Toward Net Zero Emissions from Oregon Buildings

Emissions and Cost Analysis of Efficient Electrification Scenarios

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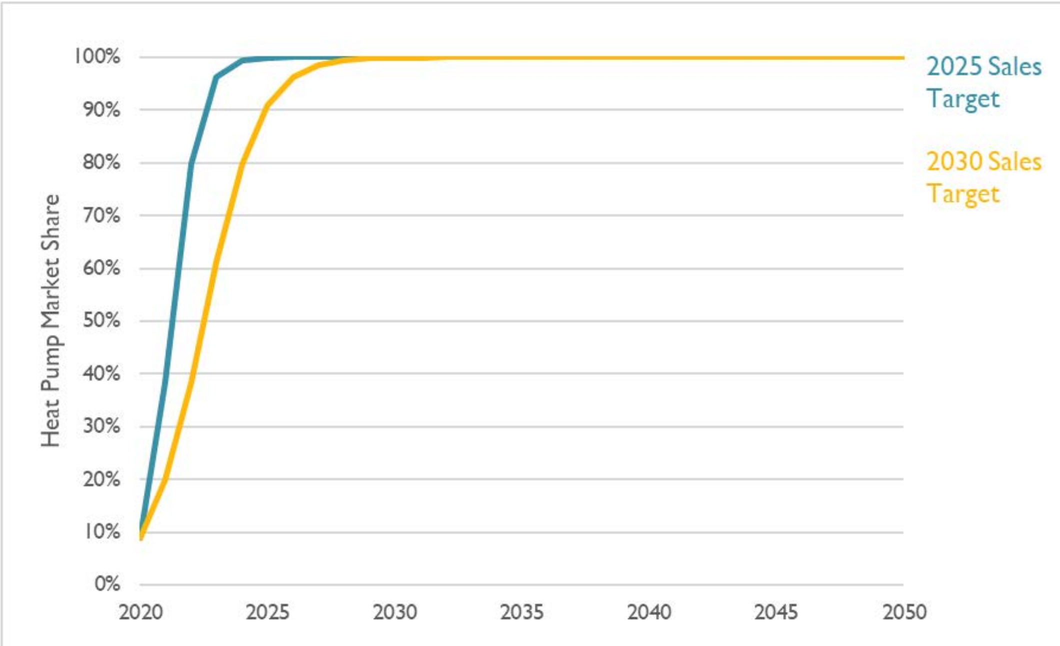
EXECUTIVE SUMMARY

The state of Oregon has committed to reducing its greenhouse gas emissions at least 25 percent below 1990 emissions levels by 2035, and at least 80 percent below 1990 emissions levels by 2050. To achieve this, the state will have to substantially cut emissions from its residential and commercial buildings, which currently account for about 35 percent of the state's carbon dioxide emissions. One core strategy for decarbonizing those buildings will be to electrify their appliances and systems using efficient appliances that can take advantage of an increasingly decarbonized electricity grid. Another core strategy for cost-effectively supporting this transition is technology switching from inefficient electric resistance space and water heating systems to efficient electric heat pumps to reduce winter electric peak demand.

At the request of Sierra Club, Synapse Energy Economics (Synapse) analyzed two different pathways through which Oregon could rapidly electrify its commercial and residential buildings (and replace inefficient electric resistance appliances in the process). These pathways are called the "2030 Sales Target" scenario and the "2025 Sales Target" scenario. Both pathways take an aggressive approach to getting to 100-percent market share for efficient electrical equipment—the point at which customers will no longer purchase fossil-fuel-based heating systems and appliances. The main difference between the two pathways is timing: the 2025 Sales Target scenario gets to 100-percent market share five years earlier than the 2030 Sales Target scenario. While the trajectories of these pathways, shown in Figure ES-1 below, appear steep, there is no shortage of examples of steeper technology adoption curves in recent history. (See Section 3.1 of the report for these examples.) More importantly, these steep adoption curves will be necessary due to the lengthy lifespans of these types of equipment, especially space heating, and the limited time remaining to meet the state's 2035 and 2050 commitments. The sales of efficient electrical equipment such as heat pumps have to ramp up very quickly for Oregon to meet its emissions reduction goals.

Figure ES-1. Fraction of retiring residential fossil-fuel space heating systems replaced with heat pumps



For this assessment, Synapse used its Building Decarbonization Calculator to model turnover of residential and commercial space heating, water heating, cooking, and drying systems across the state. We then calculated the emissions impacts of these system changes. The following table presents a high-level summary of our analyses for the two scenarios.

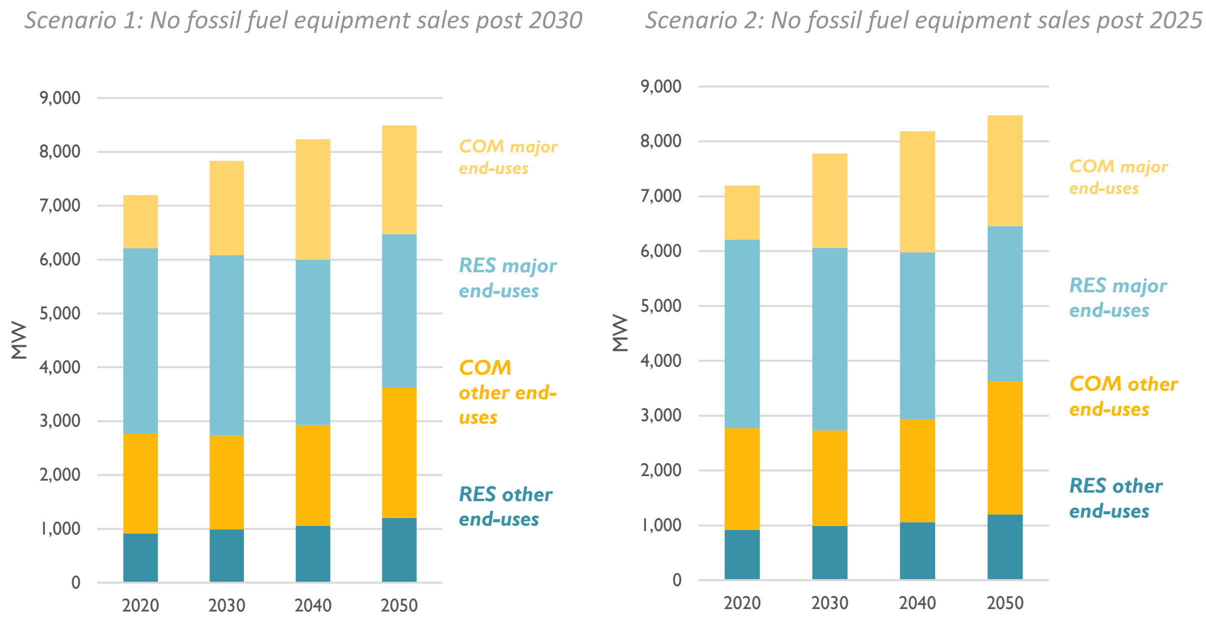
Table ES-1. High Level Summary of Two Building Electrification Scenarios

	2030 Sales Target Scenario	**2025 Sales Target Scenario**
Residential heat pump space heating equipment sales share (excluding wood heating)*	2025: 93 percent 2030: 100 percent	2025: 100 percent 2030: 100 percent
Residential heat pump space heating equipment stock share of installed residential HVAC systems in 2030 and 2040 (excluding wood heating)*	2030: 47 percent 2040: 79 percent	2030: 52 percent 2040: 82 percent
CO_2e emissions reductions relative to 1990	2035: 3.3 million metric tons (47%) 2050: 6.8 million metric tons (97%)	2035: 3.9 million metric tons (56%) 2050: 6.9 million metric tons (98%)
2050 energy consumption reductions relative to 2019	57.8. Tbtu (61%)	58.5 Tbtu (61%)
Electricity consumption increase relative to 2019	2030: 1,340 GWh (10%) 2050: 1,720 GWh (13%)	2030: 1,580 GWh (12%) 2050: 1,700 GWh (13%)

**Notes: This table presents the projections of sales and stock shares for residential space heating, as it is responsible for the largest share of energy and emissions among all residential and commercial end-uses and has the longest lifetimes. Other end uses generally have similar sales shares and higher stock shares for efficient electrification measures in 2030 and 2040, due to their more rapid stock turnover times.*

To determine the impact of the two electrification trajectories on the electric sector, Synapse then estimated future changes to the electric system's peak load and also to overall system costs. We expanded the scope of this analysis beyond the major end-uses (space heating, water heating, cooking, and drying) by including the remaining electricity consuming end-uses in the residential and commercial building sectors. We also estimated future changes to overall gas system costs. Figure ES-2 presents our forecast of winter peak loads for the major end-uses as well as other electric end-uses under the two scenarios. The total building peak load is projected to increase at an average annual growth rate of 0.6 percent in Scenario 1 and 0.5 percent in Scenario 2. The primary reason for these relatively low load growth rates is that our analysis projects declining peak loads for the residential (RES) sector, driven by switching from electric resistance heating systems to heat pump systems.

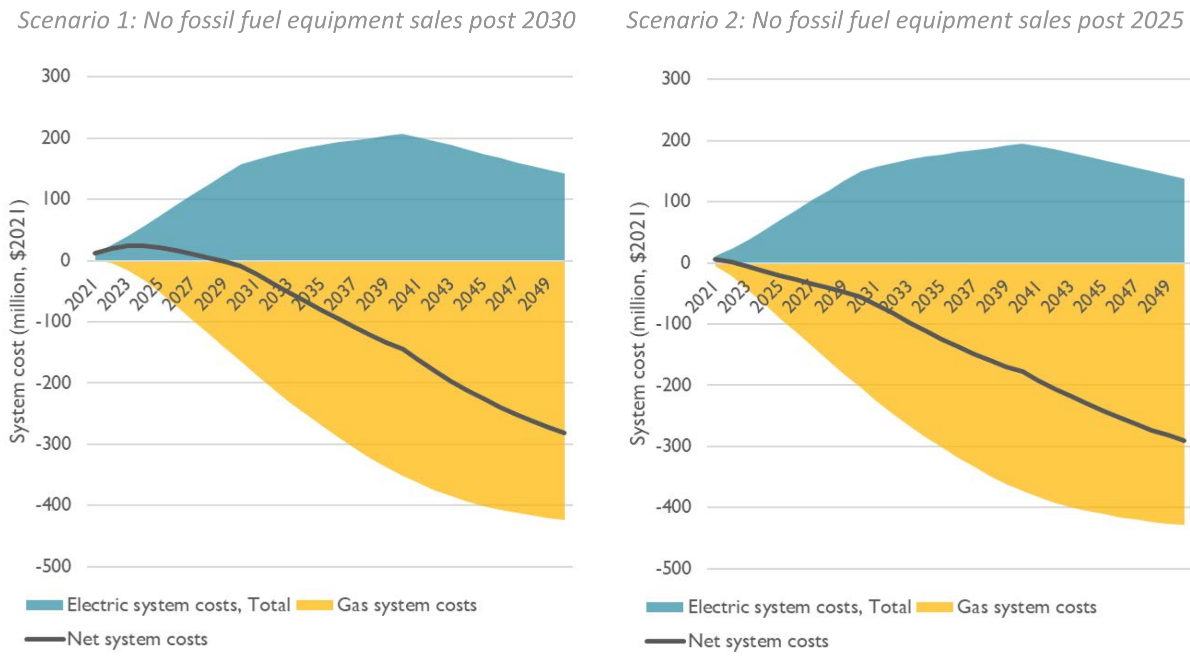
Figure ES-2. Projections of winter peak loads by end-use category



Note: COM stands for commercial, and RES stands for residential.

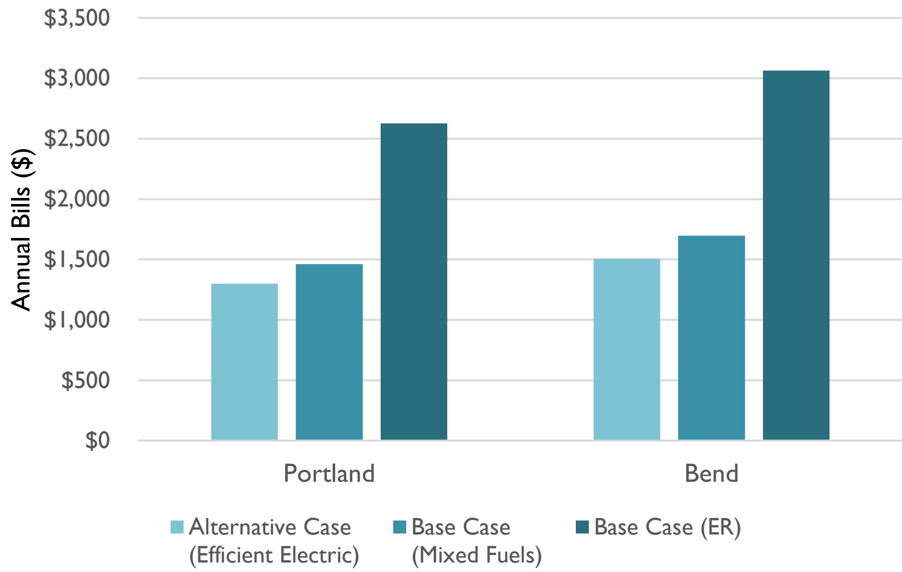
Figure ES-3 below depicts the system cost changes we forecasted for both electric and gas systems under the two electrification trajectories. In both scenarios, our analysis shows that building electrification lowers overall energy system costs for households and businesses in Oregon. Under Scenario 1, we project that building electrification starts to save system costs starting in 2030 and cost savings increase through 2050 with an annual cost savings of about $280 million in 2050. In total, the residential and commercial sectors are expected to save about $1.1 billion (net present value) through 2050. Under Scenario 2, we project that building electrification starts to save system costs from 2023 and cost savings increase through 2050 with an annual cost savings of about $290 million in that year. In total in this scenario, the residential and commercial sectors are expected to save about $1.7 billion (net present value) through 2050.

Figure ES-3. Projections of electricity and gas system cost impacts



Finally, Synapse performed a residential customer bill impact analysis to determine how electrification would currently impact two types of Oregon single-family households: one sample household that heats with gas appliances (Mixed-Fuels Base Case), and one sample household that heats with electric resistance appliances (ER Base Case). Using these two types of households as base cases, we compared those to a household in which efficient electric equipment serves all energy needs (Alternative Case). We completed this analysis for both Portland and Bend to represent the two major climate zones in Oregon. Figure ES-4 shows the results of this analysis. The Alternative Case with efficient electrification measures has the lowest annual bill in both Portland and Bend. The Mixed-Fuels Base Case examples have slightly higher annual bills than the Alternative Case examples: by 12 percent in Portland and by 13 percent in Bend. The annual bills for the ER Base Case examples were about twice as expensive as the more efficient Alternative Case examples in both cities.

Figure ES-4. Annual average bill impact summary across three cases in Portland and Bend



We also calculated the payback time for new installations of space heating heat pumps and hot water heat pumps, relative to a single-family household that continues using gas for heating. Table ES-2 provides the results. We compared the cost of a heat pump for space heating against the cost of a new furnace plus a new central air-conditioner to estimate the incremental cost of a heat pump because a heat pump provides both space heating and cooling services.

Table ES-2. Payback analysis of heat pumps and HWPH relative to the Mixed-Fuel Base Case

	Portland	**Bend**
Heat pump for space heating		
Annual average bill savings	$42	$82
Average incremental cost	same or less	same or less
Payback (years)	Immediately	Immediately
Heat pump water heater		
Annual bill savings	$51	$70
Average incremental cost	$640	$640
Payback (years)	13	9

Further, we estimated the payback time for the full electrification scenario in the two cities based on the Alternative Case relative to the Mixed-Fuel Base Case. Average payback estimates are shortened in this scenario, ranging from 3 years in Bend to 4 years in Portland, due to the additional customer charge savings from full electrification. It is important to note that our payback analysis does not include various other factors that could affect customers' purchase decisions, such as potential electrical panel upgrade costs, future changes in electric and gas prices, and qualitative customer preference factors.

Table ES-3. Payback analysis of the Alternative Case (full electrification) relative to the Mixed-Fuel Base Case

	Portland	Bend
Annual bill savings	$161	$192
Average incremental cost	$640	$640
Payback (years)	4.0	3.3

Overall, our analysis of the two building electrification scenarios found that switching to efficient electric appliances would be effective in meeting Oregon's emissions reductions goals and could bring substantial net benefits for consumers in Oregon. In addition, our payback analysis of electrification measures found that electrification at the time of equipment replacement could be economically beneficial for residential customers under many conditions.

1. INTRODUCTION

In March 2020, Governor Kate Brown of Oregon signed Executive Order No. 20-04 (EO 20-40), which directed the state to reduce its greenhouse gas (GHG) emissions at least 25 percent below 1990 emissions levels by 2035 and at least 80 percent below 1990 emissions levels by 2050. According to Oregon's most recent GHG inventory, the direct emissions from the residential and commercial building sectors contribute 35 percent of total statewide carbon dioxide (CO_2) emissions.[1] In order to achieve the goals set forth in EO 20-40, the state will need to pursue deep decarbonization of these sectors. Efficient building electrification is an important strategy that can help Oregon meet its targets.

Synapse Energy Economics (Synapse), engaged by Sierra Club, evaluated the potential impact of possible future scenarios in which Oregon reaches its 2035 and 2050 goals by incorporating aggressive efficient building electrification initiatives. We evaluated the energy, emissions, and economic impacts of two future scenarios with different trajectories for adoption of efficient electrification measures in four major building end-uses: space heating, water heating, cooking, and clothes drying. The efficient electrification measures in this study include two types of appliance and equipment replacements: (a) fuel-switching from fossil fuel appliances and equipment to energy efficient electric appliances and equipment (e.g., induction cooktops, heat pump water heaters, heat pumps for space heating); and (b) technology switching from inefficient electric resistance space and water heating systems to efficient electric heat pumps.

One of the building electrification scenarios in our analysis assumes a trajectory that rapidly accelerates adoption of electrification measures towards 100-percent market share by 2030 for the residential and commercial sectors. The second scenario assumes a more aggressive trajectory that accelerates adoption of electrification measures towards 100-percent market share 5 years earlier, by 2025.

This report continues in Section 2 with a summary of building end-use characterization in Oregon in which we describe the fuel usage for space heating, water heating, cooking, and clothes drying by sector. The section also provides a detailed sectoral breakdown of space heating system types (e.g., gas furnace, gas boiler, heat pump, electric resistance heating).

We summarize our efficient building electrification scenario analysis in Section 3, including the key methodologies, assumptions, and results. For this analysis, we used Synapse's Building Decarbonization Calculator (BDC) to model turnover of residential and commercial space heating, water heating, cooking, and drying systems across the state. We then calculated the energy and emissions impacts of these system changes.

[1] Oregon Greenhouse Gas Sector-Based Inventory. *Oregon Department of Environmental Quality*. Available at: https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx

Shifts in end-use energy consumption toward efficient electrification will have system-level impacts for both the electric and gas systems. In Section 4, we present our electric and gas systems analysis, which used the outputs from the building electrification scenario analysis. We describe our key methodologies and assumptions, as well as results for our analysis of these impacts.

Section 5 provides an illustrative analysis of energy bill impacts of building electrification for a single-family home in Oregon that currently uses utility gas for major end-uses. In addition, because most water and space heating in the state today uses electric resistance heating systems, we compared bill impacts of more efficient (i.e., heat-pump-based) electrification measures relative to a case where a household uses conventional electric resistance heaters for space and water heating end-uses. Finally, we provide a payback analysis of electrification for space and water heating measures.

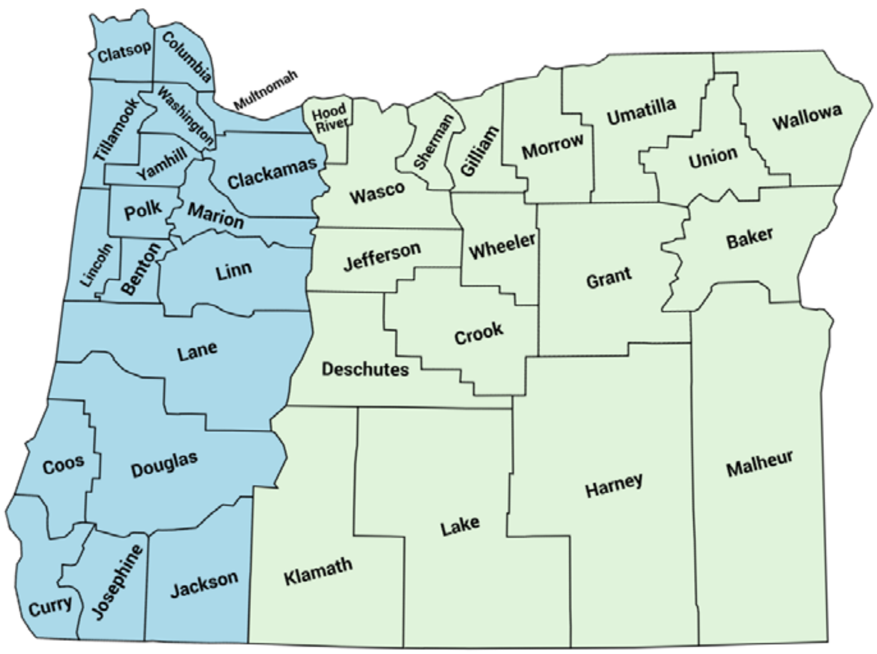
We expect that this building electrification study will help Oregonians understand pathways toward meeting or exceeding the state's targets by quantifying example electrification pathways and their potential economic impacts for residents.

2. BUILDING END-USE CHARACTERIZATION IN OREGON

2.1. Residential Buildings

There are 1.6 million households in Oregon, 87 percent of which (1.4 million) are in western Oregon and 13 percent (213,000) of which are in eastern Oregon.[2] The western region has a mild marine climate, and the eastern region has a cold climate (as shown Figure 1).[3] The Portland metropolitan area serves as the main population center for western Oregon, while the Bend metropolitan area serves the same role in the east. Single-family homes in Oregon make up about 74 percent of residential households in the state, while multifamily buildings make up about 26 percent of residential households.

