Joint Task Force on Resilient Efficient Buildings

Report on Modeling of Policies

Draft

November 21, 2022

Disclaimer

This analysis has been undertaken to identify and evaluate policies related to building codes and building decarbonization for new and existing buildings and to support policy recommendations by the Joint Task Force on Resilient Efficient Buildings created by Senate Bill 1518 (2022).

Reasonable skill, care and diligence have been exercised to assess the information provided for this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains and the information and basis on which it relies, is subject to changes that are beyond the control of the authors. The information provided by others is believed to be accurate, but has not been verified.

This analysis includes high-level estimates of costs that should not be relied upon for policy implementation or other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

This analysis applies to the State of Oregon and cannot be applied to other jurisdictions without analysis. Any use by the State, project partners, consultants or any third party, or any reliance on or decisions based on this document, are the responsibility of the user or third party.

Acknowledgements

The Joint Task Force on Resilient Efficient Buildings

Senator Kate Lieber, Co-Chair
Representative Pam Marsh, Co-Chair
Senator Lynn Findley
Representative Mark Owens
Neil Baunsgard
Andrew Beyer
Alex Boetzel
Don Bohn
Anjeanette Brown
Ashley Buchanan
Meredith Connolly
Ernesto Fonseca
Chris Forney
Elliott Gall
Mike Goodrich
Jay Hansen
David Heslam
Bob Jenks
Scott Linfesty
Jeff McGillivray
Tricia Mooney
Kim Rush
Jairaj Singh
Eli Spevak
Matt Tidwell
Lucy Vinis
Bob Westerman

Project Coordination

Legislative Policy and Research Office
Erin Pischke
Beth Reiley
Laura Wolton

Project Consultants

Sustainability Solutions Group
Deryn Crockett
Yuill Herbert
Kayla Rakes
Bas Straatman
Carol Fraser
Chris Strashok
Marcus Williams

Advisory/Data

Oregon Global Warming Commission
Cathy Macdonald, Chair

Oregon State Agencies
Alan Zelenka, ODOE
Amanda Ingmire, DEQ
Gabriela Goldfarb, OHA
Cynthia Branger-Munoz, OHA

Energy Trust of Oregon
Hannah Cruz
Jay Ward
Spencer Moersfelder
Jackie Goss

Terms and Abbreviations

BAP	Business as Planned
BAU	Business as Usual
CDD	Cooling degree days
COBRA	CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool
CPP	Climate Protection Program
ESS	Energy Systems Simulator
GDP	Gross domestic product
GHG	Greenhouse gas
HB 2021	House Bill 2021
HDD	Heating degree days
IRA	Inflation Reduction Act
kWh	Kilowatt hour
$MtCO_2e$	Metric ton of CO_2 equivalent
MW	Megawatt
MWh	Megawatt hour
NREL	National Renewable Energy Laboratory
NG	Natural gas
PV	Photovoltaic

RNG	Renewable natural gas
Roadmap to 2035	Oregon Global Warming Commission's Greenhouse Gas Reduction Plan
SCC	Social cost of carbon
sqft	Square feet (ft^2)
tCO_2e	Tonnes carbon dioxide equivalent

Notes and limitations

The modeling described in this report uses an integrated, multi-fuel, multi-sector, energy systems, emissions and finance model designed specifically for projects of this nature, the Energy Systems Simulator (ESS). ESS was previously populated with Oregon-specific data and calibrated for Oregon as part of the Oregon Global Warming Commission's Roadmap to 2035. In this project, ESS was used to support Task Force's analysis, specifically, to:

- Evaluate policies related to building codes and building decarbonization for new and existing buildings;
- Assess the impact of these policies on additional benefits, such as increasing energy efficiency, improving resilience against climate change, improving public health and air quality, reducing the percentage of household income that goes toward energy costs and mitigating displacement and toward mitigating other impacts that result from wildfires, heat waves and other climate change events; and
- Assess costs, savings and benefits of policies relating to upfront and longer-term economic, environmental, climate and health costs, savings and benefits, along with lifecycle emissions and the social cost of carbon.

The analysis undertaken in this study does not:

- Evaluate the impact of the policies on market costs of housing or the State's GDP;
- Evaluate the costs of climate change, and its associated impacts on the State's building stock;
- Assess opportunities for demand response in the building stock;
- Assess GHG emissions from refrigerants (e.g., refrigerant leakage).
- Recommend a specific scenario or pathway; and
- Assess the details of the implementation of other State policies or regulations.

Executive Summary

This report describes what might happen to energy and GHG emissions, as well as additional benefits, if different building policies achieve different targets or objectives in Oregon.

An Energy Systems Model

Modeling is a powerful tool to explore cause and effect of complex systems, such as current and future energy consumption and GHG emissions from residential and commercial buildings. The Energy Systems Simulator (ESS), which was used for this project, is a model designed specifically for exploring these types of questions.

Local Data

ESS has been populated with data specific to Oregon and calibrated to observed energy consumption for each County, to ensure a detailed representation of energy and emissions from residential and commercial buildings.

Guidance from the Task Force

The Task Force identified 25 policy concepts, which was further narrowed to a total of nine policies. Upon assessment by SSG, six of these could be modeled in ESS.

1. Building performance standards
2. Promote, incentivize, and/or subsidize energy efficiency and heating/cooling efficiency increases
3. Decarbonize institutional/public buildings
4. Promote, incentivize, and/or subsidize heat pumps
5. Assess and disclose material-related emissions
6. Enact energy-efficient building codes

SSG used scenarios as an approach to assess the impact of the policy concepts, where a scenario is a description of a possible future, but not necessarily the desired or even likely outcome.

The Task Force decided to model high and low ambition implementations of each policy concept, which were evaluated as individual scenarios. These scenarios were then combined into five integrated scenarios, which capture the interplay between different policy concepts.

Each scenario was evaluated in the model for its impact on GHG emissions, energy and additional benefits including household energy costs, abatement costs, air pollution, employment, resilience and the social cost of carbon. The impact of the five integrated scenarios on hourly electricity demand was also evaluated.

Findings

1. **Many of the policies are “no regrets”:** Most of the policies generate net financial savings.

2. **Household energy costs are reduced:** Relative to 2019, policies decrease household costs by between 2.6% and 37% by 2050, using conservative projections on energy costs.

3. **Several policies and all integrated scenarios can achieve the GHG target:** The building performance policies and the heat pump policies achieve Oregon's GHG target. All five integrated scenarios achieve Oregon's GHG target.

4. **Capital costs of the more ambitious policies are less than 1% of Oregon's GDP:** The most ambitious form of Policy 2 requires average annual capital investments of approximately $2 billion, 0.74% of Oregon's GDP.

5. **Embodied carbon is the largest opportunity for emissions reductions:** The most ambitious form of Policy 5 results in average annual reductions of 3.3 million $MtCO_2e$. Embodied emissions are accounted for differently than operational emissions, so these reductions don't directly contribute to achieving Oregon's GHG target.

6. **Electricity demand will increase in the BAP scenario:** Population growth increases electricity demand from the residential and commercial sectors in the absence of any policies considered by the Task Force.

7. **The policies reduce electricity demand from residential and commercial buildings:** Compounding efficiency benefits limit the impact of heat pumps on peak demand in the winter. For example, a poorly insulated house with baseboard heating that gets retrofitted (50% thermal reduction) and that gets a heat pump will need only 1/6 of the electricity from before. Further, Oregon has a reservoir of "free" electricity that is currently consumed by electric baseboard heating from which to heat additional existing or new buildings.

8. **The financial results are sensitive to energy costs:** The results are sensitive to energy costs. For example, the analysis assumes a 2022 cost of $13.48/MMBTU for natural gas, while the cost in August, 2022 was $18.98/MMTBU, a 41% increase. Increases in natural gas costs will increase the financial benefits of those scenarios which increase adoption of heat pumps. Similarly, increases in electricity costs will decrease the financial benefit of these scenarios.

9. **The policies reduce the implementation risks for HB 2021 and CPP:** By reducing electricity demand and GHG emissions from natural gas, the policies reduce the burden for utilities to achieve their respective targets/caps.

10. **Retrofits are more expensive but reduce electricity demand:** Deep energy retrofits are capital intensive but are instrumental in reducing peak demand, and the economic value of the avoided demand, and resulting avoided electricity generation capacity, is not included in this analysis.

11. **Retrofits provide co-benefits:** Building retrofits provide the most jobs (policy 2c and 2d) and increase the resilience of homes. They also result in public health benefits.

12. **Combining policies result in compounding benefits**: The abatement cost of the most ambitious retrofit policy (2c) is $560/MtCO2e. When combined with the most ambitious heat pump policy, which has an abatement cost of -$130/MtCO2e, the combined abatement cost is $42/MtCO2e.

13. **Highest and best use:** RNG is used in the Building Performance Standard, alongside heat pumps. Given RNG availability is constrained, it makes sense to preserve this fuel for activities which require combustion, such as industrial applications.

14. **The social cost of carbon:** Avoided damage from climate change as a result of the policies ranges from -$4 million per year to -$255 million per year. New estimates of the Social Cost of Carbon would increase these numbers by a factor of four.

15. **Policies need targets:** Policies can take many flavors, with different outcomes for energy, emissions and additional benefits. Targets, and parameters, such as which component of the building stock is applicable, are necessary in order to achieve those targets.

16. **The scenarios are guideposts, not prescriptions.** None of the scenarios may be the preferred pathway, but they provide directional guidance on what would happen if a policy achieves a particular outcome.

1. Introduction

In 2022, the Oregon State Legislature enacted Senate Bill 1518 which established the Resilient Efficient Buildings Task Force ("Task Force"). Senate Bill 1518 directed the Task Force to identify and evaluate policies related to building codes and building decarbonization for new and existing buildings that would enable the state to meet its greenhouse gas(GHG) emissions reduction goals while maximizing additional benefits. The legislation also directed the Task Force to consider the costs, savings, and benefits of recommended policies as related to residential, commercial, and industrial buildings. Senate Bill 1518 directed the Task Force to make policy recommendations to the interim committees of the Legislative Assembly before the 2023 regular session.

2. Method

2.1 Modeling Approach

SSG employed the Energy Systems Simulator (ESS), a model that has been calibrated and populated with current and future climate policies and initiatives for the State of Oregon. ESS uses bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels and energy consuming technology stocks (vehicles, appliances, dwellings, buildings, industry, etc.). For this project, the analysis focuses specifically on the residential and commercial building stock.

ESS applies a physical economy approach to provide coherent scenarios that explore the long-term impacts of ongoing energy transitions. To measure energy costs and GHG emissions, ESS traces the flows and transformations of energy from sources (e.g. power plants, PV solar) through energy currencies (e.g., electricity, hydrogen), to end uses (e.g., space heating). An energy balance is achieved by accounting for efficiencies, conservation rates, and trades and losses at each stage in the journey from source to end use. ESS is used to analyze energy and emissions associated with customized policies over time and includes modeled financial information which can inform budgetary decision-making related to energy and emissions actions.

ESS is calibrated using observed datasets, while future projections are driven by population change and employment growth. Strengths of this modeling approach are as follows:

- Bottom-up: ESS tracks physical stocks of GHG using equipment (dwellings, offices etc.), how these stocks are used, and, therefore, how GHG emissions are produced. These stocks evolve as the population grows or the economy expands. This level of detail allows us to evaluate the impacts of programs at a high sectoral and geographical resolution, assuming that the stocks can be located in a physical space.
- Geography: ESS can report on impacts both at the state level and at the sub-geographies level (i.e. county)
- Transformation: While systems dynamics models are constrained by physical systems (i.e., the turnover of housing stocks), this modeling approach is not limited to cost constraints.

This flexibility is critical for evaluating transformative change in the energy system which requires departures from historical patterns, or historically derived coefficients.

- Transparency: The modeling logic and assumptions are extensively defined and documented in the modeling tool, which can be freely accessed. Further, it is standard practice for the team to document the method and assumptions in a Data, Methods, and Assumptions Manual (Appendix 4).
- Economic impacts: ESS calculates marginal abatement costs for each program or action and evaluates economic indicators, such as operating and capital impacts.
- Public health outcomes: ESS tracks air pollutants which can be translated into health costs or avoided health costs.

Over the course of the project, Task Force members made specific requests, and the modeling approach evolved accordingly to address these requests where possible. These requests, and the responses by the modeling team are included in Appendix 3.

2.2 The Context

SSG recently developed a fully calibrated, multi-sector model for the Oregon Global Warming Commission's Greenhouse Gas Reduction Plan ("Roadmap to 2035"), which was applied to this project.

2.2.1 Population, Employment and Households

Population is projected to increase from 4.2 million in 2020 to 5.4 million people in 2050,[1] an average annual growth rate of 0.8%. The number of households increases from 1.65 to 2.1 million and employment increases from 2.1 to 2.6 million.

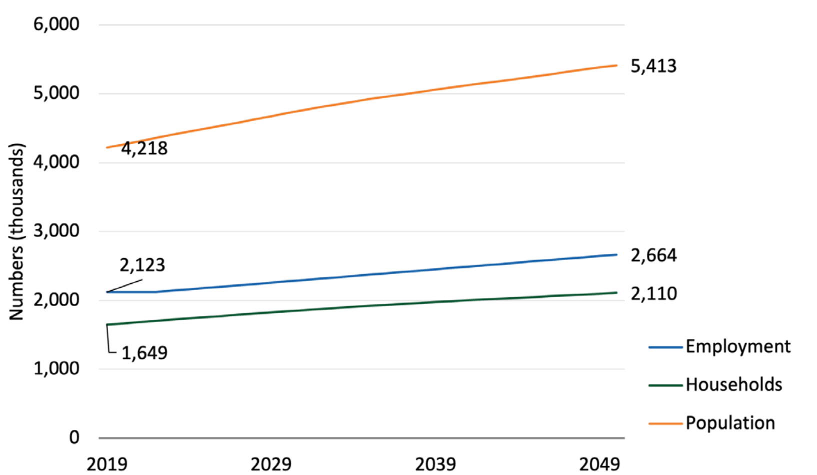


Figure 1. Trends in population, households and employment for the State of Oregon

[1] Population Research Center (2021). Population Forecasts by County. Retrieved from: https://www.pdx.edu/population-research/population-forecasts

The increase in population and employment results in new homes and commercial space respectively. Residential floor space grows by nearly 1 billion square feet, while non residential floor space grows by 255 million square feet. The breakdown between existing and new buildings is an important consideration in the design of targeted policies.

Table 1. Current and future growth of residential and non-residential floor space between 2019 and 2050

	Residential Floorspace (million sqft)	**Non Residential Floorspace (million sqft)**
Existing (2019)	2,930	2,120
New (by 2050)	970	255
Total (by 2050)	**3,900**	**2,375**
% change	*133%*	*112%*

2.1.2 Spatial Distribution

ESS tracks buildings, energy and emissions by County in Oregon, and is able to capture dynamics such as different building types and characteristics, and climatic conditions for different geographies in Oregon, as illustrated in Figures 2-5.

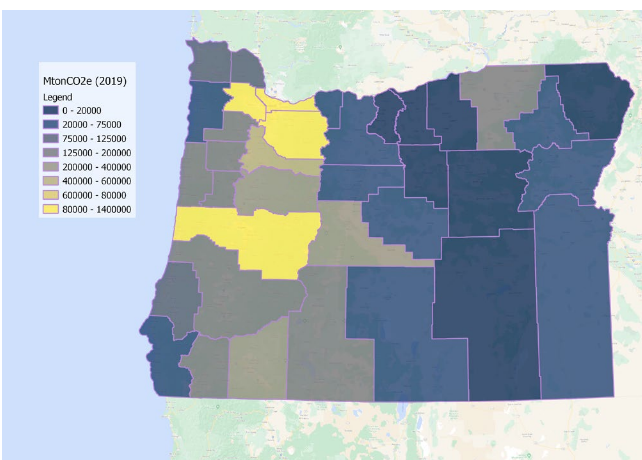


Figure 2. GHG emissions from residential buildings by County, 2019

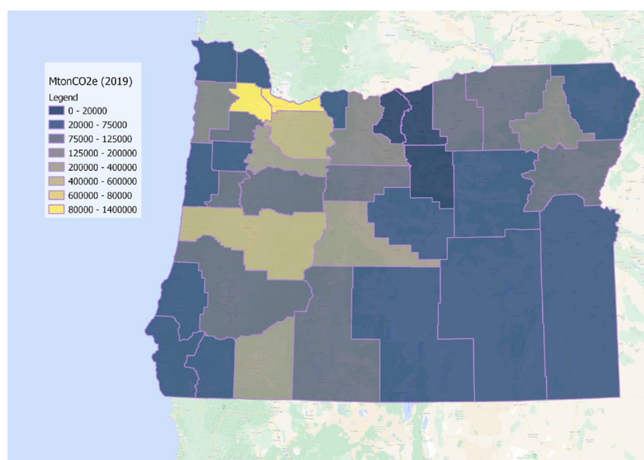


Figure 3. GHG emissions from commercial buildings by County, 2019

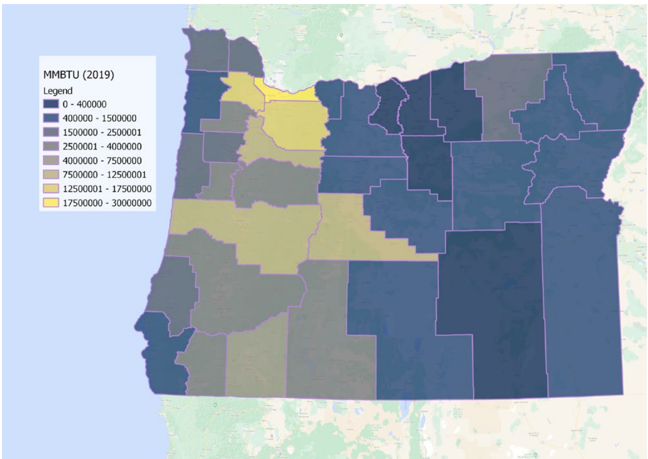


Figure 4. Energy consumption from residential buildings by County, 2019

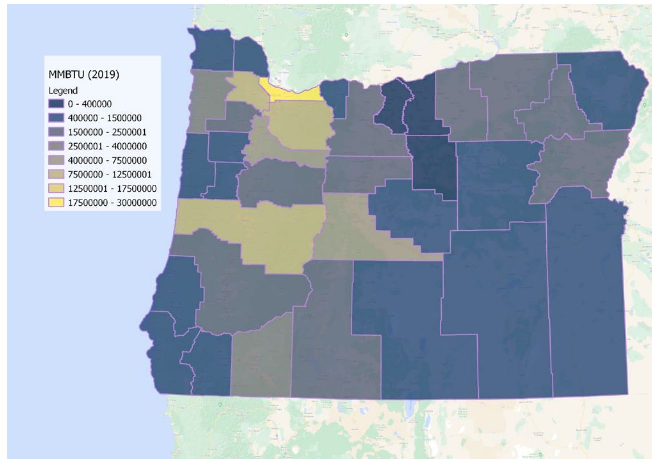


Figure 5. Energy consumption from commercial buildings by County, 2019

2.2.2 Reference Scenarios

Two scenarios were developed as part of the Roadmap to 2035 analysis. A Business as Usual (BAU) scenario illustrates the impact of population and employment growth on energy and emissions, without any additional policies. A Business as Planned (BAP) scenario includes policies that are in rule, funded, and/or legislatively required as well as market trends.

Table 1. BAU and BAP Scenarios

BAU Assumptions	**BAP Assumptions**
• Population growth • Employment growth • Transportation fuel standards • Heating and cooling degree days	• BAU Assumptions • HB 2021 • Climate Protection Program (CPP) • Clean Fuels Standard • Increased EV Light-Duty Sales • Advanced Clean Trucks • Energy Efficiency Standards for Appliances • Manufactured Home Replacement • Solar + Storage Rebate Program • Heat Pump Rebate Programs • Community Renewable Energy Program • Healthy Homes Repair Fund

Box #1: HB 2021 and CPP

House Bill 2021 (HB 2021) requires retail electricity providers to reduce greenhouse gas emissions associated with electricity sold to Oregon consumers to 80 percent below baseline emissions levels by 2030, 90 percent below baseline emissions levels by 2035 and 100 percent below baseline emissions levels by 2040.

