choosing to electrify. Phase 2 of the electrification impact study seeks to build on the analysis and context presented in Phase 1 by considering the economics of electrification from multiple perspectives. Like Phase 1, analysis of the transportation sector focuses on light-duty vehicle electrification. The building sector analysis includes the electrification of space and water heating technologies for existing buildings.

Discussion

The report attached herein provides the preliminary results from the Phase 2 analysis. This study targets the transportation and building sectors which could experience electrification over the next 30 years. Adding the economic impact provides insight into the relative benefits and costs to an EWEB customer, an EWEB ratepayer, and to society.

The preliminary results in this document focus on the residential sector. The final report, which will be provided to the board in November, will include the commercial office segment, as well as additional scenarios and sensitivities, including futures that alter the cost of gasoline, natural gas, and equipment, as well as carbon intensity of electricity and natural gas relative to the base case assumptions presented in the preliminary findings.

Requested Board Action

No Action is requested; Commissioner feedback is desired.

Electrification Impact Analysis Report

Phase 2 Preliminary Findings | August 2021

CONTENTS

1 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 economics 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 which can be electrified. The preliminary results in this document focus on the residential sector. The final report, which will be provided to the board in November, will include the commercial office segment, as well as additional scenarios and sensitivities. These scenarios and sensitivities will include futures that alter the cost of gasoline, natural gas, and equipment relative to the base case assumptions presented in the preliminary findings.

Consumer economics are influenced by forces largely beyond the control of EWEB, such as state or federal policies and technological innovation. EWEB policies, incentives, or rebates can also change consumer economics. This analysis lays out a framework that may inform potential incentive levels by end-use. Incentive levels that leave the utility/customers indifferent (held harmless) while providing the additional incentive could help drive consumer adoption. This analytical framework can also 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 work is foundational and informs other work streams such as future integrated resource plans.

Non-economic decision making is outside the scope of this study. Consumer choice has multiple drivers, but economics are nearly always a primary consideration and is the focus of our quantitative analysis. While we do not disregard qualitative impacts to customer choice (like passion for carbon reduction), these are difficult to model with any confidence.

2 BASE CASE ASSUMPTIONS

As with any study, assumptions are important. The assumptions used in this study are presented below in a summarized, preliminary fashion. The final study in November will include a more formal description of the assumptions.

For the EWEB participant perspective, EWEB's electricity rates are assumed to increase 3% on average throughout the study period. The EWEB ratepayer perspective assumes EWEB's energy needs will be met with market rate energy. 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[1] on an hourly basis used to quantify cost to the utility on an hourly basis. Modeled marginal energy costs range between $20-$33/MWh <u>on average.</u> Note, peak pricing can be much higher than average. For example, the maximum marginal energy price modeled in a single hour was $311/MWh.

<u>Electricity Supply Costs (besides energy)</u>

Generation Capacity	($16.0 nominal KW-yr.)
Transmission Capacity	($24.0 nominal KW-yr.)
Distribution Capacity	($25.0 nominal KW-yr.)

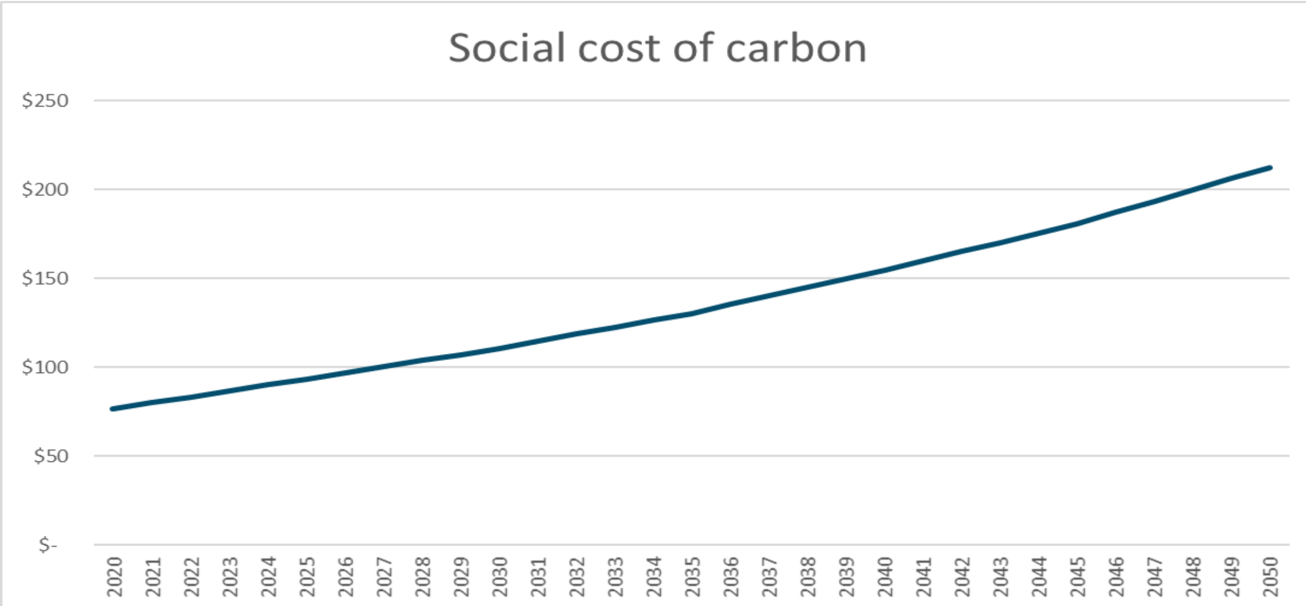
<u>Carbon Emissions Factors</u>

Gasoline CO2 = .0087 metric tonne per gallon (Raw Data from GREET 2018)

[1] Aurora is a registered trademark of Energy Exemplar Proprietary Limited.

Natural Gas CO2 = 0.005307 metric tonne per therm (Combustion emissions only))

Social cost of carbon based on values for Washington's Clean Energy Transformation Act (CETA)[2]