Figure 1. Map of western and eastern Oregon



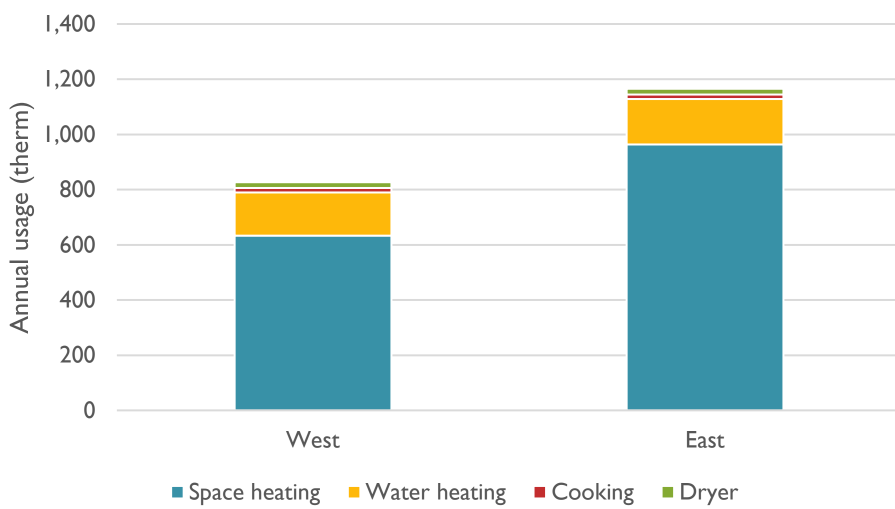
Note: Created by Synapse with mapchart.net.

[2] U.S. Census Bureau. 2021. *2019 American Community Survey Table H1: Housing Demographics.* *https://data.census.gov/cedsci/table?q=2020%20census%20population%20by%20county%20oregon&g=0400000US41%240500000&tid=DECENNIALPL2020.H1*

[3] Synapse separated counties in Oregon into east and west dependent on each county's climate as stated by the U.S. Department of Energy report: "Guide to determining the climate regions by county (2010)". Available at: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_climateguide_7_1.pdf. We assumed counties with a marine climate designation to be part of the western region and those with a cold climate designation to be part of the eastern region.

We estimated average residential utility gas (simply called "gas" in this report) use in Oregon by end-use based on various data sources as shown in Figure 2. Average household gas use in western Oregon is 826 therms. This number includes space heating at 633 therms, water heating at 156 therms, cooking at 17 therms, and drying at 21 therms. Homes in eastern Oregon consume 1,165 therms annually, with space heating using 963 therms, water heating using 165 therms, cooking using 17 therms, and drying using 21 therms. In both regions, space heating is the largest end-use, so there is the greatest opportunity for GHG savings in space heating. Water heating is the next-largest end-use. Regionally, gas consumption by end-use is similar except for space heating: gas usage in eastern Oregon is about 50 percent greater than in western Oregon due to a higher number of annual heating degree days (HDD).

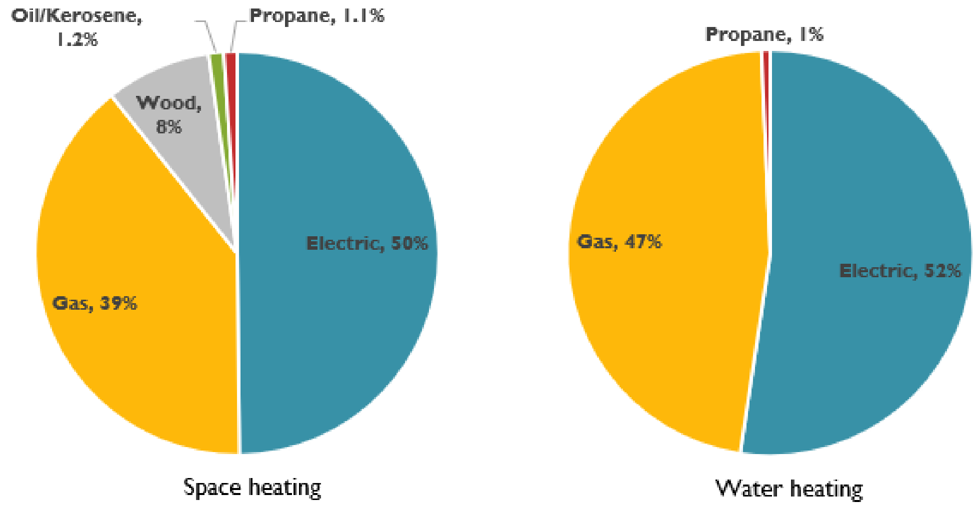
Figure 2. Annual gas usage by end-use per household in Oregon



Source: Northwest Energy Efficiency Alliance's (NEEA) Residential Building Stock Assessment (RBSA) for space heating. The RBSA values were adjusted for heating degree days; Regional Technical Forum's "Residential Gas Water Heaters v1.1" file available at: https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0; U.S. Department of Energy (2016) Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Equipment: Residential Conventional Cooking Products; and U.S. Energy Information Administration's Residential Energy Consumption Survey. Table CE5.3a for drying.

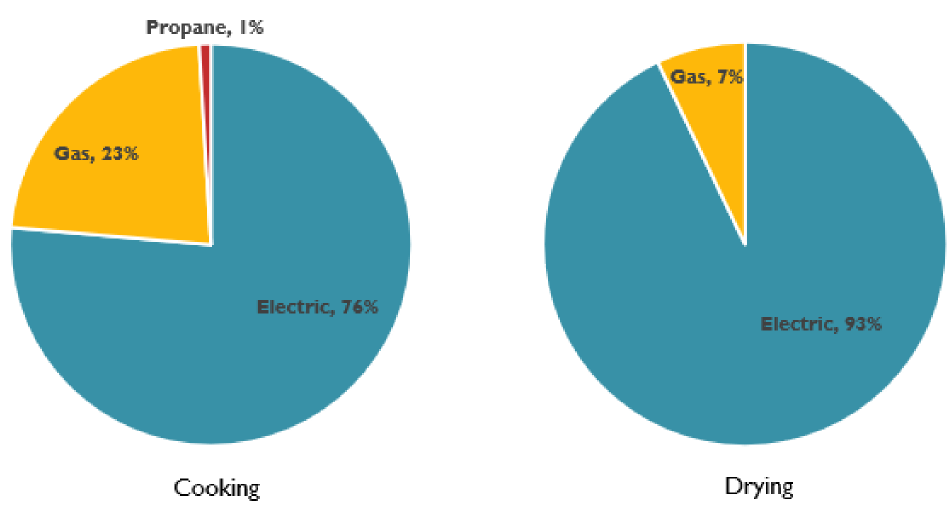
Space heating in the state is fueled by electricity (50 percent), gas (39 percent), wood (8 percent), and oil and propane (2 percent), as shown in Figure 3. Water heating nearly entirely uses either electricity (52 percent) or gas (47 percent). Meanwhile, Figure 4 shows that in cooking and drying electricity remains the dominant fuel at 76 percent and 93 percent, respectively.

Figure 3. Residential space and water heating by fuel type (% of households)



Source: Northeast Energy Efficiency Alliance (NEEA). 2019. Residential Building Stock Assessment (RBSA). Available at: https://neea.org/data/residential-building-stock-assessment.

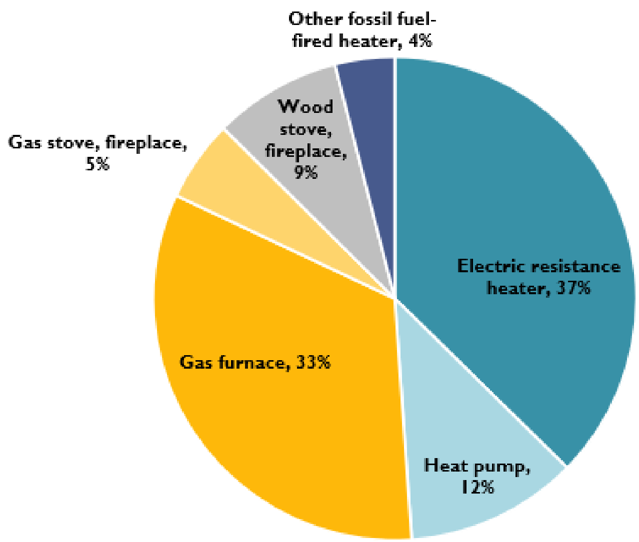
Figure 4. Cooking and drying by fuel type (% of households)



Source: NEEA RBSA.

Figure 5 provides a more comprehensive breakdown of residential space heating equipment in terms of the number of households in Oregon. Electric heat pumps account for about 12 percent of all residential systems including ducted air-source heat pumps (ASHP) (approximately 8 percent) and ductless mini-split heat pumps (approximately 3 percent). Central gas furnaces with ducts account for about 33 percent of the total systems. Three other heating systems that use ducts are electric and oil furnaces and ducted ASHPs. The rest of the space heating types, including most of electric resistance heaters (35 percent, excluding electric furnaces) and most of other fossil heaters (3 percent, excluding oil furnaces), can be converted to heat pumps through the use of ductless mini-split heat pumps. Together, the systems relying on ducts account for about 45 percent of the total residential space heating. Excluding ducted ASHPs, such systems account for 35.4 percent of the total. These represent the prime candidates for fuel-switching to ducted ASHP technologies. The rest of heat pump conversions would likely be ductless systems.

Figure 5. Residential space heating system share by equipment type



Source: NEEA RBSA.

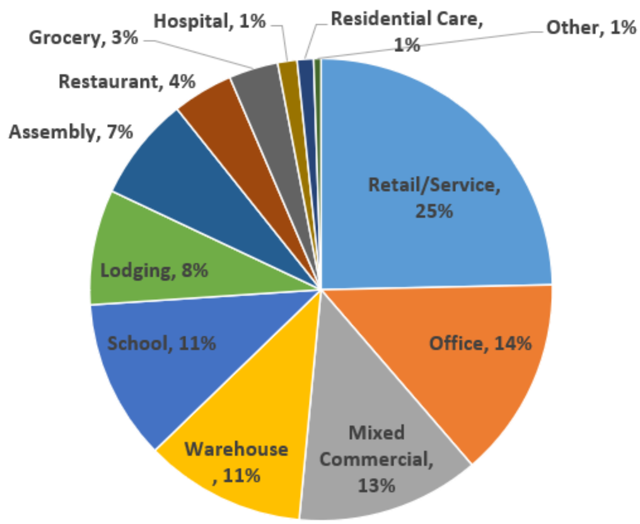
2.2. Commercial Buildings

Synapse assumed that the commercial sector in Oregon consists of 1.1 billion square feet in total with 13 percent in eastern Oregon and 87 percent in western Oregon, consistent with the share of the state population.[4]

Figure 6 depicts the share of commercial floor space by building type in the Pacific Northwest region. Approximately 40 percent of the total commercial building floor space is used for retail/service and office buildings in the region, followed by mixed commercial buildings, warehouses, and schools. Synapse was unable to find Oregon-specific building type data for floor space but expects that the mix of building types within the state is broadly consistent with the regional mix of building types.

[4] Synapse derived the commercial square footage for the state of Oregon using census-level square footage data by heating fuel type from U.S. Energy Information Administration's (EIA) Commercial Building Energy Consumption Survey (CBECS) data for the Pacific region. We then scaled this down for Oregon using historical data from U.S. EIA's *State Energy Data Systems* to quantify Oregon's share from the rest of the Pacific region. U.S. EIA's CBECS data are available at: https://www.eia.gov/consumption/commercial/.

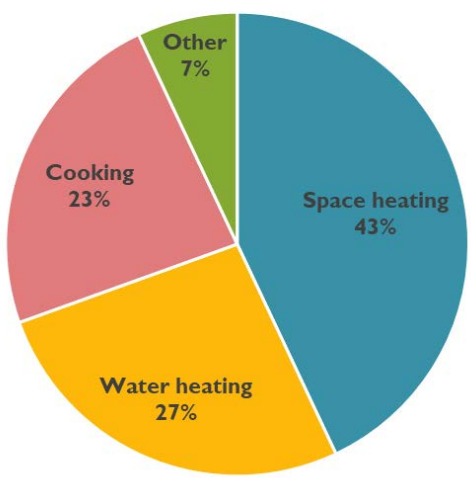
Figure 6. Commercial floorspace by building type in Pacific Northwest



Source: NEEA. 2019. Commercial Building Stock Assessment (CBSA). Available at: *https://neea.org/data/commercial-building-stock-assessments*.

Synapse assumed that the trends in gas use by end-use and overall fuel breakdown are consistent across the eastern and western regions. Figure 7 shows the gas use in commercial buildings by end-use in the Pacific census region, highlighting that space and water heating make up a majority of total annual gas consumption.[5]

Figure 7. Gas use in commercial buildings by end-use in the Pacific region

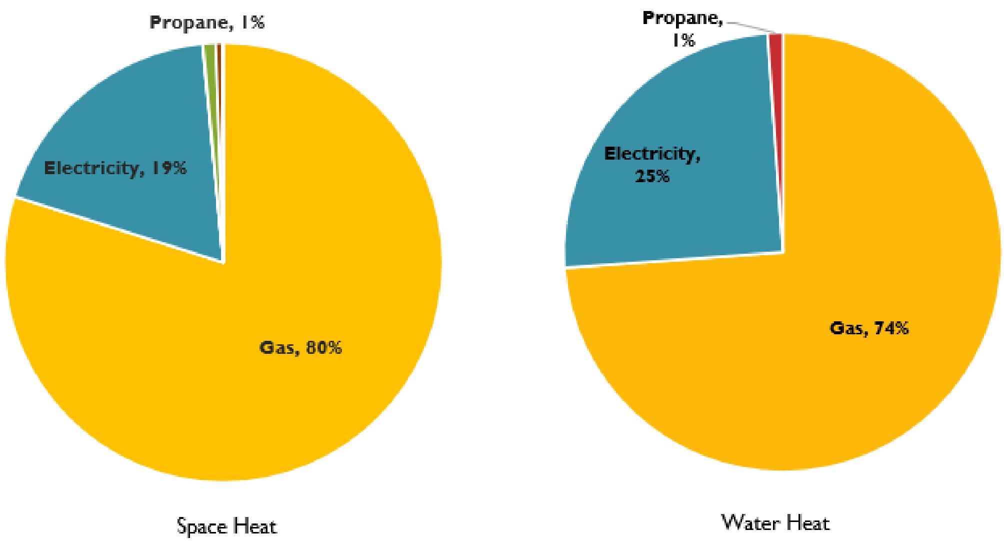


Source: EIA Commercial Building Energy Consumption Survey (CBECS). Available at: *https://www.eia.gov/consumption/commercial/*.

[5] The Pacific census region includes California, Oregon, Washington, Alaska, and Hawaii. Oregon is colder than average in the region, so space heating would likely be a higher proportion in commercial buildings in Oregon.

Across the Pacific Northwest, commercial buildings are highly reliant on gas for space heating. Gas accounts for 80 percent of space heating use while electricity makes up most of the remainder (19 percent) as depicted in Figure 8. Water heat is similarly reliant on gas, as gas makes up 74 percent of water heating with the remainder (25 percent) being electricity. Meanwhile in cooking, 85 percent of cooking energy use can be attributed to gas.

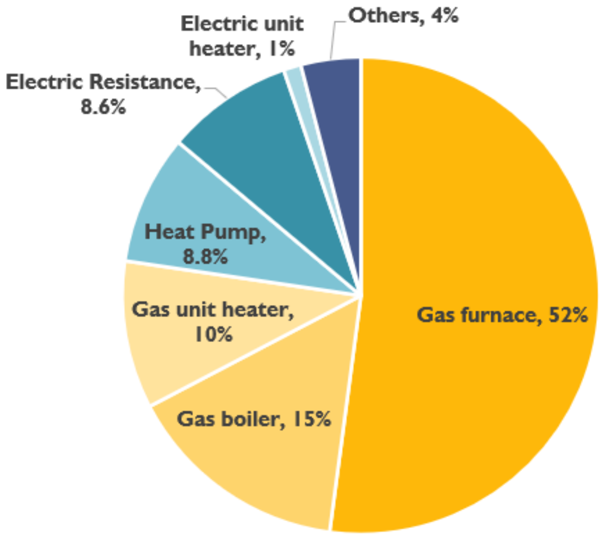
Figure 8. Space and water heat fuel breakdown in commercial buildings in the Pacific Northwest



Source: NEEA CBSA.

According to NEEA's *Commercial Building Stock Assessment* (CBSA), half of commercial buildings in the Pacific Northwest use gas furnaces for space heating, followed by gas boilers (15 percent), gas unit heaters (10 percent), heat pumps (8.8 percent) and electric resistance heaters (8.6 percent) as shown in Figure 9. Gas furnaces and boilers account for nearly 70 percent of all gas space heating systems installed in commercial buildings. These buildings are prime candidates for conversion to ducted air-source heat pumps. The rest of the buildings could use other types of heat pumps such as (a) mini-split heat pumps suitable for smaller commercial buildings, (b) variable refrigerant flow systems which offer advanced controls of heating and cooling with higher efficinecies, or (c) air-to-water heat pumps which heat water and circulate hot water in buildings (suitable for replacing boilers).

Figure 9. Space heat system breakdown in commercial buildings in the Pacific Northwest



Source: NEEA CBSA.

3. Building Electrification Analysis

3.1. Scenarios

Synapse modeled two different scenarios to demonstrate the impact of efficient building electrification and then evaluated possible future scenarios for Oregon to reach its 2035 and 2050 GHG reduction goals. To project the adoption of electrification measures, we employed a S-curve adoption trajectory originating from the Bass Diffusion Model.[6] The Bass Diffusion Model was developed using empirical data for a range of new products and is a standard industry approach for projecting the adoption rates of new technologies. Under this model, growth begins slowly, enters into a rapid growth phase, and then begins to slow as it nears market saturation (i.e., the maximum percentage of the population that might ultimately adopt the product).

We differentiate the two scenarios based on the timing of when electrification measures reach 100 percent of annual market sales, as follows:

1. **No fossil fuel equipment sales after 2030 ("2030 Sales Target").** This pathway demonstrates a trajectory that rapidly accelerates heat pump adoption for space and water heating towards 100-percent market share by 2030 for the residential and commercial sectors. For cooking,

[6] Bass, Frank. 1969. "A New Product Growth for Model Consumer Durables." *Management Science* 15 (5).

induction and electric resistance cooktops make up nearly all system sales in 2030. For drying, heat pump and electric dryers similarly replace all fossil fuel system sales by 2030.

2. **No fossil fuel equipment sales after 2025 ("2025 Sales Target")**. This pathway demonstrates a more aggressive trajectory that achieves 100-percent heat pump sales by 2025 for space and water heating in both the residential and commercial sectors. Electric cooktops and dryers also make up nearly 100 percent of sales for those end-uses by 2025.

Figure 10 below summarizes the trajectories of annual sales share of heat pumps that replace fossil fuel heating systems under each scenario. While these trends look quite aggressive, many other technologies have followed similar curves prior to becoming widely adopted, as shown in Figure 11.

Figure 10. Fraction of retiring residential fossil-fuel heating systems replaced with heat pumps

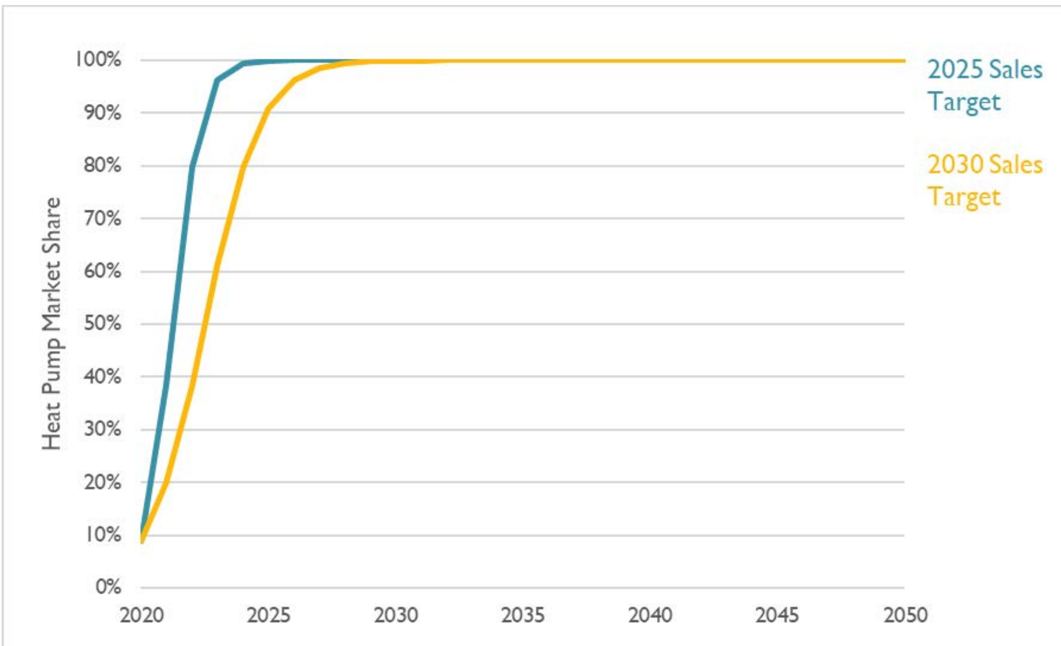
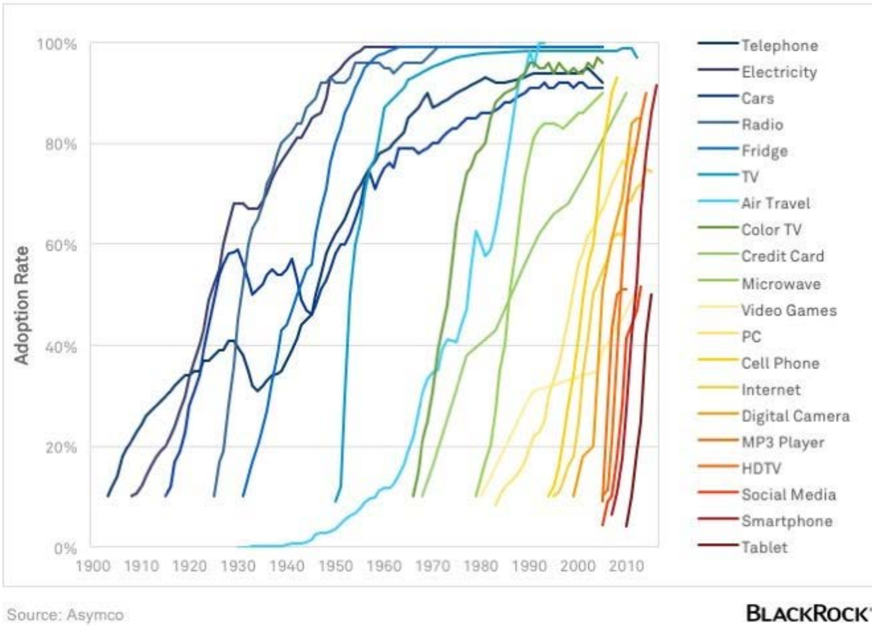


Figure 11. Adoption of technology in the United States (1900 to the present)



Source: Rieder, Rick. 2015. "There's a major long-term trend in the economy that isn't getting enough attention." Business Insider. Available at: https://www.businessinsider.com/blackrock-topic-we-should-be-paying-attention-charts-2015-12?r=US&IR=T.

