Policy Brief: Charting a Course for Oregon's Energy Future

Part I: Introduction

States across the U.S. have adopted increasingly **aggressive clean energy and climate change policies** in recent years.[1] Local governments – from Portland, Bend, and Ashland to other cities in Oregon[i] – are also adopting such policies, sometimes with even more aggressive timelines and goals than those adopted by their respective states. In almost all cases, these policies are intended to achieve significant **reductions in economy-wide greenhouse gas emissions by 2050**.

While state policies vary in specifics, recent technical analyses find that achieving these targets will require an "unprecedented transition"[2] and "substantial investments"[3] to effect "a transformation of the energy system."[4] This transformation – sometimes referred to as deep decarbonization – has the potential to boost Oregon's GDP in 2050 by as much as $4 billion,[5] driven primarily by indirect economic and health benefits, but also by taking the billions of dollars that Oregonians currently send out of state for fossil fuels and redirecting to in-state investments in clean energy.

Many of the technical analyses align in their findings that this energy system transformation to meet policy objectives is achievable by focusing on four core pillars of decarbonization:

Energy efficiency

Electrification of end uses

Decarbonizing the electric sector

Developing low-carbon fuels

Important decisions remain, however, for state policymakers on whether, and to what extent, to encourage or discourage specific technology pathways within this transition to a clean energy economy by mid-century.[6] [7] [4]

This Policy Brief series will review recent technical analyses that identify the scale of the actions required to achieve clean energy and decarbonization policies and will identify common themes and strategies from that literature. It will also frame some of the questions that Oregon policymakers will need to consider when determining how to achieve the state's 2050 climate goals and identify how the state can engage more intentionally in identifying its own priorities in the clean energy transition.

The sections of this brief that follow will explore in greater detail some of these policy decisions facing the state across the following subtopics:

- Transformation of the electric sector
- The role of conventional and alternative gaseous fuels
- Decarbonization of the transportation sector
- Trade-offs among different clean energy pathways

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[i] For information on local jurisdictions within Oregon taking climate change actions see: https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Policy-Briefs.pdf#page=13

Oregon's Policy Landscape

Two recently adopted policies play a central role in defining Oregon's clean energy and climate policy landscape: Executive Order 20-04 and HB 2021. Both policies, particularly when considered in combination, commit Oregon to deep decarbonization of the state's economy by mid-century that is similar to the types of policies modeled in the technical analyses reviewed for this Policy Brief series.

Executive Order 20-04: Directing State Agencies to Take Actions to Reduce and Regulate Greenhouse Gas Emissions[8]

Governor Brown signed EO 20-04 in March 2020.

While the order imposed requirements on several state agencies, one of the most consequential outcomes has been the establishment of the Climate Protection Program by the Department of Environmental Quality. The CPP is a regulatory program launched in 2022 designed to dramatically reduce economy-wide greenhouse gas emissions by 2050. The program adopts a cap on emissions from fossil fuels—including the direct use fuels and transportation fuels sectors—used throughout the state, with an interim target of a 50 percent reduction by 2035 and a 90 percent reduction by 2050.[9]

House Bill 2021 (2021) [10]

The most relevant element of this law for purposes of this brief is the 100 percent clean electricity standard. The law requires the state's largest retail electricity providers (investor-owned utilities and electricity service suppliers) to eliminate greenhouse gas emissions from the electricity they provide to consumers by 2040, with interim targets of an 80 percent reduction from baseline levels by 2030 and a 90 percent reduction by 2035.

Technical Studies: Charting the Course to 2050

In response to the adoption of more aggressive clean energy and climate policies, many states, energy providers, and other industry stakeholders have commissioned technical analyses to identify broad strategies and potential technology pathways for achieving these policies in the decades ahead. For this series of briefs, the authors have reviewed 20 of these technical studies published since 2018.[ii]

Some of these studies were focused on individual utility service areas or on specific states, some focused on the Pacific Northwest as a region, and others evaluated these types of policies nationwide. Table 1 illustrates the breadth of the regions and policies considered by these studies.

[ii] In October 2022, Portland General Electric published an update to the 2017 Deep Decarbonization Study used for this brief. The 2022 study explores potential decarbonization pathways across PGE's service territory considering the goals established in HB 2021. https://portlandgeneral.com/about/who-we-are/resource-planning

Table 1: Summary of the Range of Scope of the Studies Reviewed

Geographic Areas	**Regional:** Pacific Northwest, United States **States:** Oregon, Washington, Montana, California **Service Areas:** NW Natural, Portland General Electric, Eugene Water & Electric Board, Seattle City Light, SoCalGas, Los Angeles Department of Water and Power
Areas of Focus	**Sectors:** Electrification effects on electric system, evaluation of effects on gas infrastructure, heating loads **Broader:** Electricity system, economy-wide
Policy Targets	**Targets:** Carbon neutrality, net-zero emissions, 100% clean electricity, 100% electrification of buildings and transportation, economy-wide decarbonization, 80 to 100% reduction in greenhouse gas emissions from 1990 levels
Dates	**Dates:** Load growth through 2024, achieving GHG targets by 2045-2050, carbon neutrality by 2045-2050, 100% clean electricity by 2035

Despite this variation in geographic scope, sectoral focus, and range of the specific clean energy or decarbonization targets evaluated, these studies coalesce around the identification of several common strategies, or pillars of decarbonization, necessary to achieve these policy objectives in the decades ahead.

Common Strategies: Pillars of Decarbonization

Many of the technical studies reviewed identified some combination of the four pillars of decarbonization identified above. And as noted explicitly by multiple studies, a portfolio of solutions will be required to achieve clean energy and carbon policy objectives, while a pursuit of any one of these strategies alone would be insufficient.[11] [12] [13] [14]

Energy efficiency: Continued investments in energy efficiency is a core strategy to achieve decarbonization policy objectives.[15] [11] [13] [16] [17] [6] [18] [12] This strategy helps to reduce the overall amount of clean energy necessary to power the economy. In this context, energy efficiency refers both to improving the efficiency of using a particular fuel (e.g., converting home heating from electric resistance heating to a high-efficiency electric heat pump), but also to converting an end-use from one fuel type to another in certain cases (e.g., converting from a gasoline vehicle to an electric vehicle or from a vehicle to walking or biking, which use energy much more efficiently).

Electrification of end uses: Converting end-uses from fossil fuels to electricity is another core decarbonization strategy.[15] [11] [19] [20] [16] [13] [17] [21] [18] [12] In particular, many studies identify the need to electrify the transportation sector and space and water heating in buildings to varying degrees.[11] [19] [20] [16] The extent to which these sectors need to be decarbonized to achieve climate targets depends upon how ultimately stringent the targets are. In Oregon, for example, one study found that an 80 percent reduction in GHG emissions from 1990 levels by 2050 could be achieved "without decarbonizing significant quantities of liquid fuels," but that would change if the target were increased to 100 percent.[22] Expansive electrification has the potential to drive a significant build-out of the electric sector, potentially doubling the amount of installed generating capacity by 2050 compared to today.[23]

Clean electricity supply: The next strategy requires a significant increase in the availability of clean electricity supply compared to the mix on today's grid.[15] [11] [19] [13] [24] [23] [25] [26] [17] [6] [18] [12] Many of the studies reviewed identify the retirement of coal resources as a critical component, while also emphasizing the need to develop new clean electricity generation resources. Wind and solar generation are consistently identified as the primary resources needed to provide clean electricity,[3] [23] [25] while at least one study identified a scenario where wind and solar projects are constrained, and advanced nuclear and/or gas plants with carbon capture technology are necessary.[25]

Low-carbon fuels: Some end-uses – such as certain industrial processes, heavy duty transportation, and aviation fuels – are more challenging to decarbonize with electricity than others. Identifying a decarbonization strategy of other end-uses, such as space and water heating in the building sector, may require balancing trade-offs between broader electrification and the use of low-carbon fuels in existing gas infrastructure. In any case, the technical analysis finds that the development of large volumes of low-carbon fuels (e.g., biofuels or electrolytic fuels such as renewable hydrogen) are a fourth strategy to achieving decarbonization objectives.[15] [11] [22] [13] [27] [17] [28]

Several of the studies also identify one or both of the following additional strategies, neither of which will be focused on in this policy brief for the reasons described:

- **Carbon capture:**[iii] Some studies identify carbon capture, usage, and/or sequestration as another strategy.[29] [11] [21] [25] Carbon storage can be categorized in two ways: one, capture and storage of carbon in the creation of energy, such as carbon capture technology paired with a conventional natural gas; or two, carbon capture in the natural environment, as in the planting and growth of trees. Storing carbon in the process of producing energy has been identified as one potential pathway available to developing sufficient volumes of clean electricity (strategy 3 above) or low-carbon fuels (strategy 4 above). Examples of carbon capture are incorporated in this report and potential pathways. Some of the studies, however, also include carbon sequestration in working and natural lands as a component of achieving economy-wide decarbonization policy objectives, which is distinct and apart from the scale of clean energy development necessary to achieve clean energy and climate policy objectives.[iv] This paper is focused on the clean energy needs for achieving policy objectives. For these reasons, carbon capture is not included in this paper as a *distinct* strategy for achieving clean energy and climate policy objectives. However, ODOE recognizes that carbon capture and carbon

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[iii] For more information on carbon capture, see *Technology Review: Carbon Capture and Storage* from the 2020 Biennial Energy Report: https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=101

[iv] While some crops can be grown specifically to create fuels, which has implications for net greenhouse gas emissions, for the purposes of this report, these types of crops are not a consideration.

sequestration in natural and working lands can be an important component of an overall strategy for managing and reducing carbon emissions.

- **Emissions reductions not related to energy:** While most of the emissions that need to be reduced to achieve economy-wide climate policy objectives originate with the energy sector, reductions are also necessary in other sectors of the economy, including the agriculture, industrial, and waste sectors. For this reason, at least two of the studies reviewed called out the need to reduce these emissions as another strategy.[29] [18] Given that this strategy does not directly implicate the development of clean energy resources to achieve policy objectives, it is also left out of this paper as a distinct strategy.

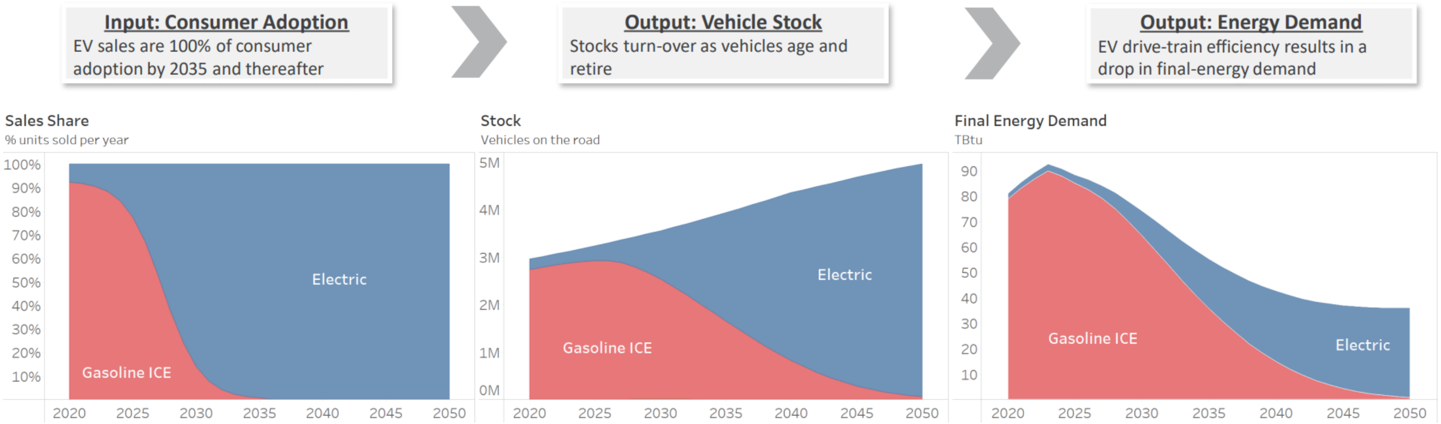
Scale and Pace of Change

A striking conclusion common across much of the analysis is the *scale* and *pace* at which clean energy development must occur in the years and decades ahead to achieve 2050 policy objectives. Take the electric sector as an example. In the *Oregon Clean Energy Pathways* study, the core decarbonization scenario projects a **90 percent increase** in electric sector demand between 2020 and 2050.[22] Depending on the scenario evaluated, the studies reviewed tended to identify increased electric demand in the range of **50 to 100 percent by 2050**.[30] [31] [26] [32] [33]

The range of expected growth in electric demand varies across these studies for several reasons, from different starting positions (e.g., the percentage of heating loads already served by electricity instead of natural gas), to different modeled policy targets (e.g., 80 percent versus 100 percent reduction in emissions), to the breadth of analysis (e.g., economy-wide versus only certain sectors). In any case, the directionality of the findings is similar, with an expectation of significant growth in electric demand in the decades ahead, and with transportation electrification specifically identified in several studies as the primary driver.[34] [35]

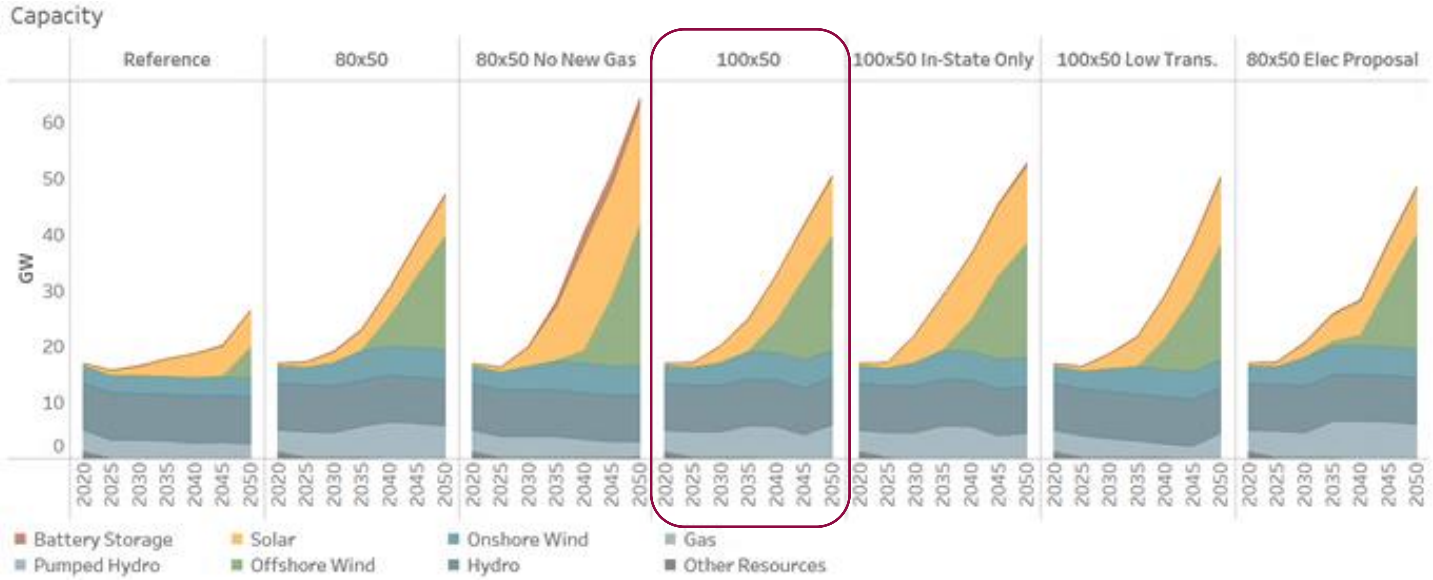
The *Washington State Energy Strategy* highlights the challenge presented by these changes: "The twin challenges of decarbonization in Washington are pace (to reach 2030) and scale (to reach 2050). Rapid change across all sectors of the economy is required to meet the 2030 challenge."[36] The identification of a need for near-term, dramatic action appears across much of the literature: "The decade ahead, between now and 2030, will be critical. . ." to establish technology deployment, market transformation, and investment trends "necessary to put the country on a realistic path" to achieving its clean energy and climate policy objectives by mid-century.[37] The long operating lifetime of appliances, vehicles, and heavy machinery results in a wide "turning radius" for the energy sector, and is a primary reason why the analysis identifies a need for rapid, near-term action.[38] [39] For example, given the estimated operating lifetime of a new light-duty vehicle, the share of electric vehicles among new sales needs to increase significantly by 2030, and likely requiring all new light-duty vehicles sales to be electric by 2035, in order to achieve 2050 objectives.[40] Figure 1, from the core decarbonization scenario of the *Oregon Clean Energy Pathways* study, illustrates what this transition will need to look like in order to phase-out gasoline powered light-duty vehicles by mid-century.[41]

Figure 1: Illustration of Model Inputs and Outputs for Light-Duty Vehicles[41]



The necessary large-scale deployment of renewable energy projects – like wind and solar facilities or the infrastructure to support biofuels or renewable hydrogen – further contributes to this wide "turning radius"[38] and the need to take near-term action to achieve mid-century policy goals.[42] [23] [43] Figure 2, from the *Oregon Clean Energy Pathways* study, for example, illustrates what its modeling identified for different renewable energy resource builds across various scenarios.[44]

Figure 2: Scenario Models to 100 Percent Clean Electricity and Deep Decarbonization by 2050



The 100 percent clean energy by 2050 scenario evaluated in the study above (circled in red) identified a need to develop the following renewable electricity generation resources in Oregon through 2050 to achieve its policy objectives:

- **Solar:** From 500 MW in 2020 to 10,550 MW by 2050 (2,000 percent growth)
- **Onshore wind:** From 3,210 MW in 2020 to 4,970 MW in 2050 (55 percent growth)
- **Offshore wind:** From 0 MW in 2020 to 20,250 MW by 2050

In total, this scenario would require a **nearly 10-fold increase** by 2050 in the amount of renewable generating capacity currently installed in Oregon through 2020. Put another way, this would require more than 1,000 MW of new renewable energy capacity to become operational in Oregon every single year, on average, between 2020 and 2050. This compares to about 2,000 MW of total utility-scale wind and solar capacity deployed over a decade in Oregon, from 2010 to 2020.[45] The annual pace of deployment would need to accelerate by approximately five times through 2050 compared to the rate of deployment last decade.

How Much Will It Cost?

There will be up-front costs associated with transitioning Oregon's energy resources, and there will also be long-term offsetting co-benefits for the state. Co-benefits will include jobs and trades, improved health, energy savings, and retention of more of the state's energy dollars that flow out of Oregon. For example, the transportation sector today largely relies on petroleum fuels that are extracted and refined outside of Oregon, which means that Oregonians send more than $5 billion each year out of the state to import these liquid fuels. Electric vehicles will use fuel that is largely supplied and delivered by local utilities or the Bonneville Power Administration and will support local, well-paying jobs in the electric sector and in the development of renewable energy and EV charging infrastructure. Further, electrification of technologies that currently use fossil fuels is likely to result in lower operating costs for consumers. Current analysis shows that fueling an EV at residential retail rates costs about one-fifth of the cost to fuel a similar vehicle with gasoline, and drivers are not subject to the volatile prices swings of the global crude oil market. Similarly, operators of wind and solar projects don't have to pay for variable fuel costs, as has been the case when operating coal and natural gas fleets.

It is also critical that policymakers consider the effects of this transition on low-income communities, which are disproportionately communities of color, rural areas, and people with disabilities.[46] Although the costs of transitioning to cleaner technologies can often more than pay for themselves over the lifetime of ownership, the up-front costs can be a barrier to adoption in these communities. Further, as Oregonians with higher incomes take more ownership of their energy resources—through on-site distributed energy resources, investments in community renewable energy projects, and energy management technologies like home battery storage—Oregonians with lower incomes may be left behind. This dynamic can result in a greater share of the cost of maintaining the energy system falling on the ratepayers who can least afford it. It is imperative that decisionmakers have the data and analysis to better understand these challenges and robust policy options to avoid an inequitable energy transition.

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While there are up-front costs associated with decarbonizing the energy sector, these up-front costs must be compared to the costs of not addressing climate change – which will be substantial. If the world fails to address the impacts of climate change, Oregonians will face significant impacts, including:[47]

- Significant detrimental effects on public health and the state's economic vitality, natural resources, and the environment;
- A disproportionate effect on the wellbeing of impacted communities; and
- An increase in the frequency and severity of wildfires.

Oregon Governor Brown identified that these effects would worsen "if prompt action is not taken" to reduce emissions and that the "executive branch has a responsibility . . . and moral imperative to reduce GHG emissions and to reduce the worst risks of climate change . . . for future generations."[47]

The technical studies reviewed in this brief identify the scope and scale of the types of investments the state can make to do its part to help avoid these costs to Oregonians. Several of the studies reviewed not only modeled strategies and specific technology pathways to achieve deep decarbonization policy objectives, but also estimated the costs of making the necessary investments.

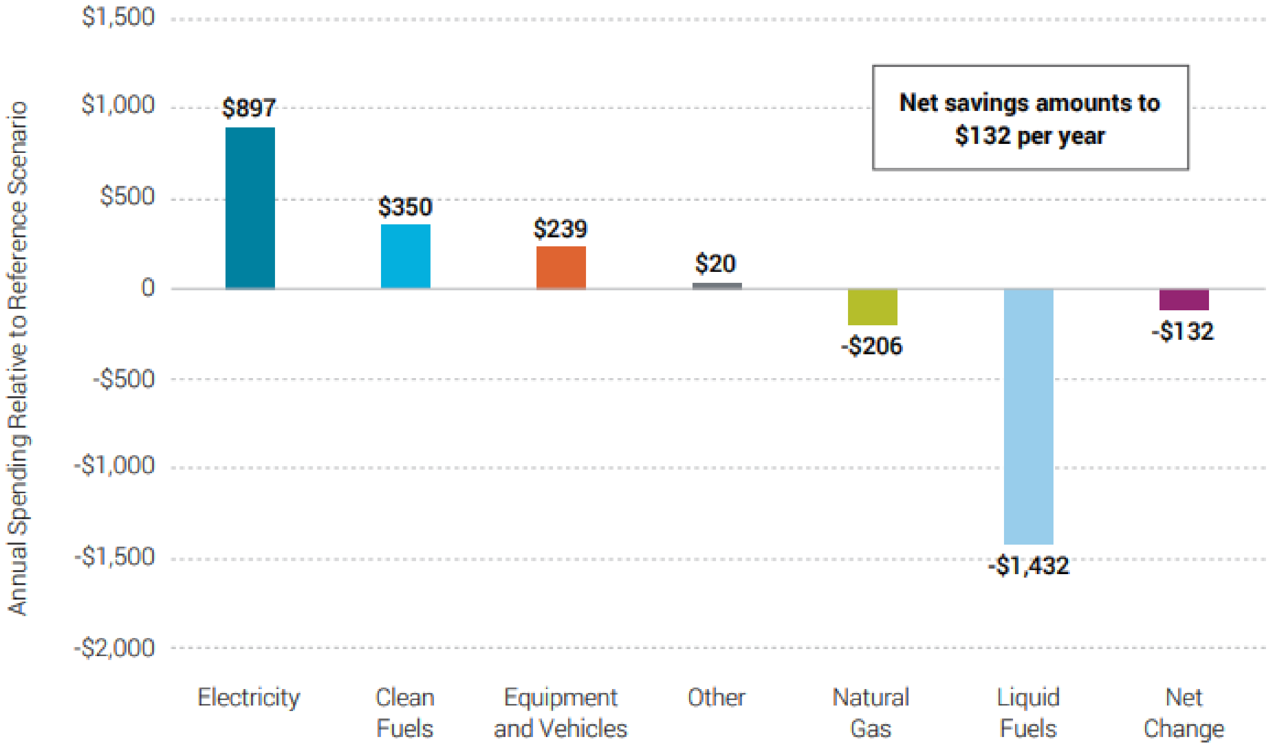
Pathway Choices. Many of the studies identified multiple technology pathways to meet mid-century policy goals, often with divergent costs to achieve the same policy objectives. For example, an aggressive electrification strategy may require a costly overbuilding of wind and solar projects to meet winter demand, while resulting in high levels of curtailments other times of year (i.e., needing to turn off power generators when there is too much power and not enough demand).[48] [18] Alternatively, if additional transmission is built in this same scenario, total costs for overbuilding renewable power projects could be partially offset by exporting more of that otherwise curtailed output.[49] Meanwhile, retaining significant volumes of liquid or gaseous fuels for the transportation or building sectors would require investments in technologies to produce low-carbon fuels and the infrastructure to move those fuels.[50] Two studies in the Pacific Northwest identified 40 to 90 percent higher total costs in 2050 when modeling scenarios where the use of fossil gas is completely prohibited, even in rare circumstances, from meeting peaking needs in the power system.[51] [52] In short, the specific technology pathways pursued to achieve mid-century goals matter, and different pathways come with different costs.

The Final 10 Percent. The preceding point about the retention of some fossil gas to meet (relatively infrequent) peak demands for power echoes an important finding identified in NREL's *LA100* study.[53] That study found similar total cost increases until approximately 80 to 90 percent of energy needs were supplied by renewable energy. The final 10 to 20 percent was identified as the most challenging and expensive, with an identification of "the cheapest option [being] storable renewable fuel used in a combustion turbine." The current challenge with this strategy, however, is that the development of renewable biofuels or hydrogen at-scale is not yet commercially viable. A similar result was found in the *Pacific Northwest Zero-Emitting Resources* study, which identified a much higher cost (requiring a much larger build-out of renewables) to achieve 100 percent clean energy compared to 95 percent clean energy, which allows for some remaining natural gas generation to meet peak demands.[54]

Total Net Costs. The analysis of the total costs to achieve mid-century clean energy and decarbonization policy goals must be considered in the context of several important caveats. First, as noted above, the specific technology pathway selected – and there are myriad options – to achieve the state's policy goals will ultimately affect total costs to Oregonians. In 2022, it remains challenging to forecast future costs for the types of technologies (such as renewable hydrogen deployed at-scale) that may be necessary to cost-effectively achieve the final 5 to 10 percent of decarbonization beyond 2040. The third and final caveat is that, while the capital investments required – in wind and solar generation, the electric grid, electric vehicles, and a range of other end-use technologies – are significant, they must be considered holistically against the reductions in expenditures for energy elsewhere in the economy. Several of the studies reviewed conducted this type of net cost analysis on achieving mid-century clean energy and deep decarbonization policy goals.

A key finding that is repeated across several studies is captured by the *Washington State Energy Strategy*: "Additional equipment costs for decarbonization are largely offset by savings from the avoided purchase of fossil fuels."[55] Figure 3 from that study illustrates annual spending per consumer in 2050 in the electrification scenario compared to the reference case.[56]

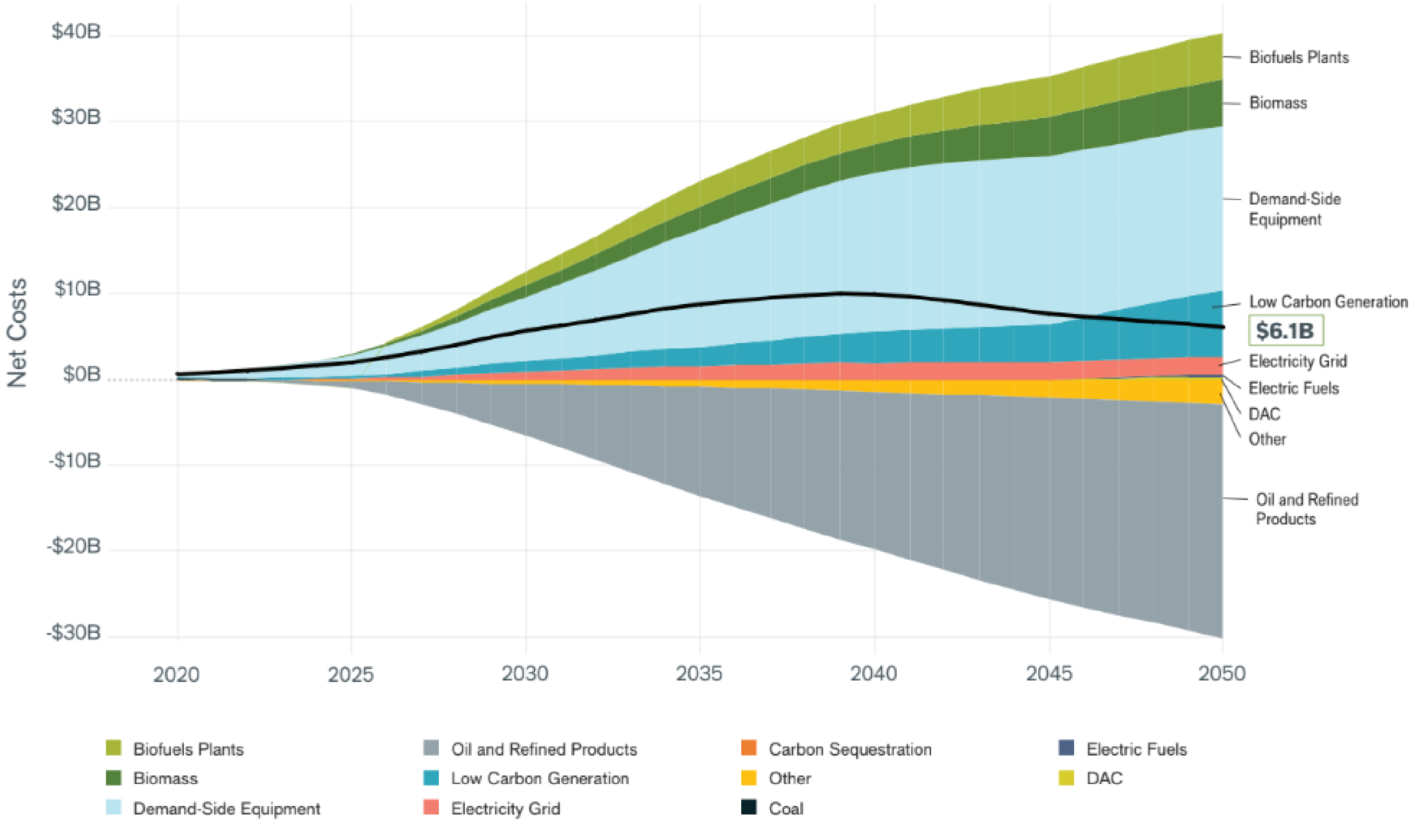
Figure 3: Change in Average Spending per Person in the Electrification Scenario (2050)[56]



Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 16).

This visual helps illustrate how the increase in per person costs for electricity – nearly $900 annually or about $75 per month – are offset by an even larger reduction in annualized costs for liquid transportation fuels. An analysis for the Pacific Northwest, meanwhile, found cumulative costs to decarbonize by mid-century result in an increase of total annual spending on energy expenditures of approximately 1 percent of GDP.[57] That study shows how these costs are projected to unfold over the next three decades, again showing costs driven by electrification (i.e., demand side equipment and low carbon generation) being largely offset by a reduction in spending on petroleum products (Figure 4).[58]

Figure 4: Annual Net Energy System Costs for the Central Case Relative to the Business-as-Usual Case (2020-2050)[58]



Source: Northwest Deep Decarbonization Pathways Study, May 2019, Evolved Energy Research, page 106.

> "Increased costs in a decarbonized system consist primarily of biofuel feedstocks and infrastructure, demand-side electrification and efficiency investments, and renewable power plants and supporting electricity infrastructure. **These costs are mitigated by the savings from reduced spending on fossil fuels, primarily liquid petroleum products such as gasoline, diesel, and jet fuel.**"
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> *— Pathways to a Clean Energy Future for the Northwest: An Economy-wide Deep Decarbonization Pathways Study* [52]

Technology Pathway Decisions and Balancing Trade-Offs

As described previously, the technical studies reviewed largely agree on some combination of the four pillars of decarbonization to achieve mid-century clean energy and deep decarbonization policy goals: energy efficiency; electrification of end-uses; clean electricity supply; and low-carbon fuels. Important policy decisions remain, however, in identifying the specific technology pathways that are preferable for Oregon to achieve its objectives.