The Climate Protection Program (CPP) sets a declining limit, or cap, on greenhouse gas emissions from fossil fuels used throughout Oregon, including diesel, gasoline, natural gas and propane, used in transportation, residential, commercial and industrial settings.

An economy-wide analysis found that GHG energy consumption declines by 30% in the BAP relative to the BAU by 2050 on a per capita basis (Figure 6), and that GHG emissions decline by 75% by 2050 also on a per capita basis (Figure 7).

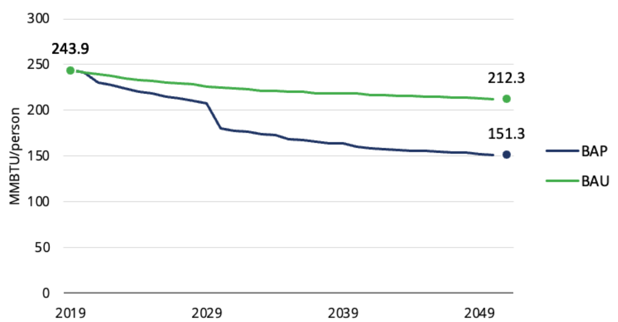


Figure 6. Per capita energy consumption for BAP and BAU scenarios, all energy sources

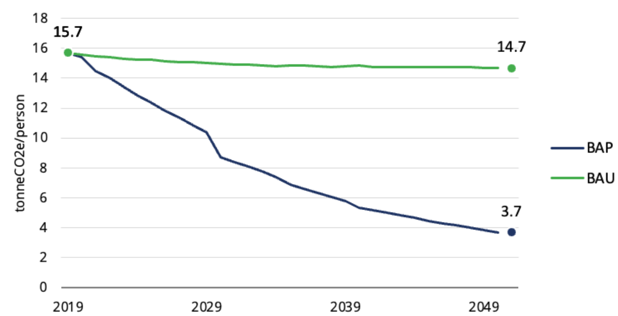


Figure 7. Per capita GHG emissions for BAP and BAU scenarios, all emissions sources

2.2.3 GHG Emissions and Energy in the Reference Scenario

Zeroing in on the buildings sector, energy consumption follows a similar trajectory in the BAU and BAP scenarios (Figure 8 and 9) but GHG emissions decline precipitously as a result of HB 2021, which reduces emissions from electricity, and CPP, which reduces emissions from natural gas consumption (Figures 10 and 11).

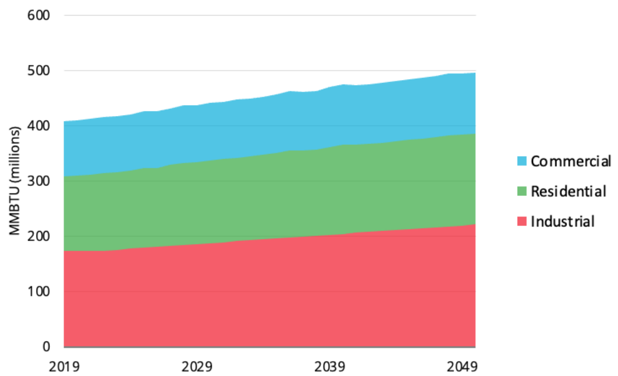


Figure 8. Annual energy consumption from buildings, BAU scenario, by sector

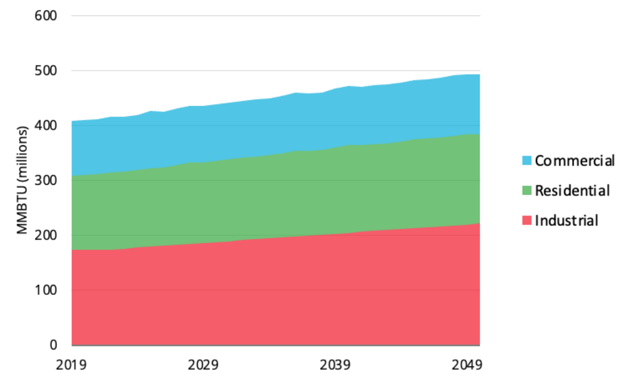


Figure 9. Annual energy consumption from buildings, BAP scenario, by sector

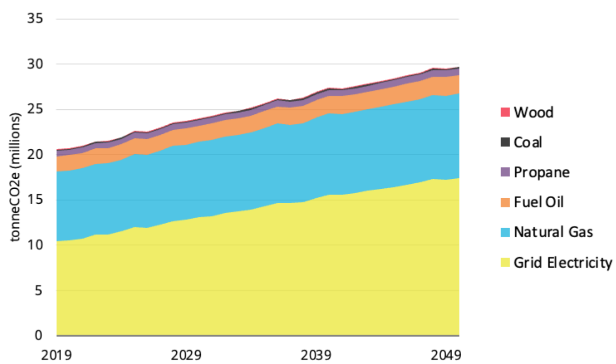


Figure 10. Annual GHG emissions from buildings, BAU scenario, by fuel

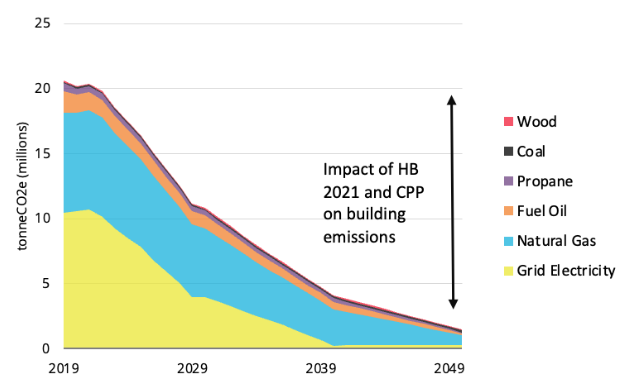


Figure 11. Annual GHG emissions from buildings, BAP scenario, by fuel

HB 2021 was modeled by assuming total GHG emissions from electricity are 80% below baseline emissions levels by 2030, 90% below baseline emissions levels by 2035 and 100% below baseline emissions levels by 2040.[2] CPP was modeled by assuming GHG emissions from fossil fuels would be reduced 50% by 2035 and 90% by 2050. For the purposes of modeling, CPP was implemented as a GHG cap on natural gas, reducing emissions in alignment with the CPP bill. Some policy measures under CPP may actually result in reductions in energy consumption, but these were not specified as there are multiple pathways as to how CPP may be implemented, including by the policies under consideration by the Task Force.

Figure 12 illustrates GHG emissions by end-use in the BAU from buildings. In 2020, major sources are industrial processes (32%), space heating (30%), water heating (15%) and lighting and plug loads with 10% each. Space cooling accounts for 2% while appliances account for 1%. Heat pumps currently constitute 8% of the total. Electricity accounts for 42% of the energy and natural gas accounts for 35% of the total energy consumed (Figure 13). A deeper dive into space heating indicates that 44% of space heating systems are electric resistance heating, roughly equal to the number of natural gas furnaces as illustrated in Figure 14.

---

[2]House Bill 2021, *Relating to clean energy; and prescribing an effective date*, Regular Session, 81st Oregon Legislative Assembly

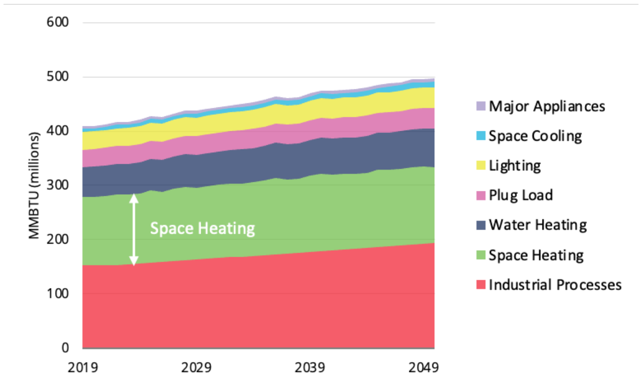


Figure 12. GHG emissions by end-use in the BAU scenario, buildings sector

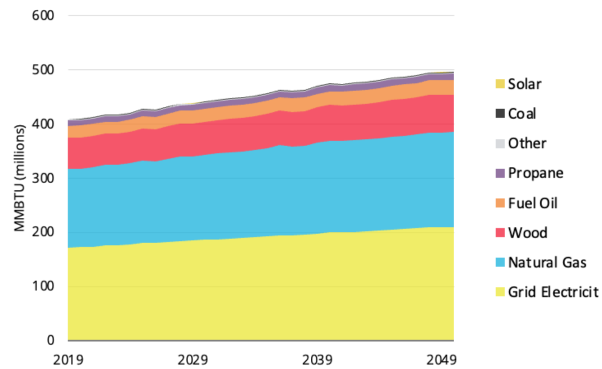


Figure 13. Energy consumption by fuel type in the BAU scenario, , buildings sector

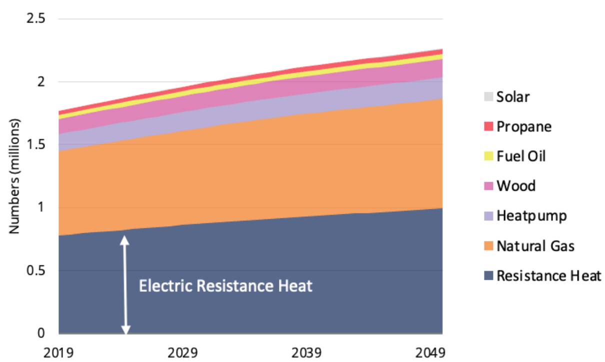


Figure 14. Number of heating systems by type in the BAU scenario, buildings sector

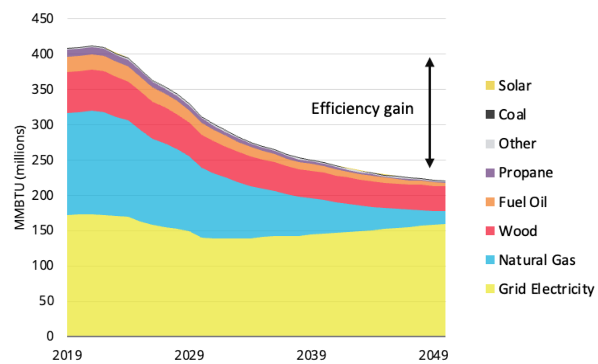


Figure 15. Annual energy consumption in buildings by fuel in the Electrification scenario for the Roadmap to 2035.

Replacing the electric resistance heaters with heat pumps can reduce electricity consumption by ⅓ due to the efficiency of the technology. Extensive building retrofits or weatherization can compound this reduction, as well as reducing consumption of other sources of energy. The opportunity for reductions in electricity consumption can mitigate the impact of electrification of heating and transportation on the existing electrical grid, as is illustrated in the electrification scenario evaluated for Roadmap in Figure 15, which includes both extensive deployment of heat pumps and deep building retrofits.

2.3 Policies

The Task Force identified 25 policy concepts, which was further narrowed to a total of nine policies. Upon assessment by SSG, six of these could be modeled in ESS.

7. Building performance standards
8. Promote, incentivize, and/or subsidize energy efficiency and heating/cooling efficiency increases
9. Decarbonize institutional/public buildings
10. Promote, incentivize, and/or subsidize heat pumps
11. Assess and disclose material-related emissions

12. Enact energy-efficient building codes

The three remaining policies were evaluated qualitatively.

13. Align energy efficiency programs with the State's climate goals
14. Modify Energy Trust of Oregon's mission
15. Promote, incentivize, and/or subsidize air purification systems

2.3.1 Policy Details

SSG used scenarios as an approach to assess the impact of the policy concepts, where a scenario is a description of a possible future, but not necessarily the desired or even likely outcome.

The Task Force used a survey to identify parameters for up to four variations of each policy concept. The parameters specified the scope of the implementation for each policy concept as described in Appendix 1. The Task Force decided to model high and low ambition implementations of each policy concept with variation in respect to which size of commercial buildings were included. For example, the Building Performance Standard was evaluated targeting bookends of a 5% reduction and a 40% reduction in emissions by 2035 below 2035 levels.

Each implementation of the policy concept was modeled as an independent scenario and was evaluated against the BAP scenario.

Box #2: What is a Scenario?

Scenarios are alternative descriptions of different possible futures that help the Task Force consider the implications of these future possibilities for planning and decision making today. Scenarios are not predictions. Rather, they are stories about how the world will or may change at some future time.

A scenario is distinguishable from a vision and forecast in two ways:
a scenario is a possible future – it need not be desirable, thus it is not a vision, and, it need not be likely, thus it is not a forecast; a scenario emphasizes a process of change, not just a point in the future.

Many people assume that the future will closely resemble the present; however, scenarios are not grounded principally in a continuation of past trends or data. Rather, they involve plausible visions of the ways that relevant uncertainties might evolve in the future.

Characteristics of Scenarios

Plausible. The scenario must be believable.
Relevant to the key strategic issues and decisions at hand. If the scenario would not cause a decision-maker to act differently compared to another scenario, there is little use in considering it.

Challenging to today's conventional wisdom. It should make one think about different possibilities and options.
Divergent from each other. Together, the scenarios should "stretch" the thinking about the future environment, so that the decisions take account of a wider range of issues.
Balanced. It is useful to ensure that a group of scenarios strike a good psychological balance between challenges and opportunities, between risks and potential benefits.

2.3.3 Policy Implementation

Policies were modeled using the following assumptions as to how they would be implemented.

Table 2. Policy Implementation

Policy	**Implementation Approach**
1. Building performance standards	A building performance standard requires new and existing buildings to reduce GHG emissions by a specific percent, implemented using a GHG intensity (GHGs/floor area). SSG selected the most cost effective measures from the Roadmap to 2035 analysis in order to achieve the GHG reductions using the order of: heat pumps for both space conditioning and water heating and RNG. RNG potential was limited to 40.5 tBTU in policy 1c and 1d because the availability of RNG is constrained[3] and is therefore best used in industries which require this type of fuel. This policy was applied to residential and commercial buildings.
2. Promote, incentivize, and/or subsidize energy efficiency and heating/cooling efficiency increases	This policy concept stimulates building retrofits to improve the thermal envelope. This policy was applied to residential and commercial buildings.
3. Decarbonize institutional/public buildings	Existing institutional and public buildings are retrofitted while new buildings are constructed to net zero energy performance.
4. Promote, incentivize, and/or subsidize heat pumps	The policy concept stimulates the uptake of air source and ground source heat pumps in new and existing residential and commercial buildings. 30% of new/existing homes or buildings were assumed to maintain natural gas as a backup energy source.

[3] (2019). *Renewable Sources OF Natural Gas: Supply and Emissions Reduction Assessment*. American Gas Foundation. https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-Report-FINAL-12-18-19.pdf

5. Assess and disclose material-related emissions	The policy concept results in decreased embodied emissions in new construction. Annual embodied carbon emissions, opportunities for reductions and associated costs were provided by DEQ, reflecting the impacts of three strategies. The first comprises using environmental product declarations (EPDs) as a tool to measure and disclose material production impacts and set GHG limits over time. There are numerous policy precedents already for this in the US. Examples include California, Colorado, and the Federal General Services Administration (GSA). The second strategy involves measuring and disclosing the whole lifecycle emissions of a building during the design process to employ a broader array of strategies to reduce embodied carbon. The policy precedents for whole building LCA include City of Vancouver BC, and US Federal GSA (buildings). The third strategy includes adaptive reuse of existing buildings. This strategy primarily applies to the reuse and renovation of an existing building as a means to offset a certain percentage of new construction. This policy was applied to new residential and commercial buildings.
6. Enact energy-efficient building codes	Building codes include energy performance requirements for new construction and renovations. An assumption was that between 2%-8% of the existing building stock was renovated each year.

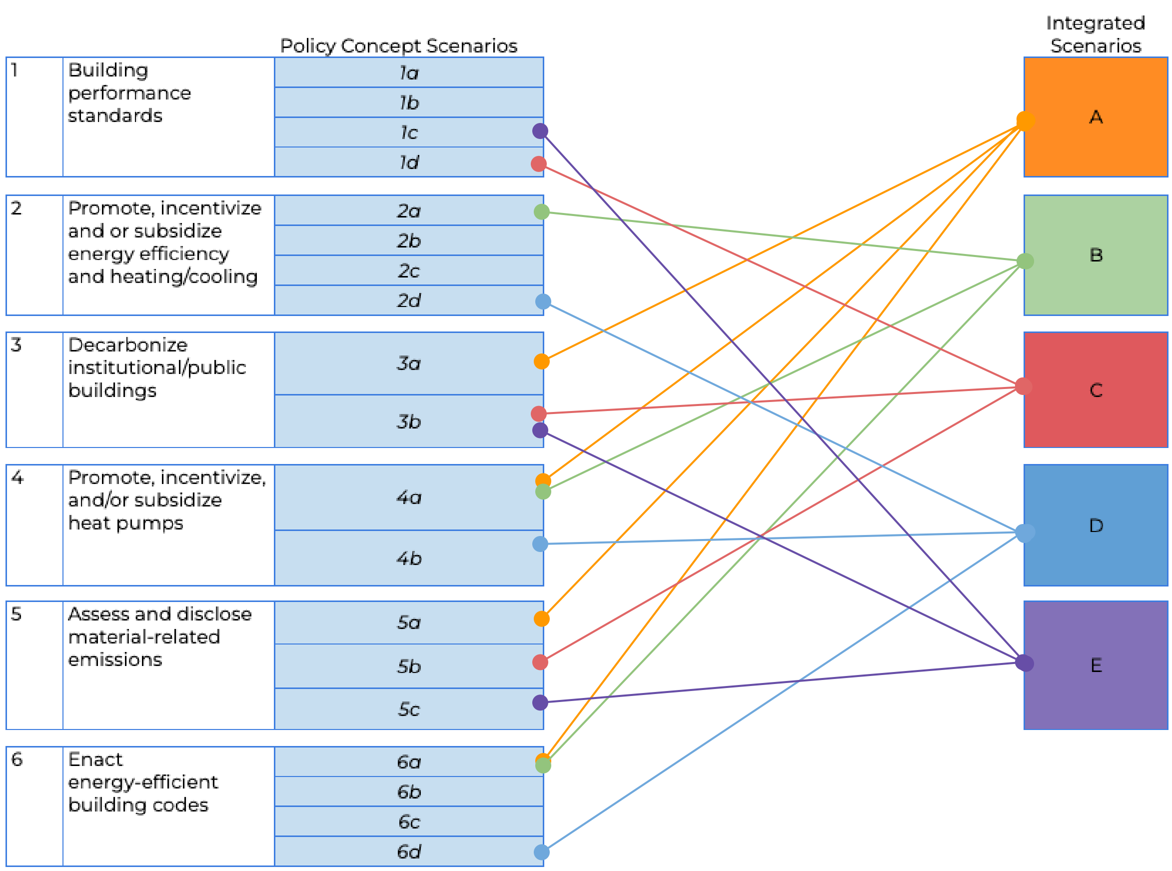
2.3.3 Integrated Scenarios

Individual scenarios were combined into integrated scenarios, which capture the interplay between different policy concepts. For example, building retrofits reduce the demand for energy consumption so that smaller heat pumps can be installed and the operating energy for those heat pumps is lower. Five integrated scenarios were developed in order to evaluate these dynamics, described in Table 4 and illustrated in Figure 16.

Table 3. Integrated scenarios

Name	A	B	C	D	E
Theme	Go slow, focus on large buildings	Medium efficiency, focus on large buildings	Medium GHG reductions, non-prescriptive	Maximum efficiency	Maximum GHG reductions, non-prescriptive

Scenarios	6a. Enact energy-efficient building codes 4a. Promote, incentivize, and/or subsidize heat pumps 3a. Decarbonise public buildings 5a* Assess and disclose material-related emissions	2a. Promote, incentivize and or subsidize energy efficiency and heating/cooling 4a. Promote, incentivize, and/or subsidize heat pumps 6a. Enact energy-efficient building codes	Building Performance Standard 1d Decarbonise public buildings 3b Assess and disclose material-related emissions 5b*	Promote, incentivize and or subsidize energy efficiency and heating/cooling 2d Promote, incentivize, and/or subsidize heat pumps 4b Enact energy-efficient building codes 6d	Building Performance Standard 1c Decarbonise public buildings 3b Assess and disclose material-related emissions 5c*



F*igure 16. Illustration of the policy concept scenarios and the integrated scenarios*

2.3.5 Peak Analysis

Peak electricity demand is generally reduced by policies which increase energy efficiency, and may be increased by adding new en-uses such as heating, cooling and transportation. Impacts on peak demand will be evaluated in the analysis of the integrated scenarios.

