CLACKAMAS COUNTY

CLIMATE ACTION PLAN

Fall 2023

Contents

Community Engagement Acknowledgement

The Community Advisory Task Force (CATF) and Youth Advisory Task Force (YATF) were formed with membership from a cross-section of residents, including representatives from various community organizations, academic institutions, businesses (including a Chamber of Commerce), and sectors within Clackamas County. Their participation, guidance, and feedback have been integral to the development of the Climate Action Plan and we gratefully acknowledge the time, dedication, and insights shared.

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Executive Summary

Executive Summary

By 2023, a Climate Action Plan is adopted for our community with specific recommendations to reach the goal of being carbon neutral by 2050.

Performance Clackamas: Clackamas County Strategic Plan, March 2021

This Clackamas County Climate Action Plan report is a strategic-level document that outlines the county's goals and objectives for addressing climate change, as well as the strategies to achieve the goal of carbon neutrality. The plan includes an Implementation Guide (separate document) that lays out the actions proposed to implement the strategies, and a Climate Lens (separate document) to support decision-making within the county.

Climate change is a global issue that is causing significant human, social, economic, and environmental hardships worldwide, and the state of Oregon is no exception. Rising temperatures, changing precipitation patterns, and other effects of climate change are leading to increased frequency and severity of heat waves, droughts, and wildfires that affect all of Oregon's water resources, agriculture, and forestry sectors. Given the significant impacts that climate change is having on the state, it is imperative that action is taken to address it.

Effective climate action can be thought of as a dance – in the sense that it involves different individuals, organizations, government and the private sector working together in a coordinated way to achieve a common goal. Just as dancers must move in unison to perform a dance routine successfully, individuals, organizations, government and the private sector must work together to address climate change.

Additionally, just as a dance is a process that requires ongoing practice and adaptation to improve, climate action also requires ongoing effort and adaptation to be effective.

Clackamas County is facing the threat of climate change and its associated impacts. This report focuses on how the county can reduce community-wide emissions from the major non-consumption-based[1] sectors in the community: buildings (residential, institutional, commercial, and industrial), transportation, and waste. To provide guidance on what actions and what scale of action are necessary to reach carbon neutrality in Clackamas County, an understanding of the local context - current energy use and emissions, and plausible projections for energy use and emissions based on current practices, policies, and demographic projections - was developed - the Business-As-Planned (BAP) scenario.

The BAP illustrates a likely scenario of community energy use and greenhouse gas (GHG) emissions between 2018 and 2050 based on the community taking no additional action on climate change beyond current policies and practices that are in place or are guaranteed through

[1] Non-consumption-based sectors are generally defined in this report as Scope 1 and Scope 2 emissions. Scope 1 emissions are direct greenhouse gas (GHG) emissions from sources controlled or owned by an organization (e.g., associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Although Scope 2 emissions physically occur at the facility where they are generated, they are accounted for in an organization's GHG inventory because they are a result of the organization's energy use. Source: *https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance*

government plans and committed funding. This scenario serves as a benchmark, or starting point, against which Clackamas County can measure the effectiveness of its emissions reduction efforts and communicate the county's reduction strategy to interested and affected parties (stakeholders) and the general public.

Modeling was conducted to illustrate a Low-Carbon Scenario (LCS) that contains actions that can be taken to reduce carbon emissions throughout the county. The financial costs and benefits of each action in the Low-Carbon Scenario were also estimated.

Carbon neutrality is achieved specifically by reducing carbon in the community, which includes energy-use avoidance, energy efficiency, and the replacement of fossil fuels with renewable energy technologies and energy systems. To balance any remaining human-driven emissions, carbon removal or sequestration can be achieved through restoring or enhancing natural lands and soils or through direct air capture and storage technology. The strategies of avoid, reduce, replace, remove, offset are prioritized to tackle the problem at the source. The state of Oregon has also initiated regulations such as the Climate Protection Program (CPP) and House Bill 2021 (HB2021) to reduce greenhouse gas emissions; these regulations align with the county's goal of a carbon neutral future.

The critical sectors for decreasing emissions in Clackamas County, which are included in this report are:

- Building Retrofits,
- Net-Zero New Construction,
- Renewable Energy Generation,
- Reducing Vehicle Emissions and
- Increasing Active Transportation and Transit Use.

All of the actions in the Climate Action Plan tackle these critical sectors to create the LCS. To achieve carbon neutrality, these actions cannot go unaddressed, nor can some actions be implemented while others are ignored.

This LCS shows that emissions will be reduced by 83% if the community fully implements the sector-based actions identified in the Implementation Plan. Employing sequestration can take the county the rest of the way to reach carbon neutrality by 2050. The LCS scenario shows the following changes in emissions:

- Buildings, which represented half of the community's emissions in 2018 (nearly 2 million $MtCO_2e$), will be 0.1 million $MtCO_2e$ in 2050.
- Transportation emissions will be reduced by 93% below the baseline.
- Emissions from waste will increase by 131%.
- Agriculture-related emissions will decrease by 9%.

The LCS shows overall community energy use decreasing by 43.5%, building energy use decreasing by 26% and transportation energy-use decreasing by 68%.

The actions recommended in the Implementation Guide reflect the high-level outcomes of the LCS, as well as engagement with the community; input from the Community Advisory Task Force (CATF), county staff and department directors, and best practices in many other communities.

An important component of this project was the consultant's high-level economic modeling of some of the low-carbon opportunities. Transitioning to a low-carbon economy will require investments in all sectors of the community. Implementing the low-carbon scenario is projected to generate a net return of $12.3 billion across the county above the business-as-planned (BAP) scenario. The net return is based on savings in operations and maintenance, savings in energy costs, and revenue generation. The overall investment across the county amounts to $8 billion, while savings amount to $23 billion.

Implementing the LCS will also generate job growth in Clackamas County, with the estimated creation of 36,000 person-years of employment[2] between 2023 and 2050.

In many cases the actual costs of implementing the LCS to Clackamas County residents and businesses will be lower than the conservative assumptions made in this analysis. That is the case because incentives and rebates currently available through local, state, and federal programs are not included in the analysis. Investigating all financial tools available to the county and other community stakeholders will be critical for the implementation of the low-carbon actions.

Transitioning to a low-carbon economy is essential to addressing the effects of climate change and ensuring a viable, sustainable future for Clackamas County. Implementing the LCS will require investments in all sectors of the community, including residents, businesses, institutions, and government. However, these investments will yield significant returns in terms of energy savings, revenue generation and job growth. Climate action taken today will ensure that Clackamas County's carbon neutral future is a bright one.

[2] Person-years of employment is defined on page 40. This estimate reflects the difference between the Business-as-Planned (BAP) and Low-Carbon (LCS) scenarios. Some areas have gains and some have losses.

How to Read this Climate Action Plan Report

Key Sections of This Report

This plan is divided into the following key sections:

The Climate Action Imperative: Clackamas County's Climate Action Plan (Overview)

Outcome One: Reduce Community-Wide Emissions

Outcome Two: Reduce Consumption-Based Emissions

Outcome Three: Adapt to Climate Change and Reduce Climate-Related Risk

What is a Climate Action Plan?

A climate action plan (CAP) is a strategic document that outlines actions that a government, business, or organization plans to take to reduce greenhouse gas emissions (GHGs) and address the impacts of climate change. It typically contains a set of specific, measurable, and time-bound goals and actions to reduce emissions, as well as strategies for adapting to the impacts of climate change that are already happening or projected to occur.

CAPs may also include information on how the organization will engage with interested and affected parties[3], monitor progress, and report on progress. Essentially, a CAP is a strategic-level document that contains a framework to guide administrative bodies in addressing the specific impacts of climate change in their communities.

CAPs are important because they can be applied at different institutional levels, from city, county and regional governments, and educational institutions, to federal programs. A climate plan's emissions targets and goals are usually decided on and approved by a governing body. Creation and adoption of the plan is often completed in collaboration with interested and affected members of the public.

While CAPs can differ in scale, based on the community or region they are addressing, several sections – listed below -- are consistently included to identify and track progress against climate targets.

- A greenhouse gas emissions inventory;
- Modeled scenarios that project future emissions in a Business-as-Planned (BAP) scenario by sector and by fuel type;
- A modeled pathway, often called a low-carbon pathway or, in this report, Low-Carbon Scenario (LCS), that shows the size, scale, and timeline for emissions reductions as guided by the target;
- A model of financial details for the actions associated with the LCS;

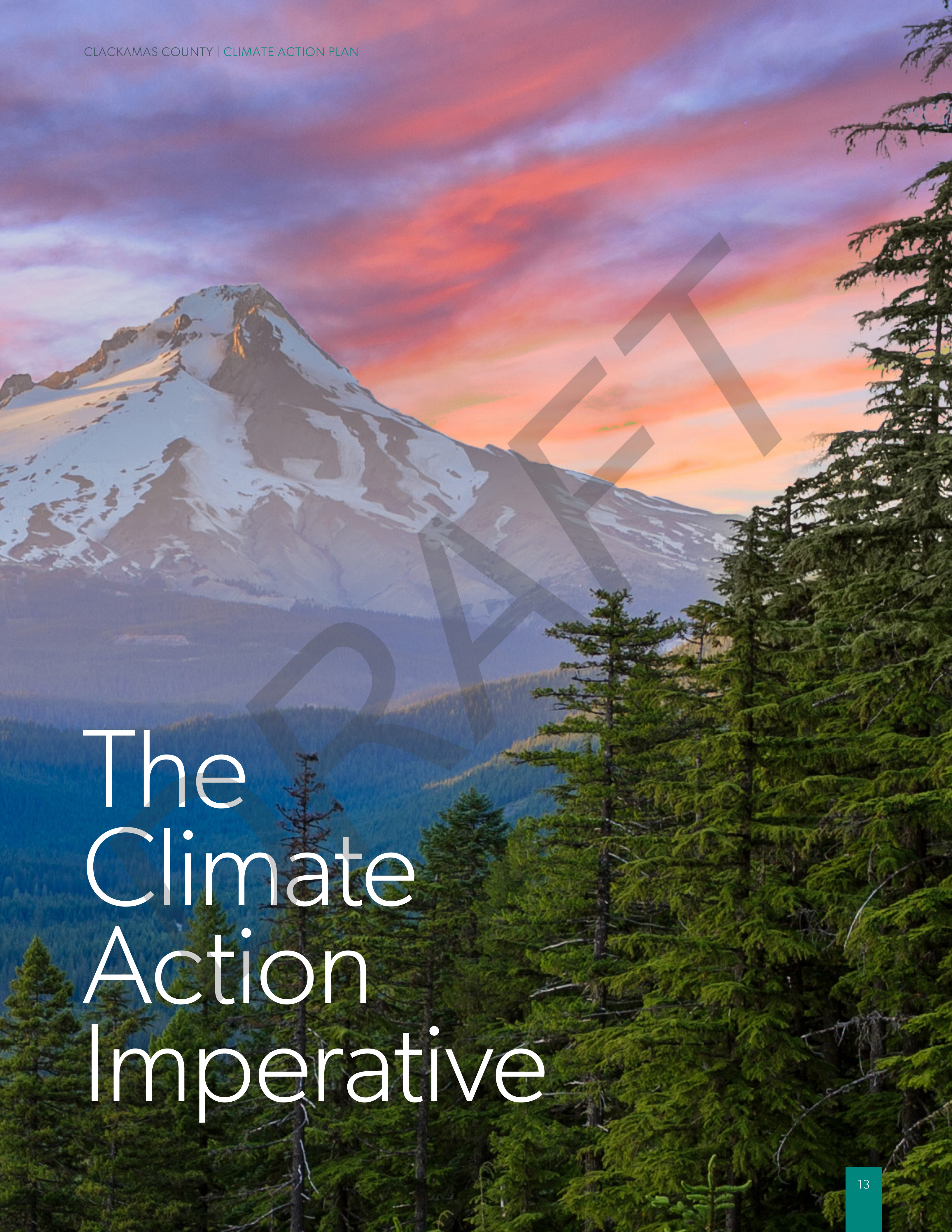
[3] Often referred to as 'stakeholders'. Interested and affected parties is a newer way of speaking of these members of the public who have an interest in or are affected by a particular decision a governing body is making.

- A target for reaching carbon neutrality or net-zero emissions;
- Strategies and mechanisms for implementation that include various recommendations such as policies, proposed regulations, partnerships, opportunities for advocacy, and programs.

Clackamas County's Climate Action Plan is accompanied by a detailed ***Climate Action Plan Implementation Guide*** that has also been developed with input from county staff and community members.

Clackamas County's Board of Commissioners directed development of this Climate Action Plan to ensure it:

- addresses greenhouse gas mitigation and adaptation,
- includes an Implementation Guide, and;
- includes a Climate Lens to support county decision-making.



The Climate Action Imperative

The Climate Action Imperative

Climate change is a global issue that is receiving increasing attention and concern from governments, organizations, and individuals around the world. In response, many countries have implemented policies and initiatives to reduce greenhouse gas emissions and transition to renewable energy sources.

Changes to global climate patterns, collectively known as 'climate change'[4] have been accelerating over the past century. These changes have disrupted Earth's natural systems and are causing social, economic, and environmental hardships that are only beginning. To take just one example of the rising cost of climate change: there were 20 climate-related disasters in the United States in 2021 that exceeded one billion dollars in damages each. Together, these events resulted in $148 billion in damages and at least 724 lives lost, adding to 323 events since 1980 with 15,347 deaths, and nearly $2.2 trillion in damages.[5]

Similar events, costs, and losses of life are being experienced around the world. Projections show vast increases in climate-driven events over the coming decades, leading the World Economic Forum to identify the lack of climate action as the greatest social, economic, and environmental risk of 2022.[6] These risks will continue to mount as local and global greenhouse gas (GHG) emissions increase and the Earth continues to warm at an unprecedented rate.

Strategic-level Plan vs. Feasibility Plan

A strategic plan is a broad outline of an organization's goals and strategies, whereas a feasibility study provides an in-depth analysis of a specific project's viability. The report at hand is a strategic plan intended to guide future actions and inform subsequent feasibility studies for validating those actions' potential for success.

Local Impacts

Here at home, climate change is having a significant impact on the state of Oregon. Rising temperatures and changing precipitation patterns are leading to increased frequency and severity of heat waves, droughts, and wildfires. These impacts are exacerbating existing environmental and economic challenges and putting communities at risk.

Climate change is having an impact on water resources, with changes in snowpack, streamflow, and sea level[7,8]. This can lead to water scarcity in some areas, and flooding and landslides in others.

4 Also referred to as 'global warming'.

5 NOAA National Centers for Environmental Information (NCEI). (2022). U.S. Billion-Dollar Weather and Climate Disasters *https://www.ncei.noaa.gov/access/monitoring/billions/, DOI: 10.25921/stkw-7w73*

6 World Economic Forum. (2022). Global Risks Report 2022. *https://www.weforum.org/reports/global-risks-report-2022*

7 Oregon Water Resources Department. Retrieved from: *https://www.oregon.gov/owrd/programs/climate/pages/default.aspx#:~:text=Increased%20air%20temperatures%2C%20changing%20precipitation,2080s%20(see%20figure%20below)*

8 EPA. Climate Change Impacts on the Northwest. Retrieved from: *https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-northwest_.html*

The agriculture and forestry sectors are also being affected, with crop yields and timber productivity declining as a result of increased pests and diseases, and more extreme weather events.

Weather vs. Climate

Think about what you'd wear each day. If it's raining, you might wear a raincoat. If it's sunny, you might wear a t-shirt. That's the weather. Weather is what's happening right now, or what might happen over a short period, like hours or days. It's the conditions we see and feel each day — like rain, sunshine, wind, or snow.

Now, imagine if you're packing for a trip to a tropical island or a snowy mountain. You would pack different clothes for these places, right? That's because you know what the climate is like there. Climate is the long-term pattern of weather in a certain area. It's what you'd expect the weather to be like over many years.

In short, weather is what you get day to day, but climate is what you expect over many years. They're different, but both are important in understanding our planet and how we live on it.

Given the significant impacts that climate change is having on the state of Oregon, causing harm to the environment, economy, and communities, it is imperative that government bodies take action to address it. This includes implementing policies and programs that reduce greenhouse gas emissions, increase resilience and adaptation to changing conditions, and support the transition to a low-carbon economy.

Now more than ever is the time to act to meet these targets. Two things have become abundantly clear over the past two decades of global GHG emissions target-setting and climate change action:

1. Targets can be set and missed. Clear, achievable, localized plans are needed so targets can be met.
2. Climate change is a global problem for which local solutions are critical. All levels of government need to participate in leading and supporting the reduction of GHG emissions, but local governments understand the unique demographics, physical landscapes, and opportunities and challenges in their communities. Local governments cannot bear the whole burden of mitigating and adapting to climate change, but they are powerful catalysts for change. They are in a unique position to lead, support, and advocate.

Climate change is expected to continue to impact Clackamas County. Rising temperatures may lead to increased frequency and intensity of wildfires, threatening homes and natural habitats. Changes in precipitation patterns could lead to both drought and flooding, affecting the county's water supply and agricultural sector (discussed in Outcome Three of this plan). Warmer winters might lead to less snow accumulation in the mountains and more powerful winter storms, altering the timing and volume of spring runoff, which can affect local hydroelectric power generation. Changes in temperature and precipitation patterns could impact the county's diverse ecosystems and the species that live within them.

For a specific example, changes in climate are likely to significantly affect rivers in the county, including the Sandy River. Reduced snowfall and earlier snowmelt due to warmer temperatures could lower the river's water levels, affecting both the aquatic life and the recreational activities it supports. More intense rainfall events, on the other hand, could lead to increased flooding and continue to affect channel repositioning along the river, posing a risk to adjacent communities and ecosystems.

Clackamas County is not alone in taking climate action; with this plan it joins a growing group of US municipalities working to accelerate net-zero emissions. In 2021, a bipartisan group of U.S. mayors representing more than 54 million Americans pledged to put equity at the heart of climate action, while doing their fair share to help the United States reach its goal to halve emissions by 2030 and achieve net-zero by 2050.[9]

For its part, Clackamas County set a community-wide GHG emissions reduction target and a goal to increase climate resilience. The Board of Commissioners directed the development of this Climate Action Plan to address greenhouse gas mitigation and adaptation, an Implementation Guide, and a climate lens to support long-term county decision-making.

Climate Impacts: Local and Global Effects, in General

Think of Oregon like a patchwork quilt. Each patch, or area, is a bit different. Some patches are mountains, some are valleys, and some are coastal areas. Because each patch is unique, the ways that climate change affects them can also be different.

For example, in the coastal areas, rising sea levels might be a big concern because they can cause flooding. In the mountains, warmer temperatures might mean less snowfall, which can affect water supply and winter sports.

However, even though the specific impacts of climate change might be different in each area, the overall theme is the same across all of Oregon: climate change is causing problems. This is like how each patch in the quilt is different, but they all come together to make one quilt.

In all parts of Oregon, people might see changes in weather patterns, shifts in seasons, or more extreme weather events like heatwaves or heavy rains. These changes can affect everything from farming to fishing to outdoor recreation.

So, while climate change might look a little different in each part of Oregon, the fact is, it's happening everywhere in the state. It's like the thread that's weaving through every patch of the quilt, connecting them all together.

[9] C40 Cities. Press Release, 25 October 2021. More than 100 American Cities Make Historic Pledge to Accelerate Net-Zero Emissions, Deliver Action Needed to Meet National Climate Goals. *https://www.c40.org/news/american-cities-net-zero-climate-goals/*

Global Action

The global community is responding to this challenge at its own pace. In December 2015, 196 countries adopted the Paris Agreement at the Conference of the Parties (COP) 21. Signatories of the Agreement agreed to curb GHG emissions to limit global warming to well below 2°C above pre-industrial levels, and preferably less than 1.5°C. At COP26 in Glasgow, Scotland in October and November 2021, the 1.5°C target was confirmed by the majority of participants as being necessary to avoid the most catastrophic climate change impacts.

Many countries are also setting targets to increase the use of renewable energy. For example, the European Union has set a target of 32% renewable energy by 2030[10], and China plans to increase the share of non-fossil fuels in its primary energy consumption to around 20% by 2030[11].

In addition, governments and organizations are investing in research and development of new technologies to reduce emissions and adapt to the impacts of climate change. For example, the US government invested in research in clean energy technologies through the Department of Energy's ARPA- E program[12], while private companies are investing in electric vehicles, energy storage, and carbon capture technologies.

Individuals and businesses are also taking action to reduce their carbon footprint and promote sustainability. For example, more and more companies are setting science- based emissions reduction targets1, and many individuals are also making changes in their daily lives, such as using public transportation, eating less meat, and consuming less energy, to reduce their carbon footprint.

[10] Reuters. 30 March 2023. EU reaches deal on higher renewable energy share by 2030. *https://www.reuters.com/business/sustainable-business/eu-reaches-deal-more-ambitious-renewable-energy-targets-2030-2023-03-30/#:~:text=Negotiators%20of%20the%20European%20Parliament,a%2032%25%20renewable%20energy%20share*

[11] International Energy Association (IEA). An energy sector roadmap to carbon neutrality in China: Executive Summary. *https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china/executive-summary*

[12] US Department of Energy ARPA-E program: *https://arpa-e.energy.gov*

Clackamas County's Climate Action Plan

In response to climate change, this Climate Action Plan (CAP) is designed to set the stage to achieve the following community-wide outcomes:

- Reduce GHG emissions to carbon neutral by 2050;
- Quantify community-wide consumption-based emissions; and
- Adapt to climate change and reduce climate-related risk.

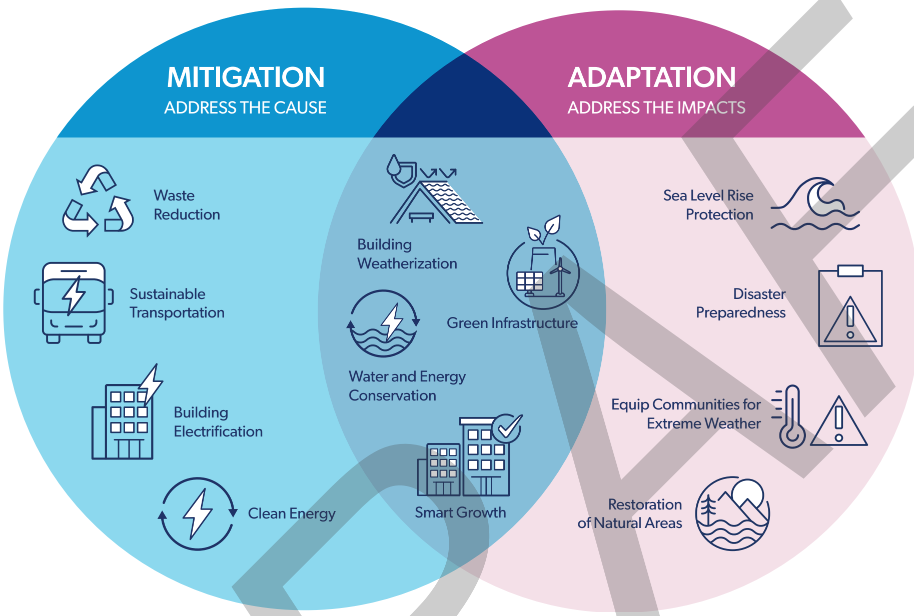


Figure 1. Adaptation and mitigation actions comparison.

The development of this CAP included a four-pronged approach:

1. Targeted engagement with interested and affected parties (stakeholders), including County staff and the community;
2. Data analysis and technical modeling to inform targets, pathways, and recommendations;
3. Review of local context including current plans, policies, legislation, demographics, and climate action readiness, and of best practices; and
4. Broad public engagement.

These approaches were iterative[13] and worked in concert to provide a robust analysis and recommendations that reflect the local context and unique needs of Clackamas County.

[13] An iterative approach to planning is a method of problem-solving that involves repeatedly refining and updating a plan until the desired outcome is achieved. This approach allows for flexibility and adaptability, as it allows for adjustments and improvements to be made as new information becomes available. It also allows for the gradual refinement of a plan, rather than expecting a perfect plan from the start.

Climate Change Mitigation vs Climate Change Adaptation

(see Figure 1, p. 18)

Mitigation: taking action to reduce human- caused GHG emissions to limit changes in the climate.

Adaptation: adjusting infrastructure and practices to decrease risk and build resilience to expected changes in climate.

Addressing both mitigation and adaptation recognizes that emissions need to be reduced to avoid the most catastrophic impacts of climate change, but also that some changes are already underway and will be unavoidable, so we must prepare and adapt to minimize the impact of those changes.