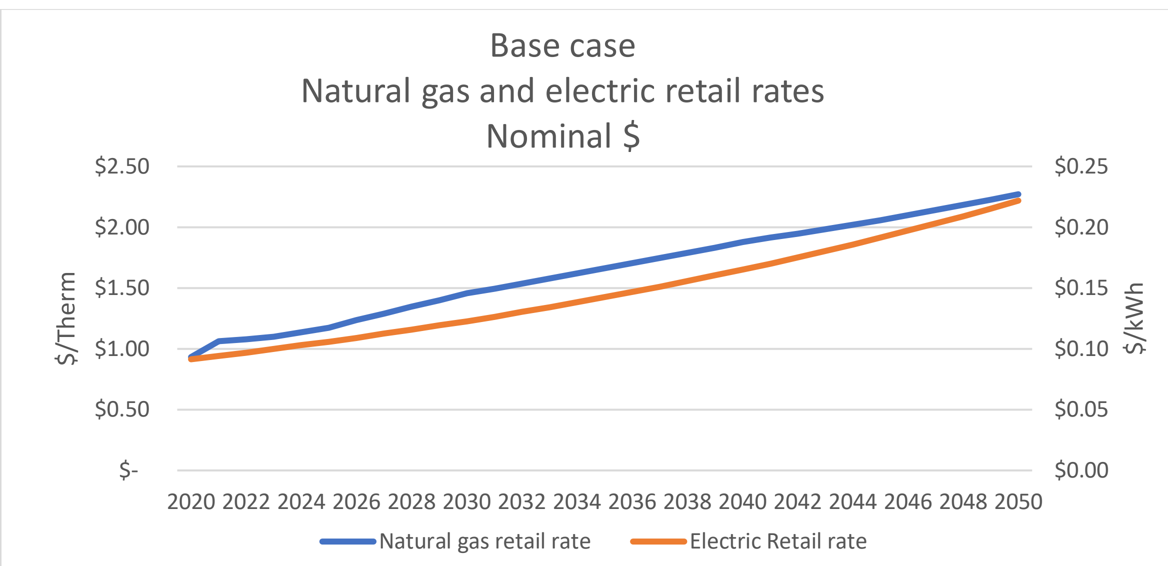
2.1 Transportation Electrification Key Assumptions

- Vehicle lifetime = 12 years
- 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) are held constant over time.
- Future gasoline prices were derived 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%
- Home Charging Access: 34% Level 1, 40% Level 2, 26% no home charging access.
- DC Fast Charging Efficiency: 85%

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

2.2 Building Electrification Key Assumptions

- Water heater lifetime = 10 years; Space Heater (heat pump/furnace) lifetime = 16 years
- Single family dwelling defined as 2,500 square foot detached home.
- 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 vs. "retrofit" replacement with a heat pump device
- Note: heat pump HVAC unit replaces both gas furnace and air conditioner.
- By default, the model assumes that AC is not fully depreciated at furnace expiration.
  - Thus, only 50% of a new AC cost is considered "avoided".
- Equipment and installation costs are based on cost estimates from 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.
- Electric panel upgrade cost ($0 base case, $1,000 sensitivity case).
- Utility incentives ($0 base case, $800 - $1,000 sensitivity case).
- Replacement of existing AC before fully depreciated (50% base case, 100% sensitivity case).
- Base case residential retail rates include 3% escalation for electric and 30% RNG blend by 2050 for natural gas.



- Renewable natural gas blend (RNG 15% by 2030 and 30% by 2050)
- Renewable natural gas cost ($22.5/mmBtu)

3 Key Context: Role of Economics in Electrification

HIGHLIGHTS

- 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 choosing to electrify (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 preserves the economic benefit needed to offset the cost of electrification investment.

Phase 2 of the electrification study utilizes benefit-cost analysis to better understand the financial considerations of a consumer choosing to electrify. EWEB's benefit-cost analysis considers the total lifecycle of targeted electrification measures, and then presents those findings on a discounted cash flow basis. However, as most consumers 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 the point of view. The consumer or "participant" is the EWEB customer who chooses to electrify, and they 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:

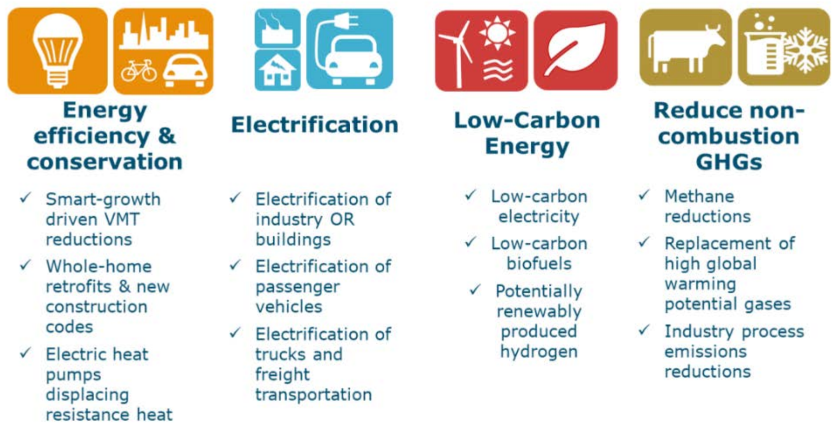
- **EWEB Participant:** Do benefits outweigh costs for an EWEB customer adopting a new technology?
- **EWEB Ratepayer:** Do benefits outweigh costs for a nonparticipant EWEB ratepayer?
- **Society:** Do benefits outweigh costs for a resident of the community?

3.1 "Smart" Electrification

Smart electrification considers the fact electrification may not be beneficial in all circumstances. Analyzing costs and benefits from multiple perspectives allows EWEB to better quantify value between the participant, ratepayers, and society. Each one of these groups considers different benefits and costs from their perspective. Smart electrification seeks to provide the greatest benefits to all parties involved while avoiding risk. Increasing peak energy use through electrification is a risk to future EWEB ratepayers because peak electricity is more expensive and often has higher carbon intensity. Smart electrification considers maximizing benefits for participants, ratepayers, and society while at the same time being mindful of potential peak impacts which could adversely impact the utility in the future.

Analyzing benefits and costs from multiple perspectives also helps the utility understand to what extent value can be exchanged between EWEB ratepayers and participants. For example, an electrification incentive (like EWEB's level 2 charger incentive) is an exchange of value from EWEB ratepayers to participants purchasing electric vehicles. However, EWEB ratepayers benefit from the additional revenue collected from the electric vehicle charging over time. Society will benefit from the emissions reductions created by electric vehicle adoption, but does the benefit to society outweigh the incremental cost to the participant? Is there a way to compensate the participant for the benefit created for society? EWEB has significant influence over the exchange of value between EWEB ratepayer and EWEB 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.

3.2 Affordability



Maintaining affordable electric rates will also play an important role in electrification. As discussed in Phase 1 of EWEB's electrification study, electrification is just one pillar of a larger decarbonization strategy[3]. The greening of the electric grid plays an important role in decarbonization as well, but as the electric sector is legislated to become cleaner, affordability of electric rates must be an important consideration. It is possible that increased electric rates could become a deterrent to electrification for the consumer. Electrification remains a critical pillar of successful, economy-wide decarbonization and encouraging consumers to adopt electric vehicles and electric heat pumps has not previously been done through legislated mandate. Absent such mandates to electrify, an attractive economic proposition is necessary to convince businesses and individuals to choose electrified technology over a fossil-based fuel alternative on a widespread basis.

4 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.

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

4.1 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[4].
- Nationally, the Biden administration has been working to advance the adoption of electric vehicles (EVs) and deploy additional charging infrastructure across the country[5].

4.2 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)[6]. 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. However, it should be noted that these commitments by OEMs have not yet been implemented, 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:

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

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

[6] IEA (2021), Global EV Outlook 2021, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2021

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

[7]

In 2020, EWEB had 559 new electric vehicles registered within the service territory. This represents a 42% increase in the number of vehicles 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.