In order to assess the impact of the policies on hourly demand of the electricity systems, an 8760 hour electricity demand model was integrated with the ESS model developed for Oregon. The integrated scenarios were tested in this model.

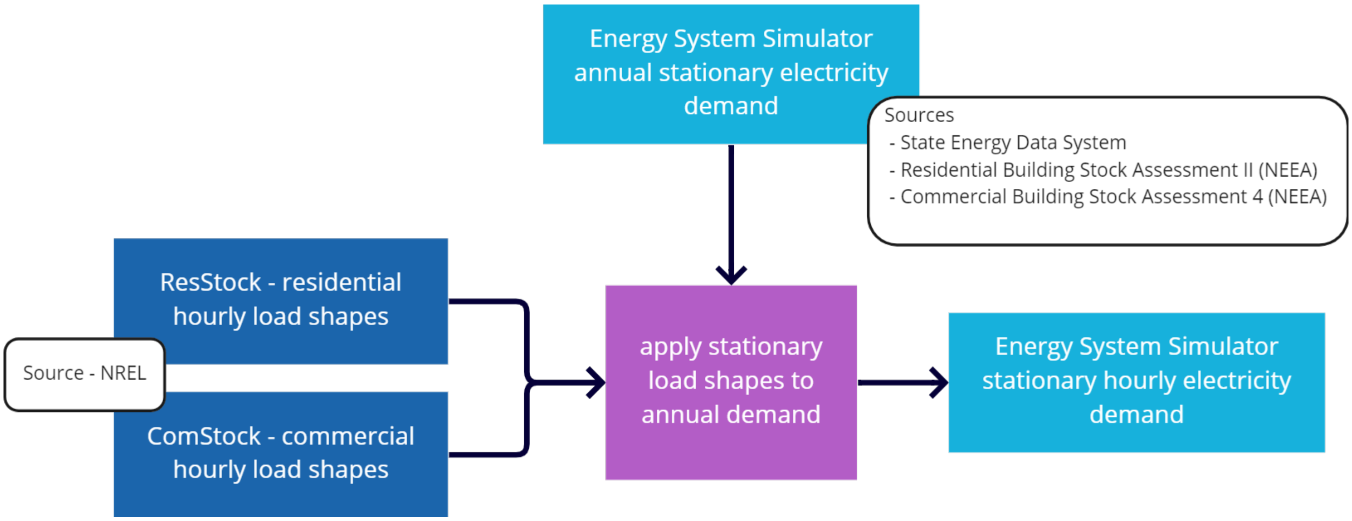


FIgure 17. Annual electricity demand to hourly demand process

National Renewable Energy Laboratory (NREL)'s ResStock and ComStock models are used to develop hourly profiles by county, which are applied to annual demand to generate total electricity demand on an hourly basis from residential and commercial buildings in Oregon.

Box #3: Restock and Comstock

ResStock and ComStock are physics-based simulation models developed to represent the energy use and energy saving potential of residential and commercial building stocks with high granularity at national, regional, and local scales.[4]

The hourly analysis completed for this study builds a bottom-up representation of electricity demand for the residential and commercial sectors and does not model total electricity demand (all sectors) for the State of Oregon or the Western Interchange. The analysis enables policy-makers to compare how different policies will impact the contribution of buildings to hourly electricity demand in Oregon, including capturing sub-regional climatic variation in heating and cooling hourly demand profiles and the impacts of climate change on decreased heating demand.[5]

---

[4] US Department of Energy (2022). End-Use Load Profiles for the U.S. Building Stock; Methodology and Results of Model Calibration, Validation, and Uncertainty Quantification. Retrieved from: https://www.nrel.gov/docs/fy22osti/80889.pdf

[5] The uses heating degree days and cooling degree days from RCP 4.5 for each Count. For more details, see: https://crt-climate-explorer.nemac.org/

The model assumes an average coefficient of performance (COP) of 2.75 for air source heat pumps.[6] In periods of extreme cold, the COP may decline below this level. The COP is a reasonable assumption given that (a) the inclusion of a share of hybrid heating systems which enable natural gas to provide heating for periods of extreme cold for some homes and buildings, (b) the COP of cold weather air source heat pumps continues to improve in cold temperatures,[7] and (c) no demand response measures were applied (for example, shifting water heating demand).

2.4 The Reference Scenario

The BAP scenario from the Roadmap to 2035 was used as the reference scenario that the policy concepts were evaluated against. HB 2021 was included in the BAP scenario, while CPP was removed. From a technical perspective HB 2021 impacts the emissions from electricity, which is an energy carrier, not an energy source. The emissions factor of electricity can be decreased by changing the mix of electricity generation, which is not considered within the scope of this study.

The pathway for CPP, however, impacts fuels and technologies used in buildings, which means that it could not be included within the reference scenario in order to avoid double counting.

2.4.1 The Treatment of CPP

CPP sets a declining limit or cap on GHG emissions from fossil fuels used throughout Oregon, including diesel, gasoline, natural gas and propane, used in transportation, residential, commercial and industrial settings.

In the case of natural gas, which is the primary fossil fuel impacted by the mandate of the Task Force, the covered entities are the natural gas utilities. Natural gas utilities must achieve emissions reductions in alignment with the CPP GHG reductions caps (50% by 2035 and 90% by 2050 from a 2017-2019 average baseline emissions), but the activities are not determined by CPP. The covered entities must achieve the emissions reductions in the context of other factors such as population growth, evolving public policy (as is being evaluated by the Task Force) and market trends, which may decrease or increase the efforts required.

In order to illustrate the impact of CPP, charts were prepared to illustrate the GHG impact of each scenario in the context of CPP implementation. Not all natural gas consumption is within the purview of the Task Force (natural gas consumed in industry and transportation was not included in this analysis), so the CPP caps were applied proportionately to natural gas consumed in the residential and commercial sectors. The impact of CPP is illustrated on GHG emissions as a wedge; if the policy achieves more GHG emissions reductions, the CPP wedge is smaller (FIgure 18); if the policy achieves less GHG emissions, the CPP wedge is larger (Figure 19). The resulting visual makes

[6] The COP averages were derived by calculating applying actual performance of a cold weather heat pump to hourly temperature data for a northern climate city.
[7] For example" US Department of Energy (2022). DOE Announces Breakthrough in Residential Cold Climate Heat Pump Technology. Retrieved from: https://www.energy.gov/articles/doe-announces-breakthrough-residential-cold-climate-heat-pump-technology

no conclusions on how CPP will be achieved,[8] but does show the impact on GHG emissions of implementing CPP.

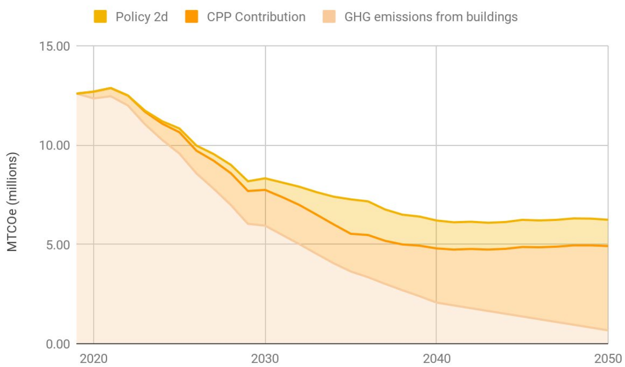


Figure 18. Impact of Policy 2D and CPP relative to the BAP scenario, GHG emissions from residential and commercial buildings

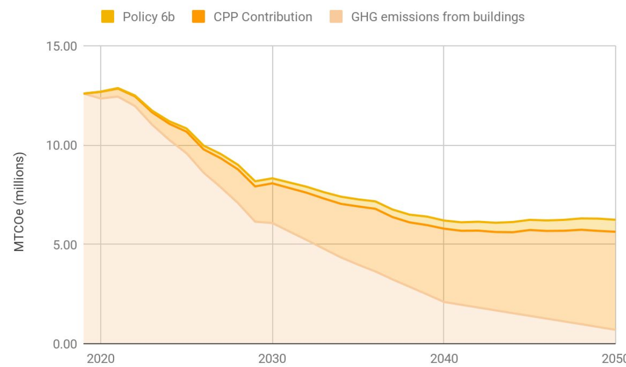


Figure 19 Impact of Policy 6b and CPP relative to the BAP scenario, GHG emissions from residential and commercial buildings

2.5 Financial Analysis

Financial impacts of each scenario are calculated by applying capital costs when investments are made and applying cost intensities for energy and maintenance costs over the lifetime of the investment.

2.5.2 Financial Methods

Costs Are Relative to a Reference Scenario

Financial impacts are calculated in comparison to the BAP scenario. The financial analysis tracked projected costs and savings of each scenario that are above and beyond the assumed BAP costs.

Discount Rate

A social discount rate of 3% applied. A social discount rate is the value to society of investments made for the common good.

Net Present Value

The net present value (NPV) of an investment is the difference between the present value of the capital investment and the present value of the future stream of savings and revenue generated by the investment.

---

[8] The natural gas utilities' Integrated Resource Plans describe pathways to achieve the CPP caps. For example, see: Northwest Natural (2022). 2022 Northwest Natural 2022 Integrated Resource Plan. Retrieved from: https://www.nwnatural.com/about-us/rates-and-regulations/resource-planning

Four aggregate categories are used to track the financial performance of the low-carbon actions in this analysis: capital expenditures, energy savings (or additional costs, operation and maintenance savings), and revenue generation (associated with renewable energy production facilities and some transit actions).

Cost Projections

SSG maintains a detailed Financial Cost Catalog for capital and operating costs and projections that has been adjusted to reflect the Oregon context. The Financial Cost Catalog is included in Appendix 5.

2.5.2 Inflation Reduction Act (IRA)

The impact of the IRA is not included in the financial analysis. IRA will provide funding in different forms that will support aspects of the policy concepts being evaluated by the Task Force. As a result, funding programs in the IRA will improve the financial results for the policy concepts being evaluated by the Task Force. Examples of IRA fundings programs that are relevant to the Task Force include:[9]

- The **Home Energy Performance-Based Whole-House Rebates** (HOMES) provides between $2,000 and $8,000 for energy efficiency retrofits.

- The **High-Efficiency Electric Home Rebate Program Rebate** provides up to $14,000 for low and moderate income homes.

Table 4. High-Efficiency Electric Home Rebate Program Rebates

Appliance	Rebate amount
Heat pump for space heating and cooling	$8,000
Electric stove, cooktop, range, or oven or clothes dryer	$840
Heat pump hot water heater	$1,750
Electric wiring	$2,500
Electric load service center (breaker box)	$4,000
Insulation, air sealing and ventilation	$1,600

- A tax credit (**IRA-25C**) provides up to $1,200 per year for energy efficiency upgrades and up to $2,000 per year for electric heat pump water heaters and electric heat pumps. **IRA-45L** provides a tax credit of $5,000 if a single-family or manufactured home is certified zero energy ready.

[9] IRA funding programs were described in a presentation to ODOE: Rinaldi, K. (2022). Inflation Reduction Act (IRA): Big Picture. AnnDyl Policy Group.

There are limitations to stacking the funding programs and more program details are being developed, but the overall impact of the financial benefits to the policy concepts will be enhanced by IRA.

2.6 Additional Benefits

SB 1518 requires consideration of "maximizing additional benefits".[10] The list of additional benefits includes increasing energy efficiency, improving resilience against climate change, improving public health and air quality, reducing the percentage of household income that goes toward energy costs, and mitigating displacement and other impacts that result from wildfires, heat waves and other climate change events. SB 1518 also requires consideration of upfront and longer-term economic, environmental, climate and health costs, savings and benefits, along with lifecycle emissions and the social cost of carbon.

2.6.1 Economic Impact, Costs and Savings

ESS uses a lifecycle approach to calculate economic costs and benefits of each policy concept, including incremental capital and operating and maintenance costs.

Table 5. Lifetime of stocks

Stocks	Lifetime (years)
Homes (singles and apartments)	40
Buildings	50
Heat pumps	15
Hot water system	10

2.6.2 Resilience

The Intergovernmental Panel on Climate Change (IPCC) defines climate resilience as "*the capacity of social, economic, and environmental systems to cope with hazardous events, trends or disturbances, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.*"[11]

---

[10] 81st Oregon Legislative Assembly (2022). Senate Bill 1518. p.2 Retrieved from: https://olis.oregonlegislature.gov/liz/2022R1/Downloads/MeasureDocument/SB1518

[11] Field, C. B. (Ed.). (2014). Climate change 2014–Impacts, adaptation and vulnerability: Regional aspects. Cambridge University Press.

The number of homes retrofitted is used as a proxy indicator of increased resilience. Retrofits improve building envelopes so that they can better regulate temperature and therefore protect inhabitants in periods of extreme weather,[12] which the US Green Building Council has defined as passive survivability or thermal safety.[13] Thermal safety is defined as maintaining thermally safe conditions during a power outage that lasts four days during peak summertime and wintertime conditions.[14]

Energy retrofits can result in improved thermal satisfaction, fewer reported financial difficulties due to lower energy costs, increased resident satisfaction with the home repair and more social interactions.[15]

2.6.3 Public Health and Air Quality

In order to evaluate impacts on health and air quality, SSG used EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA).[16] COBRA estimates the economic value of the health benefits associated with reductions in emissions of particulate matter (PM2.5), sulfur dioxide (SO2), nitrogen oxides (NOX), ammonia (NH3), and volatile organic compounds (VOCs). Reductions in these pollutants were calculated in ESS, which were used as inputs into COBRA.

COBRA uses health impact functions to estimate how changes in outdoor air quality impacts instances of health outcomes (e.g., premature mortality, heart attacks, asthma exacerbation, lost work days). The change in instances for each health outcome is multiplied by a monetary value specific to that outcome (e.g., the average cost of going to the emergency room for asthma symptoms or the cost of a lost work day) to determine the monetized health impacts.[17]

SSG assessed methods to evaluate impacts on indoor air quality as a result of the policies, and determined that the complexity of parameters, including the introduction of new materials, ventilation and combustion within the envelope would require a dedicated analysis not undertaken as a part of this work.

---

[12] Ribeiro, D., Mackres, E., Baatz, B., Cluett, R., Jarret, M, Kelly, M., Vaidyanathan, S. (2015). Enhancing community resilience through energy efficiency. Report U1508. Retrieved from: https://aceee.org/sites/default/files/publications/researchreports/u1508.pdf.

[13] USGBC. Passive survivability and back-up power during disruptions. LEED BD+C: New construction. Retrieved from: https://www.usgbc.org/credits/passivesurvivability.

[14] What constitutes thermally safe varies in various buildings, and can also be dependent on humidity and other factors. See LEED pilot webpage for more information: https://www.usgbc.org/node/9836068?return=/pilotcredits/all/all

[15] Poortinga, W., Rodgers, S. E., Lyons, R. A., Anderson, P., Tweed, C., Grey, C., … Winfield, T. G. (2018). The health impacts of energy performance investments in low-income areas: a mixed-methods approach. Public Health Research, 6(5), 1–182. https://doi.org/10.3310/phr06050

[16] EPA (2022). CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool. Retrieved from: https://www.epa.gov/cobra

[17] For more details on COBRA, see: EPA (2021). User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA). Retrieved from: https://www.epa.gov/system/files/documents/2021-11/cobra-user-manual-nov-2021_4.1_0.pdf

2.6.4 Household Expenditures

Household expenditures on energy can result in energy poverty, which can have a range of impacts. For example, households experiencing energy poverty or energy insecurity face challenges such as "pay the rent or feed the kids", "heat or eat", or "cool or eat".[18] In particular, energy insecurity disempowers low-income residents such as single parents, the elderly, persons with disabilities, and others with low or fixed incomes,[19] resulting in stresses such as utility-related debt, shutoffs, inefficient heating systems, antiquated appliances, and extreme home temperatures with the potential of resulting in significant health impacts.[20] Children may experience nutritional deficiencies, higher risks of burns from non-conventional heating sources, higher risks for cognitive and developmental behavior deficiencies, and increased incidences of carbon monoxide poisoning.[21]

Household expenditures on energy are calculated by multiplying the fuel consumption by fuel for each dwelling type by the relevant fuel cost intensity. The net change in household energy expenditures calculates the difference between the policy concept scenario from the BAP.

2.6.5 Economic Impact- Employment

The impact on employment is calculated using direct multipliers where a dollar of commodity or service output generates X number of person-years of employment. Indirect jobs are not included in the analysis to avoid double counting. Person years of employment in the policy concept scenario were subtracted from person years of employment in BAP scenario; where the number is negative, it represents a loss of employment; where positive it represents an increase in employment.

Table 6. Employment multipliers[22]

Category	Person Years of Employment
HVAC equipment manufacturing	4.6
Construction	5.5

[18] Cook, J. T., Frank, D. A., Casey, P. H., Rose-Jacobs, R., Black, M. M., Chilton, M., … Cutts, D. B. (2008). A brief indicator of household energy security: Associations with food security, child health, and child development in US infants and toddlers. PEDIATRICS, 122(4), e867–e875. https://doi.org/10.1542/peds.2008-0286

[19] Hernández, D. (2013). Energy insecurity: A framework for understanding energy, the built environment, and health among vulnerable populations in the context of climate change. American Journal of Public Health, 103(4), e32–e34. https://doi.org/10.2105/AJPH.2012.301179

[20] Hernández, D., & Bird, S. (2010). Energy burden and the need for integrated low-income housing and energy policy. Poverty & Public Policy, 2(4), 5–25. https://doi.org/10.2202/1944-2858.1095

[21] Ibid.

[22] Bivens, J. (2019). Updated employment multipliers for the U.S. economy. Economic Policy Institute. https://www.epi.org/publication/updated-employment-multipliers-for-the-u-s-economy/

2.6.6 Social Cost of Carbon (SCC)

The SCC is a measurement of the long-term economic costs associated with emitting an additional ton of carbon dioxide.[23] It is calculated using the quantifiable costs and benefits of a tonne of carbon dioxide on society, incorporating assumptions around future conditions such as population size, economic growth, rate of climate change, and the impact of climate change on these conditions.

The SCC from the Interagency Working Group on Social Cost of Greenhouse Gases was used for the analysis, with a 3% discounting rate.[24]

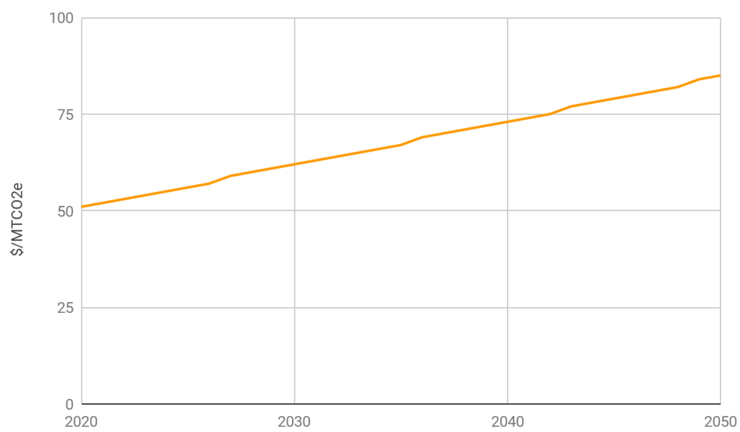


Figure 20. Social Cost of Carbon, 3% discounting rate

Subsequent to the completion of the modeling, new values for the SCC have been released, which increase the damages caused by climate change.[25] While these values have not been incorporated into the analysis, they would have the effect of increasing the economic (societal) value of GHG reductions.

2.7 Uncertainty

Models which explore the future are intrinsically uncertain, given that the future is unknowable. ESS provides a powerful tool to allow analysts to explore cause and effect in a system that is calibrated to current conditions.

[23] ODOE (2020). Primer on the Social Cost of Carbon.
[24] Interagency Working Group on Social Cost of Greenhouse Gases (2021). United States Government Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 Retrieved from: https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf
[25] EPA (2022). Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. Retrieved from: https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf

The scenarios evaluated in this analysis are not predictions of what will happen, rather they address what might happen if other conditions or assumptions are in place. This analysis of cause and effect provides insight on impacts.