3.2. Methods and Assumptions

Building Decarbonization Calculator

Synapse used its BDC model, which generates estimates for the characteristics of a given state's key building end-use stock over time given certain assumptions and inputs. For this analysis, we modeled western Oregon and eastern Oregon separately to account for differences in inputs such as space heating load, appliance saturation, and efficiency ratings.[7]

Stock values serve as the model's primary input and are derived from state-specific data on the number of existing buildings from the U.S. Census Bureau's *American Community Survey* (ACS).[8] As described in the preceding section, we segmented households and commercial buildings by different fuel types for each end-use using region-specific proportions obtained from NEEA's latest RBSA study and the CBSA.[9]

[7] Synapse used the designations published in U.S. Department of Energy's *Guide to Determining Climate Regions by County* to determine which counties in Oregon should be categorized as west and east. The report is available at: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_climateguide_7_1.pdf.

[8] U.S. Census Bureau. *2020 American Community Survey 5-Year Estimates*. House Heating Fuel. Table B25040. Available at: https://data.census.gov/cedsci/table?q=residential%20heating%20fuel&g=0100000US%2404000%24001_0400000US41&tid=ACSDT5Y2020.B25040.

[9] Northwest Energy Efficiency Alliance. 2019. Residential Building Stock Assessment II Single Family, Multifamily Homes. Commercial Building Stock Assessment. RBSA Available at: https://neea.org/data/residential-building-stock-assessment.

Synapse also relied on various data sources to inform the region-specific load requirement assumptions per end-use per household for residential buildings and per-square-foot floor space for commercial buildings. The BDC incorporates efficiency assumptions for the different appliances servicing the end-use load and estimates electricity use for fuel-switching measures from fossil-fuel-based end-uses, informed by a variety of studies. The BDC also factors in forecasted load reductions in future years due to expected weatherization, which is informed by U.S. EIA's 2021 *Annual Energy Outlook*.[10] The BDC then calibrates the resulting energy consumption outputs by fuel-type against actual historical data from U.S. EIA's *State Energy Data Systems* (SEDS) and EIA Form 176.[11,12,13] Finally, the BDC calculates carbon dioxide equivalent (CO_2e) emissions from all fuel usage using U.S. EIA emissions factors and projected grid emission rates that meet the state's clean electricity supply mandates.

The BDC generates results for energy consumption, emissions, appliance stock, and appliance sales. Stock growth over time is calculated as a function of state population growth.[14] The BDC models residential electrification measure adoption through two primary methods: (i) as a growing proportion of newly constructed homes and (ii) as a growing proportion of appliance replacements. The second method is dependent on appliance lifetimes, which is informed by the analysis conducted to support the U.S. Department of Energy's Appliance and Equipment Standards rulemakings.[15]

Key assumptions

Building end-use

Synapse modeled the state of Oregon on a regional basis as eastern and western Oregon due to the differences in climate and in building characteristics between the two. For the residential sector, Synapse relied on region-specific survey data on (a) end-use fuel and system saturation rates for space and water heating, cooking, and drying, and (b) space heating load from the latest NEEA RBSA to provide various BDC inputs at the eastern/western Oregon level. Synapse used both single-family and multifamily data from the RBSA, weighted by the mix of single-family and multifamily homes in the region. For water heating, cooking, and clothes drying, Synapse used U.S. EIA's *Residential Energy Consumption Survey* (RECS) and several other data sources to develop energy load requirements and

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CBSA Available at: https://neea.org/data/commercial-building-stock-assessments.

[10] US EIA. 2022. Annual Energy Outlook 2021. Available at: https://www.eia.gov/outlooks/aeo/.

[11] US EIA. 2020. State Energy Data Systems. Available at: https://www.eia.gov/state/seds/.

[12] US EIA. 2020. Form EIA-176 Annual Report of Natural and Supplemental Gas Supply and Disposition. Available at: https://www.eia.gov/state/seds/

[13] Synapse notes that the energy consumption estimates are inclusive of space heating, water heating, clothes drying, and cooking only.

[14] University of Virginia Weldon Cooper Center, Demographics Research Group. (2018). National Population Projections. Retrieved from https://demographics.coopercenter.org/national-population-projections.

[15] U.S. Department of Energy. 2022. "Standards and Test Procedures." Office of Energy Efficiency and Renewable Energy. Available at: https://www.energy.gov/eere/buildings/standards-and-test-procedures.

consumption per household. Details of these key assumptions and data sources are provided in Appendix A.

For the commercial sector, Synapse assumed the inputs such as end-use fuel and system saturation rates to be largely uniform across the east and west regions of Oregon, and consistent with the broader commercial sector across the Pacific Northwest region. We took this approach due to the highly limited sample size of commercial buildings in eastern Oregon within the CBSA, as well as concerns about sampling bias, wherein one type of commercial building type, such as a hospital or school, may be over-represented within the data. This higher-level approach was recommended by analysts at NEEA, who Synapse consulted regarding this issue. NEEA noted finding this homogeneity belief reinforced in its research.[16] For other key data such as energy load requirements and end-use equipment efficiency, Synapse used uniform data across the east and west regions. Synapse relied on commercial energy usage data derived from U.S. EIA's CBECS and equipment efficiency data from various sources in order to estimate energy load requirements. Appendix A has details of these key assumptions and data sources.

Heat pump technology assumptions for space and water heating

Heat pumps are versatile technologies with superb energy efficiency that can provide space heating and cooling as well as water heating. Heat pumps are one of the most important technologies for building electrification as they can displace the largest amount of fossil fuel usage, in particular gas, in buildings that are currently using fossil fuels for space and water heating. For space heating, heat pumps extract heat from outside and transfer it to the inside. When heat pumps reverse the heat transfer process, heat pumps work as efficient air conditioners by removing heat and moisture from indoor air. Because of this heat transfer process, the efficiencies of heat pumps typically exceed 250 percent (represented by a coefficient of performance, or COP, of 2.5) for heating and 400 percent (or a COP of 4) for cooling on average. The temperature of the outdoor air or other heat reservoirs (e.g., underground, mechanical room, laundry room, wastewater facility) affects the efficiency of heat pumps. Most of heat pumps installed today are air-source heat pumps which extract heat from the outdoor air. Thus, those heat pumps perform most efficiently when outdoor temperatures are high and are less efficient when outdoor temperatures are very low. However, heat pumps currently available in the market exhibit efficiency above that of resistance heating (which has a COP of about 1) and new gas furnaces (which have efficiencies ranging from 0.80 to 0.97). Current cold-climate models provide this improved efficiency even in frigid temperatures (down to -20F).[17] Figure 12 below presents an example of heat pump performance at different temperature levels. Our building electrification analysis accounts for the effects of temperature on the performance of heat pumps when estimating the annual average COP

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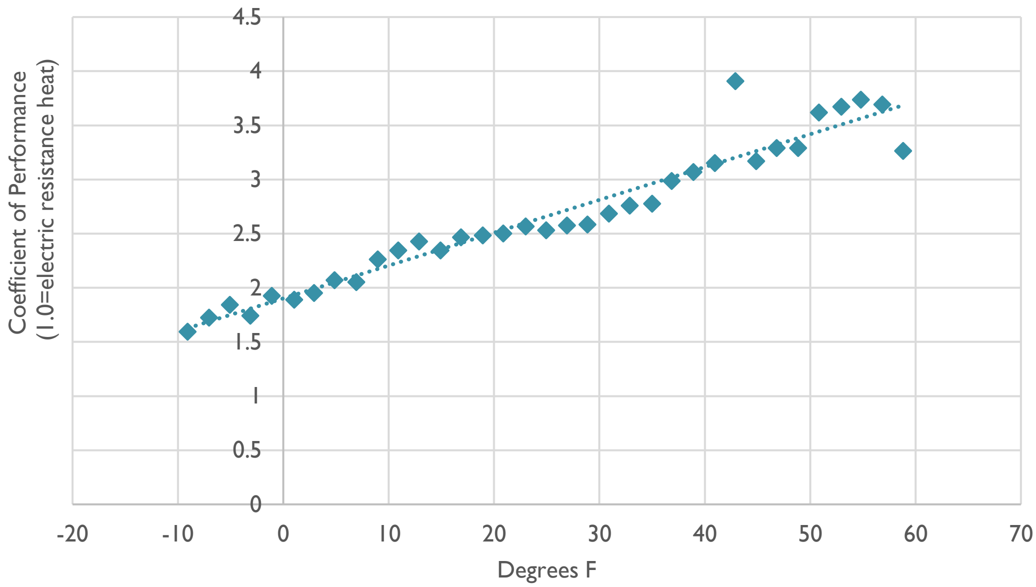
[16] Email communication with Aaron James at NEEA on January 10, 2022.

[17] A field study in Vermont found that the average performance of cold climate heat pumps was about 1.6 COP at 5 °F and above 1 even under -20°F. See Cadmus. 2017. *Evaluation of Cold Climate Heat Pumps in Vermont*. Prepared for the Vermont Public Service Department. p. 24. Available at: https://publicservice.vermont.gov/sites/dps/files/documents/Energy_Efficiency/Reports/Evaluation%20of%20Cold%20Climate%20Heat%20Pumps%20in%20Vermont.pdf.

values. Our analysis also assumes that heat pumps for space heating do not require any electric backup heating in Oregon because the state does not have a frigid climate (e.g., the typical lowest temperature in Bend is about 0°F).

Figure 12. Average space heating COP vs. outdoor temperature for cold-climate heat pumps based on field-measured performance



Source: Cadmus. 2016. Ductless Mini-Split Heat Pump Impact Evaluation. Figure 55. Available at: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-DMSHP%20Evaluation%20Report%2012-30-2016.pdf.

For space heating heat pumps, we developed forecasts of average annual energy efficiencies—expressed as COP—separately by sector, technology type (ducted or ductless), and region (the western or eastern regions). Table 1 and Table 2 below show these forecasts, which we developed based on our assessment of various data sources. The data sources include our own estimate of the current COP values using real-world heat pump performance data on residential-scale heat pumps in Oregon and other states, combined with hourly temperatures in Portland (for the west) and Bend (for the east).[18] For commercial buildings, we assumed that heat pumps are 20 percent more efficient on average than residential systems due to (a) the availability of high-temperature heat sources (e.g., mechanical room, laundry room, computer server room, wastewater facility, restaurant and food court kitchen) in some installations, (b) high COP values by variable refrigerant flow (VRF) heat pump systems due to their

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[18] Northwest Energy Efficiency Alliance. 2014. *Final Summary Report for the Ductless Heat Pump Impact and Process Evaluation*. Available at: https://neea.org/resources/final-summary-report-for-the-ductless-heat-pump-impact-and-process-evaluation; Cadmus. 2016. *Ductless Mini-Split Heat Pump Impact Evaluation*. Available at: http://www.ripuc.ri.gov/eventsactions/docket/4755-TRM-DMSHP%20Evaluation%20Report%2012-30-2016.pdf; Schoenbauer, B. 2018. "Cold-Climate Air-Source Heat Pumps." Center for Energy and Environment. Available at: http://www.duluthenergydesign.com/Content/Documents/GeneralInfo/PresentationMaterials/2018/Day1/ccASHPs.pdf.

simultaneous heating and cooling functions, and (c) advanced technologies such as multi-stage compressors. Finally, we developed projections of COP values through 2050 based on the National Renewable Energy Laboratory's (NREL) COP forecasts in its *Electrification Futures Study*.[19]

Table 1. Synapse projection of COP values for heat pump space heating in western Oregon

	2021	2030	2040	2050
Ducted				
Residential	2.6	2.9	3.0	3.0
Commercial	3.1	3.4	3.6	3.6
Ductless				
Residential	3.1	3.5	3.6	3.6
Commercial	3.7	4.2	4.3	4.4

Source: Synapse.

Table 2. Synapse projection of COP values for heat pump space heating in eastern Oregon

	2021	2030	2040	2050
Ducted				
Residential	2.4	2.6	2.7	2.8
Commercial	2.8	3.1	3.3	3.3
Ductless				
Residential	2.8	3.2	3.3	3.3
Commercial	3.4	3.8	3.9	4.0

Source: Synapse.

For heat pump water heaters (HPWHs), we developed average annual COP values separately for residential and commercial buildings, as shown in Table 3 below. We developed these values based on our assessment of several data sources. The primary source for the current COP is a national study by Natural Resources Defense Council (NRDC) and Ecotope on HPWH performance, where they estimated COP values for residential HPWHs with two tank sizes (50 gallon and 80 gallon) in 50 states for various locations in a residential house (e.g., basement, closet, garage).[20] We selected the data for Oregon from this study and estimated the average COP value. We then increased the COP values to account for technology improvement since 2016 when the study was conducted, based on the efficiency ratings for

[19] Jadun, P., et al. et al. 2017. *Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050*. National Renewable Energy Laboratory. Available at: https://www.nrel.gov/analysis/electrification-futures.html.

[20] Natural Resources Defense Council. 2016. "NRDC/Ecotope Heat Pump Water Heater Performance Data." Available at: https://www.nrdc.org/experts/pierre-delforge/very-cool-heat-pump-water-heaters-save-energy-and-money.

the HPWH products available at that time and at the present.[21] Finally, we developed our COP projections for commercial systems partly based on NREL's COP forecasts for HPWH in its *Electrification Futures Study*. NREL's COP estimates for commercial HPWH systems are generally lower than residential systems, with the difference ranging from 0 percent to about 14 percent, depending on the years. However, we assume commercial systems perform at least as well as residential systems (and therefore better than NREL's projections) because some commercial buildings have access to unique heat reservoirs that will improve HPWH performance, unlike residential buildings.[22]

Table 3. Synapse projection of COP values for heat pump water heating in Oregon

	2021	2030	2040	2050
Residential	2.7	2.9	3.1	3.1
Commercial	2.7	2.9	3.1	3.1

Source: Synapse.

Cooking and drying measure assumptions

To model the electrification of gas cooking, we assumed that electric cooktops and ovens replace gas appliances over time. Electric cooktop efficiencies were modeled to be an average of induction and electric resistance. Efficiencies of cooking equipment used in our analysis are presented in Table 4 as well as in Appendix A. While we derived these efficiencies for residential cooking equipment, we assumed the same efficiencies for commercial cooking equipment.

Table 4. Efficiencies of cooktops and ovens

	Cooktop Efficiency	Oven Efficiency	Combined Efficiency
Gas	27.2%	22.4%	25.5%
Electricity (resistance cooktop)	67.0%	29.0%	47.5%
Electricity (induction cooktop)	85.0%	29.0%	53.0%

Source: U.S. Department of Energy. 2016. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Equipment: Residential Conventional Cooking Products; Frontier Energy. 2019. Residential Cooktop Performance and Energy Comparison.

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[21] U.S. Environmental Protection Agency. 2021. "ENERGY STAR Certified Water Heaters." Available at: https://www.energystar.gov/productfinder/product/certified-water-heaters/.

[22] Due to data limitations regarding the technology improvements for commercial HPWH, NREL developed its efficiency improvement projection solely based on a technology improvement target from the International Energy Agency's 2011 technology road map. See Jadun, P., et al. 2017. pp. 47. NREL further states that commercial HPWHs are being adopted today where there are heat reservoirs and a need for simultaneous water heating and space cooling. We expect that this use of commercial building-specific heat sources will result in increased average efficiency, compensating for the challenges posed by large-scale and high demand in commercial water heating applications.

For the electrification of clothes drying, we assumed that standard electric dryers and heat pump dryers replace gas dryers in residential buildings. We further assumed that heat pump dryers accounts for 1 percent of all electric dryer sales today and that the sales share of heat pump dryers will increase to just 20 percent of new electric dryer sales by 2050 because heat pump dryers are substantially more expensive than standard electric dryers. Appendix A provides the efficiencies of clothes dryers used in our study.

We did not explicitly model commercial drying consumption. The U.S. EIA does not report specific data on commercial dryer usage because it contributes less than 5 percent to total gas consumption.[23] Instead, EIA reports an "Other" category that includes this end-use, along with multiple others. In order to account for gas consumption used for drying, we scaled up the total results to align with historical consumption data from EIA.

Building emissions rates

We used the CO_2e emissions factors for the combustion of fossil fuels in buildings based on U.S. EIA's estimates and adjusted the emission factor for gas to account for the potential methane leaks between wells and final use in buildings.[24] We estimated CO_2e impact of the methane leaks assuming (a) a methane leak rate of 2.3 percent based on a 2018 study by Alvarez et. al.[25] and (b) a global warming potential (GWP) factor of 83 corresponding to a 20-year timeframe based on a 2021 report by the Intergovernmental Panel on Climate Change (IPCC).[26] The resulting CO_2e rate of gas consumed in buildings including the global warming of leaked methane is 0.089 metric tons per MMBtu. This represents about 68 percent increase from the CO_2 emission factor (0.053 MT per MMBtu) of gas combustion.

Grid emissions rates through 2050

To estimate emissions savings through electrification, we developed a projection of electric grid emission factors that declines over time consistent with the state's clean power requirement. The current CO_2 emissions factor used in our analysis represents the average grid emission factor for Oregon in 2020 (342 lbs/MWh or 0.155 metric tons/MWh) using U.S. Environmental Protection Agency's eGrid emissions database. Because gas used in power plants is also responsible for methane leaks from wells to power plants, we adjusted the current grid emission factor for the potential methane leaks. We assumed a lower leakage rate of 1.73 percent (rather than the 2.3 percent value mentioned above) to

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[23] US EIA. 2012. Commercial Buildings Energy Consumption Survey.

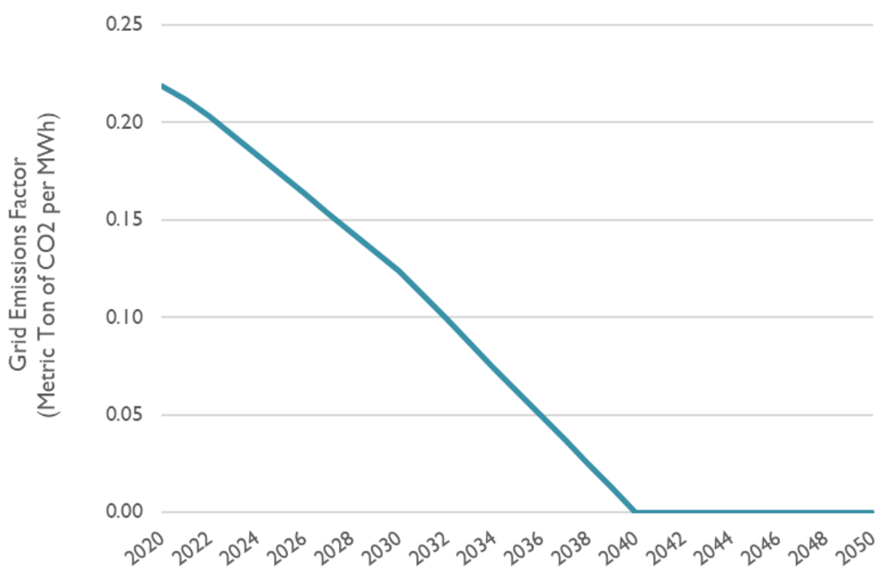
[24] U.S. EIA. 2021. "Carbon Dioxide Emissions Coefficients." Available at: https://www.eia.gov/environment/emissions/co2_vol_mass.php.

[25] Alvarez et. al. 2018. "Assessment of methane emissions from the U.S. oil and gas supply chain." *Science*. DOI: 10.1126/science.aar7204. Available at: https://science.sciencemag.org/content/361/6398/186.

[26] Intergovernmental Panel on Climate Change. 2021. Climate Change 2021 – The Physical Science Basis. Table 7.15, pp.7-125. Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf.

account for the share of leakage from wells to generation instead of wells to buildings.[27] We then applied the CO_2e factor of methane leakage to the share of gas generation in Oregon.[28] The resulting emission rate is about 0.22 metric tons of CO_2e per MWh. For estimating future emission factors, we reduced the amount of fossil fuels over time for Oregon in a way that allows the state to meet its clean energy requirements. The figure below shows the trajectory of our grid emissions factor.

Figure 13. Projection of grid CO_2e emissions factors



Oregon has a renewable portfolio standard that requires investor-owned utilities to reach 50 percent of supply by 2040 from eligible renewable energy resources. However, the state now has a stronger clean electricity requirement that was enabled by House Bill 2021 and requires all electric providers to deliver 100-percent clean power by 2040 with interim reduction requirements of 80 percent by 2030 and 90 percent by 2035 (relative to the baseline emission rate of 0.428 metric tons per MWh). Our average emission rate estimates through 2050 follow the state's current emission rates and clean electricity requirements for 2030, 2035, and 2040 with emission rates for interim years declining linearly.

3.3. Results

The following sections discuss the results of the 2030 Sales Target and 2025 Sales Target scenarios.

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[27] This adjustment was made based on U.S. Environmental Protection Agency's 2020 *Estimate of Methane Emissions From The U.S. Natural Gas Industry*. Available at: https://www.epa.gov/sites/default/files/2020-11/documents/methane.pdf

[28] Approximately 30 percent according to U.S. Environmental Protection Agency's eGRID2020 database, available at: https://www.epa.gov/egrid.

Statewide results by scenario

Statewide emissions by scenario

Figure 14 below shows the total GHG emissions trajectory for the two scenarios. Annual emissions in both scenarios fall to zero by 2050 while following different trends in the near term. Adopting a more aggressive 2025 sales target results in a cumulative reduction of 13.5 million metric tons of CO_2e through the entire modeling timeframe relative to Scenario 1 .