5 Electric Vehicle Preliminary Findings

HIGHLIGHTS

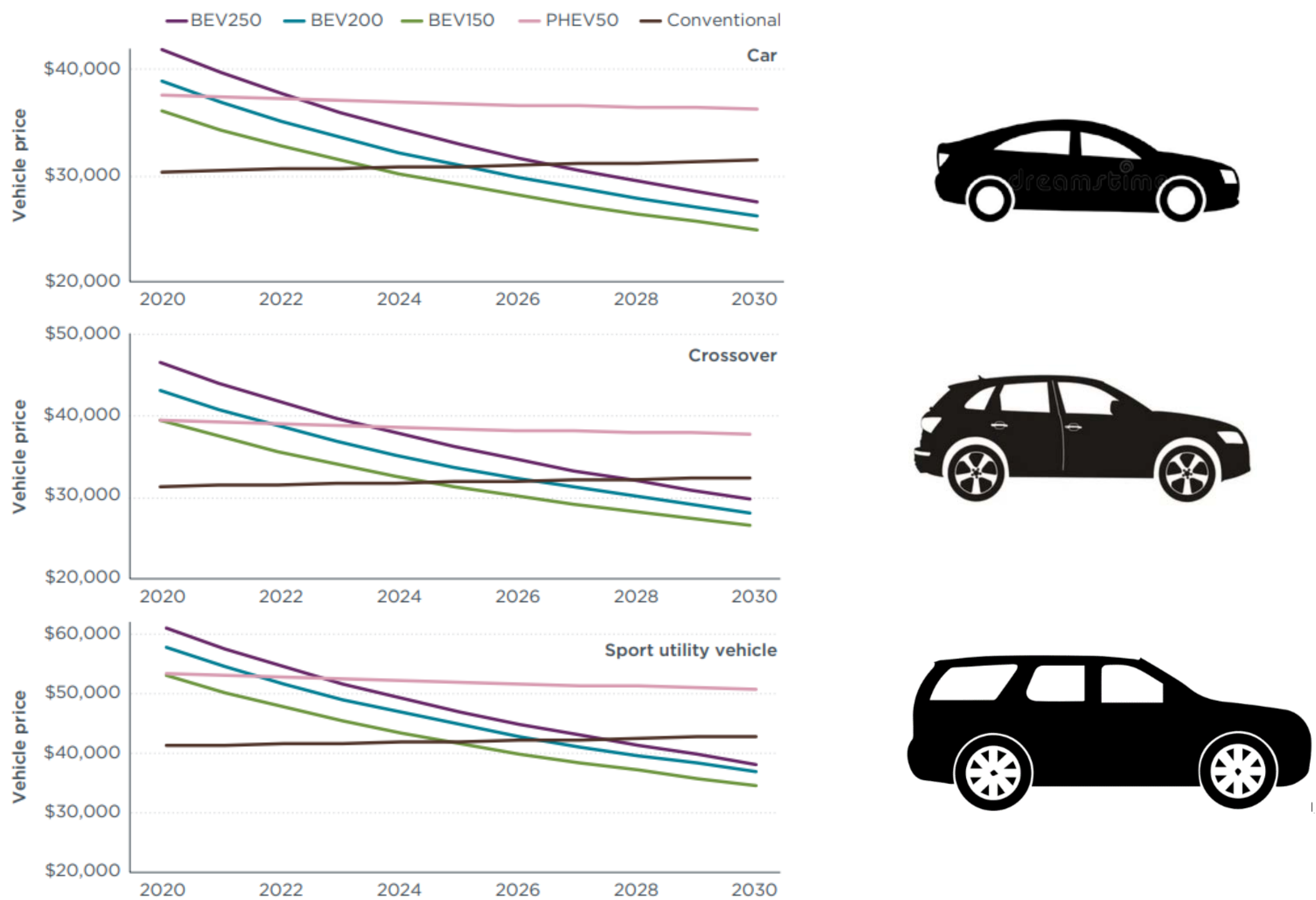
- While federal and state incentives help provide benefits to EV purchases today, the benefits of owning an EV are expected to dramatically improve by 2030, even as incentives go away.
- EVs provide benefits for owners, ratepayers, and society.
- Economic analysis indicates that EV adoption will rapidly increase after 2030, with nearly 85% of all vehicles on the road being electric by 2040.

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 A, below[8], from the International Council on

[7] https://www.iea.org/reports/global-ev-outlook-2021/trends-and-developments-in-electric-vehicle-markets
[8] 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

Clean Transportation (ICCT), compares the forecasted purchase price of EVs, at various battery sizes[9], with the forecasted price of conventional gas vehicles. Within the next decade, battery electric vehicles are projected to decline below the cost of conventional gas vehicles.

Figure A



As shown in Figure A, all battery electric vehicles, regardless of size or vehicle type, are expected to become cheaper than conventional cars before 2030. This forecasted decline in the purchase price of EVs is a key component of the benefit-cost analysis and one of the largest drivers of forecasted EV adoption. Figure A 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 forecasts remain uncertain, 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.

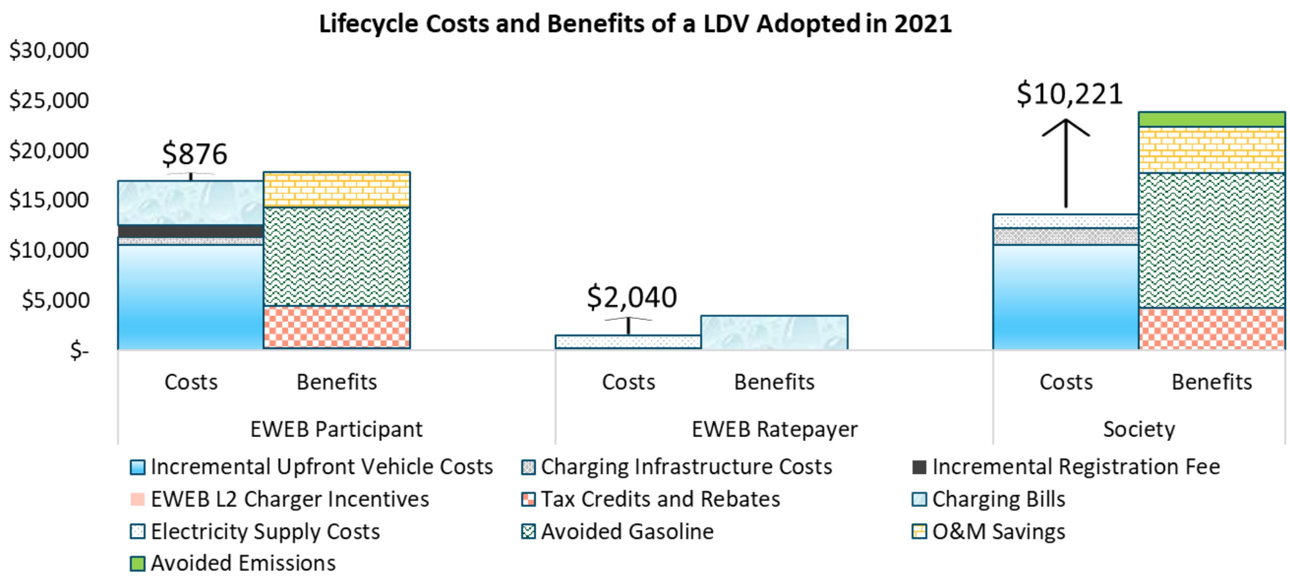
Electric vehicle incentives currently play an important role in EV benefit-cost analysis. Federal tax credits (up to $7,500) are available for certain models of electric vehicles, but the number of qualifying vehicles is currently limited to 200,000 per manufacturer. For example, EVs made by Tesla no 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 electric vehicles 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

[9] 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.