Identifying Different Pathways

The briefs that follow will explore the range of pathways available to the state across the transportation, natural gas, and electricity sectors to achieve mid-century policy objectives. Oregon will need to consider several issues in the decades ahead when contemplating potential pathways:

- **Heating loads in buildings:** How should Oregon balance its strategy to decarbonize buildings between electrification and the development of low-carbon fuels? Are there greater risks with one approach over another?
- **Medium- and heavy-duty transportation:** What role can the state play in encouraging or discouraging the decarbonization of the medium- and heavy-duty transportation sector through electrification, renewable hydrogen, or biofuels?
- **Renewable generation:** Can the state identify a preferred resource development pathway for renewables that balances multiple objectives, such as land use impacts, fish and wildlife impacts, the need for transmission development, local economic development, resilience benefits, and total costs of energy?
- **Creating space for innovation:** The optimal technology solutions to achieve the most aggressive climate targets may not yet be commercially available. To what extent should Oregon develop policy flexibility to allow for a range of solutions, such as gas power plants with carbon capture, gas turbines that use renewable hydrogen, large-scale development of biofuels, or some type of long-duration energy storage?

The state's mid-century policy goals can be achieved with a combination of different answers to these questions, and will have significant effects on the state's electric, natural gas, and transportation sectors. More importantly, how these questions are answered will have important implications for equity and for the cost to Oregonians to achieve a clean energy transition.

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Some solutions might have higher up-front capital costs, but net savings over time. Some solutions would have greater or lesser effects on land use, fish and wildlife, and other natural environments in the state. Some solutions might bolster community resilience more than others. Some solutions might have a bigger indirect impact on in-state jobs and economic development. And in all cases, priority consideration must be given to how the trade-offs among different pathways to 2050 affect environmental justice and low-income communities in the state.

Conclusion

Oregon has taken a critical first step in recognizing the seriousness of the climate crisis by adopting aggressive mid-century policy objectives. This transition is achievable, but it is imperative that more collaboration among Oregon stakeholders occur in the near-term to inform the development of an equitable, balanced clean energy pathway for the state over the decades ahead.

As outlined here, and as described in greater detail in the briefs that follow, Oregon policymakers have important questions still before them. Convening diverse stakeholders from across the state to understand varied perspectives can help Oregon become more equitable as it defines a pathway to achieving its mid-century clean energy and climate policy objectives in a manner that considers:

- **Equity:** The upfront costs required to adopt some clean energy technologies can create a disproportionate burden for some customers. In addition, in many cases, historic investments in large-scale infrastructure have failed to adequately consider the perspectives of environmental justice and low-income communities. **How can Oregon identify a pathway to 2050 that centers the concerns of historically marginalized communities?**
- **Land use:** Solar and onshore wind development both have significant land use impacts. The development of high-voltage electric transmission can also have effects that span large areas and multiple jurisdictions. Offshore wind development, meanwhile, can avoid many of these land use impacts, but comes with potentially adverse impacts to marine wildlife and the environment, coastal communities, and fishing industries. **Can Oregon identify a pathway to 2050 that balances the different land use and wildlife impacts of renewable energy development?**
- **Cost:** Technical analyses identify a multitude of pathways that can achieve mid-century clean energy and climate policy objectives, but each pathway has different costs and benefits. In some cases, those cost differences play out over various timescales and affect different customers in different ways. For example, if higher income customers are early adopters of transitioning from natural gas heating to electric heat pumps, lower income customers may be forced to disproportionately bear the costs of maintaining the natural gas system. **What policy solutions can help mitigate the costs of the clean energy transition across sectors and types of customers, particularly for the state's most energy burdened residents?**
- **Resilience:** Given the scale of clean energy necessary to achieve policy objectives, a significant amount of large-scale development will be required. In some instances, however, smaller-scale projects or a diversity of project types – which may come at a cost premium – located closer to population centers may be able to improve the energy resilience of Oregon communities. **Is there a pathway to 2050 that balances the scale and total cost of the clean energy transition with a secondary objective to improve community energy resilience across the state?**
- **Fuel choice:** Technical analyses find that climate policy objectives can be met in many cases by either electrifying existing end-uses of natural gas, or by continuing to use the existing gas system but with increasing volumes of low-carbon fuels instead of conventional gas. In the latter case, large amounts of new electric generation would still be required to produce clean, electrolytic fuels at scale. **Is there a pathway to 2050 that balances maintenance of existing gas infrastructure with an increasing electrification of end-uses?**
- **Regionalization:** The energy system in many respects already operates on a regional basis. In the electric sector, for example, excess Pacific Northwest hydropower in the spring has long been sold to utilities in California. Increasingly, Oregon utilities are importing low-cost solar power from the south. There are both benefits and challenges to pursuing more localized or more regionalized approaches to the energy system. **Is there a regionalization strategy that**

can balance interests in developing in-state clean energy resources with the benefits that might accrue from increased regionalization?

The state has adopted bold policies, and it is assembling the technical analysis necessary to understand the range of choices yet to be made. In the years ahead, Oregon has a unique opportunity to control its own destiny by intentionally engaging with stakeholders to identify Oregon's preferred pathway to 2050.

It's the Oregon way.

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Policy Brief: Charting a Course for Oregon's Energy Future

Part II: Electric Sector

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

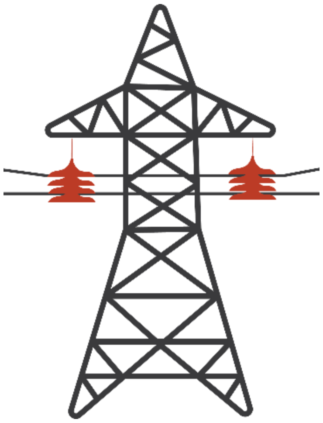
Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

There is wide agreement among the studies reviewed that demand for electricity will grow in the decades ahead if mid-century clean energy and climate policy objectives are to be achieved. The electrification of end uses – one of the four pillars of decarbonization – is the primary reason that demand is expected to increase, even though that growth will be tempered to some extent by savings from energy efficiency, another of the four pillars.

> "Energy efficiency plays a crucial role in all pathways, and total energy demand *[for electricity, gasoline, natural gas, etc.]* in 2050 is approximately 10 to 20 percent below today's level, while the population grows by more than 40 percent. **Despite overall energy demand decreasing, electricity consumption increases in all pathways** . . . As a result, electricity's share of overall energy demand is projected to increase in a deeply decarbonized future."
>
> — *Exploring Pathways to Deep Decarbonization for the PGE Service Territory* [1]

This brief will explore the range of potential electric load growth scenarios modeled in the studies and will identify the anticipated drivers of that growth after accounting for expected savings from energy efficiency. In addition, the brief will consider the impacts of that growth on peak demand, not just annualized or average energy, and will then examine the multitude of pathways available to serve this expected increase in demand across the following three areas:

- **Transmission development:** The technical literature identifies the need for a large buildout of renewable generating capacity, much of which will be large-scale projects interconnected to the high-voltage transmission system. Depending on the scenario, this buildout may require the development of a lot of new transmission capacity.
- **Distribution system:** Distribution-level solutions will also play a role in achieving mid-century policy objectives. These solutions include investments in energy efficiency, load flexibility, small-scale renewables, batteries, and in the distribution grid itself.



- **Emerging solutions:** There is also a range of emerging solutions that could play a meaningful role, including evolving regionalized markets, widespread use of energy storage technologies, and new types of renewable generation resources, such as offshore wind or other innovative generation technologies, like small modular nuclear reactors.

In short, this brief will explore what this projected growth in electric demand might mean for Oregonians, and what pathways are available so the state can intentionally choose the portfolio of clean energy solutions that makes the most sense for Oregon.

Growth in Electric Demand

The reviewed studies anticipate significant growth in electric demand—after accounting for savings from energy efficiency—by mid-century to achieve deep decarbonization policy objectives. There is a range of increased electric demand found across several of the studies:

- **Oregon Pathways:** In its core decarbonization scenario, electric sector demand is expected to increase by 90 percent between 2020 and 2050 [2]
- **Portland General Electric:** 60 to 75 percent increase in total retail electricity sales between 2018 and 2050 [1]
- **Eugene Water & Electric Board:** High electrification of buildings and light-duty vehicles (heavy-duty vehicles and industrial loads not evaluated) is expected to result in a 20 to 30 percent increase in annual load by 2050 [3]
- **Washington Energy Strategy:** Electric sector demand expected to increase by 90 percent from 2020 levels by 2050 [4]
- **Seattle City Light:** In its aggressive electrification scenario, annual electric sector loads are expected to increase by 116 percent between 2020 and 2042 [5]
- **Montana Pathways:** Electrification scenario finds total loads increase by 56 percent from 2018 levels by 2050 [6]

The range of expected growth in electric demand varies across these studies for several reasons, from different starting positions (*e.g.*, the percentage of heating loads already served by electricity instead of natural gas), to different modeled policy targets (*e.g.*, 80 percent versus 100 percent reduction in emissions), to the breadth of analysis (*e.g.*, economy-wide versus only certain sectors).

> "By 2045, electricity demand (both annual consumption and peak demand) is likely to grow. High levels of energy efficiency can offset this growth in the buildings sector due to hotter climate, population growth, and electrification. **It is the electrification of the transportation sector that propels overall growth in electricity demand**."
>
> — *LA100: The Los Angeles 100% Renewable Energy Study* [7]

Many studies identify electrification of the transportation sector as a primary driver of this projected growth in demand in the decades ahead. Electrifying industrial processes and heating loads in the building sector are often cited as additional significant drivers.[5] [8] [9] [10] [4] [1] [11] [12] [13] In some scenarios, however, mid-century policy objectives can be met by relying on a greater use of low-carbon fuels (*e.g.*, renewable hydrogen) in the industrial and building sectors rather than on electrification.[1] [14] [15] These scenarios still have the potential to increase electric demand—for example, the production of electrolytic clean hydrogen to decarbonize conventional fuel use in buildings. In these cases, large-scale electrolysis to produce hydrogen could ramp production during times of plentiful renewable output and could lower production during times of constraint, actually helping to balance the grid and maintain reliability while contributing to the overall increased demand for electricity.[15]

Key Considerations for Electric Load Growth through 2050

In addition to the traditional drivers of electric load growth, such as population and economic growth, the answers to key questions specific to the clean energy transition will affect expected growth in electric demand.

Transportation:

- How quickly will the state's fleet of light-duty vehicles transition to electric?
- What percentage of light-duty vehicles will ultimately convert to electric by 2050?
- Will the heavy-duty transportation sector (e.g., trucking, buses, aviation, marine) transition to electric or to another low-carbon alternative, such as hydrogen?
- To what extent will the production of electrolytic fuels, like renewable hydrogen, increase demand for electricity?

Heating and Cooling:

- What percentage of residential and commercial customers in Oregon will convert from gas to electric for heating?
- How many customers will continue to use gas heating systems but source the gas from low-carbon sources, some of which (like electrolytic hydrogen) will still drive an increase in electric demand to produce those fuels?
- How many customers that currently have electric heating will upgrade to more efficient electric systems?
- With hotter summers driven by climate change, how many Oregonians will install electric air conditioning technologies?

Industrial Processes:

- How many energy-intensive industrial processes will convert from direct-use of fossil energy to electricity?
- How many of these energy-intensive industrial processes will seek to use renewable hydrogen, the production of which would also drive an increase in electric demand?

There are not inherently 'right' or 'wrong' answers to these questions, and many combinations of answers can enable the state to achieve its policy goals. Some answers may make it easier or harder to achieve decarbonization policy objectives, and some answers may involve a different set of trade-offs (including costs) than others. But how Oregon answers these questions will likely have a profound effect on the state's pathway to 2050.

Peak Demand

An important consideration of the electrification of end uses is not simply how much total energy these end uses will consume over the course of a year, but also the potential that these end uses will contribute to higher local or system peaks in demand. Primarily because of the historic difficulty in storing electricity at scale, the power system has necessarily been designed to be able to simultaneously generate and deliver enough energy to meet the highest customer demands for electricity at a given moment. For more information on this, and how peak demands have a disproportionate effect on total system costs, see the Resource Adequacy 101 from the *2020 Biennial Energy Report*.[16]

In some respects, projecting future *peak* demand is more challenging than projecting future energy demand overall.

In some respects, projecting future *peak* demand is more challenging than projecting future energy demand overall. Consider, as an example, an electric vehicle: it is easy to calculate how much energy it takes to charge a particular vehicle (based on the size of the battery) and how much energy it will consume annually (based on estimates of miles driven). But assessing the same vehicle's potential contribution to peak demand is driven by what time the owner of the vehicle will charge the car – and that is much harder to project. This concept of flexible demand is discussed more later in this section.

The following highlights from the technical literature identify the potential challenges associated with increased peak demand driven by electrification, but also indicate that the development of strategies to influence *when* new loads, like vehicles, use the grid can mitigate these potential impacts to peak demand:

- **Pacific Northwest:** Particularly in scenarios with high levels of building electrification, "significant new investments"—including upgrades to the distribution system and building new winter peak capacity generating resources—may be required to address winter peak demand from heating loads.[17]
- **Eugene Water & Electric Board:** The cumulative impacts of high levels of electrification of vehicles and buildings could "add between 50-70% to peak load during colder, less frequent (1-in-10) weather events," [3] but that this can be mitigated, particularly with vehicles, through "managed or diversified charging behavior."[18]
- **Portland General Electric:** Widespread adoption of electric vehicles is expected to drive increases in total energy demand, which, if unmanaged, would increase peak demand. However, "charging off-peak, such as when renewable generation is high or during the middle of the night can mitigate peak load impacts."[1]
- **Seattle City Light:** The electrification of space and water heating could result in "significant increases in system peak" unless "peak mitigation strategies" are employed.[19]

Exploring Pathways to 2050

Given the expected increase in electric demand, combined with the need to replace existing emitting resources with clean energy resources, it is perhaps unsurprising that the studies reviewed find the need to develop a significant amount of new renewable generation.

> "**The scale of renewable resource development present in all scenarios highlights the need for proactive planning to ensure that these resources are available to come online in a timely fashion.** This includes identifying promising areas for resource development, possible transmission network upgrades to ensure renewable generation is delivered to load, and operational considerations to balance a highly renewable grid."
>
> — *Exploring Pathways to Deep Decarbonization for the PGE Service Territory* [20]

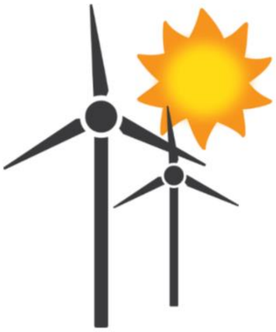
Nearly all the studies reviewed identify the need to develop a substantial amount of new wind and solar generation in the years ahead:

- **Oregon Pathways:** Modeling deep decarbonization of the Oregon economy by 2050 found the need for "significant investment" in new renewables that "should begin in the 2030s," with investments first in onshore wind and solar followed by a "large and rapid investment in offshore wind" beyond 2035.[8] The same study found a wide range of potential resource builds, from a couple GW of offshore wind to as much as 20 GW of offshore wind, and between 7 GW of solar and dozens of GW of solar in cases where no new gas is permitted. [21]
- **Washington Energy Strategy:** In its state energy strategy, Washington acknowledges that its electric supply is already 69 percent clean because of the state's existing hydropower resource, but assumes there is "no opportunity to expand" that supply in the future.[15] As a result, its modeling of an electrification scenario finds the need to deploy 12 GW of in-state solar and 4 GW of offshore wind by 2050. Those numbers increase (to 18 GW and 10 GW, respectively) in a scenario where new transmission (and the ability for more imports) is constrained.[15]
- **Pacific Northwest:** A study evaluating the elimination of greenhouse gas emissions in the Pacific Northwest by 2045 and exclusive reliance on renewables and storage found the need to develop 57 GW of wind and 42 GW of solar. The same study, however, found these projections dropped dramatically—to between 5 and 10 GW of solar, and between 7 and 11 GW of wind—in scenarios where other innovative sources of dispatchable, clean generation are available (e.g., small modular reactors or renewable gases)[22] and in scenarios where the target is a 95 percent (rather than 100 percent) reduction in emissions.[23]
- **Montana Pathways:** Modeling a 100 percent clean economy by 2050 shows the need to approximately double the amount of installed power-generating capacity in place today in the state. Assuming the elimination of coal and gas generation and stable output from hydropower results in needing approximately 8 GW of new wind and solar by 2050.[24]
- **Los Angeles 100 Study:** Given the low costs and access to high-quality resources, the LA100 study finds that "wind and solar resources are responsible for providing the majority of the energy" (accounting for between 69 and 87 percent) required to achieve a 100 percent clean

power system.[25] The same study found that up to one-third of residential homes would adopt on-site solar, up from 6 percent in 2020.[26]

- **National:** In a compendium that reviewed multiple studies from across the country there was identified a "dramatic increase in wind and solar capacity" combined with a phase out of coal by 2030 as a core strategy to achieve aggressive mid-century policies.[27]

Transmission Development

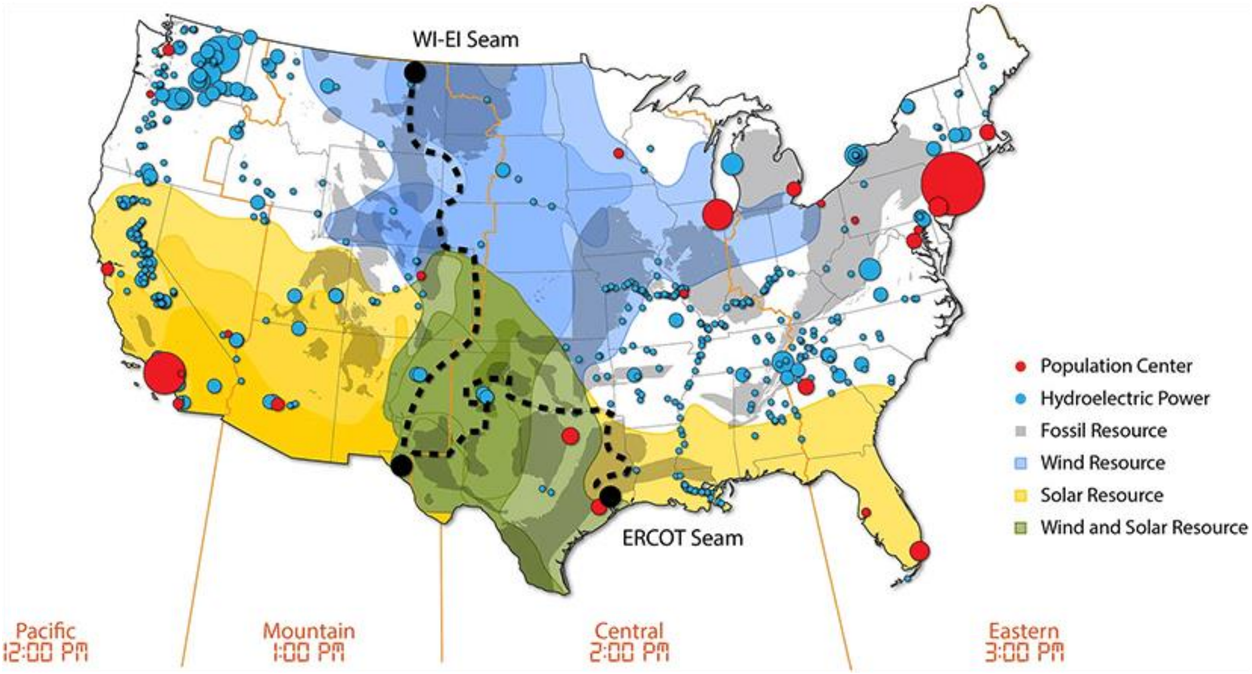


Technical studies evaluating mid-century clean energy and deep decarbonization policy objectives identify a need to develop substantially more wind and solar capacity than exists today. Renewable energy projects are most effective at generating electricity when they are located where the wind and solar resources are the highest quality—the strongest and most consistent. It is largely for this reason that the same technical analyses generally identify the development of new high-voltage transmission as a component of the least-cost decarbonization pathway, because transmission lines allow customers to access the highest quality renewables. Transmission projects themselves, however, are large infrastructure projects with potential adverse effects on private property, wildlife, cultural resources, open space, and other resources, and often have long, complex development timelines. Policymakers will have to balance the need for new transmission to support the highest quality, least-cost renewable resources with its potential adverse effects and often long development timelines.

> "**A regionally integrated power grid is critical to enabling Oregon to take advantage of out-of-state clean energy resources, export power to other states, and efficiently plan for grid reliability.** Regional grid integration will also be key to efficient decarbonization throughout the West. Early action is needed to identify how regional coordination can facilitate increasing clean energy transmission and construction of new transmission lines."
>
> — *Oregon Clean Energy Pathways Analysis* [28]

Figure 1, produced by the National Renewable Energy Laboratory (NREL), broadly illustrates the relative strength of different renewable resources across large geographic areas. Note, for example, the amount of hydropower (blue circles) in the Pacific Northwest, the strong onshore wind resources in Wyoming and Montana (shaded blue), and the strong solar resources in California and the desert southwest (shaded yellow). Note also that this map, while illustrative, is not perfect and it does not indicate, for example, the exceptional offshore wind resource located off the southern Oregon and northern California coast.[29]

Figure 1: Renewable Resources Available Across the United States[29]



Identified Need for Transmission Development

Many of the technical studies identified transmission expansion as an essential component of achieving mid-century policy objectives:

- **Oregon Pathways:** To achieve 100 percent clean energy by 2050, "a large expansion of transmission connections between Oregon and surrounding states" will be required. Specifically, the study found that Oregon would benefit from increasing transmission connections to Idaho to import onshore wind resources from the Rocky Mountain states, while increasing transmission connections to California would allow Oregon to import low-cost solar and export offshore wind.[30]
- **Washington Energy Strategy:** The state's energy strategy found that a power system that relies on solar and wind resources to meet load "will require a more robust and flexible transmission network" compared to the one that exists today, and that modeling across all scenarios points to the importance of expanded transmission across western states to lower overall decarbonization costs.[31] As a result, the state's clean energy strategy identifies investing in new transmission as a key action.[32]
- **Los Angeles 100 Study:** A study by NREL of 100 percent clean energy for the City of Los Angeles found that, across all scenarios, there is a "need for new transmission to accommodate future growth in both electricity supply and demand."[7]
- **National:** Analyses of deep decarbonization scenarios nationally "show significant increases in long distance transmission post-2030," particularly when the grid is modeled with large amounts of wind and solar that benefit "greatly from optimizing . . . over a wide geographic region."[33]

- **National:** A review of multiple national and regional studies evaluating what is required to achieve mid-century policy targets identified transmission expansion as a "priority focus area for clean electricity."[34]

Transmission projects are large infrastructure investments that require substantial capital to finance. Multiple studies not only identified a need for significant transmission development, but explicitly found those investments to be part of a least-cost pathway to achieving mid-century policy objectives in the Pacific Northwest. [35] [36] [37]

Bonneville Power Administration: 2022 Transmission Cluster Study

The Cluster Study process is the primary mechanism that BPA uses to process and offer service in response to customer requests for long-term firm transmission over BPA's transmission system. In 2022, BPA's Cluster Study—its largest to date—evaluated 144 requests for service representing 11,118 MW of capacity. The bulk of these requests were from solar, wind, and storage projects mostly seeking "to move renewable energy from east of the Cascades and the Mid-Columbia area to Portland and Seattle."[38]

Of those requests, BPA awarded service to 11 of them (totaling 1,046 MW) that would not require system upgrades. Another 59 (3,161 MW) would require BPA upgrades, while the remaining 74 (6,911 MW) would require BPA upgrades and third-party mitigation. [39]

The 2022 study represents a significant increase from just one year earlier in 2021. That Cluster Study only saw 116 transmission service requests filed representing 5,842 MW of capacity. The jump in requests seen in 2022 was likely driven by the adoption of aggressive clean energy policies in both Washington and Oregon. [39]

Transmission service requests to be considered in BPA's 2023 Cluster Study were submitted in August 2022. That study is expected to begin in early 2023.[38]

Process for Developing Transmission

New transmission lines can increase access to the best renewable resource areas across the western U.S. and could allow Oregon to import more low-cost solar from the south and to export more hydropower or other abundant renewables, such as offshore wind. The challenge comes not just from the cost of financing and developing these types of large, multi-state projects but also from the complicated and lengthy processes for identifying which projects are needed, siting and permitting those projects, and determining how costs will be allocated.

> "Expanding transmission . . . is a long, difficult process with many hurdles to overcome. **Early planning and determination of feasible projects and project costs should begin now to prepare for transmission in the future**. . . The needed expansion of transmission capacity will require coordination among utilities, planning agencies and governments."
>
> — *Washington 2021 State Energy Strategy: Transitioning to an Equitable Clean Energy Future* [40]

Multiple studies identified that the long development timelines for large transmission investments require near-term regional coordination and action to ensure needed projects are operational by the 2030s and beyond. [27] [36] In addition to regional coordination to identify high priority projects, stronger support will also likely be required at the state and federal level, particularly regarding streamlined permitting.[41] [42]

Traditionally, most transmission development occurs to maintain the reliability of the power system and to deliver power from individual generation projects. An additional mechanism has been used in some states to drive transmission development for policy reasons, such as to access broad geographic areas where strong renewable resources exist. Two such examples:

- **Renewable Energy Transmission Initiative (California):** In response to the adoption of clean energy and climate goals, the California Independent System Operator and multiple state agencies developed the Renewable Energy Transmission Initiative, or RETI, in 2009 to examine “where potential new renewable energy generation could be developed and assess what transmission may be needed” to deliver that power to customers. The first RETI process occurred in the late 2000s, and RETI 2.0 was designed as an update in 2016-17 following the passage of California’s SB 350, which adopted more stringent policies.

  RETI 2.0 was designed to explore the emerging transmission implications of “accessing a diverse and balanced renewable energy portfolio” and the “diverse transmission system needed” to build a future grid based on renewable energy. The process was not a regulatory process, but rather a scoping exercise to identify significant transmission resources needed to achieve clean energy policies and “an overview of the potential energy, environmental, and land-use issues” that may need to be addressed if those resources are developed.[43]

- **Competitive Renewable Energy Zone (Texas):** The Texas State Legislature introduced the CREZ concept in 2005; it was approved by the Public Utility Commission in 2008 as “a means of connecting areas with abundant wind resources to more highly populated parts of the state.” The concept called for developing a robust network of high-voltage transmission to “bring wind power generated atop remote western mesas to cities” in eastern Texas. Once completed in 2013, the CREZ projects included more than 3,500 miles of transmission lines capable of delivering more than 18,000 MW of power.[44]

U.S. Department of Energy: National Transmission Planning Study

In support of implementation of the Infrastructure Investment and Jobs Act, the USDOE has initiated, in collaboration with NREL and the Pacific Northwest National Laboratory, the development of a National Transmission Planning study. The NTP is designed to:

- Identify new transmission that will provide broad-scale benefits to electric customers;
- Inform regional and interregional transmission planning processes; and
- Identify interregional and national strategies to accelerate decarbonization while maintaining system reliability.

USDOE is expected to release interim results of its study in Fall 2022 before publishing its final results in Fall 2023.[45]

Different Pathways for Transmission Development

There is no single pathway to expand the transmission system to enable achievement of clean energy policy objectives. In many cases, there will be options in terms of broad strategies for transmission expansion, each with disparate impacts on individual states and stakeholders:

- **In-State vs. Out-of-State Resources:** In some cases, the best quality, lowest cost renewable resources will be located out of state, requiring transmission to deliver the power to in-state customers. The extent to which a state commits to developing this transmission could have a substantial impact on whether more or less of the renewable capacity needed to meet policy objectives is located in-state or out-of-state. **To what extent does Oregon want to identify pathways that support the in-state development of clean energy resources?**
- **Net Import vs. Net Export:** Oregon is currently a net exporter of electricity at most times of year on account of the region's abundant hydropower. As the need to develop new renewable capacity to achieve policy targets increases, this import-export balance could shift. For example, Oregon may find it cost-effective to develop more transmission to import solar from California and the southwest states during certain months, and to export a resource like offshore wind during other times of year. **Does the state have a preference about the extent to which it seeks to use clean energy exports as an opportunity to generate revenue for the state and its utilities?**
- **Distributed vs. Large-Scale Resources:** Developing distributed renewable resources can reduce the need for new transmission to deliver power from large-scale renewables. For example, as more electric vehicles are adopted in the Portland metro area, PGE may be faced with a choice of building more transmission to access large-scale renewables that can charge those vehicles, or it may have opportunities to deploy more distributed renewables and reduce the need for as much new transmission and large-scale renewables. There are, however, limitations on how much distributed resources can contribute to meeting the overall scale of system needs—due to land use constraints, challenges deploying projects on existing built structures, and conflicts with existing urban development—and this will be exacerbated as demand increases due to the electrification of end-uses. **Can the state identify a role for the contribution of distributed resources that balances the potential trade-offs (e.g., higher costs) with its benefits (e.g., resilience, avoided transmission)?**
- **Type of Renewable Technology:** Decisions about new transmission investments will be a critical factor in determining which types of renewables can be used to serve Oregon customers in the years ahead. In some cases, transmission investments can simply make it more cost-effective to deliver power from a renewable resource located in a specific area. In other cases, significant transmission investments might be a prerequisite to delivering power from a particular resource, which is likely the case with Oregon's sizable offshore wind resource. **Can Oregon stakeholders reach consensus around preferences for developing particular types of renewable resources that balance trade-offs, such as in-state land use impacts?**

For more information on the opportunities and challenges for the development of renewables and transmission in Oregon, see the Oregon Renewable Energy Siting Assessment.[46]

- **Role of Gas-Based and Thermal Resources:** The need for new transmission development will also be affected by the extent to which the state's clean energy strategy incorporates thermal power resources (e.g., gas plants powered by conventional gas or an alternative like renewable hydrogen, or nuclear power plants) and its approach to decarbonization of the fuels sector. For example, varying levels of new transmission and new renewable generating capacity may be required depending on the extent to which the transportation sector relies upon electrification versus the development of electrolytic fuels, like renewable hydrogen. A finding in a study by PGE was revealing on this point: "*Although the low electrification pathway has the lowest retail energy deliveries* [in the electric sector] *by 2050, the pathway requires the highest levels of transmission-connected renewable generation due to electric loads from producing hydrogen and synthetic natural gas.*"[1] **What role does Oregon seek for gas-based resources (using either conventional gas or renewable gas) in achieving its mid-century policy objectives?**

The state can achieve its aggressive mid-century clean energy and climate policy objectives across a range of transmission development pathways. The examples described above characterize some of these choices and their broad respective impacts. In each case, the policy objectives can be achieved, but pursuing one path over another may come with different overall costs and benefits to Oregonians and varying levels of land use impact in the state.

The state can achieve its aggressive mid-century clean energy and climate policy objectives across a range of transmission development pathways.

The Distribution System as a Resource

This section considers the contribution of resources located within the distribution system (and nearer to customers), along with an identification of the high-level trade-offs.

Identified Need for Solutions within the Distribution System

The technical studies identified a range of solutions within the distribution system that can make a meaningful contribution to achieving clean energy and decarbonization targets, including: energy efficiency, upgrades to the distribution grid, flexible demand, and distributed renewables.

Energy Efficiency

Identified as one of the four pillars of decarbonization, continued investments in energy efficiency are an important component of achieving clean energy and decarbonization policy goals. The realization of savings from efficiency, however, can result in some counterintuitive outcomes. For example, electrification of the transportation sector can result in significant *economy-wide* gains in energy efficiency because electric engines are more efficient than internal combustion engines, yet this can still result in a significant overall increase in demand for electricity. The energy efficiency savings in this case come from a reduction in societal consumption of another fuel – gasoline. These types of savings from energy efficiency will play an important role in achieving policy objectives, as will continued savings from traditional energy efficiency investments within the built environment to use electricity more judiciously. For more information on the evolution of the cost-effectiveness of energy efficiency within the electric sector, see the Policy Brief on Co-Benefits of Energy Efficiency.