Figure 14. Statewide CO_2e emissions by scenario

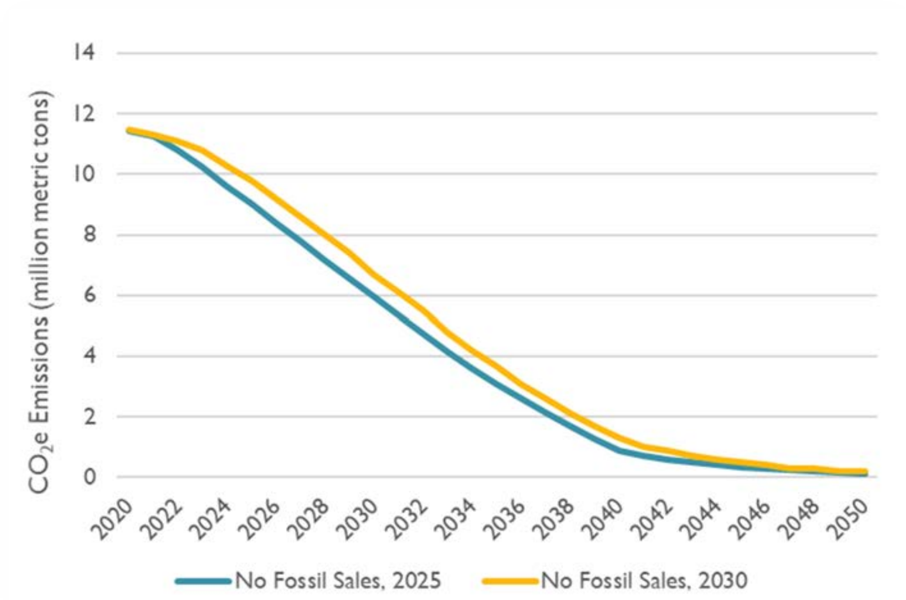


Table 5 presents emissions results from our analysis for the two regions separately and for the entire state in two scenarios. These emissions represent emissions from the use of electricity, gas, oil, and propane for space heating, water heating, cooking, and clothes drying in the building sector. The emission reductions reflect the impacts of building decarbonization measures for these end-uses from our analysis through 2050. Both scenarios decarbonize rapidly enough to achieve GHG reductions above what is currently required by EO 20-40.[29] This is largely a result of high electrification and a fully decarbonized grid beginning in 2040. Our scenario analysis shows that both scenarios are projected to reduce GHG emissions by 98 percent by 2050. The remaining GHG emissions in 2050 are primarily due to a small amount of remaining fossil-fuel space heat systems (roughly 1–2 percent of households and businesses). Our model did not enforce an early retirement requirement in these scenarios, meaning

[29] 1990 and 2019 values are from the state’s GHG inventory for the residential and commercial sectors. The values are scaled up to account for methane emissions resulting from gas leakages. Categories that were fully included in this total are residential gas and petroleum combustion and commercial gas and petroleum combustion. Emissions associated with residential and commercial electricity usage were scaled down to solely include end-uses modeled in the BDC: space heating, water heating, cooking, and drying. We developed scaling factors using EIA RECS and CBECS. Data may not sum to totals due to rounding.

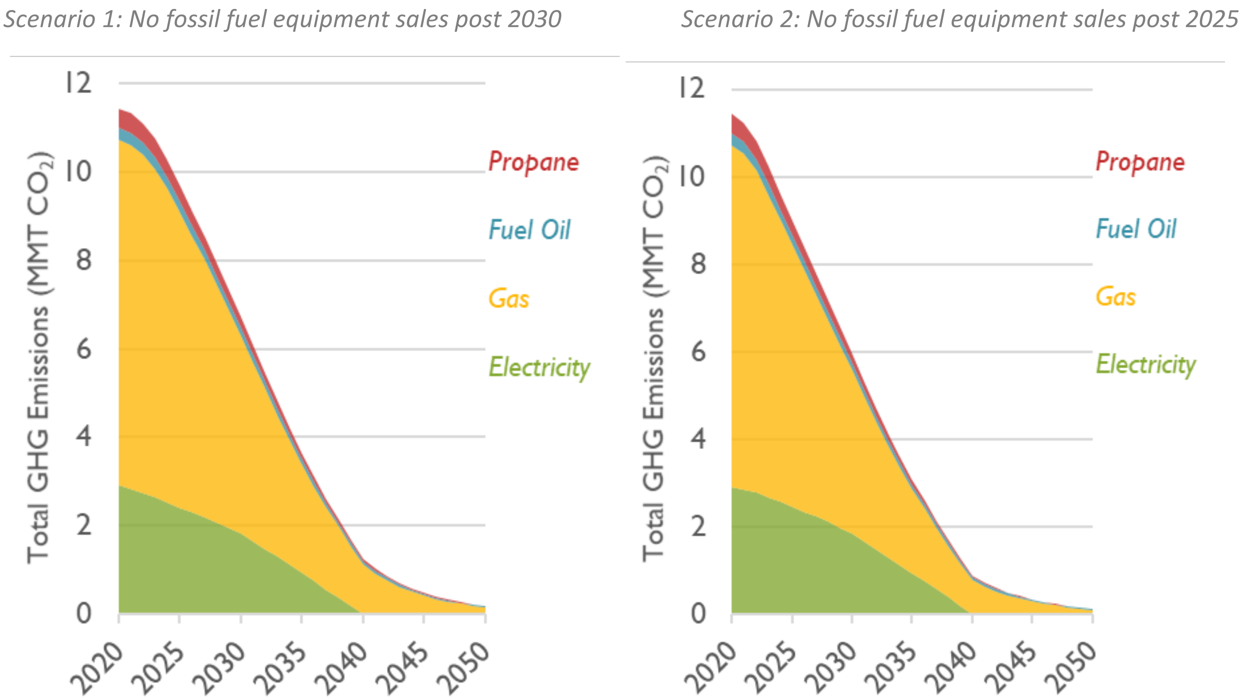
that the model did not replace fossil fuel systems with heat pumps if they had not yet reached the end of their useful life by 2050. The cumulative emissions for the 2020–2050 period are approximately 145 MMT in the 2030 Scenario and 131 MMT in the 2025 Scenario. Thus, phasing out fossil-fuel-heating systems 5 years earlier in the 2025 Scenario results in an additional CO_2e reduction of approximately 13 MMT (or 9 percent) through 2050.

Table 5. Statewide space heating, water heating, cooking, and clothes drying related CO_2e emissions results by scenario

		Actual	Actual	Forecast	Forecast	Cumulative Emissions
		1990	2019	2035	2050	2020-2050
Executive Order 20-40						
GHG Emissions	MMT CO_2e	7.8	11.1	4.3	1.6	---
GHG Reductions	percentage			45%	80%	---
Synapse Results for No Fossil Sales, 2030 Scenario						
Western OR GHG Emissions	MMT CO_2e		9.6	3.1	0.1	121.8
Eastern OR GHG Emissions	MMT CO_2e		1.8	0.6	0.0	23.0
Statewide GHG Emissions	MMT CO_2e		11.4	3.7	0.2	144.7
GHG Reductions	percentage			52%	98%	---
Synapse Results for No Fossil Sales, 2025 Scenario						
Western OR GHG Emissions	MMT CO_2e		9.6	2.6	0.1	110.4
Eastern OR GHG Emissions	MMT CO_2e		1.8	0.5	0.0	21.0
Statewide GHG Emissions	MMT CO_2e		11.4	3.1	0.1	131.4
GHG Reductions	percentage			60%	98%	---

Emissions reductions are greatest and fastest at the early periods of the modeling horizon from 2020–2035 and plateau between 2040 and 2050 (see Figure 15).

Figure 15. Statewide building emissions for space heating, water heating, cooking, and drying by fuel type and scenario



Statewide electricity and energy consumption by end-use

Electric resistance systems make up a significant portion of current residential space and water heating systems. Because of this, efficiency gains caused by switching from electric resistance to heat pump technologies are expected to reduce electricity consumption for space and water heating in the residential sector (see Figure 16). On the other hand, electricity consumption increases substantially in the commercial sector as most systems are switching from gas to electric. Overall, statewide electricity consumption for the end-uses analyzed in this study is expected to increase gradually over time. The difference in electricity consumption is small between both scenarios.

While statewide electricity consumption may be rising in these scenarios, the overall consumption of energy decreases rapidly with the increase in heat pump space and water heaters. Figure 17 shows that energy consumption for space and water heating, cooking, and drying decreases from roughly 150 TBtu in 2020 to under 60 Tbtu by 2050, a 60 percent reduction.

Figure 16. Statewide electricity consumption by end-use and scenario

Scenario 1: No fossil fuel equipment sales post 2030 *Scenario 2: No fossil fuel equipment sales post 2025*

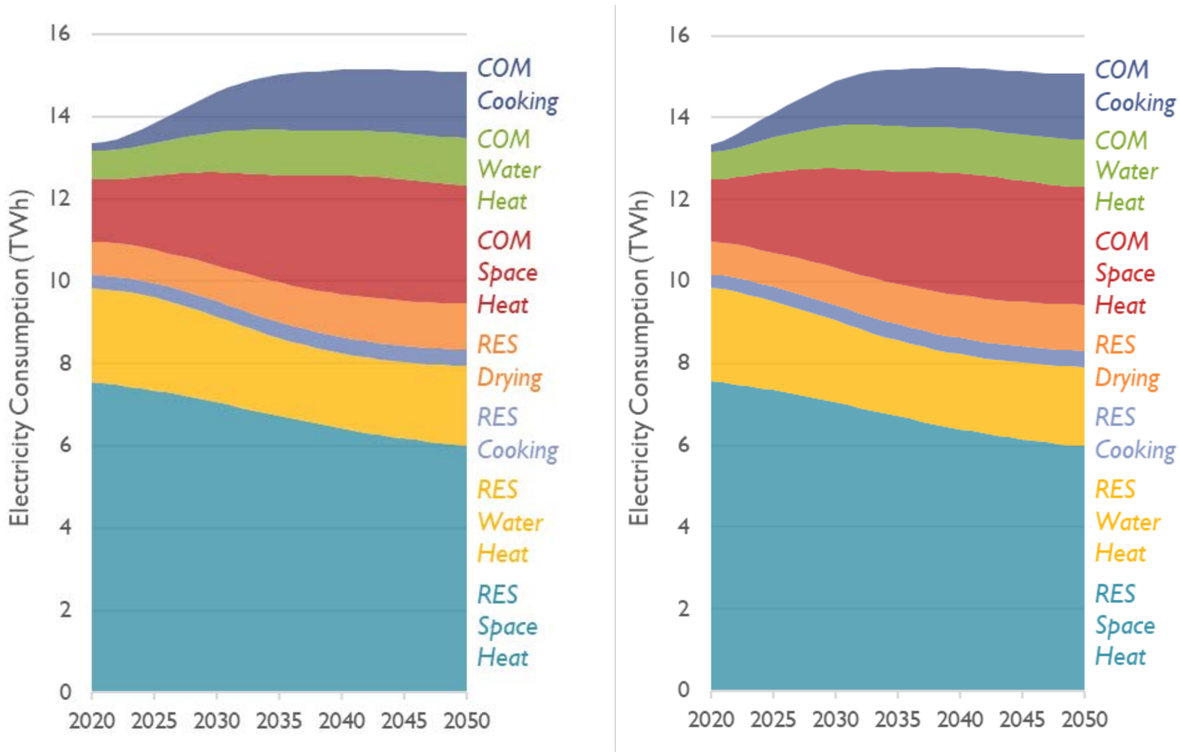
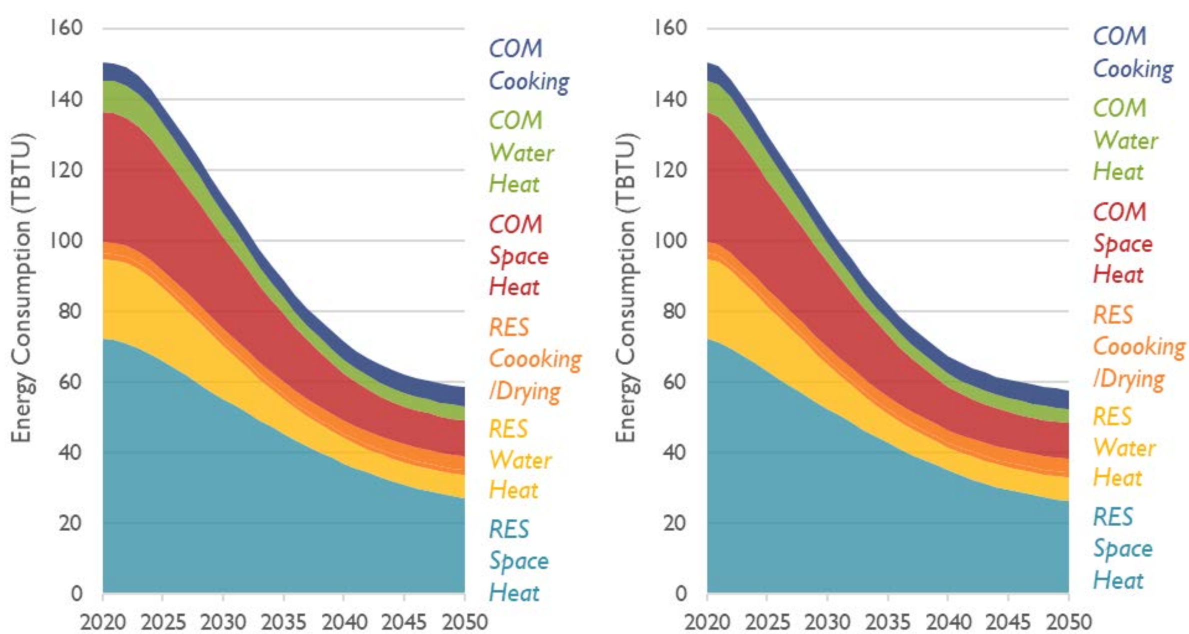


Figure 17. Statewide energy consumption by end-use and scenario

Scenario 1: No fossil fuel equipment sales post 2030 *Scenario 2: No fossil fuel equipment sales post 2025*

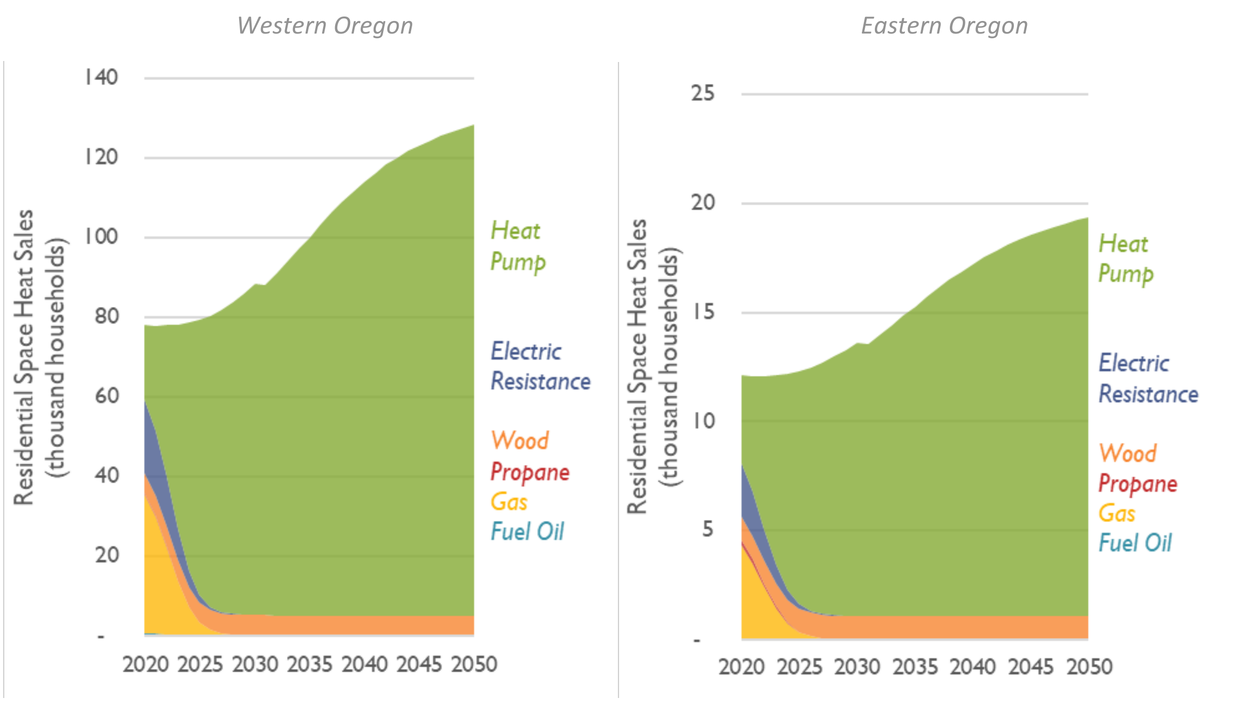


Scenario 1: No fossil fuel equipment sales post 2030

Space heating

In this scenario, air-source heat pumps sales rapidly increase. No new gas or propane systems are sold beginning in 2030 as shown in Figure 18.[30] We assume that market share for heat pumps increases rapidly between now and 2030 as contractors and building owners develop familiarity with the equipment and the market prepares for the modeled 2030 requirement. We assumed homes that heat with wood continue using wood throughout the study period, resulting in constant heating stock for that fuel type. The total number of system sales increases over time to account for population growth. Because the rate of population growth in Oregon is expected to slow down starting in 2030,[31] our modeling shows equipment sales slowing down in 2030. However, sales increase again in the following years due to the replacement of a large number of heating systems installed in the 2020s.

Figure 18. Residential space heating sales by region

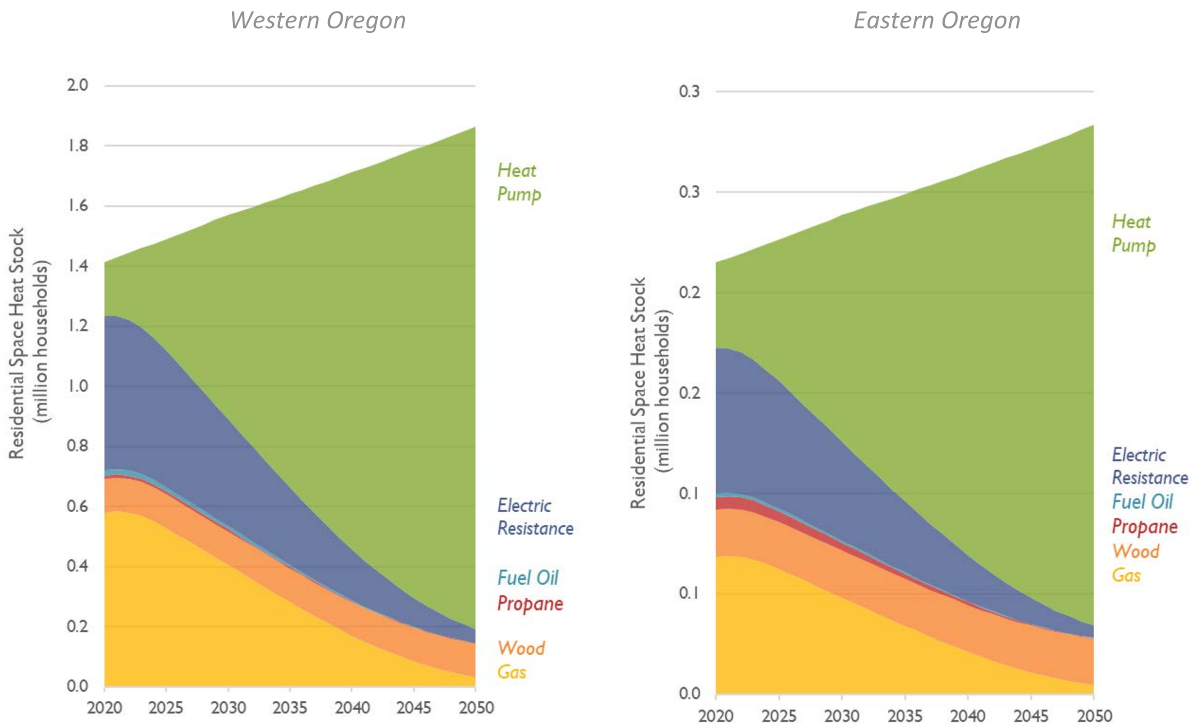


As a result of the rapid increase in heat pump sales, the stock of heat pumps increases substantially over time as shown in Figure 19 below. By 2050, less than 2 percent of homes are projected to be heated by fossil fuels (see Figure 19).

[30] The equivalent figures for commercial space heating or for other end-uses present similar rapid shifts to heat pumps, aside from the continuing role for wood in residential space heating.

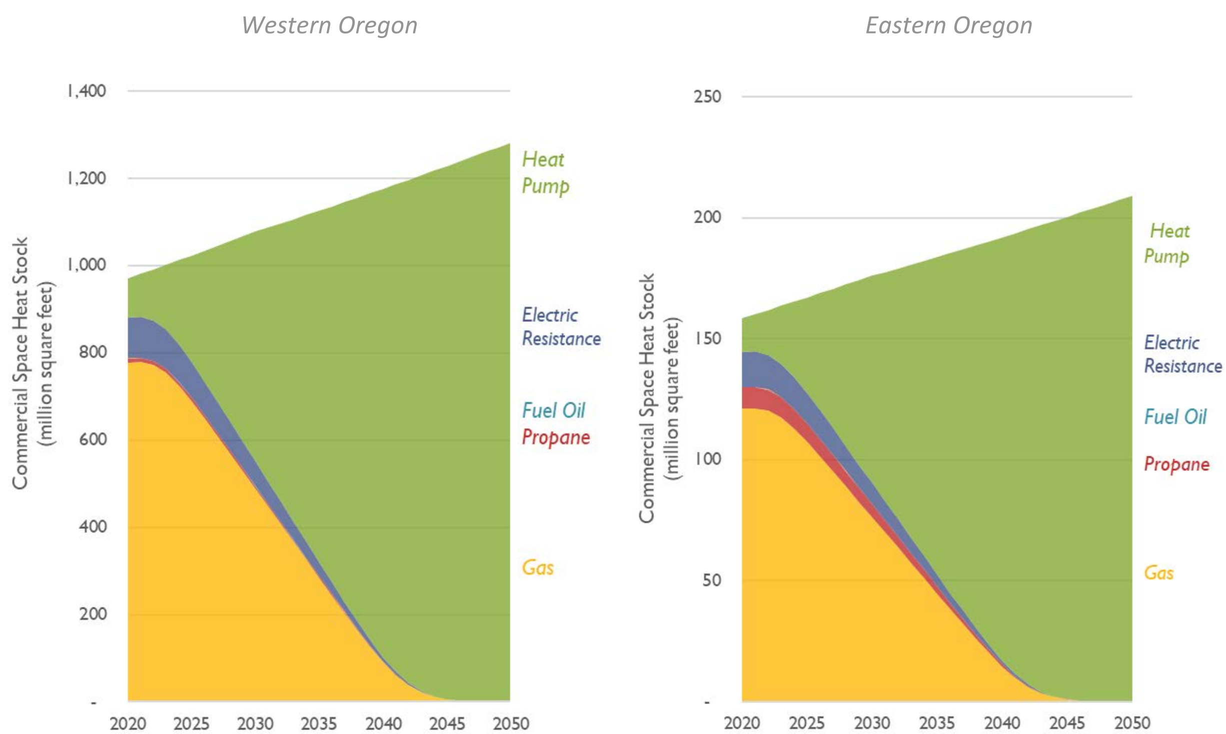
[31] University of Virginia Weldon Cooper Center, Demographics Research Group. 2018. National Population Projections. Retrieved from https://demographics.coopercenter.org/national-population-projections.