The actions identified in the CAP, and in the more detailed Implementation Guide[14], describe how Clackamas County, by implementing this plan, can:

- Lead by example in the community through changes to its own infrastructure, services, and internal policies;
- Support the community through programs, education, incentives, and pilot projects, and
- Advocate for the community through partnerships and dialogue with other decision-makers and service providers.

The major actions in the CAP are briefly described below, in Table A.

Table A. Major outcomes addressed in the Climate Action Plan

OUTCOME	DESCRIPTION	METHOD
Reduce community-wide emissions	Community-wide GHG emissions reach carbon neutral by 2050.	Identify local actions to address emissions-producing sectors (buildings, land use, energy generation, transportation, waste), leveraging community engagement, data analysis, and modeling.
		Identify sequestration actions through engagement, research, and data analysis, to close the gap between the target outcome and the emissions that can be reduced through direct sector action.
Reduce community- wide consumption- based emissions	Consumption-based emissions decrease over time.	Identify consumption-based emissions through engagement, research, and data analysis, to reduce consumption-based emissions at a community scale in the future.

[14] The Implementation Guide is an accompanying document to the CAP that identifies how the county can implement the CAP through leadership, support, and advocacy functions, including governance, policies, regulations, programs, pilots, incentives, education, and direct advocacy. The Implementation Guide can be accessed on the county's website *www.clackamas.us/sustainability/climateaction* or by contacting the county.

OUTCOME	DESCRIPTION	METHOD
Adapt to climate change and reduce climate-related risk	Climate-related risk is reduced through policy, infrastructure, and planning changes as well as through preparedness and education.	Identify and implement actions benefiting people, the economy, and the environment through engagement, research, and data analysis that reduce risks and vulnerabilities.

A Local Perspective

Located in northwest Oregon in the Willamette Valley, Clackamas County has a diverse landscape and settlement pattern, including urban, suburban, rural, and wild areas, spanning 1,879 square miles. The northwest part of the county includes part of the Portland Metropolitan Region while the eastern portion is in the Cascade Mountain Range. The county has 16 cities within both the urban metro area and rural areas. The county encompasses rich forest and farmland, as well as many rivers, the Mount Hood National Forest and associated wilderness areas, the Clackamas River Watershed, which provides much of the water for county residents, and the Bull Run Watershed, which provides the primary drinking water supply for the nearby City of Portland.

The county's diverse economy includes professional business services; wholesale trade, transportation and distribution; high tech manufacturing/software and media; health care; advanced manufacturing; food and beverage processing; agriculture, nurseries and greenhouses, and wood manufacturing. The county's largest employers include Providence Health & Services, a healthcare provider with several hospitals and clinics in the area, Kaiser Permanente, Clackamas County government, and the North Clackamas School District. The county's proximity to Portland and its growing technology sector also help to drive economic growth.

Climate Change in Clackamas County[15]

The impact of climate change is already being felt in Clackamas County. Average annual temperatures have increased by approximately 4°F (2.2°C) since 1901.[16] Just during the time this plan was developed, Clackamas County had a rare tornado that felled trees and damaged property; wildfires that burned homes and hundreds of thousands of acres of forest; floods, landslides and road closures caused by unusually heavy rains; a late-June heatwave that led to the deaths of at least 14 people; a snow and ice storm that led to fallen trees, property damage and widespread power outages; a late winter atmospheric river that broke daily rainfall records in several areas and led to urban flooding; the hottest October on record; and a severe drought that reduced the amount of available well water and shortened agricultural growing seasons.

If, on a global scale, greenhouse gas emissions remain on a Business-as-Planned trajectory, a 5.4 to 9°F (3 to 5°C) increase in average temperature in Clackamas County is projected by 2100. The greatest temperature increases will continue to occur in the summer, increasing the risk and frequency of extreme heat and heatwaves, which put stress on human and ecological health,

[15] The content in this section is largely derived from the summary and analyses of the Fifth Oregon Climate Assessment, published by the Oregon Climate Change Research Institute at Oregon State University in January 2021 - Dalton, M., and E. Fleishman (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. *https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka*

[16] Dalton, M., and E. Fleishman (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. *https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka*

and agricultural output. Precipitation is expected to increase during the spring and winter and decrease in the summer months, increasing the risks for both flooding and drought. Extreme heat and drought, combined, increase the risk of forest fires.

Between now and 2100 the snowpack, which is a key contributor to streamflow and health, is also projected to decrease.

A more detailed review and analysis of climate change projections in Clackamas County can be found in Appendix E: The Data, Methods, and Assumptions (DMA) Manual.

Local Influence for a Local Plan

The LCS development was a technical modeling process influenced by public engagement throughout the CAP development process.

Clackamas County engaged the public in the development of the CAP through various means, including articles in county publications, emails to advisory boards and commissions, focus groups, newsletters, a community advisory task force (CATF) and a youth advisory task force (YATF). These efforts gathered input and feedback from a diverse range of community members and interested or affected parties (stakeholders).

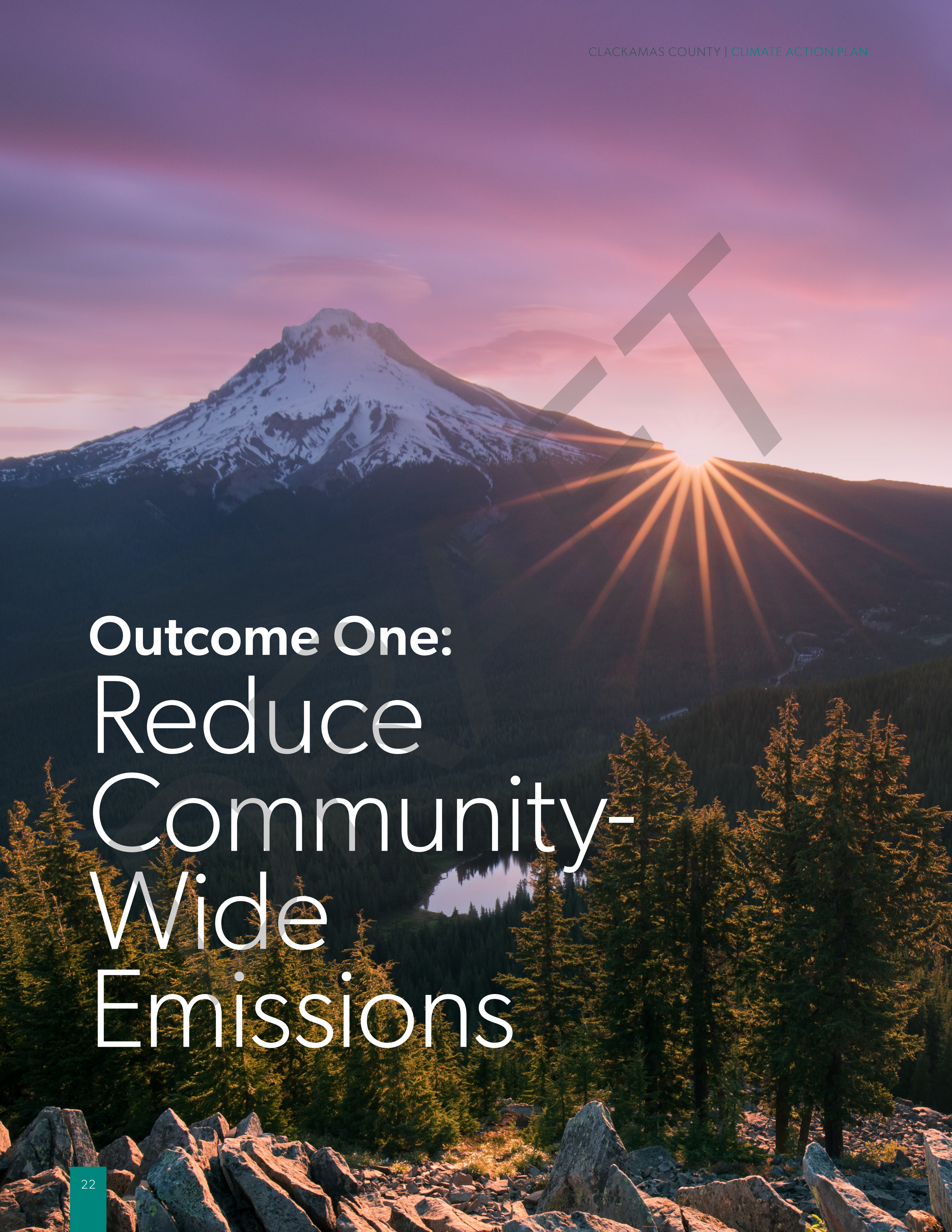
The county actively promoted the CAP project through various county publications such as #ClackCo Monthly, #MyClackCo, and #ClackCo Weekly, which featured articles and information about the project and opportunities for public input. Additionally, the county sent emails to various advisory boards and commissions to inform them of the project and opportunities for input.

The county also held focus groups in fall 2022 to gather input from specific groups of residents, including seniors, small business owners, rural residents, migrant farmworkers, and members of minority communities, including Latino/Hispanic, African American, and Asian.

The YATF was formed to gather input from youth under 25 years old. The YATF held 15 monthly meetings from March 2021 through June 2022, where they discussed the most pressing climate issues and provided input on high-level action areas to the CATF in September 2021.

The CATF was made up of 24-people representing various communities, viewpoints, stakeholder groups and areas of expertise from throughout the county. It was charged with helping to develop a climate action plan to meet the county's goal of reducing greenhouse gas emissions so the county can be carbon neutral by 2050. The group met a total of 12 times to provide input and reviews of modeling, discuss experiences and share expertise, and advise the project team on the final report and implementation mechanisms. As to be expected with such a lively and diverse group, consensus was not reached on all CAP recommendations.

Additionally, the county held community conversations and meetings with key communicators, such as cities (including the Clackamas County Coordinating Committee [C4] of city and county elected leaders, and a cities work group), rural residents, and businesses, to gather input and feedback on the CAP. A survey conducted in spring 2022 received 950 responses, with feedback on actions needed to respond to climate change and help achieve the county's goal. The county also utilized social media channels such as Facebook, Twitter, and NextDoor to share information about the project and provide opportunities for public input.



Outcome One: Reduce Community-Wide Emissions

Outcome One: Reduce Community-Wide Emissions

Clackamas County, like communities all over the world, is facing the threat of climate change and the many associated social, economic, and environmental impacts.

This section focuses on how Clackamas County can act to reduce community-wide emissions from the major sectors in the community that are not primarily involved with consumption-based emissions: buildings (residential, institutional, commercial, and industrial), transportation, and waste.

Understanding the Size of the Challenge

To provide guidance on what actions and what scale of action would be necessary to reach carbon neutrality in Clackamas County, we needed to develop an understanding of the local context - current energy use and emissions, and plausible projections for energy use and emissions based on current practices, policies, and demographic projections.

Modeling was conducted to illustrate a Low-Carbon Scenario (LCS) with actions that can be taken to reduce carbon emissions throughout the county. The financial costs and benefits of each action in the LCS were estimated. The scenario as a whole can be found in Appendix B.

What the Business-as-Planned (BAP) scenario showed is that GHG emissions were likely to decrease by 20% (Figure 2) by 2050, with current policy (that does not include a low-carbon climate action plan).

What this means is that without a climate action plan, emissions are not reduced to a low-carbon state. With full implementation by the community of the sector-based actions identified in the LCS, emissions would be reduced by 83%. Along with sequestration, this would take the county to carbon neutral by 2050.

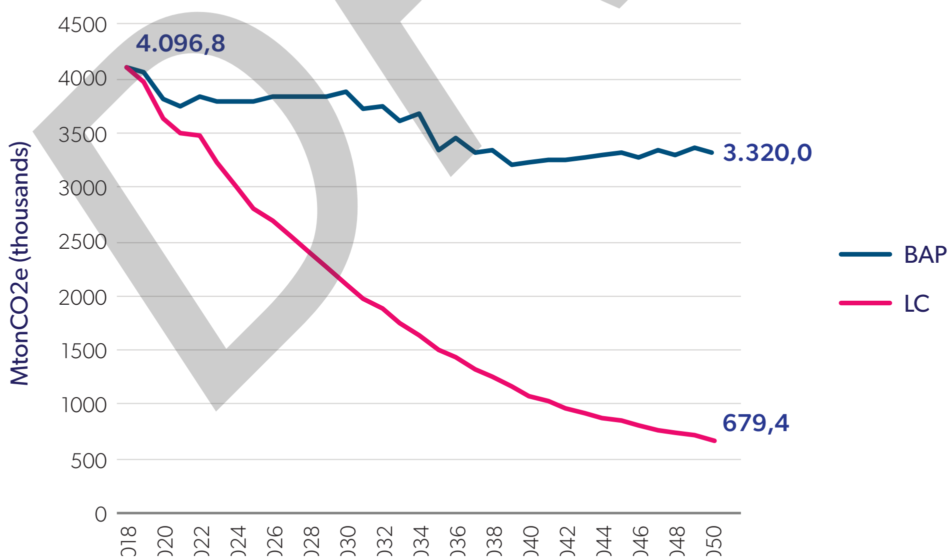


Figure 2. The opportunity of the low-carbon scenario (sequestration not included).

A Future Clackamas County Without Further Climate Action: The Business-as-Planned Scenario

The Business-as-Planned (BAP) scenario developed for Clackamas County illustrates a likely scenario[17] of community energy use and GHG emissions between 2018 and 2050 based on the community taking no additional action on climate change beyond current policies and practices that are in place or are guaranteed through government plans and committed funding. The scenario, which accounts for the county's population and demographics trends, estimates and uses energy and emissions data and information from local, state, and federal governments to inform modeling assumptions about buildings, transportation, energy generation, and solid and liquid waste. The BAP assumptions were reviewed by county staff and the Community Advisory Task Force (CATF) before being modeled.

Clackamas County's BAP shows declining GHG emissions in the community, with emissions expected to decrease by 19%, from approximately 4.1 million metric tons of carbon dioxide equivalents ($MtCO_2e$) in 2018 to approximately 3.3 million $MtCO_2e$. Energy use is expected to increase slightly from 49 million MMBTUs to 52 million MMBTUs, or six percent, over the same period. These opposing trends indicate that there will be a partial shift toward energy sources that are less emissions-intensive, resulting in fewer emissions per unit of energy used.

Business-as-Planned (BAP) Scenario

A BAP scenario projects the county's expected emissions levels with current policies and practices, and no additional (i.e., beyond what is currently planned) policy or climate action intervention. It includes projections for energy consumption, and emissions from transportation, industrial processes, and other sources, and serves as a benchmark against which to measure effectiveness of its emissions reduction efforts.

The projections are based on locally available data that includes utility use records, transportation and demographic data, and forecasts for population and employment. Policy implications at the local, state, and federal level, such as the federal electric vehicle target, are also considered.

This scenario essentially describes the size of the emissions reduction challenge the County faces. It can be used to set low- carbon emissions reduction targets and track progress towards achieving them, and to communicate the county's reduction strategy to interested and affected parties (stakeholders) and the public.

After this BAP was created, Oregon passed House Bill 2021 — the Clean Energy Targets Bill and the Climate Commitment Act, which would have normally been in the scenario. However, these pieces of legislation and their impacts are factored into the low- carbon scenario (LCS) discussed in that section of this document.

[17] A scenario is an internally consistent view of what the future might turn out to be. Because we cannot know for certain how individual behavior, world events, policy changes, and technological advancements will unfold, it is not a forecast, but one possible future outcome based on what we know today. It is based on locally available data including utility use records, transportation data, demographic data, and forecasts for population and employment changes. Policy implications at the local, state, and federal level, such as the federal electric vehicle target, are also considered.

In 2018, all buildings located in Clackamas County accounted for over half of community emissions. Residential buildings made up 25% of emissions, industrial operations were responsible for 15% and commercial buildings accounted for 11%. The transportation sector was responsible for a significant portion of the community's emissions as well, at 43%. Agriculture accounted for 4% of emissions, while emissions from garbage and sewage (waste) accounted for 2%, and county emissions, defined as county owned and/or operated buildings, accounted for 0.5%.

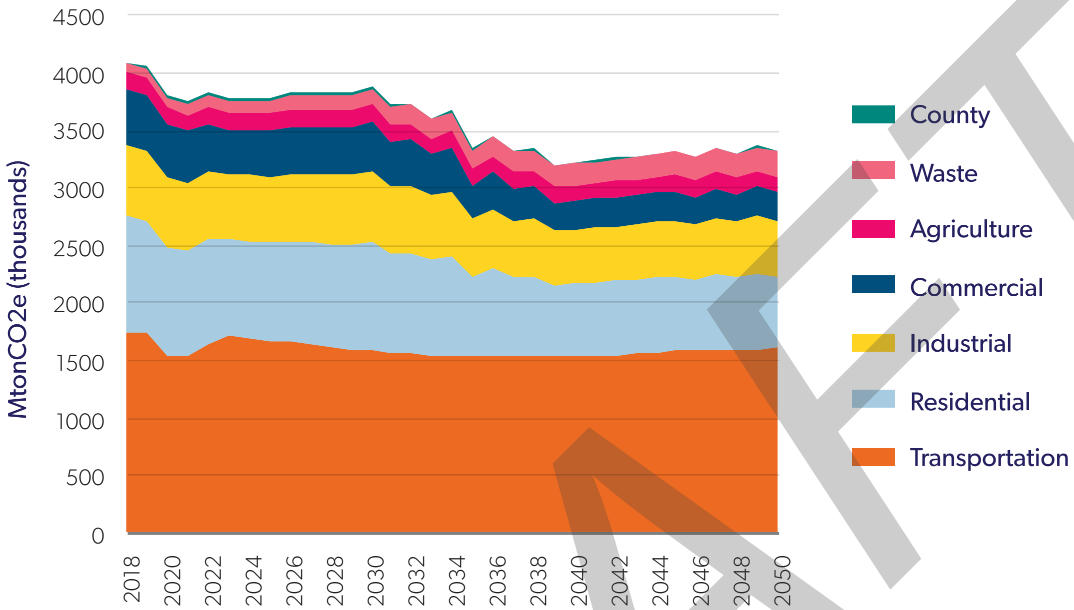


Figure 3. Emissions by sector in the Business-as-Planned scenario

By 2050, as shown in Figure 3 above, buildings make up 41% of overall community emissions. This decrease in emissions is largely due to a decrease in the grid electricity factor, meaning in 2050 electricity is coming from cleaner sources than it was in 2018.

Transportation accounts for 48% of emissions in 2050, 5% more than in 2018, despite a slight decrease in emissions overall. In this sector, while vehicles are expected to become more efficient over time and increasingly rely on cleaner sources of energy, the number of vehicles on the road is expected to increase significantly with population growth.

Emissions from the agriculture sector stay nearly constant between 2018 and 2050, while emissions from the waste sector double, mostly due to an increase in population without a change in waste and diversion programs.

On a per capita basis, from 2018 to 2050, emissions decrease by 42% from 9.8 million metric tons (MT) of CO_2e to 5.7 million $MTCO_2e$.

In terms of the energy sources of emissions (Figure 4, below), in 2018:

- Grid electricity is responsible for 33% of emissions and gasoline is responsible for more than a quarter of emissions;

By 2050:

- Grid electricity is responsible for only 16% of community emissions, a reduction of over 60% in real terms, which is a testament to the impact of a clean electricity grid;

- Emissions from gasoline decrease by 26%, reflecting a move toward electric vehicles;
- Emissions from diesel decrease at a slower rate, 13%, as efficiency increases and alternatives enter the market;
- Emissions from natural gas use increase by 8%, reflecting an increased use due to population growth;
- Emissions from waste also increase due to population growth, with a 36% jump;
- Emissions from jet fuel are expected to increase by 67% as population and travel increase; and
- Emissions from wood decrease by 10% as wood as a heating source continues on a downward trend, while emissions from oil and propane increase by 10% and 6% respectively, as the population grows.

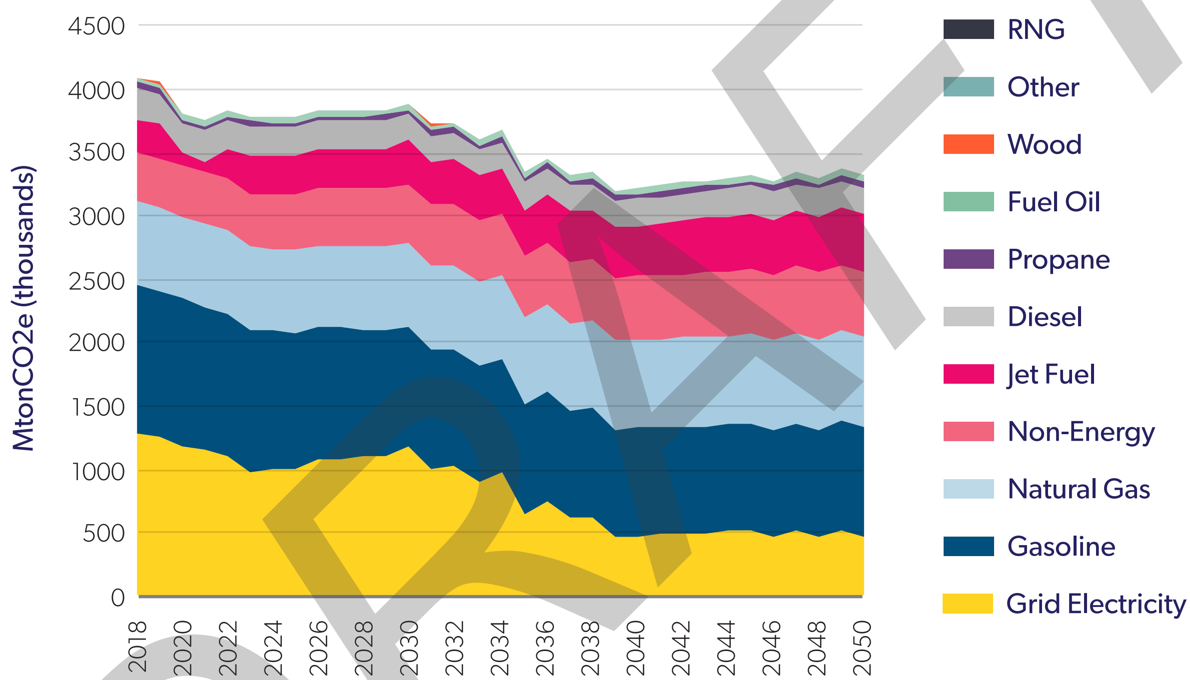


Figure 4. Emissions by fuel source in the Business-as-Planned scenario

Business-as-Planned Energy

In 2018, as shown in Figure 5 on the next page, the buildings sector accounted for 54% of energy use in the community. Overall, 20% of energy use was in residential buildings, and 12% each came from commercial and industrial buildings. The transportation sector accounted for 45% of all energy use.

Due to the projected increase in dwelling units, residential sector energy use is expected to rise the most, by 26%, accounting for one-third of Clackamas County's total projected energy use in 2050.

Transportation is expected to use 18% less energy compared to 2018, as vehicle efficiency standards increase and new vehicles purchased are increasingly electric. There are also increases of 38% in industrial energy and 17% in the commercial sector due to the employment increase that will follow population increase trends. Together these sectors continue to contribute approximately one-third of the total energy consumption split evenly between them.