Within the electric system, savings from efficiency in the building sector are expected to help offset increased electric demand elsewhere (such as from the electrification of transportation):

- **Washington Energy Strategy:** The state energy strategy recommends "deep levels of efficiency for new and existing buildings." [47] The same strategy, however, acknowledges that the "pace of stock rollover to new efficient technologies limits action" that can deliver savings by 2030, pointing to the "value of early and aggressive action to improve energy efficiency" that can reduce or avoid the need for other infrastructure investments.[48]
- **Pacific Northwest:** Continued investments in energy efficiency will be a "key strategy to reduce costs and meet goals," and can reduce the need for "new energy supply and associated infrastructure." [49] This will require significant investments in buildings – including building shell improvements and retrofits – to minimize increases to peak demand, in particular.[50] [51]
- **National:** Two broad ways to categorize sub-sectors on the demand-side are among those where decarbonization will occur through fuel switching (e.g., from using natural gas for heating to using electricity) and those where energy efficiency will be the primary mechanism. "Non-heat applications in buildings" are likely to be the areas where energy efficiency contributes the most in the building sector.[52]
- **Montana Pathways:** Savings from energy efficiency investments will offset "most of the increase in demand" associated with the electrification of space and water heating in the building sector.[53]
- **Los Angeles 100 Study:** In its study of deep decarbonization for Los Angeles, NREL found that "high levels of energy efficiency can offset" growth in electric demand in the building sector "due to hotter climate, population growth, and electrification."[7]
- **California:** One study in California compared the amount of renewable electricity required to deliver 1,000 Btu of heat to a residential customer across two different scenarios. Using an electric heat pump, about 0.1 kWh of renewable electricity would be required. But using a gas furnace to deliver the same amount of heat from synthetic clean gas would require about 1.0 kWh of renewable electricity.[54]

Distribution Grid

There are also potential investments needed in the electric distribution grid itself to accommodate the expected increase in demand for electricity from electrification. Depending on the technology pathway pursued to achieve decarbonization policy goals, the stresses on the electric distribution grid may vary. For example, a pathway that includes the production of a significant volume of electrolytic renewable hydrogen may require deploying high amounts of renewable generation and associated transmission infrastructure – but it would be unlikely to have much effect on the electric distribution grid. On the other hand, aggressive electrification of end uses, such as residential heating and transportation, would likely have more of a direct effect on the electric distribution grid.

Few of the studies reviewed explicitly considered the potential impacts on the electric distribution grid itself, but examples included:

- **Northwest:** A key challenge in the Pacific Northwest will be ensuring the winter peak demand for electricity can be met if building heating loads are increasingly electrified. This will require "significant new investments" including "an expansion of the electricity system in the form of upgraded distribution systems" in addition to more winter peak capacity generating resources.[17]
- **Seattle City Light:** The electric distribution grid of Seattle City Light "has significant capacity available for electrified load" but there will be certain times where that system may be constrained if the growth in electric demand is unmanaged.[19]
- **Los Angeles 100 Study:** The LA100 study expects that up to one-third of customers (up from 6 percent today) in single-family homes will install rooftop solar systems. The study found that "the distribution grid can manage this growth in local solar – along with the projected growth in electricity demand" from electrification. This would require "a modest number of equipment upgrades" to the distribution grid, representing only a "small fraction of the total cost of the clean energy transition."[7]

Flexible Demand

Flexible demand strategies are concerned with *when* energy is consumed.

Given the stresses that peak demands place on the power grid, technical analyses increasingly identify flexible demand as an important component of the clean energy solution. Energy efficiency investments are focused on reducing the amount of total energy consumed, while flexible demand strategies are more concerned with *when* energy is consumed. For example, the electric grid today tends to be most stressed during times of extreme weather – such as when home heating demands are high on cold winter mornings, or when air conditioning demands are high on hot summer afternoons. These conditions have always presented a challenge for the electric grid and driven the need to deploy additional capacity to accommodate these peaks. As the grid relies more on variable wind and solar output, however, these challenges are expected to become more pronounced. Deploying flexible demand technologies and strategies, particularly with large new loads (such as charging electric vehicles) added to the electric grid, can help to cost-effectively minimize increasing peak demands as more end-uses are electrified.

- **Los Angeles 100 Study:** A study of deep decarbonization scenarios in Los Angeles identified the high "value of energy efficiency and demand flexibility," finding an 8.5 percent reduction in total annual energy consumption and a 17 percent reduction in peak demand in the scenario that pursued significant efficiency and demand flexibility. In addition, the energy savings also "reduces the cumulative (2021-2045) costs of that scenario by 13 percent."[55]
- **Portland General Electric:** The shift in operational paradigm to a power system built upon variable output wind and solar "necessitates a transition to new forms of balancing resources" to integrate renewables. In particular, new sources of flexible demand will be needed,

including (a) flexible end-use loads, such as smart EV charging, and (b) flexible transmission-connected loads, such as facilities for the production of electrolytic hydrogen.[56]

- **Washington Energy Strategy:** In its state energy strategy, Washington identified a need for "structural changes" to ensure that electric resources can replace fossil fuels across the economy. Among the changes identified is the need to develop distributed resources and consumer appliances with "smart grid capabilities . . . to ensure reliability and flexibility."[32]
- **Montana Pathways:** Identified a significant increase in peak demand flexibility in its electrification scenario compared to its business-as-usual scenario – from 842 MW to 1,400 MW – driven by a conversion of water and space heating loads from natural gas to electricity.[57]

Distributed Renewables

The scale of the clean energy transition is going to require the development of a large amount of new renewable capacity. While much of this buildout will come from transmission-connected, large-scale renewable projects, there will also be a role for smaller-scale projects connected to the utility distribution grid – often called "distributed renewables." In some cases, these smaller projects have the potential to deliver unique benefits to Oregonians, including improvements to local energy resilience, avoiding land use and other environmental impacts associated with large-scale projects, providing grid services including a reduction in net demand, and creating local economic opportunities.[i] These projects may come with higher costs, however, as they will not be able to take advantage of economies of scale compared to large-scale projects. There are also likely to be physical constraints that serve as a barrier to the development of distributed renewables and limit the scale of their ultimate contribution to the clean energy transition.

The following examples illustrate the findings of the technical studies:

- **Portland General Electric:** Rooftop solar "can play a key role" in meeting clean energy targets, but its ultimate share of the generation mix in a "deeply decarbonized energy system is limited by the resource quality in Northwest Oregon" combined with anticipated increases in electric demand from electrification. Distributed solar, therefore, "reduces the need for" but does not replace the need for large-scale, transmission-connected renewables.[1]
- **Montana Pathways:** The co-optimization of distributed renewables in one of the scenarios modeled reduces peak load by 3 percent, which helps defer some distribution system upgrades and reduces total system costs.[58]
- **Los Angeles 100 Study:** In a city known for its abundant sunshine and mild weather, the LA100 study projects that between 22 and 38 percent of all existing single-family homes in Los Angeles will have rooftop solar by 2045 (up from 6 percent in 2020).[26] The contribution

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[i] For more information on the benefits and opportunities associated with small-scale and community-based renewable energy projects, see ODOE's 2022 study on Small-Scale and Community-Based Renewable Energy Projects: www.oregon.gov/energy/Data-and-Reports/Pages/SSREP-Study.aspx

of these systems will still fall far short of what's required to decarbonize the Los Angeles economy.

- **Los Angeles 100 Study:** The LA100 study also evaluated the potential for developing ground-mount solar resources within the LA Basin (in addition to on rooftops in the built environment). While the study identified 4.8 GW of additional potential in this category, the model selected "only a fraction of this potential due to the overall lower costs and higher performance" of siting large-scale, transmission-connected solar projects elsewhere in the state.[59]

Why can't Los Angeles just rely on lots of rooftop solar and battery storage to reach 100%?

> "The solar resource in LA is great. But putting solar on every available rooftop in LA would not be enough – even accounting for future energy efficiency upgrades. Solar is only available during daylight hours, and even if it is paired with batteries for energy storage, it remains insufficient to meet load reliably."
>
> — *LA100: The Los Angeles 100% Renewable Energy Study*[60]

Process for Developing the Distribution Grid as a Resource

In many respects, there are already robust processes in place (or being developed) that can evaluate the need for resources located within the distribution grid to contribute to achieving policy goals. In other instances, such as with the role of distributed renewables, the process may not be as clear.

Energy Efficiency as a Resource

The Pacific Northwest has long been an industry leader in identifying energy efficiency as a resource to meet customer demand.

The Pacific Northwest has long been an industry leader in identifying energy efficiency as a resource to meet customer demand. That is, rather than investing in a new power plant, utilities have looked first to make investments in energy efficiency to reduce consumer demand. Only after achieving all cost-effective savings from energy efficiency will the utility sector look to develop new sources of generation.

According to the Northwest Power and Conservation Council, the region has realized more than 7,000 average megawatts (or more than 60,000,000 MWh) of savings from investments in energy efficiency since 1978.[61] In other words, the region's cumulative investments in efficiency offset annually the need for more energy than the entire state of Oregon consumes in a year (approximately 50,000,000 MWh in 2020).[62]

The results of the studies presented here all account for expected future savings from energy efficiency. The scale of buildout of wind and solar capacity called for in the technical analyses provides a strong reason for Oregon and the region to redouble efforts on energy efficiency in the years ahead. Every MWh saved through investments in efficiency means one less MWh of renewable generation, and its associated trade-offs, that will need to be developed to achieve clean energy and climate policy objectives.

Launching Energy Efficiency as Service in Seattle

Seattle City Light launched its Energy Efficiency as Service (EEaS) pilot with an aim to unlock deep energy efficiency in commercial buildings within its service territory. The program is a potential solution to the "split-incentive" problem. For example, a building owner might pay for the energy efficiency upgrades but they do not benefit directly from the savings as they are passed on to the tenants in the form of decreased energy bills. As a result, there is often a lack of motivation by building owners to make the necessary improvements in energy efficiency because they are not directly benefitting from their investment in these green initiatives.

SCL created the Energy Efficiency as Service pilot to directly address the issue by paying measured electricity savings over time, instead of paying up-front incentives. As a pilot, it allows the utility to test how it could lessen the split-incentive between owners and energy users to encourage greater energy efficiency. It also gains the added value of continuing to grow and learn in this space while building upon lessons gleaned from the innovative MEETS™ prototype project at the Bullitt Center.

The EEaS program's initial goal is to execute agreements for up to 30 buildings up to the next 20 years with hope to sign 15 agreements in the initial phase of this pilot program. City Light works with participants who wish to invest in deep energy efficiency upgrades. Participants recoup their investment through the value of the energy savings from tenants who pay the energy bills as if the building had not received an energy improvement. This occurs via an energy efficiency service fee placed on the building's energy bill. City Light uses a power purchase agreement to transfer the financial value of the energy savings to the entity responsible for financing the energy improvements.

To be eligible for the EEaS program, an existing structure much be a commercial, master-metered building that is greater than 50,000 square feet. Only exclusively electric new construction projects that pursue total building performance standard compliance with Seattle Energy Code are considered. In both cases, projects should target at least 25 percent electricity savings relative to existing operations or code expectations for new buildings. Energy efficiency service fees and PPA payments commence once more than 10 percent savings are achieved for existing buildings.

To date, the Energy Efficiency as Service program has enrolled one participant with two more applicants. Projects are targeting 30 percent of electricity savings on average. City Light looks forward to further expanding the program as building efficiency technology and initiatives continue to flourish.

Integrated Resource Planning

In the 1980s, Oregon became one of the first states in the country to require state-regulated electric utilities – Portland General Electric, PacifiCorp, and Idaho Power – to develop least-cost plans, later called integrated resource plans.[63] Some of the state's consumer-owned utilities, like the Eugene Water & Electric Board, also develop IRPs. An IRP is designed to identify a utility's need for resources in the future. Development of a plan is typically led by specialists that deploy sophisticated computer modeling tools to evaluate a range of possible future scenarios. Important inputs to this process include a forecast of future customer demand based on expected population and economic growth, the adoption of new electric technologies (such as electric vehicles), and variable weather conditions. The state's three IOUs develop IRPs for submission to the Oregon Public Utility Commission every two years. According to the OPUC:

> *The IRP presents a utility's current plan to meet the future energy and capacity needs of its customers through a* ***'least-cost, least-risk'*** *combination of energy generation and demand reduction. The plan includes estimates of those future energy needs, analysis of the resources available to meet those needs, and the activities required to secure those resources.*

The IRP process allows for utilities to better understand how a diverse suite of resources, including those located within the distribution grid can contribute to meeting the utility's future needs. The IRP process can incorporate evaluation of a wide range of potential solutions, from investments in energy efficiency or to enable flexible demand (e.g., smart thermostats), to the deployment of battery storage systems or distributed renewables.

For more information on utility resource planning, see the Resource Planning and Acquisition Energy 101.

Distribution Resource Planning

Oregon's electric utilities have always evaluated their systems to make necessary investments to maintain the operation of safe, reliable, affordable distribution systems to serve customers. Typically, these types of investments would be focused on routine maintenance or upgrades, or extension of distribution service to new customers (e.g., a new industrial load or a new residential neighborhood).

Oregon's electric utilities have always evaluated their systems to make necessary investments to maintain the operation of safe, reliable, affordable distribution systems to serve customers.

In recent years, however, technology advancements have created new opportunities for utilities to consider other types of investments within the distribution system that can optimize system efficiency and maximize customer value to contribute to meeting broader system needs. Examples include whether utilities can:

- Make more data available about where on their distribution grids there is excess capacity that could accommodate more distributed resources.

- Identify strategic investments in the distribution system that could accommodate more distributed renewables in a particular location.
- Identify a suite of non-wires alternatives (e.g., energy efficiency, storage, distributed renewables, flexible loads) that, if deployed within a particular area of the distribution grid, may allow the utility to delay or eliminate the need for some other large-scale investment, like a new transmission line.

These types of more granular planning processes focused on the distribution system are still evolving. For more background on distribution system planning, see 2020 BER – Distribution System Planning 101. [64]

For more information on the evolving distribution system planning processes of the state's investor-owned utilities, see the Oregon PUC's website: https://www.oregon.gov/puc/utilities/Pages/Distribution-System-Planning.aspx

Pathways to 2050

As with the development of new transmission and large-scale renewables, there are multiple pathways available to Oregon and the region as they consider the optimal role for resources located within the distribution grid to achieve policy objectives. For example:

- **Commitment to Energy Efficiency:** While the Pacific Northwest has long been a leader in achieving savings from energy efficiency, the Northwest Power and Conservation Council identified that savings have slowed in recent years.[65] There is an increasing interest, however, in reconsidering how the value of energy efficiency investments are assessed, including a consideration of the climate, capacity contributions, resilience, and other benefits of such investments in addition to kWh savings of energy. **How much will the region increase its efforts to maximize savings from energy efficiency in the years ahead?**

  For more information on emerging efforts to explore the diversity of benefits provided by energy efficiency investments, see the Policy Brief on Co-Benefits of Energy Efficiency.
- **Role of Distributed Energy Resources (DERs):** As identified above in the transmission pathways discussion, here again at issue will be the extent to which distributed energy resources are developed to contribute to meeting system needs. Pursuing a pathway with more or less reliance on DERs will have implications on the need to develop the distribution grid. In many cases, cost-effective development of the resources necessary to achieve policy objectives will require the deployment of large-scale resources that can capture economies of scale. In other cases, however, DERs can deliver a suite of unique benefits, such as local energy resilience and mitigation of the land use impacts of large-scale projects. **Can Oregon identify a role for DERs that can inform the need for future investments in the distribution grid?**

  For more information on the benefits and challenges associated with small-scale and community-based renewables, see the Oregon Department of Energy's 2022 study on Small-Scale and Community Based Renewable Energy Projects.
- **Competing Sources of Flexibility:** Given the changing nature of the power grid with increasing penetrations of variable wind and solar power, studies identify the need for more

flexibility to manage the grid. There are numerous sources of flexibility that could contribute to meeting this need, from participation in broader regional markets, to developing more grid-connected battery storage, to incentivizing customer load flexibility programs. Depending on the relative emphasis on one flexibility solution over another will have disparate impacts on the distribution grid. **Can Oregon identify a role for different sources of flexibility to achieve its policy objectives?**

Emerging Solutions in the Electric Sector

The previous subsections addressed the anticipated growth in electric demand to meet clean energy and climate policies and explored different pathways across the transmission and distribution systems to achieve those policies. Several of the studies reviewed by ODOE also identified a need for solutions that are not currently deployed at scale, at least in Oregon, as of 2022. These emerging solutions in the electric sector include: battery energy storage, certain innovative technologies, and expanded regional energy markets.

> "The 2021 State Energy Strategy avoids reliance on yet to-be-invented technologies, but it embraces many solutions that are not yet widely deployed, such as electric and hydrogen vehicles, advanced building techniques, green hydrogen production and intelligent grid devices. **The emphasis on advanced technology is unavoidable given the ambition of the state's emissions reduction limits.** It presents an opportunity to make even more and faster progress through research and innovation, and to boost the state's economy. These efforts might yield efficiency gains or cost reductions for energy storage, nuclear power generation, geothermal energy, offshore wind, power grid control or many other technologies."
>
> — *Washington 2021 State Energy Strategy*[66]

Identified Need

An important consideration for many of these emerging solutions involves the potential complementarity of some solutions with others, but also the extent to which some solutions may compete with one another. For example, increasing the deployment of solar generation can result in surplus amounts of clean energy during certain times of the day and year. The deployment of battery storage can be a valuable complement in this circumstance, allowing the grid to maximize the use of low-cost solar power. Batteries can also be used for a multitude of other use cases, such as providing ancillary services to maintain grid stability or serving as a capacity resource to help meet periods of extreme demand. Meanwhile, flexible demand solutions can provide many of the same grid services, and several of the studies identified the competitive nature of the deployment of these resources.[67] For example, in scenarios where battery costs are assumed to be lower, the modeling selects less of a deployment of flexible demand solutions because of the overlap in the values and grid services that each technology delivers. Similarly, scenarios that model an increase in regional transmission connections can make it more cost-effective to import surplus solar power from other regions and may undercut some of the value of deploying more batteries for that purpose in Oregon.

Most the studies reviewed rely heavily on geographically diverse wind and solar projects, electric vehicles, and battery storage as core elements of achieving clean energy and decarbonization policies. But will those technologies be enough? One study reviewed found that "at least one reach technology that is not yet commercially proven is needed" to achieve 2050 policy goals, particularly in sectors that are more difficult to electrify (such as trucking and heavy industry).[68]

> "Emerging technologies will play a critical decarbonizing role. . . **it is likely that a range of technological developments will emerge to solve some of the most challenging deep decarbonization problems in the years beyond 2030.** These technologies, which include electrolysis, direct air capture, hybrid boilers, hydrogen, synthetic fuels, and carbon capture, will provide economic value for excess renewables, displace conventional gas and liquid fuels, and help balance the grid."
>
> — *Pathways to a Clean Energy Future for the Northwest: An Economy-wide Deep Decarbonization Pathways Study*[37]

Innovative Technologies

As the analysis presented earlier shows, a large amount of renewable energy requiring significant capital investment will need to be deployed to achieve policy goals. The challenge, including the costs, of supplying clean energy will vary depending on the time of year and hour of the day. For example, one megawatt of solar capacity might be able to deliver least-cost power during a sunny, mild spring afternoon. But it will be much more costly to generate and deliver the same amount of power from that one megawatt of solar capacity in the overnight hours in January. To do this would require pairing that solar with storage capabilities, and potentially building additional solar capacity, to deliver the same amount of energy.

The challenge of providing clean energy across 8,760 continuous hours of the year – 24 hours a day, 365 days a year – may necessitate the deployment of innovative technologies. Examples identified in the studies include:

- **Clean Firm Resources:** Several studies identify a need, particularly as the power system approaches higher levels of clean energy (typically beyond 80 or 90 percent), for innovative clean firm capacity[ii] resources that can maintain reliability during times of high demand and/or during times of low availability of wind and solar output. Oregon, and the Pacific Northwest, may have less of a need for these types of resources than some parts of the country on account of the scale of its existing, flexible, carbon-free hydropower system that can help to integrate large amounts of wind and solar.

[ii] Firm capacity refers to the capability of a generating resource to guarantee its availability to produce a certain amount of energy at a specific time. Most firm capacity in the northwest has historically been provided by hydropower and fossil power plants.

The following examples were identified as possible clean firm solutions that may play a role in achieving 2050 policy objectives:

  - *Advanced Nuclear*: A major breakthrough in costs is likely needed,[69] but advanced nuclear (such as small modular reactors, of the type developed by Oregon-based NuScale Power) is one potential source of clean firm capacity.[34] [70]
  - *Renewable Gas*: Another option is the use of renewable gas (e.g., biofuels or renewable hydrogen) in combustion turbines.[70] [34] [55] These technologies could operate much like the conventional, dispatchable gas power plants in operation today except that their fuel source would be renewable. In its *Vision 2050*, NW Natural identified its facility in Mist, Oregon as providing "20 billion cubic feet of underground storage capacity . . . [or] 6 million MWh of renewable energy storage capability" that could be used to store renewable gas.[71]

> "Today, the cheapest option for this peaking capacity *[in a 100 percent clean energy power system]* is storable renewable fuel used in a combustion turbine. . . *[Los Angeles]* can produce its own clean fuel in the form of hydrogen (produced from renewable electricity). This option is not yet commercially available at scale, so building the necessary infrastructure **could represent a significant portion of total costs associated with the clean energy transition**."
>
> — *LA100: The Los Angeles 100% Renewable Energy Study* [55]

  - *Fossil Gas with Carbon Capture*: Another low-carbon firm capacity solution identified in some studies is the continued use of natural gas power plants paired with carbon capture and sequestration.[69] [70]

> "Despite the declining costs of variable renewable energy (VRE) and short-duration battery storage, multiple studies have concluded that some amount of firm energy and capacity will be necessary to reliably meet load and maintain stable grid operations in a deeply decarbonized power system. Where a small amount of gross emissions are allowed in the power sector, firm energy needs are typically met with natural gas combustion turbines. **When a zero emissions constraint is applied, firm capacity needs are met with technologies that are not yet commercial at a large scale today if available in the model.** These include advanced nuclear, natural gas with carbon capture and sequestration (CCS), combustion turbines fueled with renewable natural gas or hydrogen, and multi-day, or seasonal energy storage resources."
>
> — *Pathways Toward Carbon Neutrality: A Review of Recent Mid-Century Deep Decarbonization Studies for the United States* [72]

- **Offshore Wind:** The offshore wind resource off the southern Oregon coast is among the highest quality wind resource areas in the world. But to capture that renewable resource for the power grid requires further development of innovative floating offshore wind turbines because of the ocean depths off the Oregon coast. Two of the more recent studies reviewed – *Oregon Clean Energy Pathways* (2021)[73] and the *Washington State Energy Strategy* (2021)[74] – both identified the need to deploy offshore wind resources beyond 2040 to achieve policy goals. One of those studies noted that the level of offshore wind deployment that would be beneficial to achieving policy targets "would require a rapid scale-up of new supply chains and production capacity."[75]

For more information on the challenges and opportunities associated with floating offshore wind in Oregon, see ODOE's 2022 report on Floating Offshore Wind.[76]

- **Automated Load Flexibility:** Flexible loads were identified above as a potential clean energy solution within the distribution system. Maximizing the effectiveness of these strategies may require the flexibility to be automated to align with dynamic grid conditions. This will likely require "investments in information and communication technologies"[77] and market transformation to support flexible load integration.[34] One potential large source of flexible loads is likely to come from electric passenger vehicles and trucks charged at home.[67]
- **Advanced Transmission Technologies:** One of the studies reviewed specifically identified a need to develop "advanced transmission technologies, such as flexible AC transmission systems," that can maximize the use of existing transmission assets.[77]
- **Long Duration Energy Storage:** Most battery storage systems currently being deployed in the power sector can discharge power at full output over 2 to 8 hours of duration. Some studies have identified a need to develop and deploy long-duration energy storage technologies to achieve policy goals as the power system approaches 100 percent clean energy.[69] [27] [70] Typically, this refers to technologies that can discharge energy over a duration of 10 to 100 hours, but sometimes is used to refer to storage technologies that operate on a seasonal timeframe (e.g., storing excess solar power from the summer months so that it can be used in the winter months).

  Learn more about long-duration energy storage in the Energy 101 section of this report.
- **Continued Wind & Solar Advancements:** Across most of the studies reviewed, there is an expectation of a significant deployment of wind and solar technologies. One study focused on the need for innovation to achieve clean energy policies and cautioned that ongoing research & development "should not be deprioritized" around those technologies simply because cost reductions have already occurred. The study continues: "In a low-carbon economy, a large portion of energy services are ultimately provided by renewable electricity, which means that even modest cost reductions have large impacts on total costs."[78]

Battery Storage

Battery storage is being deployed rapidly on the power grid in some parts of the country (like California), arguably taking it out of the category of an emerging solution in the electric sector. But battery storage has yet to be deployed at scale in Oregon and the Pacific Northwest. The deployment of battery storage systems alongside wind and solar generation has been identified as a "near-term, no-regrets option" to help achieve aggressive clean energy goals.[77] The following are examples of the identified need for battery storage in the studies reviewed:

- **National:** A review of multiple studies nationally identifies a dramatic increase in wind and solar capacity "accompanied by the deployment of 4-hour and 8-hour battery storage capacity in order to avoid curtailment" of renewables and to balance the grid.[27] Short duration storage is identified as a focus area for deployment.[34]
- **Los Angeles 100 Study:** Wind and solar resources will be "fundamental to providing the majority of energy required" to meet future energy demand and will be "enabled by storage."[79]
- **National:** By 2050, the average duration of energy storage deployed on the grid is 6 to 7 hours and modeled scenarios "build more storage early" when wind and solar are deployed at a faster rate. The amount of battery storage on the system, however, is "extremely sensitive to the amount of flexible end-use load" that is assumed to be available, while an elimination of flexible demand "approximately doubles the amount of storage" necessary.[80]
- **Portland General Electric:** In its deep decarbonization analysis, PGE found that the shift to a power grid dominated by wind and solar "necessitates a transition to new forms of balancing resources," including energy storage which can complement traditional sources of flexibility. The study notes, as do others, that the exact portfolio of available balancing options will depend upon specific pathways chosen to develop a clean energy economy.[56]

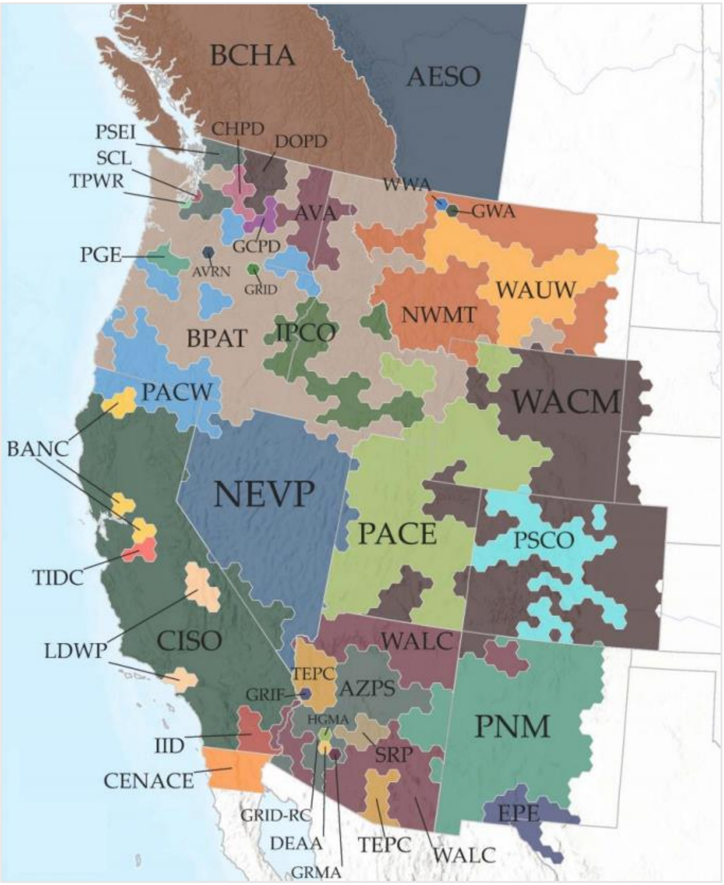
Siting Snapshot

Wheatridge Facilities (PGE)

The Energy Facility Siting Council, staffed by the Oregon Department of Energy, plays a role in approving utility-scale storage when batteries are proposed for major natural gas, wind, solar, or wind and solar projects. So far, storage has been proposed as an addition to existing EFSC-approved facilities and as part of new applications.

The first project proposed to include storage was Obsidian Solar Center in Lake County, whose developers included storage in the Notice of Intent in January 2018. That project was approved in February 2022 and is not yet operational. The first project to be approved with storage was Wheatridge Wind Energy Facility in 2018 – an existing facility that has since become four separate facilities. Three of the now-four facilities have been approved to add a total of 150 MW of storage.

Regional Energy Markets



BPAT: Bonneville Power Administration
PACW: PacifiCorp
PGE: Portland General Electric
IPCO: Idaho Power
CISO: California ISO

Currently, most electricity in the Pacific Northwest is exchanged through bilateral markets between utilities or Balancing Authorities (BAs). Similarly, the region's transmission system is operated by individual transmission owners, requiring projects to pay separate charges (often referred to as "wheeling" charges) to deliver power across each transmission system. There are approximately three dozen BAs currently operating across the western United States, with each responsible for balancing supply and demand within their footprint:[81]

Most of the studies reviewed, whose scopes were statewide or regional in nature, note that the technical models used to conduct the study assumed that these separate BAs did not exist. Instead, as described by the *Oregon Clean Energy Pathways* study, "the modeling examines how the electricity grid could be decarbonized at lowest cost if existing resources were dispatched and new resources were built optimally within a single balancing area across the western United States."[82] The *Washington State Energy Strategy* similarly assumed "efficient dispatch [of generators], akin to a single balancing authority for the western grid."[36] With the status quo, each BA on the map balances supply and demand within its footprint. If the BA anticipates a deficit, it will enter into a bilateral agreement with another BA to purchase power – or to sell power in cases of surplus. This process of using bilateral agreements cannot capture the maximum economic efficiencies that would be possible to achieve through a centralized economic dispatch that optimizes supply and demand across multiple BAs.

The *Oregon Pathways* study continued by describing the need for regional grid integration as a "critical requirement" for "achieving the lowest cost regional decarbonization portfolio."[83] A regionally integrated grid would enable Oregon to better take advantage of low-cost out-of-state renewables (e.g., solar from the desert southwest), to export its own power to other states across the west, and to efficiently plan for a reliable decarbonized power grid.[28]

> "Increased grid integration and transmission between the Northwest and California is cost-effective. **Significant cost savings can be realized if the Northwest and California electric grids are expanded and operations are better integrated.** Building additional transmission lines between the Northwest and California electricity grids could reduce the costs of decarbonization by an estimated $11.1 billion in net present value over the 30-year study period accrued to the combined California and Northwest region."
>
> — *Pathways to a Clean Energy Future for the Northwest: An Economy-wide Deep Decarbonization Pathways Study*[37]

Steps toward increased regionalization have been occurring, and are continuing to develop, in the Pacific Northwest. The *Washington Strategy* concludes that, while some stakeholders "advocate for creation of a regional transmission organization," the owners of the region's transmission resources (e.g., BPA and various electric utilities) are "in the best position to advance this work and build on recent progress."[40]

For more information on regional transmission organizations and an overview of Oregon stakeholder perspectives on the same, see ODOE's *Regional Transmission Organization Study: Oregon Perspectives*.[84]

Update: Evolving Wholesale Electricity Markets

In the 2020 Biennial Energy Report, ODOE published a policy brief on *Evolving Wholesale Electricity Markets*.[85] Those markets have continued to evolve over the last two years, with highlights including:

- **BPA joins the Energy Imbalance Market (EIM):** After engaging with its customers for several years, BPA joined the EIM in May 2022. According to BPA, it anticipates that its participation will help to "optimize surplus capacity and load service, providing operational and economic benefits for surplus power and savings on short-term purchases."[86]
- **Benefits of the EIM:** In 2020, ODOE reported on the cumulative gross benefits through Q3 2020 (total gross benefits at the time had just recently exceeded $1 billion). Through Q3 2022, the EIM now reports the following benefits:[87]

Table 1: EIM Participants and Cumulative Gross Benefits (Through Q2 2022)

EIM Participants	Cumulative Gross Benefits ($ Millions)
PacifiCorp (Oregon + Non-Oregon)	$537.53
Portland General Electric	$175.96
Idaho Power	$160.80
Bonneville Power Administration	$13.43
Non-Oregon Participants	$2,024.44
TOTAL BENEFITS SINCE 2014:	**$2,912.16**

- **Extended Day-Ahead Market:** As discussed in the 2020 BER, this would extend the California Independent System Operator's day-ahead market to EIM participants. According to CAISO, EDAM will "improve market efficiency by integrating renewable resources using day-ahead unit commitment and scheduling across a larger area." The current schedule for implementation of EDAM follows:[88]
    - **September 2022** – Draft EDAM Tariff framework published
    - **November 2022** – Draft EDAM Tariff published
    - **December 2022** – Final EDAM proposal published, and a vote is expected by the joint CAISO Board of Governors and EIM Governing Body

  After the creation of EDAM, current participants of EIM will be able to choose whether to voluntarily participate in EDAM or not.