Figure 19. Residential space heating stock by region



In the commercial sector, our results show that the majority of square footage will be heated by heat pumps by 2031 as existing gas heating systems retire and are replaced with cleaner alternatives, as shown in Figure 20.

Figure 20. Commercial space heating stock by region

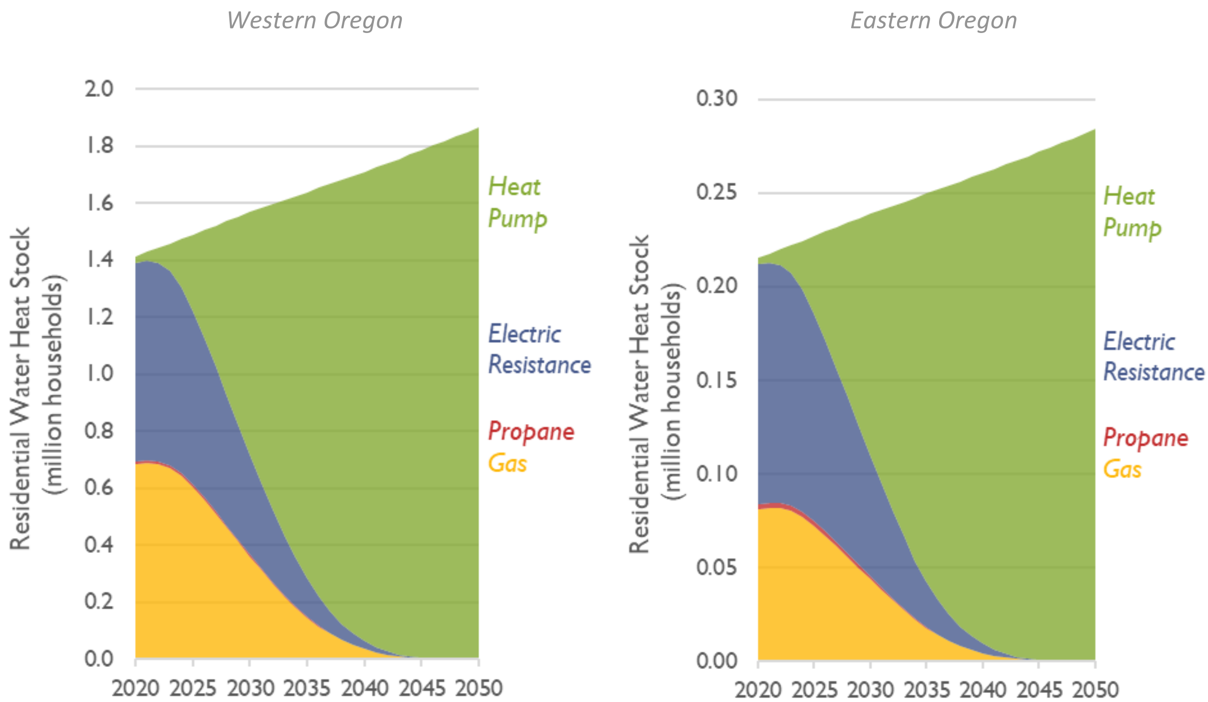


Water heating

As of 2020, gas water heaters made up roughly 50 percent of stock in western Oregon and 40 percent of stock in eastern Oregon as shown in Figure 21. Current residential appliance saturation surveys for Oregon show that electric resistance and gas water heaters are the primary fuel types for water heating.

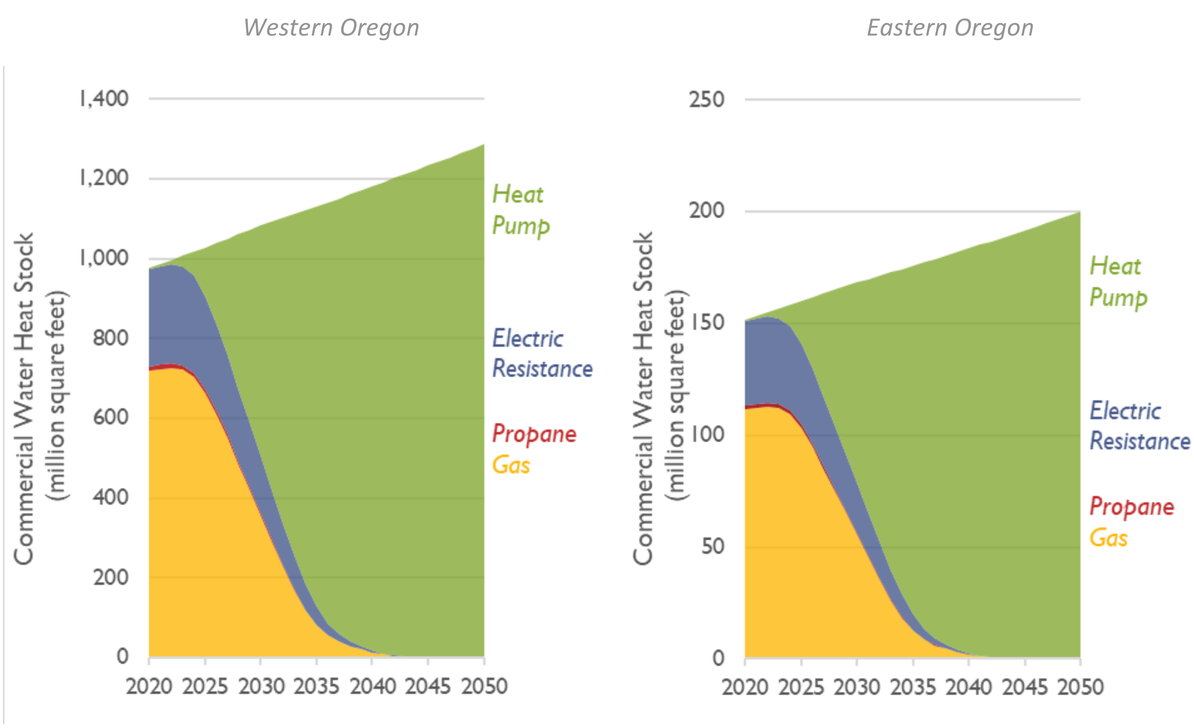
In this scenario, sales of residential heat pump water heaters increase rapidly over the next several years and reach nearly 100 percent by 2030. The model projects the total stock of heat pump water heaters will reach over 95 percent of total residential water heating systems by 2040, as shown in Figure 21.

Figure 21. Residential water heating stock by region



In the commercial sector, heat pump water heaters comprise over 99 percent of total water heating systems by 2040, as shown in Figure 22.

Figure 22. Commercial water heating stock by region



Scenario 2: No fossil fuel equipment sales post 2025

In Scenario 2, heat pump sales are even more accelerated. Starting in 2025, no new fossil fuel system sales are allowed.

Space heating

In this scenario, air-source heat pumps sales increase even faster than in Scenario 1. Figure 23 shows the rapid change in market share. The model still assumes homes that currently heat with wood continue to do so throughout the study period, resulting in constant heating stock for that fuel type. In order to meet the 2025 no-new-fossil-fuel-systems target, sales of gas furnaces and boilers rapidly decline over the next few years. ASHPs replace fossil fuels as the primary space heating system. The model projects that by 2050 roughly 1 percent of homes will be heated by fossil fuels, as shown in Figure 24.

Figure 23. Residential space heating sales by region

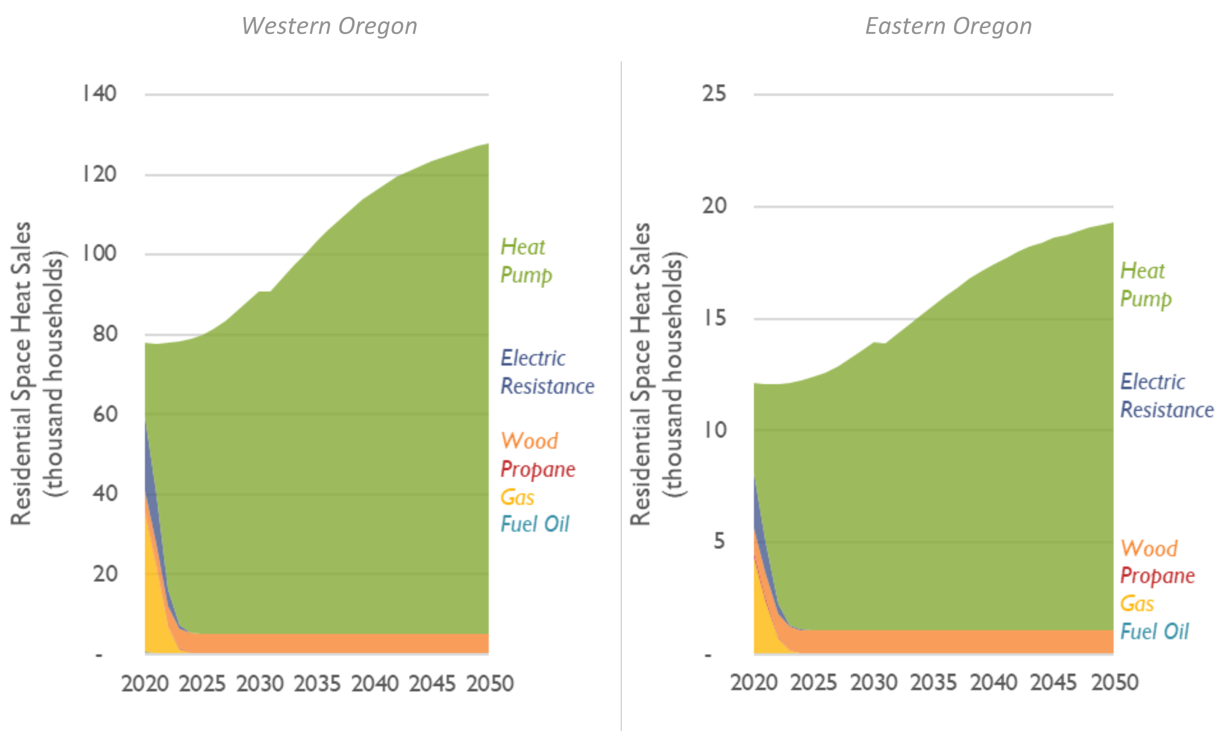
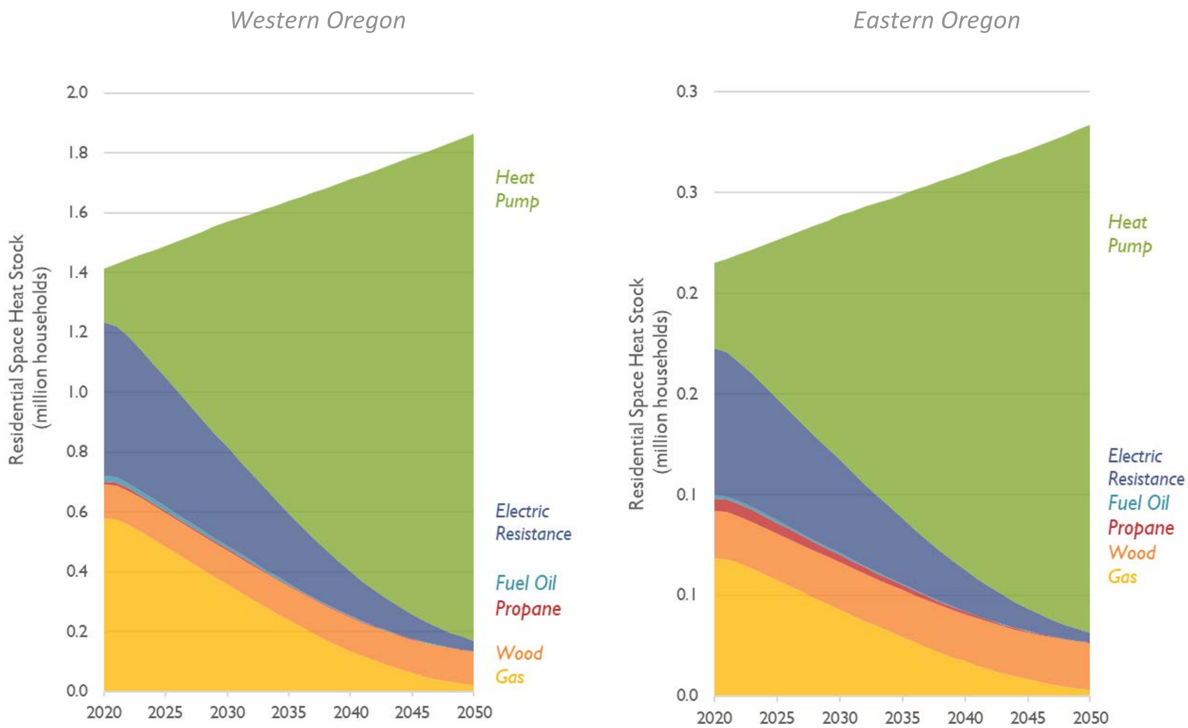
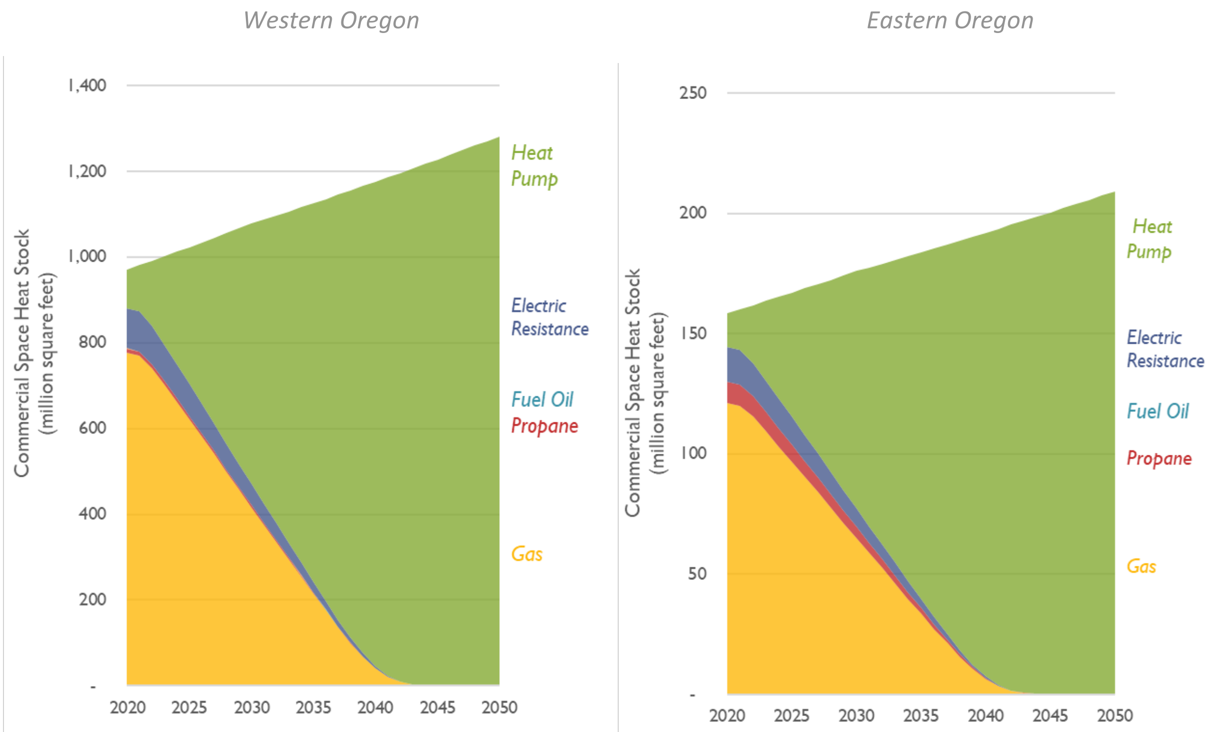


Figure 24. Residential space heating stock by region



In the commercial sector, our results show that the majority of square footage will be heated by heat pumps by 2029 as existing gas heating systems retire and are replaced with cleaner alternatives (see Figure 25 below).

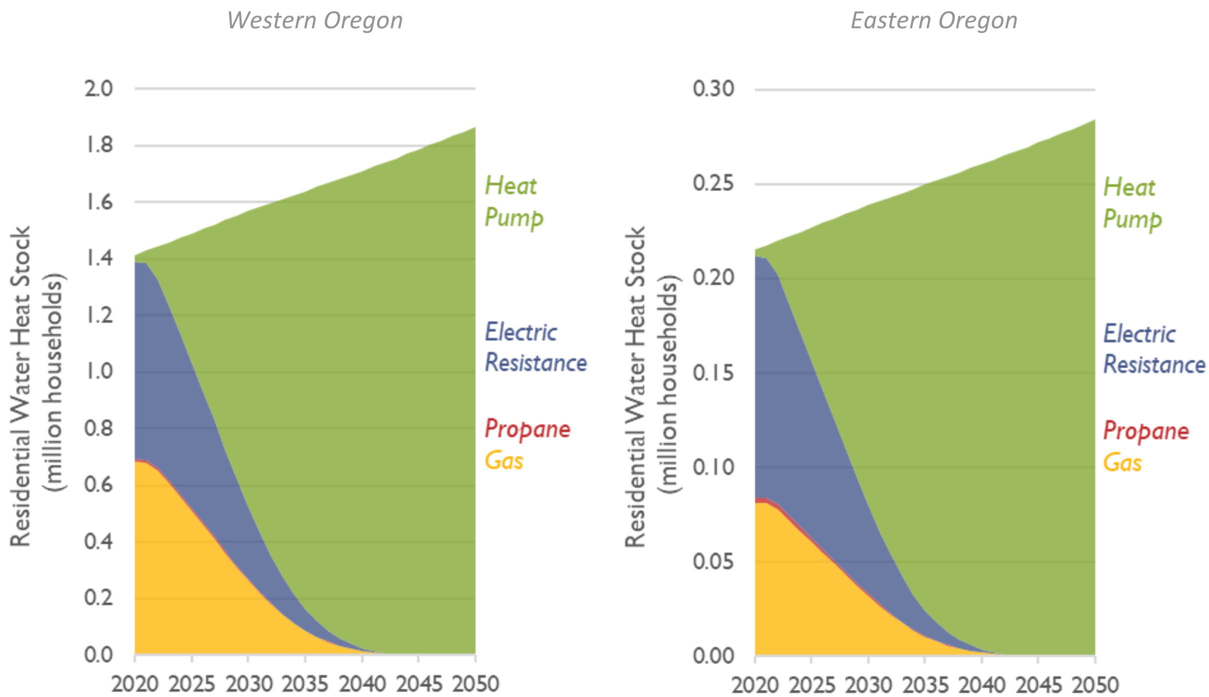
Figure 25. Commercial space heating stock by region



Water heating

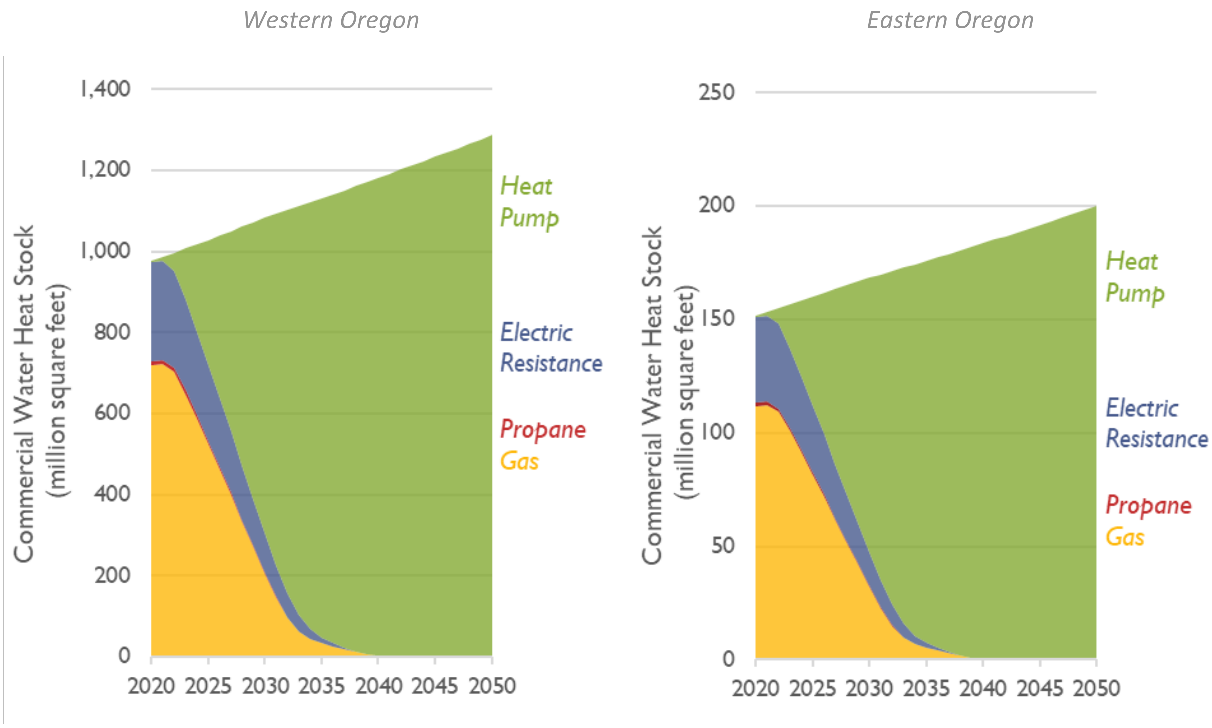
In this scenario, heat pump water heaters comprise over 98 percent of total residential water heating systems by 2040 (see Figure 26).

Figure 26. Residential water heating stock by region



In the commercial sector, heat pump water heaters make up over 95 percent of water heating systems by 2035 (see Figure 27).

Figure 27. Commercial water heating stock



4. Energy System Impact Analysis

Section 3 described how we estimated energy and emission impacts from efficient building electrification for Scenarios 1 and 2 using our BDC model. In this section, we present our analysis of electricity and gas system impacts due to efficient building electrification, including the impacts of technology switching from electric resistance heating systems to heat pump systems. While we presented the results for eastern and western Oregon separately in Section 3, in this section we present the aggregated system cost impacts for the entire state.