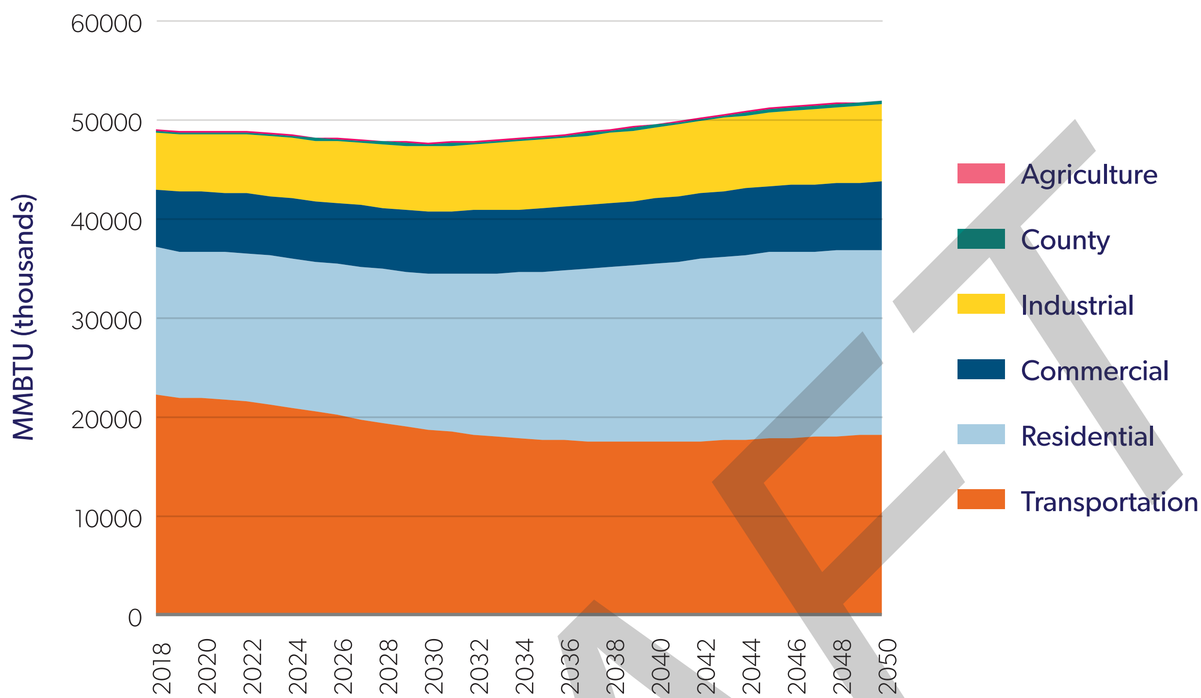


Figure 5. Energy use by sector in the Business-as-Planned (BAP) scenario

A Pathway to a Carbon Neutral Clackamas County

Carbon neutrality is achieved when decarbonization of the economy reduces carbon emissions to as close to zero as possible through energy-use avoidance, energy efficiency, and the replacement of fossil fuels with renewable energy technologies and energy systems. Any remaining human-driven emissions are balanced out by an equivalent amount of carbon removed from the atmosphere. Carbon removal or sequestration can be achieved by restoring or enhancing natural lands and soils or through direct air capture and storage technology.

Much like the reduce, reuse, recycle paradigm[18] in waste diversion, the avoid, reduce, replace, remove, offset paradigm in energy use and emissions reductions relies on prioritizing those actions that tackle the problem at its source (Figure 6, below). These actions are often the most cost-effective, yield the greatest impact for the effort expended, and offer more predictable results.

Removal, due to its indirect and relatively small impact on overall emissions, and offsets, due to their cost and lack of return on investment, are considered after direct sector-based action, although they are necessary for some situations where approaches to eliminating emissions directly are not feasible.

[18] In general, a paradigm is a framework, a model, or a pattern that guides how people think and how they approach a particular subject.

1. AVOID	2. REDUCE	3. REPLACE	4. REMOVE	5. OFFSET
Avoid activities that generate emissions or require energy.	Reduce energy required by using less, and by avoiding wasted energy.	Switch to renewable energy sources.	Use natural systems or technology to sequester greenhouse gases.	Invest in emissions reductions initiatives to decrease their costs and address local emissions that cannot be eliminated for a lower cost.

Figure 6. The emissions reduction hierarchy

Critical Sectors for Decreasing Emissions in Clackamas County

Building Retrofits

Energy use in buildings accounted for more than half of GHG emissions in Clackamas County in 2018 and is expected to decrease only slightly by 2050. Emissions from buildings result from heating and cooling spaces, lighting, and running appliances and equipment. Building emissions come from all types of buildings including homes, schools, offices, stores, and industrial spaces. Retrofitting buildings by replacing windows and doors, increasing insulation, replacing weather-stripping, and replacing inefficient heating systems with more efficient technologies (such as heat pumps) makes buildings more efficient. When buildings are retrofitted to be more efficient, they use less energy overall regardless of whether the energy comes from a renewable source. This decreases emissions from the baseline and decreases the amount of renewables required later to meet community needs.

State Regulations Pushing Toward Low Carbon

The Climate Protection Program (CPP) is a regulatory program initiated by the State of Oregon in 2022. The CPP goal is to dramatically reduce Oregon GHG emissions over the next 30 years. It sets a cap on GHG emissions from fossil fuels used throughout the state from diesel, gasoline, natural gas and propane, used in transportation, residential, commercial and industrial sectors. The program also regulates site-specific GHG emissions at manufacturing facilities, such as emissions from industrial processes.

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

These regulations are key to the low-carbon scenario. Many outcomes being explored by the County complement work toward achieving the goals set by these regulations while also decreasing the burden on the county to find local renewable energy solutions to reduce emissions.

Net-Zero New Construction

Buildings and the systems within them, such as heating and cooling, are long-lasting assets. They can also be significant sources of GHG emissions depending on how efficient they are and the types of energy that they use to operate. Constructing new buildings that do not meet net-zero standards creates an emissions burden now that will last well into the future unless there are costly retrofits to meet the GHG reduction target before the building systems are due to be renewed. Net-zero buildings eliminate that burden throughout the lifecycle of the building, right from the beginning.

The upfront capital cost of more efficient construction is typically more than offset by utility savings over time. Currently, the Oregon Residential and Commercial Reach Codes are available for optional use by builders, consumers, contractors, and others to achieve between 5% and 10% improved performance over the statewide Oregon Energy Efficiency Specialty Code. At this time, local governments in Oregon do not have the authority to require use of or adopt the Reach Code as the minimum construction standard.

Renewable Energy Generation

Renewable energy systems ensure that buildings and transportation sectors can operate emissions-free. In Clackamas County, a mix of natural gas, electricity, gasoline, and diesel power day-to-day activities. By 2050, the same energy sources are expected and need to be replaced by renewable energy sources such as wind, solar, and renewable natural gas. As technologies and consumer products evolve, new energy sources such as green hydrogen may also come online. While the cost of renewables is decreasing year-over-year, efficiency measures such as building retrofits and net-zero construction will still contribute to their viability for widespread use.

Reducing Vehicle Emissions

Vehicle emissions result from travel in personal vehicles, commercial fleet vehicles, the movement of goods, agricultural vehicles, and mass transportation such as buses and trains. There is an expected trend toward more electric vehicles (EVs). EVs reduce emissions compared to gasoline or diesel vehicles because they are significantly more efficient, and can operate emissions-free if they are charged using infrastructure connected to renewable (e.g., solar, wind) energy sources. New technologies (e.g., renewable diesel) are also being refined for medium and heavy-duty vehicles to become non-emitting, but no target date for their uptake is currently outlined at the federal level.

Increasing Active Transportation and Transit Use

Active transportation (walking, cycling and rolling) and transit use can help reduce transportation emissions when single-occupancy vehicle trips can be avoided. Well-thought-out active transportation and transit networks with a supportive mix of land use, programming, operations, and maintenance can help decrease congestion, promote active and healthy lifestyles, and complement efforts to promote walkable and bike-able neighborhoods while decreasing emissions. Active transportation and transit networks are complex to implement in Clackamas County due to multiple municipalities and transit operations, and the mix of rural and urban spaces that have different transportation needs.

Reducing Waste Emissions

Waste (including solid waste) releases emissions, mostly methane, as it decomposes over time. The county has a plan to significantly divert food waste in the coming years, and most waste is sent to landfills that capture methane for energy use. However, even as per capita waste decreases, the growing population means there is a projected increase in waste overall, which means efforts need to be made to account for a growing population.

Engaging Utilities

Portland General Electric (PGE) and Northwest Natural (NWN)[19] — the primary utilities in Clackamas County — were represented on the Community Advisory Task Force (CATF). Both utilities have and continue to adapt and plan for shifts to renewable energy and new state regulations.

PGE is exploring opportunities to add more grid-scale renewables, while NWN is exploring different ways to generate renewable natural gas and adding new fuels such as hydrogen to its energy offerings.

The utilities have stated they are committed to meeting state regulations - and that it will require innovation within their operations, and demand side management (energy efficiency), as well as government support.

[19] Information on NWN renewable natural gas programs can be found here: *https://www.nwnatural.com/about-us/environment/renewable-natural-gas*

Low-Carbon Scenario (LCS) Emissions

An important component of this project was the emissions modeling of some of our low-carbon opportunities (the Low-Carbon Scenario, or LCS). The intent of this component of the project was to identify how far a mix of high-level actions could go towards the carbon neutral goal.

By 2050 the actions considered in the LCS would achieve an 83% reduction in GHG emissions through direct mitigation actions (see Figure 7, on the following page). Emissions would fall from 4.1 million $MtCO_2e$ in 2018 to less than 0.7 million $MtCO_2e$ in 2050.

The actions include a 98% reduction in total building emissions including:

- 98% reduction in residential buildings,
- 52% reduction in industrial (both buildings and processes) operations,
- 99% reduction in commercial, institutional, and county-owned buildings.

Overall, the buildings, which represented nearly 2 million $MtCO_2e$, or half of the community's emissions in 2018, will represent 0.1 million $MtCO_2e$ in 2050.

Transportation emissions are reduced by 93% below the baseline figure. Small amounts of emissions remain from gasoline in cars and light-duty trucks as the transition to clean fuels is completed and some diesel remains in rail. In addition, some emissions continue to result from aviation despite significant reductions if emissions fall in line with targets set by the International Air Transport Association.

Emissions from waste increase by 131%.[20] This is considerably less than the 190% waste emissions would have increased in the BAP scenario, but still an area of concern.

Agriculture-related emissions decrease by 9%.

[20] The driver for this increase is population growth. Actions to reduce emissions from waste are included in the implementation plan, and further actions can be considered once implementation has started.

Low-Carbon Scenario (LCS)

An LCS is a projected future in which the amount of carbon emissions is significantly reduced in order to mitigate the effects of climate change. This can be achieved through a combination of measures such as increasing the use of clean energy sources, improving energy efficiency, and reducing overall consumption of fossil fuels.

LCSs can be modeled using computer simulations that take into account different economic, technological, and policy factors to project just how emissions will change over time under different assumptions. The assumptions used for this plan were reviewed by county staff and the CATF. They are used to evaluate the effectiveness of different policy options for reducing emissions and to inform decisions about how to achieve a low-carbon future.

LCSs are used in the context of energy and power systems, transportation and mobility, buildings and urban systems, industry and manufacturing, and agriculture and land-use.

The most common LCSs are those that are consistent with the Paris Agreement's target of limiting global warming to well below 2°C above pre-industrial levels, and pursuing efforts to limit warming to 1.5°C.

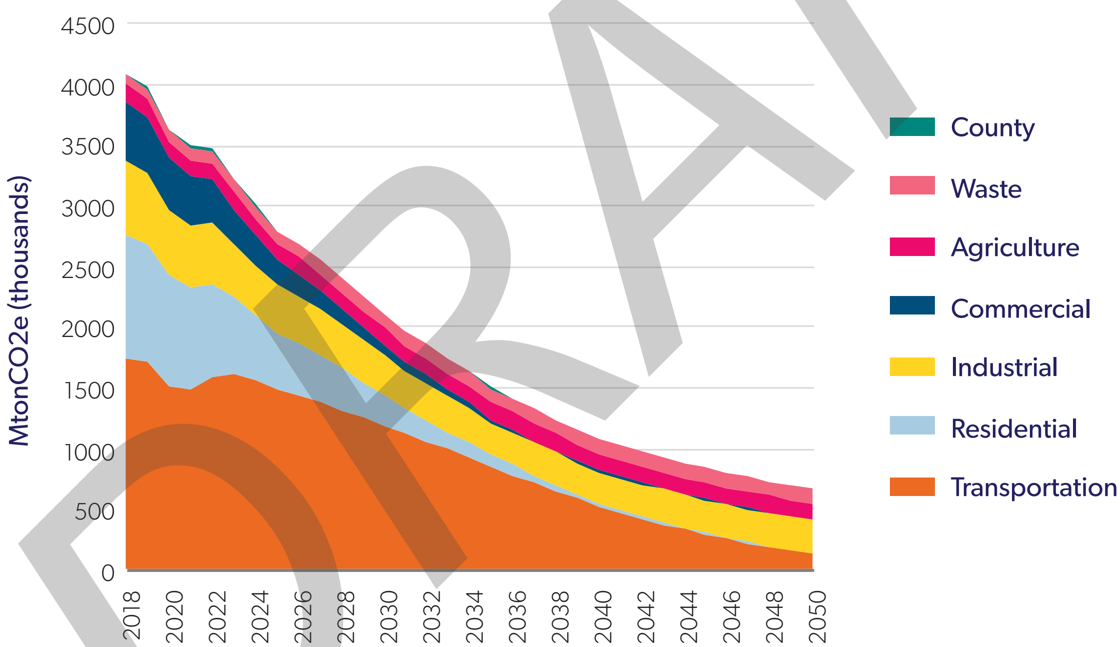


Figure 7. Emissions by sector in the Low-Carbon Scenario

In this scenario, as shown in Figure 8, the energy sources responsible for remaining emissions in 2050 include a small amount of natural gas in the residential, commercial, and industrial sectors; fuel oil and propane in industrial processes; small amounts of diesel, gas, and jet fuel in transportation, and non- energy (methane-related) emissions in the industrial, agriculture, and waste sectors.

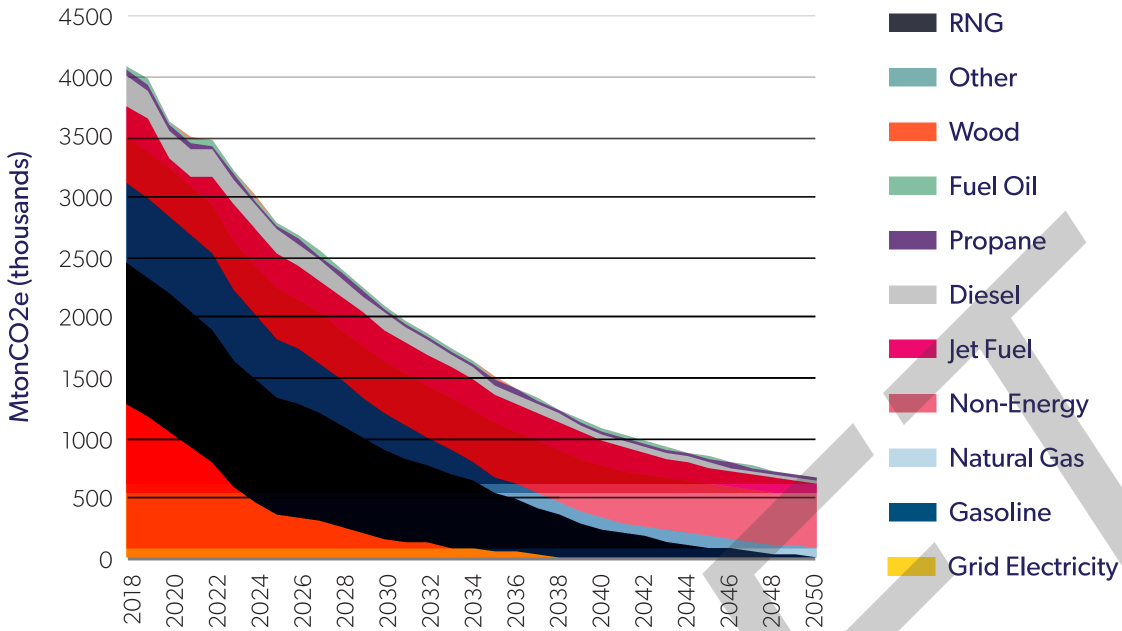


Figure 8. Emissions by fuel type in the Low-Carbon Scenario

The actions considered in the LCS were not specific recommendations. Instead, they served as an illustration of the need for reductions across all sectors and to identify the economic benefits of climate action. Recommended actions in the Implementation Guide are informed by the high-level actions of the LCS, as well as consideration of practices in many other communities, engagement with the community, the CATF, and county staff and department directors.

A Note on Low-Carbon Actions

All of the actions in the plan tackle the six critical sectors described earlier to create the LCS. In order to achieve the target of carbon neutrality, no sector can go unaddressed, nor can some actions be implemented while others are ignored. Said another way, in order to successfully achieve the target outlined in the LCS, all actions must be implemented. For a full list of actions in the LCS, see Appendix B.

Energy Use in the LCS

Overall, community energy use decreases by 43.5%, with building energy use reduced by 26% and transportation energy use reduced by 68%. These decreases are due to 'avoid' activities, such as energy waste reduction and 'reduce' activities, such as using more efficient technologies and assets like electric vehicles and heat pumps.

Making the Difference with Sequestration

Much of the remaining community emissions can potentially be removed from the atmosphere via sequestration. The Oregon Global Warming Commission has a statewide goal of sequestering an additional 5 million $MTCO_2e$ per year by 2030 and 9.5 million $MTCO_2e$ per year by 2050 relative to 2019 activity.[21] These were not modeled in the LCS since the LCS only modeled direct reductions. Strategies for implementation related to sequestration are included in the Implementation Guide.

Low-Carbon Co-Benefits

Community co-benefits associated with the county's LCS and carbon sequestration activities include improved health outcomes, economic prosperity, opportunities for equity enhancement, and climate resilience.

Air Quality and Health Benefits

Combusting fossil fuels for energy use releases particulate matter and air pollutants, such as sulfur dioxide, nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), and others, and can create ground-level ozone. These pollutants impact human health as they are breathed in during regular daily activities. For example, air pollution from traffic is linked to cardiovascular disorders, bronchitis, asthma, and other respiratory illnesses. Often low-income residents experience the impacts of air pollution to a greater extent compared to other residents due to proximity to pollution sites, lack of indoor air filtration, and other inequities affecting health outcomes.

A quantitative assessment of impact was conducted for Clackamas County using the U.S. Environmental Protection Agency (EPA) CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) tool. The total health benefits of reducing particulate matter by implementing the LCS amounted to between $3.5 and $7.9 billion dollars by 2028 and resulted in an overall decrease in total mortalities[22]. A U.S.-based study quantified the health benefit of reducing tailpipe pollution at between $0.02 and $0.12 per mile[23].

Indoors, natural gas stoves[24] and fireplaces are being identified as contributors to negative health impacts, especially for children[25]. This means their replacement with electric units over time can further decrease negative health outcomes and the associated human and financial costs of those outcomes.

Retrofits in existing buildings can also reduce indoor air pollutants (i.e., NOx, CO, and VOCs), mold and dampness, and improve the thermal comfort. Health benefits associated with these

[21] Natural & Working Lands Proposal. Oregon Global Warming Commission. *https://static1.squarespace.com/static/59c554e0f09ca40655ea6eb0/t/6148a9d36431174181e05c7c/1632152029009/2021+OGWC+Natural+and+Working+Lands+Proposal.pdf*

[22] US Environmental Protection Agency. CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA). *https://www.epa.gov/cobra*

[23] Choma, E. F., Evans, J. S., Hammitt, J. K., Gómez-Ibáñez, J. A., & Spengler, J. D. (2020). Assessing the health impacts of electric vehicles through air pollution in the United States. Environment International, 144, 106015.

[24] Multnomah County. 10 November 2022. "The Board of Commissioners briefed on the Public Health review of health risks posed by gas stoves," *https://www.multco.us/multnomah-county/news/board-commissioners-briefed- public-health-review-health-risks-posed-gas-stoves*

[25] Seals, B. and Karasner, A. (2020). Health effects from gas stove pollution. Retrieved from: *https://rmi.org/insight/gas-stoves-pollution-health*

changes can include reduced risks of cardiovascular and respiratory illnesses and cancer[26,27]. Evidence also suggests that these improvements contribute to better mental health outcomes[28].

Natural and Working Lands Proposal

Oregon's natural and working lands — including forests, grasslands, rangelands, farmlands, tidal and subtidal wetlands, and the parks and open spaces in urban environments — provide a range of environmental, social, health, and economic benefits statewide including opportunities to increase carbon sequestration to reduce Oregon's overall GHG emissions.[29]

In Executive Order 20-04, the governor directed the Oregon Global Warming Commission (OGWC) to work with the state departments of Agriculture and Forestry, and the Watershed Enhancement Board to develop a proposal for setting a carbon sequestration and storage goal for Oregon's natural and working lands.[30]

1. These groups convened a natural and working lands advisory committee. Before forming the committee, OGWC identified four strategies to achieve its goals:
2. Position the state to leverage federal lands and investments in climate-smart natural and working lands practices.
3. Investigate options and create a sustained source of state funding to increase sequestration in natural and working lands.
4. Fund and direct the agencies to take actions to advance natural and working lands strategies.
5. Invest in improvements to Oregon's natural and working lands inventory.

To help evaluate progress, the OGWC recommended establishing activity-based metrics including the number of acres with adopted soil health practices, maintained resource lands, riparian reforestation, and urban forest canopy expansion.

[26] Wu, F., Jacobs, D., Mitchell, C., Miller, D., & Karol, M. H. (2007). Improving Indoor Environmental Quality for Public Health: Impediments and Policy Recommendations. Environmental Health Perspectives, 115(6), 953–957. https://doi.org/10.1289/ehp.8986.

[27] Barton, A., Basham M., Foy C., Buckingham, K., and Somerville, M., on behalf of the Torbay Healthy Housing Group. 2007. The Watcombe Housing Study: the short term effect of improving housing conditions on the health of residents. Journal of Epidemiol Community Health, 61(9):771e7.

[28] Bonnefoy, X. 2007. Inadequate housing and health: An overview. International Journal of Environment and Pollution, 30(3/4), 411. doi: 10.1504/IJEP.2007.014819

[29] Oregon Global Warming Commission. 2021. Natural and Working Lands Proposal. Retrieved from: https://static1.squarespace.com/static/59c554e0f09ca40655ea6eb0/t/6148a9d36431174181e05c7c/1632152029009/2021+OGWC+Natural+and+Working+Lands+Proposal.pdf

[30] Oregon Global Warming Commission. 2021. Natural and Working Lands Proposal. Retrieved from: https://static1.squarespace.com/static/59c554e0f09ca40655ea6eb0/t/6148a9d36431174181e05c7c/1632152029009/2021+OGWC+Natural+and+Working+Lands+Proposal.pdf

COBRA Model Summary: What accounts for the benefits?

COBRA's estimates reflect current scientific thinking on the relationship between particulate matter and human health, and the economic valuation of these health effects. Additionally, EPA's methodology for characterizing health impacts has been reviewed by two National Academy of Sciences panels and multiple EPA Science Advisory Boards. Because the health impacts of air pollution and approaches to assign a value to these impacts are areas of active research, the selection of studies used in COBRA may evolve over time as new evidence and studies emerge.

Active Transportation and Health Benefits

Increasing walking, cycling, and rolling is one of the most significant ways to improve the physical health of those in the community. Health benefits from routine physical exercise include reductions in rates of diabetes, cancer, and heart-related illnesses[31], as well as improvements in mental health[32].

Equity

Increased equity is possible but not guaranteed by the outcomes considered in the LCS. Equity is a broad term that encompasses fairness for many different demographics across many different situations. The LCS can only contribute to, not create, equity by addressing intergenerational equity, income equality, housing affordability, and global equity.

Intergenerational Equity

As the impacts of climate change increase in frequency, duration, and severity, younger generations and generations yet to be born are and will be increasingly affected by the impacts and the responsibility of reducing emissions contributed to systems created by older and past generations. Addressing emissions in the short-term decreases that burden.

Income Equality

We often hear that it is expensive to be poor, and that is true in the low-carbon transition unless an effort is made to decrease the financial burden for individuals and families living on low incomes. For example, if a person cannot afford energy efficiency upgrades in their home due to the upfront cost, it could mean an increase in their ongoing costs or missing out on utilities savings that others in higher income brackets can access.

In addition, most utility fees are determined based on the fixed cost of operating and usage fees. This means that if a greater number of higher-income-earning homes are using less energy, the fixed costs could increase per unit of energy used, disproportionately impacting lower income households by costing them more per unit of energy used. However, if individuals and families living on a low income are supported to make their homes and vehicles more efficient, they could see utility savings. It is vital for the county and other levels of government to play a role in this for

[31] CSEP (2019). Canadian 24-Hour Movement Guidelines. Canadian Society for Exercise Physiology. Retrieved from: https://csepguidelines.ca/

[32] Sampasa-Kanyinga, H., Colman, I., Hamilton, H. A., & Chaput, J. P. (2020). Outdoor physical activity, compliance with the physical activity, screen time, and sleep duration recommendations, and excess weight among adolescents. Obesity science & practice, 6(2), 196-206.

it to be successful, including ensuring that the support is accessible for low-income earners. For example, instant rebates and other time-of-purchase financial supports may be more realistic than post-purchase rebates.

Access to transit and active transportation can also increase equity. For people who do not own a vehicle, especially those who cannot own a vehicle due to cost, access to transit and active transportation increases their ability to get to services, appointments, activities, and employment. This is only possible if robust transit and active transportation networks are extended to areas within the community where lower-income earners reside and are connected to areas with employment opportunities and services.