- **SPP Markets+:** The Southwest Power Pool, based in Little Rock, Arkansas, is another regional transmission organization, like CAISO, that also operates day-ahead and real-time markets for the wholesale transaction of electricity. In February 2021, SPP extended its real-time market – named the Western Energy Imbalance Service (WEIS) market – to entities in the west (primarily to utilities located in Colorado, Wyoming, and portions of northern Montana).[89]

  In addition to the WEIS market, SPP is also offering what it calls Markets+. Markets+ is a conceptual bundle of services that would "centralize day-ahead and real-time unit commitment and dispatch" and "provide hurdle-free transmission service" across its footprint. SPP describes this suite of services as delivering some of the value of expanded regionalization for those utilities not "ready to pursue full membership in a regional transmission organization."[90] SPP released its Draft Service Offering for Markets+ on September 30, 2022.

  At this time, no utility operating in the Pacific Northwest is participating in either SPP's WEIS market or in Markets+.

- **Western Resource Adequacy Program:** While the maintenance of resource adequacy does not suggest an evolution of wholesale electricity markets, per se, an adequate power system is a foundational pre-requisite for the operation of healthy wholesale markets.

  At the request of several stakeholders across the west in 2019, the Western Power Pool (formerly the Northwest Power Pool) initiated development of the Western Resource Adequacy Program to address the "urgent and immediate challenge" of maintaining resource adequacy across the west.[91] It has since been designed to deliver a region-wide approach for "assessing and addressing resource adequacy" to ensure regional reliability of the power system. By working together, the intention is to find opportunities for savings and using fewer resources compared to each Balancing Authority across the west maintaining resource adequacy on its own.

  The Board of the Western Power Pool approved the WRAP's Tariff in August 2022 and filed it with the Federal Energy Regulatory Commission for approval.[92] It is anticipated the FERC will make a decision on approval by the end of the year. Meanwhile, in September 2022, current participants in WRAP made their first non-binding filings of data, including Winter 2022-2023 and Summer 2023 forward-showing submittals.[93]

Process for Pursuing Emerging Solutions

The range of emerging solutions that could make a meaningful contribution to achieving Oregon's clean energy and climate policy objectives are likely to be developed through numerous processes. In some cases, additional research and development of a particular technology may still be required, perhaps necessitating involvement by the federal government. This is likely the case with several of the innovative technologies identified, such as clean firm resources or long-duration energy storage technologies.

In other cases, such as increasing regional coordination, utilities have already taken steps in recent years and other efforts are currently being explored. A combination of utility interest, combined with stakeholder advocacy and state policies, is likely to continue to encourage increased regional collaboration in the years ahead.

And in yet other cases, such as with some types of innovative generation, like offshore wind, or with battery storage, utility planning efforts are likely to identify the need for these types of resources. In some cases, there may be opportunities for state policies (such as HB 2193,[94] which mandated the procurement of battery storage by PGE and PacifiCorp) or regulators to require the pursuit of particular solutions, though customer cost impacts are an important consideration.

One of the near-term challenges will be to clearly identify the required emerging solutions to optimally achieve the state's policies objectives by mid-century, and then to work backwards to define processes and timelines that ensure those resources can be planned for and developed in alignment with those policy objectives. Depending on the type of emerging solution that is identified as necessary, policymakers may have options to advance those solutions through regulation, incentives, or stakeholder and public education.

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Pathways to 2050

At this juncture, it is not yet certain which emerging solution (or solutions) might be required for Oregon to achieve its mid-century clean energy and climate policy objectives. But, as several of the studies noted, it is probable that at least one of these solutions will be necessary.

As Oregon considers potential pathways to achieve its policy objectives, it must evaluate these types of issues when assessing emerging solutions:

- **The Role of Dispatchable Gas Generation:** Some of the studies find that the most cost-effective, deeply decarbonized energy system relies on some residual amount of gas power generation (which could be fueled by conventional natural gas or a renewable gas alternative) to maintain system reliability during extreme conditions. **Given these types of findings, how should the state view the need for gas infrastructure in the near-term?**

- **Need for Innovative Technologies:** Particularly in scenarios where gas generation is phased out or severely limited, Oregon may be reliant on the development of one or more innovative technologies to maintain power system reliability. **What role should the state play in supporting or pursuing the development of these types of innovative technologies?**
- **Sources of Flexibility:** Several studies identified that both battery storage and flexible demand may be necessary elements of the clean energy transition, but that they also compete with one another in certain respects to help provide system flexibility to integrate large amounts of wind and solar generation on the grid. Developing more transmission can also provide increased flexibility through greater use of regional transfers. **How should the state balance its support for the development of different types of flexibility?**
- **The Effects of Increased Regionalization:** Multiple studies identify increased regionalization as a critical requirement to achieving the most cost-effective decarbonization of the electric grid. This may incur trade-offs, however, such as less development of certain types of energy resources in Oregon. **How should the state balance support for increased regionalization against potential trade-offs that regionalization may incur?**

Conclusion

The studies reviewed by Oregon Department of Energy staff universally find that an increasingly clean electric sector will play a dominant role in achieving mid-century clean energy and climate policy objectives. The scale and pace of the investments required are enormous, they must accelerate now, and they must be sustained for decades.

But importantly, Oregon has significant opportunities to develop an intentional pathway to achieve its policy objectives in a way that balances trade-offs and meets the needs of Oregon stakeholders and communities. The state has opportunities, for example, to evaluate the extent to which it seeks to rely on distributed resources, whether to maximize the development of a particular type of renewable or to develop a diverse portfolio of resources, and to identify which innovative technologies may be required.

Oregon has significant opportunities to develop an intentional pathway to achieve its policy objectives in a way that balances trade-offs and meets the needs of Oregon stakeholders and communities.

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Policy Brief: Charting a Course for Oregon's Energy Future

Part III: Natural Gas Sector

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

Conventional gaseous fuels, including natural gas and propane, play important roles in Oregon's energy system. In the electric sector, natural gas-fired power plants provide needed flexibility to the grid and help to maintain reliability. Natural gas is also delivered to consumers across the state for "direct use" in buildings and industrial processes. Many homes and businesses rely on natural gas (and to a lesser extent, propane) for space and water heating, cooking, and to fuel other gas appliances and systems. Industrial facilities often use natural gas to generate heat and/or power for industrial processes. But while natural gas has historically served as a reliable and affordable energy source, it is primarily comprised of methane, a potent yet relatively short-lived greenhouse gas that has more than 80 times the warming potential of carbon dioxide (CO_2) over a twenty-year period. (Methane's global warming potential declines to about 25 times that of CO_2 over a 100-year timeframe, though individual methane molecules only survive in the atmosphere for around 12 years.) When combusted, natural gas emits CO_2 and other harmful air pollutants.[1] In 2019, natural gas combustion produced 14 percent of Oregon's annual greenhouse gas emissions.[2]

To achieve its mid-century climate goals, Oregon must substantially reduce emissions from natural gas combustion. Two recently adopted state policy frameworks—the 100 percent clean electricity standard established by HB 2021, and the Climate Protection Program administered by the Oregon Department of Environmental Quality—require steep reductions in emissions from electricity generation and direct use natural gas in the coming decades. Achieving these mandatory emissions reductions in a manner that ensures all Oregonians have equitable access to reliable and affordable energy will require coordinated action by regulators and utilities, with guidance and input from consumers, stakeholders, and community members.

To achieve its mid-century climate goals, Oregon must substantially reduce emissions from natural gas combustion.

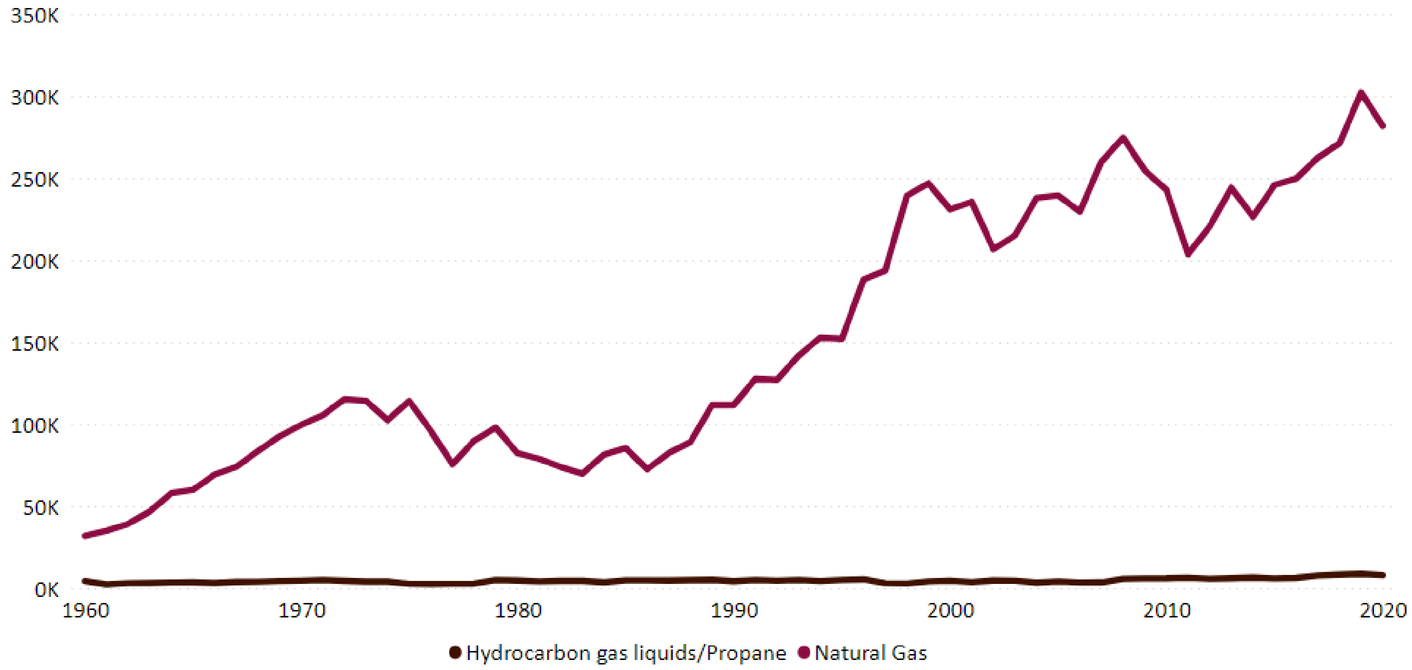
The studies reviewed for this policy brief series commonly identify three key strategies for reducing emissions from natural gas: 1) decrease the quantity of gas consumed through conservation and energy efficiency improvements, 2) reduce reliance on direct use gas through electrification of building systems and components, and 3) transition from fossil gas to low- or zero-carbon alternative fuels. Each of these strategies presents unique challenges, opportunities, trade-offs, and uncertainties. Moreover, it is likely to be more difficult to electrify some uses of dispatchable gaseous fuels, and in those circumstances the most cost-effective pathway to decarbonization may be through using existing gas infrastructure to carry low-carbon gaseous fuel like renewable natural gas.

Oregon has an opportunity to engage the public to find the right balance between replacing gas end uses and continuing to use existing gas infrastructure in innovative ways to achieve its clean energy and climate policies. Drawing from recent studies, this policy brief describes the role that natural gas currently plays in Oregon's energy system; explores pathways to decarbonizing natural gas through a combination of energy efficiency, electrification, and low-carbon alternative fuels; discusses the cost and equity implications of these decarbonization strategies; and explores key policy considerations and tradeoffs associated with these strategies.

The Role of Natural Gas in Oregon

Natural gas is the primary focus of this brief, but most of the decarbonization strategies reviewed could also apply to propane. Natural gas consumption volume and applications far outpace propane, as shown in Figure 1. Total natural gas consumption (in billion British thermal units) in the chart includes fuels used for electricity generation, and the residential, commercial, industrial and transportation sectors.

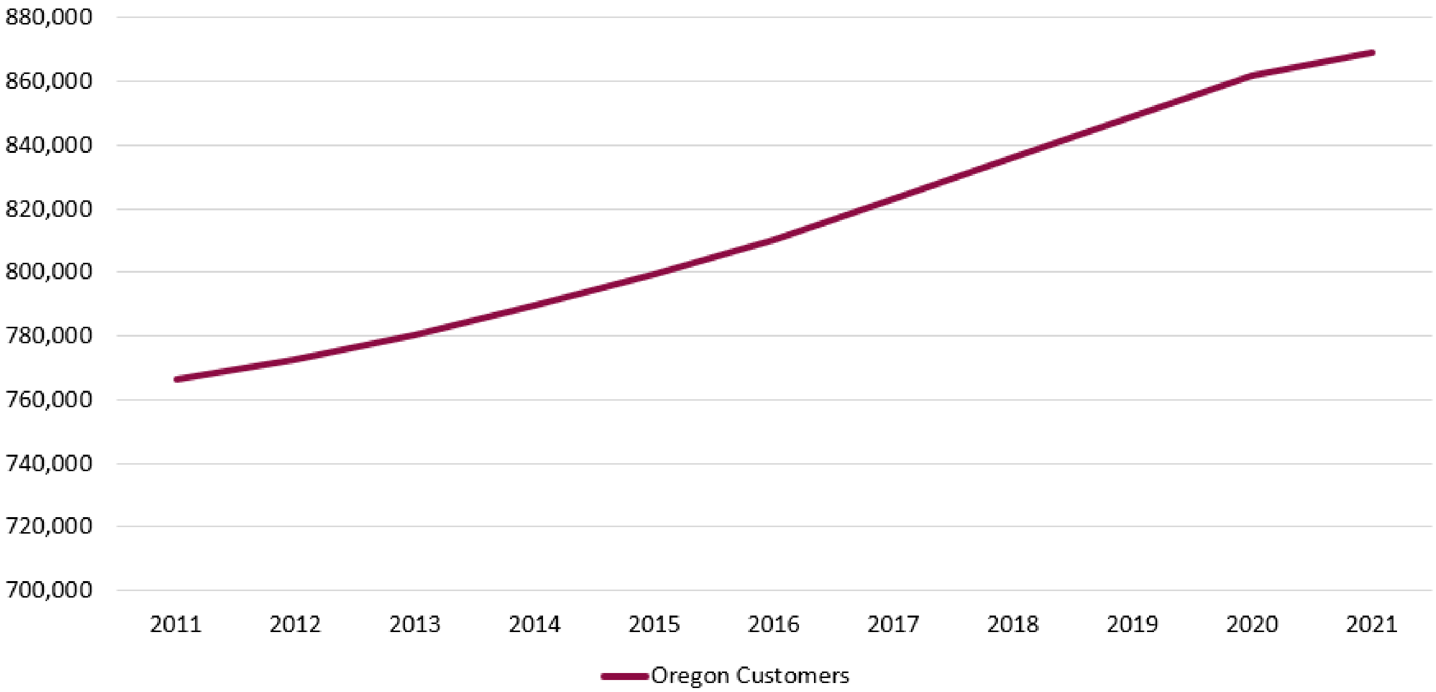
Figure 1: Total Natural Gas and Propane Consumption 1960 – 2020 (Billion Btu)[3]



Consumption of natural gas in Oregon has increased significantly in recent decades. Figure 1 shows Oregon's aggregate consumption of natural gas and propane from the electricity, residential, commercial, industrial, and transportation sectors between 1960 and 2020. Oregon consumed 282 trillion Btu of natural gas as a direct use fuel in 2020, an increase of three percent from the 275 trillion

Btu Oregon consumed in 2008.[3] In 2019, natural gas use produced an estimated 9 million metric tons of CO_2 equivalent emissions ($MTCO_2e$), or 14 percent of Oregon's total emissions.[2] Figure 2 shows that the total number of natural gas retail customers in Oregon has steadily increased over the last decade; in 2021, there were approximately 870,000 retail gas customers in the state. Learn more about natural gas and propane consumption in Oregon in the Energy by the Numbers section of this report.

Figure 2: Total Natural Gas Retail Customers in Oregon 2011–2021[4]



Electric utilities are also using more natural gas. Total consumption by Oregon's electric power sector increased from 119 trillion Btu in 2008 to 137 trillion Btu in 2020, an increase of 15 percent.[3] Natural gas has been a low-cost generation resource that helps utilities meet load growth with fewer greenhouse gas emissions and other air pollutants than coal. Natural gas plants are also able to play different roles in grid management, including serving as steady baseload power generators and acting as highly flexible generators that can ramp up and down quickly to meet constantly changing electricity demand.

Recent Trends: Natural Gas Consumption for Electricity Generation

- Economic and population growth have driven Oregon's total annual electricity consumption to increase from 47 million MWh in 2012 to 54 million MWh in 2020.[5]
- Electricity generation from coal plants decreased from 33 trillion Btu in 2011 to just under 17 trillion Btu in 2020.[3]
- Natural gas demand varies year to year because demand is highly dependent on natural fluctuations in the Pacific Northwest's annual precipitation and corresponding hydropower production.
- Flexible natural gas generation is often used to respond quickly to increases in electricity demand and support the variability of renewable energy resources such as solar and wind.

Oregon Natural Gas Facts

- The natural gas industry supports an estimated 46,100 jobs in Oregon[6]
- In 2020, Oregon consumed 59 trillion Btu of natural gas in the industrial sector, second only to electricity generation.[3]
- Industry uses gaseous fuels for process heat, combined heat and power, and as a feedstock for fertilizer.[7]
- In 2020, Oregon consumed 7 trillion Btu of natural gas as a transportation fuel.[3]

The Natural Gas Market

Oregon is highly dependent on natural gas resources from other states and Canada. In 2020, the state's only natural gas resource, the Mist facility in Columbia County, produced the equivalent of 0.12 percent of Oregon's total natural gas consumption.[3] Most of Oregon's natural gas is imported from the U.S. Rocky Mountain region, northern Alberta, and Northern British Columbia. (Learn more in the Transportation Fuels 101 in the *2020 Biennial Energy Report*.)

The rapid development of liquid natural gas export terminals around the world has implications for the future of low-cost natural gas, as the commodity will be subject to the effects of a more global marketplace. Global trade of LNG increased 4.5 percent in 2021 and more growth is expected, with the United States as the world's largest exporter and China as the largest importer.[8] [9] Oregon natural gas utilities have contracts with producers, but increased demand and capacity to distribute natural gas globally will influence future prices. The Russian invasion of Ukraine in 2022 lead to European policies that limit or prohibit purchases of Russian natural gas, resulting in an increasing demand for LNG from the United States.[10] Global supply and demand will have an increasingly larger effect on the affordability of natural gas in Oregon.[11] [12]

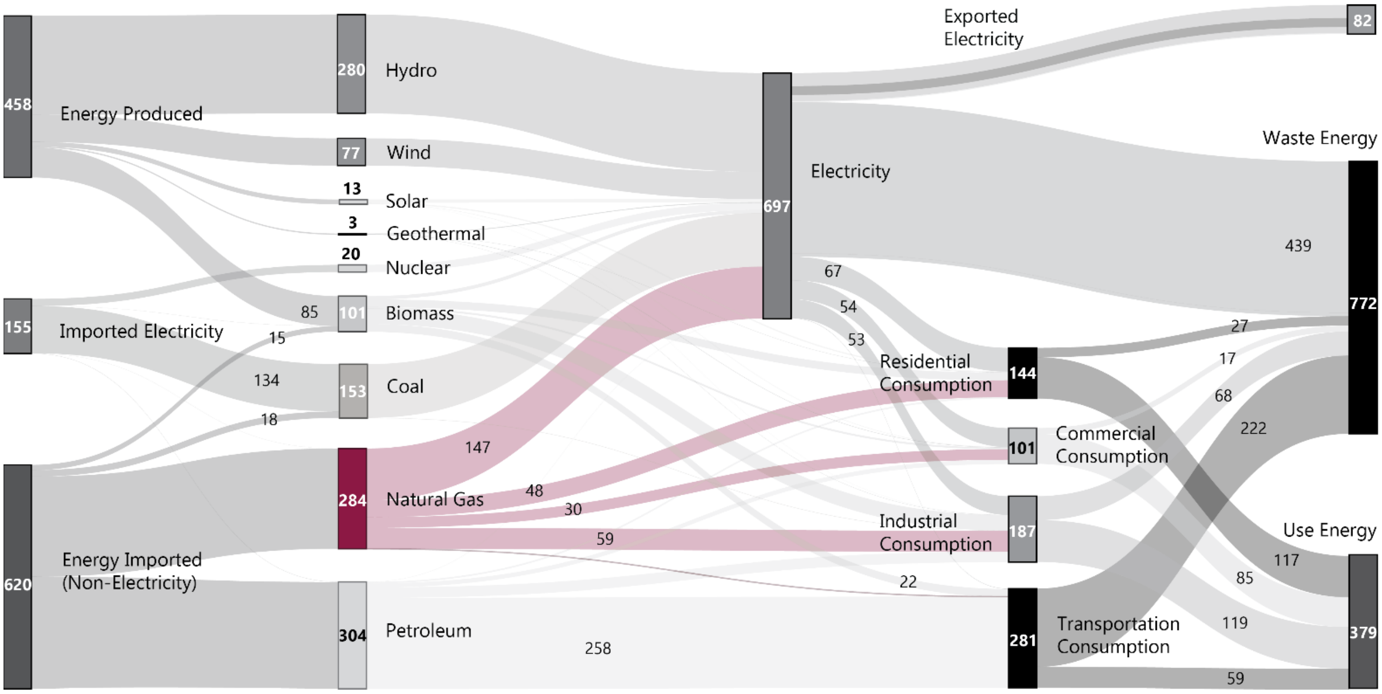
Natural Gas Alternatives

As Oregon seeks to meet its climate and energy goals, there is interest in identifying alternatives to natural gas in both direct use applications and electricity generation. Strategies for reducing emissions from natural gas used in commercial or residential spaces largely focus on either electrifying the end uses or supplementing or replacing natural gas with lower carbon fuels, such as renewable natural gas or hydrogen. Similar options exist in many industrial sectors, including using waste process heat to generate electricity, heat water, or conserve energy through other mechanisms. Electrification, the replacement of existing natural gas equipment with electric equipment, is another strategy identified in the analyses.

Through the adoption of HB 2021 in 2021, Oregon legislators signaled a shift away from new natural gas electricity generation, prohibiting the siting of new gas plants in the state. Replacing the flexibility and low-cost of natural gas for electricity generation will be a challenge. While utilities are beginning to invest in battery storage to help balance variable renewable energy generation and meet system load needs, most of the reviewed studies concluded that some dispatchable capacity will still be needed to meet demand and maintain stable and reliable electrical grid operations.[13] Alternative fuels like renewable natural gas and hydrogen are also being investigated as potential alternative fuel replacements for fossil natural gas in the electricity sector. Many of the studies reviewed conclude natural gas will be replaced or supplemented by increasing volumes of alternative low-carbon gaseous fuels by 2050.

Exploring Pathways to 2050

Figure 3: How Natural Gas Moves Through Oregon's Energy Flow[i]



Numbers are in trillions of British thermal units.

There are many pathways to reduce emissions in the natural gas sector, including increasing energy efficiency, converting natural gas end uses to electricity, or transitioning to lower carbon alternative fuels. Energy efficiency improvements to buildings and industrial applications can reduce emissions by decreasing the amount of natural gas needed to fuel building systems and processes. Electrifying appliances and building systems, such as replacing natural gas furnaces with high-efficiency electric heat pumps, can reduce emissions by eliminating the need for natural gas as a direct use fuel. Low-carbon alternative fuels, such as renewable natural gas and hydrogen, and potentially new carbon capture and sequestration technologies, can reduce emissions while continuing to use existing natural gas infrastructure. A combination of some or all of these strategies is necessary for Oregon to achieve its mid-century climate policy goals.

Decarbonization studies consistently identify the need to address emissions from natural gas use but vary on their recommendations of which strategies to use and to what degree. The National Renewable Energy Laboratory modeled the resources needed for Los Angeles to meet a 100 percent renewable electricity target by 2045, and many of the scenarios modeled included replacing natural gas for electricity generation with hydrogen and renewable natural gas.[14] The Washington State Department of Commerce modeled several scenarios for decarbonizing the state's economy by 2050,

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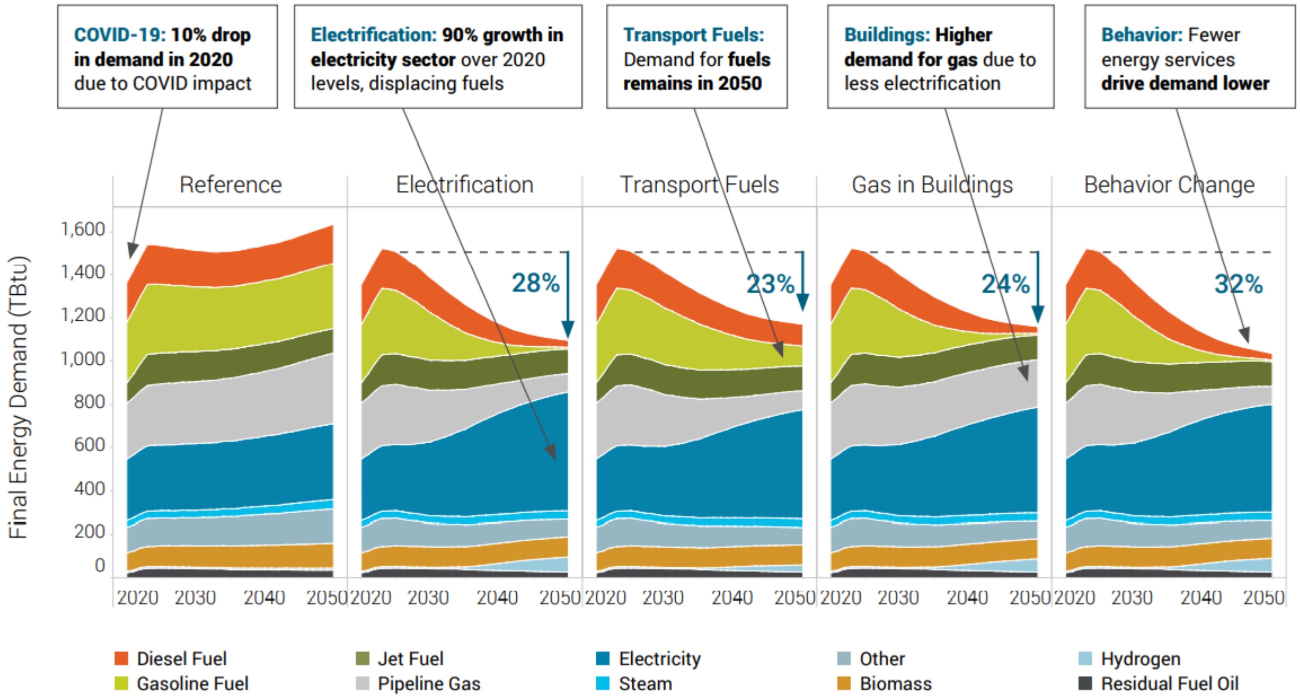
[i] Learn more about Oregon's energy flow in the Energy by the Numbers section of this report.

including a scenario in which overall energy demand is reduced through energy efficiency improvements and electrification. The results of Washington's decarbonization scenario analysis are illustrated in Figure 4. The state's "Gas in Buildings" scenario retained the most continued use of conventional gas fuels, with a greater use of low-carbon alternative fuels for transportation and increased use of renewable natural gas in buildings. While the scenario achieved the state's GHG reduction goal, its projected costs were higher than the costs of other scenarios modeled. However, the gas in buildings scenario offered some added benefits by allowing for continued use of existing conventional natural gas infrastructure.[15]

Figure 4: Washington Energy Strategy Decarbonization Scenarios, Final Energy Demand 2020-2050[15]



COVID-19: 10% drop in demand in 2020 due to COVID impact

Electrification: 90% growth in electricity sector over 2020 levels, displacing fuels

Transport Fuels: Demand for **fuels remains in 2050**

Buildings: Higher demand for gas due to less electrification

Behavior: Fewer energy services **drive demand lower**

In most studies reviewed for this brief, continuing to use some amount of gas power plant capacity—whether powered by natural gas (with or without carbon capture) or by lower carbon fuels—is an essential tool for maintaining a reliable power system and supporting high amounts of renewable energy. Studies differ on the amount of natural gas remaining in the system by 2050, whether and how much renewable natural gas or hydrogen will be needed, and the cost effectiveness of different actions, but for many studies the most cost-effective scenarios include continued use of existing gas infrastructure to some extent.

> "**[N]o Energy and Environmental Economics, Inc. (E3) study has yet identified a strategy that eliminates the use of pipeline gas altogether**, since zero carbon gas alternatives can replace natural gas in the pipeline. Every scenario leaves residual gas demands in industry, while others allow gas usage in the buildings or transportation sector."
>
> — The Challenge of Retail Gas in California's Low-Carbon Future[16]

Energy Efficiency

Reducing consumption of gaseous fuels through improved efficiency is one of the simplest and most cost-effective decarbonization solutions available. Natural gas and propane are used for space and water heating and cooking in Oregon's built environment, as well as for a variety of industrial applications. Improving the thermal envelope of buildings and the efficiency of appliances reduces the amount of gas needed to support building functions, while also reducing energy costs and preserving occupant comfort benefits.[ii] [17] All natural gas utilities in Oregon have identified reductions in natural gas consumption that can reduce overall system demand through 2040.

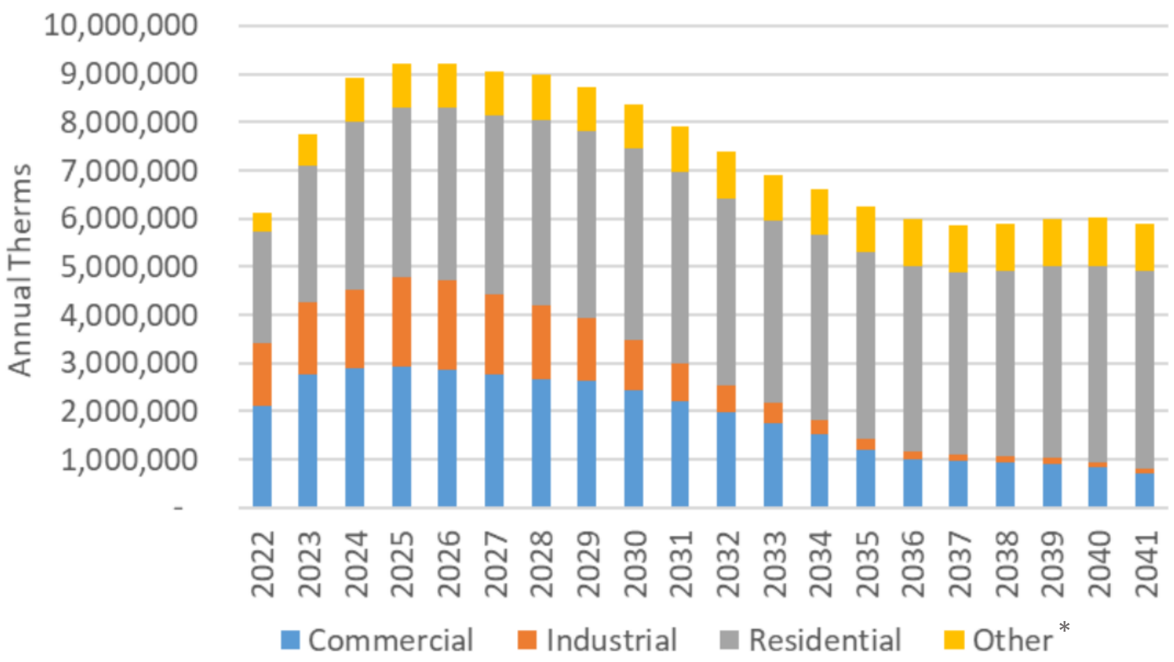
Table 1: Energy Trust of Oregon Energy Savings Projections for Oregon Natural Gas Utilities

Utility	Natural Gas Delivered in 2020 (million therms)	Energy Efficiency Savings Projections (million therms)	Timeline	Source
Cascade	318.9[4]	12.1	2020-2039	2020 Integrated Resource Plan[18]
Avista	130.9[4]	14.8	2021-2040	2021 Natural Gas Integrated Resource Plan[19]
NW Natural	1,044.8[4]	147.1	2022-2041	2022 Integrated Resource Plan[17]

Energy efficiency gains in the near-term will lead to immediate fuel and carbon savings, reducing the need for additional natural gas production resources, and addressing potentially limited quantities of available alternative fuels.[15] In Figure 5 below, NW Natural's most recent integrated resource plan projects that between 2022 and 2025, energy efficiency improvements will conserve approximately 50 percent more gas than is currently conserved, largely due to increased savings in the industrial and residential sectors.[17]

[ii] Learn more in the Energy Efficiency Options for Existing Buildings Policy Brief.