4.1. Electric System Impact Analysis

Peak-load impact analysis

Methodology

We projected statewide electric peak-load impacts due to building electrification through 2050 for the two scenarios we analyzed in the previous section. We estimated hourly loads at the end-use level based on NREL's "End-Use load Profiles for the U.S. Building Stock" database consisting of calibrated outputs from NREL's ResStock and ComStock models.[32] The NREL database provides annual sub-hourly load profiles for the residential and commercial segments, across a variety of end-use appliances, for 48 states and the District of Columbia and for a variety of building types. ResStock and ComStock are physics-based simulation models that draw upon many granular data sources to derive a truly representative building stock input. Outputs from the models were then calibrated against measured load from a variety of empirical data sources.[33]

We aggregated all the residential and commercial building load data for Oregon available in NREL's end-use load database. We then developed hourly load factors for the entire building sector as well as for several key end-uses including space heating, water heating, cooking, and clothes drying. We estimated hourly load factors by calculating the load for each hour as a percentage of the total annual load for a given end-use. We then applied the end-use-specific hourly load factors to our estimates of annual total electric loads by end-use and estimated hourly loads every 10 years from 2020 through 2050 (i.e., 2020, 2030, 2040, and 2050).[34] We did not assume any peak-load mitigating measures in our analysis. Such

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[32] NREL. No date. "End-Use load Profiles for the U.S. Building Stock." Available at: https://www.nrel.gov/buildings/end-use-load-profiles.html.

[33] U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. 2022. *End-Use Load Profiles for the U.S. Building Stock - Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification*. Available at: https://www.nrel.gov/docs/fy22osti/80889.pdf.

[34] Our analysis used NREL's end-use load data for space heating instead of the hourly space heating load model we discussed in Section 3.2 because NREL's load data represent combined diversified loads across the state while our load model estimates load just for a single building. One downside of NREL's load data for this analysis is that it combines the shapes of various electric heating systems (including heat pump systems) and does not provide heat-pump-specific load data. However, we

measures could include HPWH demand management and targeted energy efficiency and demand response measures for buildings that implement electrification measures. This means that our analysis presents a conservative picture, meaning that the state's electric utilities should be able to reduce the rate of winter peak-load growth more than our scenario analysis presents if they employ peak-load mitigation measures.

Results

Figure 28 shows our forecast of winter peak loads for the major end-uses (space heating, water heating, cooking, and drying) under two scenarios. Our analysis found that peak loads for the major end-uses grow from approximately 4,430 MW today to 4,870 MW in Scenario 1 and 4,850 MW in Scenario 2, for an average annual growth rate in these end-uses of approximately 0.3 percent through 2050. Peak loads from these uses reach their highest level in 2040 with an average annual growth rate of 0.9 percent through 2040 before falling by 2050. The main reason for these relatively low peak-demand growth rates is that our analysis projects declining peak loads for the residential (RES) sector, primarily due to technology switching from electric resistance heating systems to heat pump systems. We project a substantially higher load growth for the commercial (COM) sector, where this switch is less relevant.

consider NREL's load data to be the best publicly available data and it provides us with reasonable statewide aggregated load impacts for heat pumps. The net result of our use of NREL load shape data is likely that we slightly understate winter peak impacts from deployment of heat pumps.

Figure 28. Projections of winter peak loads for major end-uses

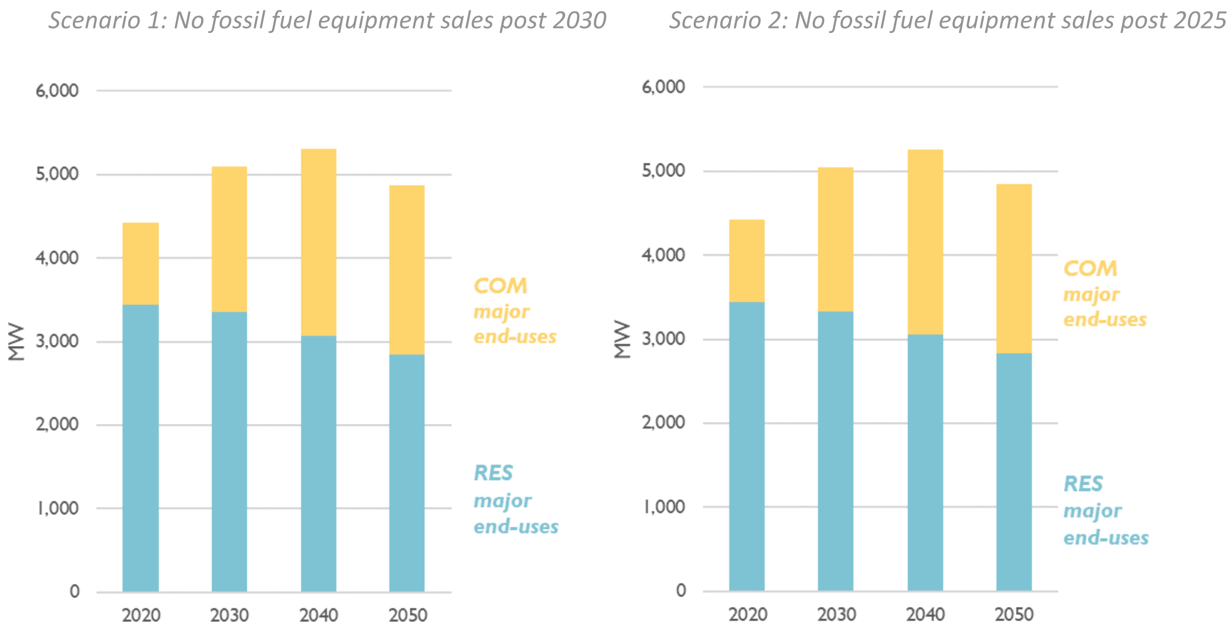


Table 6 shows detailed load projections for Scenario 1. As shown in this table, in this scenario the commercial load for major end-uses will double over the next 30 years from about 990 MW today to 2,000 MW in 2050. This represents an annual growth rate of 2.4 percent. On the other hand, we project that the residential peak load for these end-uses will be reduced by about 600 MW (or 17 percent) from the current 3,400 MW, with an annual growth rate of negative 0.6 percent.

The vast majority of residential peak load comes from electric resistance space heating systems which are currently owned by nearly 40 percent of all households in the state (see Figure 5 in Section 2). Our analysis assumes that these households will switch to energy efficient heat pumps over time voluntarily or due to state programs, policies, or mandates and thereby reduce their energy consumption and peak loads dramatically. On the other hand, electric resistance space heating systems in the commercial sector currently only account for about 9 percent of the total heating systems. Thus, the impact of replacing electric resistance systems with heat pump systems is much smaller in the commercial sector compared to the residential sector. Similarly, we also assume that electric resistance water heaters will be switched to HPWHs. This also has a large impact on peak loads in the residential sector because slightly over half of that sector's water heaters in the state are electric resistance water heaters. In contrast, electric resistance water heaters in the commercial sector account for less than 25 percent of all water heaters (see Figure 7 in Section 2).

Table 6. Projections of winter peak loads for major end-uses: Scenario 1

	2020	2030	2040	2050	MW changes in 2050 relative to 2020	2050 Load Increase relative to 2020 (%)	Growth rate 2020-2050
Residential major end-uses	3,443	3,353	3,068	2,847	-596	-17%	-0.6%
Commercial major end-uses	986	1,749	2,238	2,020	1,034	105%	2.4%
Residential & commercial major end-uses	4,429	5,102	5,307	4,867	438	10%	0.3%

Figure 29 shows our projections of winter peak loads including other electric end-uses for Scenario 1 and Scenario 2. The peak-load projections for the major end-uses are the same as those presented in Figure 28 above. The total building peak load is projected to increase with an average growth rate of 0.6 percent in Scenario 1 and 0.5 percent in Scenario 2. The total residential and commercial loads are projected to change with annual growth rates of negative 0.3 percent and 1.5 percent, respectively.

We estimated the peak-load estimates for the other end-uses for 2020 based on (a) the aggregated load shapes for the entire sector we obtained from NREL's end-use load database, (b) the 2020 total electricity consumption for the residential and commercial sectors, and (c) our estimates of hourly energy consumption for the major end-uses. We then estimated future hourly loads for the other end-uses using the energy growth rates for Oregon projected by the Northwest Power and Conservation Council's (NWPCC) 2021 Power Plan. NWPCC projects that electric loads increase from about 5460 average megawatts (aMW) in 2020 to about 7,150 aMW by 2050 with an annual load growth rate of 0.9 percent.[35] We applied the annual energy growth rates for each decade to project the energy and peak-load estimates for the other end-uses. The resulting hourly loads for the other end-uses are included in Figure 30, discussed below.

[35] Northwest Power and Conservation Council. 2021. "2021powerplan_State-level Forecasts.xlsx" file. Available at: https://www.nwcouncil.org/2021powerplan_state-level-energy-use-forecast/.

Figure 29. Projections of electricity peak loads for all end-uses

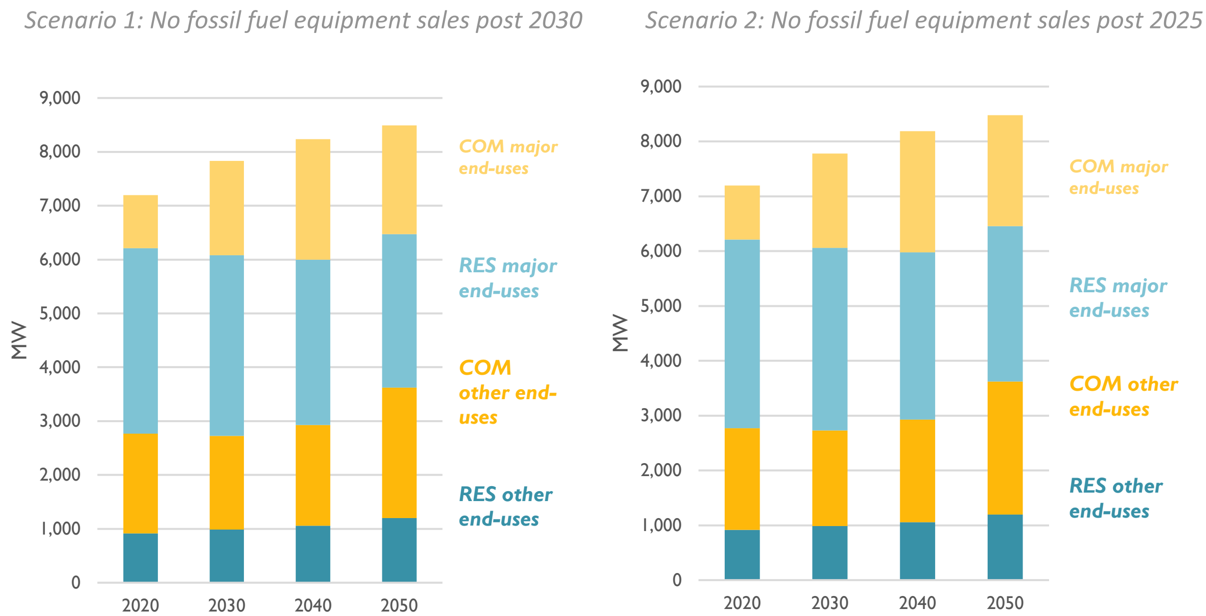
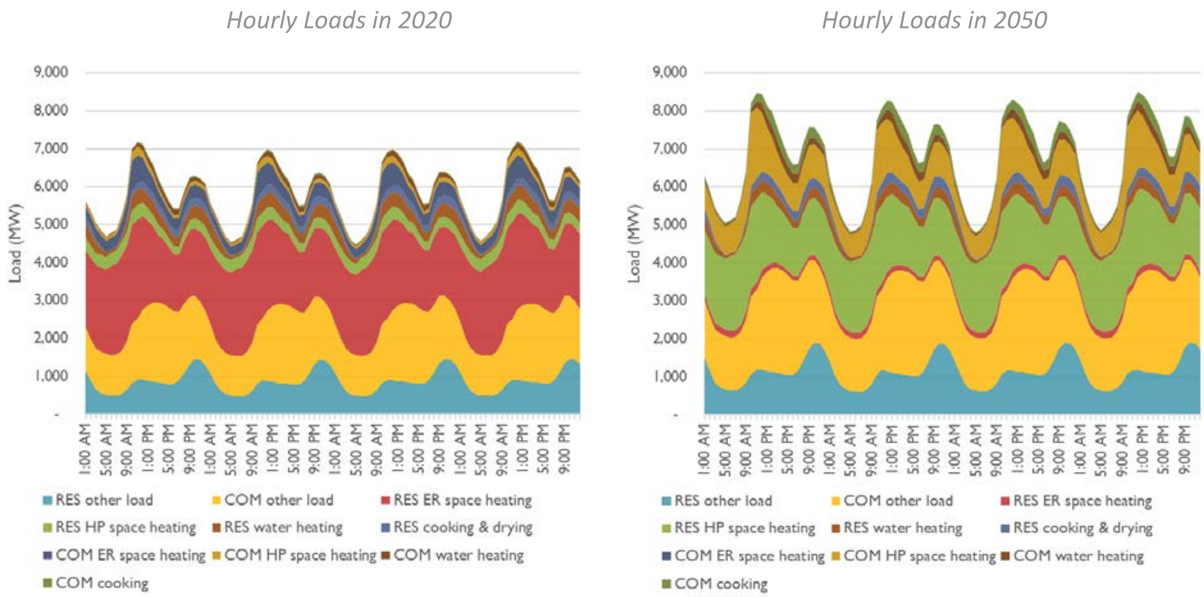


Figure 30 below presents our estimates of hourly end-use loads during typical winter peak days in 2020 and 2050 in Scenario 1. This graph shows hourly loads for the major end-uses as well as the other electric end-uses, covering the entire electricity loads in the residential and commercial sectors in the state. As shown in this graph, the largest change between these two time periods is the type of space heating technologies. In 2020, the largest load is residential electric resistance space heating (as shown in red in the left chart). In 2050, instead of residential electric resistance space heating, residential heat pump space heating (as shown in light green in the right chart) accounts for the largest component of peak loads. However, as discussed above, the total peak load from residential heat pump space heating in 2050 is smaller than residential electric resistance heating in 2020 even though the number of heat pumps in 2050 is much greater than the number of electric resistance heating systems today. This is because heat pumps are much more efficient than electric resistance heating systems. The second largest change is commercial space heating technologies. In 2020, electric resistance space heating (as shown in purple in the left chart) was the second largest load besides the residential and commercial other loads. In 2050, commercial heat pump space heating (as shown in light brown in the right chart) becomes the second largest load among the major end-uses.

Figure 30. Projected changes in hourly loads by end-use for Scenario 1: winter peak days



Electricity system cost impact analysis

Methodology

We estimated electric system cost impacts of electrification using the state's avoided electric cost estimates developed by the state's investor-owned utilities and the statewide energy efficiency program administrator, the Energy Trust of Oregon. We provide a summary of the avoided electric costs in Table 7 below. These costs represent the statewide average costs that the Energy Trust of Oregon developed for its 2023 program-year based on the avoided costs provided by the two electric investor-owned utilities.[36] We applied these avoided costs to the changes in energy and peak loads associated with the four major end-uses (space heating, water heating, cooking, and clothes drying) and estimated net electric system cost impacts. We consider these avoided costs of electric power supply as reasonable values to assess the costs of accommodating additional loads from electrification.

[36] We converted the original values from the 2023$ to $2021, based on the inflation rates available in the following two filings: Energy Trust of Oregon. 2021. *Draft 2023 Electric Avoided Cost Update Summary*. Available at: https://apps.puc.state.or.us/orders/2021ords/21-476.pdf; and Energy Trust of Oregon. 2019. *Draft 2021 Electric Avoided Cost Update Summary*. Available at: https://apps.puc.state.or.us/orders/2021ords/21-476.pdf.

Table 7. Avoided electricity supply costs for Oregon ($2021)

Avoided Cost Component	Unit	Value
Transmission capacity	$/kW-year	7.6
Distribution capacity	$/kW-year	19
Generation capacity	$/kW-year	103
Total system capacity	$/kW-year	130
Energy price	$/MWh	46

Source: Energy Trust of Oregon. 2021. Draft 2023 Electric Avoided Cost Update Summary. Available at: https://apps.puc.state.or.us/orders/2021ords/21-476.pdf.

Results

For the purpose of our analysis, we estimated additional electricity supply costs for accommodating the net load growth expected from building electrification. This analysis does not include the cost associated with the load growth for the other end-uses as those are outside of the scope of our analysis.

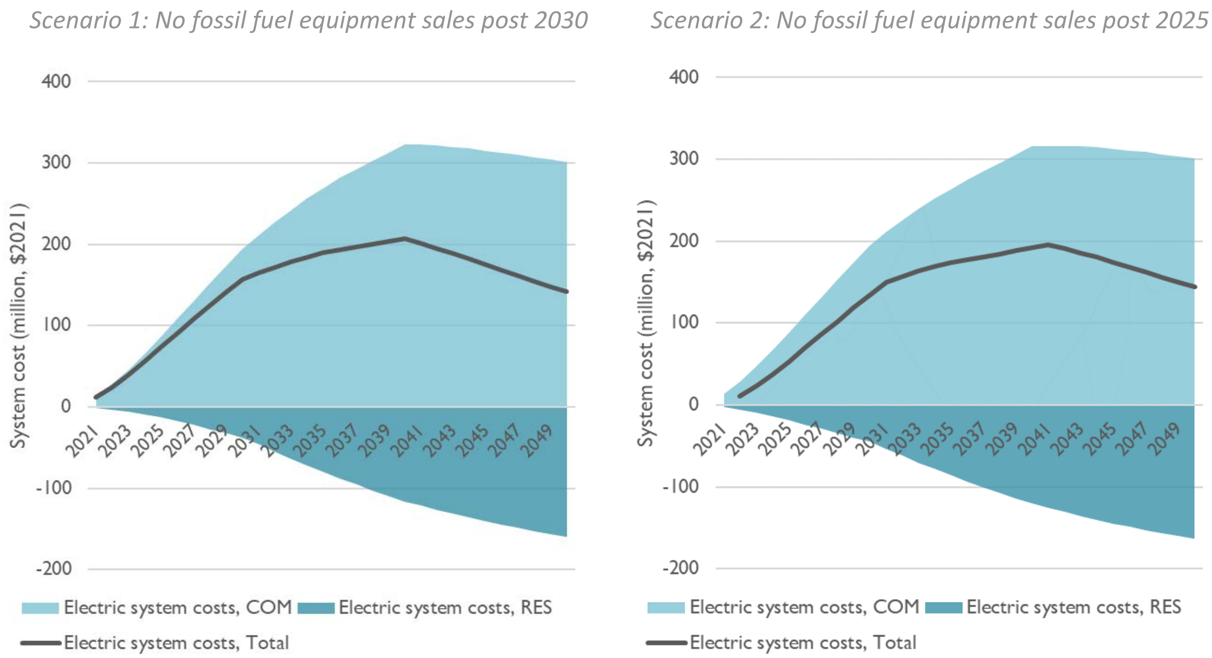
Figure 31 presents a summary of our estimates of electricity system costs for Scenario 1 and Scenario 2. Our analysis estimates that the total annual electricity system costs (shown as the black lines in the chart) increase gradually to about $207 million in Scenario 1 and $196 million in Scenario 2 in 2040. These costs decline to about $142 million in Scenario 1 and $138 million in Scenario 2 in 2050. The net present values of the entire electric system costs are about $2.2 billion in Scenario 1 and $2.1 billion in Scenario 2, using the real discount rate of 4.5 percent currently used by the Energy Trust of Oregon.[37] Using a lower discount such as 3 percent, the total cost would increase to $2.6 to $2.8 billion (present value).[38]

The area charts in Figure 31 show the costs separately for the residential and commercial sectors. We project that electrification along with switching from electric resistance to heat pump technologies will reduce residential-sector annual system costs by about $160 million to $163 million by 2050. On the other hand, we project that electrification in the commercial sector will increase the system costs by about $300 million by 2050.

[37] Energy Trust of Oregon. 2021. *Draft 2023 Electric Avoided Cost Update Summary*. Attachment 3 to Oregon Public Utilities Commission Order No. 21-476. CA8 – UM 1893. Available at: https://apps.puc.state.or.us/orders/2021ords/21-476.pdf.

[38] Discount rates are used to convert future values to the present value.

Figure 31. Projections of electricity system cost impacts



4.2. Gas System Impact Analysis

Methodology

We estimated the impacts on gas system costs due to electrification using our estimates of declining gas sales and customer counts. Our gas system cost impact analysis is a high-level and conservative analysis; it excluded any cost impacts associated with the retirement of the existing gas systems. In a scenario where gas end-use systems are fully electrified, we expect that many gas pipelines serving customers will no longer be used and useful, and the gas utilities will need to remove those assets from their rate base as a result. This will reduce both the operating costs of the existing pipelines and the cost recovery of those assets for all customers. However, our analysis did not incorporate this impact as it would require a detailed analysis of gas asset management.

In 2020, Oregon's three gas investor-owned utilities spent about $570 million ($2021) for their system operating expenses. Table 8 below shows a detailed breakdown of the operating expenses, along with our assumptions of how we projected declining operating costs. For projecting declining cost impacts due to electrification, we assumed that gas commodity fuel supply costs decline in proportion to gas sales reduction based on our building electrification scenario analyses. We then reduced the operating costs associated with customers and sales based on our estimates of customer counts reduction. Some customers who electrify space heating may retain gas for other services such as water heating and cooking. However, we used the customers with space heating as a proxy for counting customers who switch to fully electrify and leave the gas system because space heating has the longest system life among all end-uses. Finally, we reduced the administration and general expenses in proportion to the overall cost reduction for distribution, transmission, customer, and sales costs.

Table 8. Gas utility operating costs by the gas investor-owned utilities in Oregon

Oregon system	Operating Costs (million $2021)	Assumptions for Future Operating Costs
Commodity fuel supply	$287	Reduce based on sales volume reductions
Distribution & Transmission	$84	No change
Customer Accounts	$107	Reduce cost based on customer counts for space heating
Customer Service & Information	$20	Reduce cost based on customer counts for space heating
Sales	$12	Reduce cost based on customer counts for space heating
Administrative & General	$63	Reduce in proportion to the cost reductions for distribution, transmission, customer, and sales operating costs
Total Operating Expenses	$573	

Source: Oregon Public Utility Commission. 2021. Oregon Utility Statistics 2020. P. 53. Available at: https://www.oregon.gov/puc/forms/Forms%20and%20Reports/2020-Oregon-Utility-Statistics-Book.pdf.