Individuals living on low and fixed incomes are also more susceptible to climate risks than wealthier individuals for a variety of reasons, including:

- Lack of money to prepare for climate-related events,
- Limited access to transportation to flee during climate-related events,
- Lack of money for alternative accommodations,
- Lack of money to repair or restore their dwellings after an event,
- Lack of air conditioning during heat-related events,
- Lack of access to affordable healthcare, and
- Higher rates of comorbidities[33].

Global Equity

Climate change is currently having a disproportionate impact on poorer nations, with more climate-related events[34] and resulting in higher mortality rates. Many of the countries impacted by climate have also had a lesser impact on the increased use of fossil fuels that has led to the current climate crisis. Led by C40[35], many communities have set GHG reduction targets that acknowledge that those in wealthier countries must act more rapidly to reduce emissions than communities that have been struggling with widespread poverty. While action by wealthier countries is imperative from an equity standpoint, global climate mitigation can also help reduce the risk of climate-driven instabilities, refugee crises, conflicts, and threats to international security.

Climate Resilience

Some actions that support reducing emissions can also increase the capacity to adapt to climate change impacts. Some of the key resilience co-benefits associated with climate mitigation and sequestration include:

[33] Comorbidities refer to the presence of multiple chronic conditions in a single individual. These conditions can be related or unrelated, and they can have a significant impact on a person's overall health and well-being. Examples of comorbidities include diabetes and heart disease, or depression and anxiety.

[34] Climate-related events, such as extreme weather events and sea level rise, can happen more frequently and with greater severity in poorer nations due to a combination of factors. These nations often lack the resources and infrastructure to prepare for and recover from severe weather events and other climate-related impacts. They also tend to be in areas that are particularly vulnerable to the impacts of climate change, such as coastal regions or areas prone to drought. Additionally, poorer nations are less likely to have the economic means to adapt to the changing climate, making them more susceptible to the negative effects of climate change.

[35] C40 is a network of mayors of nearly 100 world-leading cities collaborating to deliver the urgent action needed right now to confront the climate crisis. Learn more: *https://www.c40.org*

- Ensuring safer buildings during extreme weather events (flooding, extreme heat/cold) because older buildings having been retrofitted;
- Decreased impacts of power outages to homes having been fitted with renewable energy and storage systems;
- Decreased impacts of power outages for homes that are connected to district energy systems[36];
- Decreased stress on water and wastewater systems from retrofits and more stringent efficiency standards for new buildings;
- Development and implementation of water conservation and management plans to ensure a reliable and resilient water supply during times of drought or water shortages;
- Implementation of green infrastructure and low-impact development techniques, such as rain gardens, green roofs, and permeable pavement, to improve water quality, reduce heat island effects, and cool surface temperatures in urban areas;
- Protection and restoration of wetlands, riparian areas, and other natural water systems to act as buffers against floods and heat waves, and to improve water quality and quantity;
- Development and implementation of heat warning and response systems to protect vulnerable populations from extreme heat events, including the use of cool roofs and other shading strategies, as well as public education and outreach;
- Building and retrofitting homes and other buildings to be more energy-efficient and resilient to extreme weather events, including the use of resilient materials, improved ventilation, and shading strategies;
- Encouraging the use of electric vehicles and installing charging infrastructure to support increased back-up power during power outages;
- Encouraging the use of sustainable transportation methods such as cycling, walking and public transport to reduce urban heat island effect and decrease the stress on water and wastewater systems;
- Developing and implementing policies and regulations to ensure the protection and restoration of urban and suburban green spaces, including parks and community gardens, which can provide cooling, improve air quality, and support biodiversity;
- Promoting sustainable land-use planning and urban design to reduce heat island effects and support the conservation of natural areas and green spaces;
- Enhancing the resilience of ecosystems and communities by promoting the growth of vegetation that can act as carbon sinks (natural sequestration) and help stabilize the local climate; and
- Increasing back-up power from electric vehicles.

[36] A district energy system is a network of interconnected heating and cooling systems that serves multiple buildings or structures within a defined geographic area, like a neighborhood. These systems are designed to provide centralized heating and cooling to buildings using a combination of energy sources such as natural gas, electricity, or renewable energy. The goal of a district energy system is to improve energy efficiency, reduce greenhouse gas emissions, and provide a reliable source of heating and cooling for buildings within the neighborhood.

Economic Prosperity

Clackamas County's economy will benefit from implementing the LCS. Building retrofits and the expanded construction of active transportation networks contribute to jobs that can be held locally. Decreased utility and fuel costs can also decrease household and business costs, which offsets capital investments in low-carbon assets over time. All these factors can be built into an economic strategy to encourage residents to think and buy locally to ensure more money stays within the community.

Capturing an Economic Opportunity

Up-front large investments lead to bigger returns on investment in jobs and long-term low-carbon savings.

Transitioning to a low-carbon economy will require investments in all sectors of the community from residents, businesses, institutions, the county, and other levels of government. The investments need to begin now and continue to 2050. While the need for capital is high, the paybacks of the investments are higher, especially if they happen in the short term.

Overall, implementing the LCS to address sector-based emissions is projected to generate a net return of $12.3 billion across the county above the Business-as-Planned scenario.

Further, research on the cost of implementing natural climate solutions in the U.S. estimates that 25% of the maximum potential of 1.2 billion MT CO_2e can be achieved at less than $10 per ton, and an additional 51% can be achieved at between $10 and $50 per ton[37].

The net return from the LCS, shown in Figure 9 (next page), is based on savings in operations and maintenance, savings in energy costs and health care costs due to improved outdoor air quality, and social cost of carbon (SCC)[38]. The overall investment across the county amounts to $8 billion while savings amount to $20.3 billion.

[37] Fargione et al, 2018. Natural climate solutions for the United States. Science. Retrieved from: *https://www.science.org/doi/10.1126/sciadv.aat1869*

[38] The social cost of carbon (SCC) is an estimate of the economic damage associated with each additional ton of carbon dioxide emissions. It considers the impacts of climate change, such as changes in temperatures, sea levels, and precipitation patterns, as well as the impacts on human health, agriculture, and ecosystems. The SCC provides a monetary value that can be used to inform policy decisions and investments aimed at reducing greenhouse gas emissions and mitigating the effects of climate change.

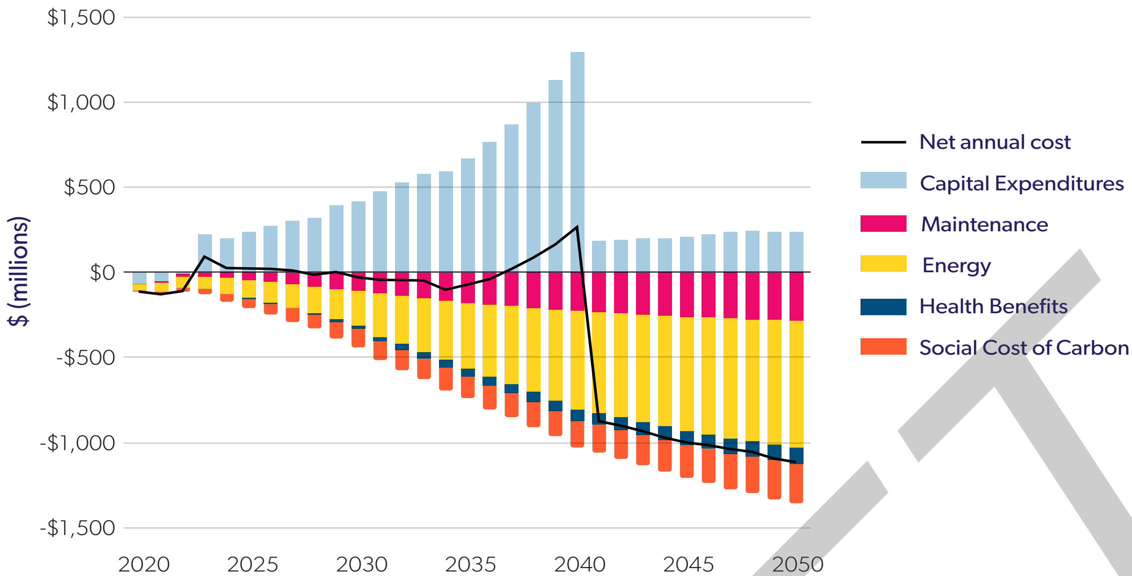


Figure 9. Net investments and returns resulting from the Low-Carbon Scenario, with health costs associated with outdoor air quality and the social cost of carbon (SCC) included.

Implementing the LCS will also generate job growth in Clackamas County (Figure 10, next page). More than 36,000 person-years of employment between 2023 and 2050 are estimated to be created through implementation of the scenario. This is equal to 1,300 full-time equivalent jobs above the jobs that would be created in the Business-as-Planned scenario.

What are 'person-years of employment'?

Imagine you're building a house. You hire a carpenter, and they work full-time for one whole year to get the job done. That's one 'person year' of employment because one person worked for one year.

But what if the house is bigger, and you hire two carpenters? If they both work full-time for a whole year, that's two 'person years' of employment.

Now, what if you only need one carpenter, but the house is really big and takes two years to build? That's still two 'person years' of employment. One person worked for two years.

In short, 'person years of employment' is a way to measure how much work is done. It considers both the number of people working and the time they spend working. It's not just about jobs, but also about how long those jobs last.

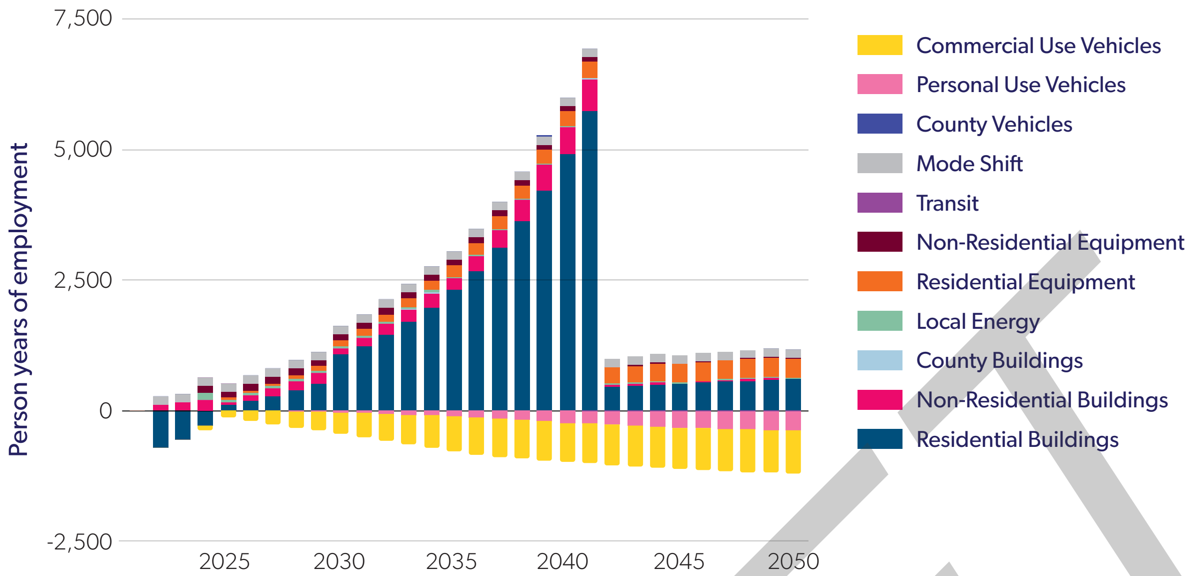


Figure 10. Person years of employment resulting from the Low-Carbon Scenario.

The financial analysis was developed at the Low-Carbon Scenario (high-level), which means it represents total costs across the community. It does not allocate costs or savings specifically to the county or other sectors or investors, although it does assign costs to current asset owners[39].

Actual costs to the county are dependent on third-party funding available for direct county actions (e.g., in its own buildings and fleet) and the degree to which the county chooses to invest in certain actions and incentivize other sectors. Investigating all financial tools available to the county and other community stakeholders — including individuals, businesses, and other levels of government — is critical to the implementation of the low-carbon actions.

Incentives and rebates currently available to residents and businesses through local, state, and federal programs are not included in the analysis above, which means that the actual costs of mitigation to Clackamas County residents and businesses would in many cases be lower than the conservative assumptions made in this analysis.

A cursory analysis of funding available at the federal level was completed to determine the approximate value of incentives currently available to residents in Clackamas County.

[39] For example: While the cost of a retrofit would be assigned to a homeowner, it does not necessarily mean the homeowner will pay the entire cost. This number allows for financial analysis across the county to help understand the source of individual costs and to help incentivize potential programs to help invest in the low-carbon economy.

Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA) Funding Opportunities

Table B, below, outlines the major programs offered in the recently-passed US IRA and IIJA.

Table B. Oregon Department of Energy and Department of Environmental Quality IRA and IIJA opportunities

PROGRAM	DESCRIPTION	TIMING
Energy Efficiency and Electrification	$113 million in rebates for energy efficiency retrofits and upgrades and electric and energy efficient appliances like heat pumps	Oregon Department of Energy (ODOE) expects to receive funding in late 2023 or early 2024
Energy Auditor Training	Up to $2 million to train energy auditors to help home business owners identify opportunities to save energy and money	ODOE applied for a competitive grant around the first quarter 2023
Investing In Communities	$3.2 million for the Energy Efficiency and Conservation Block Grant (EECBG) Program, which provides grants to states, local governments, and Tribes to help them implement strategies to reduce fossil fuel emissions, reduce total energy use, and improve energy efficiency.	State and local governments slated to receive a direct allocation were able to apply in spring 2023
Weatherization	$34.7 million for Oregon Housing and Community Services to support weatherization and energy conservation services for low-income households	Unknown

All the actions outlined in the LCS need to be implemented to achieve the emissions reductions target. Therefore, for actions that do not have an attractive payback to individual residents or businesses, it is logical for the county to provide financial support when it is financially able to do so, especially when funding opportunities from other levels of government have already been considered or applied.

When there is a clear and timely financial payback for community members, the county's role is to educate and support using non-financial mechanisms. The Climate Action Plan Implementation Guide provides initial recommendations on how the county can support residents and sectors in the community to act using financial and non-financial mechanisms.

For a more detailed financial analysis, please review Appendix B.

Moving Toward Implementation

The LCS sets an ambitious course for sector-based emissions reductions and sequestration actions. These actions must all be implemented to reach the carbon neutral target, but they cannot all be completed at once. They must also be balanced with achieving other Climate Action Plan outcomes.

Outcome Two: Quantify Consumption-Based Emissions

Outcome Two: Quantify Consumption-Based Emissions

Consumption-based Emissions

Consumption-based emissions — GHG emissions associated with the production and delivery of the goods and services we consume, regardless of where they were manufactured — account for emissions through the entire lifecycle of a product or service.

When consumption-based emissions are included in the Clackamas BAP, emissions increase by 11% between 2018 and 2050, from 7.2 MtCO_2e to nearly 8 MtC02e.

Throughout the BAP scenario, consumption-based emissions increase in line with population growth and make up the largest share of community emissions. As the largest emissions sector, and with measuring emissions being the first step in any reduction plan, quantifying consumption-based emissions is important.

With respect to reducing consumption-based emissions, shifts are typically needed in individual choices, such as reducing overall consumption, eating more local and sustainable foods, and purchasing less carbon-intensive products. Other shifts include using less carbon-intensive building and construction materials across the community.

Consumption-based emissions are the most difficult emissions to reduce, for several reasons.

1. **Globalization[40] and trade patterns:** Goods and services are often produced in one country and consumed in another, making it difficult to trace and attribute emissions to specific countries or consumers.
2. **Complex supply chains:** Many products go through multiple stages of production in the supply chain before they reach the end-consumer, making it challenging for any one entity to identify all opportunities for reducing emissions.
3. **Difficulty in changing consumer behavior:** Reducing consumption-based emissions requires changes in consumer behavior, which is often challenging due to a lack of awareness, motivation, incentives, and options for low-carbon alternatives. In many cases, choosing a more carbon- ntensive product is easier, more easily available, and less expensive than a low-carbon alternative. In some cases, low-carbon options don't yet exist.
4. **Lack of cross-jurisdictional policies and regulations:** There are limited policies and regulations in place that address consumption-based emissions, making it difficult to incentivize or enforce reductions.
5. **Technological challenges:** Developing low-carbon alternatives and new technologies to reduce emissions associated with consumption is a complex and ongoing process that requires significant investment and research.

[40] Globalization is a process where countries, businesses, and people from all over the world become more connected and interdependent. This happens when goods, ideas, and information are easily exchanged between countries. As a result of globalization, people can easily buy products made in other countries, and companies can expand their business across borders.

For long-term success, it is recommended that action planning continue to reduce consumption-based emissions, which are linked to but some of which are beyond the control of Clackamas County. Preliminary actions to reduce consumption-based emissions are suggested in the Implementation Guide.

Outcome Three:

Adapt to Climate Change; Reduce Climate Change Risk

Outcome Three: Adapt to Climate Change; Reduce Climate-Related Risk

Adapting to climate change requires that a community explore the climate hazards it is facing due to a changing climate and address those hazards by addressing risk.

Climate Hazards and Risks in Clackamas County

The Fifth Oregon Climate Assessment published by the Oregon Climate Change Research Institute at Oregon State University in January 2021 outlines the climate hazards and related risks across the state.

Climate and Natural Hazards

As evidenced by increasing average annual temperatures and wildfires, climate change impacts are becoming more prominent across Oregon and in Clackamas County. Historical climate data analysis and climate change modeling projections provide estimates for the types and scales of climate impacts expected in the region in the coming years. Of central interest are:

- Temperature;
- Precipitation;
- Snowpack and runoff; and
- Natural hazards, such as extreme heat, drought, wildfire, and floods.

Much of the information in this section represents studies and modeled projections for the whole state of Oregon and is presented as average values. Precise projected values will vary by geographic region throughout the state and throughout Clackamas County.

Temperature

Oregon's annual average temperature is increasing at the average national rate (Figure 11, following page). Annual average temperatures in Clackamas County have increased by about 4°F degrees F (2.2°C) since 1901.

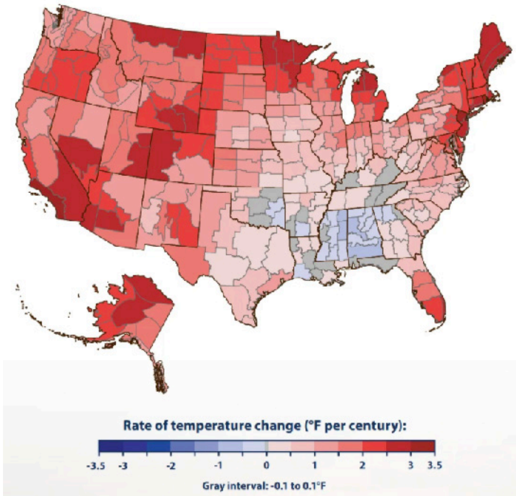


Figure 11. Rate of temperature change in the United States, 1901-2015.

Oregon's temperatures are projected to increase in all seasons, with summer temperatures increasing the most (Figure 12). In Figure 12, blue and red bars are observed temperatures (1900–2019) from the National Centers for Environmental Information. Solid lines are the mean values of 35 climate model simulations for the 1900–2005 period, which were based on observed climate forcings[41] (black line), and the 2006–2099 period for the two future scenarios RCP 4.5 and RCP 8.5 (orange and red lines). Shading indicates the range in annual temperatures.

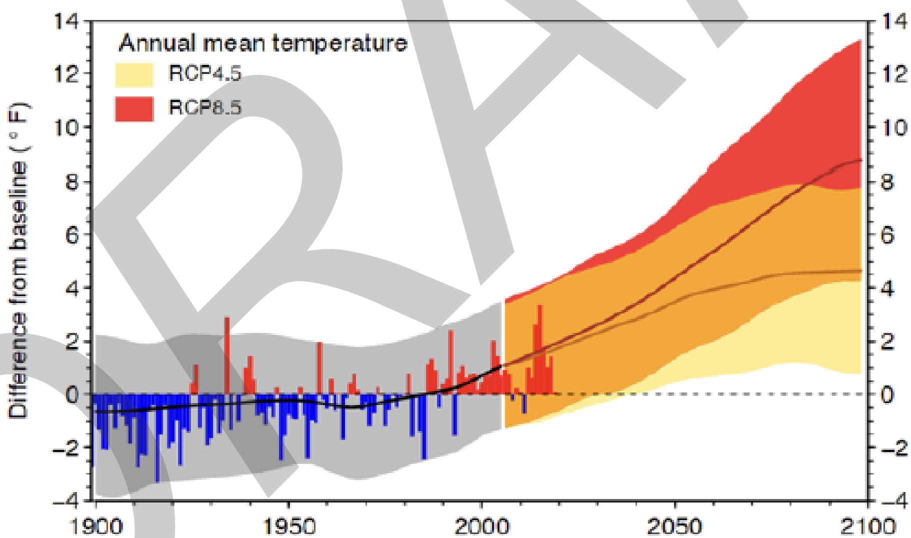


Figure 12. Observed, simulated, and projected changes in Oregon's mean annual temperature relative to 1970-1999 (baseline) under RCP 4.5 and RCP 8.5 future scenarios.

A representative concentration pathway (RCP) is a GHG concentration trajectory used in climate modeling to describe different climate futures that are considered possible depending on the volume of GHG emissions in the future. RCP 4.5 is an intermediate scenario representing global temperature rise between 2 and 3°C (3.6 and 5.4° F). RCP 8.5 is the worst-case scenario, under

[41] A climate forcing is a factor that can alter the Earth's climate, such as changes in the amount of greenhouse gasses in the atmosphere (creating an imbalance in the Earth's energy budget) or changes in solar radiation. These changes can cause the Earth's climate to warm or cool, leading to changes in precipitation patterns, sea level, and other aspects of the climate system.

which temperatures rise between 3 and 5°C (5.4 and 9°F).

Elevated and sustained temperatures will result in longer, hotter summers likely to induce droughts and heat waves, which are major threats to human survival, especially in vulnerable populations.

Extended heat can have many negative impacts, including on water supply and water quality, agricultural yields, livestock survival, ecosystem health, and soil erosion rates. In addition, increased energy demand for air conditioning can put strain on electricity generation and transmission infrastructure.

Precipitation

The historical annual variability of Oregon's precipitation is expected to continue in future years, with a slight increasing trend (Figure 13).

Precipitation is expected to increase during the spring and winter and decrease in summer months. It is likely that the intensity of heavy precipitation events will increase in coming years.

RCP 4.5 and RCP 8.5 Explained

Representative Concentration Pathway (RCP) 4.5 is the scenario developed by the United Nations Intergovernmental Panel on Climate Change (IPCC) that describes a future where GHG emissions increase at a slower rate than in the higher-emissions RCP 8.5 scenario, but still exceed the levels needed to stabilize the climate. This scenario assumes that there will be a rapid deployment of renewable energy technologies, as well as some reduction in energy demand through energy efficiency measures. As a result, CO_2 emissions peak at around 2040 and then decline until they stabilize at approximately 4.5 times pre- industrial levels by the end of the century. This scenario projects a warming of about 2.6 to 3.9°C (4.7 to 7.0°F) by 2100, compared to preindustrial levels.

Representative Concentration Pathway (RCP) 8.5 is the scenario developed by the IPCC that describes a future where GHG emissions continue to increase at a high rate, resulting in high levels of warming by the end of the century. This scenario assumes that there will be limited efforts to reduce emissions and that fossil fuels will continue to be the primary source of energy. As a result, CO_2 emissions continue to rise throughout the century and stabilize at approximately 8.5 times preindustrial levels. This scenario projects a warming of about 4.8 to 7.4°C (8.6 to 13.5°F) by 2100, compared to preindustrial levels. This scenario is often considered the "worst-case" scenario and is used as a benchmark to evaluate the potential impacts of high emissions.