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 B, below, from the perspective of the EWEB participant, EWEB ratepayer and society. 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.

Figure B



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 stacking of benefits from the other two perspectives and adds an additional benefit of $1,400 for carbon reduction. The NPV of carbon reduction is estimated using the social cost of carbon[10] multiplied by the emission savings over the vehicle life.

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

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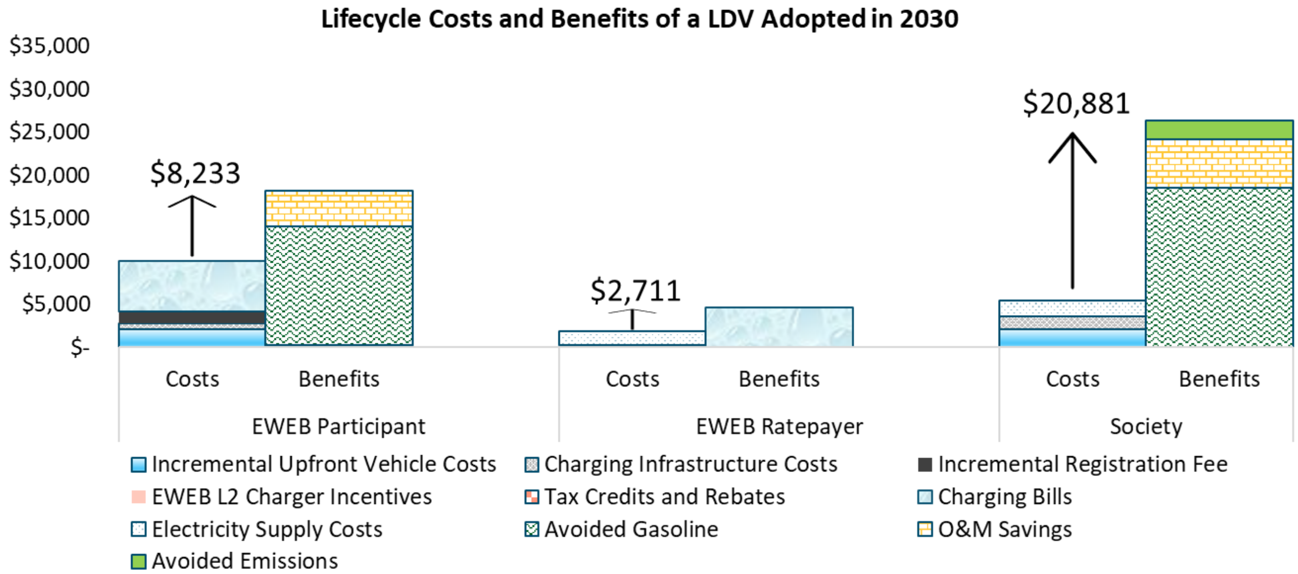
[10] To estimate the value of emissions reductions, the model used the social cost of carbon as adopted in the Washington Clean Energy Transformation Act and adjusted for an assumed inflation rate of 2%. The resulting social cost of carbon forecasted prices from $80/MTCO2e in 2021 to $155/MTCO2e in 2040.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

calculations assume that State and Federal incentives phase out before 2030. In Figure C, below, the benefit-cost calculations are shown for purchasing an EV in 2030.

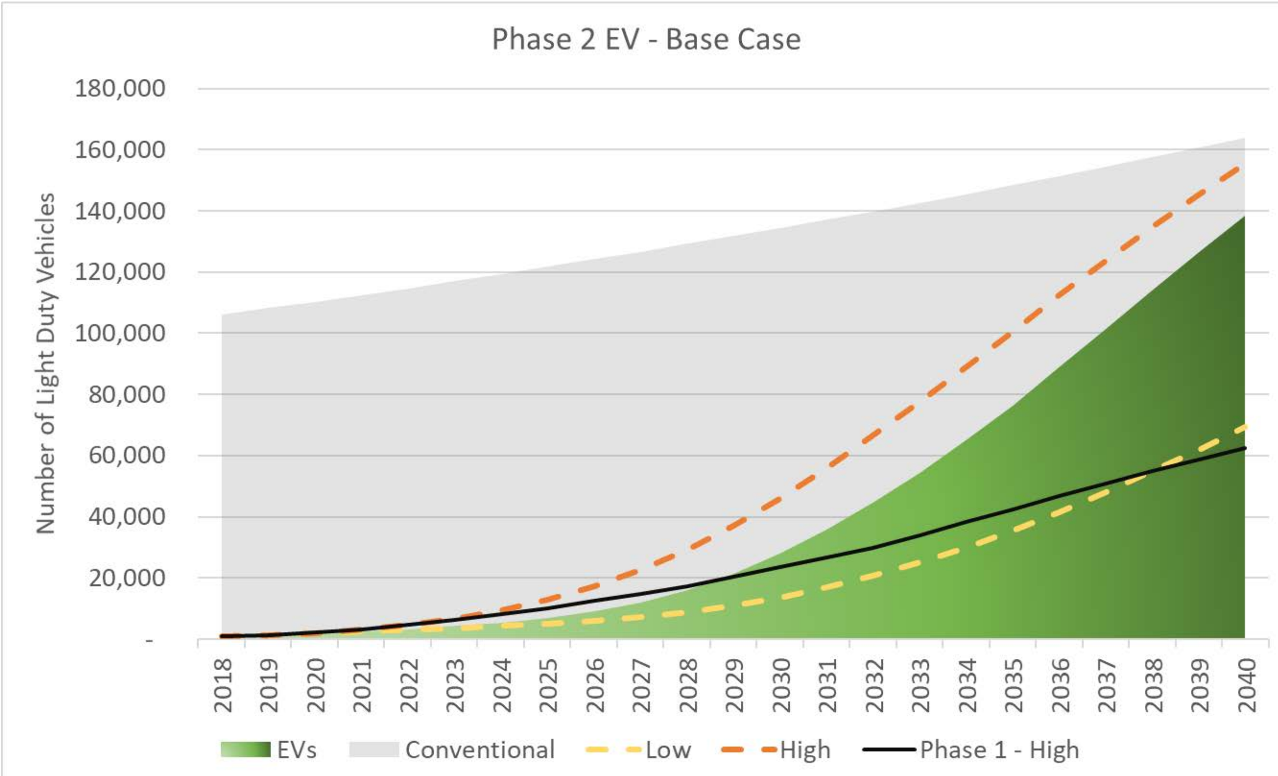
Figure C



The incremental upfront vehicle costs for purchasing an EV are expected to decline from $10,500 in 2021 to less than $2,000 in 2030. This forecasted decline in upfront costs, combined with projected annual savings[11] 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[12]. 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.