Figure 5: Modeled Future Cost-Effective Energy Efficiency Savings for NW Natural's Portfolio[17]

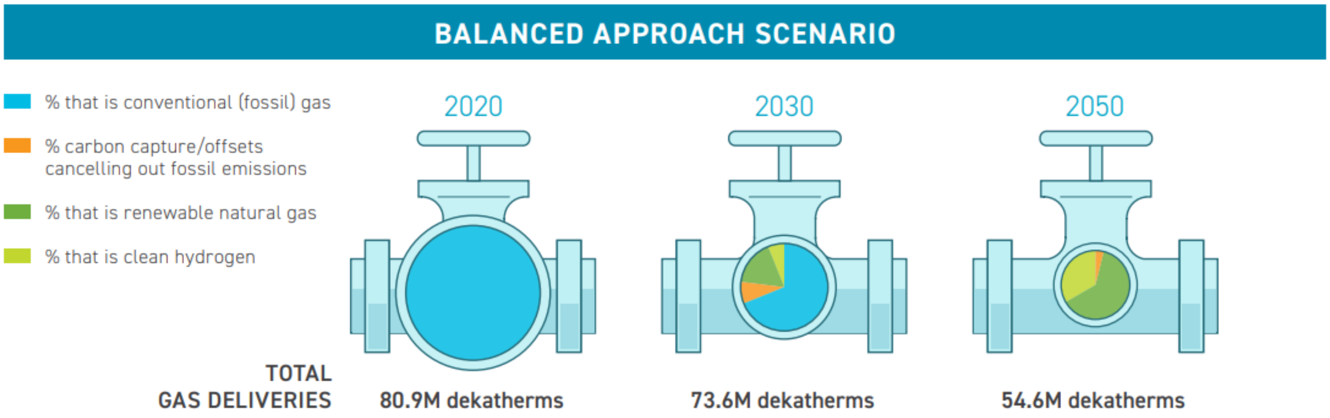


Other includes energy efficiency gains from building codes and market transformation.

Reducing Greenhouse Gas Emissions with Energy Efficiency

Energy efficiency savings are projected to achieve direct greenhouse gas reductions. For example, as illustrated in Figure 6, NW Natural modeled a scenario in which its total gas deliveries were reduced by more than 25 dekatherms, reflecting an approximately 30 percent reduction in deliveries, from to 2020 to 2050. While most of the emissions reductions in the scenario resulted from electrification of some end uses and transitioning pipeline gas to low-carbon gas, savings from energy efficiency were expected to account for roughly a quarter of these reductions.[20] In 2021, Energy Trust of Oregon, which administers energy efficiency programs for NW Natural, Cascade Natural Gas and Avista, invested $2.66 million to acquire 7.1 million therms of natural gas efficiency savings.[21]

Figure 6: NW Natural Modeled Natural Gas Demand Reductions [20]

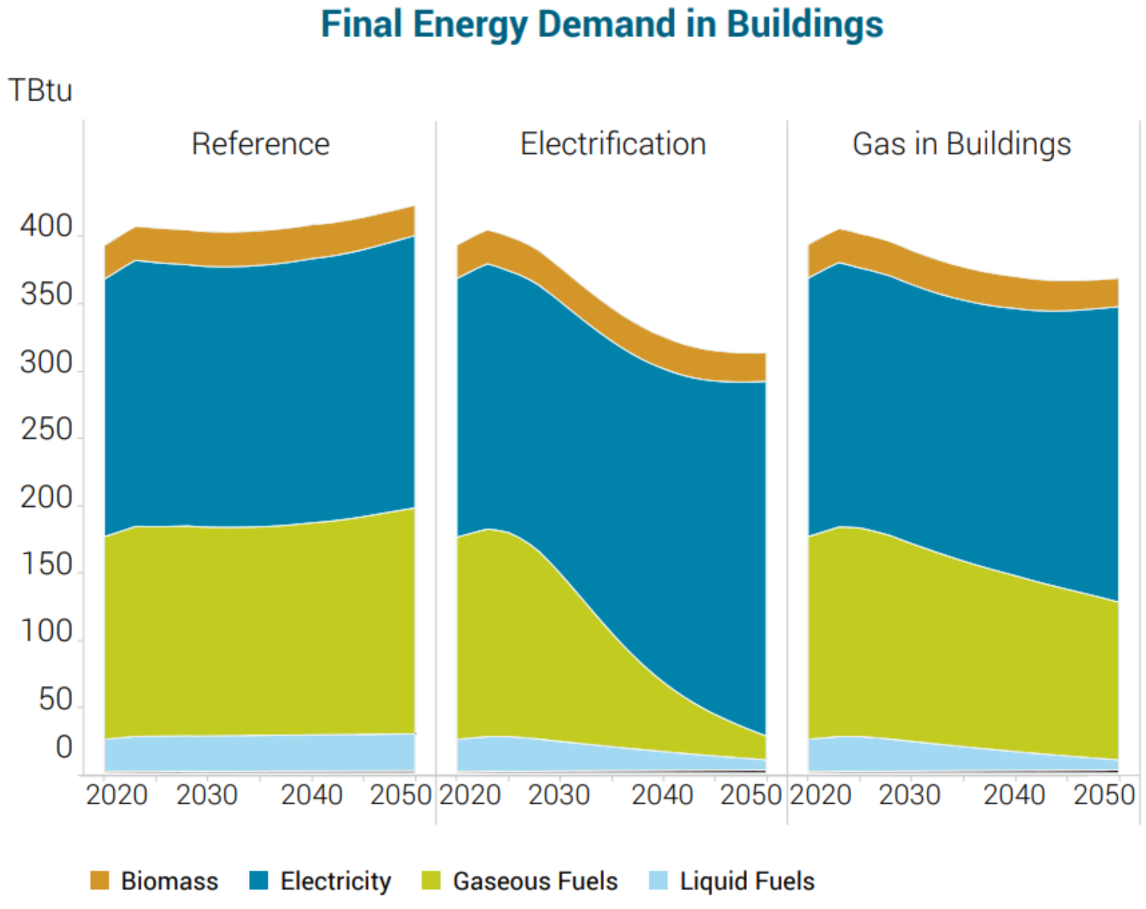


2020: 100% conventional (fossil) gas
2030: 69% conventional (fossil) gas, 8% carbon capture/offsets cancelling out fossil emissions, 17% renewable natural gas, 6% clean hydrogen
2050: 0% conventional (fossil) gas, 4% carbon capture/offsets cancelling out fossil emissions, 62% renewable natural gas, 33% clean hydrogen*

* Carbon capture in 2050 begins to sequester biogenic CO_2 emissions from renewables, meaning that the scenario has shifted to a carbon-negative system.

To achieve decarbonization objectives in the gas sector, the studies reviewed found that savings from increased energy efficiency will be complimented by increased electrification of end uses in buildings and the availability of alternative fuels by 2050. In Figure 7, for example, Washington's *2021 State Energy Strategy* projected a significant reduction in gaseous fuel use in buildings by 2050 in its high electrification scenario. Similarly, studies that focused on reducing natural gas demand to achieve GHG targets also relied on high levels of energy efficiency adoption in buildings.[22] In scenarios where lower-carbon alternative gaseous fuels replaced natural gas, gaseous fuels continued to support a significant amount of building energy needs, as shown in the "Gas in Buildings" scenario depicted in the figure. It is important to note that non-fuel-specific energy efficient building technologies and designs will provide benefits under any scenario by reducing overall demand for energy irrespective of the fuel source.

Figure 7: Energy Use Reductions Required to Meet Washington State's Net-Zero Emissions Targets[15]



Barriers

The studies reviewed generally concluded that reducing energy consumption through building energy efficiency improvements is necessary to achieve aggressive clean energy mid-century policy targets. However, acquiring the amount of energy efficiency savings needed to dramatically reduce demand will require more efficient building codes and operating practices, programs to engage hard-to-reach customers, and significant capital investments. It is also difficult to predict when new, efficient technologies (*e.g.,* natural gas heat pumps) may become commercially available, and what the associated costs, emissions impacts, and deployment rates will be for new technologies once they enter the market.

Energy efficient building designs and technologies are most cost-effective when incorporated into buildings during initial construction, and efficiency retrofits in existing buildings are most cost-effective when undertaken during major upgrades or when appliances and equipment fail. Builders are required to meet minimum efficiency designs and standards during construction and renovation, but Oregon does not require independent additional efficiency investments in existing buildings. There are multiple mechanisms to drive energy efficiency improvements in existing commercial buildings.

Deep energy efficiency retrofits in existing buildings would likely require significant capital investment. For projects to be cost-effective, they must provide sufficient energy savings to offset their up-front costs within a reasonable time period. Therefore, unless natural gas dramatically increases in price, the cost-effectiveness of energy efficiency retrofits will likely continue to be a barrier to adoption. This challenge with the cost-effectiveness of energy efficiency retrofits in the gas sector makes it more difficult to serve low-income and other hard to reach communities. These customers may require additional resources and policy support to help them improve the energy efficiency of gas usage in their buildings and appliances.

In addition to a shortage of regulatory tools and high upfront costs that may deter efficiency upgrades, there is uncertainty around the timing, availability, and impacts of new, high-efficiency technologies. For example, there are innovative natural gas technologies under development that aim to achieve greater efficiency rates than currently available technologies. However, these technologies are not yet commercially available in Oregon, making it challenging to predict the timing of their availability, cost, and potential market penetration. Dual fuel appliances, natural gas heat pumps, natural gas heat pump water heaters, and new efficient furnaces are expected to provide improved energy efficiency benefits once they become available. The unknown viability and availability of these technologies creates some uncertainty about how much achievable natural gas savings from efficiency investments is possible, and if they will have implications for achieving mid-century clean energy policies.

Electrification

Most of the studies reviewed concluded that in addition to energy efficiency, the least-cost, least-risk decarbonization strategies rely heavily on electrification of building end uses. Electrification is the process of converting appliances and building systems currently powered by natural gas to comparable technologies powered by electricity. HB 2021 requires Oregon's large investor-owned utilities and electricity service suppliers to eliminate carbon emissions from electricity sold in Oregon by 2040, which will make electricity an even cleaner alternative to the direct use of conventional gaseous fuels than it is today. Most of the studies reviewed identified an increasing share of total energy consumption coming from the electrification of end-uses through 2050, driven by transitioning to electric vehicles, and by converting many current end-uses of natural gas to electricity.

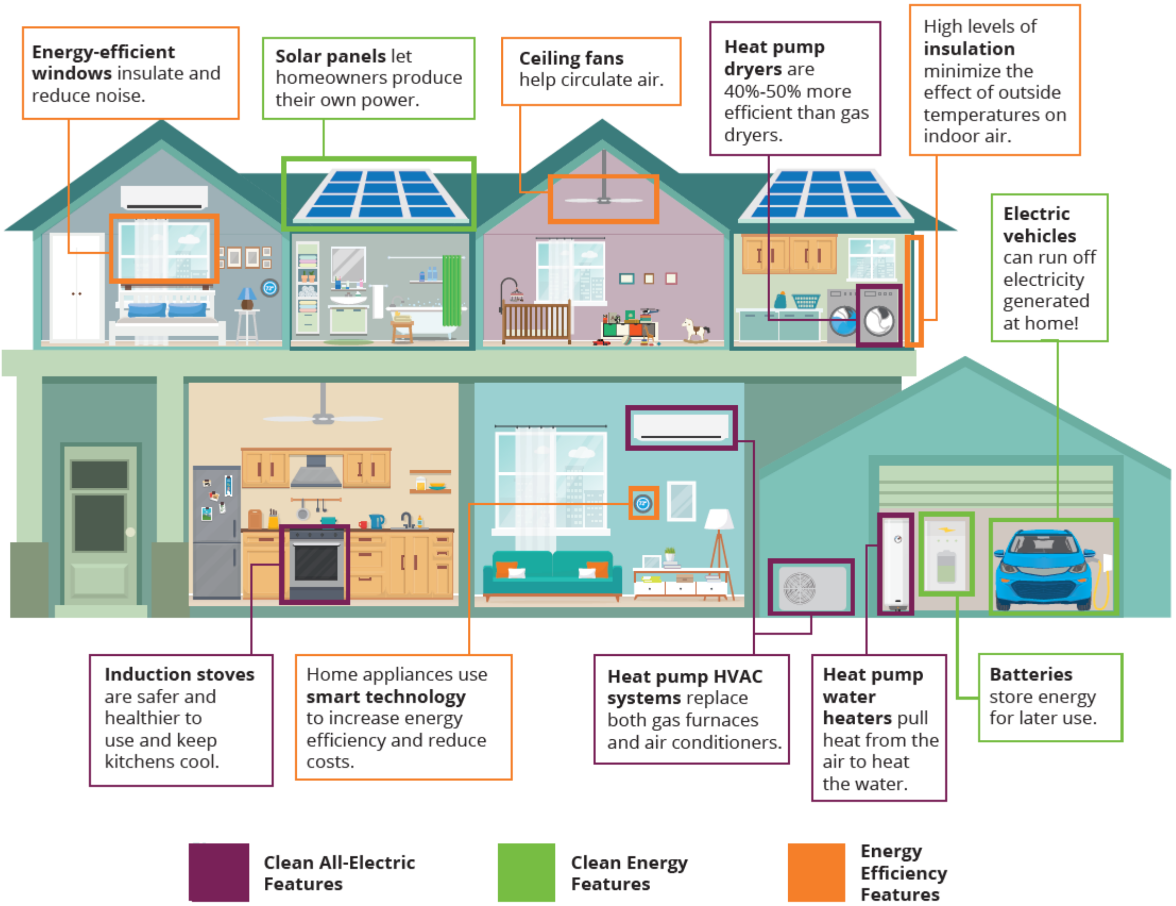
> “Efficiency and electrification are **low-cost and low-risk pillars** of energy decarbonization.”
>
> — The Role of Electricity in Decarbonizing California’s Energy System[23]

Reducing Greenhouse Gas Emissions with Electrification

Electrification of many current natural gas end uses will likely play an important role in reducing emissions from the natural gas sector. For example, SoCalGas—a large investor-owned gas utility in California—found that 55 to 95 percent of building space heating could be cost-effectively electrified by 2050.[24] Evolved Energy Research similarly found that “aggressive electrification of demand and development of clean electricity could meet 80 percent of Oregon’s decarbonization targets.”[25]

Electric options are readily available in many sectors, but some end uses lend themselves to electrification more easily than others. There are electric versions of heating, drying, cooking, and other technologies that are used in residential and commercial buildings. Other sectors that have historically relied on natural gas, such as drying equipment in agricultural operations, also have increasingly more electric options (see more in the Electrification Options in the Agricultural Sector Energy 101). Other end uses may be harder to electrify, at least in the near-term, including industrial applications that use high-heat processes, such as those used in the steel and chemical processing industries. Further, the gas sector may be able to help other sectors decarbonize, such as by providing renewable natural gas or renewable hydrogen to fuel heavy-duty trucks, ships, or trains.

Figure 8: Home Electrification Opportunities[26]



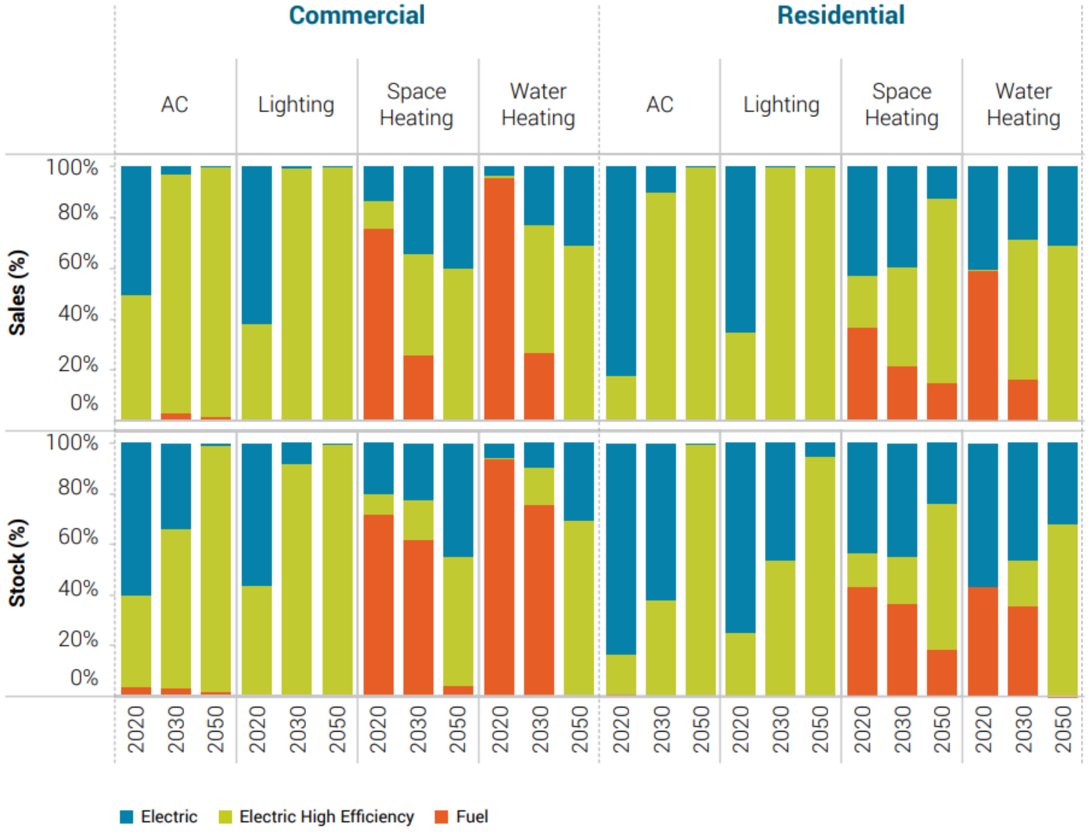
Barriers

Widespread electrification will likely take time to accomplish without policy and market intervention. As noted above, some end uses, such as heavy-duty transportation and some industrial processes, are expected to remain more difficult or costly to electrify than others. In many studies, several end uses are not expected to fully electrify until 2050, and the success of electrification as a decarbonization strategy is dependent on widespread changes to construction practices, as well as consumer adoption of electric appliances.

Retrofitting buildings and switching from natural gas space and water heating systems to electric options can potentially present a net cost over equipment lifetimes using current natural gas utility prices.[27] In addition, electrification of residential heating demand, in particular, has the potential to contribute to increases in electric system peaks, which could cause cost increases as well if new generating resources are needed to meet peak demand. If natural gas prices rise substantially in the future, however, the economics around electrification could change.

Figure 9 illustrates the pace in which building equipment must electrify to achieve Washington State's decarbonization targets under an electrification-oriented scenario. The bar graphs in the top row show the percentages of newly sold equipment that are electric, high-efficiency electric, or powered by direct use fuels in 2020, 2030, and 2050. The bar graphs in the bottom row show the composition of installed building equipment in those same years. The graphs help illustrate the rate at which building equipment must be electrified and become more efficient between now and 2050 to achieve Washington's decarbonization goals.

Figure 9: Building Equipment Sales and Stock Shares in Washington's 2021 State Energy Strategy Electrification Scenario[15]



The pace of consumer adoption of electric appliances may also present a challenge for electrifying natural gas end uses. Relying on consumer markets to change absent policy intervention may take too long, given the pace and scale of change required. Consumer behavior and preferences may be slow to change. For example, many Oregonians may currently prefer gas ranges, but also may be unfamiliar with the effectiveness, potential cost savings, improvements to indoor air quality, and climate benefits of electric ranges. Slow consumer adoption of electric technologies thus has the potential to be one of the greatest barriers to electrification.[16]

Technologies like ductless heat pumps can support the efficient electrification of buildings.

Widespread building electrification could also require a significant buildout of the electric grid. Large, rapid increases in demand for electricity occurred several times in the last century in the U.S., most notably during the wave of in-home electrification that occurred from the 1930s through 1960s, and again with the adoption of home air conditioning in parts of the country in the 1980s. Electrification of large portions of the direct fuel and transportation sectors has the potential to drive growth in electric demand as much as, if not exceeding, those periods of rapid growth seen in the twentieth century.

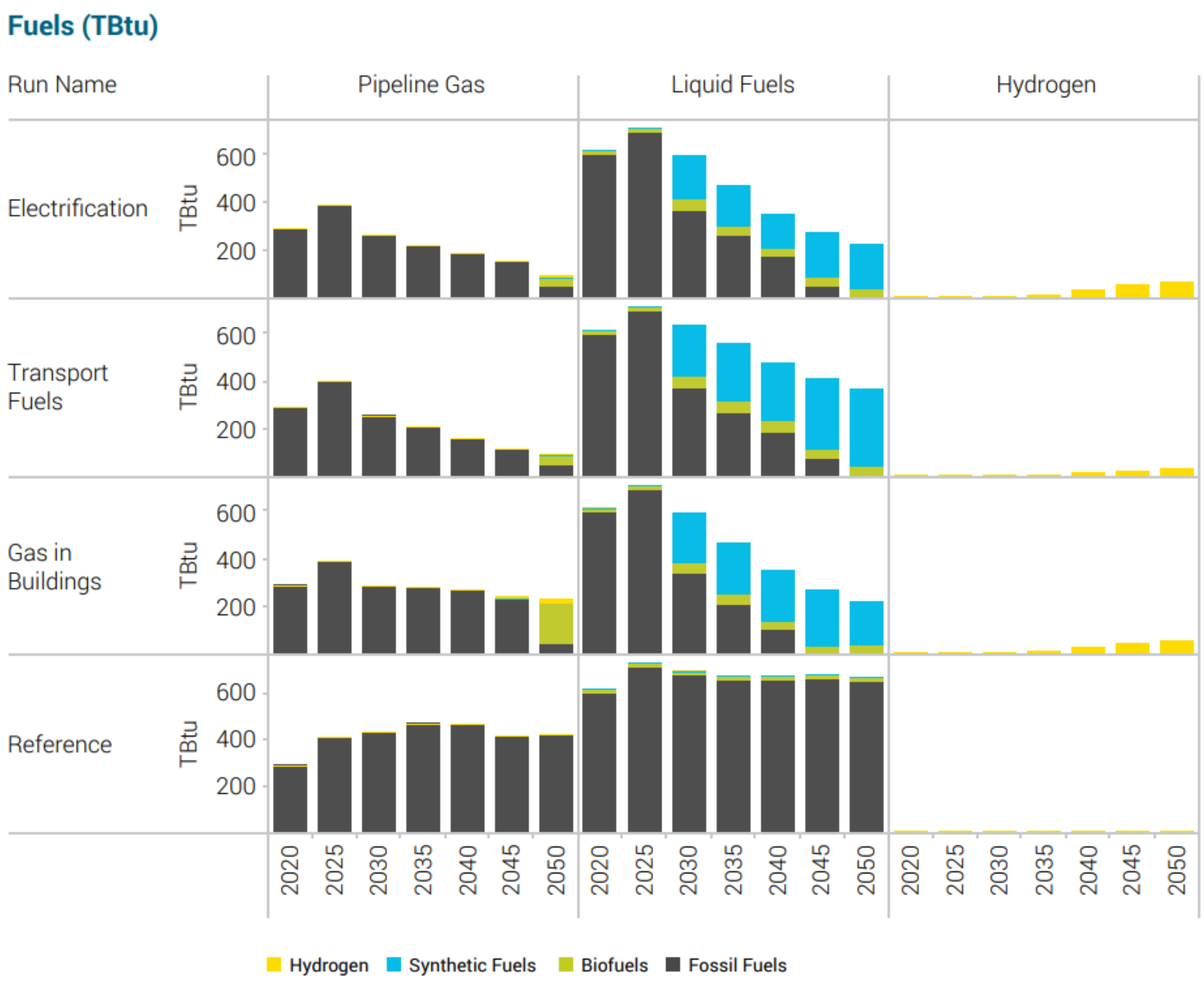
Electric stoves offer cost, efficiency, and performance benefits.[28]

For more information on what the studies identified in terms of potential growth in electric demand and the need to develop substantial amounts of new wind and solar generation, see the Electric Sector section of this Policy Brief.

Low-Carbon Alternative Fuels

Many studies concluded that some degree of alternative fuel adoption would be needed to provide direct use fuels to hard-to-decarbonize end users and to support the electric grid during extreme peak events such as major heat waves or cold snaps. Energy and Environmental Economics, Inc., in a study for the California Energy Commission, concluded that there are no viable decarbonization strategies for California’s energy system that completely eliminate the need for a dispatchable gas fuel.[16] Washington’s *2021 State Energy Strategy* reached similar conclusions. Figure 10 below illustrates the rate and pace at which Washington’s energy mix must transition to cleaner fuels to achieve the state’s mid-century decarbonization targets.[15] Washington’s analysis indicated that pipeline gas will likely play a reduced yet not insignificant role in the state’s energy system in 2050, though biogas is projected to replace a large portion of the fossil-based natural gas consumed in the state.

Figure 10: Fuel Decarbonization in Washington's 2021 State Energy Strategy[15]



Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 42).

One Oregon-specific study found that to meet a 100 percent clean energy target by 2050, most gas usage remaining in the economy would need to be decarbonized with low-carbon alternative fuels.[25] Similar to renewable electricity production, these low-carbon fuels could be made in Oregon, creating new economic, resilience, and energy security opportunities. Local production of fuels would reduce the effects of the global natural gas marketplace on energy prices in Oregon and retain more energy dollars in state. Local energy resources also afford opportunities to support local community energy resilience because they can provide a fuel source during extreme events, ensuring access to direct fuels for first responders and other critical needs.

Reducing Greenhouse Gas Emissions with Alternative Fuels

Alternative gas fuels include renewable natural gas and renewable hydrogen, which have lower carbon intensities than fossil natural gas. Each of these fuels (and others that are being researched today) have benefits and challenges involving the total amount of fuel that can be produced, the development and deployment of infrastructure and production facilities, and infrastructure to transport the fuel. In some cases, end users may need to retrofit or replace existing gas equipment to be able to use alternative fuels. In this section, the term "alternative fuels" is used when describing the range of natural gas alternatives, and individual fuels will be referenced by name when describing attributes specific to that fuel.

Low-carbon alternative fuels offer a decarbonization strategy that allows for continued use of existing gas equipment and infrastructure and provides a potential bridge to future electrification. These fuels can either be blended with existing natural gas or serve as a clean replacement for it. Many studies found that even with high rates of electrification, achieving decarbonization targets will require scaling up production and supply of alternative fuels.[15] [24] Producing and using low-carbon alternative gas fuels would allow some building, transportation, and industrial applications that are more challenging or more costly to electrify to continue to use gaseous fuels and existing infrastructure. This approach would require significant investment to develop new production facilities and feedstocks, and potentially new infrastructure and end-use technologies. Most studies reviewed identified low-carbon fuels as one of the pillars of decarbonization, and many of those studies found it most beneficial to prioritize the use of low-carbon fuels for end uses that are most difficult to electrify.[15] [22]

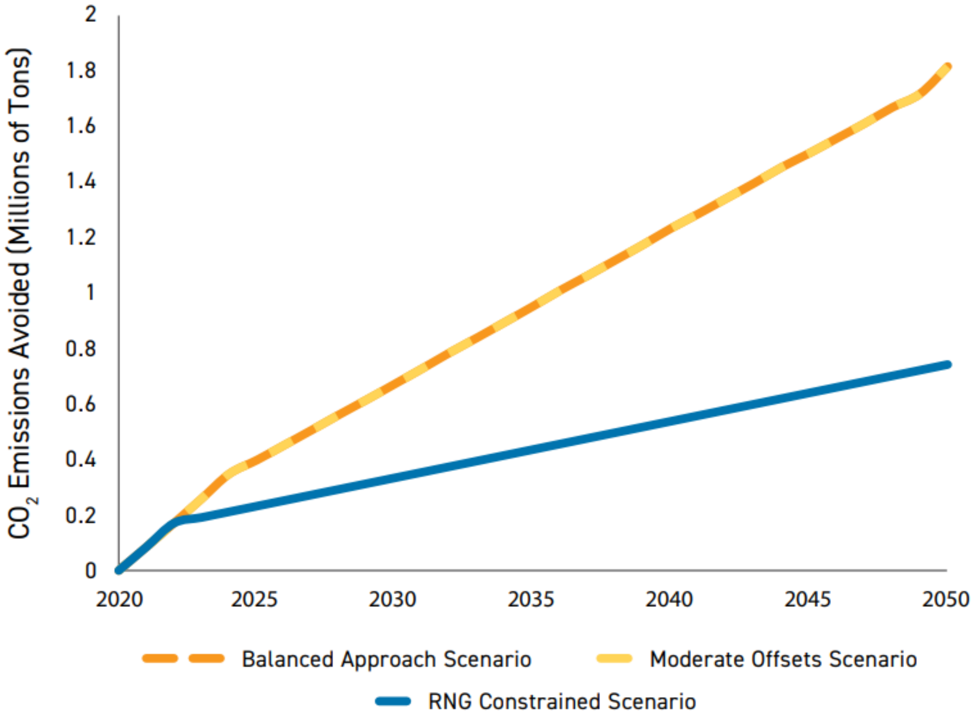
Renewable Natural Gas

Renewable natural gas (RNG), or biomethane, is a fuel derived from biogas, a methane byproduct of municipal waste streams such as garbage, wastewater, and waste food or agricultural waste streams like manure. Once processed, it can replace fossil natural gas without the need for upgrades or replacement of existing natural gas infrastructure. Opportunities to produce renewable natural gas exist around the state, but investments in the development of biogas capturing and processing facilities in addition to transmission infrastructure to connect to the larger natural gas transmission and distribution system are necessary to bring this fuel to customers.

The amount of RNG able to be captured today in Oregon could replace up to 4.5 percent of Oregon's total annual natural gas use (including gas used to generate electricity and gas used directly in buildings and industrial processes), and could rise to as much as 17.5 percent if future technical advancements in collection and gasification become commercially available.[iii] [29] NW Natural estimates RNG, with imports from other parts of the country, could displace between 14 and 34.2 million dekatherms by 2050, 17.5 to 43 percent of its 2020 volume. In Figure 11 below, NW Natural estimates the associated emission reductions could be between 0.6 and 1.8 million metric tons of carbon dioxide, or roughly 11.1 to 35 percent of the utility's reported 2020 emissions.[20] [30] Because natural gas use in the electric sector is expected to decline significantly to comply with the 100 percent clean energy standard established by HB 2021, the anticipated supply of RNG could meet a greater percentage of Oregon's gas demand in the future.