The use of multiple scenarios provides further insight on how variation in policies can impact outcomes.

2.8 Transparency

The ESS model and its logic is available for download to ensure that the method and framework is fully transparent.[26] Additionally, a detailed description of the method is included in the Data, Methods and Assumptions Manual (Appendix 4).

3. Analysis

Results are presented in several policy score cards and summary charts.

3.1 The Scorecard

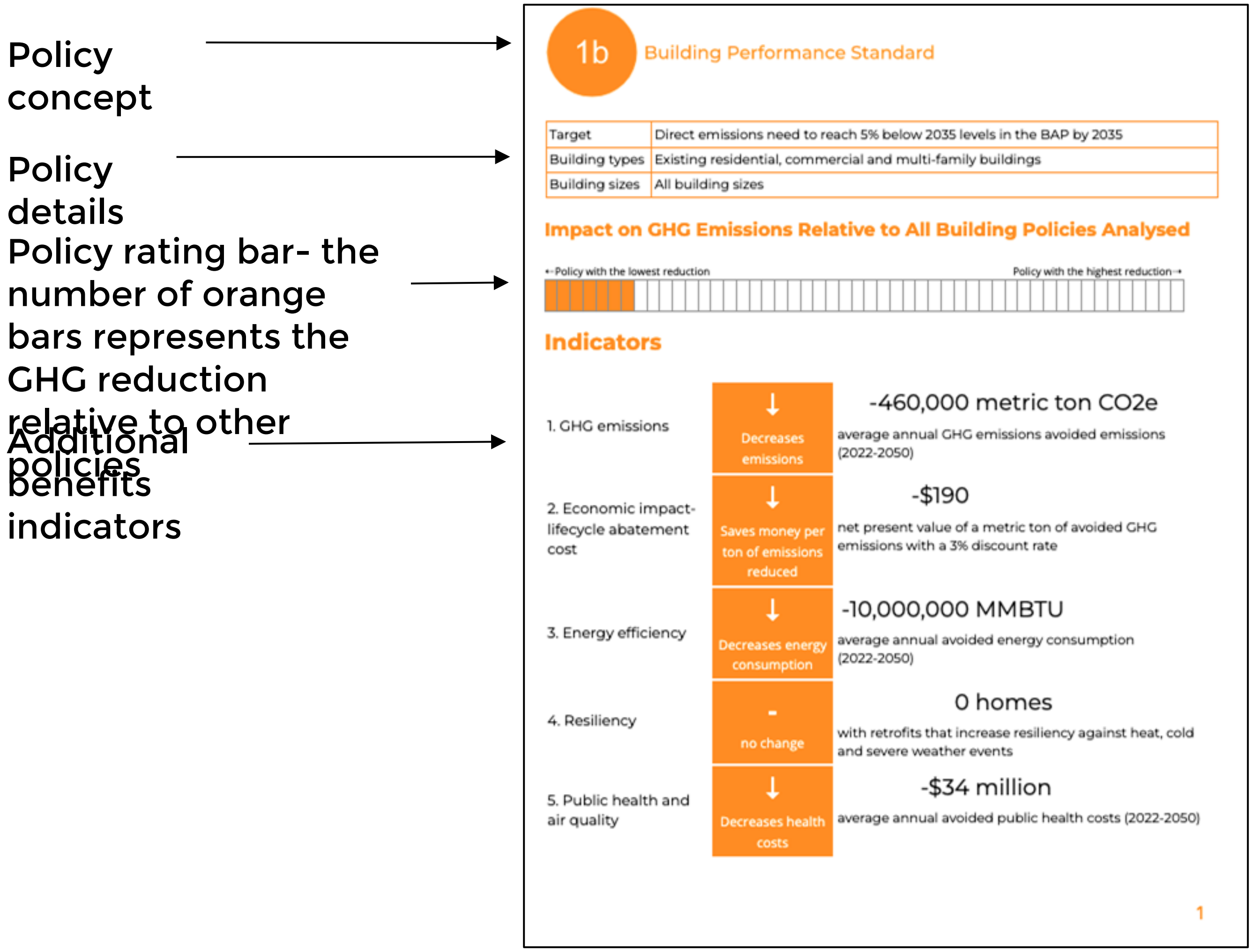
Scorecards were prepared for each policy concept. The scorecards include indicators for GHG emissions and the additional benefits, which are presented using a consistent format across all policy concepts to ensure comparability.

An indicator bar illustrates the relative impact of the policies on GHG emissions at a glance; complete shading of the bar indicates the policy which had the greatest emissions reduction while no shading indicates the policy with lowest emissions reduction.

A series of charts show cumulative impacts between 2022 and 2050, as well as annual curves over time.

A complete set of scorecards is included in Appendix 3.

[26] ESS can be downloaded at: ess.ssg.coop



1b Building Performance Standard

Target	Direct emissions need to reach 5% below 2035 levels in the BAP by 2035
Building types	Existing residential, commercial and multi-family buildings
Building sizes	All building sizes

Impact on GHG Emissions Relative to All Building Policies Analysed

←Policy with the lowest reduction Policy with the highest reduction→

Indicators

1. GHG emissions	↓ Decreases emissions	-460,000 metric ton CO2e average annual GHG emissions avoided emissions (2022-2050)
2. Economic impact-lifecycle abatement cost	↓ Saves money per ton of emissions reduced	-$190 net present value of a metric ton of avoided GHG emissions with a 3% discount rate
3. Energy efficiency	↓ Decreases energy consumption	-10,000,000 MMBTU average annual avoided energy consumption (2022-2050)
4. Resiliency	- no change	0 homes with retrofits that increase resiliency against heat, cold and severe weather events
5. Public health and air quality	↓ Decreases health costs	-$34 million average annual avoided public health costs (2022-2050)

1

FIgure 21: Page 1 of the policy scorecards

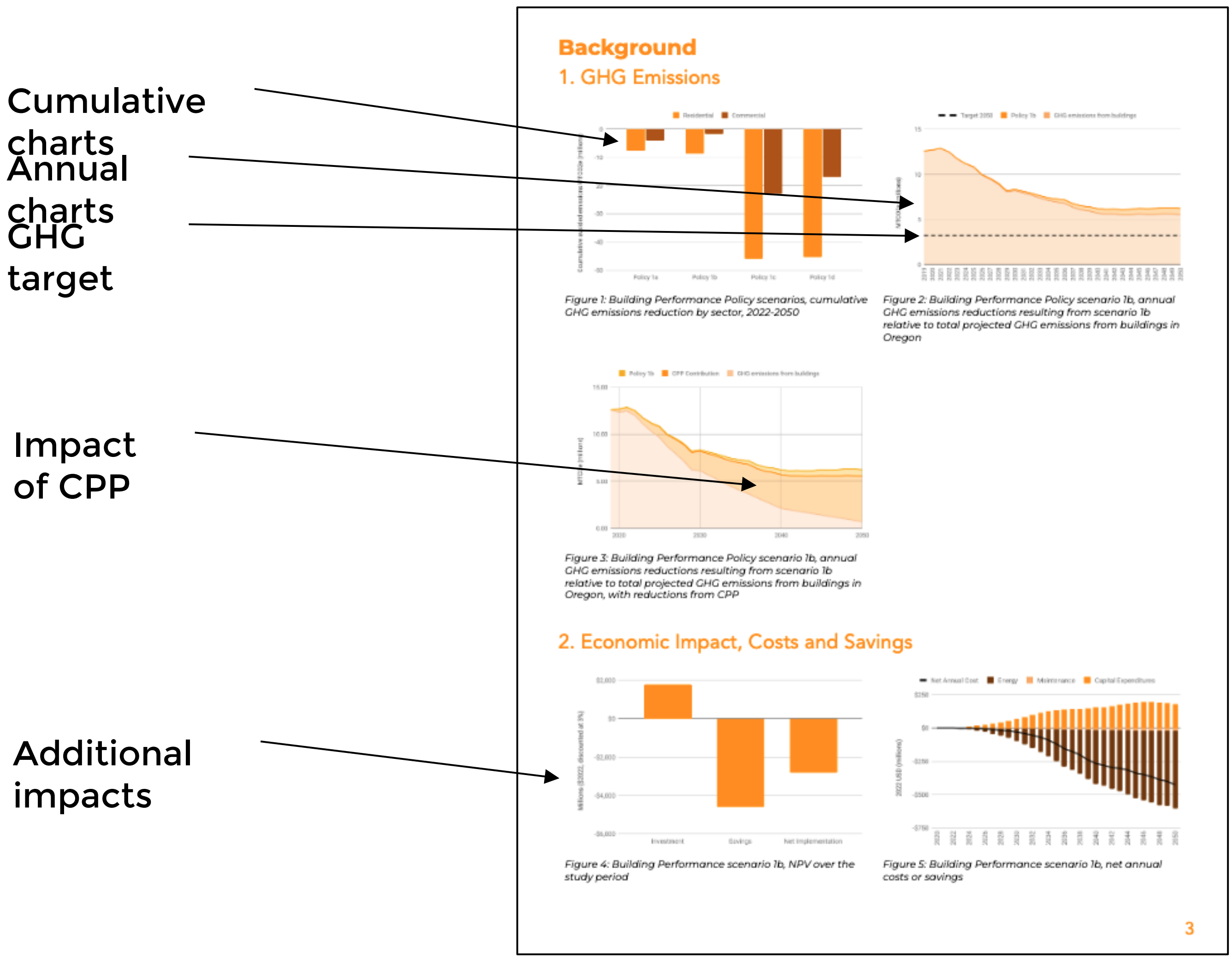


Figure 22. Page 3 of a policy scorecard

3.2 Policy Concepts

The policy concepts apply to different aspects of the building stock with a range of physical interventions as determined by the Task Force. Figure 23 illustrates which policies apply to new buildings, existing buildings or both and whether the policy is focused on energy efficiency, technologies such as heat pumps, does not specify the approach or addresses material-related emissions. The figure illustrates which policies overlap (i.e. policy 2 and 6 on existing buildings; depending how it is implemented, policy 1 and policies 4 and 6).

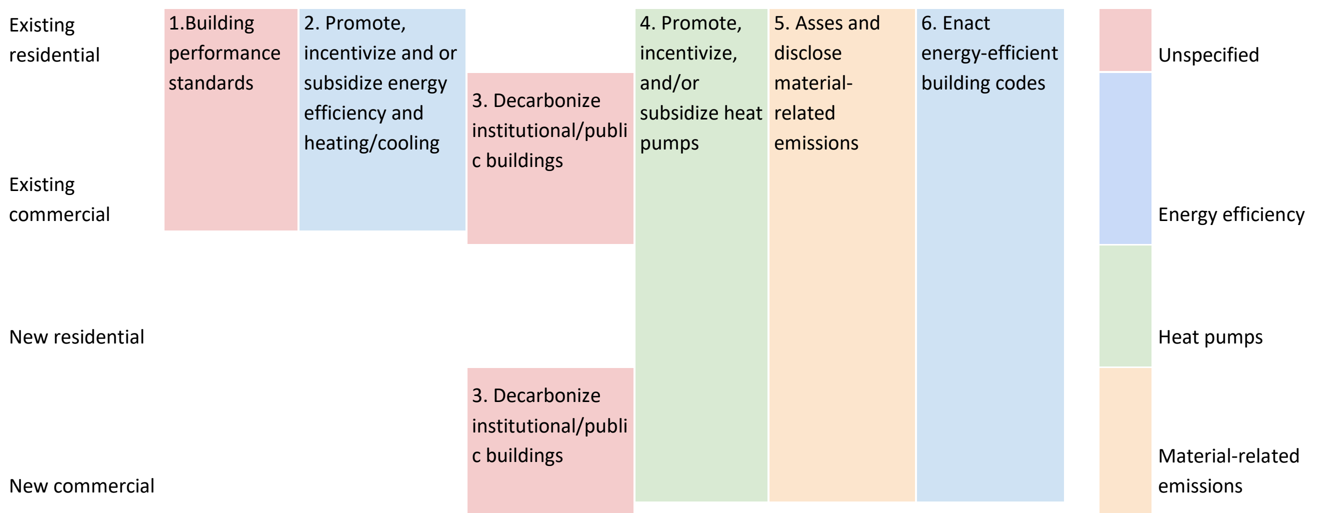


FIgure 23. Mapping the policy impacts

3.2.1 GHG Emissions

The implementation of heat pumps in the building stock by 2035 results in average annual reductions of 3.6 million $MtCO_2e$ (4b). Note that this is an indicator, and modeled GHG reductions follow a curve that starts slowly and accelerates over time as the rate of adoption increases.[27] Policies 1c and 1d achieve 82% and 77% of the reductions of 4b respectively, and because the policy is based on a GHG intensity, it does specify technologies or interventions. A combination of heat pumps and RNG was modeled in order to achieve these reductions.

Carve outs for smaller buildings in the commercial sector (≥ 35,000 ft2) reduces the average annual emissions reduction by 5% in policy 1 and by 7% in policy 5 (≥ 50,000 ft2). In both cases, all residential buildings are included.

Efficiency improvements in Policy 2 reduce energy consumption without fuel switching, achieving ¼ of the average annual reductions of Policy 4b.

GHG reductions from policy 3 are relatively small, even in the ambitious implementation (-176,000 $MtCO_2$/year), because of the size of public sector building stock in Oregon. This policy can be useful to stimulate net zero new construction and deep retrofits.

Policy 6 is effective for new buildings, but implementation for the larger existing building stock is limited by the rate of renovations, which triggers building energy efficiency improvements.

---

[27] S-curves are used to describe the diffusion of innovations in which a technology is adopted by pioneers, it then becomes mainstream experiencing rapid growth, before slowing down.

Policy 5 can unlock a previously untapped source of GHG emissions reductions. Average annual reductions in embodied emissions in policy 5b are 3.3 million $MtCO_2e$ across commercial and residential buildings; these GHG emissions reductions are not included in the operational emissions inventory in Oregon but may be included in other sectors such as industry or emissions from outside of Oregon's geographic boundary.

Policies 1c, 1d, 4a and 4b achieve Oregon's GHG target proportionately applied to residential and commercial buildings as stand alone policies; the other policies do not. Note that because of accounting protocols policy 5 is not included in the same bucket.

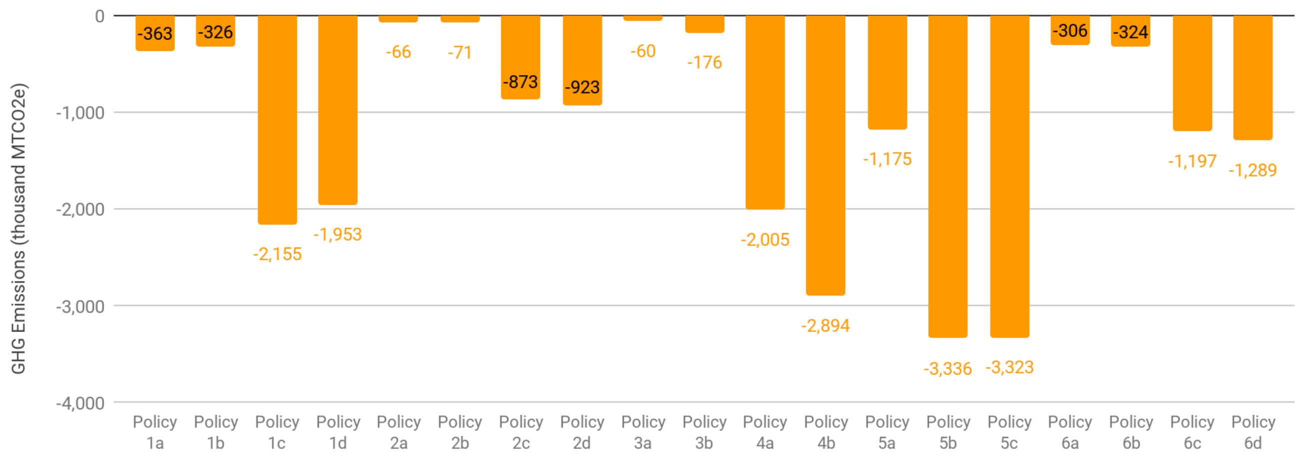


FIgure 24. Average annual GHG emissions reductions for each of the policy concepts

3.2.2 Additional Benefits

Many of the additional benefits illustrate patterns similar to those found for GHG emissions. All of the policy concepts reduce energy consumption, with the exception of Policy 5, which addressed embodied emissions in materials.

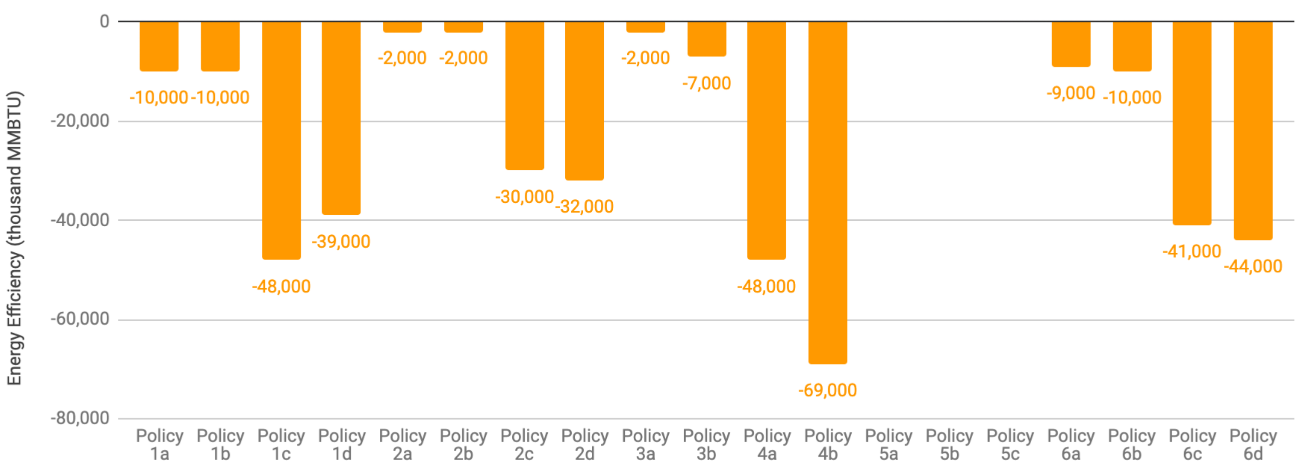


FIgure 25. Average annual avoided energy consumption (2022-2050)

Not all of the policies result in retrofits of homes, which is the proxy indicator of increased resilience for households. Policy 2 and policy 6 specifically target retrofits at different rates. Note that policy 4, which results in heat pump installation, would result in additional households having access to cooling during heating waves, although this benefit was not analyzed in the modeling.

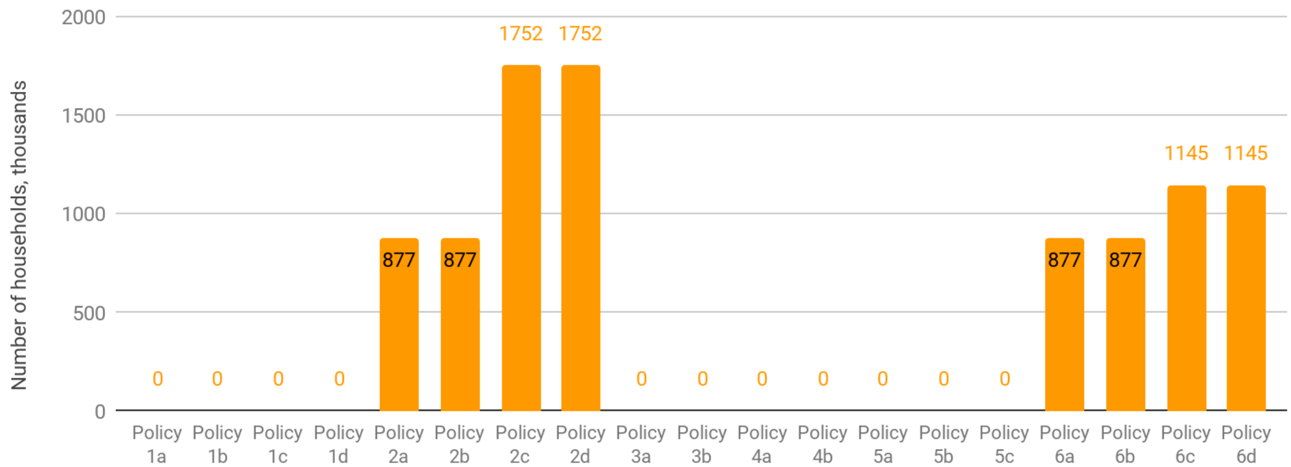


FIgure 26. Number of household retrofits that increase resiliency against heat, cold and severe weather events (2022-2050)

The health-related benefits of reduced air pollution demonstrate a different pattern, in part because of reduced air particulates from displaced wood combustion, as well as other sources of combustion.