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

Figure D



The Phase 2 forecast of EV adoption, shown in Figure D, 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 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.

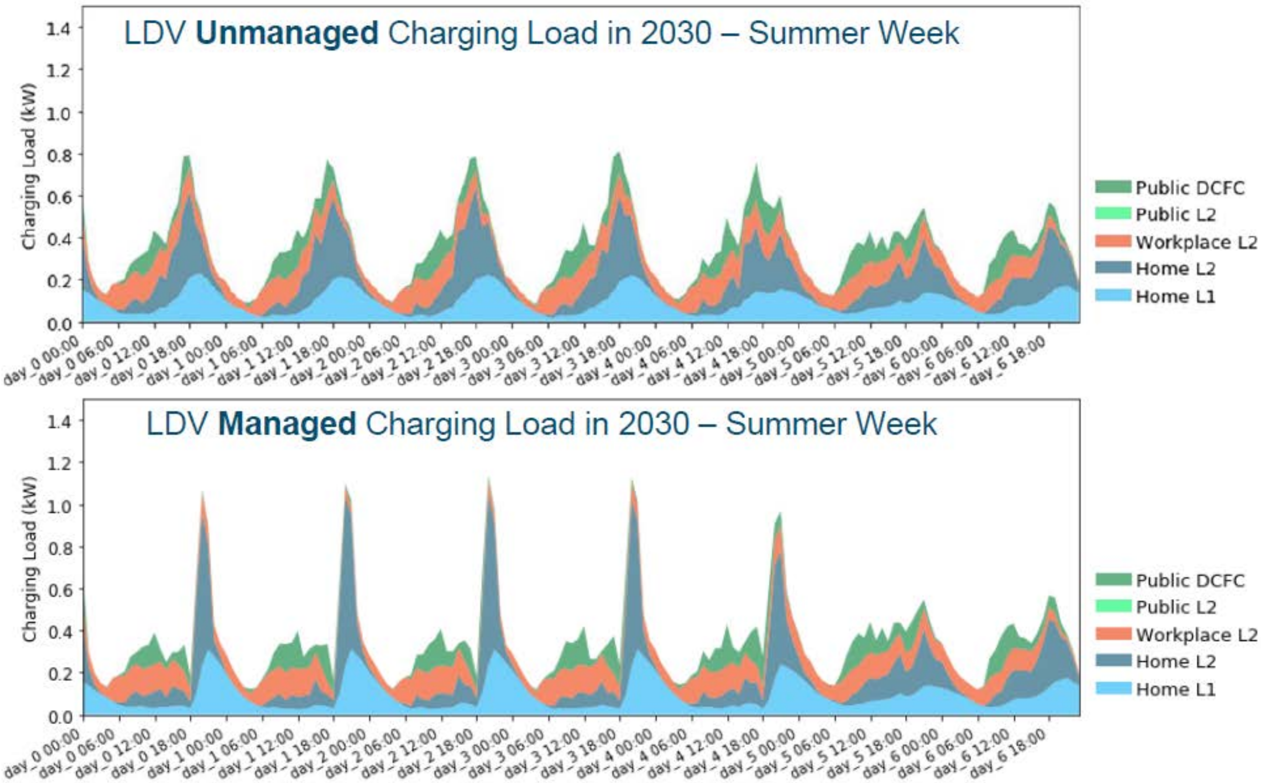
5.1 Energy Impacts of EV Adoption

EWEB worked with E3[13] 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

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

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 charging load of a single EV, but with the collective profile and mix of charging locations across an entire population of drivers.

Figure E



In Phase 1 of the electrification study, staff utilized a 2018 NREL charging behavior simulation to estimate the load shape of EV charging which showed higher levels of at home level 2 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 and 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 to utilize workplace and public charging based on the location of their vehicle throughout the day.

Below is a table of peak and average energy impacts to EWEB based on the adoption ranges presented above, assuming unmanaged charging behavior. The percentage increase shown is based on today's average load of 270 MW and a 1-in-10 peak of 510 MW.

2030	Low	Base Case	High	% Increase
Average	6 MW	12 MW	19 MW	2-7%
Peak	13 MW	27 MW	43 MW	3-8%

2040	Low	Base Case	High	% Increase
Average	29 MW	57 MW	64 MW	11-24%
Peak	68 MW	131 MW	147 MW	14-29%

Under a high EV adoption scenario, the Phase 2 peak energy impacts are 18% higher than estimates provided in Phase 1. This is due to increased levels of modeled EV adoption, which is partially offset by the lower peak impact per EV derived from E3's advanced charging behavior model.

5.2 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[14]). 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[15]	7%	38%

[14] 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

[15] Total City of Eugene Cap 2.0 Market-based emissions in 2017 was 1,013,600 MTCO2e

6 Building Electrification Preliminary Findings

HIGHLIGHTS

- Heat pump equipment for space and water heating has an upfront premium cost when compared to natural gas equipment and that trend is unlikely to change dramatically over time.
- Economic analysis indicates low levels of space heating and moderate levels of water heater electrification by 2040.
- Cold climate and dual fuel heat pumps offer have lower impact on EWEB's peak energy use but are not financially beneficial for participants.
- Of the technologies studied, cold climate heat pumps have greatest carbon reduction potential.

6.1 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. There are other reasons a customer may choose to electrify, but staff believe that at this time, de-carbonization is likely the main driver. In Phase 1 of the electrification study, staff estimated the potential range and impact of electrification in residential and commercial customers with simplified adoption scenarios (i.e., low, medium, and high). This analysis focused on existing building stock and did not include new construction. In Phase 2 of the study, staff refined the forecast of EWEB participant electrification by incorporating economics to estimate adoption using a simple payback methodology. Further, staff conducted benefit-cost analysis from multiple perspectives (EWEB participant, ratepayer, society) to understand which stakeholders benefit from building electrification, and what limits may exist on the transfer of those benefits between groups. The details of this benefit-cost analysis are generally described in the role of economics in electrification section.

6.2 Economic Approach

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. However, while insightful, this analysis lacked economic grounding. In the absence of a legislated mandate to fuel switch, interest in building electrification will likely be governed by financial constraints. As such, this study examines adoption rates of various technologies based on the economics of consumer choice.

Single family dwellings (SFDs) are the customer segment most likely to electrify. It is estimated that there are approximately 16,300 SFDs and 3,900 multi-family units served by natural gas (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.

The path to commercial segment electrification is more complex than the residential segment because commercial end use of natural gas is generally more varied. Only small commercial buildings share similar equipment replacement options like those found in the residential sector. As such, commercial segment electrification will likely need a broader set of solutions, with unique economic factors, which are beyond the scope of this phase of the study.