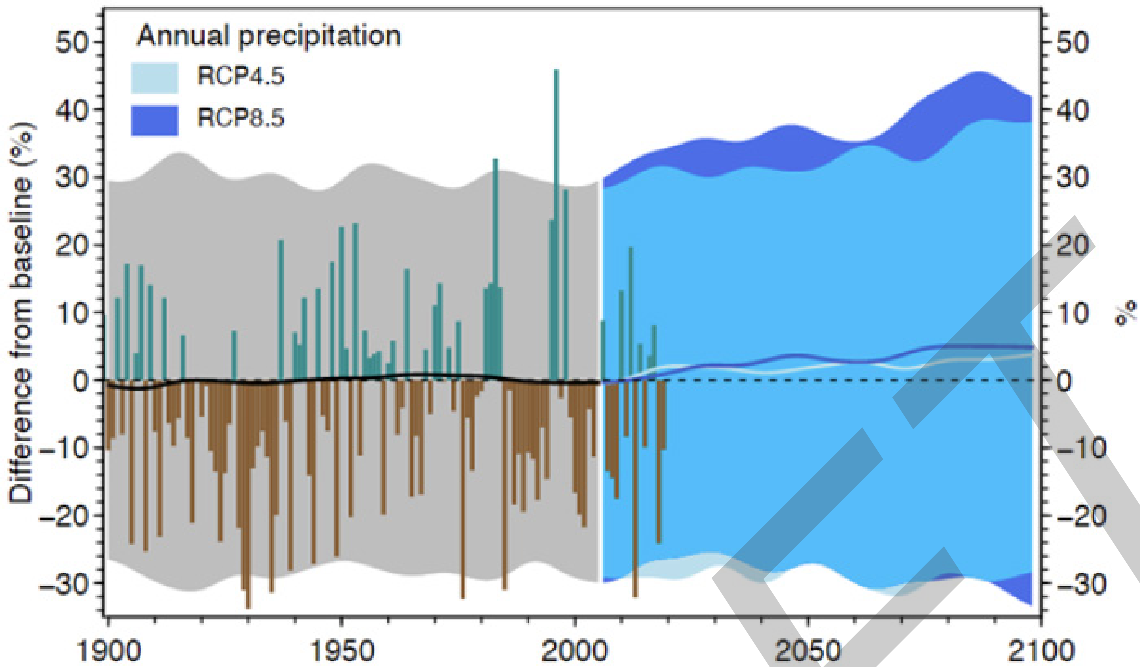


Figure 13. Observed, simulated, and projected changes in Oregon's mean annual precipitation relative to 1970–1999 (baseline) under RCP 4.5 and RCP 8.5 future scenarios. Green and brown bars are observed precipitation amounts (1900–2019) from the National Centers for Environmental Information. Solid lines are mean values of simulations from 35 climate models for 1900–2005, based on observed climate forcings (black line), and 2006–2099 for the two future scenarios, RCP 4.5 and RCP 8.5 (light and dark blue lines). Shading indicates the annual precipitation range from all models.

Increased precipitation and more intense storms risk overwhelming stormwater management systems resulting in flooding and wastewater overflow in urban areas. Flooding and landslide risks also increase, threatening housing, infrastructure, transportation, and energy generation and distribution networks.

Snowpack and Runoff

Many Clackamas County rivers and streams rely on the melting of winter snowpack in the Oregon Cascade Mountain Range. Annual snowpack in these mountains has been in decline in recent decades and is likely to continue to decrease as the climate warms. Warmer air temperatures will mean more moisture in the air, which will fall more often as rain than snow. In the Oregon Cascades, fewer than 25% of wet days are projected to be days with snow by the mid-21st century, compared to about 50% of wet days during the late 20th to early 21st centuries. Continued warming is projected to result in earlier streamflow, declining summer flows, and increasing winter flows.

Median summer runoff in the Clackamas River watershed is projected to decline 50% under an RCP 8.5 scenario. Extreme high flows are projected to increase up to 19%, and extreme low flows are projected to decrease by as much as 20 m^3/s[42] by the middle and late 21st century. The center timing of flow is projected to shift two to three weeks earlier by the 2080s (2070–2099).

[42] m3/s means "cubic meters per second." It tells us how much of something is flowing every second. Imagine filling up a big box that's 1 meter wide, 1 meter long, and 1 meter tall with water every second. In this case, it means that each second, a volume of one cubic meter of the fluid (or material) passes through the area in question. It's commonly used in contexts like fluid dynamics, water treatment, and various engineering applications.

Decreased snowpack and runoff will result in lessened stream flows and increased stream temperatures that may pose risks to stream and riparian wildlife. Hydroelectric utilities rely on steady stream flows and temperatures for consistent generation operation and thus are at risk from these climate change impacts.

Extreme Heat

Warming temperatures are increasing the frequency and severity of extreme heat days, seasons, and waves. Since 1940, the number of days exceeding 90°F increased by over eight days per year in Portland and Pendleton, and 21 days per year in Medford (Figure 14). The number of 90°F days in Portland in 2015 (29) and 2018 (31) broke records.

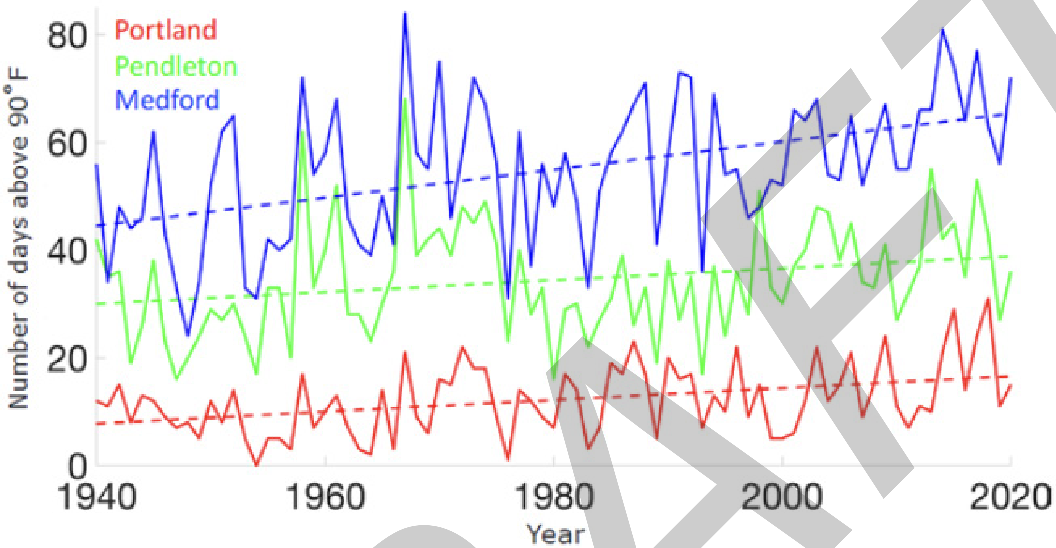


Figure 14. Number of days per year on which daily high temperature exceeded 90°F at Medford, Pendleton, Portland.

Projections indicate that most areas in Oregon can expect annual extreme heat day (above 86°F) totals to increase by 30 days by the end of the century (Figure 15). The increase in extreme heat days will likely be smaller in Clackamas County's mountainous regions.

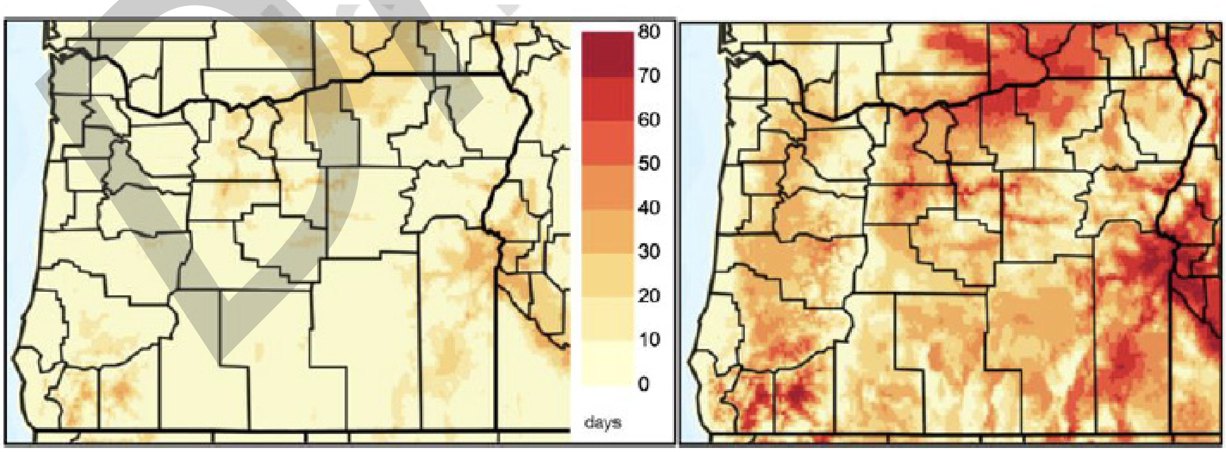


Figure 15. Number of days from April through October with a heat index ⇢90°F in historic (1971–2000, left) and future (2040–2069, right) periods under RCP 8.5.

The rising frequency of extreme heat events will increase heat-related illness and death frequency, particularly among vulnerable populations (elderly; children; people with chronic illnesses; people with low incomes; Black, Indigenous, and People of Color; and outdoor workers). Projections indicate a 422% increase in heat-related deaths under RCP 8.5 during the 2031-2080 period across the country. Cooling systems in buildings can reduce extreme heat mortality risk. However, these systems contribute to climate change through their use of high greenhouse gas-intensive refrigerants and create increased electrical demand, posing challenges for the electricity grid. Sustained high temperatures and aridity can also contribute to the transmission of infectious diseases present in the state, such as Lyme disease and West Nile virus.[43]

Drought

Persistent drought is common in the Pacific Northwest. Over the last 20 years, the incidence, extent, and severity of drought has increased in the Northwest compared with the 20th century. These droughts have had numerous adverse impacts on agriculture, water availability, drinking water quality[44], recreation, ecosystems, and wildfire risk. Anticipated warmer, drier summers and decreased snowpack due to warmer winter temperatures are expected to result in more frequent droughts. As climate change reduces mountain snowpack, seasonal drought will become less predictable in Clackamas County and winter snow droughts will increase the likelihood of hydrological or agricultural drought during the following spring and summer.

Increased summer drought conditions may warrant new infrastructure for water storage for potable and agricultural uses. Elevated water efficiency measures may be required for both users and utilities. Drought also affects the availability of water for hydroelectric generation, risking decreased generation output.

Wildfire

Wildfire is a naturally occurring phenomenon whose frequency and severity is increased by climate change. The Oregon 2020 fire season was one of the worst on record, with five wildfires of over 100,000 acres each. These fires resulted in thousands of displaced people, destroyed structures and infrastructure, while also contributing to hazardous air quality in many parts of Oregon and the Northwest US.

Various wildfire modeling efforts predict that under a mean temperature increase of 3.6°F the median annual area burned by wildfires in Oregon will increase 200%. The incidence of very large fires (burning more than 5000 acres) is likely to increase 200-400% under RCP 8.5. Increased wildfire frequency and severity are likely to increase risk of drought, insect outbreaks, and pathogens that can lead to substantial ecological changes and further risk to human health and survivability.

Clackamas County has many communities in wildland-urban interfaces, which are high-risk areas for wildfire damage to infrastructure and threat to human life. Wildfire depletion of vegetation increases erosion, flood and landslide risk. These, in turn, pose additional risks to water supply infrastructure (e.g., treatment plants, reservoirs) via overflow, turbidity, and contamination.

[43] National Environmental Health Association, (2019). Regional Climate and Health Monitoring Report. Blueprint for a Healthy Clackamas County: *https://www.blueprintclackamas.com/tiles/index/display?alias=ClimateChange*

[44] According to the Oregon Water Resources Department, droughts can lead to reduced stream flows and groundwater levels, which can make it more difficult to access and treat water for drinking. During droughts, water demand increases, and water sources may become over-allocated, leading to competition between different users and potentially reducing the availability of water for drinking. Additionally, droughts can cause wells to go dry, making it difficult to access groundwater. State of Oregon, Water Resources Department. Drought Impacts on Water Quality: *https://www.oregon.gov/owrd/programs/drought/Pages/impacts.aspx*

Transportation is also at risk from wildfires, primarily due to on-road wildfire debris. Human and animal health is at risk during wildfire events as well; extremely elevated levels of airborne particulate matter pose threats to breathing, resulting in increased hospitalization for asthma and chronic lung disease exacerbations, heart attacks and strokes, as well as increased susceptibility to respiratory viruses. Vulnerable groups, including children and the elderly, face higher risks.

Floods

Floods across Oregon are likely to be more severe in years to come because of three key climate impacts: large precipitation events are expected to be more intense, precipitation will fall more as rain than snow, and total wet-season precipitation volumes will increase. As the air warms it holds more moisture, causing more frequent and more severe precipitation. As less precipitation falls as snow, rain events have more volume. More frequent rain events mean wetter soil and reduced depth to groundwater—conditions that enable floods. Flood modeling predicts that by the 2030s and 2070s, major flood events on the nearby lower Columbia River (below the confluence with the Willamette River) will be 44% and 151% larger, respectively, under an RCP 8.5 scenario. Wetter soils and increased flood conditions present greater risk of landslides in hilly and mountainous areas. As of 2020, less than 6% of Oregon's levees were certified by FEMA.

Flooding poses risks to water supply, wastewater, and hydroelectric infrastructure, with the potential to overwhelm each. As many dams and reservoirs across the state are aging, their susceptibility to increased flood frequency and severity is elevated.

Climate Change Impacts on Human Health

A variety of studies have attempted to qualitatively and quantitatively estimate the effects of climate change to human health. Table C summarizes six categories of climate effects, the major health risks associated with them, and the populations vulnerable to these effects.

Table C. Climate effects, health risks, priority populations, and example actions by the Oregon Health Authority.

CLIMATE EFFECTS	HEALTH RISKS[45]	PRIORITY POPULATIONS	EXAMPLE ACTIONS
Storms, floods, landslides and sea-level rise	Injuries	People dependent on medical equipment that requires electricity	The Oregon Health Authority (OHA) partnered with the Oregon Department of Transportation (ODOT) to conduct a case study on creation of climate resilience on Oregon's North Coast (*https://www.oregon.gov/odot/Programs/TDD%20Documents/Case-Study-Tillamook.pdf*). The project interviewed state and local transportation and health leaders and documented lessons learned.
	Toxic Exposures	Socially isolated people	
	Displacement	Older adults	
	Disruptions in medical care	Coastal communities	
	Mental health effects	Children	
		Pregnant individuals	

[45] Note: the categories in the Health Risks and Priority Populations are not a direct comparison. Each column is its own independent list.

CLIMATE EFFECTS	HEALTH RISKS[45]	PRIORITY POPULATIONS	EXAMPLE ACTIONS
Wildfire	Respiratory diseases	People with pre-existing conditions	The 2019 OHA report More days with haze: how Oregon is adapting to the public health risks of increasing wildfires (*https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/CLIMATECHANGE/Documents/2020/oha2688_0.2.pdf*) identified ways in which the public health system is adapting to increasingly severe wildfires and opportunities for climate adaptation.
	Cardiovascular diseases	Outdoor workers	
	Cancer	Children	
	Injuries	Pregnant individuals	
	Displacement	Older adults	
	Toxic exposures	Rural communities	
	Mental health effects	Tribal communities	
Infectious disease	Lyme disease	Outdoor workers	In 2016, OHA developed a guidance document for use of weather and environmental data with syndromic surveillance data for rapid assessment of the correlation.
	West Nile disease	Outdoor recreationalists	
	Fungal diseases	People experiencing homelessness	
	Shigellosis	Tribal communities	
		Rural communities	
Drought and water quality hazards	Mental health effects	Low-income communities	In 2017, OHA partnered with members of the Confederated Tribes of Warm Springs on a digital storytelling project (*https://www.oregon.gov/oha/ph/healthyenvironments/climatechange/pages/perspectives.aspx*) that documented climate-driven change in water quality in rivers and water shortages on the reservation. OHA also has assessed water insecurity in Oregon (Schimpf and Cude 2020).
	Dehydration	Tribal communities	
	Toxic exposures	Rural communities	
	Diminished living conditions	Farming and farmworker communities	
		Coastal communities	
Extreme heat	Heat-related illness & death	People with pre-existing conditions	OHA contributed to the State of Oregon's 2020 Natural Hazard Mitigation Plan (*www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx*). For the first time, the plan includes a chapter on extreme heat. Inclusion makes the state eligible for Federal Emergency Management Agency funding for mitigation actions that reduce identified risks.
	Violence	Outdoor workers	
		Outdoor athletes	
		People without air conditioning or housing	
		Residents of urban heat islands	
		Children	
		Pregnant individuals	
		Low-income communities	
		Communities of color	

CLIMATE EFFECTS	HEALTH RISKS[45]	PRIORITY POPULATIONS	EXAMPLE ACTIONS
Air quality and allergens	Ozone and smog	Low-income communities	In 2018, at the request of the governor's Carbon Policy Office, OHA prepared a policy paper on climate change and public health (*www.oregon.gov/oha/ph/healthenvironments/climatechange/documents/2018/2018-OHA-Climate-and-Health-Policy-Paper.pdf*) that identifies communities most affected by health risks of climate hazards and pollutants from greenhouse gas emissions.
	Airborne pollen	Communities of color	
	Airborne molds	Communities near highways and industrial facilities	
		Outdoor workers	
		People with pre-existing conditions	
		Farmworker communities	

The Cost of Inaction

Studies point to climate change being a threat multiplier. The frequency and severity of natural events are increased under a climate that is warming and fostering unstable and fluctuating conditions. This is accompanied by increased costs incurred in response to climate change events. Limiting climate change impacts through GHG emissions mitigation has costs, but these are dwarfed by the costs of inaction, which increase with each year action is not taken.

Various studies have modeled estimated economic damages of climate change impacts. The World Resources Institute summarizes several studies in ***10 Charts Show the Economic Benefits of US Climate Action*** (2020). Figure 16 from this summary demonstrates how the damages from climate change and associated recovery costs will increase the longer action is delayed.

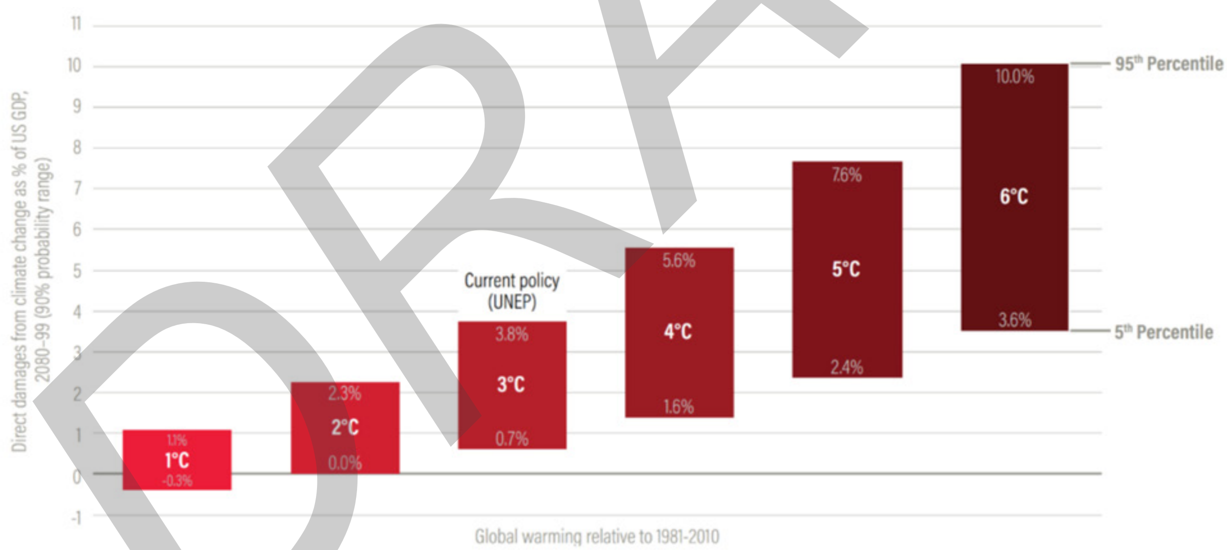


Figure 16. US economic damages at different levels of global warming.

From 1980 to 2020[46], Oregon experienced 32 natural disaster and storm events whose recovery exceeded $1 billion in costs (Table D). Twenty-five of these events have occurred in the past 20 years during which time the Earth experienced its 19 hottest years on record.

[46] The interactive NOAA chart including 2023 data can be found here: *https://www.ncei.noaa.gov/access/billions/*

Table D. Billion-dollar events to affect Oregon from 1980 to 2020 (CPI-Adjusted).

DISASTER TYPE	EVENTS	EVENTS/YEAR	PERCENT FREQUENCY	TOTAL COSTS	PERCENT OF TOTAL COSTS
Drought	13	0.3	40.6%	$2.0B-$5.0B	34.6%
Flooding	3	0.1	9.4%	$1.0B-$2.0B	15.9%
Freeze	1	0.0	3.1%	$100M-$250M	1.3%
Severe Storm	2	0.0	6.3%	$5M-$100M	1.0%
Wildfire	13	0.3	40.6%	$2.0B-$5.0B	47.1%
All Disasters	32	0.8	100.0	$5.0B-$10.0B	100.0%

The Oregon Global Warming Commission's 2020 Biennial Report includes this summary of recent climate change-exacerbated events and their costs:

In Oregon in 2020, an extreme runoff event caused damage to and closed I-84 and flooded homes in the Pendleton area; Governor Brown issued drought declarations for 14 counties from the coast to northeastern Oregon; and in the fall we experienced devastating fires across the state—in which at least nine Oregonians lost their lives and more than 40,000 had to evacuate; more than 4,000 structures and nearly 1.1 million acres were burned with an estimated $354 million in fire-fighting costs. A 2018 Headwaters Economics study found that wildfire suppression costs may account for only 9 percent of the total direct and indirect costs of major wildfires. By all measures the costs to Oregonians are incalculable.

This is one example from one state agency. Climate change impacts will elicit such responses from many departments at all levels of government, as well as from businesses, organizations, and institutions. The incalculable costs will be all the more so. The cheapest option is emissions mitigation, even given the investments that must be made in sectors like renewable energy, building energy efficiency retrofits, EV infrastructure, etc. These investments are proactive, controllable, and predictable, unlike climate change impact responses.

Clackamas County Multi-Jurisdictional Hazards Mitigation Plan

Clackamas County developed a Multi-Jurisdictional Natural Hazards Mitigation Plan (NHMP)[47] in 2019. The plan was developed to help the county plan for actions that can lessen the impact of disasters, which allows the county to identify risks associated with natural disasters and work on long-term strategies for protecting people and property.

The goals of the NHMP are to:

- protect life and property;
- enhance natural systems;
- augment emergency services;

[47] The NHMP does not significantly discuss if it was informed by RCP 4.5 or 8.5. Clackamas County Multi-Jurisdictional Hazard Mitigation Plan, 2019. Retrieved from: https://www.clackamas.us/dm/naturalhazard.html

- encourage partnerships for implementation, and
- promote public awareness.

The plan ranks hazards and vulnerabilities (Figure 17), which also helps us to determine the key topics to address when identifying impacts, exposure, risks, and vulnerabilities.

Hazard	History	Vulnerability	Maximum Threat	Probability	Total Threat Score	Hazard Rank	Hazard Tiers
Earthquake - Cascadia	4	45	100	49	198	#1	Top Tier
Earthquake - Crustal	6	50	100	21	177	#2	
Wildfire	12	25	70	56	163	#3	
Winter Storm	10	30	70	49	159	#4	
Drought	10	15	50	56	131	#5	Middle Tier
Flood	16	20	30	56	122	#6	
Windstorm	14	15	50	42	121	#7	
Landslide	14	15	20	63	112	#8	Bottom Tier
Volcanic Event	2	35	50	14	101	#9	
Extreme Heat	2	20	40	14	76	#10	

Source: Clackamas County NHMP Hazard Mitigation Advisory Committee, 2018

Figure 17. Hazard and vulnerability assessment summary

Climate Adaptation Assessment and Methodology

SSG (the consultants for this plan) accepts the climate change projections and hazards assessed in the Fifth Oregon Climate Assessment, published by the Oregon Climate Change Research Institute at Oregon State University, and supports the recommendations made in the Clackamas County NHMP (Figure 17, above).

SSG did not conduct further quantitative analysis of the climate change projections and hazards, but did investigate the relationship between the hazards and vulnerabilities such as demographic factors (e.g., poverty) and asset management and any asset deficits. SSG focused on engagement and best practices to identify risks, vulnerabilities, exposure, impacts, and stressors.

Short-Term Implementation

The CAP is an ambitious plan that spans every sector of the community. While climate action is essential, all the changes required cannot happen at once. Clackamas County can take five key steps to set the foundation to ensure climate action is a priority within the county and the broader community.