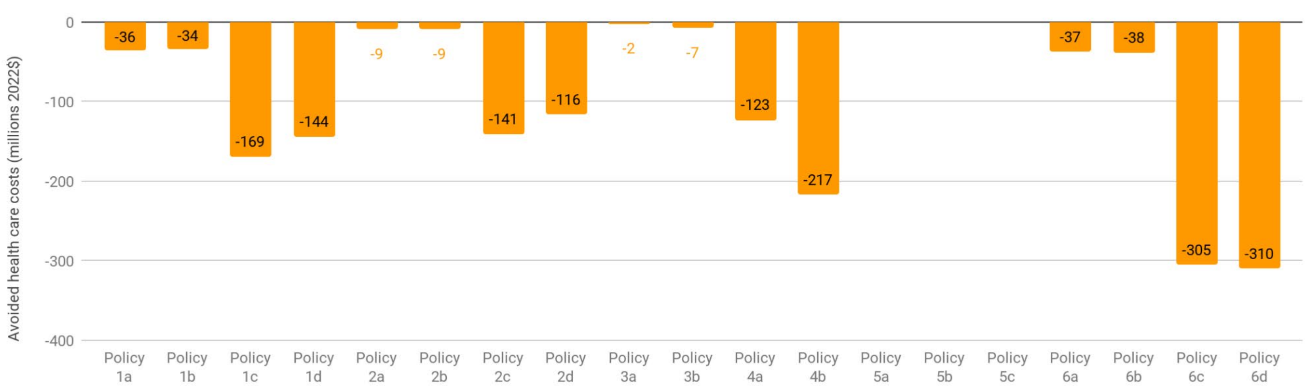


FIgure 27. Change in public health costs related to air quality (2022-2050)

Policies 1,2,4 and 6 reduce household energy expenditures between 2022 and 2050, with the most significant reductions resulting from the maximum ambition of Policy 4b (-37%), followed by Policy 6d (-31%) and 1d (-24%). Policies 3 and 5 do not impact household energy expenditures. The greater reduction in Policy 4b is primarily as a result of the displacement of electric resistance heating with heat pumps, which results in a drop in electricity costs. The lower ambition implementation of Policy 2 increases household energy expenditures, indicating that deeper energy savings (-50% as in Policies 2c and 2d) deliver greater financial benefits to households than shallower reductions (-

15% as in Policies 2a and 2b), because shallower reductions do not keep up with increasing energy costs.

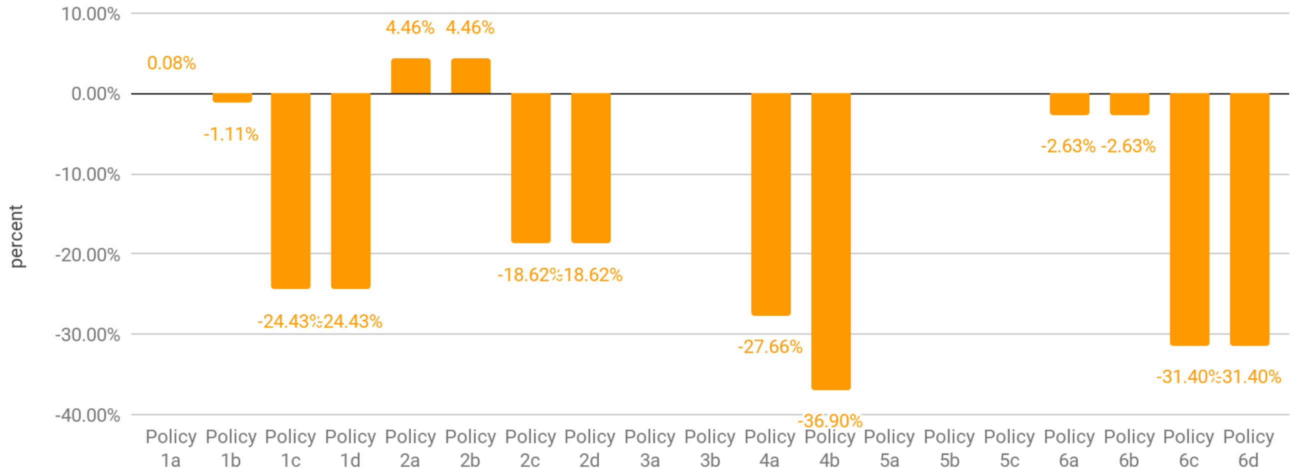


FIgure 28. Change in household energy costs from 2022-2050

Average capital investments peak at $2 billion per year (policy 2d), accounting for the relevant high costs of building retrofits. The retrofits in policy 6c and 6d also drive the capital costs in that scenario. For reference, Oregon's GDP in 2021 was $272 billion.[28]

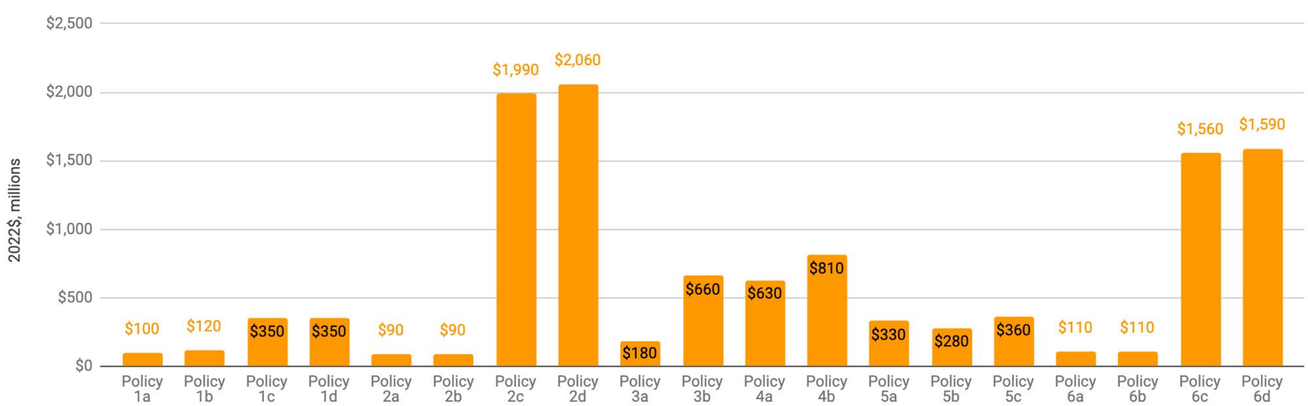


FIgure 29. Average annual capital investment (2022-2050), undiscounted

The net present value is a sum of costs and savings for each of the policies over the period between 2022-2050. Policies 1c, 1d, 2a, 2b, 4a, 4b, 6a and 6b generate net savings, while the other policies generate costs. IRA funding will reduce the costs and increase the savings of the policies across the board, but the specific impacts have not been calculated. Further cost reductions may be achieved through economies of scale for heat pumps and building retrofits, which have not been modeled.

---

[28] Bureau of Economic Analysis (2020). Gross Domestic Product by State and Personal Income by State, 2nd Quarter 2022. Retrieved from: https://www.bea.gov/sites/default/files/2022-09/stgdppi2q22-a2021.pdf

.

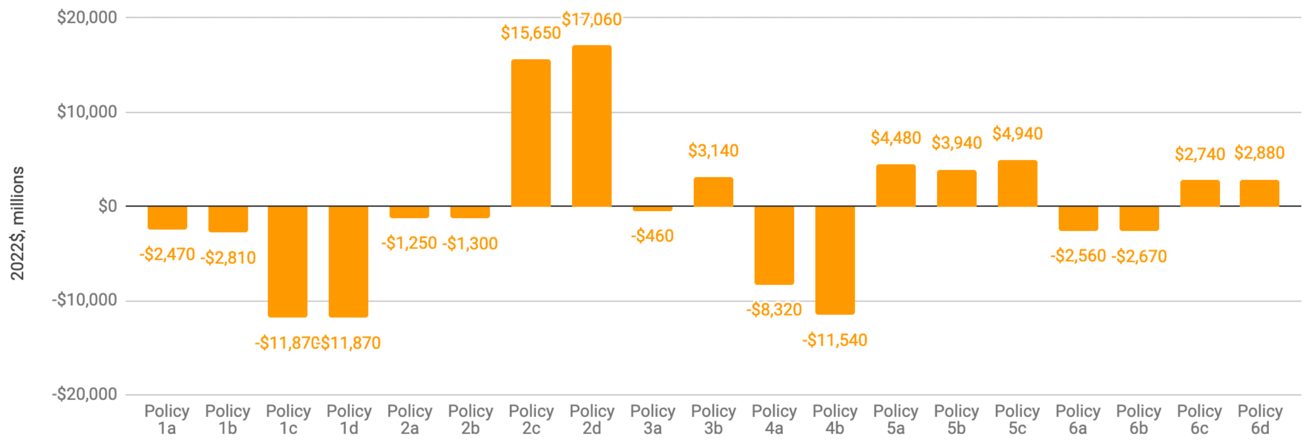


FIgure 30. Cumulative net costs discounted at 3% (2022-2050)

The positive or negative pattern of the abatement cost or saving is similar to that of the net costs, but the value is normalized on a per $MtCO_2e$ basis. Policies 1a, 1b, 1c, 1d, 2a, 2b, 3a, 4a, 4b, 6a and 6b are no-regrets policies in that they generate cost savings for each Mt of GHG emissions reduced. Policies 2c, 2d and 3b can be targeted for innovation or combinated with policies which save money, as they have a cost of more than $500/MtCO_2e$. Policies 5a, 5b, 5c, 6c and 6d also have net costs/$MtCO_2e$, which could be addressed with incentives or subsidies.

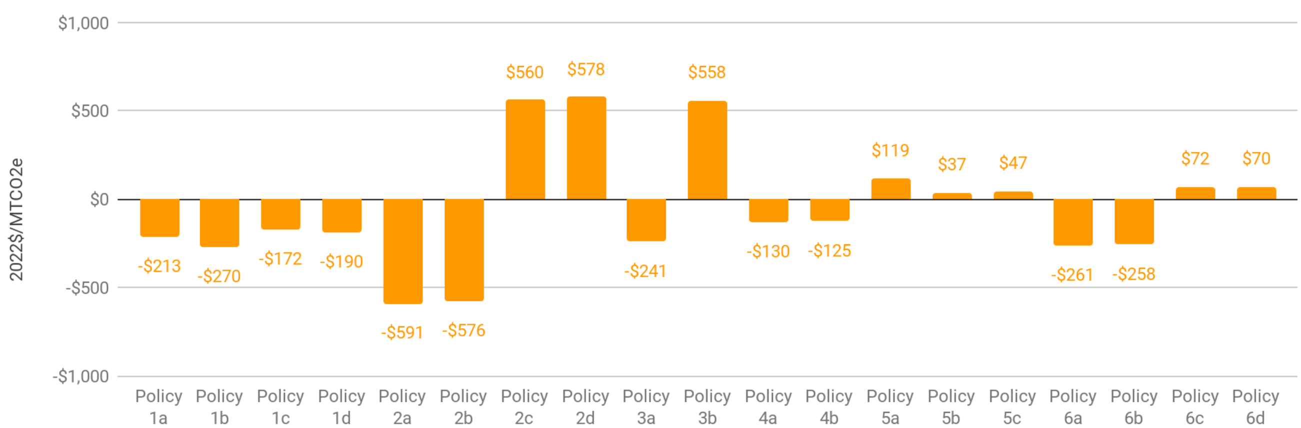


FIgure 31. Lifecycle abatement cost (2022-2050)

Policies 2c and 2d result in the greatest number of person years of employment, totalling an average of 10,000 per year. The remainder of the policies generate between 500 and 3,300 of employment per year. Note that the adoption curves of the policy start slowly so that the person years of employment accelerate towards the end of the period.

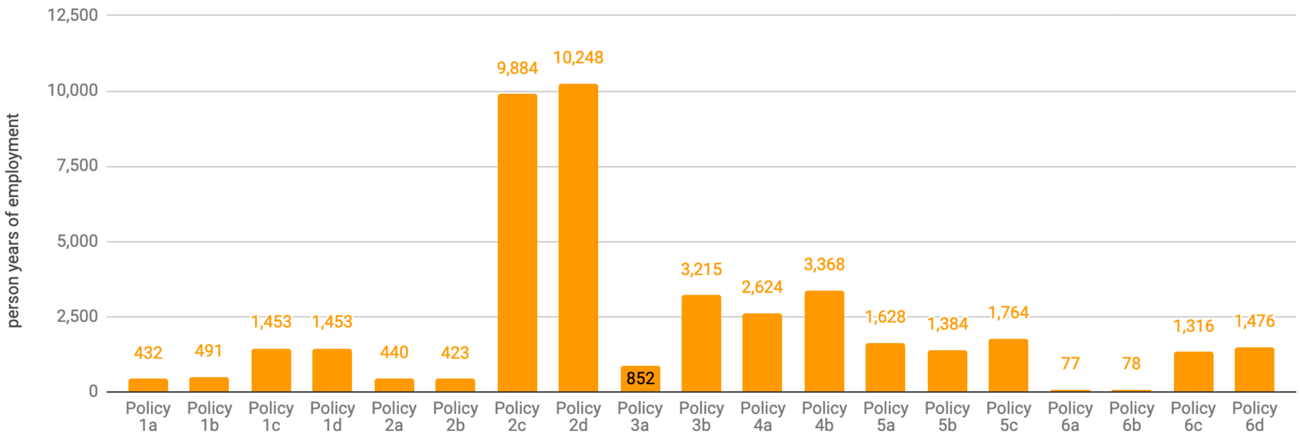


FIgure 32. Average annual person years of employment (2022-2050)

The value of avoided damage from climate change is proportional to the GHG emissions reduced, as well as when the GHG emissions are reduced. The value of the policies which result in the greatest GHG emissions reductions totals an average of $270 million per year (4b), or $7.5 billion over the period.

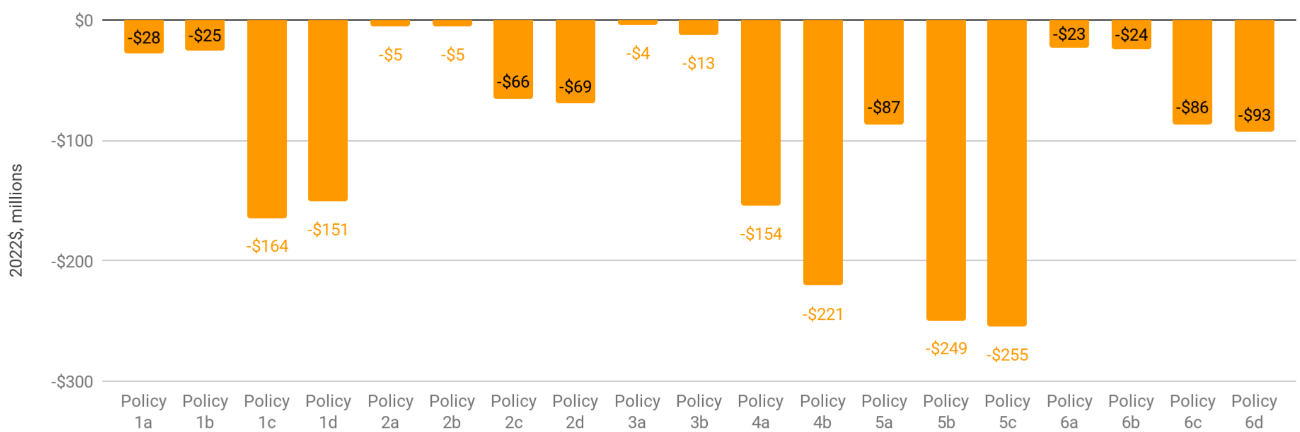


FIgure 33. Avoided annual damage as a result of climate change globally (2022-2050)

3.3 Integrated scenarios

Oregon may choose to implement several policies and the policies may result in feedback between policies.

Table 7. Integrated scenario policy summary

Scenario	Policy Elements
Scenario A	Building envelope retrofits New building energy reduction targets Space and water heating heat pump adoption Solar PV for new public buildings

	Embodied carbon reductions
Scenario B	Building envelope retrofits Space and water heating heat pump adoption New building energy reduction targets
Scenario C	Space and water heating heat pump adoption RNG replacement of NG Public building envelope retrofits New public building energy reduction targets Solar PV for new public buildings Embodied carbon reductions
Scenario D	Building envelope retrofits Space and water heating heat pump adoption New building energy reduction targets
Scenario E	Space and water heating heat pump adoption RNG replacement of NG Public building envelope retrofits New public building energy reduction targets Solar PV for new public buildings Embodied carbon reductions

3.3.1 GHG Emissions

Four of the integrated scenarios (A, B, C, E) result in similar average annual GHG emissions reductions, approximately 2.1 million $MtCO_2e$ per year. Scenario D increases this reduction by 30% to 3.4 million $MtCO_2e$ by maximizing retrofits and the deployment of heat pumps.

The implication of these results is that various combinations of policies can achieve the same level of GHG emissions reductions. For example Scenario A uses building codes to improve the performance of new and existing buildings (6a), incentivises heat pumps (4a) and decarbonizes public buildings (3a). Scenario B incentivises building retrofits (2a) and heat pumps (4a) and improves the performance of new buildings using building codes (6a). Scenario C applies a Building Performance Standard (1d) combined with decarbonising public buildings (3b). Scenario D undertakes an ambitious program of retrofits (2d) combined with rapid deployment of heat pumps (4b) and increase the performance of new buildings (6d). Scenario E applies the high ambition version of the Building Performance Standard to existing buildings (1c) and decarbonizes public buildings (3b).

The policy on material-related emissions is also included in Scenario A (5a), Scenario C (5b) and Scenario E (5c), but the emissions reduction is accounted for as negative emissions below the x-axis (Figures 35-39).