Beyond transportation, space and water heating are two of the most impactful end-use choices that residential customers can make. Customers have multiple electric technology options to consider when replacing existing natural gas technology. In addition, many homes with natural gas heating would have a separate air conditioning unit. Therefore, both space heating and 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[16] (Single-family)
Gas Furnace	80 AFUE	$4,800
Split Air Conditioner	10.8 EER, 2-speed	$6,100
Ducted Minimum Standard 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	Min. Standard + Gas Furnace	$11,000

Water Heating Equipment	Modeled Efficiency (Single-family)	2021 installed cost[17] (Single-family)
Gas Storage[18]	0.6 Uniform Energy Factor (UEF)	$1,500
Heat Pump Storage	3.5 Energy Factor (EF)	$2,700

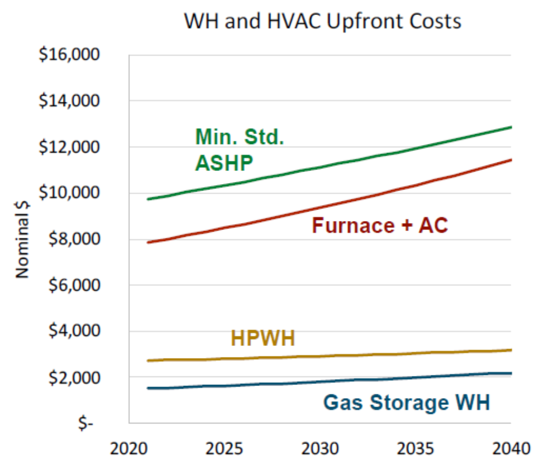
It should be noted that during this phase of the study, staff did not analyze the potential use of ductless heat pumps or “mini-splits” as a replacement technology for natural gas heating. While ductless heat pumps will likely be installed in specific electrification applications, it is more likely that 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.

[16] Equipment and installation costs are based on cost estimates from AECOM and benchmarked against data from the Energy Trust of Oregon.
[17] Equipment and installation costs are based on cost estimates from AECOM and benchmarked against data from the Energy Trust of Oregon.
[18] 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).

6.3 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.



6.4 Other Drivers

Though our preliminary results focus on residential customers under base case conditions, there are other scenarios that could drive space and water heating electrification that will be more fully addressed in the final report. These drivers include:

- Natural gas price forecast: The cost of natural gas can impact the rate of electrification over time. For this study we will test low price and high price scenarios.
- Renewable Natural Gas (RNG) blending ratios: Natural gas prices are likely to be driven by RNG policies that require increasing levels of RNG to natural gas blending. Higher ratios of RNG will increase the economic impact of fuel to electric cost differentials.
- Rebates: Utility rebates or tax incentives reduce upfront cost barriers, which reduce simple payback periods and increase unit adoption rates.
- Generation capacity cost: Electric generation capacity cost can shift the cost of electric energy. We assume $16/kW-yr capacity cost in 2021 base case, but we will test other scenarios for impact.
- Avoided costs: Avoided costs for replacing existing air conditioner equipment can negate the effective saving to electrify space heating.
    - Base case assumes AC unit is only 50% depreciated at furnace end-of-life; thus, only 50% of the cost of a new AC is avoided when electrifying. Alternatively, assuming the AC unit also needs replacement would improve the benefit of electrification.
- Electric rate structure: Testing the impact of both flat and time of use rate structures.

6.5 PRELIMINARY RESULTS – RESIDENTIAL BUILDING ELECTRIFICATION

Electrification of space and water heating will be moderate in the base case, due to high upfront costs. Policies that drive higher rates of carbon reduction will likely create incentives for higher rates of RNG production. Higher differentials between fuels (electric vs. natural gas) may have significant impacts. A high ratio blend of RNG (e.g., 80% by 2050) and other driver scenarios will be more fully addressed in the final report.

Benefit-cost Ratio Analysis - Residential

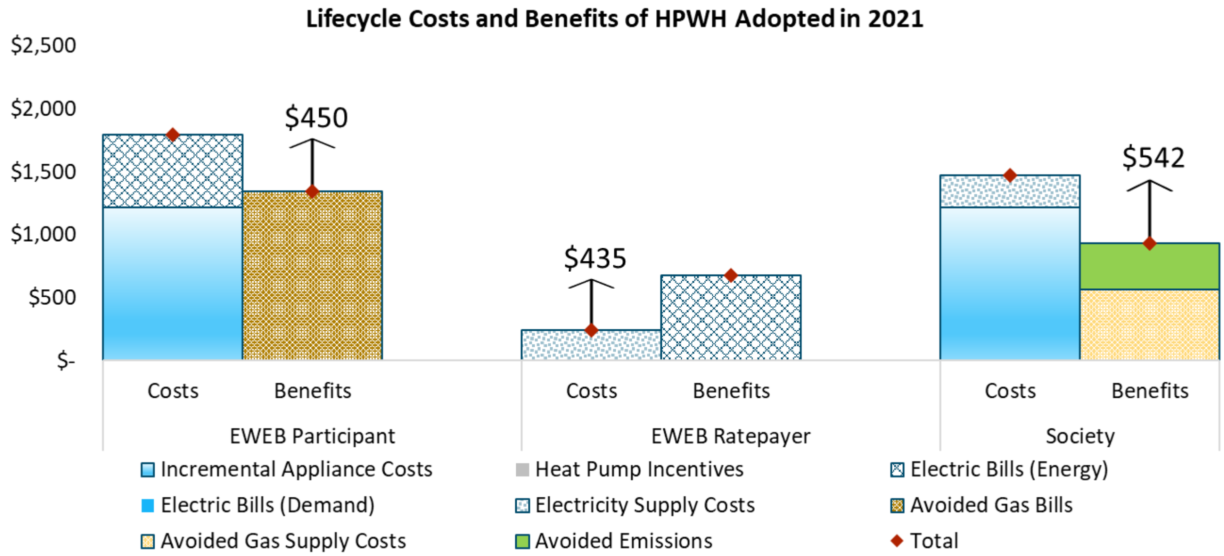
For the base case, electrification has a positive benefit from the EWEB ratepayer perspective, but the benefits for the participant and society are neutral to slightly negative. The table below summarizes the Benefit-Cost Ratio of an electrification measure by stakeholder group in both 2021 and 2030. 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 to the stakeholder group. 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.

	Residential 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	0.9	1	3.1	1.3
Cold Climate HP	0.6	3.1	0.6	0.7	3.2	0.8
Dual Fuel	0.8	3.7	0.9	0.9	3.8	1.3
Heat pump WH	0.7	2.8	0.6	1	2.7	1

Below is an example of the Residential Heat Pump Water Heating Benefit-cost calculation for a water heater purchased in 2021, itemized by component. Note the zero value for "Heat Pump Incentives." Without incentives, the net cost to the EWEB participant of $450 is greater than the $367 value of carbon reduction from the society perspective.