1. Hire dedicated staff to manage the implementation of the CAP.
2. Confirm and apply for funding from federal and state programs aligned with action implementation.
3. Establish an ongoing advisory committee with members from the public to provide feedback and support of implementation initiatives.
4. Identify and evaluate readiness of key potential partners to assist with implementation of actions not fully within Clackamas County's jurisdictional control.
5. Establish a set of key performance indicators to report on progress and challenges related to implementation.

As these foundational pieces are put into place, the county can be planning how to operationalize the implementation actions outlined in the Implementation Guide.

The challenges that climate change poses on Clackamas County, as well as globally, can seem daunting. This plan has described how climate change poses a significant threat to human well-being, including impacts on health, food and water security, and economic growth. Failure to act on climate change could lead to more frequent and severe heat waves, droughts, floods, and storms, which could cause widespread damage to infrastructure and communities, as well as loss of life.

The cost of inaction on climate change is likely to be much greater than the cost of action. The longer we wait to act, the more difficult and expensive it will be to reduce emissions and adapt to the impacts of climate change.

Notably, taking action on climate change also brings economic benefits, such as job creation in clean energy and energy efficiency sectors, and reduced reliance on fossil fuels that can lead to energy independence and security.

Tackling climate change is a global responsibility and taking action can help to ensure that future generations inherit a planet that is hospitable to human life and that can support continued sustainable development now and for generations to come.

Appendix A: Glossary of Terms and Abbreviations

Glossary

Adaptation: the process by which human systems adjust to actual or expected climate change and its effects. Adaptation seeks to moderate or avoid harm or even to take advantage of potential beneficial opportunities with the changing climate.

Atmospheric river: a narrow corridor or filament of concentrated moisture in the atmosphere. Atmospheric rivers can be hundreds of miles wide and over a thousand miles long; the amount of water in the form of vapor that flows through them is comparable to the largest land rivers in the world. They typically form over oceans when large cold fronts move from west to east.

Carbon sink: anything, natural or otherwise, that accumulates and stores some carbon-containing chemical compound for an indefinite period and thereby removes carbon dioxide (CO_2) from the atmosphere.

Climate hazards: the potential occurrence of climate-related physical events, such as extreme weather (heatwaves or floods), or climate change trends, such as increasing temperatures, that result in an impact on natural, built, or human systems.

Climate lens: an assessment framework developed to help decision-makers understand the climate change risks and impacts associated with new or changed projects, policies and programs.

Comorbidities: the presence of multiple chronic conditions in a single individual. These conditions can be related or unrelated, and they can have a significant impact on a person's overall health and well-being. Examples of comorbidities include diabetes and heart disease, or depression and anxiety.

Ecosystem: a community of organisms and the physical environment with which they interact.

Exposure: the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social, or cultural assets in places and settings adversely affected by climate-related events. Examples include assets located in a floodplain or people living in poor-quality housing.

Forcings: things that change the balance between incoming and outgoing energy in the climate system. Natural forcings include volcanic eruptions. Human-made forcings include air pollution and greenhouse gases.

Greenhouse gases: gases in the Earth's atmosphere that trap heat, causing the planet's surface to warm up. The most well-known greenhouse gas is carbon dioxide, but other examples include methane, nitrous oxide, and water vapor. These gases are produced naturally, but human activities such as burning fossil fuels, deforestation, and industrial processes have significantly increased their levels in the atmosphere. This has led to global warming and climate change, which have been linked to rising sea levels, more severe weather events, and other environmental problems.

Grid electricity: electricity delivered *on a network that interconnects power generation,* *transmission, and distribution units.*

Heat pump: a device that warms or cools a building by transferring heat from a relatively low-temperature reservoir to one at a higher temperature.

Impacts, also referred to as consequences or outcomes: primarily the effects of climate hazards on natural, built, and human systems. This includes the effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure. Impacts generally manifest in some form of damage, disruption, or complete (irretrievable) loss and can be generally categorized as physical, social, or economic. Impacts result due to the interaction of climate events or trends (occurring within a specific time period) and vulnerability of an exposed society or system.

Additionally, impacts can be considered direct (damage to a building) or indirect (loss of a job or income as a result of damage to a building).

Natural Climate Solutions: actions to protect, better manage and restore nature to reduce greenhouse gas emissions and store carbon, such as practices that improve forest management to help forest owners increase the carbon stored in their trees; reducing fertilizer use to decrease greenhouse gas emissions; and restoring coastal wetlands to sequester carbon in submerged soil.

Permeable pavement: a pavement type with a porous surface that is composed of concrete, open pore pavers or asphalt with an underlying stone reservoir that allows water to run through it rather than accumulate on it or run off it.

REACH Code: an Oregon statewide optional energy construction standard approved by the State Building Codes Division. It is separate from the state building code and applicable at the designer's and contractor's discretion.

Resilience: the capacity of a social, economic, or environmental system to cope with hazardous events or disturbances. This can involve responding to hazards or reorganizing systems in ways that allow them to maintain their essential function, identity, and structure.

Risk: results from the interaction of vulnerability, exposure, and hazard. In this context, the term primarily refers to the risks of climate change impacts (see Figure 6). Risk is also the potential for consequences where something of value is at stake and where the outcome is uncertain. It is often represented as the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. However, this mathematical approach requires the consideration of vulnerability and exposure intrinsically for it to be valuable.

Renewable Natural Gas (RNG): a type of natural gas produced through anaerobic digestion from renewable resources, such as organic waste from landfills, sewage treatment plants, and agricultural operations. It is considered a low-carbon energy source because it is produced from organic matter that would otherwise decompose and release methane, a potent greenhouse gas, into the atmosphere. It also can displace fossil fuel-based natural gas and reduce the overall greenhouse gas emissions.

Stressors: events and trends, which are often not climate-related, that have an important effect on the system exposed and can increase vulnerability to climate-related risk. For example, growing income inequality is a stressor that is pushing already low-income families to their financial limits, further increasing these families' vulnerability because they have fewer resources (and therefore decreased capacity) to respond to the impacts of a major climate event. This framing underscores that the development of a society has significant implications for exposure, vulnerability, and risk. Climate change does not pose a direct threat; rather it interacts with the changing vulnerability and exposure of systems, which in turn determines the fluctuating level of risk associated with climate-related hazards. Identifying key vulnerabilities facilitates the estimation of key risks when coupled with information about evolving hazards and exposure associated with climate change.

Vulnerability: the likelihood of being adversely affected; primarily refers to characteristics of human or social-ecological systems that are exposed to hazardous climatic events or trends. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (adaptive capacity).

Ecosystems, geographic areas, assets, humans, etc. can be classified as vulnerable, and this is of particular concern if vulnerability in one area (e.g., humans) increases as a result of potential impairment or increased vulnerability in other areas (e.g., assets).

Watershed: an area of land that drains or "sheds" water into a specific waterbody.

Abbreviations of Frequently Used Terms

BAP: Business-as-Planned Scenario

BEV: Battery Electric Vehicle

CAFE: Corporate Average Fuel Economy (a measure of the average fuel efficiency of an organization's fleet of vehicles)

CAP: Climate Action Plan

CATF: Community Advisory Task Force

CoP: Conference of Parties (supreme governing body of an international convention)

EPA: U.S. Environmental Protection Agency

EV: Electric Vehicle

GHG: Greenhouse Gas

GJ: Gigajoule (a measurement of energy)

ICI: Institutional, Commercial, and Industrial

IPCC: Intergovernmental Panel on Climate Change (the United Nations body for assessing the science related to climate change)

kWh: Kilowatt Hour (a composite unit of energy equal to one kilowatt sustained for one hour)

$MTCO_2e$: Metric Tons Carbon Dioxide Equivalent

SDC: System Development Charge (a one-time fee assessed to new customers of utilities or transportation infrastructure to help finance development of utility and transportation systems)

LCS: Low-Carbon Scenario

MMBTU: One Million British Thermal Units

MW: Megawatt (a measurement of electricity)

NZ: Net-Zero Emissions

O&M: Operations and Maintenance

PJ: Petajoule (a measurement of energy)

PV: Photovoltaics (e.g., solar panels, that generate power using devices that absorb energy from sunlight and convert it into electrical energy through semiconducting materials)

RNG: Renewable Natural Gas

SCC: Social Cost of Carbon

tCO_2e: Tons Carbon Dioxide Equivalent

TJ: Terajoule (a measurement of energy)

UNFCCC: United Nations Framework Convention on Climate Change

ZEV: Zero Emission Vehicle

Appendix B: Marginal Abatement Costs (MACs)

The Marginal Abatement Cost (MAC) is the incremental cost of one ton of GHG reductions. The lower the cost, the more affordable the action and, in some cases, the action can be profitable. It is calculated by adding the net present value of capital costs and operating costs over the lifetime of the investments divided by the tons of GHGs reduced.

Abatement Curve of Actions

Figure 19 illustrates an abatement curve of actions. Actions on the left save money and are therefore financially interesting to investors. Actions in the middle have a net present value (NPV) that is either slightly negative or slightly positive and may require credit enhancements to be compelling. Finally, on the right are actions that are NPV negative, which will require subsidies. A capital-constrained public sector must concentrate on the less expensive projects and those difficult to otherwise fund (but important for reducing emissions) while relying on the private sector for the rest. A capital-rich public sector can invest in projects that are more expensive and those which may generate more interesting financial returns.

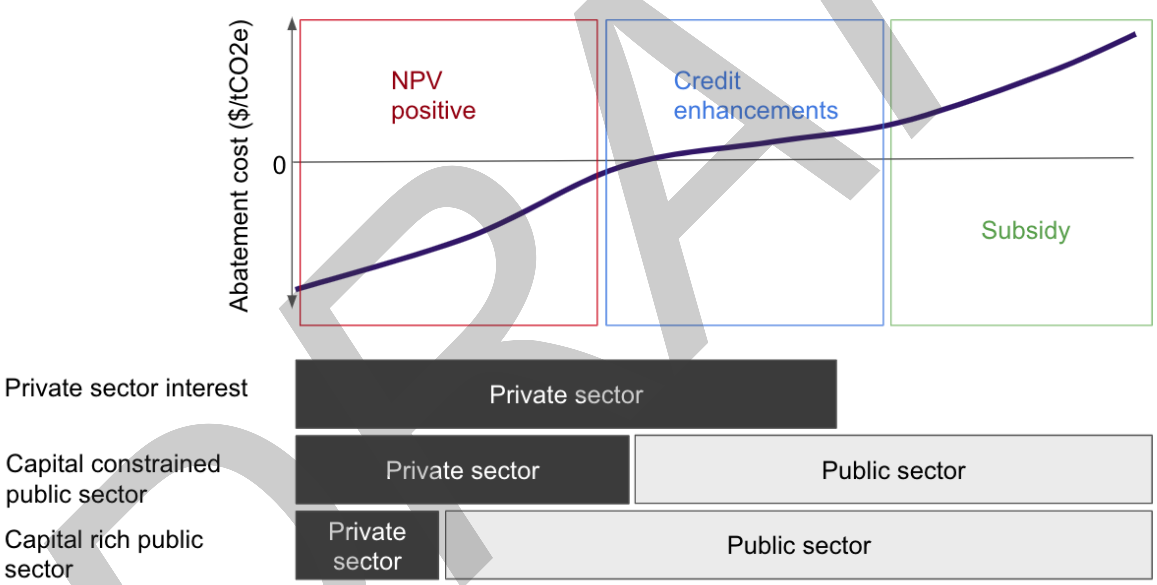


Figure 17. Aligning the abatement costs with investor interest.

By providing individual costs for actions, MACs can imply that the actions are a menu from which individual actions can be selected. In fact, many of the actions are dependent on each other; for example, energy costs increase without retrofits. Another important message is that to achieve Clackamas County's target, all the actions need to be undertaken as soon as possible.

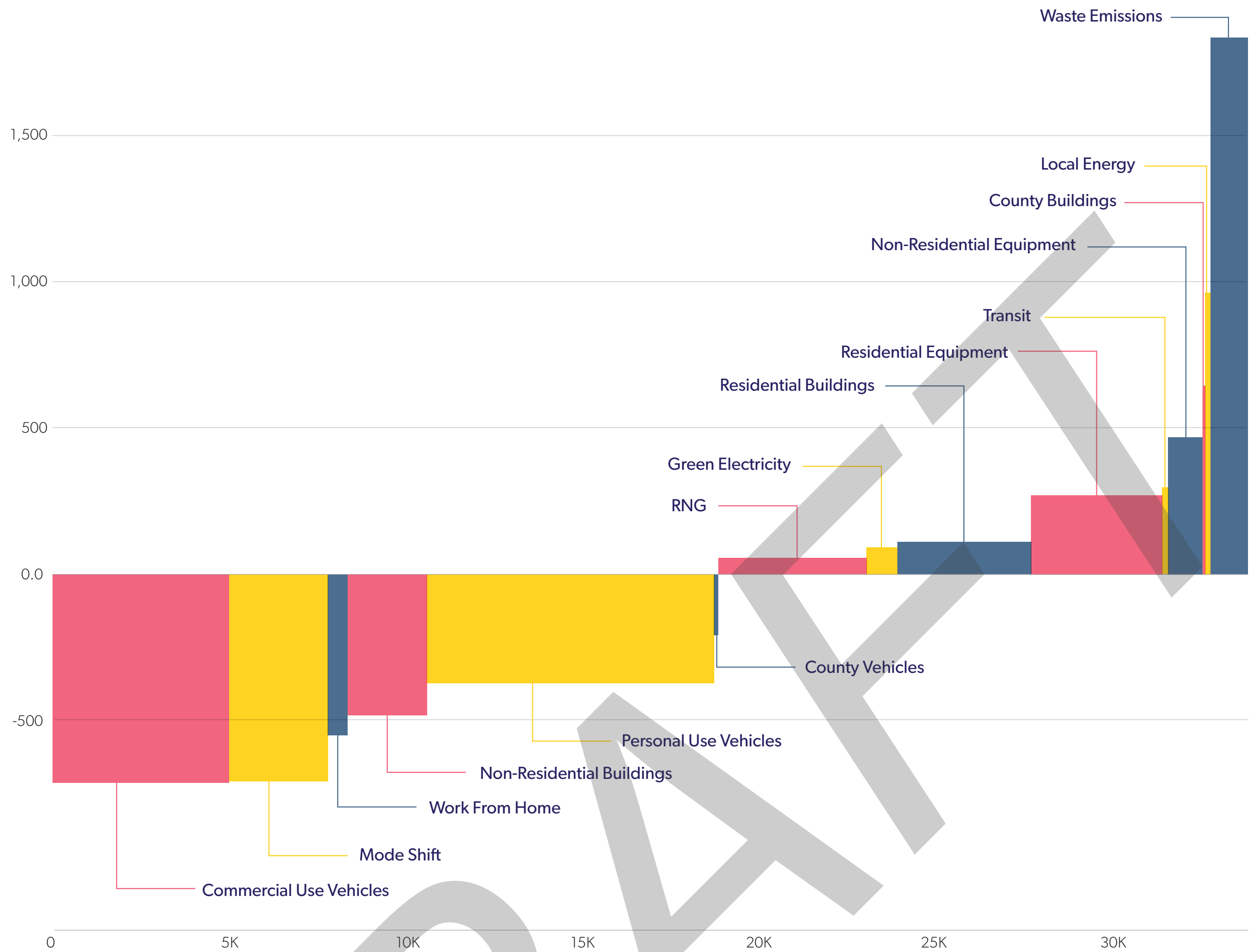


Figure 18. Marginal Abatement Cost Curve (MACC)

Decoding the MAC Curve Table (Table E)

Table E reviews marginal abatement costs for modeled actions in the County's low-carbon future.

The actions with green, or negative abatement generates financial returns over their lifetimes.

A red, or positive abatement, costs money over the span of the project.

This comparison provides one way to view the costs and benefits of implementing emissions-reducing actions, but should not be the only metric used to measure an action.

The MAC Curve table above provides information on the cost-effectiveness of various carbon emissions reduction outcomes for different sectors. The table shows the cumulative emissions reduction (in kt CO_2eq), the net present value (NPV) of the reduction strategy discounted at 3%, and the marginal abatement cost (MAC) of the outcome measured in dollars per ton of CO_2eq. The MAC column also shows the marginal cost of reducing one additional ton of CO_2eq emissions.

From the MACC table below, the most cost-effective carbon reduction outcomes are:

Reducing emissions from personal use vehicles, with a marginal abatement cost (MAC) of

-\$370/tCO_2eq and a net present value (NPV) of -\$3 billion

Reducing emissions from commercial use vehicles, with a MAC of -\$710/tCO_2eq and a NPV of

-\$3,570 billion

Shifting away from vehicle travel, with a MAC of -\$710/tCO_2eq and a NPV of \$2 billion

Non-residential buildings, with a MAC of -\$480/tCO_2eq and a NPV of -\$1,000,000,000

Cost-effectiveness is subjective. Some people might consider other criteria more important when choosing an outcome, for example, how much or how fast emissions are reduced.

This table only shows the cost of reducing one additional ton of CO_2eq emissions. If the outcome is to achieve a certain target, the total cost of achieving the target will be different.

This table can be used to inform decisions about which emissions reduction strategies to pursue, as it shows the cost-effectiveness of different options, and to identify the lowest-cost options to achieve a given emissions reduction target.

Table E. The marginal abatement costs of key actions identified in the MACC

SECTOR	CUMULATIVE EMISSIONS REDUCTIONS (THOUSAND $MTCO_2E$)	NET PRESENT VALUE (DISCOUNTED AT 3%)	MARGINAL ABATEMENT COST ($ / $MTCO_2$ EQ)
Residential Buildings	3,785	$420,000,000	111
Non-Residential Buildings	2,241	-$1,080,000,000	-482
County Buildings	16	$10,000,000	639
Local Energy	114	$110,000,000	961
Residential Equipment	3,711	$1,000,000,000	269
Non-Residential Equipment	1,026	$480,000,000	468
Transit	169	$50,000,000	295
Mode Shift	2,801	-$1,990,000,000	-710
County Vehicles	96	-$20,000,000	-208
Personal Use Vehicles	8,158	-$3,040,000,000	-373
Commercial Use Vehicles	5,013	-$3,570,000,000	-712
Work From Home	562	-$310,000,000	-551
Waste Reduction	322	$0	0
Waste Emissions	1,108	$2,030,000,000	1,833
Green Electricity	878	$80,000,000	91
RNG	4,187	$240,000,000	57

Appendix C: Additional Climate Benefits and Risks of Action

Additional climate benefits, also known as co-benefits, are positive effects that a policy or measure might have beyond its primary objective. One distinction made by the Organization for Economic Cooperation and Development (OECD), is that co-benefits are effects that are valued in the mitigation (emissions reduction) costs of a policy or action, whereas ancillary or additional benefits are effects that are incidental and are not accounted for in that analysis.[48] In this analysis, co-benefits are assumed to be any potential or anticipated benefits of the action in addition to its impact on GHG emissions.

Not all co-benefits and risks of action (co-harms) are equal

Not all co-benefits nor co-harms are equal. One set of criteria by which to consider the co-benefits of actions to reduce greenhouse gas emissions follows:[49]

- Synergies: Many low carbon actions -- including improving transit, energy efficiency, and compact urban design -- have multiple socio-economic benefits.
- Urgency: Some actions are associated with a higher degree of urgency to avoid loss of inertia on action already taken, lock-in effects,[50] irreversible outcomes, or deferred costs that become even more elevated as a result of deferment. And then there are some low-carbon actions that require time to be effective, which makes immediate implementation all the more important.
- Costs: The cost of early action is generally lower than the cost of later action, in particular because delayed action involves ongoing investments in infrastructure, activities, and utilities that have higher emissions than low carbon solutions. Examples include renewable energy infrastructure, transit, and energy efficiency.
- Longevity: Related to urgency, the longevity of investment decisions locks society into their effects for decades[51], if not centuries.
- Distribution effects: Low-carbon actions have different impacts on different subsets of the population, including income levels, generations (including future generations), race, and ethnicities.

[48] IPCC. (2014). Annex II: Glossary [Agard, J., E.L.F. Schipper, J. Birkmann, M. Campos, C. Dubeux, Y. Nojiri, L. Olsson, B. Osman-Elasha, M. Pelling, M.J. Prather, M.G. Rivera-Ferre, O.C. Ruppel, A. Sallenger, K.R. Smith, A.L. St. Clair, K.J. Mach, M.D. Mastrandrea, and T.E. Bilir (eds.)]. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1757-1776. p. 1762.

[49] Adapted from (Fay et al., 2015).

[50] Lock-in effect: implementation of a strategy or action that improves performance of an object or activity in the short term but prohibits future change, for example, building upgrades or land use. E.g. where quick building retrofits are undertaken, no additional improvements in the equipment installed can be expected over the course of its lifetime without considerable additional expense. In this way, lower levels of energy reductions are locked in for a long period.

[51] For example: when a new building is constructed, if it does not have low-carbon design built in from the beginning, it is an infrastructure choice with a multi-decade set of consequences (as most buildings are built to last 50+ years).

Examples of Co-benefits (Additional Benefits)

Energy Efficiency

Initiatives that lead to greater energy efficiency in households may also have the benefit of reducing the burden of household energy costs; however, only some energy efficiency programs may specifically benefit low-income community members, depending on how they are designed. For example, if household energy efficiency incentives are limited to rebates offered after retrofits, these may be out of reach for low-income households. Low-income households would, over time, disproportionately bear the fixed costs of maintaining the energy utility.

Improving Outdoor Air Quality

One of the most beneficial and immediate health co-benefits of actions to reduce GHG emissions is improved air quality. Improving air quality reduces premature death, improves equitable health outcomes for all Oregonians, and will save the state and its residents billions of dollars per year in avoided costs.

Climate change is bringing hotter temperatures to Oregon, leading to more frequent heat waves, drier conditions, more wildfires and wildfire smoke, and elevated ozone levels.[52] At the same time, while air quality in Oregon has been improving steadily over recent decades, climate change will increase the likelihood of conditions that exacerbate poor air quality. In 2020, nearly all areas of Oregon experienced multiple days of "unhealthy," "very unhealthy" and "hazardous" Air Quality Index scores due to record high temperatures and wildfire smoke.[53]

Burning fossil fuels such as gasoline, diesel, and natural gas releases air pollutants, such as sulfur dioxide, nitrogen oxides, particulate matter, carbon monoxide, polycyclic aromatic hydrocarbons, mercury, volatile organic compounds, and others, all of which have adverse impacts on human health.[54]

Air pollution does not affect everyone in Oregon equally. In 2017, approximately 1 in 10 adults in Oregon reported having asthma, making them more sensitive to poor air quality.[55] Low-income communities and communities of color experience a greater burden of air pollution across the entire state; due to historic and ongoing inequities and discrimination, they are more likely to live in neighborhoods with close proximity to highways, railyards, polluting industries, lack of trees and green space, and urban heat islands.[56] People living in households with an annual income of less than $20,000, as well as Native American and African American communities, experience higher rates of asthma and heart disease than other groups.[57] Outdoor workers and farmworker communities are also particularly at risk of exposure to air pollutants from transportation and industrial activities, in addition to wildfire smoke and ozone. Air pollution also increases cancer risk; according to the Environmental Protection Agency's 2014 National Air Toxics Assessment, the state of Oregon has the third-largest population at risk of excess cancer due to air pollution

[52] "2020 - 2020 Biennial Report to the Legislature.pdf," accessed October 30, 2021, https://static1.squarespace.com/static/59c554e0f09ca40655ea6eb0/t/5fe137fac70e3835b6e8f58e/1608595458463/2020-OGWC-Biennial-Report-Legislature.pdf.

[53] "Oregon Air Quality Monitoring Annual Report: 2020" (Portland, OR: Oregon Department of Environmental Quality, December 2021), https://oraqi.deq.state.or.us/Pagesfiles/2020%20Oregon%20Air%20Quality%20Monitoring%20Annual%20Report.pdf.

[54] Nicholas A. Mailloux et al., "Nationwide and Regional PM2.5-Related Air Quality Health Benefits From the Removal of Energy-Related Emissions in the United States," GeoHealth 6, no. 5 (2022): e2022GH000603, https://doi.org/10.1029/2022GH000603.

[55] Oregon Health Authority, Public Health Division, Health Promotion and Chronic Disease Prevention section, "Chronic Diseases among Oregon Adults, by County, 2014-2017," May 24, 2019, https://www.oregon.gov/oha/PH/DiseasesConditions/ChronicDisease/DataReports/Pages/index.aspx.

[56] Emily York et al., "Climate and Health in Oregon - 2020 Report."

[57] Emily York et al.

within the United States, behind California and New York.