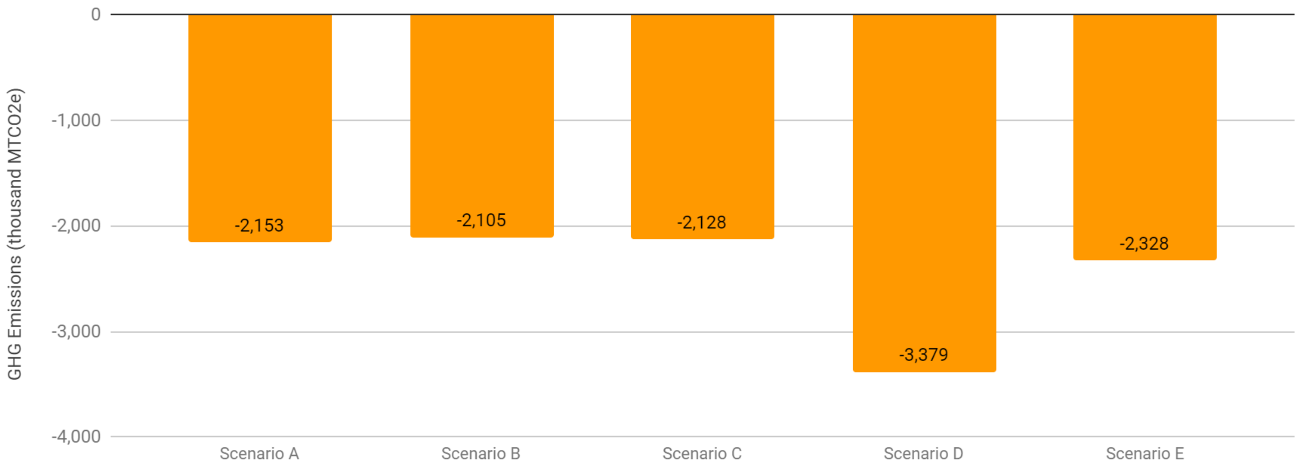


FIgure 34. Average annual GHG emissions reductions (2022-2050)

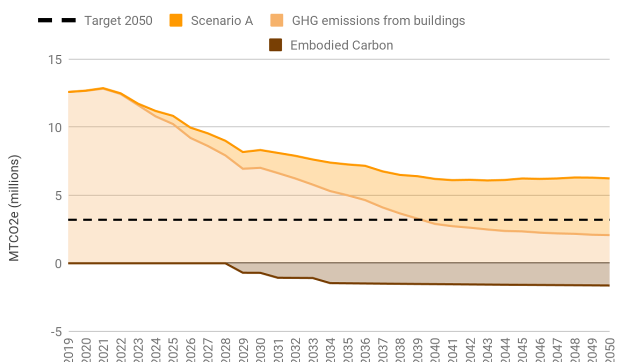


Figure 35. Annual GHG emissions from Scenario A

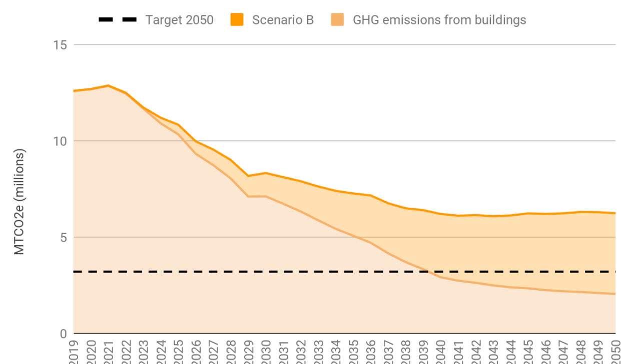


Figure 36. Annual GHG emissions from Scenario B

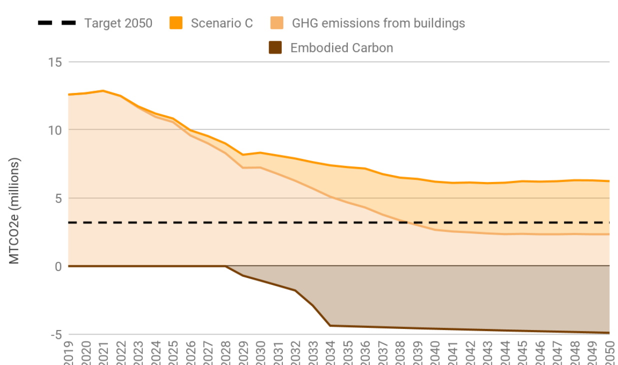


Figure 37. Annual GHG emissions from Scenario C

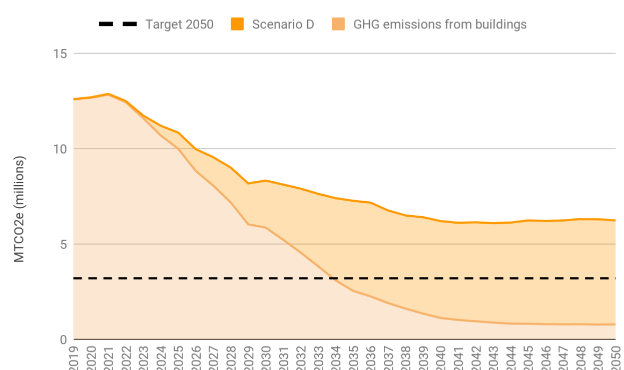


Figure 38. Annual GHG emissions from Scenario D

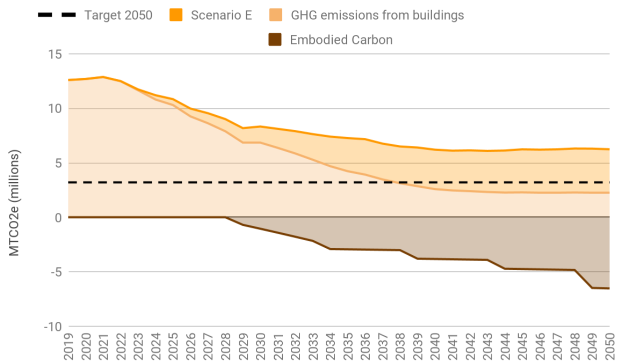


Figure 39. Annual GHG emissions from Scenario E

3.2.2 Additional Benefits

All of the scenarios reduce annual energy consumption, with Scenarios A, B, C and E reducing approximately 55,000 MMBTU. Scenario D achieves double this reduction through a more rapid and extensive deployment of heat pumps, which displace electric resistance heaters, and deep building retrofits.

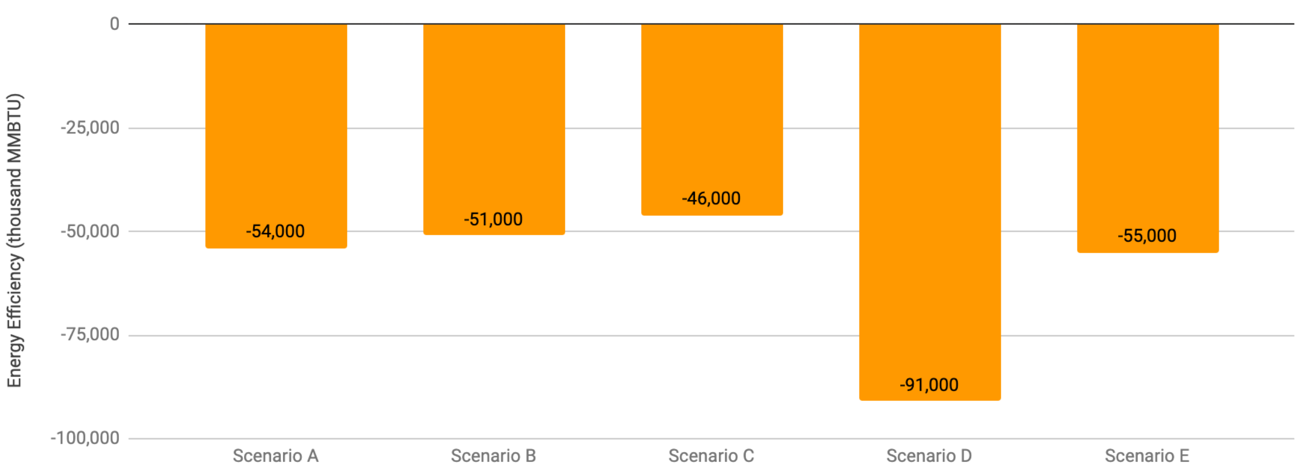


FIgure 40. Average annual avoided energy consumption (2022-2050)

Scenario D maximizes the retrofit of homes by 2035, increasing the resilience of the housing stock. Scenarios C and E don't include retrofits of homes, as it is possible to achieve the Building Performance Standard without retrofits. Scenario A implements retrofits through building code requirements at the point of renovation, while Scenario B incentivises retrofits.

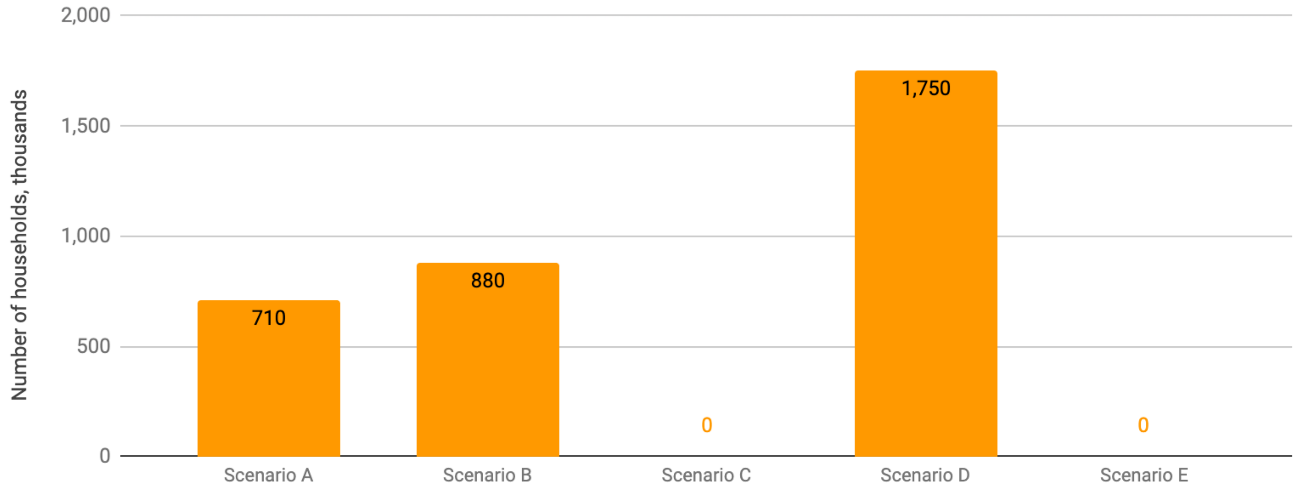


FIgure 41. Number of household retrofits that increase resiliency against heat, cold and severe weather events (2022-2050)

All of the scenarios reduce air pollution and therefore result in reduced health care costs.

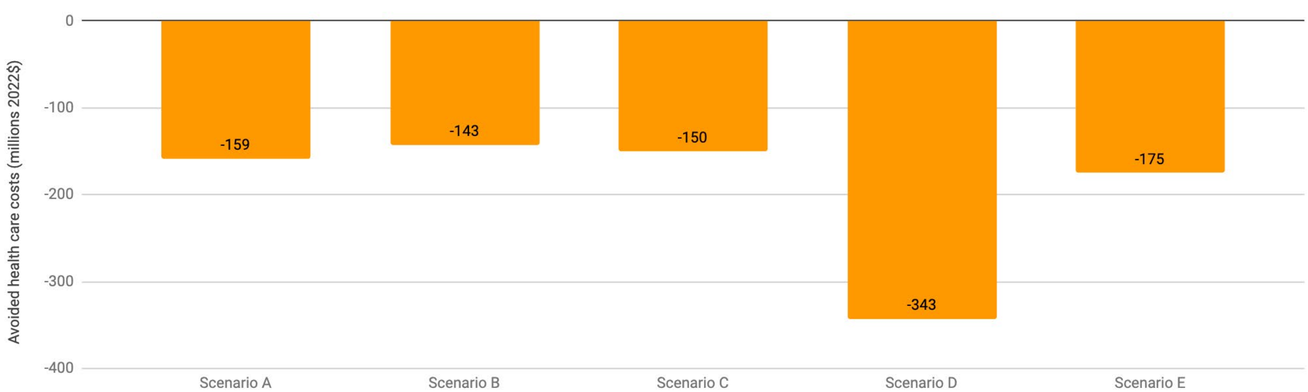


FIgure 42. Change in public health costs related to air quality (2022-2050)

All of the scenarios result in reductions in household energy costs between 2022 and 2050, of between 25% and 32%. The deep energy reductions in Scenario D (Figure 40) result in reductions of household energy costs of nearly 60%. Achieving the reductions in Scenario D has a higher capital cost as illustrated in Figure 44.

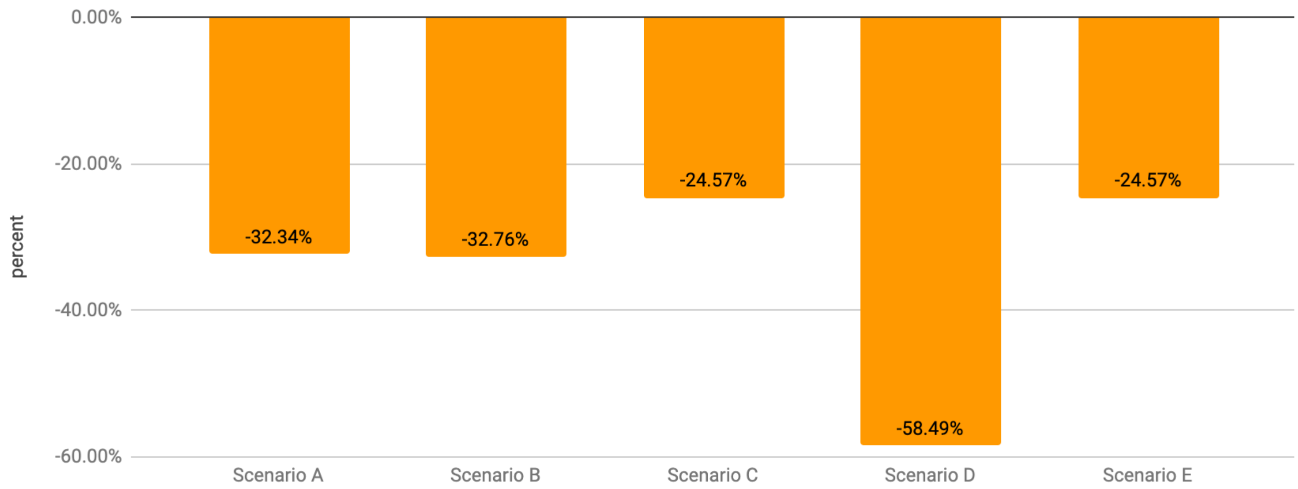


FIgure 43. Change in household energy costs from 2022 to 2050

The average annual capital costs vary from $760 million (Scenario B) to $3.1 billion in Scenario D. For reference, Oregon's GDP in 2021 was $272 billion.[29] The higher capital cost of Scenario D results from the objective of retrofitting 100% of the building stock by 2035 and installing heat pumps in 100% of buildings by 2035.

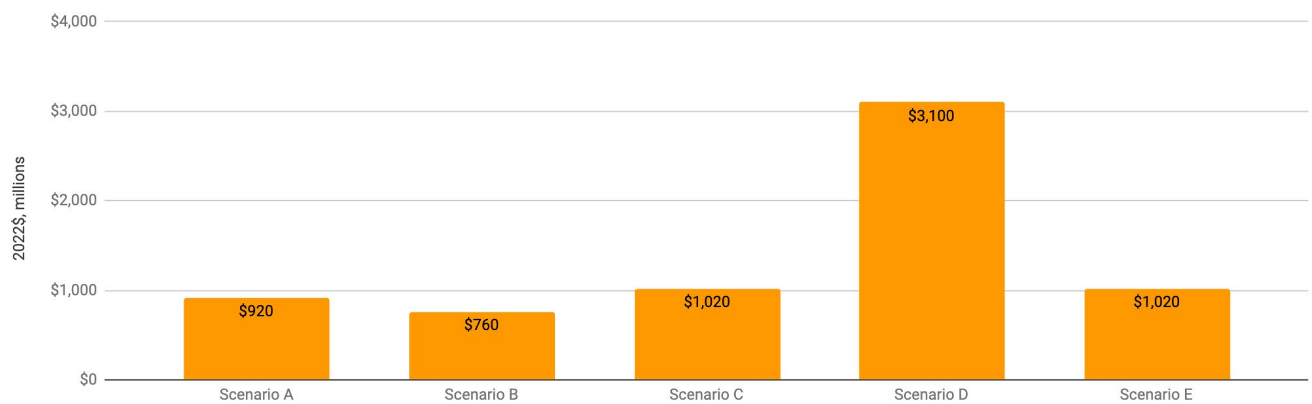


FIgure 44. Average annual capital investment (2022-2050)

Four scenarios result in net financial benefits over the period, savings between $4 billion and $12.4 billion. Scenario C's scope includes a narrower portion of the building stock and therefore captures less financial savings opportunities. Scenario D results in a net cost of $4.5 billion, as a result of higher upfront capital costs for retrofits than the other scenarios.

[29] Bureau of Economic Analysis (2020). Gross Domestic Product by State and Personal Income by State, 2nd Quarter 2022. Retrieved from: https://www.bea.gov/sites/default/files/2022-09/stgdppi2q22-a2021.pdf

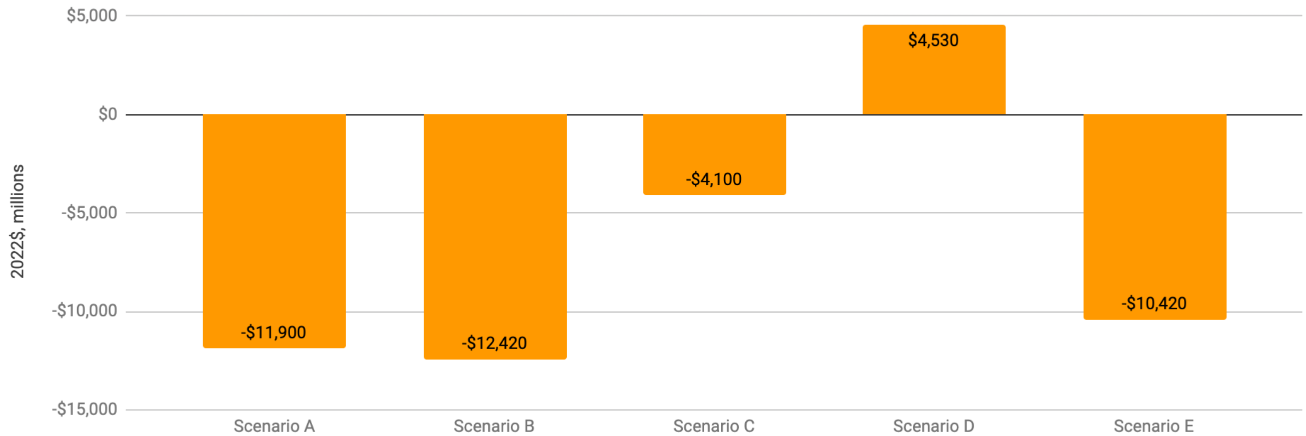


FIgure 45. Cumulative net costs discounted at 3% (2022-2050)

The cost savings in the four scenarios is reflected in the abatement costs. Scenarios A, B, and E save between $140 and $184/MtCO$_2$e. Scenario D costs $42/MtCO$_2$e, an example of how combining a cost negative abatement cost policy (4b:-$100) with a positive abatement cost policy (2d: $578) can increase emissions reductions, energy savings and decrease costs.

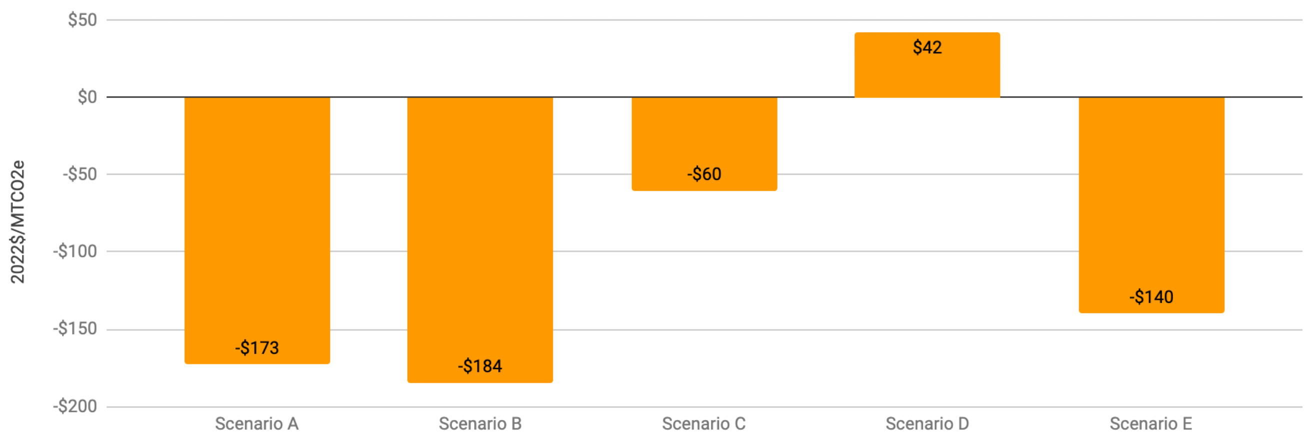


FIgure 46. Lifecycle abatement cost (2022-2050)

Annual person-years of employment reflect annual investments, with a stronger weighting for retrofits. Scenario D results in nearly 15,000 person-years of employment per year, while the other policies range from 3,200 (Scenario B) to 6,480 in Scenario E. Scenario A results in higher average annual person years of employment because of the inclusion of retrofits in the public/institutional sector.