Water Heating						
Discount Rate	9%		5%		3%	
	Participant		Ratepayer		Society	
2021 NPV	Costs	Benefits	Costs	Benefits	Costs	Benefits
Electric Bills (Energy)	$ 577			$ 675		
Electric Bills (Demand)	$ -			$ -		
Incremental Appliance Costs	$ 1,215				$ 1,215	
Avoided Gas Bills		$ 1,342				
Heat Pump Incentives		$ -	$ -			
Electricity Supply Costs			$ 239		$ 260	
Avoided Gas Supply Costs						$ 565
Avoided Emissions						$ 367
Net Costs/Benefits	**$ 450**	**$ -**	**$ -**	**$ 435**	**$ 542**	**$ -**
Total	**$ 1,792**	**$ 1,342**	**$ 239**	**$ 675**	**$ 1,475**	**$ 933**
Score	**0.75**		**2.82**		**0.63**	

The chart below is a visual representation of the Residential Heat Pump Water Heating Benefit-cost calculation.



Impact of EWEB's Residential incentives[19]

Incentives can be an important influence over the economics of electrification. Below is a table illustrating the 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 $435 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 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.

	Benefit-Cost Ratio (with EWEB incentives[20])					
	2021			2030		
Technology:	EWEB participant	EWEB ratepayer	Society	EWEB participant	EWEB ratepayer	Society
Standard HP	0.9	3.1	0.9	1.0	3.1	1.3
Cold Climate HP	0.7	1.7	0.6	0.8	1.9	0.8
Dual Fuel	0.8	3.7	0.9	0.9	3.8	1.3
Heat pump WH	1.2	0.6	0.6	1.4	0.8	1.0

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 the Figure E, below. Staff analysis shows that without

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

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

incentives, adjustments to rate structures, or other polices that drive fuel cost differentials, we expect space and water heating sector electrification adoption to be low.

Figure E

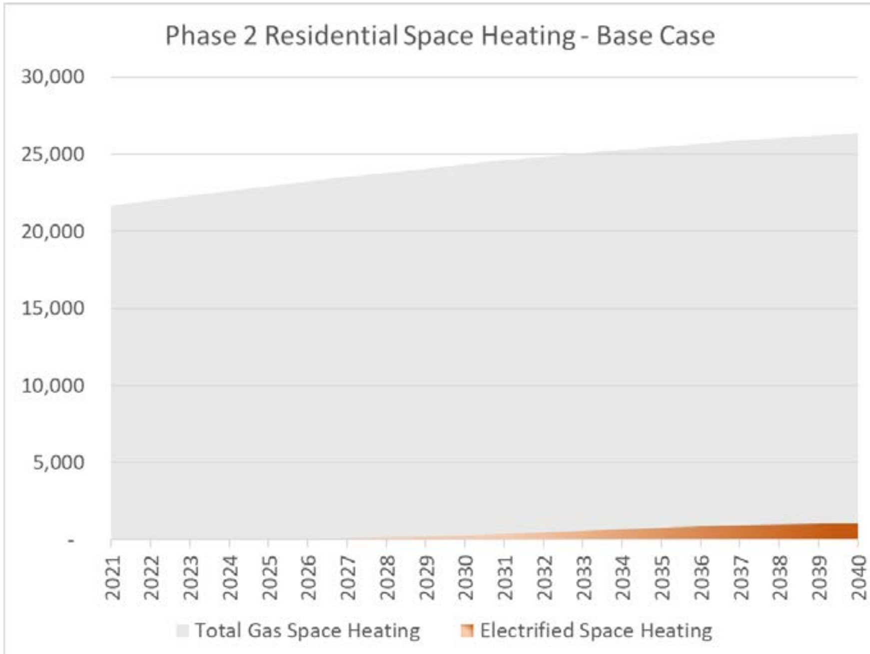
Residential Heat Pump Water Heater			
Total Costs			
Incremental Upfront Water Heater Costs	$	1,215	
Utility Incentive	$	-	
Total	**$**	**1,215**	
Total Opearting Cost Savings			
Avoided Gas Bills	$	1,969	
Increased Electricity Bills	$	(842)	
Annual Average	**$**	**113**	
Simple Payback Period		11	*Years*

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

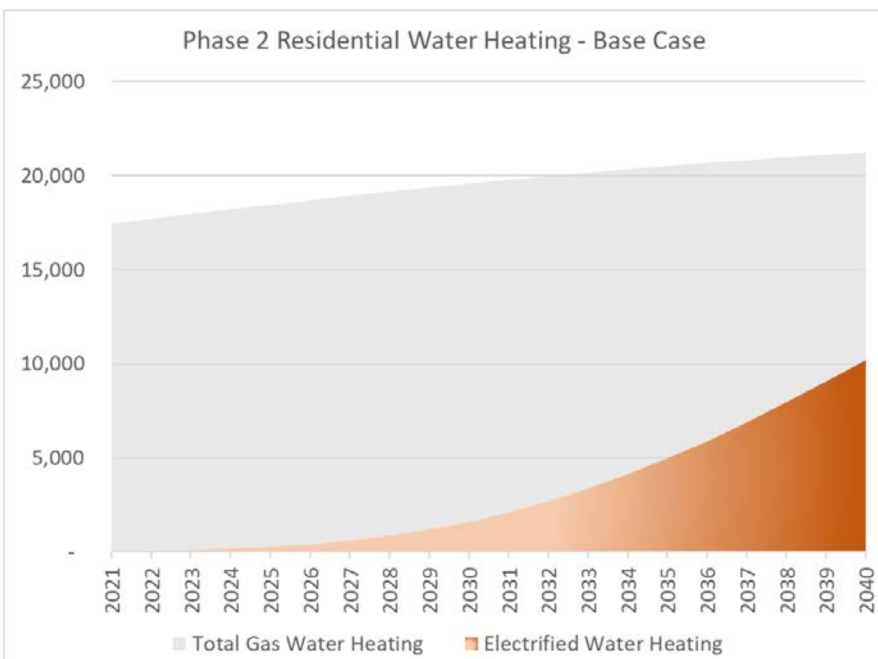
		Simple Payback		Simple Payback (with incentive)	
		2021	2030	2021	2030
Technology:	Assumed useful life	Base case		Base case	
Standard HP	16	14	11	no incentive	
Cold Climate HP	16	19	16	16	14
Dual Fuel	16	14	11	no incentive	
Heat pump WH	10	11	7	4	2

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 consumers 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. This is primarily driven by the improvements in the cost competitiveness of heat pump water heaters compared to natural gas water heaters.