[iii] See ODOE's 2018 RNG Inventory Report: https://www.oregon.gov/energy/Get-Involved/Pages/Renewable-Natural-Gas-Inventory.aspx

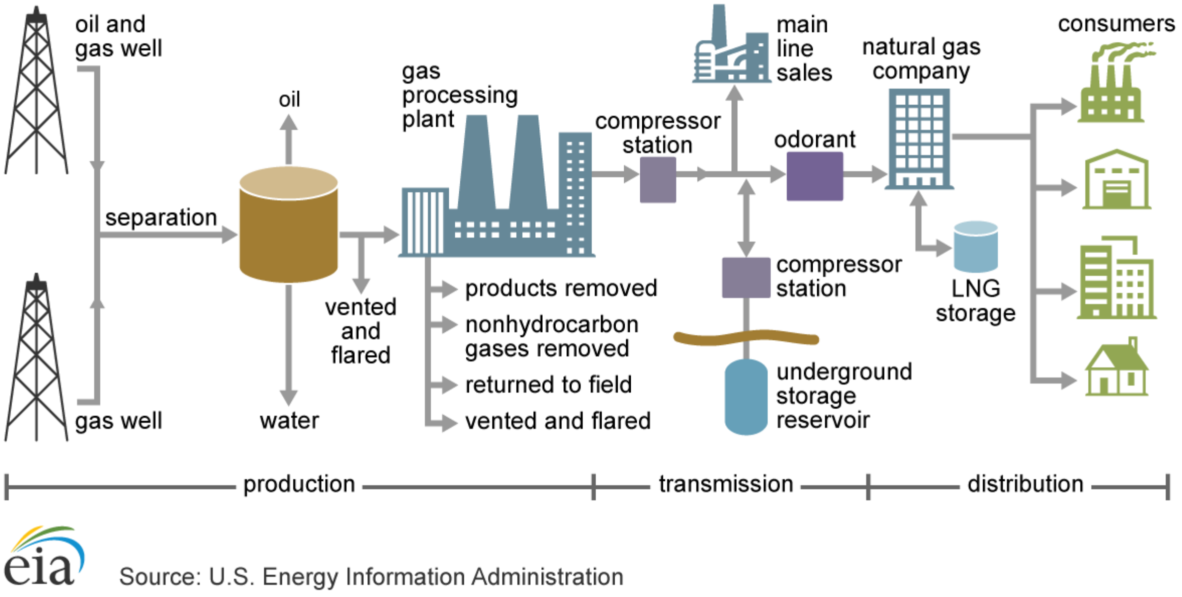
Figure 11: Potential Emission Reductions Resulting from RNG in NW Natural's Vision 2050 Modeling Scenarios[20]



Natural gas—both fossil and renewable—consists almost entirely of methane, a potent greenhouse gas, the rapid reduction of which is important to address climate change. Depending on how RNG is produced and processed, it generally has a lower carbon intensity attributed to it than fossil natural gas. RNG derived from manure is considered to have the lowest emission intensity, often with a negative value, because it captures large amounts of methane that would otherwise end up directly in the atmosphere.

Like fossil natural gas, there are associated fugitive emissions of methane from transporting and combusting RNG, although combustion emissions are 21 times less potent than methane released directly into the environment.[31] [32] As shown in Figure 12 below, the large and complex production and transmission system for natural gas provides the fuel to many parts of Oregon and the rest of the country, but also offers multiple opportunities for methane leaks. (In contrast, the local gas distribution networks in Oregon have been upgraded to reduce leakage.) These fugitive emissions can be limited by consuming the gas close to where it is produced to avoid long-distance transmission. One major opportunity with RNG development is that it can provide fuel in many parts of Oregon and reduce the distance gas must travel before being used. Many farms, landfills, and wastewater treatment plants already use the gas they generate on site to supplement their energy needs.

Figure 12: Natural Gas Production and Delivery Pathway[33]



Source: U.S. Energy Information Administration

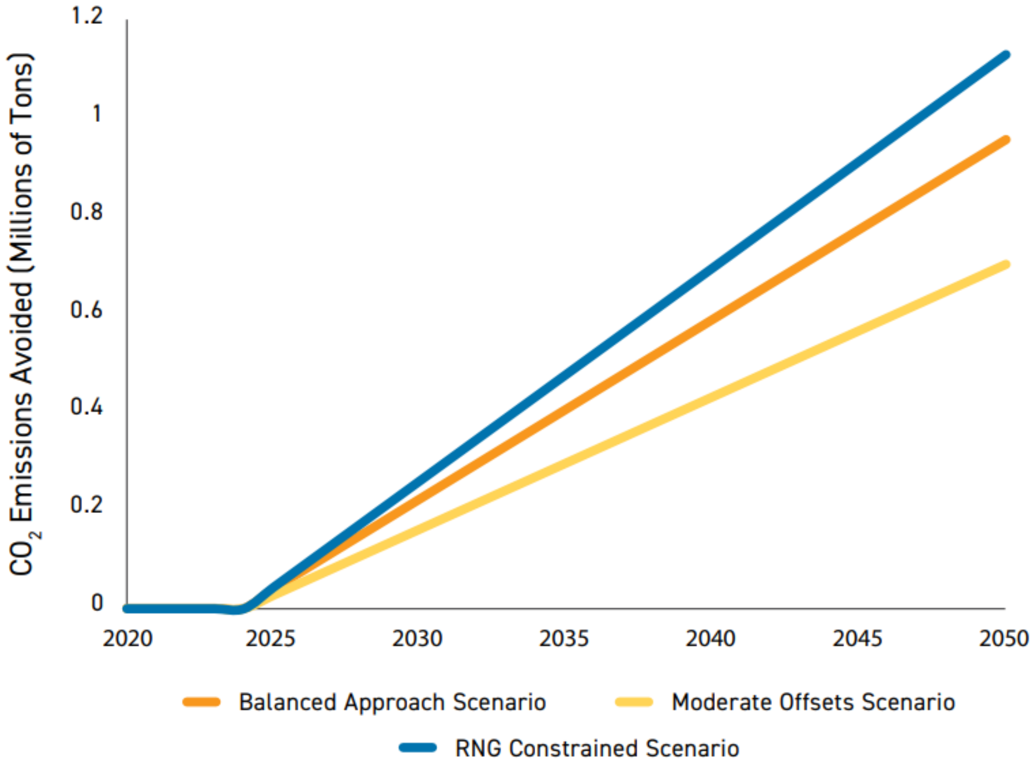
One barrier to greater use of RNG is lack of a cost-effective means to inject the gas into the existing gas pipeline system. This is largely due to high costs to process biogas to remove contaminants to meet pipeline quality standards, and the costs to interconnect biogas production facilities to transmission or distribution systems. Gas pipelines cost about $250,000 to $1.5 million per mile to build, meaning even relatively short distances to interconnect would be very costly.[34] This could be particularly challenging for landfills and animal operations, which in many cases can only produce relatively small volumes of gas and which tend to be located in less densely populated areas that may be further from existing infrastructure.

Renewable Hydrogen

Renewable hydrogen can be produced in several ways. The least-carbon-intensive method for producing renewable hydrogen involves using electrolyzers powered by renewable electricity to split water into hydrogen and oxygen. Hydrogen, like natural gas, can be combusted in a turbine to generate electricity. Using this fuel in its pure form as a direct use fuel would require replacing or significantly upgrading existing infrastructure and end use appliances or technologies. However, it can be blended into natural gas at 10 to 20 percent concentrations without the need for any changes to equipment or infrastructure.[35] There are currently no hydrogen electrolyzers operating in Oregon, although one pilot project is in the initial stages of development in Eugene (for more information on renewable hydrogen, see the Energy Resource & Technology Reviews section of this report).

NW Natural estimated renewable hydrogen could displace between 13.2 million and 21.2 million dekatherms of natural gas, or 16.3 to 26.2 percent of the utility's 2020 gas volume. As illustrated in Figure 13 below, the utility estimated this would result in emission reductions of 0.7 to nearly 1.2 million metric tons of CO_2, or about 12.9 to 22.1 percent of NW Natural's reported 2020 emissions.[20 30]

Figure 13: Potential Emission Reductions Resulting from Clean Hydrogen in NW Natural's Vision 2050 Modeling Scenarios



Renewable hydrogen can be produced at any site where water and renewable electricity are available, so hydrogen development, like RNG, could help to increase Oregon's energy security and support clean energy jobs. In addition, electrolyzers could use renewable electricity to produce hydrogen for storage, which could be used later in a turbine or fuel cell to generate zero-carbon electricity to support the grid or provide a local energy resource.[15]

Blending renewable hydrogen into a natural gas pipeline may not be a cost-effective end use for hydrogen if greenhouse gas emission reductions are the primary goal. Hydrogen is less dense than natural gas and requires increased pressure to move it through pipelines; adding 20 percent hydrogen by volume (the assumed maximum practical and safe limit for blending) only results in a six to seven percent reduction of GHG emissions. For this reason, many studies find that hydrogen may initially be more cost-effective as a transportation fuel.

The cost of renewable hydrogen infrastructure is a major barrier to development of the technology. Even in scenarios where buildings are not largely electrified, the volume of low-carbon fuels needed to meet demand leads to higher gas costs for consumers, further bolstering the cost-effectiveness of building electrification as an alternative to decarbonization of the gas sector.[16] For example, Energy + Environmental Economics found that 1 kWh of renewable electricity could generate 10 times as much heat by powering a high efficiency electric heat pump than that same 1 kWh of renewable electricity could generate in heat if used to power an electrolyzer to produce renewable hydrogen for delivery through the gas system to provide end-use heat to a customer.[23] Given these challenges, policymakers must take into account the various pathways available to decarbonize the natural gas sector and identify an optimal role for the use of hydrogen as part of the solution to achieving mid-century policy goals.

Carbon Capture and Storage

Carbon capture and storage (CCS) is a process of capturing carbon dioxide (CO2) emissions at the source of fossil fuel combustion such as at electricity generating power plants or industrial facilities creating steel or cement (learn more in the *2020 Biennial Energy Report*). Once CO_2 is captured, it is compressed and transported to a site, and injected deep underground into rock formations for long-term storage. CCS has the potential to collect and remove existing carbon from the atmosphere to help address global warming. CCS has been used in the U.S. since 1972 and several natural gas plants in Texas have captured and stored more than 200 million tons of CO_2 underground.[36]

Incorporating CCS into gas power plants would allow continued use of conventional gas fuels in electricity generation and industrial applications while mitigating some of the emissions of natural gas without using low-carbon fuel as a replacement. Carbon captured from industrial processes could be used as a feedstock to produce synthetic fuels, and while the carbon would still be released into the atmosphere at combustion, the potential of using the gas twice would reduce the overall emission intensity. Two of the studies reviewed identified a potential role for CCS:

- **Washington State** highlighted the potential of carbon to be collected from industrial smokestacks and the need to provide technical assistance to industry as CCS is evaluated.[15]
- **NW Natural** incorporated various levels of CCS in the modeling of its Vision 2050 approaches to decarbonization to demonstrate how it could be used as a supply-side solution. [20]

CCS is an emerging solution that remains an expensive process. As Oregon transitions electricity generation to more renewable resources, natural gas will likely be used less frequently and at lower capacity to maintain grid reliability under extreme conditions. With modest and inconsistent utilization, building CCS infrastructure for the remaining natural gas plants that are being operated less frequently may not be a cost-effective, long-term solution.[37] Advancements in CCS technology may make this a more viable solution in the decades to come.

Costs

The potential pathways for decarbonizing the natural gas sector each have unique cost profiles. Ultimately, it is likely that a combination of the following different pathways will be required to cost-effectively achieve the state's decarbonization objectives for the sector.

Energy Efficiency. Energy efficiency investments are one of the least-cost options available to reduce greenhouse gas emissions today. All of the natural gas utilities serving Oregon project significant savings from energy efficiency improvements supported by financial assistance from Energy Trust of Oregon. Energy Trust-funded efficiency investments are required to be "cost-effective," meaning the total cost of an energy efficiency investment cannot exceed the utility's avoided costs—the costs the utility would otherwise incur to meet the same demand with other supply-side energy resources. Energy Trust of Oregon's cost effectiveness determination assigns an economic value to energy savings that accounts for both the energy and some of the non-energy benefits of an efficiency investment. To some degree, the cost of carbon is included in the calculation as an avoided regulatory expense. For more information on cost-effectiveness of energy efficiency, and the inclusion of non-energy benefits see the Co-Benefits of Energy Efficiency Policy Brief.

Oregon's Ten-Year Plan: Reducing the Energy Burden in Oregon Affordable Housing

Oregon Housing and Community Services recommends energy efficiency as one of the best tactics to reduce the low-income population's energy burden.[38]

Electrification. Once cost-effective savings from energy efficiency have been realized, the studies reviewed find that electrification of many end uses is often the least-cost option to reduce greenhouse gas emissions from the building sector. In all cases, electrification was broadly more cost-effective than widespread adoption of alternative fuels, largely due to the costs to develop and make these fuels commercially viable, and the costs to upgrade pipelines and other infrastructure specifically to accommodate hydrogen development. Several studies found that expected natural gas cost increases in the future would create a feedback loop that will make electrification even more cost-effective by comparison in the years ahead.[15] [16]

> "Converting building end uses to electricity is **less expensive and more energy efficient than a strategy focused on creating synthetic pipeline gas**, even if buildings convert to high-efficiency gas equipment."
>
> — Washington 2021 State Energy Strategy[15]

Energy planning and policies that complement each other across all energy sectors are needed to achieve decarbonization goals.[24] Promoting fuel switching and encouraging Oregonians to transition homes and businesses from natural gas to electricity would be a significant shift for the state, natural gas and electric utilities, as well as customers. Electric utilities would need to prepare for a large increase in electric load coupled with a transition to largely renewable energy generation assets, while natural gas utilities may have to maintain a system with reduced demand while developing infrastructure to access and deliver lower carbon alternative fuels.

Alternative Low-Carbon Fuels. The use of gaseous fuels will continue to be a necessary resource for electricity generation and hard-to-electrify sectors in the near- to medium-term. Over time the reliance of this smaller group of end users on these gaseous fuels will make them more vulnerable to changes in gas prices. Most studies anticipate natural gas prices to rise in the future, largely due to increased demand from overseas markets for liquefied natural gas.[11,12] Future decarbonization actions, particularly those that send price signals to disincentivize fossil fuel consumption, will likely also create upward pressure on natural gas prices. Costs to comply with these emission reduction programs may increase natural gas rates across all customer classes,[39] but those increases will be in part offset by the energy savings from energy efficiency. As natural gas rates increase, low-carbon fuels will become more attractive as an alternative for utilities and customers.

However, substantial public and private investment would be required to create the necessary infrastructure to produce RNG or renewable hydrogen at-scale. Given the likely cost, it may be more cost-effective to electrify the end-uses of certain customers. This would make it easier to allocate the limited supply of RNG or renewable hydrogen to transportation, industry, or other hard to decarbonize customers.

Consumer Costs and Equity

How costs are allocated, and the equity implications of those allocations, will be important considerations in future policy development.

Decarbonizing the natural gas sector will require significant investment and create unique equity challenges. How costs are allocated, and the equity implications of those allocations, will be important considerations in future policy development. Many Oregonians already suffer from disproportionately high energy burdens and are highly vulnerable to energy cost increases. Transitioning to electric appliances may not currently be an option for many households due to cost barriers or a lack of control over building systems or investments (which is often the case for rental households). At the same time, growing interest in building electrification could reduce the number of customers reliant on natural gas service, which could in turn cause bill increases for remaining gas utility customers. State policy solutions will be necessary to address and mitigate adverse equity impacts that could arise from the clean energy transition.

Oregonians experiencing low incomes often must devote a much higher percentage of their income to their energy bills than higher-income households. The percentage of household income devoted to energy bills represents a household's "energy burden." When a household's energy costs exceed six percent of the household's income, the household is considered to experience a high energy burden.[40] A recent analysis of home energy affordability found that "Oregon households with incomes of below 50 percent of the Federal Poverty Level pay 23 percent of their annual income simply for their home energy bills."[41] An increase in fuel costs could increase the energy burden for vulnerable Oregonians, many of whom may already be forced to choose between paying for food, medicine, or their energy bills.[40] At the same time, many households lack the financial resources to invest in high-efficiency electric appliances and efficiency retrofits. These households are at risk of being left behind by a clean energy transition in which higher-income households embrace building electrification and disconnect their homes from the gas system. Under this scenario, a shrinking pool of natural gas utility customers would be forced to cover the remaining fixed costs associated with the gas system, with each remaining customer responsible for a higher share of those costs.

Oregonians that rent their homes are also at risk of incurring rising energy costs during the clean energy transition, because many renters have limited options to decarbonize. Landlords have a disincentive to invest in energy efficiency retrofits or efficient electric appliances due to the high upfront costs, which forces renters to bear the financial burden of higher energy bills.[42] Renters also often lack control over the types of energy they consume in their units. In 2021, approximately 21 percent of Oregon renters heated their homes with natural gas.[41] Many of these renters may not have the option of electrifying their heating systems. And rental units heated by inefficient electric baseboard heaters may not have the option to install efficient electric heat pumps. The relative lack of control that many renters have over the type and amount of energy they consume in their residences puts them at greater risk of incurring higher energy burdens if fuel costs increase. This risk is even more pronounced for low-income renters.

The Oregon legislature took action to address disproportionate energy burdens through the adoption of HB 2475 in 2021. HB 2475 directed the Oregon Public Utility Commission to consider "differential energy burdens on low-income customers and other economic, social equity or environmental justice factors that affect affordability for certain classes of utility customers" when setting retail rates for electric or natural gas service. The bill allows the OPUC to develop new utility bill rate structures based on customer needs or characteristics, such as income or equity factors.[43] The OPUC and the retail electric and natural gas utilities it regulates are in the process of developing differential rates that could help mitigate disproportionate energy burden impacts moving forward.[43]

All the decarbonization studies reviewed projected reductions in natural gas demand by mid-century, which may lead to price increases that could disproportionately impact low-income gas customers. At an economywide level, several studies estimated that increases in gaseous fuel prices will be largely offset by cost savings elsewhere in the energy economy, such as savings from reductions in fuel consumption and from a transition to lower-cost electrified end-uses. How these shifting costs impact individuals is likely to vary, however, and a key challenge will be to manage this transition to protect those who may not be able to adapt quickly and equitably share in the benefits of this transition. The following paragraphs briefly summarize the findings from three recent studies analyzing the potential cost impacts from decarbonizing natural gas sectors in California, Oregon, and Washington.

California Energy Commission Analysis. In 2020, the California Energy Commission published a study evaluating decarbonization scenarios to achieve the state's mid-century GHG reduction targets, with a focus on identifying and evaluating impacts to gas customers and the gas system as a whole. The study concluded that building electrification represented the least-cost strategy for reducing emissions from the natural gas sector, but cautioned that absent policy intervention, the cost savings from electrification would likely accrue to households that can afford to electrify, and could cause costs to increase for low-income gas customers. The study estimated that demand for natural gas will likely decline in California over time, and declining demand would put upward pressure on gas prices. This decline in demand and associated cost increase would create a feedback loop in which rising gas prices make electrification a more appealing and economical option for consumers who can afford to switch, causing gas demand to drop and prices to increase even further. Recognizing that residential customers pay most of the fixed costs to maintain and operate the gas distribution system, the study projected that the reduction in gas customers resulting from electrification would cause those fixed costs to be shared by a smaller number of customers. Lower-income customers that cannot afford to electrify could be forced to shoulder a disproportionate share of these fixed system costs, in addition to higher gas rates. The study concluded that a well-managed transition from gas to electricity would help mitigate these impacts, while also supporting the financial viability of gas utilities to ensure customers continue to receive safe and reliable service at just and reasonable rates. State building electrification policies, incentives, and support for low-income or vulnerable communities may also be needed to provide consumer protection from future fuel price increases.[16]

Oregon Public Utility Commission Investigation. Following the adoption of the Oregon Department of Environmental Quality's Climate Protection Program (CPP), the OPUC launched a natural gas fact finding investigation to identify the actions natural gas utilities plan to take to comply with the CPP and evaluate the associated cost impacts on the utilities and their customers. Following an extensive public stakeholder process, the OPUC issued a draft report describing its preliminary findings. The draft report found that natural gas utilities will need to take significant near-term actions to meet their future greenhouse gas emissions reduction obligations under the CPP, and that these decarbonization actions will likely increase natural gas costs. Table 2 shows the estimated bill impacts resulting from the utilities' compliance activities in 2025, 2035, and 2050. The utilities' decarbonization models and cost estimates varied significantly due to differences in utility characteristics and future uncertainties. The utility modeling was also constrained by uncertainties around the viability of certain decarbonization pathways, because some of the alternative fuels or technologies utilities are planning to implement are not currently available in the market.[39] The draft report concluded that while most, and potentially all, of the utilities' CPP compliance strategies would carry additional costs and risks that must be tracked and addressed, "the transition to a decarbonized gas sector can create benefits and long-term cost savings for customers and the Oregon economy."[39]

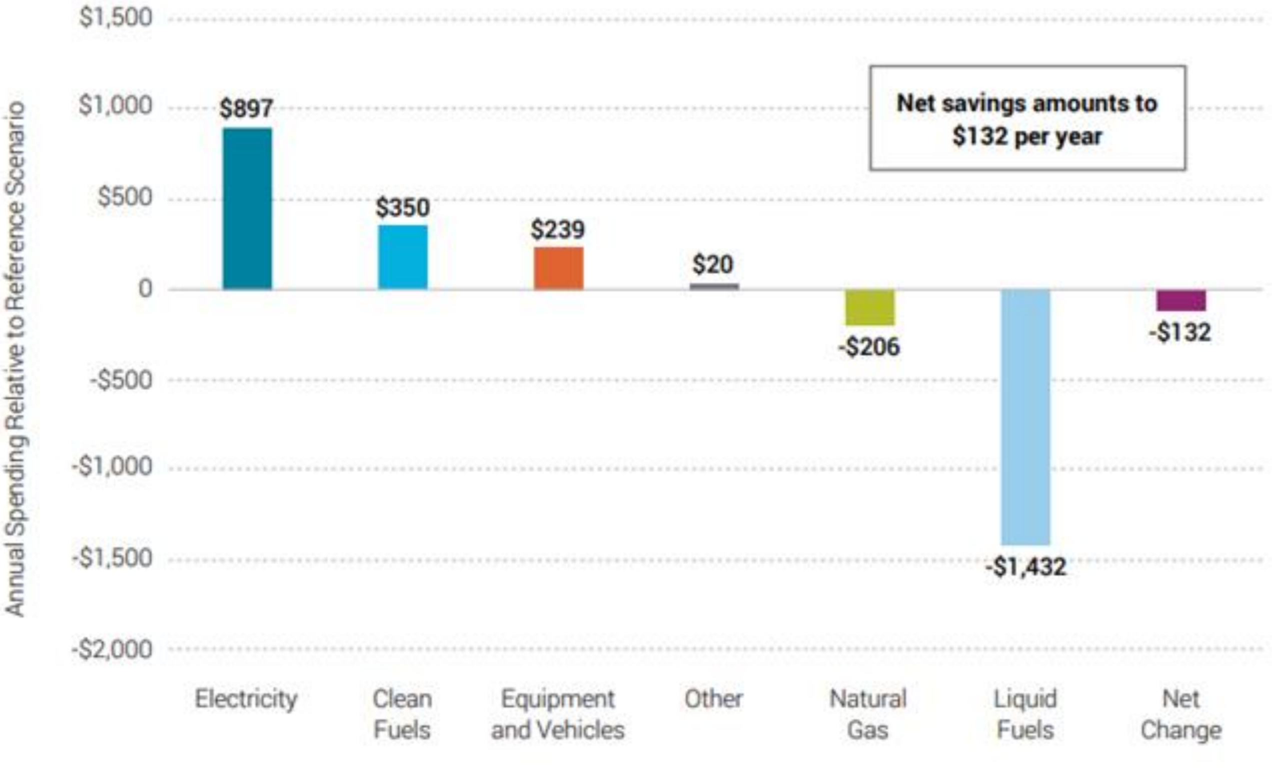
Table 2: Estimated Bill Impacts from Gas Utility Compliance with the Oregon Climate Protection Program[39]

	2025			2035			2050*		
	Res	Com	Ind	Res	Com	Ind	Res	Com	Ind
Avista	1%	7%	14%	21%	53%	60%	26%	162%	72%
Cascade Natural Gas	13%	15%	16%	27%	28%	32%	43%	26%	50%
NW Natural	9%	17%	22%	9%	17%	35%	-2%	12%	39%

**Avista and Cascade modeled compliance costs through 2040, so those values were used in place of 2050*

Washington State Energy Strategy. In 2020, the Washington State Department of Commerce updated Washington's State Energy Strategy to align it with the state's climate and energy targets. The Department conducted a deep decarbonization pathway analysis to determine the lowest cost path for reducing emissions. This analysis modeled potential cost impacts to consumers under several scenarios, including electrification. The analysis found that although the average annual cost of electricity, clean fuels, and equipment would likely increase under a high-electrification scenario, the savings from reductions in liquid fuel and natural gas costs would lead to an overall net reduction in energy expenditures for consumers by 2050.[15] Figure 14 below shows the projected net costs and savings under the analysis's electrification scenario.

Figure 14: Change in Average Spending per Person in the Electrification Scenario (2050)[15]



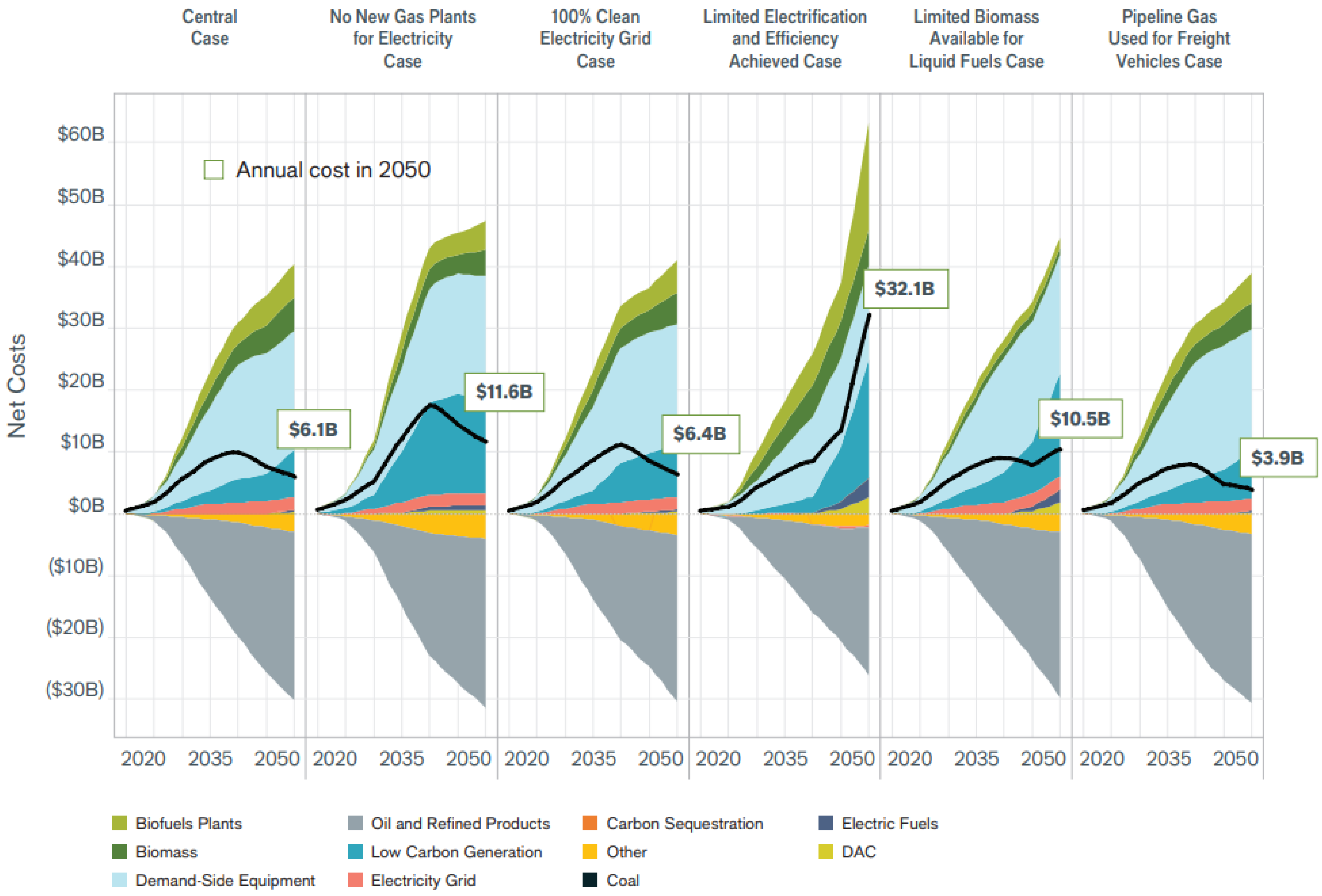
Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 16).

Energy System Costs

Most of the evaluated studies modeled potential costs and trade-offs between different deep decarbonization pathways across the entire energy economy. Examples include:

- **Clean Energy Transition Institute** evaluated decarbonization pathways in the Northwest, including Idaho, Montana, Oregon, and Washington. Figure 15 below illustrates the results of six different decarbonization scenarios that were modeled through 2050 as part of that study. The costs to deploy clean energy resources are shown above the x-axis, while the modeled reduction in costs associated primarily with using smaller volumes of fossil fuels are shown below the x-axis. This visual illustrates how expenditures on clean energy solutions are expected to be mitigated, to varying extents, by reductions in expenditures on fossil fuels—this net cost figure is represented on the visual by the bolded black line. One notable finding illustrated here is that the scenario with the highest net cost in 2050 ($32.1 billion) is the scenario with limited electrification of end uses, and which results in the greatest demand for biofuels and electric fuels (e.g., renewable hydrogen). On the other hand, the scenario with the lowest net cost ($3.9 billion) is shown at far right and incorporates the use of pipeline gas to decarbonization the heavy-duty transportation sector.

Figure 15: Annual Net Energy System Costs Under Six Decarbonization Scenarios[25]



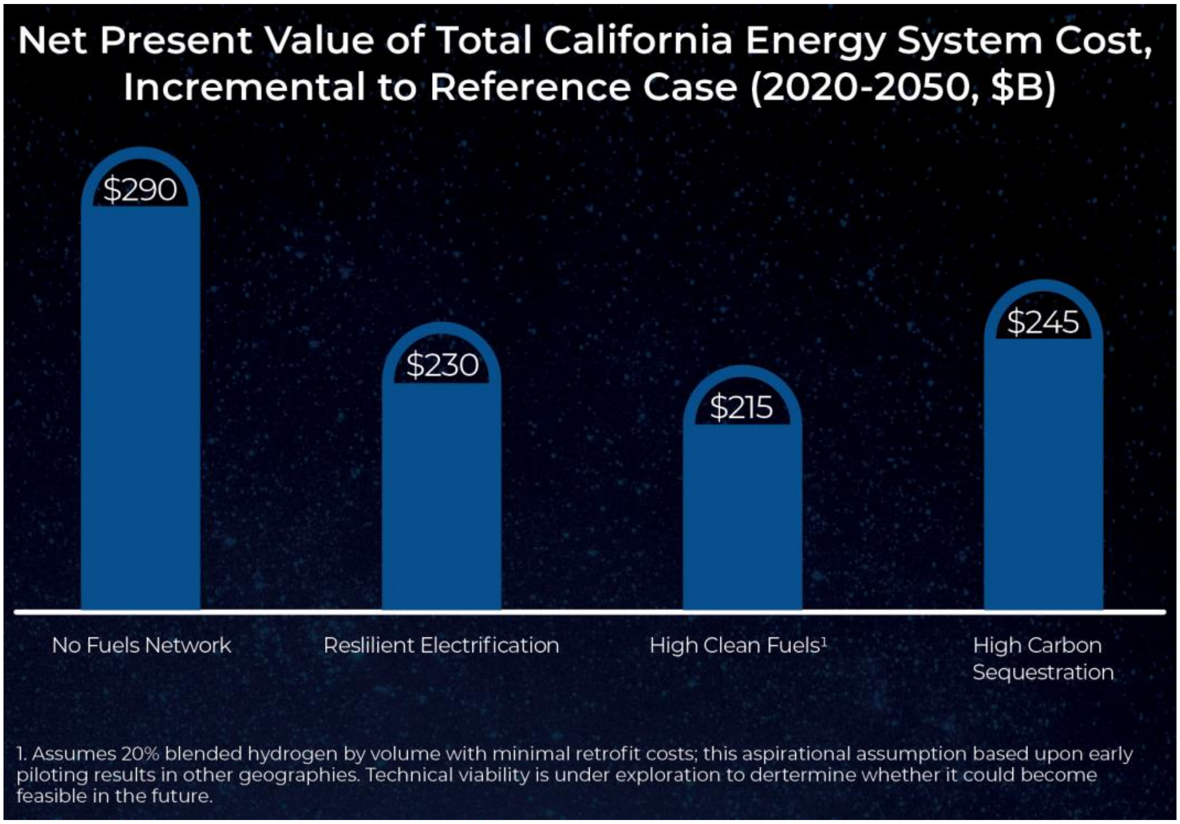
Source: Northwest Deep Decarbonization Pathways Study, May 2019, Evolved Energy Research, page 107

- **Evolved Energy Research's** Oregon Clean Energy Pathways study estimated that meeting emission targets of 80 to 100 percent reduction from 1990 levels will require additional state spending of 0.2 percent GDP per year. But if there is low adoption of electrification in the built environment and transportation sectors it would lead to greater alternative energy demands and decarbonized fuels, making decarbonization approximately 0.4 percent of state GDP more expensive between 2040 and 2050.[25] This finding illustrates the potential downside of pathways that rely more on decarbonized fuels versus electrification.
- **SoCalGas'** technical analysis of California's clean energy future also evaluated the total estimated costs of across four modeled scenarios to achieve 2050 policies:[24]
  - *No Fuels Network:* Modeled a scenario in which all of the gas utility's existing customers (commercial, industrial, and residential) convert to electrification to meet their energy needs by 2045. This eliminates any remaining need for a gas fuels network.
  - *Resilient Electrification:* This scenario modeled most residential and commercial end-users (but not industrial) electrifying their gas end uses by 2045.