Switching from fossil fuels to using cleaner energy sources can produce health benefits from improved air quality in the near term while also providing climate benefits in the longer term. Eliminating air pollutants from fossil fuel combustion would also have massive economic benefits, with researchers estimating up to $600 billion in annual benefits from avoided PM2.5-related illnesses and deaths each year in the U.S. as a whole.[58] Scenarios run in early 2022 using the Oregon Energy Policy Simulator, an online modeling tool, indicate that Oregon could see economic benefits between $3 and $5 billion in 2050, depending on the level of emissions reduced.[59] Researchers from Harvard University have concluded that a total decarbonization of the American energy sector would pay for itself through public health benefits alone, before even factoring in the cost-benefit analysis of reducing emissions.[60]

58 Mailloux et al., "Nationwide and Regional PM2.5-Related Air Quality Health Benefits From the Removal of Energy-Related Emissions in the United States."

59 Shelley Wenzel, Megan Mahajan, and Eric Strid, "Oregon Policy Simulator Insights: Recent Developments, Policies to Meet Emissions Goals," n.d., 18.

60 David Wallace-Wells, "Opinion | The True Cost of the Climate Stalemate in Congress," The New York Times, May 19, 2022, sec. Opinion, *https://www.nytimes.com/2022/05/19/opinion/environment/build-back-better-joe-manchin.html*.

Appendix D: A History of Action

The county's board-adopted carbon-neutral target and desire to build resilience to climate change guided the development of the Climate Action Plan.

Clackamas County has acknowledged the need to take steps toward greenhouse gas mitigation since 2008 when it adopted the U.S. Cool Counties Climate Stabilization Declaration and a resolution on climate change. That same year, the county appointed the Sustainable Clackamas County Task Force to develop a three- to five-year sustainability action plan. The task force created the Action Plan for a Sustainable Clackamas County, which set a goal for the county to become carbon neutral and reduce its GHG emissions by 80% by 2050. Work was completed in the community through an Energy Efficiency Conservation Block Grant, staffing and other implementation support.

Though these programs and support were later discontinued, they have been reviewed for their impact on the community as one indicator for this plan. Other actions included:

- In 2017, the Board reaffirmed the county's climate goals. County staff developed a greenhouse gas emissions inventory for county operations and began exploring ways to reduce their GHG impact through actions such as fleet electrification and renewable electricity.
- In 2018, the Board directed staff to develop an updated countywide climate action plan.
- In 2018, the county formed the Clackamas County Climate Exchange, bringing together staff from across county departments several times a year to support the development of the Climate Action Plan and coordinate climate action. The departments currently represented on the Climate Exchange are Transportation and Development; Water Environment Services; Health, Housing and Human Services; Disaster Management; Business and Community Services; and Public and Government Affairs.
- In 2019, the Climate Exchange Steering Committee was formed, made up of a small, focused group of Climate Exchange members, to provide direction and produce work to support the CAP. This group worked with the Institute for Sustainable Solutions from Portland State University to define the CAP scope of work.
- In 2019, the Board set a goal to adopt a climate action plan by January 2022, which was extended to 2023 in recognition of the delays created by COVID-19, historic wildfires in 2020, and a severe ice storm in 2021.

Additional information about climate action in Clackamas County, and at the State and Federal levels can be found in Appendix E: The Data, Methods, and Assumptions (DMA) Manual.

The county has also made changes to its own operations. Actions include purchasing nearly 100% renewable electricity for county operations beginning in the 2019-20 fiscal year, moving toward low-carbon county-owned vehicles and EV charging, and expanding opportunities for commercial food scraps composting in the community. Community education initiatives include offering a climate change presentation for schools and hosting Repair Fairs for people to fix their broken appliances and tools instead of disposing of them.

Another ongoing effort is the Leaders in Sustainability program, through which staff trains and certifies local businesses, and recognizes them for their positive impact on our environment and community. The businesses demonstrate their commitment to sustainability through recycling and composting, energy and water efficiencies, sustainable transportation and community engagement.

The County has also been working diligently to address climate-related risks through its Natural Hazards Mitigation Plan (NHMP). The NHMP helps the county prepare for actions that can lessen the impact of disasters. The NHMP allows the county to identify risks associated with natural disasters and work on long-term strategies for protecting people and property. When it was last updated in 2019, emerging climate-related hazards including drought and extreme heat were included. A NHMP update planned for 2023 is expected to identify opportunities to mitigate and build resilience to disasters that are increasingly likely due to climate change.

Appendix E: Data, Methods, and Assumptions (DMA) Manual

Summary

This Data, Methods and Assumptions (DMA) manual details the modeling approach used to provide community energy and emissions benchmarks and projections while providing a summary of the data and assumptions used in scenario modeling. The DMA makes the modeling elements fully transparent and illustrates the scope of data required for future modeling efforts.

Accounting and Reporting Principles

The municipal greenhouse gas (GHG) inventory baseline development and scenario modeling approach correlate with the Global Protocol for Community-Scale GHG Emissions Inventories (GPC). The GPC provides a fair and true account of emissions via its principles:

Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the county boundary. The inventory will also serve the decision-making needs of the county, taking into consideration relevant local, state, and national regulations. Relevance applies when selecting data sources and determining and prioritizing data collection improvements.

Completeness: All emissions sources within the inventory boundary shall be accounted for. Any exclusions of sources shall be justified and explained.

Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology.

Transparency: Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.

Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process should be reduced to the extent possible and practical.

Scope

Geographic Boundary

Energy and emissions inventories and modeling for the project will be done in relation to the geographical boundary shown in Figure 1.

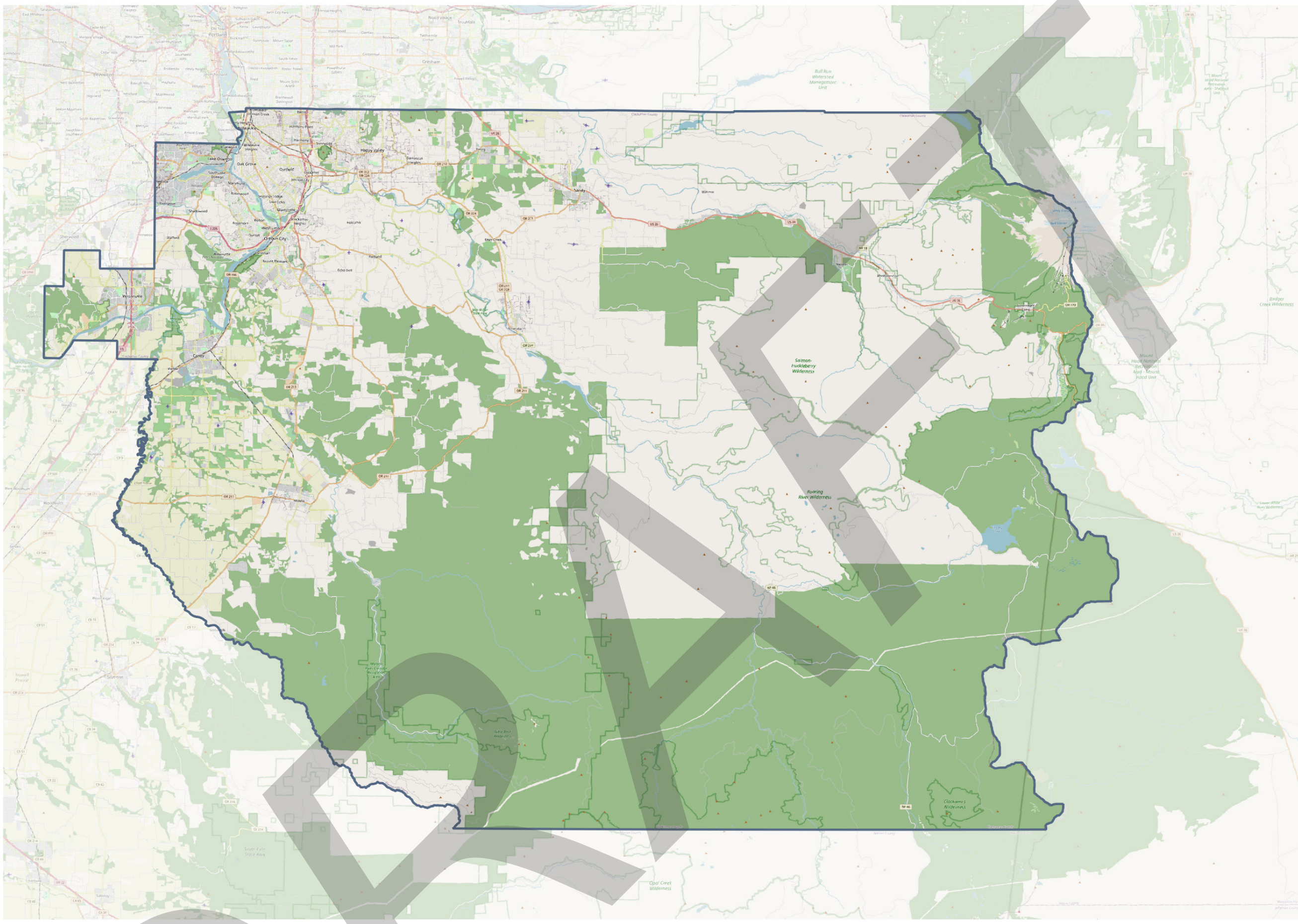


Figure 1: Geographical boundary considered for the project.

Time Frame of Assessment

The modeling time frame will include the years 2018-2053. The year 2018 will be used as the baseline year since it aligns with the county's existing inventory, and 2050 as a target year. Model calibration for the baseline year uses as much locally observed data as possible.

Energy and Emissions Structure

The total energy for a community is defined as the sum of the energy from each of the aspects:

$$Energy_{county} = Energy_{transport} + Energy_{buildings} + Energy_{waste\&wastewatergen}$$

Where:

$Energy_{transport}$ is the movement of goods and people.

$Energy_{buildings}$ is the generation of heating, cooling and electricity.

$Energy_{wastegen}$ is energy generated from waste.

The total GHG emissions for a community is defined as the sum from all in-scope emissions sources:

$$GHG_{landuse} = GHG_{transport} + GHG_{energygen} + GHG_{waste\&wastewater} + GHG_{agriculture} + GHG_{forest} + GHG_{landconvert}$$

Where:

$GHG_{transport}$ is emissions generated by the movement of goods and people.

$GHG_{energygen}$ is emissions generated by the generation of heat and electricity.

$GHG_{waste\&wastewater}$ is emissions generated by solid and liquid waste produced.

$GHG_{agriculture}$ is emissions generated by food production.

GHG_{forest} is emissions generated by forested land.

$GHG_{landconvert}$ is emissions generated by the lands converted from natural to modified conditions.

Emissions Scope

The inventory will include emissions Scopes 1 and 2, and some aspects of Scope 3, as defined by GPC (Table 1 and Figure 2). Refer to Appendix 1 of this DMA for a list of included GHG emission sources by scope.

Table 1. GPC scope definitions.

SCOPE	DEFINITION
1	All GHG emissions from sources located within the municipal boundary.
2	All GHG emissions occurring from the use of grid-supplied electricity, heat, steam and/or cooling within the municipal boundary.
3	All other GHG emissions that occur outside the municipal boundary as a result of activities taking place within the boundary.

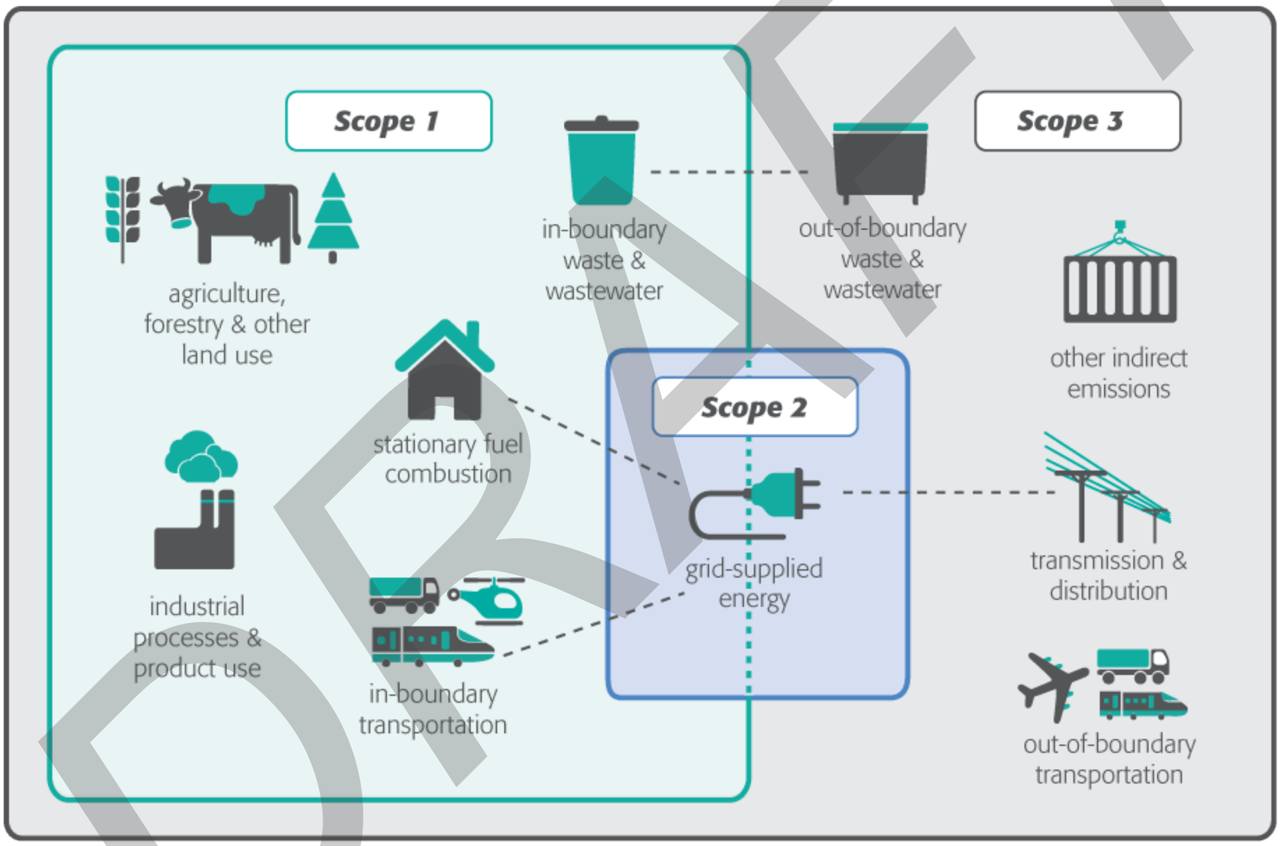


Figure 2: Diagram of GPC emissions scopes from C40.org.

The Model

Our model is an energy, emissions, and finance tool developed by Sustainability Solutions Group and whatIf? Technologies. The model integrates fuels, sectors, and land uses and is partially disaggregated. It enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g., vehicles, appliances, dwellings, buildings), and all intermediate energy flows (e.g., electricity and heat). Energy and GHG emissions values are derived from a series of connected stock and flow models, evolving based on current and future geographic and technology decisions/assumptions (e.g., EV uptake rates). The model accounts for physical flows (e.g., energy use, new vehicles by technology, vehicle miles traveled [VMT]) as determined by stocks (buildings, vehicles, heating equipment, etc.).

The model incorporates and adapts concepts from the system dynamics approach to complex systems analysis. For any given year, the model traces the flows and transformations of energy from sources through energy currencies (e.g., gasoline, electricity, hydrogen) to end uses (e.g., personal vehicle use, space heating) to energy costs and to GHG emissions. An energy balance is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use.

Table 2. Model characteristics.

Characteristic	Rationale
Integrated	The tool models and accounts for all county-scale energy and emissions related sectors and captures relationships between sectors. The demand for energy services is modelled independently of the fuels and technologies that provide the energy services. This decoupling enables exploration of fuel switching scenarios. Physically feasible scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, the model enables the creation of dozens of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	Built environment configuration determines walkability and cyclability, accessibility to transit, feasibility of district energy, and other aspects. The model therefore includes spatial dimensions that can include as many zones (the smallest areas of geographic analysis) as deemed appropriate. The spatial components can be integrated with GIS systems, land-use projections, and transportation modeling.
GHG reporting framework	The model is designed to report emissions according to the GHG Protocol for Cities (GPC) framework and principles.
Economic impacts	The model incorporates a high-level financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies, and actions. This allows for the generation of marginal abatement costs.

Model Structure

The major components of the model and the first level of modelled relationships (influences) are represented by the blue arrows in Figure 3. Additional relationships may be modelled by modifying inputs and assumptions - specified directly by users, or in an automated fashion by code or scripts running "on top of" the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a GHG emissions constraint.

The model is spatially explicit. All buildings, transportation, and land use data are tracked within the model through a GIS platform, and by varying degrees of spatial resolution. A zone type system is applied to divide the county into smaller configurations, based on the county's existing traffic zones (or another agreeable zone system). This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future dates using GIS-based platforms. The model's GIS outputs can be integrated with the county's mapping systems.

For any given year various factors shape the picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors - some contextual and some part of the energy consuming or producing infrastructure - and the energy flow picture.

Some factors are modelled as stocks - counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration), and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year, with a similarly classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g., furnaces, water heaters) and harvesting technologies (e.g., electricity generating capacity).

Major Components + Relationships
Influence Diagram

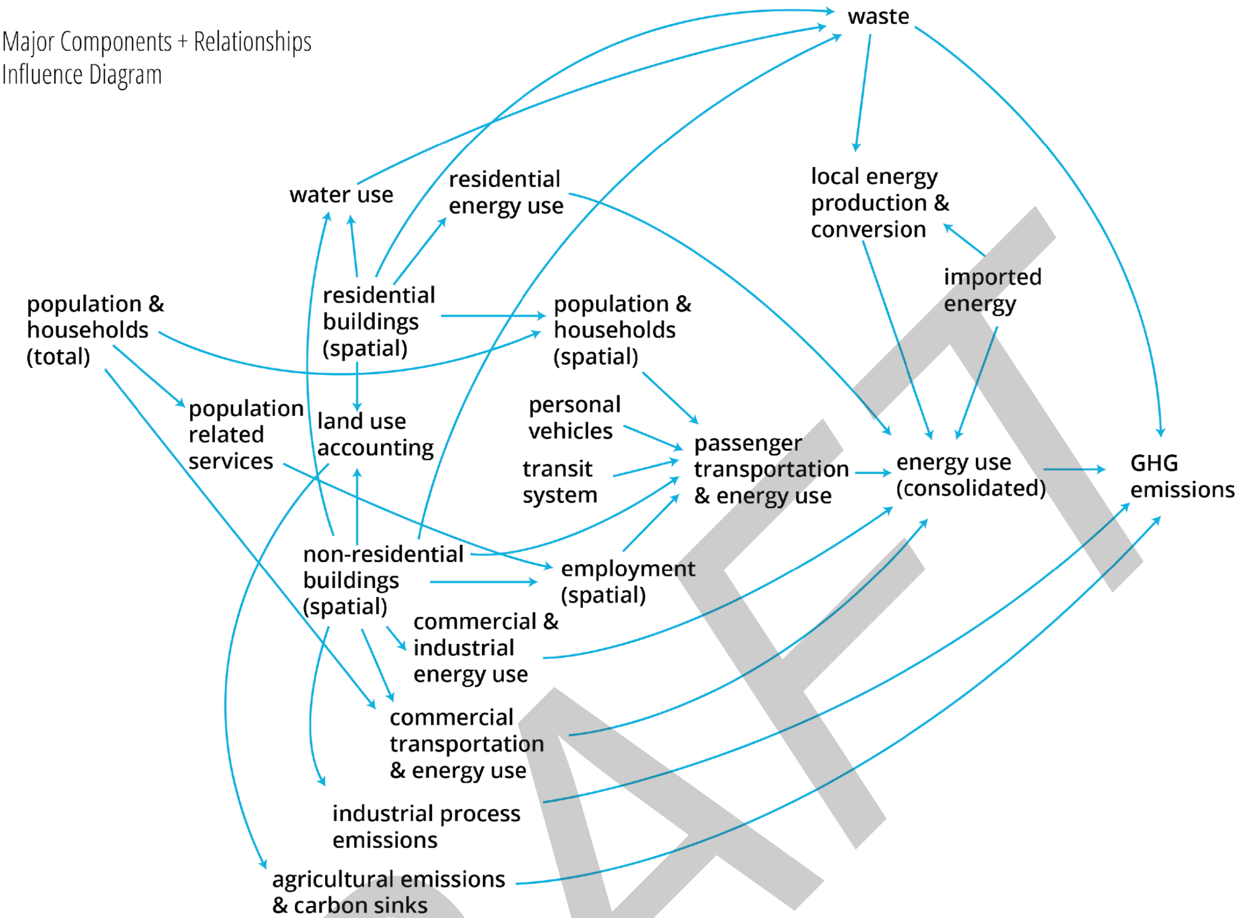


Figure 3. Representation of the model's structure.

Sub-models

Population and demographics

County-wide population is modelled using the standard population cohort-survival method, disaggregated by single year of age and gender. It accounts for various components of change: births, deaths, immigration and emigration. The age-structured population is important for analysis of demographic trends, generational differences and implications for shifting energy use patterns. These numbers are calibrated against existing projections.

Residential buildings

Residential buildings are spatially located and classified using a detailed set of 30+ building archetypes capturing footprint, height and type (single, double, row, apt. high, apt. low), in addition to year of construction. This enables a "box" model of buildings and the estimation of surface area. Coupled with thermal envelope performance and degree-days the model calculates space conditioning energy demand independent of any space heating or cooling technology and fuel. Energy service demand then drives stock levels of key service technologies (heating systems, air conditioners, water heaters). These stocks are modelled with a stock-turnover approach capturing equipment age, retirements, and additions - exposing opportunities for efficiency gains and fuel switching, but also showing the rate limits to new technology adoption and the effects of lock-in (obligation to use equipment/infrastructure/ fuel type due to longevity of system implemented). Residential building archetypes are also characterized by number of contained dwelling units, allowing the model to capture the energy effects of shared walls but also the urban form and transportation implications of population density.

Non-residential buildings

These are spatially located and classified by a detailed use/purpose-based set of 50+ archetypes. The floorspace of these archetypes can vary by location. Non-residential floorspace produces waste and demand for energy and water, and provides an anchor point for locating employment of various types.

Spatial population and employment

County-wide population is made spatial through allocation to dwellings, using assumptions about persons-per-unit by dwelling type. Spatial employment is projected via two separate mechanisms: population-related services and employment - which is allocated to corresponding building floorspace (e.g., teachers to school floorspace) - and floorspace-driven employment (e.g., retail employees per square foot).

Passenger transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior change, and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial drivers (population, employment, classrooms, non-residential floorspace). Trips are distributed - trip volumes are specified for each zone of origin and zone of destination pair. For each origin-destination pair, trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit), and automobile. A projection of total personal vehicle miles travelled (VMT) and a network distance matrix are produced following the mode share calculation. The energy use and emissions associated with personal vehicles is calculated by assigning VMT to a stock-turnover personal vehicle model. The induced approach is used to track emissions. All internal trips (trips within the boundary) are accounted for, as well as half of the trips that terminate or originate within the municipal boundary. Figure 4 displays trip destination matrix conceptualization.

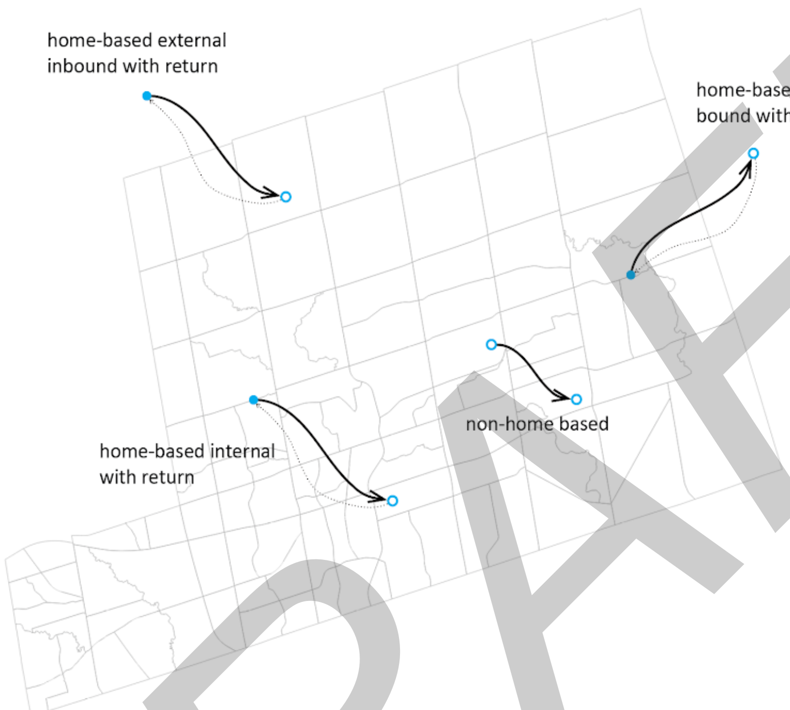


Figure 4. Conceptual diagram of trip categories.