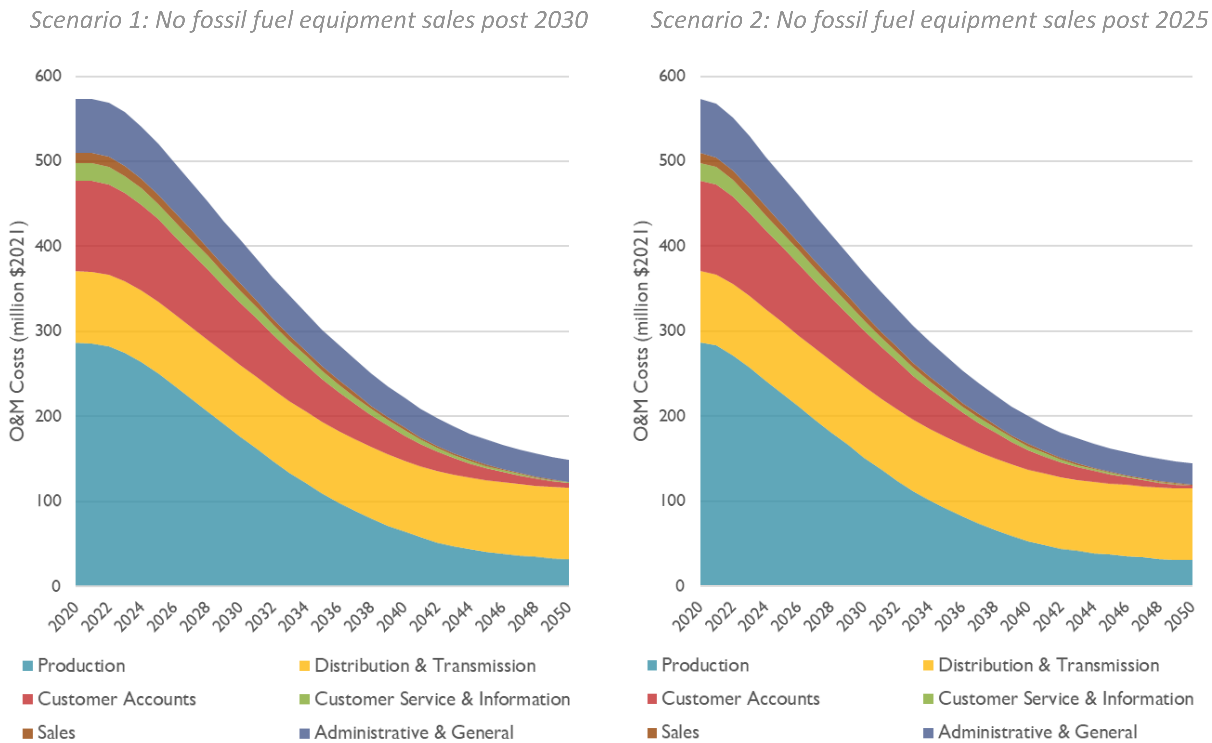
Results

Figure 32 presents our forecast of gas system cost impacts for the entire state under Scenario 1 and Scenario 2. We project that the operating costs decline gradually over time in both scenarios while the reduction in operating costs in Scenario 2 is faster. The annual operating costs are currently about $570 million ($2021) and projected to decline to $126 million in Scenario 1 and $121 million in Scenario 2 by 2050. Most of the remaining operating costs are related to transmission and distribution pipelines because our analysis did not assume any retirement of pipelines due to electrification. Further, some gas production-related (fuel supply) operating costs remain in 2050. Most of these costs are for supporting gas sales for industrial customers, which is outside of the scope of our analysis.

Our analysis found that by 2050 the building electrification in the residential and commercial sector in both scenarios will avoid approximately $450 million per year in gas system operating costs. Through 2050, Scenario 1 avoids approximately $3.3 billion (present value) of gas operating costs and Scenario 2 avoids approximately $3.8 billion (present value) of gas operating costs, using a real discount rate of 4.5 percent.[39] Using a lower discount such as 3 percent, the total cost savings would increase to $4.3 to $4.8 billion (present value).

[39] Energy Trust of Oregon. 2021.

Figure 32. Projections of gas system cost impacts



4.3. Total Energy System Impact Analysis

Figure 33 and Table 9 provide our estimate of the total energy system impacts due to the building electrification and switching from electric resistance to heat pump systems for Scenario 1 and 2. This combines the electric system impacts from Figure 31 and the gas system impacts from Figure 32 above.

In both scenarios, our analysis shows that building electrification saves overall energy system costs for households and businesses in Oregon. Under Scenario 1, we project that building electrification starts to save system costs from 2030 and cost savings increase through 2050 with an annual cost savings of about $280 million in 2050. In total, the residential and commercial sectors are expected to save about $1.1 billion (net present value) through 2050 with a real discount rate of 4.5 percent. Using a lower discount rate of 3 percent, the cost savings would increase to nearly $1.7 billion. Under Scenario 2, we project that building electrification starts to save system costs from 2023 and cost savings increase through 2050 with an annual cost savings of about $290 million in that year. In total in this scenario, the residential and commercial sectors are expected to save about $1.7 billion (net present value) through 2050 with a real discount rate of 4.5 percent. Using a lower discount rate of 3 percent, the present value of savings would increase to nearly $2.2 billion.

Figure 33. Projections of electricity and gas system cost impacts

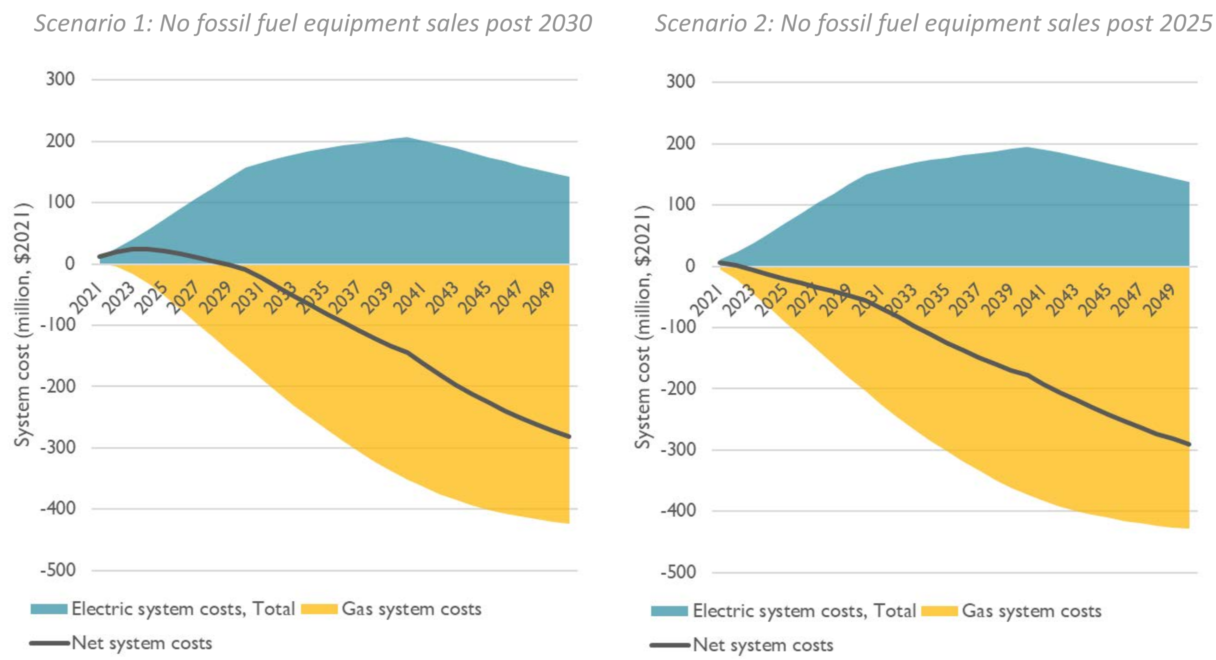


Table 9. Projection of electricity and gas system cost impacts (million, $2021)

	2030	2040	2050	Total (net present value)
Scenario 1	-8	-145	-282	-1,088
Scenario 2	-55	-177	-290	-1,661

5. Residential Bill Impact Analysis of Full Building Electrification

To assess the affordability implications of efficient residential building electrification, we conducted an illustrative analysis of energy bill impacts of electrification measures for an existing single-family household in Oregon that currently uses utility gas for major end-uses. In addition, because the majority of water and space heating in the state today uses electric resistance heating systems, we also compared bill impacts of more efficient (i.e., heat-pump-based) electrification measures relative a case where a household uses conventional electric resistance heaters for space and water heating end-uses. Finally, we conducted a payback analysis of electrification for space and water heating measures.

5.1. Bill Impact Methodology and Assumptions

We used Synapse's Building Electrification Bill Impact Model (Bill Impact Model) to assess annual bill impacts of building electrification for residential customers in Oregon. Our Bill Impact Model estimates energy consumption by end-use on an hourly basis and estimates bill impacts for electrification of end-uses switching from gas services using detailed electricity and gas tariffs. Our model also incorporates electricity usage for other end-uses such as air conditioning, lighting, and appliances to estimate approximate total bill impacts for residential customers.

We modeled energy bills for an existing single-family household in each of two climate zones in Oregon. We selected Portland (for western Oregon) and Bend (for eastern Oregon) as representative cities for the climate zones. Our analysis assumes that two types of single-family household (in each climate zone) are considering replacing their existing systems. One type of house uses utility gas as the primary fuel for many end-uses. Another type of house uses electricity as the primary fuel for many end-uses. We describe the base cases for these two houses along with a single alternative case below:

- **Mixed-Fuel Base Case**: Installing new gas equipment for major end-uses (i.e., space heating, water heating, cooking, and clothes drying) and a new air conditioner with minimum efficiency levels (e.g., seasonable energy efficiency rating or SEER 14)[40]
- **ER Base Case**: Using the existing electric resistance space and water heating systems, the existing electric resistance cooktop, and the existing standard electric clothes dryer, and installing a new AC with minimum efficiency level (SEER 14).
- **Alternative Case (efficiently electrified house)**: Installing a high efficiency, ducted air-source heat pump for space heating and cooling (SEER 18), a heat pump water heater, an induction cooking stove, and a standard electric clothes dryer.

[40] An air conditioner with a SEER of 14 is 14/3.412 = 410% efficient at moving heat out of the building (which can be expressed as a COP of 4.1 for cooling).

We use two different bases cases—one with mixed fuels and one with electric resistance—because these are the two most common configurations for existing homes in Oregon. Electric resistance space heating systems are equally dominant to gas furnaces, and electric resistance water heaters account for over 50 percent of all residential water heaters in the state, according to NEEA's RBSA. We also assume that these two base cases will install a new central air conditioner as it appears that installing a new air conditioner is becoming a common trend in Oregon.[41]

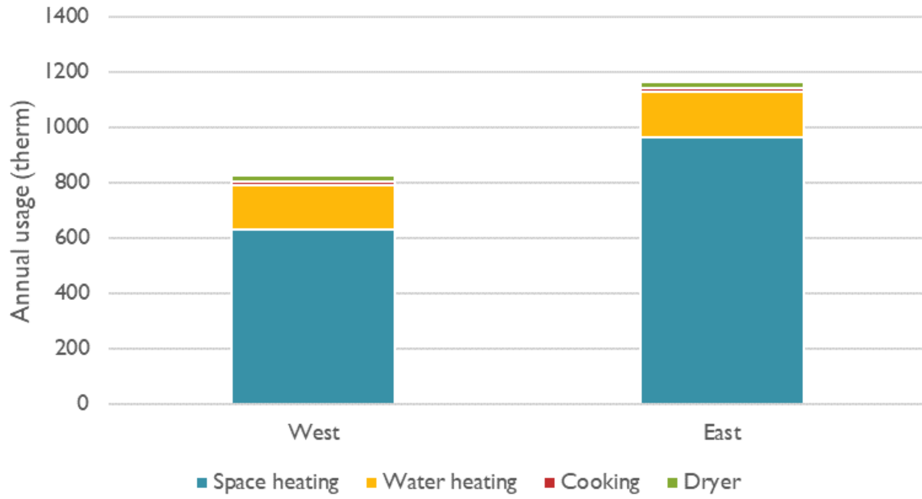
As discussed in Section 2, approximately 38 percent of the households currently use gas for space heating, and the majority of those customers use gas furnace systems with ducts. Thus, we assumed a ducted air-source heat pump instead of a ductless mini-split heat pump for the Alternative Case. Our heat pump performance assumption reflects this technology choice.[42]

To assess the impacts of electrification loads against the Mixed-Fuel Base Case, our analysis used gas end-use consumption data as shown in Figure 34. Secondly, we estimated end-use energy loads (or energy outputs) by end-use using the efficiencies of the existing systems and the gas usage data. We then estimated final energy usage for the Mixed-Fuel Base Case and for the Alternative Case (efficiently electrified house). For the Mixed-Fuel Base Case, we estimated gas usage using the efficiencies of new gas systems, and for the Alternative Case, we estimated electricity usage using the efficiencies of new electric systems including heat pumps, induction cooktops and electric dryers. A summary of the efficiency ratings used in our analysis is provided in Appendix B.

[41] According to the American Housing Survey, air conditioning is present in about 80% of Portland homes in 2019, up 10% from 2015, and almost doubled from 2011. This growth indicates that most people replacing HVAC system in Oregon are likely opting to add a central AC system.

[42] One major difference between these two technologies is the performance of heat pumps. Ductless heat pumps tend to be more energy efficient than ducted heat pumps. Our bill analysis incorporates the performance of ducted heat pumps, and therefore greater electricity consumption than a ductless case.

Figure 34. Annual gas usage by end-use per household in Oregon



Source: Northwest Energy Efficiency Alliance (NEEA)'s Residential Building Stock Assessment (RBSA) for space heating. The RBSA values were adjusted for heating degree days; Regional Technical Forum's "Residential Gas Water Heaters v1.1" file available at: https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0; U.S. Department of Energy. 2016. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Equipment: Residential Conventional Cooking Products; and U.S. Energy Information Administration's Residential Energy Consumption Survey. Table CE5.3a for drying.

Electricity usage data for other end-uses included in our bill impact analysis are shown in Table 10. For all the end-uses except central air conditioning, we assume the same energy usage level between the western and eastern regions. For central air conditioning, we obtained energy usage data from the Regional Technical Forum (RTF) and adjusted the data for cooling degree days (CDDs) for Portland and Bend. There are several other end-uses we did not include in our analysis (e.g., dishwashers, pool pump, spa, ceiling fan). Thus, the total electricity usage in our study is lower than state average electricity usage. However, the difference between the base cases and the Alternative case is not impacted by these other electricity end-uses.

Table 10. Electricity usage assumptions for other electricity end-uses (kWh)

End-use	West	East	Source
Central air conditioning	611	262	Regional Technical Forum (RTF)'s analysis "Res Efficient Central Air Conditioners v1.0", adjusted for CDDs for Portland and Bend. Available at: https://rtf.nwcouncil.org/measures/.
Interior Lighting	489	489	2019 California Residential Appliance Saturation Study (RASS). Available at: https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.
Exterior Lighting	224	224	2019 California RASS
Clothes washer	120	120	EPA EnergyStar website, available at: https://www.energystar.gov/productfinder/product/certified-clothes-washers/.
Refrigerator/freezer	550	550	Average baseline fridge/freezer models based on RTF's analysis "ResRefrigeratorsAndFreezers_v5_0"
Microwave	150	150	2019 California RASS
Personal computer	272	272	2019 California RASS
Television	462	462	2019 California RASS

As mentioned above, our bill impact analysis involves an analysis of hourly energy consumption for each end-use. We took a few different approaches to develop hourly energy consumption by end-use type as shown in Table 11 below.

Table 11. Approaches for estimating end-use hourly loads

End-use	Approach
Space heating	A detailed COP performance curve and hourly weather data (typical meteorological year or TMY weather data) specific to Portland and Bend.
Water heating	Hourly load data for a heat pump water heater and an electric resistance water heater obtained from Pierre Delforge of NRDC regarding a 2018 study by NRDC/Ecotope. The data for the coldest climate zone (climate zone 16) in California was used as heating degree days (HDDs) in this climate are close to Portland and Bend.
Other end-uses	NREL's "End-Use load Profiles for the U.S. Building Stock" database consisting of calibrated outputs from NREL's ResStock and ComStock models.

Notes: The COP performance data are based on Center for Energy and Environment (2018) "Cold-Climate Air-Source Heat Pumps" Available at: http://www.duluthenergydesign.com/Content/Documents/GeneralInfo/Presentation Materials/2018/Day1/ccASHPs.pdf. NRDC/Ecotope. 2018. Heat Pump Water Heater Electric Load Shifting: A Modeling Study. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=232168&DocumentContentId=64120. NREL. "End-Use load Profiles for the U.S. Building Stock." Available at: https://www.nrel.gov/buildings/end-use-load-profiles.html.

Finally, we calculated annual bill impacts using residential base electric and gas rates available to residential customers in Portland and Bend. For Portland, we used the electric rate Schedule 7 of Portland General Electric (PGE) and the gas rate "Schedule 2" of NW Natural.[43] For Bend, we used the electric rate Schedule 4 of Pacific Power and the gas rate "Schedule 101" of Cascadia NG.[44]

5.2. Bill Impact Analysis Results

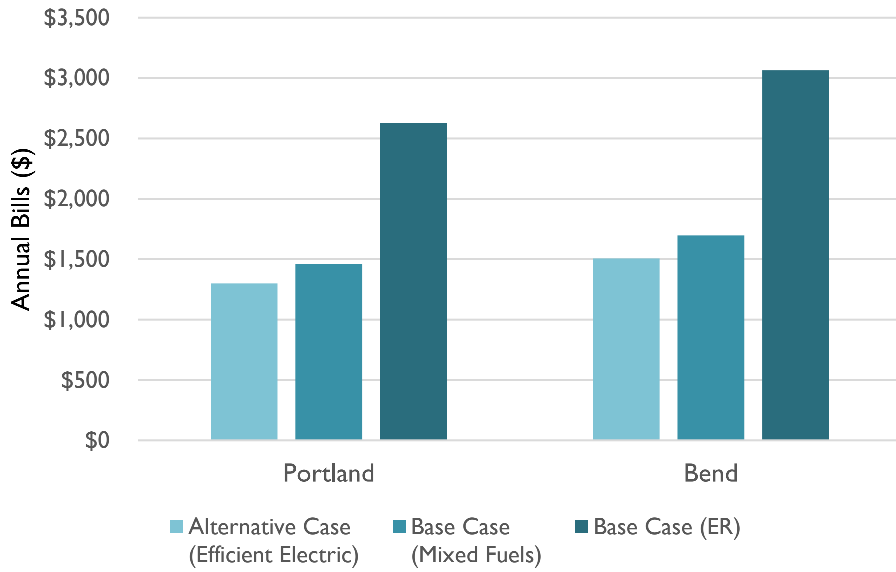
Bill impact high-level results

Figure 35 presents a high-level summary of our annual bill impact analysis for all three cases in Portland and Bend. Our analysis found that the Alternative Case with efficient electrification measures has the lowest annual bill in both Portland and Bend. The Mixed-Fuels Base Case for both cities has slightly higher annual bills than the Alternative Case: by 12 percent in Portland and by 13 percent in Bend. The annual bills for the ER Base Case were about twice as expensive as the more efficient Alternative Case in both cities. Detailed annual bill impact results are presented in the following sections. Detailed annual energy impact results are presented in Appendix C.

[43] PGE. Schedule 7. Available at: https://assets.ctfassets.net/416ywc1laqmd/6RgTNk5RU1bldl0LdPpIY9/b15306776f15d00e4eee8688957e9877/Sched_007.pdf; NW Natural. Schedule 2. Available at: https://www.nwnatural.com/about-us/rates-and-regulations/oregon-tariff-book.

[44] Pacific Power. Schedule 4. Available at: https://www.pacificpower.net/content/dam/pcorp/documents/en/pacificpower/rates-regulation/oregon/tariffs/Oregon_Price_Summary.pdf; Cascadia NG. Schedule 2. Available at: https://www.cngc.com/rates-services/rates-tariffs/.

Figure 35. Annual bill impact summary across three cases in Portland and Bend



Bill impact detailed results: Portland

Table 12 presents our comparison of annual energy bills for the Mixed-Fuel Base Case and the Alternative Case in Portland. Our analysis found that the Alternative Case saves annual energy bills by about $160 relative to the Mixed-Fuel Base Case where gas is used for the four major end-uses (space heating, water heating, cooking and clothes drying). The largest bill savings result from reduced customer charges ($96 per year). This is because a household in the Alternative Case is assumed to fully electrify their end-uses and thus does not need to pay for any gas utility customer charges. The second largest savings result from the water heating end-use ($51). We also found that a standard electric clothes dryer is almost $40 per year more expensive to operate than a gas clothes dryer.

Table 12. Annual bill impacts for the Mixed-Fuel Base Case and for the Alternative Case (efficient electric): Portland

End-Uses / Bill Components	Annual Operating Cost ($)		
	Mixed-Fuel Base Case	**Alternative Case (efficient electric)**	**Delta**
Space Heating	$707	$665	($42)
Water Heating	$164	$113	($51)
Cooking	$17	$18	$0
Clothes Drying	$22	$61	$39
Air Conditioning	$69	$55	($14)
Lighting & appliances	$255	$257	$2
Customer Charges	$228	$132	($96)
Total Cost	**$1,462**	**$1,300**	**($161)**

Our analysis found that the ER Base Case is substantially more expensive (about $2,630 per year) than the Alternative Case (see Table 13). Overall, the Alternative Case saves about $1,330 per year; the largest savings come from space heating. Note some end-uses such as cooking, clothes drying, lighting and appliances have the same usage levels but the allocated bills for these end-uses are slightly different between the cases. This is because the electricity tariffs used in this analysis have two tiers. The second tier, charged for a higher monthly consumption level above 1,000 kWh, has a higher rate than the first tier.

Table 13. Annual bill impacts for the ER Base Case and for the Alternative Case (efficient electric): Portland

End-Uses / Bill Components	Annual Operating Cost ($)		
	ER Base Case	**Alternative Case (efficient electric)**	**Delta**
Space Heating	$1,732	$665	($1,067)
Water Heating	$331	$113	($218)
Cooking	$23	$18	($6)
Clothes Drying	$65	$61	($3)
Air Conditioning	$72	$55	($18)
Lighting & appliances	$270	$257	($13)
Customer charges	$132	$132	$0
Total Cost	**$2,626**	**$1,300**	**($1,325)**

Bill impact detailed results: Bend

Table 14 presents our comparison of annual energy bills for the Mixed-Fuel Base Case and the Alternative Case in Bend. Annual bills for Bend are markedly higher than the bills for Portland mainly because Bend has a much colder climate and thus has more heating needs. Our analysis found that the Alternative Case reduces annual energy bills by about $190 relative to the base cases. The largest bill savings are found in space heating end-use ($82 per year). Similar to what we found for Portland, a regular electric clothes dryer is more expensive to run than a gas clothes dryer.