- *High Clean Fuels*: This scenario modeled the use of low carbon fuels to decarbonize transportation (100 percent of long-haul heavy duty, and 50 percent of medium duty and short-haul heavy duty) and replaced residential and commercial gas demand with low carbon fuels (20 percent hydrogen blended in the pipeline, plus extensive use of biogas) without requiring major upgrades to gas infrastructure.
- *High Carbon Sequestration:* This scenario modeled continued use of primarily conventional natural gas with direct carbon capture or indirect offset by carbon capture. This scenario assumed limited hydrogen blending in the pipeline, and the creation of a hydrogen hub to deliver hydrogen directly to specific end users that require it.

SoCalGas' modeling found that full electrification, with complete elimination of the existing gas fuels network, would be the most expensive pathway. As Figure 16 illustrates, the three scenarios that rely upon continued use of gas infrastructure are lower cost, with the least-cost scenario being the *High Clean Fuels* scenario:

Figure 16: SoCalGas Incremental Costs by Scenario, 2020–2050[24]



1. Assumes 20% blended hydrogen by volume with minimal retrofit costs; this aspirational assumption based upon early piloting results in other geographies. Technical viability is under exploration to dertermine whether it could become feasible in the future.

Policy Considerations

To reach Oregon's decarbonization targets, intentional policy choices will need to guide the role of conventional and alternative gas fuels in the state.

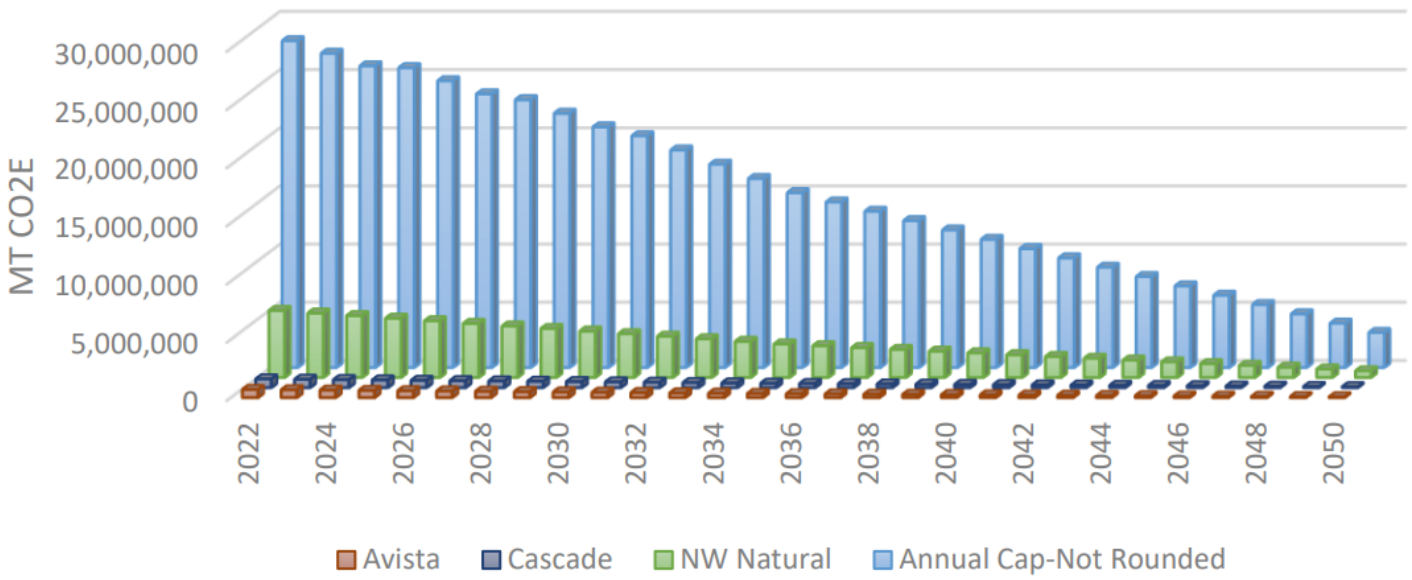
Existing Policy

Oregon has two key regulatory programs in place to reduce carbon emissions from natural gas and direct-use fossil fuels consumed in the state. The Oregon Climate Protection Program establishes a declining cap on the *quantity* of carbon emitted from natural gas consumed in Oregon, and the Oregon Clean Fuels Program requires reductions in the average *carbon intensity* of transportation fuels sold in Oregon, including natural gas. In addition to these two statewide regulatory programs, some local governments have taken steps to reduce natural gas emissions within their jurisdictions.

Oregon has two key regulatory programs in place to reduce carbon emissions from natural gas and direct-use fossil fuels consumed in the state.

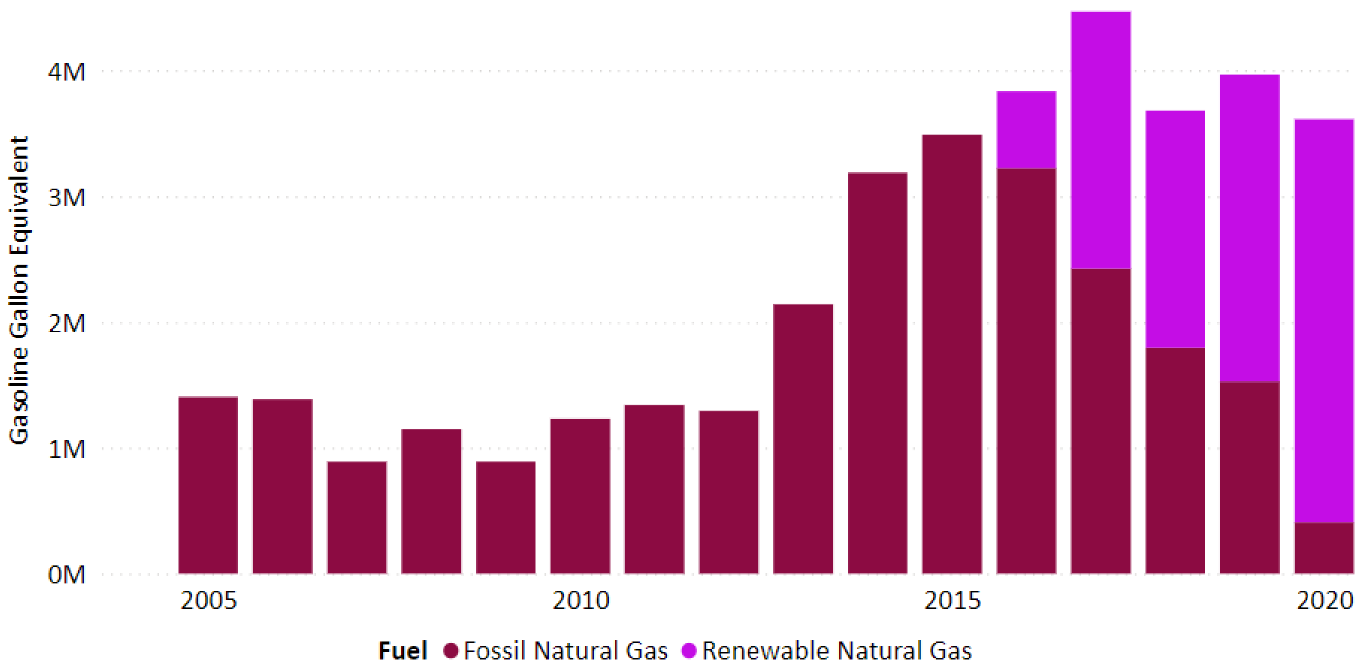
The Oregon Department of Environmental Quality's Climate Protection Program (CPP) sets a declining limit, or cap, on greenhouse gas emissions from fossil fuels used in Oregon, including natural gas.[44] The CPP has a requirement to reduce GHG emissions 90 percent by 2050 with an interim target to reduce emissions 50 percent by 2035. These requirements are designed to drive fuel suppliers, natural gas utilities, and industrial facilities to invest in low-carbon alternative fuels and other decarbonization strategies over time.

Figure 17: Oregon Climate Protection Program Emission Caps[39]



The Oregon Department of Environmental Quality's Clean Fuels Program supports a market-driven credit and debit system that incentivizes lower carbon fuel use and requires reductions in the average carbon intensity of Oregon's transportation fuels over time. The program was updated in 2022 to require a 37 percent reduction in average carbon intensity by 2035. Natural gas sold as a transportation fuel in Oregon is subject to regulation under the Clean Fuels Program. Figure 18 shows the quantities of natural gas and renewable natural gas sold as transportation fuels in Oregon from 2005 to 2020. Gaseous fuels that have lower carbon intensity values than gasoline or diesel generate credits under the program, while gasoline and other high-carbon intensity fuels earn deficits under the program. The clean fuels standards gradually increase in stringency over time, requiring a 10 percent reduction in carbon intensity by 2025, a 20 percent reduction in 2030, and a 37 percent reduction in 2035. As the carbon intensity reduction targets rise, fuels with carbon intensity values below the current standard (and therefore receive compliance credits under the program) may exceed the carbon intensity standard in future years (and generate deficits under the program). Fossil natural gas is an example of a fuel that generates compliance credits under the current standard, but will become a regulated fuel that generates deficits when the carbon intensity target rises after 2025. (Liquified natural gas became a regulated fuel in 2022.) Low-carbon intensity alternatives like renewable propane and renewable natural gas will continue to generate credits that will likely increase in value as the standards increase.

Figure 18: Oregon On-Highway Natural Gas Consumption 2005–2020[45]

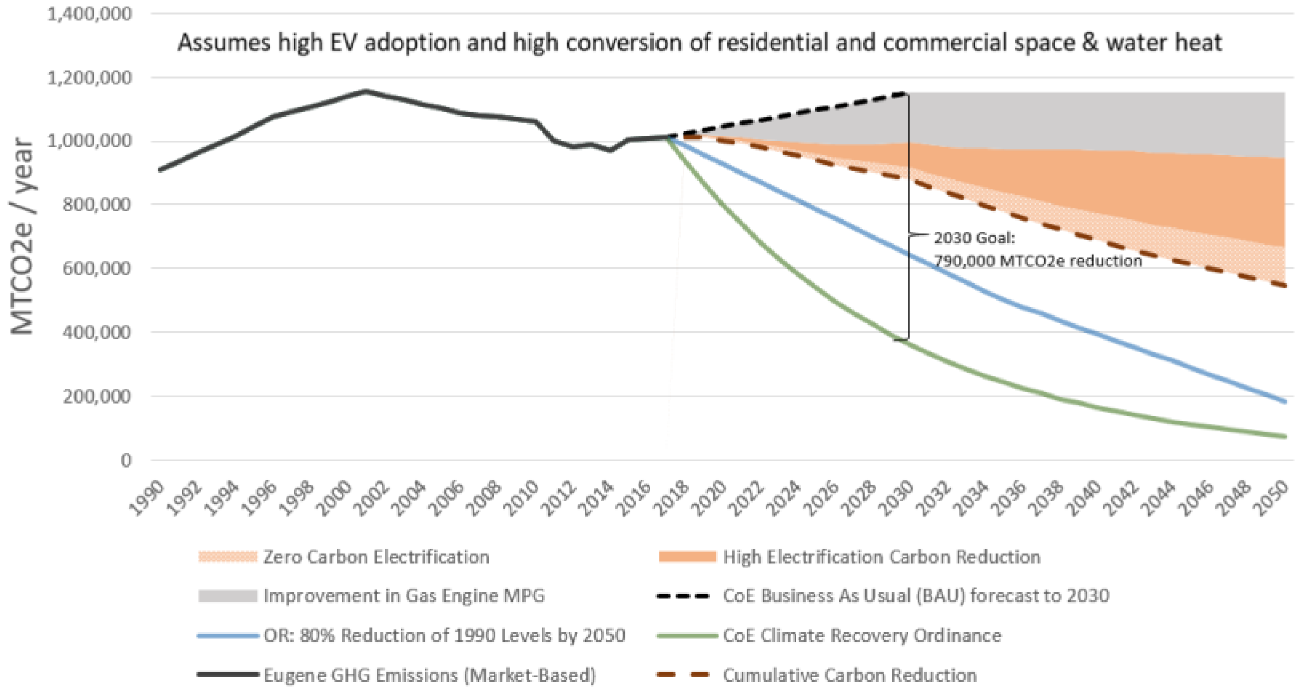


Recent Trends: Natural Gas Consumption for Transportation

- Oregon's transportation sector consumed 4.7 million gasoline gallon equivalent of natural gas and propane in 2020, which is 0.19 percent of all transportation fuels consumed in Oregon.[45]
- In 2020, 89 percent of natural gas used as a transportation fuel in Oregon was renewable natural gas and 49 percent of propane consumed as a transportation fuel was renewable propane.[45]

Oregon jurisdictions are also developing local climate action plans with decarbonization targets, leading to their own evaluation of the role of natural gas and gaseous fuel consumption within their communities. The **City of Eugene** is exploring limiting new natural gas infrastructure development in favor of electrification as part of their climate change mitigation strategy. The Eugene City Council is engaged in talks with its local utility, NW Natural, and is evaluating adding a new section to their health and environmental code prohibiting natural gas infrastructure in newly constructed buildings. Seventy-six cities throughout the country have placed various restrictions on natural gas use, including limiting natural gas in new construction and encouraging the electrification of buildings.[46]

Figure 19: Eugene Carbon Reduction Goals (MTCO2e)[27]



Conclusion

In working to achieve its mid-century clean energy and decarbonization policy targets, Oregon will need to determine the continued role of natural gas within that future. The development of a statewide energy strategy would empower the state to better guide gas decarbonization policy, provide clearer direction to utilities and fuel suppliers, and set appropriate expectations for the market and consumers.

Review of recent studies evaluating deep decarbonization pathways identified four pillars of decarbonization and multiple pathways available to accelerate Oregon's clean energy transition. Decarbonizing Oregon's natural gas will likely not come from one strategy but through a combination of energy efficiency investments, electrification, and the development of low-carbon alternative fuels like RNG and renewable hydrogen. The approach and scale of Oregon's investment in the clean energy transition will vary depending on technical innovations, market changes, costs, and timelines. A comprehensive state energy strategy could support a transparent, fair, and cost-effective clean energy transition that meets the needs of Oregon stakeholders.

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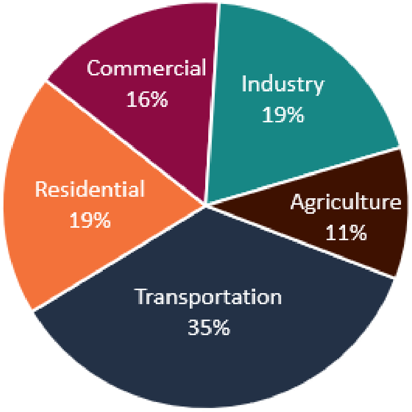
Policy Brief: Charting a Course for Oregon's Energy Future

Part IV: Transportation Sector

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

Figure 1: Greenhouse Gas Emissions by Sector (2019)[1]



The transportation sector[i] is responsible for the largest share of greenhouse gas emissions in Oregon, 35 percent in 2019, or 22.8 million metric tons of carbon dioxide-equivalent emissions.[1] These emissions come from the combustion of fossil fuels in a wide variety of vehicles that are the backbone of the state's economy. Oregon's transportation sector consumes 29 percent of all energy used in the state, with most of it coming from imported petroleum fuels, like gasoline and diesel.[2] [3] Emissions in the sector continue to rise, largely due to Oregon's growing economy and an increasing population, but they have been growing more slowly than would otherwise have occurred due to state and federal renewable and clean fuels programs. The U.S. Department of Energy projects that economic and population growth will spur continued growth in all areas of the transportation sector.[4]

Oregonians spend about $5.7 billion on transportation fuels each year. Oregon imports approximately 98 percent of its transportation fuels, with domestic supplies largely coming from electricity, biodiesel production, and ethanol production. Most of the money Oregonians spend on transportation fuels is sent to other states that extract, transport, and refine the petroleum fuels that keep Oregon moving. In-state fuel production is anticipated to grow as more Oregonians purchase vehicles that are fueled with electricity from Oregon utilities. Increasing interest in renewable biofuels may also contribute to more in-state fuel production.

Recognizing this large challenge of reducing transportation emissions in the state, the Oregon Department of Transportation developed the Statewide Transportation Strategy in 2013. The STS is a broad overview of actions to achieve emissions reductions in Oregon's transportation sector.[5] This brief will focus on two elements of the State Transportation Strategy: adopting cleaner fuels and making vehicles more efficient. It will also explore the pathways identified in recent technical analyses for how the state and region can reach decarbonization goals in the transportation sector.

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[i] Learn more about Oregon's transportation sector in the Energy by the Numbers section of this report.

Current State Policies

Oregon has several programs across multiple agencies supporting decarbonization of the transportation sector. These programs inform policy discussions, reduce vehicle miles traveled, make lower carbon fuels more widely available, lower the up-front costs to purchase zero-emission vehicles, and support widespread availability of charging infrastructure. Two key programs that reduce emissions in the transportation sector are the Clean Fuels Program and the Climate Protection Program.

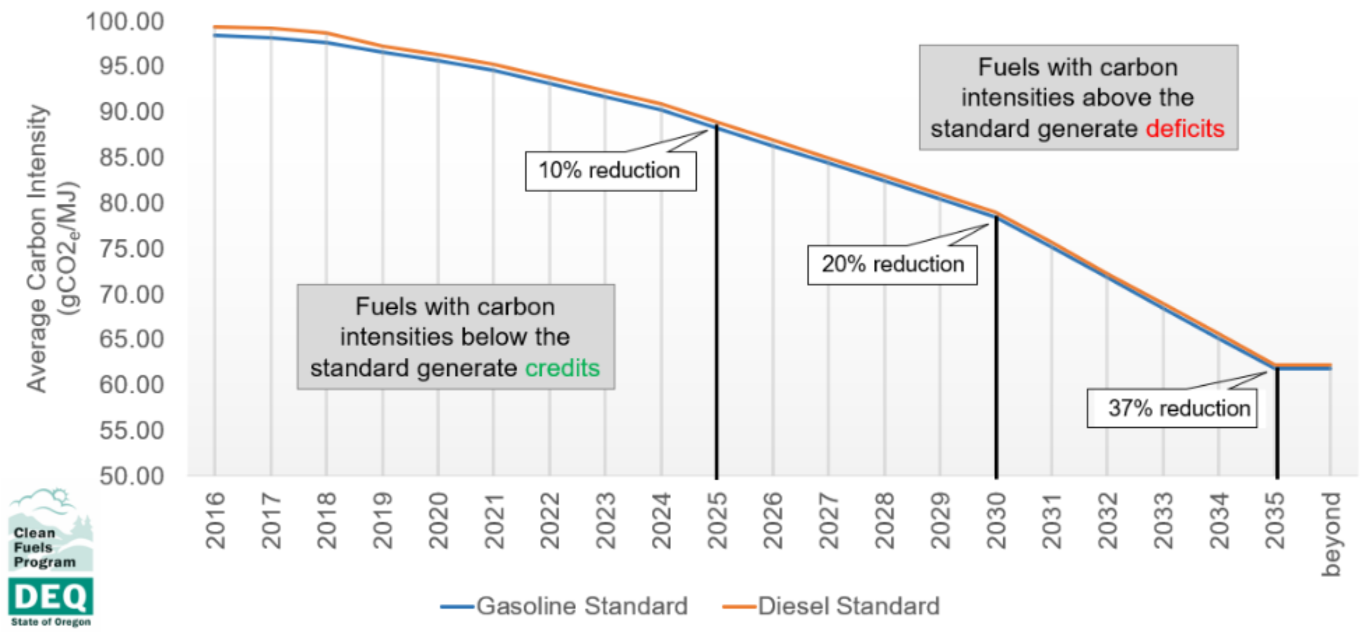
Oregon's Zero Emission Vehicle Goals[6]

In 2019, the Oregon legislature established the following ZEV targets in SB 1044:

- 50,000 registered ZEVs by 2020
- 250,000 registered ZEVs by 2025
- 50% of vehicle sales and 25% of registered vehicles by 2030
- 90% of vehicle sales by 2035

The **Clean Fuels Program**, managed by the Oregon Department of Environmental Quality, drives lower-carbon alternative fuel availability in the state.[7] The program establishes carbon intensities for all types of fuel consumed in Oregon, and it incentivizes lower carbon fuel consumption through a credit/deficit system. As shown in Figure 2, the program has a goal to reduce the average carbon intensity of Oregon fuels 37 percent by 2035 compared to 2015.[8] Carbon intensities represent the *lifecycle* of the fuel, including emissions from the extraction, generation, transportation, refinement, and combustion of each fuel. A particular fuel will generate credits or deficits based on its carbon intensity. Higher carbon intensities mean more greenhouse gas emissions are produced to move a vehicle the same distance as a fuel with a lower carbon intensity.

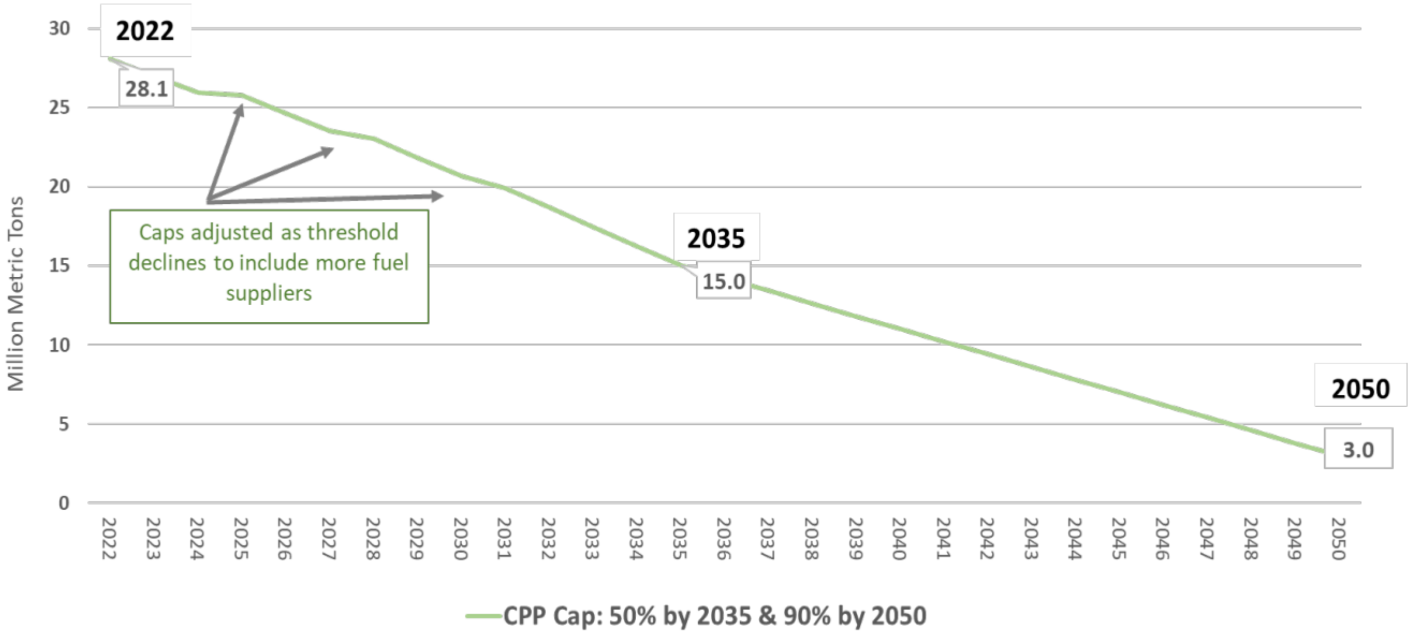
Figure 2: Clean Fuels Program Carbon Intensity Targets for Gasoline and Diesel Fuels and Alternatives[9]



The program does not have specific greenhouse gas emissions targets, but it will result in emissions reductions by lowering carbon intensity. DEQ estimates that achieving a 37 percent reduction in carbon intensity by 2035 will reduce tailpipe emissions by 50 percent.[8] All gasoline, diesel, ethanol, biodiesel, and renewable diesel fuel importers must comply with the program.[7] Other fuels developers or importers, such as aviation fuel and other renewable fuels, can voluntarily register to participate.

The Oregon **Climate Protection Program**, also administered by DEQ, aims to reduce emissions from transportation fuels 90 percent by 2050, compared to the 2017-19 average, and 50 percent by 2035.[10] It sets a declining limit on greenhouse gas emissions from fossil fuels used throughout Oregon including gasoline, diesel, natural gas, propane, and aviation fuels. The program mandates reductions in emissions but allows the market to choose how the reductions will occur. Transitioning to biofuels and zero-emission vehicle technologies like battery electric and fuel cells are two strategies to achieve these reductions.

Figure 3: Climate Protection Program Greenhouse Gas Emissions Reduction Goals[10]



In addition to DEQ, several other state agencies also administer programs to reduce greenhouse gas emissions from the transportation sector. Agency collaboration is conducted through the *Every Mile Counts* initiative, led by the Oregon Department of Transportation.[11] ODOT, ODOE, DEQ, the Oregon Public Utility Commission, and the Department of Administrative Services also collaborate and cooperate specifically on clean vehicles through the Zero Emission Vehicle Interagency Working Group to support transportation electrification. Figure 4 below shows the array of work that ZEVIWG member agencies engage in to support transportation electrification.

Figure 4: Zero Emission Vehicle Interagency Working Group Member Agency Actions[11]

Vehicle & Fuel Costs

- Clean Vehicle & Charge Ahead EV Rebates (DEQ)
- Investor-Owned Utility (IOU) Transportation Electrification Investments and Rates (OPUC)
- School Bus Funding (ODE, DEQ)
- Public Purpose Charge Schools Funds (ODOE)
- Diesel Emission Reduction Grants (DEQ)
- Transit Bus Funding (ODOT, DEQ)
- Utility Grants Funded by Clean Fuels Program (DEQ)
- State Fleet Pricing Agreements (DAS)

Equity

- Charge Ahead EV Rebate (DEQ)
- Every Mile Counts Equity Engagement (ODOT, DEQ, ODOE, DLCD)
- TEINA Assessment for rural, low-income, and BIPOC needs (ODOT)
- IOU TE Surcharge and CFP Investments in Underserved Communities (OPUC, DEQ)
- Prioritize Equity in Federal EV Funding (ODOT)
- Biennial ZEV Report EV Adoption Demographic Assessment (ODOE)

OVERARCHING

- ZEVIWG and Every Mile Counts Interagency Coordination (ODOT, ODOE, DEQ, OPUC, DAS, DLCD, OHA)
- Clean Fuels Program (DEQ)
- ZEV Regulations (DEQ)
- Investor-Owned Utility Transportation Electrification Investments (OPUC)
- State Fleet ZEV Goals (DAS)
- Climate Protection Program (DEQ)
- State Clean Electricity and Renewable Electricity Goals (OPUC, ODOE)

Infrastructure Needs & Costs

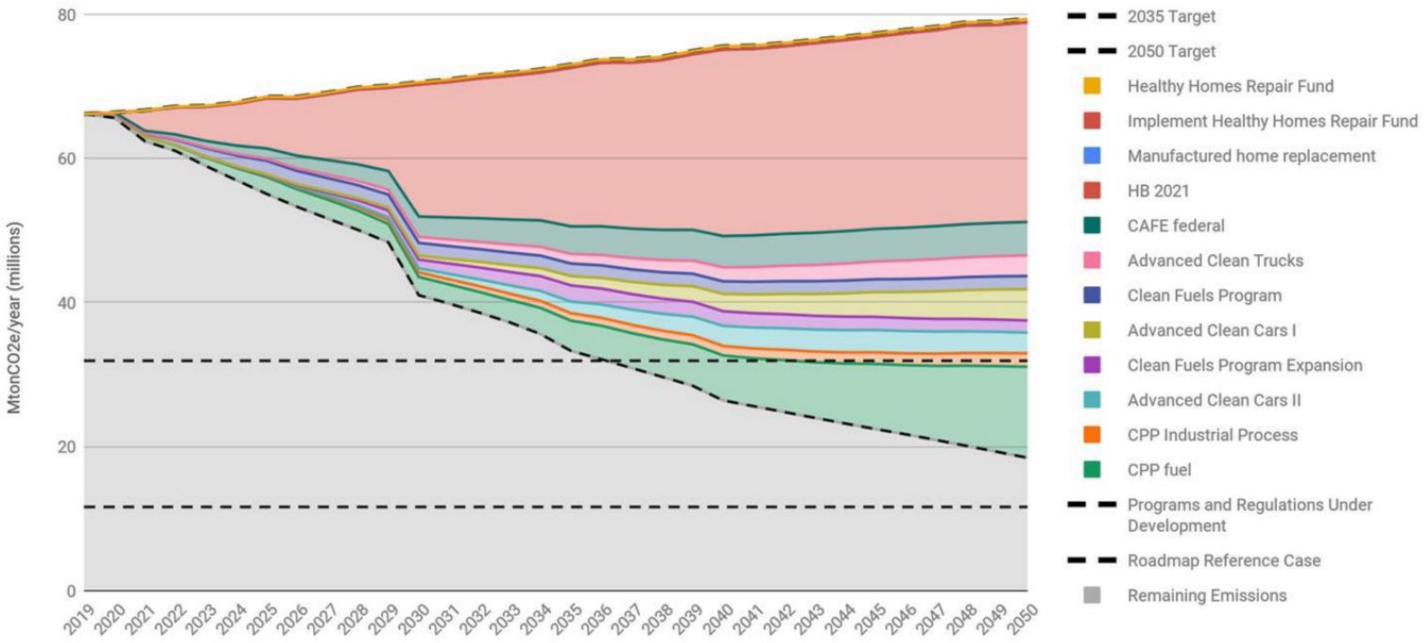
- Transportation Electrification Infrastructure Needs Analysis Study (ODOT)
- TEINA EV Charging Deployment Strategy (ODOT)
- Federal EV Funding – IIJA (ODOT, ODOE)
- Community Charging Program (ODOT)
- IOU TE Infrastructure Investments (OPUC)
- CFP funding for Chargers and Utility Grants (DEQ)
- Public Purpose Charge Schools Funds (ODOE)
- Consumer-owned Utility EV Mapping Tool (ODOE)
- State Pricing Agreements (DAS)
- State Agency EV and Infrastructure Cost Analysis Tool (DAS, ODOE)

Awareness

- Biennial ZEV Report (ODOE)
- Go Electric Website (ODOE)
- EV Dashboard (ODOE)
- EV Rebate Outreach (DEQ)
- Community Charging Program Outreach (ODOT)
- Transit and School Bus Cost Analysis Tools & Electric Bus Guidebooks (ODOE, ODOT, DEQ)
- Oregoin' Electric Support (DEQ, ODOT, ODOE, DAS, OPUC)
- Biennial Energy Report (ODOE)

These programs and policies are making progress on reducing emissions. In 2021 and 2022, the firm SSG conducted a study for the Oregon Global Warming Commission that assessed greenhouse gas emissions reductions that can be achieved through existing and planned state programs.[12] The Transformative Integrated Greenhouse Gas Emissions Reduction (TIGHGER) Study included anticipated transportation emissions reductions from the adoption of federal fuel efficiency standards, the Clean Fuels Program, the Climate Protection Program, and other DEQ zero-emission vehicle programs, including the Advanced Clean Cars I program and the Advanced Clean Trucks program.[13] SSG also assessed the Advanced Clean Cars II rule, which is currently in rulemaking at DEQ but has not been adopted as of the publication of this report. Figure 5 below shows that the combined reductions of all these programs and others applying to buildings and electricity, have the potential to achieve Oregon's 2035 interim greenhouse gas reduction goal of 45 percent below 1990 levels. Successful implementation of each of the programs in the chart below is needed to achieve this 2035 goal, and more actions are needed to achieve the 2050 goal.