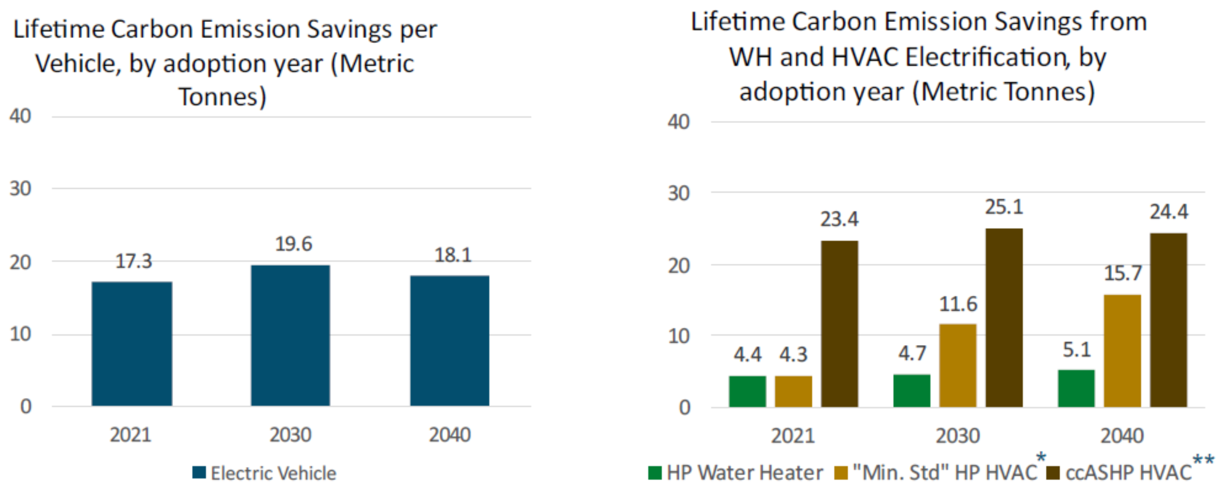
The adoption forecasts for space and water heating would have minimal levels of energy impact to the utility. **Based on preliminary analysis, these low levels of adoption would lead to less than 1% increase in average energy and 4% increase in peak energy by 2040.** Under base case conditions, the estimated levels of electrification are likely to be very low.

6.6 CARBON SAVINGS

Residential space heating represents the highest energy use and the highest potential impact for carbon savings. Cold climate heat pumps are the most energy efficient technology studied, and over the life of the equipment, can save more carbon than an electric vehicle.

Figure F, below, illustrates the potential carbon savings for space and water heating electrification measures.

Figure F



Emissions savings decrease as fuel economy improves in conventional cars

Emissions savings increase over time as marginal grid emissions decline in space heating hours

**Minimum standard heat pumps rely on electric resistance heating in the coldest hours when the grid has higher emissions.*
*** Cold climate heat pumps maintain high efficiencies in the coldest hour when the grid has higher emissions.*

Emission savings generally increase over time as the electric grid gets cleaner while natural gas has limited RNG blending in the base case. However, absent changes in legislation or benefit-cost for consumers, the levels of electrification and related carbon reduction are estimated to be low. According to Eugene's Greenhouse Gas Inventory for 2017, residential natural gas use is estimated to be approximately 85,000 MTCO2e annually[21]. Using the base case space and water heating electrification levels, approximately 8,000 MTCO2e could be reduced by 2040 (roughly 10%). This reduction would represent less than 1% of total market-based carbon emissions.

[21] City of Eugene Climate Action Plan 2.0 – Appendix 6 Greenhouse Gas Inventory.

7 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[22] and meter information from MDM[23], it becomes possible to group together AMI 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[24] 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).

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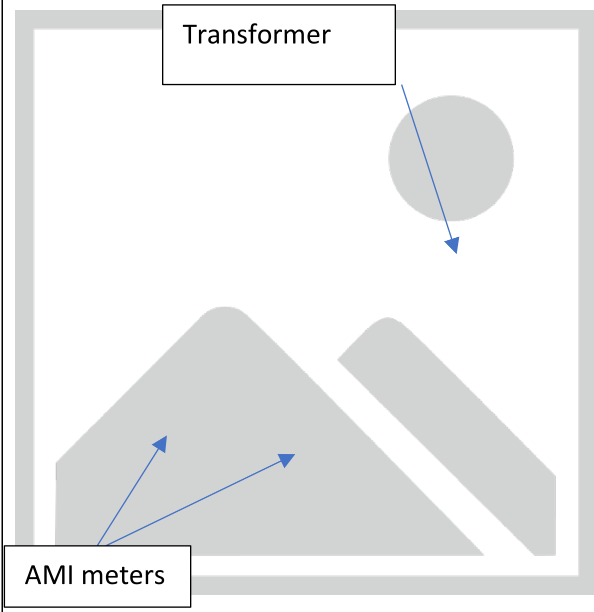
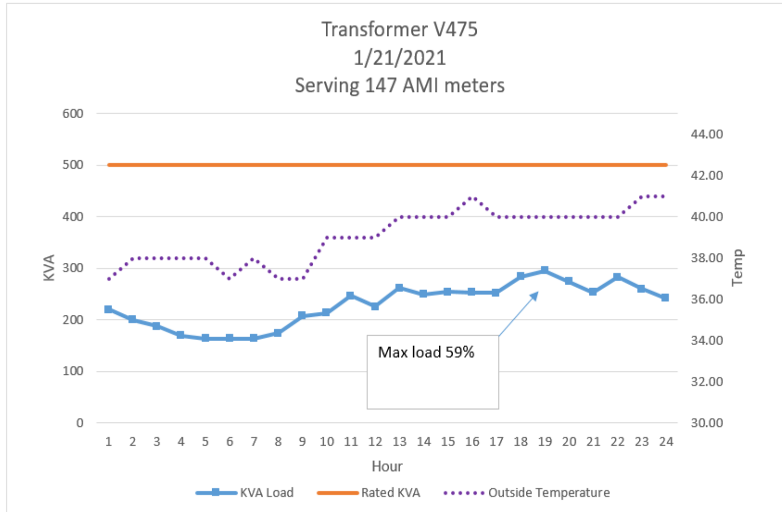
[22] Geographical Information System (GIS) is mapping software used to visually represent, map, and analyze information about equipment used by utilities.

[23] Meter Data Management (MDM) is software used to track consumption data gathered from customer meters.

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



100 % percent of meters associated with this transformer are AMI



Average winter day transformer load (blue) compared to its rated capacity (orange).

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 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.

Grid Visibility and Modernization

Electric utility customers expect affordable, clean, and reliable power. As the distribution network become progressively dynamic, complexity is increasing, and the volume of data that utilities need to understand and integrate continues 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[25], GIS, MDM, EMS[26], 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[27], DR[28], 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.

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

8 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.
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[29].
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[30].
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

[29] https://www.eia.gov/tools/glossary
[30] https://www.eia.gov/tools/glossary

	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[31]. • 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.
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.
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[32].
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

[31] https://www.energy.gov/eere/electricvehicles/charging-home
[32] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

	indoor/outdoor coils are used reversibly as condensers or evaporators, depending on the need for heating or cooling[33].
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).
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.
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[34]. 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[35].
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[36].
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.

[33] https://www.eia.gov/tools/glossary
[34] https://www.eia.gov/tools/glossary
[35] https://www.epa.gov/fueleconomy/text-version-electric-vehicle-label
[36] https://www.eia.gov/tools/glossary

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)[37].
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.
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.
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 of how much energy the water heater uses and how much energy is used to power the water heater itself.
Wholesale Market	The market for buying and selling of electricity before it is sold to the end-user.

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