Waste and wastewater

Households and non-residential buildings generate solid waste and wastewater. The model traces various pathways to disposal, compost and sludge including those which capture energy from incineration and recovered gas. Emissions accounting is performed throughout the waste sub-model.

Energy flow and local energy production

Energy produced from primary sources (e.g., solar, wind) is modelled alongside energy converted from imported fuels (e.g., electricity generation, district energy, CHP). As with the transportation sub-model, the district energy supply model has an explicit spatial dimension and can represent areas served by district energy networks.

Finance and employment

Energy-related financial flows and employment impacts are captured through an additional layer of model logic (not shown explicitly in Figure 2). Calculated financial flows include the capital, operating, and maintenance cost of energy consuming stocks and energy producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities and energy infrastructure is modelled. The financial impact on businesses and households of the strategies is assessed. Local economic multipliers are also applied to investments.

Consumption emissions

Emissions attributable to the production of some items produced outside, but consumed in, Clackamas County are estimated and included in the emissions inventory and modeling (e.g., those for electronics, food, and clothing). These are estimated based on number of households and a weighted average consumption per household (across all income levels). A total baseline emissions value is derived by multiplying the weighted average emissions per household intensity by number of households. This methodology enables accurate comparison to previous Clackamas County inventories.

Model Calibration for Local Context

Data request & collection

Local data was supplied by the jurisdiction. Assumptions were identified to supplement any gaps in observed data. The data and assumptions were applied in modeling per the process described below.

Zone system

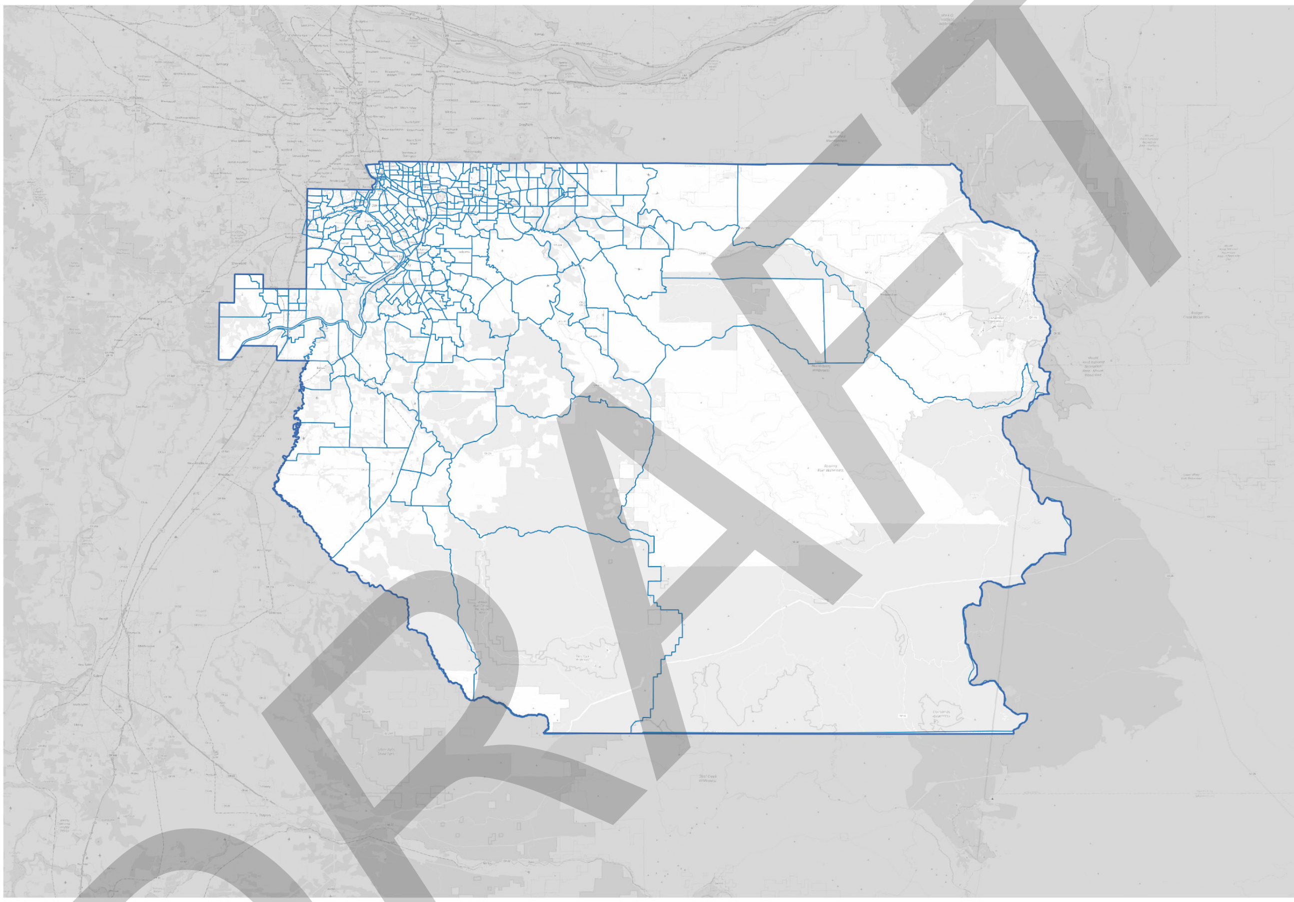


Figure 5. Zone system used in modeling.

The model is spatially explicit: population, employment, residential, and non-residential floorspace are allocated and tracked spatially within the model's zone system. These elements drive stationary energy demand. The passenger transportation sub-model, which drives transportation energy demand, also operates within the same zone system.

Buildings

Buildings data including type, footprint area, number of stories, total floorspace area, number of units, and year built was sourced from county property assessment data. Buildings were allocated to specific zones using their spatial attributes, based on the zone system. Buildings are classified using a detailed set of buildings archetypes (see Appendix 2). These archetypes capture footprint, height and type (e.g., single-family home, semi-attached home, etc.), enabling the creation of a "box" model of buildings, and an estimation of surface area for all buildings.

Residential buildings

The model multiplies the residential building surface area by an estimated thermal conductance (heat flow per unit surface area per degree day) and the number of degree days (heating and cooling) to derive the energy transferred out of the building during winter months and into the building during summer months. The energy transferred through the building envelope, the solar gain through the building windows, and the heat gains from equipment inside the building constitute the space conditioning load to be provided by the heat systems and the air conditioning. The initial thermal conductance estimate is a regional average by dwelling type from a North American energy system simulator, calibrated for the Pacific Northwest. This initial estimate is adjusted through the calibration process as the modelled energy consumption from the market profile in the 2015 Residential Energy Consumption Survey (RECS).

Non-residential buildings

The model calculates the space conditioning load as it does for residential buildings with two distinctions: the thermal conductance parameter for non-residential buildings is based on floor space area instead of surface area and incorporates data from Clackamas County.

Starting values for output energy intensities and equipment efficiencies for non-residential end uses are taken from the 2012 Commercial Buildings Energy Consumption Survey (CBECS). All parameter estimates are further adjusted during the calibration process. The calibration target for non-residential building energy use is the observed commercial and industrial fuel consumption in the baseline year.

Using assumptions for thermal envelope performance for each building type, the model calculates total energy demand for all buildings, independent of any space heating or cooling technology and fuel.

Population and employment

Federal census population and employment data was spatially allocated to residential (population) and non-residential (employment) buildings. This enables indicators to be derived from the model (such as emissions per household) and drives the BAP energy and emissions projections (buildings, transportation, waste).

Population for 2018 was spatially allocated to residential buildings using initial assumptions about persons-per-unit (PPU) by dwelling type. These initial PPUs are then adjusted so that the total population in the model (which is driven by the number of residential units by type multiplied by PPU by type) matches the total population from census/regional data.

Employment for 2018 was spatially allocated to non-residential buildings using initial assumptions for two main categories: population-related services and employment, allocated to corresponding building floorspace (e.g., teachers to school floorspace); and floorspace-driven employment (e.g., retail employees per square foot). Like population, these initial ratios are adjusted within the model so that the total employment derived by the model matches total employment from census/regional data.

Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior change, and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by a different combination of spatial drivers (population, employment, classrooms, non-residential floorspace). Trip volumes are distributed as pairs for each zone of origin and zone of destination (Figure 4). For each origin-destination pair, trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit), and automobile. Total personal VMT is produced when modeling mode shares and distances. The energy use and emissions associated with personal vehicles is calculated by assigning VMT to model personal vehicle ownership.

Passenger transportation model was anchored with the travel demand forecasting models found in the Travel Demand Forecasting: Parameters and Techniques paper informing the spatial travel demand model and the results compared for reasonableness against indicators such as average annual VMT per vehicle. For medium-heavy duty commercial vehicle transportation, the ratio of local retail diesel fuel sales to State retail diesel fuel sales was applied to estimate non-retail diesel use.

The modelled stock of personal vehicles (by size, fuel type, efficiency, vintage) was informed by regional vehicle registration statistics. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.

The GPC induced activity approach is used to account for emissions. All internal trips (within boundary) as well as half of the trips that terminate or originate within the municipal boundary are accounted for. This approach allows the municipality to understand its transportation impacts on its peripheries and the region.

Transit VMT and fuel consumption was modelled based on data provided by Oregon Metro Data Research Center.

Waste

Solid waste stream composition and routing data (landfill, composting, recycling) was sourced from local data sources. The base carbon content in the landfill was estimated based on historical waste production data. Total methane emissions were estimated for landfills using the first order decay model, with the methane generation constant and methane correction factor set to default, as recommended by and based on values from IPCC Guidelines for landfill emissions. Data on methane removed via recovery was provided by the landfills.

Data and Assumptions

Scenario Development

The model supports the use of scenarios as a mechanism to evaluate potential futures for communities. A scenario is an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. Scenarios must represent serious considerations defined by planning staff and community members. They are generated by identifying population projections into the future, identifying how many additional households are required, and then applying those additional households according to existing land-use plans and/or alternative scenarios. A simplified transportation model evaluates the impact of the new development on transportation behavior, building types, agricultural and forest land, and other variables.

Business-as-Planned Scenario

The Business-as-Planned (BAP) scenario estimates energy use and emissions volumes from the baseline year (2018) to the target year (2050).

Methodology:

1. Calibrate model and develop 2018 baseline using observed data and filling in gaps with assumptions where necessary.
2. Input existing projected quantitative data to 2050 where available:
    - Population, employment and housing projections by transport zone
    - Build out (buildings) projections by transport zone
    - Transportation modeling from the municipality
3. Where quantitative projections are not carried through to 2050, extrapolate the projected trend to 2050.
4. Where specific quantitative projections are not available, develop projections through:
    - Analyzing current on the ground action (reviewing action plans, engagement with staff, etc.), and where possible, quantifying the action.
    - Analyzing existing policy that has potential impact and, where possible, quantifying the potential impact.

Low Carbon Scenario (LCS)

The model projects how energy flow and emissions profiles will change in the long term by modeling potential changes in the context (e.g., population, development patterns), projecting energy services demand intensities, and projecting the composition of energy system infrastructure.

Policies, actions and strategies

Alternative behaviors of various energy system actors (e.g., households, various levels of government, industry, etc.) can be mimicked in the model by changing the values of the model's user input variables. Varying values creates "what if" type scenarios, enabling a flexible mix-and-match approach to behavioral models which connect to the physical model. The model can explore a wide variety of policies, actions and strategies via these variables. The resolution of the model enables the user to apply scenarios to specific neighborhoods, technologies, building or vehicle types or eras, and configurations of the built environment.

Methodology

1. Develop a list of potential actions and strategies;
2. Identify the technological potential of each action (or group of actions) to reduce energy and emissions by quantifying actions:
   - If the action or strategy specifically incorporates a projection or target; or,
   - If there is a stated intention or goal, review best practices and literature to quantify that goal; and
   - Identify any actions that are overlapping and/or include dependencies on other actions.
3. Translate the actions into quantified assumptions over time;
4. Apply the assumptions to relevant sectors in the model to develop a low-carbon scenario (i.e., apply the technological potential of the actions to the model);
5. Analyze results of the low-carbon scenario against the overall target;
6. If the target is not achieved, identify variables to scale up and provide a rationale for doing so;
7. Iteratively adjust variables to identify a pathway to the target;
8. Develop marginal abatement cost curve for low carbon scenario;
9. Define criteria to evaluate low carbon scenario (i.e., identify criteria for multi-criteria analysis);
10. Prioritize actions of low carbon scenario;
11. Reflect prioritization in the final low-carbon scenario, removing and scaling the level of ambition of actions according to the evaluation results.

Addressing Uncertainty

There is extensive discussion of the uncertainty in models and modeling results. The assumptions underlying a model can be from other locations or large data sets and do not reflect local conditions or behaviors, and even if they did accurately reflect local conditions, it is exceptionally difficult to predict how those conditions and behaviors will respond to broader societal changes and what those broader societal changes will be.

The modeling approach uses four strategies for managing uncertainty applicable to community energy and emissions modeling:

1. Sensitivity analysis: One of the most basic ways of studying complex models is sensitivity analysis - quantifying uncertainty in a model's output. To perform this assessment, each of the model's input parameters is drawn from a statistical distribution in order to capture the uncertainty in the parameter's true value (Keirstead, Jennings, & Sivakumar, 2012).

Approach: Each input variable is modified by ±10-20% to illustrate the impact that an error of that magnitude has on the overall total.

2. Calibration: One way to challenge untested assumptions is the use of 'back-casting' to ensure the model can 'forecast the past' accurately. The model can then be calibrated to generate historical outcomes, calibrating the model to better replicate observed data.

Approach: Variables are calibrated in the model using two independent sources of data. For example, the model calibrates building energy use (derived from buildings data) against actual electricity data from the electricity distributor.

3. Scenario analysis: Scenarios are used to demonstrate that a range of future outcomes are possible given the current conditions and that no one scenario is more likely than another.

Approach: The model will develop a reference scenario.

4. Transparency: The provision of detailed sources for all assumptions is critical to enabling policymakers to understand the uncertainty intrinsic in a model.

Approach: Modeling assumptions and inputs are presented in this document.

Appendix 1: GPC Emissions Scope Table for Detailed Model

Green rows = Sources required for GPC BASIC inventory

Blue rows = Sources required GPC BASIC+ inventory

Red rows = Sources required for territorial total but not for BASIC/BASIC+ reporting

Exclusion Rationale Legend

N/A	Not Applicable, or not included in scope
ID	Insufficient Data
NR	No Relevance, or limited activities identified
Other	Reason provided in other comments

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Exclusion rationale
I	STATIONARY ENERGY SOURCES			
I.1	Residential buildings			
I.1.1	1	Emissions from fuel combustion within the territorial boundary	Yes	
I.1.2	2	Emissions from grid-supplied energy consumed within the territorial boundary	Yes	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.2	Commercial and institutional buildings/facilities			
I.2.1	1	Emissions from fuel combustion within the territorial boundary	Yes	
I.2.2	2	Emissions from grid-supplied energy consumed within the territorial boundary	Yes	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.3	Manufacturing industry and construction			
I.3.1	1	Emissions from fuel combustion within the territorial boundary	Yes	
I.3.2	2	Emissions from grid-supplied energy consumed within the territorial boundary	Yes	
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.4	Energy industries			
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the territorial boundary	No	NR
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the territorial boundary	No	NR
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	No	NR
I.4.4	1	Emissions from energy generation supplied to the grid	No	NR
I.5	Agriculture, forestry and fishing activities			
I.5.1	1	Emissions from fuel combustion within the territorial boundary	Yes	
I.5.2	2	Emissions from grid-supplied energy consumed within the territorial boundary	Yes	
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.6	Non-specified sources			

I.6.1	1	Emissions from fuel combustion within the territorial boundary	No	NR
I.6.2	2	Emissions from grid-supplied energy consumed within the territorial boundary	No	NR
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal			
I.7.1	1	Emissions from fugitive emissions within the territorial boundary	No	NR
I.8	Fugitive emissions from oil and natural gas systems			
I.8.1	1	Emissions from fugitive emissions within the territorial boundary	Yes	
II	TRANSPORTATION			
II.1	On-road transportation			
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the territorial boundary	Yes	
II.1.2	2	Emissions from grid-supplied energy consumed within the territorial boundary for on-road transportation	Yes	
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the territorial boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes	
II.2	Railways			
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the territorial boundary	Yes	
II.2.2	2	Emissions from grid-supplied energy consumed within the territorial boundary for railways	Yes	
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the territorial boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes	
II.3	Water-borne navigation			
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the territorial boundary	Yes	
II.3.2	2	Emissions from grid-supplied energy consumed within the territorial boundary for waterborne navigation	Yes	
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the territorial boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes	
II.4	Aviation			
II.4.1	1	Emissions from fuel combustion for aviation occurring within the territorial boundary	No	N/A
II.4.2	2	Emissions from grid-supplied energy consumed within the territorial boundary for aviation	No	N/A
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the territorial boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes	
II.5	Off-road			
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the territorial boundary	Yes	
II.5.2	2	Emissions from grid-supplied energy consumed within the territorial boundary for off-road transportation	No	NR
III	WASTE			
III.1	Solid waste disposal			
III.1.1	1	Emissions from solid waste generated within the territorial boundary and disposed in landfills or open dumps within the territorial boundary	No	NR
III.1.2	3	Emissions from solid waste generated within the territorial boundary but disposed in landfills or open dumps outside the territorial boundary	Yes	
III.1.3	1	Emissions from waste generated outside the territorial boundary and disposed in landfills or open dumps within the territorial boundary	No	N/A

III.2	Biological treatment of waste			
III.2.1	1	Emissions from solid waste generated within the territorial boundary that is treated biologically within the territorial boundary	Yes	
III.2.2	3	Emissions from solid waste generated within the territorial boundary but treated biologically outside of the territorial boundary	No	N/A
III.2.3	1	Emissions from waste generated outside the territorial boundary but treated biologically within the territorial boundary	No	N/A
III.3	Incineration and open burning			
III.3.1	1	Emissions from solid waste generated and treated within the territorial boundary	No	N/A
III.3.2	3	Emissions from solid waste generated within the territorial boundary but treated outside of the territorial boundary	No	N/A
III.3.3	1	Emissions from waste generated outside the territorial boundary but treated within the territorial boundary	No	N/A
III.4	Wastewater treatment and discharge			
III.4.1	1	Emissions from wastewater generated and treated within the territorial boundary	Yes	
III.4.2	3	Emissions from wastewater generated within the territorial boundary but treated outside of the territorial boundary	No	NR
III.4.3	1	Emissions from wastewater generated outside the territorial boundary	No	N/A
IV	INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
IV.1	1	Emissions from industrial processes occurring within the territorial boundary	No	ID
IV.2	1	Emissions from product use occurring within the territorial boundary	Yes	ID
V	AGRICULTURE, FORESTRY AND LAND USE (AFOLU)			
V.1	1	Emissions from livestock within the territorial boundary	Yes	
V.2	1	Emissions from land within the territorial boundary	No	NR
V.3	1	Emissions from aggregate sources and non-CO_2 emission sources on land within the territorial boundary	No	ID
VI	OTHER SCOPE 3			
VI.1	3	Other Scope 3	Yes	
TOTAL				

Appendix 2: Building Types in the Model

Residential Building Types	Non-residential Building Types	
Single_detached_1Storey_tiny	college_university	commercial_retail
Single_detached_2Storey_tiny	school	commercial
Single_detached_3Storey_tiny	retirement_or_nursing_home	commercial_residential
Single_detached_1Storey_small	special_care_home	retail_residential
Single_detached_2Storey_small	hospital	warehouse_commercial
Single_detached_3Storey_small	municipal_building	warehouse
Single_detached_1Storey_medium	fire_station	religious_institution
Single_detached_2Storey_medium	penal_institution	surface_infrastructure
Single_detached_3Storey_medium	police_station	energy_utility
Single_detached_1Storey_large	military_base_or_camp	water_pumping_or_treatment_station
Single_detached_2Storey_large	transit_terminal_or_station	industrial_generic
Single_detached_3Storey_large	airport	food_processing_plants
Double_detached_1Storey_small	parking	textile_manufacturing_plants
Double_detached_2Storey_small	hotel_motel_inn	furniture_manufacturing_plants
Double_detached_3Storey_small	greenhouse	refineries_all_types
Double_detached_1Storey_large	greenspace	chemical_manufacturing_plants
Double_detached_2Storey_large	recreation	printing_and_publishing_plants
Double_detached_3Storey_large	community_centre	fabricated_metal_product_plants
Row_house_1Storey_small	golf_course	manufacturing_plants_miscellaneous_
Row_house_2Storey_small	museums_art_gallery	processing_plants
Row_house_3Storey_small	retail	asphalt_manufacturing_plants
Row_house_1Storey_large	vehicle_and_heavy_equiptment_service	concrete_manufacturing_plants
Row_house_2Storey_large	warehouse_retail	industrial_farm
Row_house_3Storey_large	restaurant	barn
Apartment_1To4Storey_small		
Apartment_1To4Storey_large		
Apartment_5To14Storey_small		
Apartment_5To14Storey_large		
Apartment_15To24Storey_small		
Apartment_15To24Storey_large		
Apartment_25AndUpStorey_small		
Apartment_25AndUpStorey_large		
inMultiUseBldg		

Appendix 3: Emissions Factors Used

Category	Value	Comment
Natural gas	CO2: 53.02 kg/MMBtu CH4: 0.005 kg/MMBtu N2O: 0.0001kg/MMBtu	ICLEI–Local Governments for Sustainability USA. "US community protocol for accounting and reporting of greenhouse gas emissions." (2012).
Electricity	2018 CO2e: 771 lbs CO2e per MWh	Portland General Electric Average Emissions Factor
Gasoline	CO2: 0.07024 MT/MMBtu CH4: 0.000000017343 MT/mile N2O: 0.000000009825 MT/mile	ICLEI–Local Governments for Sustainability USA. "US community protocol for accounting and reporting of greenhouse gas emissions." (2012).
Diesel	CO2: 0.073934483 MT/MMBtu CH4: 0.000000001 MT/vehicle mile N2O: 0.0000000015 MT/vehicle mile	ICLEI–Local Governments for Sustainability USA. "US community protocol for accounting and reporting of greenhouse gas emissions." (2012).
Fuel oil	CO2: 73.9 kg per mmBtu CH4: 0.003 kg per mmBtu N2O: 0.0006 kg per mmBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." ***Stationary Combustion Emission Factors," US Environmental Protection Agency2014, Available: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf*** (2014). Table 1 Stationary Combustion Emission Factor, Fuel Oil No. 2
Wood	CO2: 93.80 kg per mmBtu CH4: 0.0072 kg per mmBtu N2O: 0.0036 kg per mmBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." ***Stationary Combustion Emission Factors," US Environmental Protection Agency2014, Available: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf*** (2014). Table 1 Stationary Combustion Emission Factor, Biomass fuels: Wood and Wood Residuals
Propane	CO2: 62.87 kg per mmBtu CH4 : 0.003 kg per mmBtu N2O: 0.0006 kg per mmBtu For mobile combustion: CO2: 5.7 kg per gallon	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." ***Stationary Combustion Emission Factors," US Environmental Protection Agency2014, Available: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf*** (2014). Table 1 Stationary Combustion Emission Factor, Petroleum Products: Propane Table 2 Mobile Combustion CO2 Emission Factors: Propane
Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2018 to be determined based on % recovery of landfill methane and waste composition.	Landfill emissions: IPCC Guidelines Vol 5. Ch 3, Equation 3.1
Wastewater	CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH4 wastewater: IPCC Guidelines Vol 5. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N2O from advanced treatment: IPCC Guidelines Vol 5. Ch 6, Box 6.1 N2O from wastewater discharge: IPCC Guidelines Vol 5. Ch 6, Section 6.3.1.2

Greenhouse gases	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N20) are included. Global Warming Potential $CO_2 = 1$ $CH_4 = 34$ $N_2O = 298$	Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) are not included.