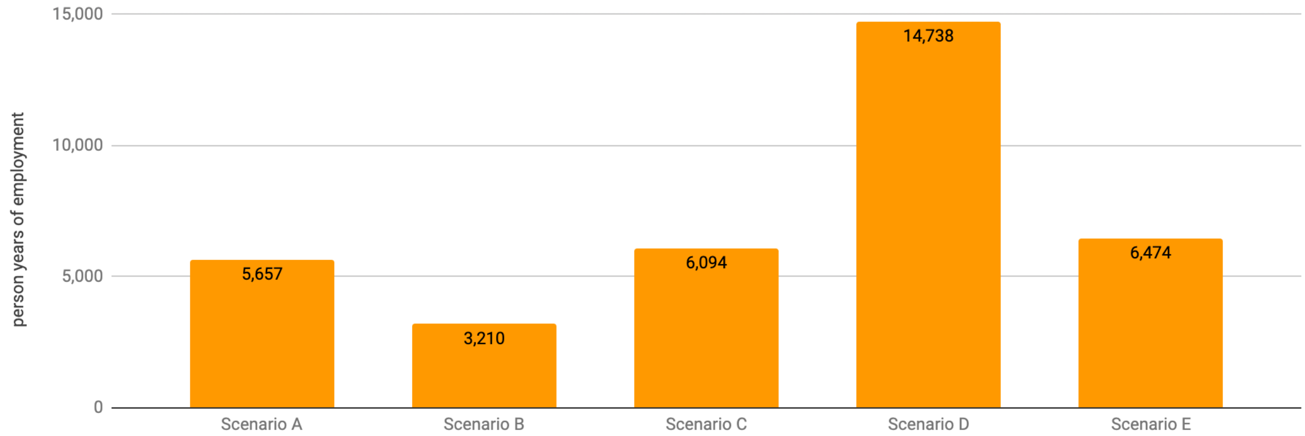


FIgure 47. Average annual person years of employment (2022-2050)

Average annual avoided costs of climate change range from $164 million to $255 million (Scenario 3). On a cumulative basis, the avoided damages total between $6.2 and $9.2 billion.

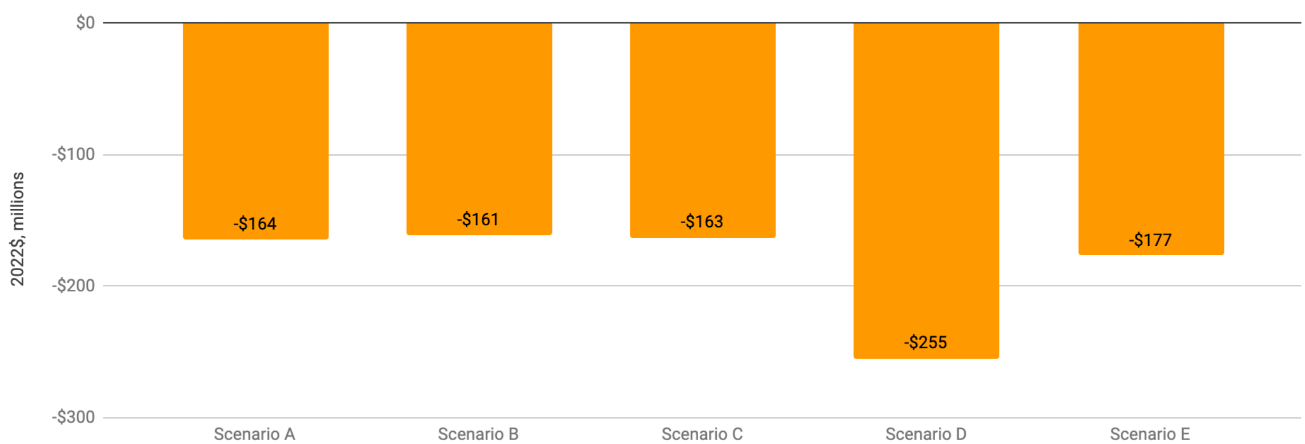


FIgure 48. Average annual value of avoided damages from climate change (2022-2050)

3.4 Hourly analysis

The impact of each of the scenarios on hourly demand is illustrated in an 8760 curve in Figure 49, against 2019 demand (purple) and a 2050 projection for the BAP scenario (red).

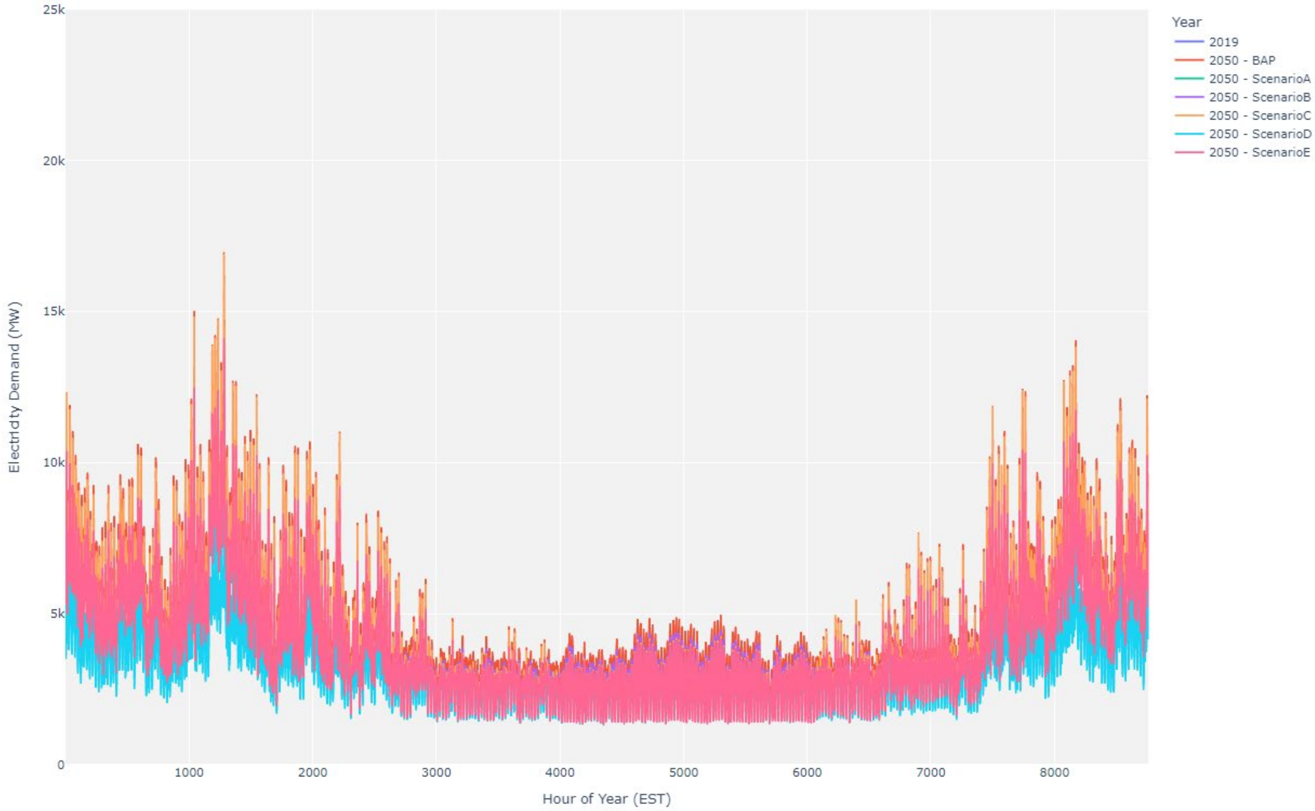


FIgure 49. 8760 illustration of peak demand for each of the integrated scenarios in 2050

In general, the scenarios reduce demand at all times of the year relative to both the 2019 scenario and the 2050 BAP scenario, which reflects population growth. Scenario C increases hourly demand over 2019, but is still below the 2050 BAP scenario, because it includes heat pumps but no building retrofits, which reduce energy demand.

24-hour demand curves are illustrated for summer, fall, spring and winter in Figures 50-54.

Despite population growth, winter peaks do not increase as a result of the combination of improved building efficiency and the replacement of electric baseboard heaters with heat pumps. Additionally, there is back-up natural gas heating in 30% of the households, which reduces increasing demand resulting from decreased efficiency of heat pumps on extremely cold days.

Growth in air conditioning load is also mitigated in most scenarios by the improved efficiency of heat pumps over air conditioners and improved thermal performance of the building stock.

The reductions in demand are most evident in Scenario D (Figure 50), where demand is reduced by more than 50% in the winter and to a much lesser degree in the summer.

Figures 51 and 52 illustrate hourly demand by end-use for a 24-hour period for residential buildings in Scenario A and D. Demand falls against the 2019 scenario and the 2050 BAP scenario in every season. The demand for space heating is apparent in the winter and to a lesser degree in the fall.

Electricity demand in commercial buildings increases in the spring and summer in both Scenario A and Scenario D relative to the 2019 demand curve but in both cases remains below the 2050 BAP demand curve.

The demand curves also highlight opportunities for demand response, notably for domestic hot water heating, and space heating, if storage is installed.