Table 14. Annual bill impacts for the Mixed-Fuel Base Case and for the Alternative Case (efficient electric): Bend

End-Uses / Bill Components	Annual Operating Cost ($)		
	Mixed-Fuel Base Case	Alternative Case (efficient electric)	Delta
Space Heating	$1,062	$981	($82)
Water Heating	$172	$102	($70)
Cooking	$17	$15	($2)
Clothes Drying	$22	$53	$31
Air Conditioning	$25	$20	($5)
Lighting & Appliances	$194	$221	$7
Customer charges	$186	$114	($72)
Total Cost	**$1,678**	**$1,506**	**($192)**

Table 15 below compares our bill analysis for the ER Base Case with the Alternative Case. Similar to the findings for Portland, our analysis found that the ER Base Case is substantially more expensive (about $3,060 per year) than the Alternative Case. Overall, the Alternative Case saves about $1,560 per year, with the largest savings coming from space heating ($1,320 per year).

Table 15. Annual bill impacts for the ER Base Case and for the Alternative Case (efficient electric): Bend

End-Uses / Bill Components	Annual Operating Cost ($)		
	ER Base Case	Alternative Case (efficient electric)	Difference
Space Heating	$2,299	$981	($1,318)
Water Heating	$300	$102	($197)
Cooking	$21	$15	($6)
Clothes Drying	$59	$53	($6)
Air Conditioning	$28	$20	($7)
Lighting & Appliances	$243	$221	($23)
Customer Charges	$114	$114	$0
Total Cost	**$3,064**	**$1,506**	**($1,558)**

5.3. Payback Analysis Results

We conducted a payback analysis of the Alternative Case relative to the Mixed-Fuel Base Case and the ER Base Case. This payback analysis focuses on HVAC and water heating electrification measures. This analysis is a simple payback analysis in which we estimate the number of years to recoup the upfront incremental costs of the electrification measures by dividing the incremental cost by the first-year annual bill savings.

We conducted a literature review and reviewed the installed costs of space heating and cooling and water heating systems for a residential house in order to estimate the incremental costs of electrification measures. In Table 16 through Table 18, we present our estimates of incremental costs. The average incremental savings of a heat pump relative to the combined cost of a gas furnace and AC system is about $1,640, as shown in Table 16. The average incremental cost of a heat pump relative to a central AC is about $2,860, as shown in Table 17. This represents the incremental cost relative to the electric resistance Base case where a household keeps the existing electric resistance space heater, but installs a new central AC system. Lastly, we found the average cost of a HPWH is about $640 more than a gas storage water heater, as shown in Table 18.

Table 16. Incremental costs of heat pumps (Alternative Case) relative to gas furnace and central air conditioning (Mixed-Fuel Base Case)

Study	Location	Heat pump (Total cost)	Gas furnace and central air conditioning (Total cost)	Heat pump (Incremental cost)
LBNL 2021	National	$8,207	$10,955	($2,748)
SWEEP 2018	Reno	$8,200	$7,937	$263
RMI 2018	Oakland	$8,641	$11,088	($2,447)
Average		**$8,349**	**$9,993**	**($1,644)**

Source: Lawrence Berkeley National Laboratory. 2021. The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes. Available at: https://escholarship.org/uc/item/0818n68p; Southwest Energy Efficiency Partnership. 2018. Benefits of Heat Pumps for Homes in the Southwest. Available at: https://www.swenergy.org/pubs/one-page-overview-of-heat-pumps-in-the-southwest; RMI. 2018. The Economics of Electrifying Buildings. https://rmi.org/insight/the-economics-of-electrifying-buildings/.

Table 17. Incremental costs of heat pumps (Alternative Case) relative to central air conditioning only (ER Base Case)

Study	Location	Heat pump (Total cost)	Central AC (Total cost)	Heat pump (Incremental cost)
LBNL 2021	National	$8,207	$5,930	$3,182
SWEEP 2018	Reno	$8,200	$5,500	$2,700
RMI 2018	Oakland	$8,641	$7,507	$1,134
Average		**$8,349**	**$6,011**	**$2,339**

Source: LBNL. 2021; SWEEP. 2018; and RMI. 2018.

Table 18. Incremental costs of HPWH (Alternative Case) relative to gas tank WH (Mixed-Fuel Base Case)

Study	Location	HPWH (Total cost)	Gas Tank WH (Total cost)	HPWH (Incremental cost)
LBNL 2021	National	$2,242	$1,972	$270
SWEEP 2018	Southwest	$2,300	$1,640	$660
RMI 2018	Oakland	$2,416	$1,426	$990
Average		**$2,319**	**$1,679**	**$640**

Source: LBNL. 2021; SWEEP. 2018; and RMI. 2018.

Using the results of our annual bill savings analyses from the previous sub-section and the average incremental electrification measure costs in Table 16 and Table 18 presented above, we estimated payback years for a heat pump and a HPWH relative to the two base cases. Table 19 presents our payback analysis relative to the Mixed-Fuel Base Case. For this end-use by end-use analysis, we used the results for bills savings without eliminating the customer charge. This reflects the customer economics of incremental changes in equipment, rather than full electrification. The additional customer charge savings from full electrification would make electrification more attractive to households.

As discussed above, our analysis found that the cost of a heat pump is on average less than the cost of a new gas furnace and a new central air conditioner combined. Thus, we conclude that residential customers in Portland and Bend areas can potentially save money from the first year with the installation of a heat pump if their base case scenario is a new gas furnace and a new central air conditioner. On the other hand, we found that the cost premium of a HPWH is about $640 relative to a standard gas tank water heater. With the annual bill savings we expect from a HPWH, it takes 13 years for a household in Portland and 9 years for a household in Bend to recoup the cost premium. Given the measure life of a storage water heater including HPWH is about 10 years (although they could in actuality last over 13 years)[45] choosing an HPWH may not be as economical a choice as a standalone measure in Portland; however, an HPWH could be economical in conjunction with all electric appliances in a home to remove customer charges and speed up payback time. On the other hand, a household in Bend is likely to recoup the cost premium in 9 years, before the end of the system's life, and see net lifetime savings.

Table 19. Payback analysis of heat pumps and HWPH relative to the Mixed-Fuel Base Case

	Portland	Bend
Heat pump for space heating		
Annual average bill savings	$42	$82
Average incremental cost	same or less	same or less
Payback (years)	Immediately	Immediately
HPWH		
Annual bill savings	$51	$70
Average incremental cost	$640	$640
Payback (years)	12.7	9.2

Table 20 presents our payback analysis of the full electrification scenario in the two cities based on the Alternative Case relative to the Mixed-Fuel Base Case. Average payback estimates are shortened in this scenario, ranging from 3 years in Bend to 4 years in Portland, due to the additional customer charge savings from full electrification. The incremental cost in this scenario includes the incremental cost of a

[45] RTF assumes HPWHs and gas storage WHs last for 13 years. See RTF's analysis files for the measure life data at https://rtf.nwcouncil.org/measure/hpwh/ and https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/.

heat pump and an HPWH. While the calculation of the incremental cost does not include the incremental cost of electric cooktops and standard electric dryers, their prices are very comparable to standard gas systems based on products available in the market. Thus, we consider that our estimate of the incremental cost is appropriate for the analysis of full electrification where electrical system upgrades are not necessary. See the following section for a discussion of the impact of electrical system upgrades.

Table 20. Payback analysis of the Alternative Case (full electrification) relative to the Mixed-Fuel Base Case

	Portland	**Bend**
Annual bill savings	$161	$192
Average incremental cost	$640	$640
Payback (years)	4.0	3.3

Table 21 presents our payback analysis relative to the ER Base Case based on our analysis of annual bill savings in the previous sub-section and our estimate of the incremental measure costs in Table 17 and Table 18. Our analysis found the payback years for both a heat pump and for an HPWH are very short, at about 2 years relative to the ER Base Case in both cities. This is primarily because the cost of operating an electric resistance space heating system and an electric resistance water heater is very expensive and efficient heat pump technologies will allow households to save a substantial amount money each year. The incremental cost for a heat pump was estimated against the cost of a central air conditioner. Even if we take the entire installed cost of a heat pump as the incremental cost (for example if the home would not otherwise have cooling), we estimate that the payback years would be 6 to 8 years.

Table 21. Payback analysis of space heating and water heating electrification measures relative to the ER Base Case

	Portland	**Bend**
Heat pump		
Annual bill savings	($1,067)	($1,318)
Average incremental cost	$2,339	$2,339
Payback (years)	2.2	1.8
HPWH		
Annual bill savings	($218)	($197)
Average incremental cost	$640	$640
Payback (years)	2.9	3.2

Note: we assume the cost of an electric resistance water heater is similar to the cost of a gas tank water heater for estimating the cost premium for a HPWH in this table.

5.4. Important Factors Not Reflected in Customer Payback Analysis

Our analysis of the incremental costs and payback did not assume any potential cost of electric panel upgrades for a household. Not all households require electric panel upgrades to accommodate the heat pumps we analyzed here. For example, many of the residential buildings in Oregon already have enough capacity to use electric resistance space and water heating systems. For such buildings, the use of heat pump technologies could free up the electrical capacity in the buildings, which may allow the installation of a fast EV charging system at home without any panel upgrade. In addition, new homes have high electrical capacity and thus may not require any major update to their electrical systems to accommodate building electrification measures. On the other hand, old homes that are currently using fossil fuels for space and water heating may not have enough electrical capacity to fully electrify all of the end-uses. According to the online source HomeAdvisor, the cost of electrical panel upgrades typically ranges from $500 to about $2,000.[46] While this could reduce the payback of electrification measures, such upgrade costs could be similar to the average installed cost savings estimate for a heat pump (see Table 16 above). However, the upgrade costs could go beyond $3,000 for some households.[47] On the other hand, manufactures are developing 120 volt-based heat pump products that can be plugged into regular electrical sockets. For example, Rheem is planning to introduce its new 120-volt HPWH in the market in the first half of 2022.[48] In addition, another heat pump company has developed a window unit heat pump with a 120-volt plug and just recently started taking customer orders.[49] These new products will likely help avoid panel upgrades.

Our payback analysis also did not incorporate any potential price changes for gas and electricity in the future. In Section 4, we noted that the two aggressive electrification scenarios are expected to change the costs of gas and electricity systems over time with the expected gas system cost reduction exceeding the electric system cost increases substantially. However, this does not mean that pipeline gas prices will decrease in the future. In fact, we expect that in electrification scenarios gas prices would increase substantially instead. This is because as building electrification progresses, the gas utilities will have to recover the costs of the existing assets from fewer sales and customers over time. On the other hand, we expect that increases in electric prices will be modest in the future as the electric utilities can recover the system cost increases over a growing amount of electric sales. This means that customer payback on future electrification is likely to be more favorable than what we have shown in this section.

Finally, it is also important to note that customers are often influenced by other factors beyond customer payback when making a purchase decision. For example, health concerns may be influencing

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[46] HomeAdvisor. 2022. "How Much Does It Cost To Upgrade Or Replace An Electrical Panel?" Accessed April 22, 2022. Available at: https://www.homeadvisor.com/cost/electrical/upgrade-an-electrical-panel/

[47] Ibid.

[48] See CleanTechnica. 2021. "120 Volt Heat Pump Water Heaters Hit The Market & Make Gas Replacements Even Easier." Available at: https://cleantechnica.com/2021/11/29/120-volt-heat-pump-water-heaters-hit-the-market-make-gas-replacements-even-easier/.

[49] Gradient. Available at: https://www.gradientcomfort.com/pages/products-air-conditioners-120-volts-9000-btu-window-ac.

customers' decisions regarding building electrification. Burning pipeline gas produces a range of pollutants including nitrogen oxides (NO_X), carbon monoxide (CO), methane (CH_4), nitrous oxide (N_2O), and formaldehyde. Recent studies have found negative health impacts (e.g., increased respiratory symptoms, asthma attacks, and hospital admissions in people with asthma) from burning gas in buildings (in particular, from NO_x emissions from indoor gas appliances).[50] Safety risks from gas equipment may also be influencing customer choices. In the United States, local fire departments respond to about 4,200 home fires caused by the ignition of gas per year. The National Fire Protection Association reports that, on average, each year these fires result in $54 million in direct property damage, 140 civilian injuries, and 40 civilian deaths.[51]

Finally, benefits specific to new electric appliances and equipment may also be influencing consumers' decisions. For example, induction cooking offers more precise cooking temperature and faster cook times than gas stoves, as well as easier cleaning and reduced burn risk. In space heating, modern variable speed heat pumps now widely available in the market can provide greater comfort because they offer a steady indoor temperature instead of the wider swings in temperatures characteristic of traditional combustion heating systems.

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[50] See, for example, Seals, B., Krasner, A. 2020. *Health Effects from Gas Stove Pollution*. Rocky Mountain Institute, Physicians for Social Responsibility, Mothers Out Front, and Sierra Club. Available at: https://rmi.org/insight/gas-stoves-pollution-health/.

[51] The National Fire Protection Association. 2018. "Natural Gas and Propane Fires, Explosions and Leaks: Estimates and Incident Descriptions." Available at https://bit.ly/3vCjxLw.

Appendix A. Building End-Use Data for BDC Modeling

Residential

Category	Value	Unit	Sources and notes
Load requirement			
Space heating	36.2 (west), 55.1 (east)	MMBtu/house	Calculated based on Northwest Energy Efficiency Alliance (NEEA)'s Residential Building Stock Assessment (RBSA) (for energy use, fuel and equipment saturation, average system efficiency) (https://neea.org/data/residential-building-stock-assessment) and regional heating degree days (HDD)
Water heating	9.2 (west), 9.7 (east)	MMBtu/house	Average UEF (0.637) estimated based on NEEA RBSA for equipment saturation and California eTRM for UEF (https://www.caetrm.com/measure/SWWH012/02/) as well as the NWPCC Regional Technical Forum (RTF) for usage (https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0)
Cooking	0.42	MMBtu/house	Based on Frontier Energy (2019) Residential Cooktop Performance and Energy Comparison Study (https://cao-94612.s3.amazonaws.com/documents/Induction-Range-Final-Report-July-2019.pdf) and U.S. DOE (2016) Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Equipment: Residential Conventional Cooking Products (https://www.regulations.gov/document/EERE-2014-BT-STD-0005-0052)
Dryer	1.46	MMBtu/house	Based on usage data from EIA Residential Energy Consumption Survey (RECS) and end-use efficiency ratings as shown below in this table.
Efficiency			
Space heating (gas)	82 to 90, differ by year	AFUE	BDC's default value based on U.S. Department of Energy's Appliance and Equipment Standards Rulemakings and Notices studies
Space heating (electric resistance)	1	COP	
Space heating (HP)	n/a	COP	Estimated based on typical meteorological year (TMY) weather data and field measured COP data, projected based on NREL's 2017 Electrification Futures Study (EFS): End-Use Electric Technology Cost and Performance Projections through 2050. See the sources and detailed methodology in Section 3.2.
Water heating (gas)	0.637	UEF	Based on water heating system share from RBSA and base efficiency ratings from California eTRM (https://www.caetrm.com/measures/)
Water heating (HPWH)	n/a	COP	Ecotope/NRDC HPWH study (https://www.nrdc.org/experts/pierre-delforge/very-cool-heat-pump-water-heaters-save-energy-and-money), adjusted for technology improvements, and projected based on NREL's 2017EFS. See the sources and detailed methodology in Section 3.2.
Cooking (electric, cooktop)	85% (induction), 67% (electric resistance)	% of output	Frontier Energy (2019) Residential Cooktop Performance and Energy Comparison Study; U.S. DOE (2016) Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Equipment: Residential Conventional Cooking Products (ER)

Category	Value	Unit	Sources and notes
Cooking (electric, oven)	29%	% of output	Derived based on U.S. DOE (2016)
Cooking (gas, cooktop)	27.2%	% of output	Derived based on U.S. DOE (2016)
Cooking (gas, oven)	22.4%	% of output	U.S. DOE (2016)
Dryer (electric)	67%	% of output	Bendt, P. 2010. Are We Missing Energy Savings in Clothes Dryers? (https://www.aceee.org/files/proceedings/2010/data/papers/2206.pdf); 3.73 CEF (lbs/kWh) federal minimum efficiency
Dryer (HP)	87% [60% + (45%*60%)]	% of output	Average CEF of 6 based on EnergyStar products; 45% more efficient than gas units (3.3 minimum CEF)
Dryer (gas)	60%	% of output	Bendt, P. 2010. Are We Missing Energy Savings in Clothes Dryers?

Commercial

Category	Value	Unit	Sources and notes
Load requirement			
Space heating	34 (west), 52 (east)	kBtu/ sf	Based on EIA's Commercial Building Energy Consumption Survey (CBECS) (derive space heating usage per HDD per SF)
Water heating and cooking	8.3	kBtu/sf	Based on CBECS and end-use efficiency ratings as shown below in this table
Cooking	1.7	kBtu/sf	Based on CBECS and end-use efficiency ratings as shown below in this table
Efficiency			
Space heating (HP)	East and west, varies by year	COP	Estimated based on TMY and actual COP data, with some adjustments for higher performance for commercial systems, projected based on NREL's 2017 EFS. See the sources and detailed methodology in Section 3.2.
Water heating (HPWH)	Statewide, varies by year	COP	Ecotope/NRDC HPWH study, adjusted for technology improvements, and projected based on NREL's 2017 Electrification Futures Study. See the sources and detailed methodology in Section 3.2.
Water heating (gas)	0.8	Thermal Efficiency	Based on system saturation rates from NEEA CBSA and efficiency ratings from California eTRM (https://www.caetrm.com/measures/)
Cooking	Same as residential	% of output	

Appendix B. Efficiency Ratings for the Bill Impact Analysis

	Unit	Rating	Sources and notes
Base Case			
Gas furnace (existing)	AFUE	81.0%	NEEA RBSA, Table 47 A 6.4% performance degradation factor is applied based on DOE (2015). Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life
Gas furnace (new)	AFUE	82.0%	AFUE for a baseline measure from: RTF's analysis "Residential Gas Furnaces v1.1", https://rtf.nwcouncil.org/measure/residential-gas-furnaces/; A 6.4% performance degradation factor is applied based on DOE (2015).
Central air conditioner	SEER	14.2	Baseline value defined by RTF's AC analysis "Res Efficient Central Air Conditioners v1.0"
Gas tank water heater	UEF	0.58	Assuming a 40-gallon system, medium draw using "0.6483 − (0.0017 × Vr)" based on federal standards. (https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32#p-430.32(d))
Gas dryer	CEF	3.3	Federal minimum efficiency
Gas cooking stove	% of output	27%	Derived from: U.S. DOE. 2016. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial and Industrial Equipment: Residential Conventional Cooking Products
Alternative Case			
Ducted heat pump (heating)	COP	vary by temp	Center for Energy and Environment. 2018. "Cold-Climate Air-Source Heat Pumps" (http://www.duluthenergydesign.com/Content/Documents/GeneralInfo/PresentationMaterials/2018/Day1/ccASHPs.pdf)
Ducted heat pump (cooling)	SEER	18	SEER for an efficient ducted heat pump available in the market
Heat pump water heater	COP	2.67	Average COP for Oregon based on (a) NRDC. 2016. "NRDC/Ecotope Heat Pump Water Heater Performance Data." Available at: https://www.nrdc.org/experts/pierre-delforge/very-cool-heat-pump-water-heaters-save-energy-and-money, and (b) our adjustment for performance improvements based on the difference in COP between the currently available products and the assumed COP (3.25) of the old model in the study. (https://www.nrdc.org/resources/nrdc-ecotope-heat-pump-water-heater-performance-data)
Electric dryer	CEF	3.73	Federal minimum standard
Induction cooking cooktop	% of output	85%	Frontier Energy. 2019. Residential Cooktop Performance and Energy Comparison Study. (https://cao-94612.s3.amazonaws.com/documents/Induction-Range-Final-Report-July-2019.pdf)

Notes: AFUE = Annual Fuel Utilization Efficiency; UEF = Uniform Energy Factor; CEF = Combined Energy Factor; SEER = Seasonal Energy Efficiency Rating; COP = Coefficient of Performance.

Appendix C. Energy Impact Results

Table 22. Energy results for the Mixed-Fuels Base Case and for the Alternative Case (efficient electric): Portland

Component	Mixed-Fuels Base Case	Alternative Case (Efficient electric)	Savings
Gas (Therms)			
Space Heating	623	-	623
Water Heating	156	-	156
Cooking	17	-	17
Dryer	21	-	21
Gas Subtotal	*817*	-	*(817)*
Electric (kWh)			
HVAC Fan	481	-	481
Space Heating	-	-	(5,858)
Water Heating	-	998	(998)
Cooking	-	156	(156)
Dryer	-	539	(539)
AC	611	482	129
Interior Lighting	489	489	-
Exterior Lighting	224	224	-
App	1,554	1,554	-
Misc	-	-	-
Electric Subtotal	***3,359***	***10,300***	***6,941***

Table 23. Energy results for the ER Base Case and for the Alternative Case (efficient electric): Portland

Component	Base (ER)	Alternative case (Efficient electric)	Savings
Gas (Therms)			
Space Heating	-	-	-
Water Heating	-	-	-
Cooking	-	-	-
Dryer	-	-	-
Gas Subtotal	-	-	-
Electric (kWh)			
HVAC Fan			-
Space Heating	15,002	5,858	(9,144)
Water Heating	2,883	998	(1,885)
Cooking	197	156	(41)
Dryer	539	539	-
AC	611	482	(129)
Interior Lighting	489	489	-
Exterior Lighting	224	224	-
App	1,554	1,554	-
Misc	-	-	-
Electric Subtotal	***21,499***	***10,300***	***(11,199)***

Table 24. Energy results for the Mixed-Fuels Base Case and for the Alternative Case (efficient electric): Bend

Component	Base (Mixed Fuels)	Alternative (Efficient Electric)	Savings
Gas (Therms)			
Space Heating	949	-	949
Water Heating	165	-	165
Cooking	17	-	17
Dryer	21	-	21
Gas Subtotal	***1,151***	***-***	***(1,151)***
Electric (kWh)			
HVAC Fan	733	-	733
Space Heating	-	-	(10,034)
Water Heating	-	1,049	(1,049)
Cooking	-	156	(156)
Dryer	-	539	(539)
AC	262	207	55
Interior Lighting	489	489	-
Exterior Lighting	224	224	-
App	1,554	1,554	-
Misc	-	-	-
Electric Subtotal	***3,262***	***14,252***	***10,990***

Table 25. Energy results for the ER Base Case and for the Alternative Case (efficient electric): Bend

Component	Base (ER)	Alternative	Savings
Gas (Therms)			
Space Heating	-	-	-
Water Heating	-	-	-
Cooking	-	-	-
Dryer	-	-	-
Gas Subtotal	***-***	***-***	***-***
Electric (kWh)			
HVAC Fan			-
Space Heating	22,840	10,034	(12,806)
Water Heating	3,032	1,049	(1,983)
Cooking	197	156	(41)
Dryer	539	539	-
AC	262	207	(55)
Interior Lighting	489	489	-
Exterior Lighting	224	224	-
App	1,554	1,554	-
Misc	-	-	-
Electric Subtotal	***29,138***	***14,252***	***(14,885)***