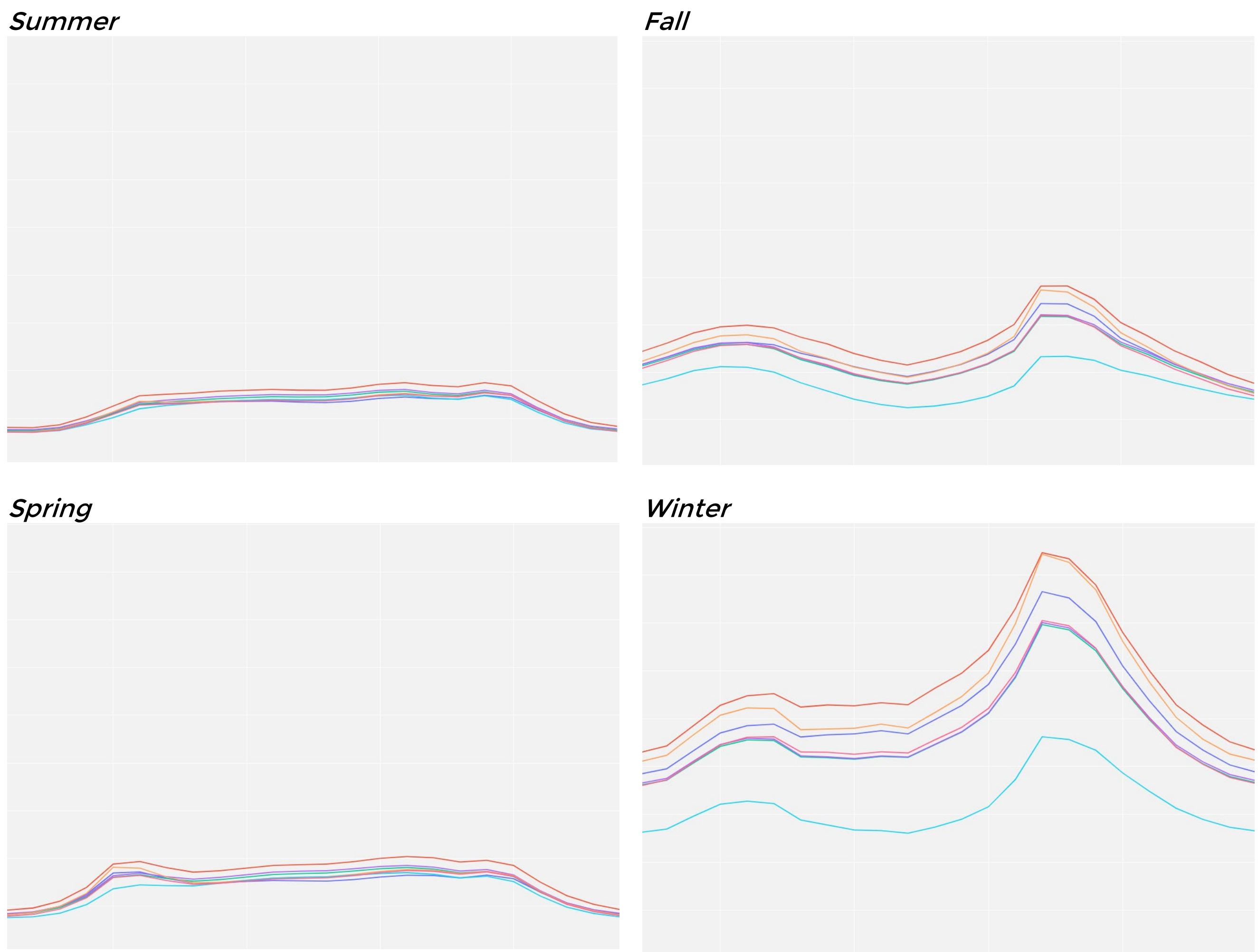


FIgure 50. Seasonal daily demand curves for the integrated scenarios

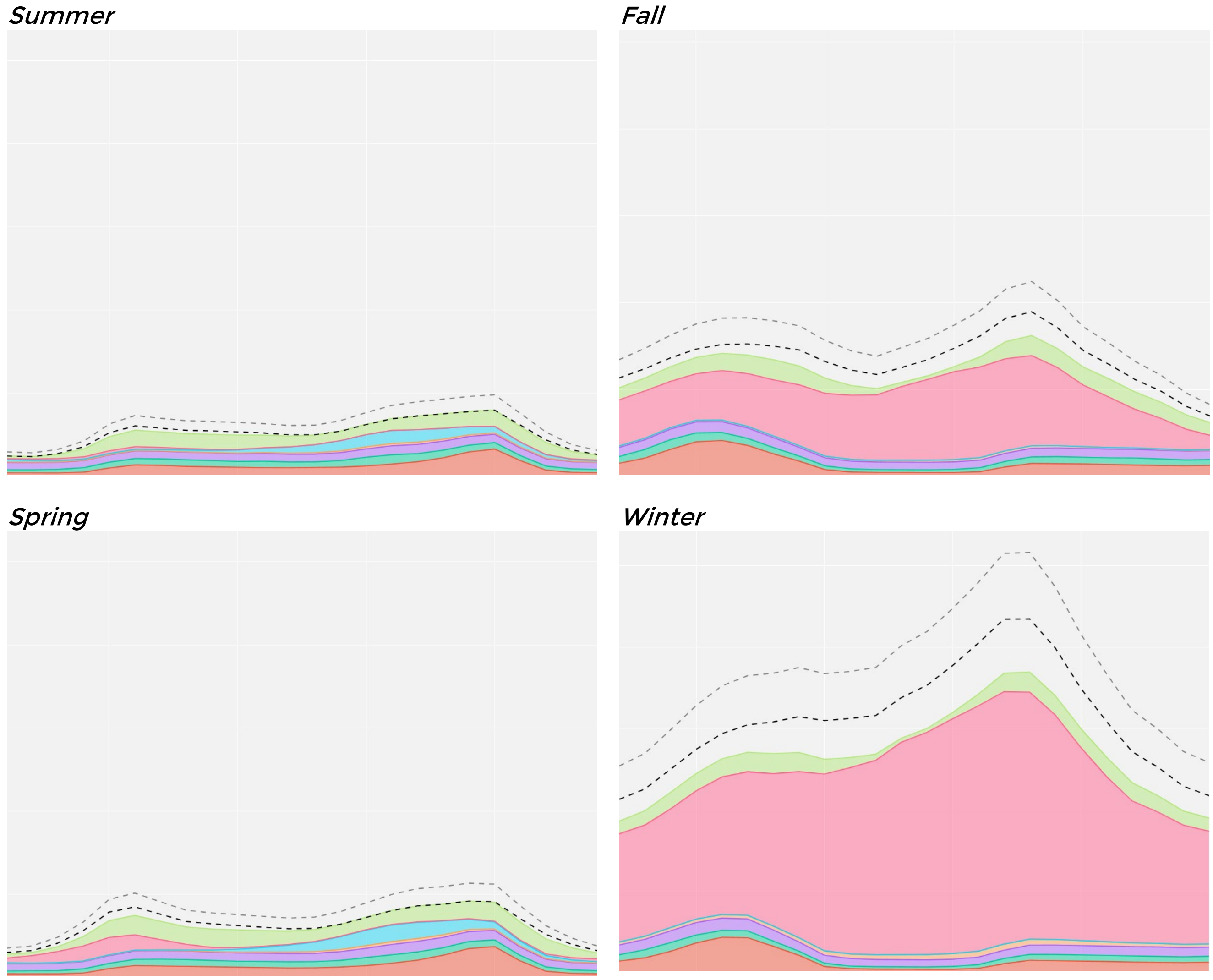


Figure 51. Seasonal daily residential demand curves for scenario A by end use

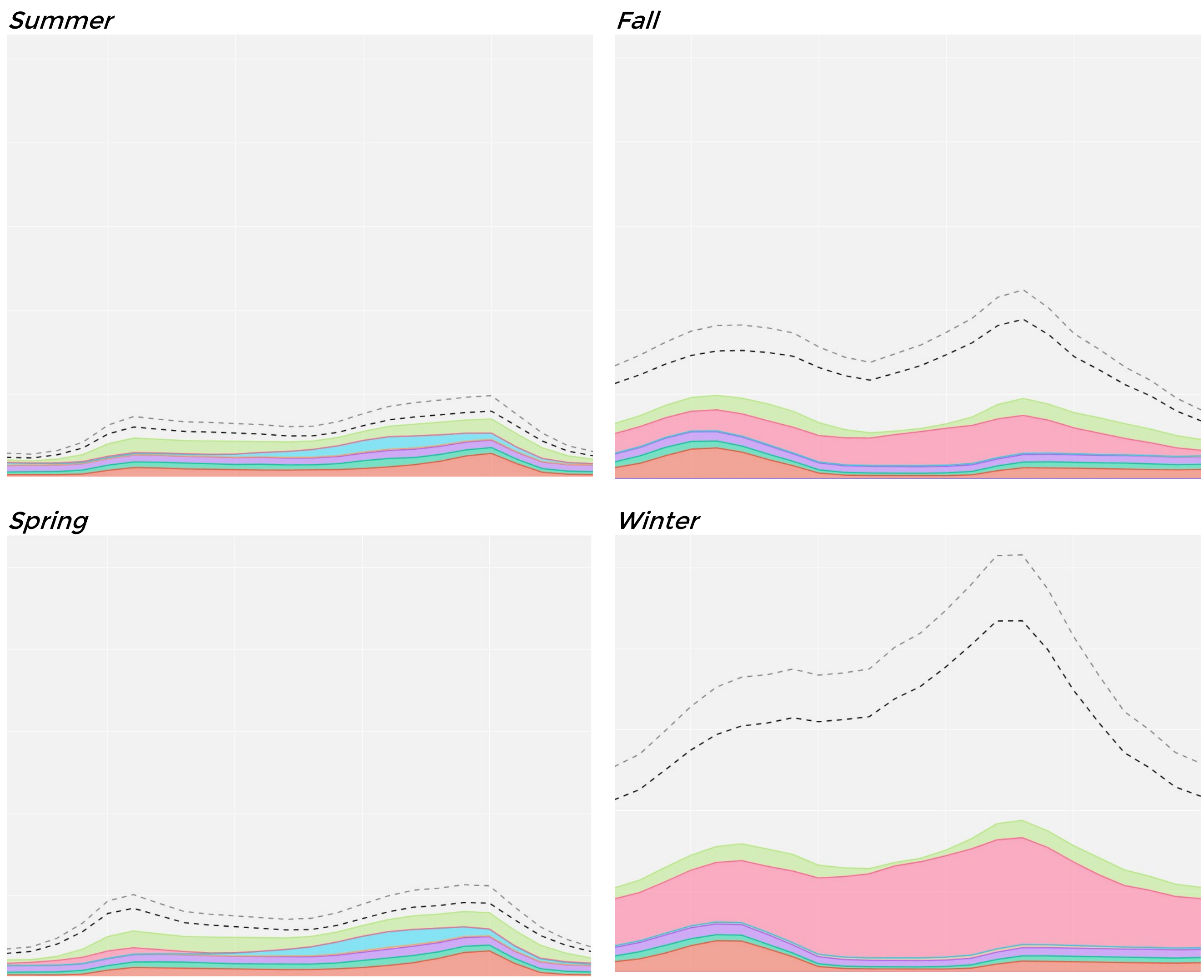


Figure 52. Seasonal daily residential demand curves for scenario D by end use

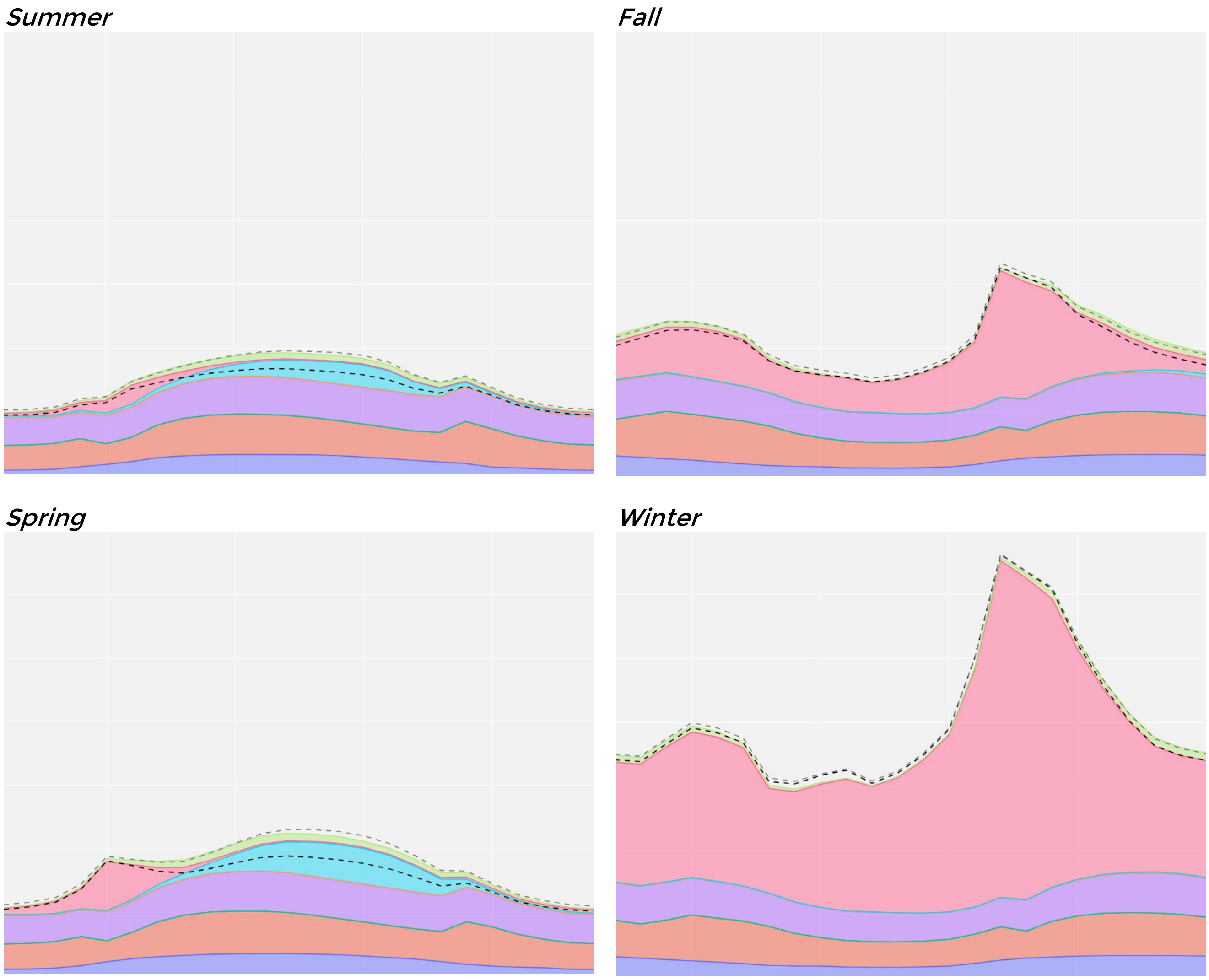


Figure 53. Seasonal daily commercial demand curves for scenario A by end use

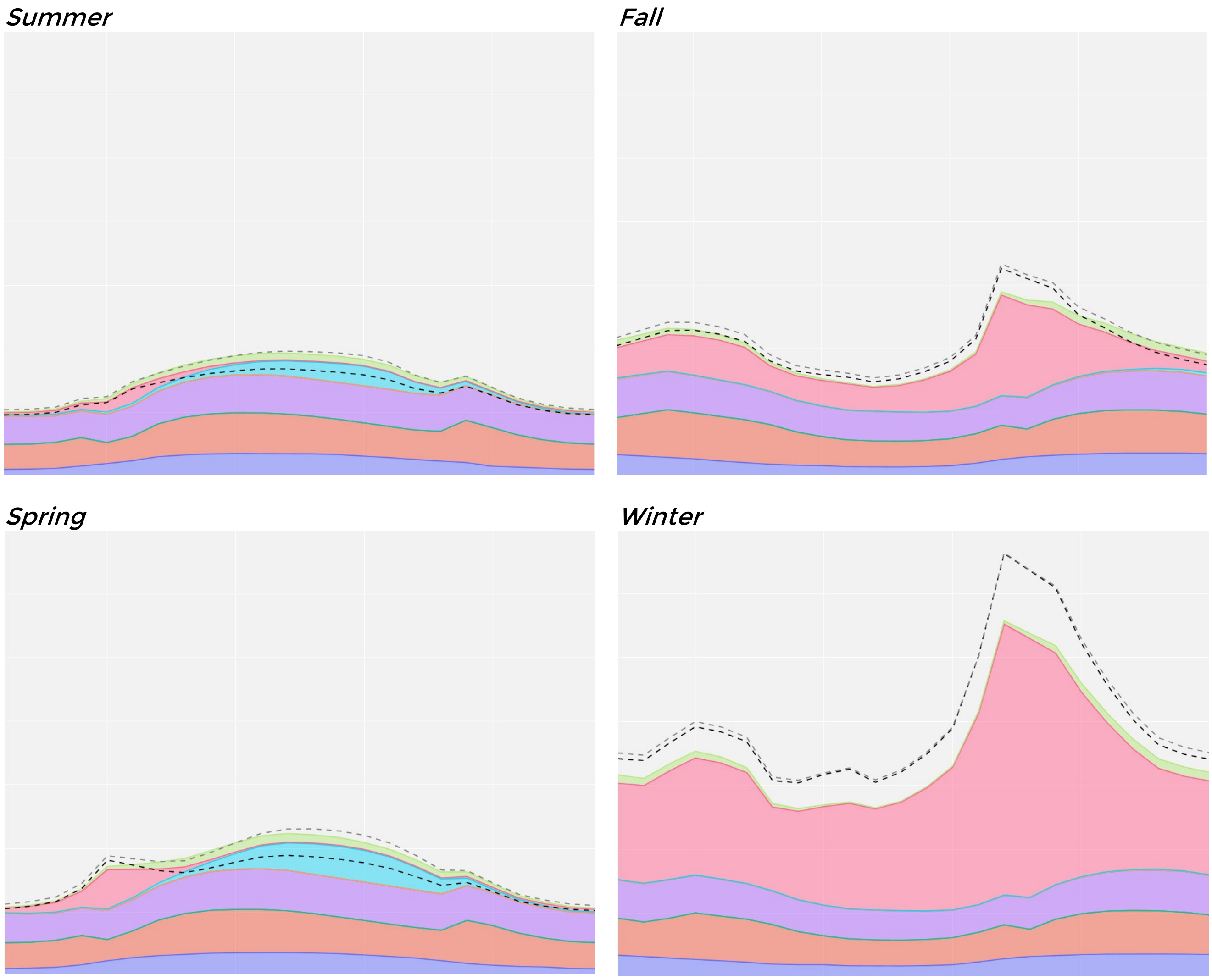


FIgure 54. Seasonal daily commercial demand curves for scenario D by end use

4. Discussion

1. **Many of the policies are "no regrets":** Most of the policies generate net financial savings, including:
    a. Policy 1a, 1b, 1c, 1d: Building Performance Standards
    b. Policy 2a, 2b: Promote, incentivize and or subsidize energy efficiency and heating/cooling
    c. Policy 3a: Decarbonize institutional/public buildings
    d. Policy 4a, 4b: Promote, incentivize, and/or subsidize heat pumps
    e. Policy 6a, 6b: Enact energy-efficient building codes
    f. The addition of the financial benefits of avoided climate damage (the social cost of carbon) or avoided health costs further increases this benefit; in this case only policy 2c and 2d have a net cost.

2. **Household energy costs are reduced:** Relative to 2019, policies decrease household costs by between 2.6% and 37% by 2050, using conservative projections on energy costs.

3. **Several policies and all integrated scenarios can achieve the GHG target:** The building performance policies (1c and 1d) and the heat pump policies (4a and 4b) achieve Oregon's GHG target. Policy 4b achieves the deepest GHG emissions reduction. All five integrated scenarios achieve Oregon's GHG target.

4. **Capital costs of the more ambitious policies are less than 1% of Oregon's GDP:** Policy 2c and 2d (Promote, incentivize and or subsidize energy efficiency and heating/cooling) require the highest average annual capital investments of approximately $2 billion, 0.74% of Oregon's GDP. Policy 6c and 6d are the second highest at $1.6 billion.

5. **Embodied carbon is the largest opportunity for emissions reductions:** Policy 5b results in average annual reductions of 3.3 million MtCO2e. Embodied emissions are accounted for differently than operational emissions, so these reductions don't directly contribute to achieving Oregon's GHG target.

6. **Electricity demand will increase in the BAP scenario:** Population growth increases electricity demand from the residential and commercial sectors in the absence of any policies considered by the Task Force.

7. **The policies reduce electricity demand from residential and commercial buildings:** Compounding efficiency benefits limit the impact of heat pumps on peak demand in the winter. For example, a poorly insulated house with baseboard heating that gets retrofitted (50% thermal reduction) and that gets a heat pump will need only 1/6 of the electricity from before. Further, Oregon has a reservoir of "free" electricity that is currently consumed by electric baseboard heating from which to heat additional existing or new buildings.
8. **The financial results are sensitive to energy costs:** The results are sensitive to energy costs. For example, the analysis assumes a 2022 cost of $13.48/MMBTU for natural gas, while the cost in August, 2022 was $18.98/MMTBU, a 41% increase. Increases in natural gas costs will

increase the financial benefits of those scenarios which increase adoption of heat pumps. Similarly, increases in electricity costs will decrease the financial benefit of these scenarios.

9. **The policies reduce the implementation risks for HB 2021 and CPP:** By reducing electricity demand and GHG emissions from natural gas, the policies reduce the burden for utilities to achieve their respective targets/caps.

10. **Retrofits are more expensive but reduce electricity demand:** Deep energy retrofits are capital intensive but are instrumental in reducing peak demand, and the economic value of the avoided demand, and resulting avoided electricity generation capacity, is not included in this analysis.

11. **Retrofits provide co-benefits:** Building retrofits provide the most jobs (policy 2c and 2d) and increase the resilience of homes. They also result in public health benefits.

12. **Combining policies result in compounding benefits**: The abatement cost of the most ambitious retrofit policy (2c) is $560/MtCO2e. When combined with the most ambitious heat pump policy, which has an abatement cost of -$130/MtCO2e, the combined abatement cost is $42/MtCO2e.

13. **Highest and best use:** RNG is used in policy 1c, alongside heat pumps. Given RNG availability is constrained, it makes sense to preserve this fuel for activities which require combustion, such as industrial applications.

14. **The social cost of carbon:** Avoided damage from climate change as a result of the policies ranges from -$4 million per year to -$255 million per year. New estimates of the Social Cost of Carbon would increase these numbers by a factor of four.

15. **Policies need targets:** Policies can take many flavors, with different outcomes for energy, emissions and additional benefits. Targets, and parameters, such as which component of the building stock is applicable, are necessary in order to achieve those targets.

16. **The scenarios are guideposts, not prescriptions.** None of the scenarios may be the preferred pathway, but they provide directional guidance on what would happen if a policy achieves a particular outcome.

Appendix 1: Policy Details

1	**Building performance standards**	*1a*	*1b*	*1c*	*1d*
		Direct emissions need to reach 5% below 2035 levels in the BAP by 2035		Direct emissions need to reach 40% below 2035 levels in the BAP by 2035	
		Existing residential, commercial and multi-family buildings			
		All building sizes	Buildings ≥ 35,000 ft2	All building sizes	Buildings ≥ 35,000 ft2
2	**Promote, incentivize and or subsidize energy efficiency and heating/cooling**	*2a*	*2b*	*2c*	*2d*
		50% of buildings are retrofitted by 2050, thermal energy requirements reduced by 15%		100% of buildings are retrofitted by 2035, thermal energy requirements reduced by 50%	
		All building types			
		Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2	Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2
3	**Decarbonize institutional/public buildings**	*3a*	*3b*		
		New buildings after 2035 are carbon neutral	New buildings after 2023 are carbon neutral		
		50% of buildings are retrofitted by 2045; thermal energy requirements reduced by 15%; plug load reduced by 15%	100% of buildings are retrofitted by 2035: thermal energy requirements reduced by 50%; Plug load reduced by 50%		
4	**Promote, incentivize, and/or subsidize heat pumps**	*4a*	*4b*		
		80% of covered buildings have a heat pump installed by 2040	100% of buildings that are covered have a heat pump installed by 2035		
		New and existing residential and commercial buildings			
5	**Assess and disclose material-related emissions**	*5a*	*5b*	*5c*	
		Reduce embodied carbon from construction by 20% by 2030, compared to 2015	Reduce embodied carbon from construction by 60% by 2030, compared to 2015	Reduce embodied carbon from construction by 100% by 2050, compared to 2015	
		Residential and commercial buildings			
6	**Enact energy-efficient building codes-Existing**	*6a*	*6b*	*6c*	*6d*
		2% of existing buildings are retrofitted each year until 2050, thermal energy requirements reduced by 15%, plug load		8% of existing buildings are retrofitted each year until 2035, thermal energy requirements reduced by 50%,	

		reduced by 15%		plug load reduced by 50%	
		Existing residential and commercial buildings			
		Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2	Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2
	Enact energy-efficient building codes- New	A 40% reduction in new building energy consumption from the 2006 Oregon codes		A 80% reduction in new building energy consumption from the 2006 Oregon codes	
		New residential and commercial buildings			
		Buildings ≥ 50,000 ft2	All buildings	Buildings ≥ 50,000 ft2	All buildings

Appendix 2.Comments from the Task Force

Comment/ question from the Task Force	Adjustment to the modeling approach	Details
What is the definition of "plug load"? How will the reductions be accomplished?	No change	Plug loads are energy used by equipment that is usually plugged into an outlet. These sources would include equipment such as appliances, computer equipment and AV equipment. Plug loads are not related to general building lighting, heating, ventilation, cooling, and water heating, and typically do not provide comfort to the occupants. Modern technology usually incorporates a variety of power modes with most electronic devices (computers, stereos, tvs) drawing power even when they are turned off. Some strategies involved in reducing plug load include • Upgrading equipment • Turning equipment off when not in use • Employing plug-load automation and controls • Promoting beneficial occupant behaviour The following source is a good resource for commercial buildings but many of these strategies can be applied to residential buildings as well. Plug Load Frequently Asked Questions (FAQ) | GSA
The use of the AVERT tool	No change	EPA's AVERT tool calculates the change in air pollutants as a result of electricity generation on an hourly basis. The change in outputs is calculated within the model used by the modelling team. While AVERT has a higher temporal resolution, it does not include the full energy system. Additionally, the AVERT tool doesn't project future emissions as the generation mix changes.
The inclusion of	RNG is included in	RNG is included in Policy 1. Policy 1 is a Building Performance

Renewable Natural Gas (RNG)	Policy 1	Standard that applies GHG targets, but does not specify how those GHG targets will be achieved. The amount of RNG available to Oregon is based on the current state of the RNG supply for the US. The total RNG supply in 2040 in the US is assumed to be 3,750 trillion BTUs. Power to gas/Methanation was excluded from this total. This total was shared out to Oregon according to the population of Oregon relative to the total US population, resulting in a total of 47.5 trillion BTUs of RNG available to Oregon by 2040. RNG was distributed to the residential building sector based on the share of natural gas left in this sector after the policy mechanism was implemented. "Best use" scenarios may direct RNG to sectors that are harder to decarbonize and these results may change. Policy 1c and policy 1d consume 7.5 trillion BTUs of RNG by 2040.
The inclusion of CPP	A figure illustrating the impact of CPP has been added to the scorecard (Figure 3)	The impact of CPP is represented in a figure for each policy (Figure 3). Because the analysis applied only to residential and commercial sectors while CPP applies to all natural gas consumption, the assumption was made that CPP GHG reduction requirements apply directly to the residential and commercial sectors to generate the CPP curve in the figure. In this figure, the reductions from the policy are subtracted from CPP, illustrating the additional emissions beyond the impact of the policy that must be reduced in order to achieve the CPP requirements. CPP was not illustrated for policy 5, because policy 5 does not apply to the energy system. The remaining CPP wedge varies in size according to the size of the policy wedge evaluated. No determination was made with respect to how the CPP GHG emissions reductions will be achieved.
The inclusion of hot water heaters	Heat pumps for hot water heaters have been added	Hot water heat pumps were added to policy 1 and policy 4.
GHG targets	A line representing the GHG target has been added to Figure 2	A line has been applied to Figure 2 to illustrate a proportional application of Oregon's GHG target of 80% below 1990 levels by 2050. The target is proportional in that the percent reduction has been applied to the residential and commercial building sectors.
The inclusion of indoor air quality	Not assessed	SSG explored strategies to assess indoor air quality changes as a result of the policies, including meeting with OHA. Given the complexity of factors influencing indoor air quality, such as access to and rate of ventilation, exposure to new materials within the building envelope, combustion within the building envelope and other factors, there was insufficient time to develop a substantive approach.
The inclusion of peak demand	Peak demand will be modeled for the integrated scenarios	Peak demand is generally reduced by policies which increase energy efficiency, and may be increased by fuel switching. Impacts on peak demand will be evaluated in the analysis of the integrated scenarios.

The inclusion of climate resilience	An indicator of resilience is included in the scorecards.	The indicator of climate resilience is the number of homes retrofitted, where a retrofit is assumed to increase the resilience of the building against extreme heat or cold for a longer duration, known as passive survivability. The benefit of access to cooling for dwellings which have heat pumps installed was not assessed.
Method for assessing embodied carbon policy	The modeling approach is aligned with DEQ's approach	SSG worked with data provided by DEQ to model this policy, ensuring alignment with their work.
Inclusion of Inflation Reduction Act Tax Incentives and Rebates	The financial benefits of the IRA have not been quantified. We may include this benefit in the analysis of the integrated scenarios	IRA will reduce the capital cost of applicable actions, increasing the financial benefit.
Inclusion of avoided costs/stranded investments	Not assessed	Stranded investments are investments in fossil fuel assets that could be lost if climate policies limit emissions in line with climate targets. SSG believes a more detailed representation of gas infrastructure would be required to evaluate this impact.
Inclusion of future price volatility	Not assessed	SSG uses the future price projections from the EIA for the Pacific Region.
Analysis of energy burden	Energy burden will be assessed for the integrated scenarios	If a home's energy costs exceed 6 percent of income it is considered energy burdened. If a household spends more than 10 percent of its income on energy, it is considered extremely energy burdened.
Range of policies	Both a less and more stringent policy implementation has been modeled	
Data from Oregon	Datasets from Oregon are applied.	The model uses data from Oregon wherever possible; in some cases national sources are used which report on data for Oregon (i.e. EIA). A complete set of data sources will be included in the Data, Methods and Assumptions Manual
Full costs to homeowners and businesses	No change	Capital, maintenance and operating costs are evaluated for each policy over the lifetime of the investment.

Appendix 3. Policy Scorecards

Attached

Appendix 4. Integrated Scenario Scorecards

Attached

Appendix 5. Qualitative Policy Scorecards

Attached

Appendix 6. Data, Methods and Assumptions Manual

Attached

Appendix 7. Financial Cost Catalog

Attached