Figure 5: Modeled GHG Reductions from Oregon Programs[14]



> *"No sector is* ***as important as transportation*** *to achieving decarbonization, nor as complex in its operation and governance."*
>
> — 2021 Washington State Energy Plan[15]

Exploring Pathways to 2050

The studies reviewed for this brief were consistent in their findings for the transportation sector: Pathways to cleaner transportation begin with extensive electrification of as many vehicles as possible. This largely depends on the availability of electric models and the charging infrastructure needed to support them.[16] Where vehicles cannot be electrified, low- and zero-carbon replacement fuels are needed. As new vehicle models are electrified, the need for these alternative fuels may go down. However, as discussed below, some vehicles will be difficult or impossible to electrify in the near to mid-term, and these vehicles will need zero-carbon fueling options to achieve full sector decarbonization.

Pathways to cleaner transportation begin with extensive electrification of as many vehicles as possible.

Electrification

Electrifying road vehicles – passenger vehicles, trucks, and buses – is a key element of most deep decarbonization studies.[17] All types of electric vehicles[ii] are more energy efficient than gasoline internal combustion engine vehicles, and this, combined with the state's relatively clean electricity

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[ii] Electric vehicles include battery electric, plug-in hybrid electric, and fuel cell (hydrogen) vehicles. Oregon currently has no hydrogen vehicles, so unless otherwise noted, the term electric vehicles indicates BEVs or PHEVs.

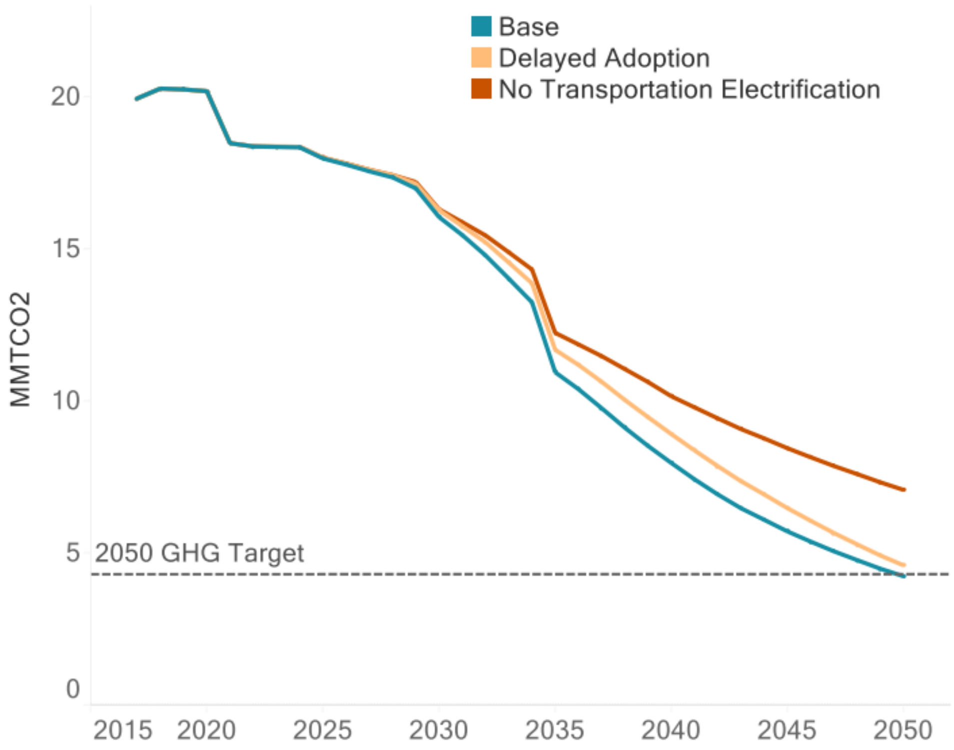
resource mix, means that switching to an electric vehicle in Oregon will immediately result in greenhouse gas emissions reductions.[18] Further, as Oregon's investor-owned electric utilities move toward 100 percent clean by 2040, electric vehicles in the state will become cleaner over time.[18] Electrifying the light-duty passenger vehicle sector alone could achieve a 19 percent reduction in *overall* state emissions.[19] Many studies indicate that sales of new passenger vehicles will need to be all electric by 2035 to achieve significant decarbonization by 2050.

- **Washington 2021 State Energy Strategy**: "For passenger cars to be fully zero-emissions by mid-century, nearly all new car sales will need to be EVs by 2035."[20]
- **Exploring Pathways to Deep Decarbonization for the Portland General Electric Service Territory**: "Electrification of passenger transportation is a critical component of decarbonizing the energy system, and passenger vehicles are at least 90 percent BEV by 2050 across all pathways. To ensure these vehicles are on the road by 2050 requires consumer adoption to be near 100 percent of vehicle sales during the mid-2030s. Delays in adoption increase the likelihood of missing the 2050 target."[21]
- **SoCalGas – The Role of Clean Fuels**: "All scenarios assume that 85% of light duty vehicles sales are battery electric vehicles (BEVs) by 2035 and 15% of light duty vehicles sales by 2035 are fuel cell electric vehicles (FCEVs)."[22]
- **Princeton Net-Zero America Project: "**We assume battery electric vehicles dominate the transition in the light duty sectors with fuel cell vehicles playing a larger role in medium- and heavy-duty vehicles."[23]
- **Oregon Clean Energy Pathways Analysis**: **"**Early electrification is key to avoiding large decarbonization costs in the future. Oregon should strive to reach 100% electrification sales of light-duty vehicles and building appliances by 2035."[24]

Figure 6 below from Evolved Energy Research's *Exploring Pathways to Deep Decarbonization for the Portland General Electric Service Territory* demonstrates how the timing of electrification matters. It shows a sensitivity analysis[iii] of different vehicle electrification options. The base case represented by the line in blue shows the anticipated reduction in greenhouse gas emissions with 100 percent of new passenger vehicle sales and 50 percent of medium- and heavy-duty sales being electric by 2035. Changing this date to 2050, as shown in the yellow "Delayed Adoption" line, increases total emissions in 2050 by 8 percent because over 10 percent of on-road vehicles have not been electrified. The "No Transportation Electrification" scenario shown by the red line removes all sales requirements, resulting in significantly higher emissions in 2050. This increase occurs despite the higher uptake of renewable diesel that was included in both scenarios.

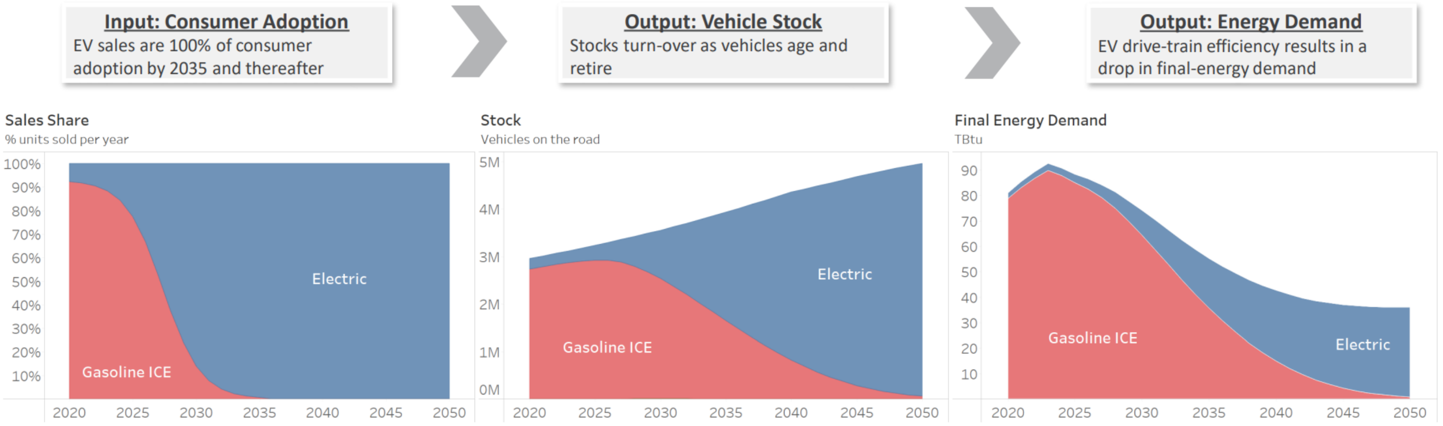
[iii] A sensitivity analysis is a modeling technique where one or more variables is adjusted while everything else remains constant to assess the effect of that variable on modeling results.

Figure 6: Modeled Effects of Reduced Electric Vehicle Sales Requirements[25]



Electrifying the transportation sector will eventually require replacing the non-electric vehicles in use today. This involves ensuring that electric vehicles are available, accessible, affordable, and meet consumer needs. Most vehicle replacements occur when a current vehicle stops working or at planned replacement cycles. Passenger vehicles tend to stay in the fleet for 15 to 16 years,[26] which means turning over a significant portion of the fleet will take time. In 2021, new electric vehicles were 7.8 percent of all passenger vehicle sales.[27] Figure 7 below from the *Oregon Clean Energy Pathways* report shows the rate of new vehicle sales in the first graph, followed by the expected rate of change in the overall passenger vehicle fleet, or stock, in the second graph.

Figure 7: Illustrative Example of Vehicles Sales and Existing Stock Turnover[28]



Input: Consumer Adoption
EV sales are 100% of consumer adoption by 2035 and thereafter

Output: Vehicle Stock
Stocks turn-over as vehicles age and retire

Output: Energy Demand
EV drive-train efficiency results in a drop in final-energy demand

22% of medium- and heavy-duty trucks on the road in 2020 were 20 years or older.

The reviewed studies indicate that medium- and heavy-duty vehicle electrification will also contribute to decarbonization. Due to the challenges associated with weight and range limitations of current battery technology, it is likely that other options, such as hydrogen fuel cells, will also be necessary for these vehicles.[22] [29] Medium- and heavy-duty vehicles that can charge at centralized warehouses (e.g., fleets of delivery vehicles) may be easier to electrify. The amount of electrification will depend on technological advancements in vehicle models and batteries as well as the potential development of clean hydrogen infrastructure. Like passenger vehicles, there is a significant lag in timing for converting these larger vehicles due to how long they tend to remain in operation. For example, in a statewide fleet survey, DEQ found that 22 percent of medium- and heavy-duty trucks on the road in 2020 were 20 years or older.[30]

- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "Widespread transportation electrification (100% of light-duty, 60% of medium-duty, and 40% of heavy-duty vehicles in the study's Central Case) will be crucial to reduce emissions at least cost and avoid using either scarce biofuel supplies or relatively expensive electric fuels [such as clean hydrogen] for transport."[31]
- **Washington 2021 State Energy Strategy**: "For heavy-duty trucks, we assume demand for hydrogen for long-distance hauling by 2050, including electric trucks. This drives the need for hydrogen refueling and delivery infrastructure. Whether hydrogen fuel cells are favored for some transportation applications in the future will depend on the relative development of propulsion technologies. For short-haul trucks, we assume a transition to 100% electric."[32]

Continued Use of Liquid Fuels

In addition to some medium- and heavy-duty vehicles, marine vessels, trains, aircraft, non-road construction, agriculture, warehouse, port, and forestry vehicles have limited electric options today, and some of these are likely to be very difficult to electrify even in the long-term. These will continue to rely on fossil gasoline, diesel, aviation fuel, or lower-carbon alternatives until zero-emission fuels become commercially available.

- **Washington 2021 State Energy Strategy**: "Not all segments of the transportation sector can be readily electrified through onboard battery storage. As the deep decarbonization modeling results suggest, long-haul freight trucks, some off-road vehicles, and long-distance rail, shipping and aviation will likely need to rely on liquid or gaseous fuels for the foreseeable future."[33]

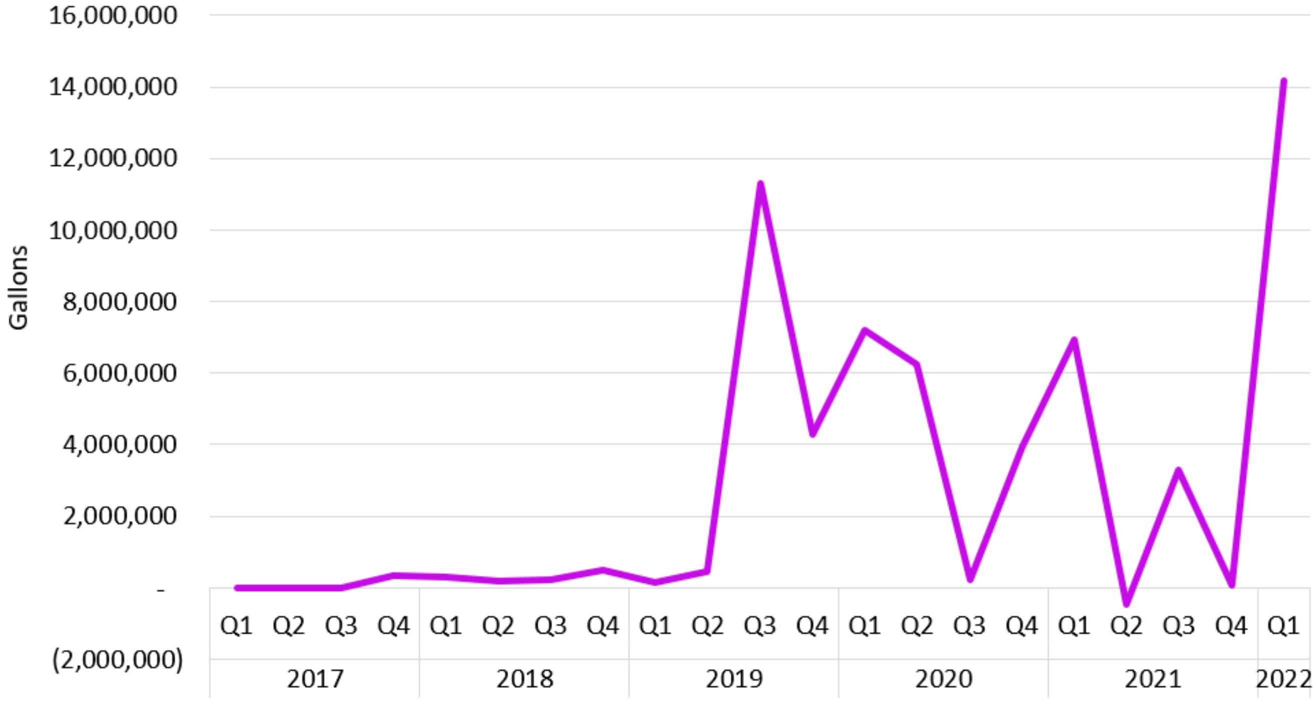
Lower-carbon liquid fuels, such as renewable versions of diesel, natural gas, and aviation fuel, can reduce emissions today and over the next 30 years.[34] [35] For example, renewable diesel has 42 to 80 percent fewer emissions than fossil diesel. These fuels can be substituted directly, without the need for a new vehicle or retrofit, and stored and transported in existing fossil fuel infrastructure. This makes them easier to adopt in the near-term and an important transitional fuel until zero-carbon options are commercially available. Often referred to as "drop-in" fuels, they are increasingly available, although not currently in sufficient amounts to replace *all* existing diesel and aviation fuel use.[9]

The most widely available drop-in fuel is renewable diesel, which has seen growth in Oregon since 2018, although it remains challenging to procure outside of the Willamette Valley.[9] The fuel is in high demand because it performs better than fossil diesel.[36] [37] [38] The Clean Fuels Program is the main driver of renewable fuel supply in Oregon because it makes the production of these fuels more cost-effective. Figure 8 shows renewable diesel was largely unavailable until 2019, and supply has been somewhat inconsistent. This occurred in part because Oregon markets compete with California, where a more mature Low Carbon Fuel Standard offers a higher credit price for suppliers. As Oregon's Clean Fuels Program continues to mature, credit values for suppling renewable diesel will help create a better business case in Oregon markets. COVID-19 has also affected fuel supply and demand. (See the Transportation Fuels Energy Resource and Technology Review for more information.)

Renewable Diesel in the Pacific Northwest[39]

In 2018, BP began producing renewable diesel at its Cherry Point petroleum refinery in Washington State and became the only producer of this fuel in the Pacific Northwest region. It has since made additional investments to expand its renewable diesel production capacity, which BP says will reduce carbon emissions from the plant by 400,000 – 600,000 tons per year.

Figure 8: Deliveries of Renewable Diesel into Oregon in Gallons[72]

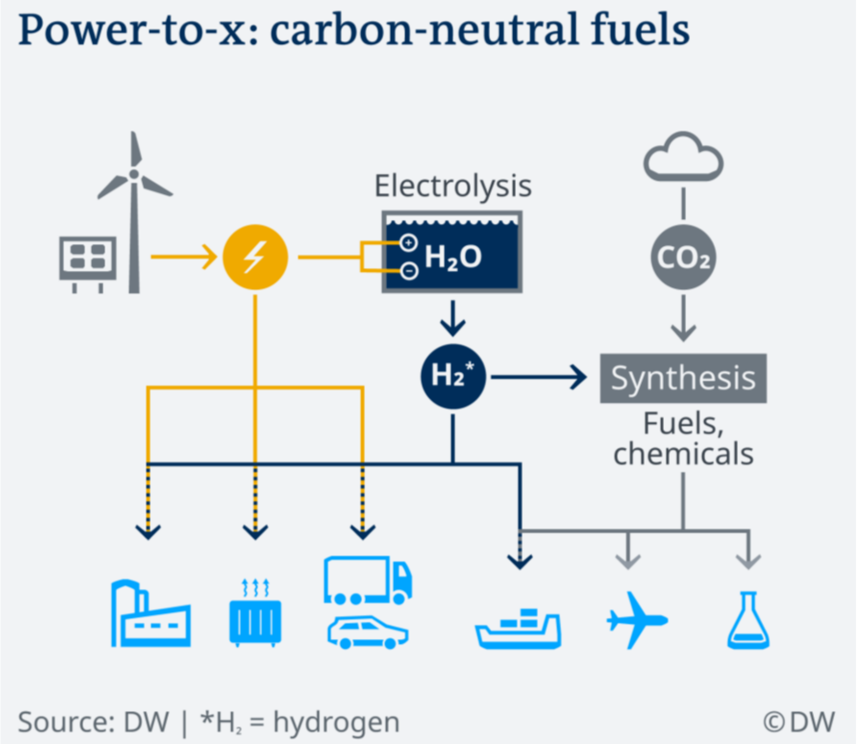


> "In all decarbonization scenarios, liquid fuels are not eliminated, but they are **fully decarbonized by 2050** with a combination of synthetic fuels, biofuels and hydrogen."
>
> — *Washington 2021 State Energy Strategy*[34]

While lower-carbon fuels like renewable diesel can drive immediate emissions reductions, zero-carbon liquid fuels like hydrogen produced with renewable electricity will be necessary to achieve near 100 percent reductions in the transportation sector. In its *Oregon Clean Energy Pathways Study,* the Clean Energy Transition Institute found that it may be feasible for Oregon to meet its 2050 greenhouse gas reduction target of 80 percent below 1990 levels without significant investments in zero-carbon fuel development; to meet a target of 100 percent reduction will require the production and use of zero-carbon fuel for hard-to-electrify sectors.[29] Other studies point to the need to consider and prepare for which vehicles are most likely to be difficult to electrify and what zero-carbon liquid fuel options are the most opportune alternative. Clean hydrogen could be an alternative for freight vehicles, and biomass-based fuels and synthetic fuels as zero-carbon alternatives where hydrogen is not an option.

- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "Sustainable biomass is best used for jet and diesel fuel. The best use for sustainable biomass is creating liquid fuels to power the hardest-to-electrify subsectors within transportation, namely aviation and long-distance freight shipping."[35]
- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "For energy-dense transportation, such as aviation, long-haul trucking, and some industrial heat processes, carbon-beneficial biomass and synthetic fuels may be used."[40]

Figure 9: Potential Future Energy Pathways Using Clean Electricity[41]



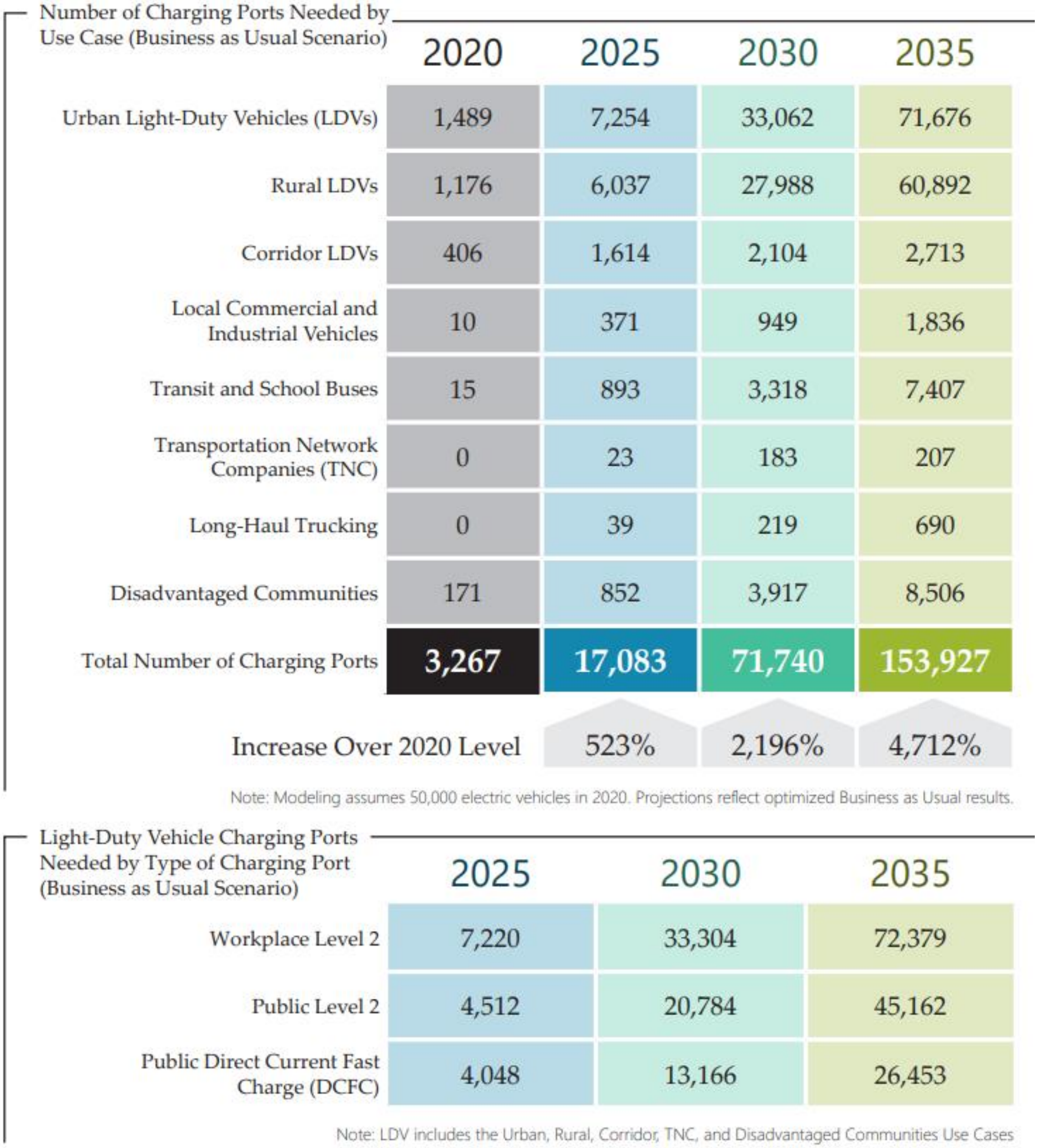
The processing and transportation infrastructure for these low-carbon fuels is not commercially available today.[42] While hydrogen is a commodity that is produced and delivered around the world, more than 95 percent of it comes from natural gas, which means it is not currently a zero-emission fuel.[43] Hydrogen electrolyzers are needed to produce hydrogen from water, and to make it clean, those electrolyzers must be powered by zero-emission electricity (see the Hydrogen Energy Resource and Technology Review for more). Similarly, synthetic biofuels are not commercially produced today, and would require infrastructure to produce the fuels at scale and deliver them to customers.[44]

Opportunities and Challenges

Infrastructure

Successful transportation electrification depends on the efficient deployment of charging infrastructure that is as ubiquitous and convenient as fueling with gasoline or diesel.[45] The Oregon Department of Transportation conducted a statewide gap analysis for EV charging necessary to meet the state's zero-emission vehicle adoption goals. Figure 10 shows the future need for different vehicles and charger types, including a 4,700 percent increase in charging infrastructure by 2035.

Figure 10: Oregon State Charger Needs to Meet Battery Electric Vehicle Adoption Targets[46]



Number of Charging Ports Needed by Use Case (Business as Usual Scenario)	2020	2025	2030	2035
Urban Light-Duty Vehicles (LDVs)	1,489	7,254	33,062	71,676
Rural LDVs	1,176	6,037	27,988	60,892
Corridor LDVs	406	1,614	2,104	2,713
Local Commercial and Industrial Vehicles	10	371	949	1,836
Transit and School Buses	15	893	3,318	7,407
Transportation Network Companies (TNC)	0	23	183	207
Long-Haul Trucking	0	39	219	690
Disadvantaged Communities	171	852	3,917	8,506
Total Number of Charging Ports	3,267	17,083	71,740	153,927
Increase Over 2020 Level		523%	2,196%	4,712%

Note: Modeling assumes 50,000 electric vehicles in 2020. Projections reflect optimized Business as Usual results.

Light-Duty Vehicle Charging Ports Needed by Type of Charging Port (Business as Usual Scenario)	2025	2030	2035
Workplace Level 2	7,220	33,304	72,379
Public Level 2	4,512	20,784	45,162
Public Direct Current Fast Charge (DCFC)	4,048	13,166	26,453

Note: LDV includes the Urban, Rural, Corridor, TNC, and Disadvantaged Communities Use Cases

The infrastructure need is significant, and includes not only addressing gaps in charger availability, but also highlights other challenges, such as local electric distribution system availability and upgrade costs. Once charging infrastructure is in place, ensuring that infrastructure is reliable will be key to consumer confidence.

- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Pacific Northwest**: "The level of transportation electrification called for by 2050 requires immediate attention to accelerating the widespread adoption of electric vehicles, investing in the essential charging infrastructure, and determining how the grid will handle the additional load required to serve this new demand."[47]
- **Washington 2021 State Energy Strategy**: "Infrastructure must be widely available, affordable and accessible to communities and the full range of vehicle classes. Rural areas outside the reach of mass transit systems will require BEV and FCV options to achieve low-carbon transportation."[20]

Electricity Demand

All transportation decarbonization options will increase electricity demand. More electricity is needed to support charging electric vehicles, and it is also needed to refine renewable diesel, produce clean hydrogen, or to produce synthetic biofuels.

- **Eugene Water & Electric Board's Electrification Impact Analysis Phase I**: "A high level of EV adoption, could increase EWEB's 'average system load [energy] up to 15% and increase peak demand [capacity] up to 30%.'"[48]
- **Montana Deep Decarbonization Pathways**: "Electrification of transportation is the largest contributor to demand growth in the electrification scenario."[49]
- **Seattle City Light**: "In 100% electrification scenario - electricity needed for transportation sector is 90x greater than it is today."[50]

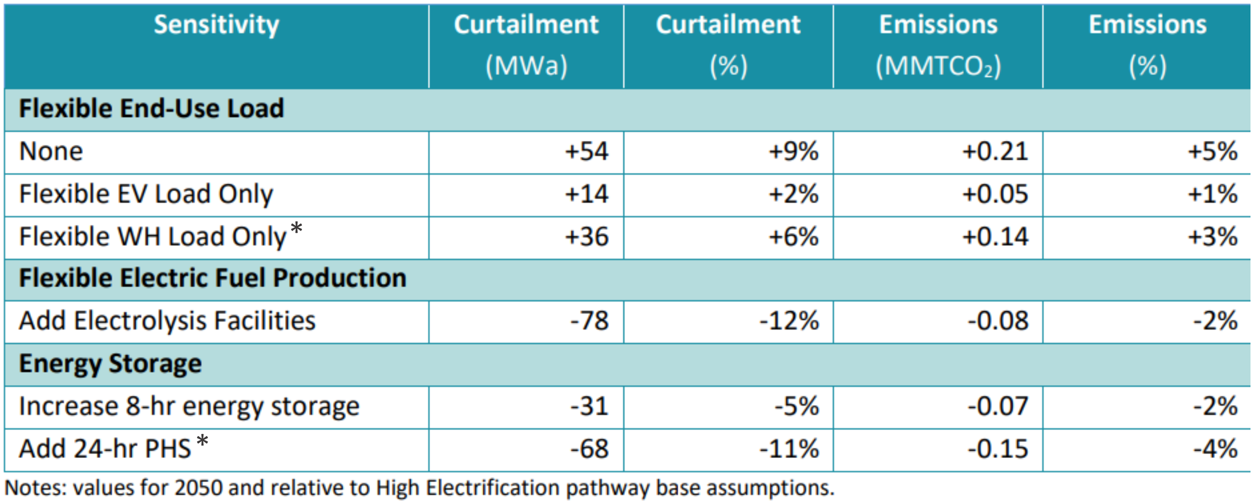
In some cases, particularly for passenger vehicles, utilities have tools available to manage the demands from this new electric load in ways that can limit the need for major investments in grid infrastructure. These focus on demand-side management actions, such as programming vehicles to charge during off-peak hours and enabling the utility to control vehicle charging in ways that optimize the grid while still meeting drivers' needs.

- **Eugene Water & Electric Board's Electrification Impact Analysis Phase II**: "Phase 2 of the study estimates a lower coincident peak of EV charging (1 kW per EV) compared to Phase 1 of the study due to increased levels of off-peak workplace and public charging in the future. The electric peak impact, while still significant, can be mitigated with managed or diversified charging behavior."[51]
- **Exploring Pathways to Deep Decarbonization for the Portland General Electric Service Territory**: "Widespread adoption of electric vehicles (EVs) is projected to be the largest source of increased electricity consumption, and, left unmanaged, would increase peak demand. However, the fleet of EVs across PGE's service territory can employ smart charging by shifting their demand to more efficient times of day. Charging off peak, such as when renewable

> generation is high or during the middle of the night can mitigate peak load impacts while ensuring that passengers complete all of their intended trips.”[21]

Electrification of vehicles can also offer opportunities for utilities to use the vast future network of electric vehicle batteries to better manage the electric grid. Electric vehicles can be charged at times when there is low-cost renewable electricity on the grid, and may eventually be able to operate as flexible demand resources, shifting electricity use to better match the needs of the grid. In Figure 11, a sensitivity analysis conducted for Portland General Electric shows that if 75 percent of available electric vehicles could be used as flexible demand, it would allow for increased use of available renewable energy (a reduction in curtailments[iv] by 7 percent) and thus reduce carbon emissions compared to not using EVs as a flexible load.

Figure 11: Sensitivity Analyses for EV and Electrolysis Flexible Load Options[53]



Sensitivity	Curtailment (MWa)	Curtailment (%)	Emissions ($MMTCO_2$)	Emissions (%)
Flexible End-Use Load				
None	+54	+9%	+0.21	+5%
Flexible EV Load Only	+14	+2%	+0.05	+1%
Flexible WH Load Only *	+36	+6%	+0.14	+3%
Flexible Electric Fuel Production				
Add Electrolysis Facilities	-78	-12%	-0.08	-2%
Energy Storage				
Increase 8-hr energy storage	-31	-5%	-0.07	-2%
Add 24-hr PHS *	-68	-11%	-0.15	-4%

Notes: values for 2050 and relative to High Electrification pathway base assumptions.

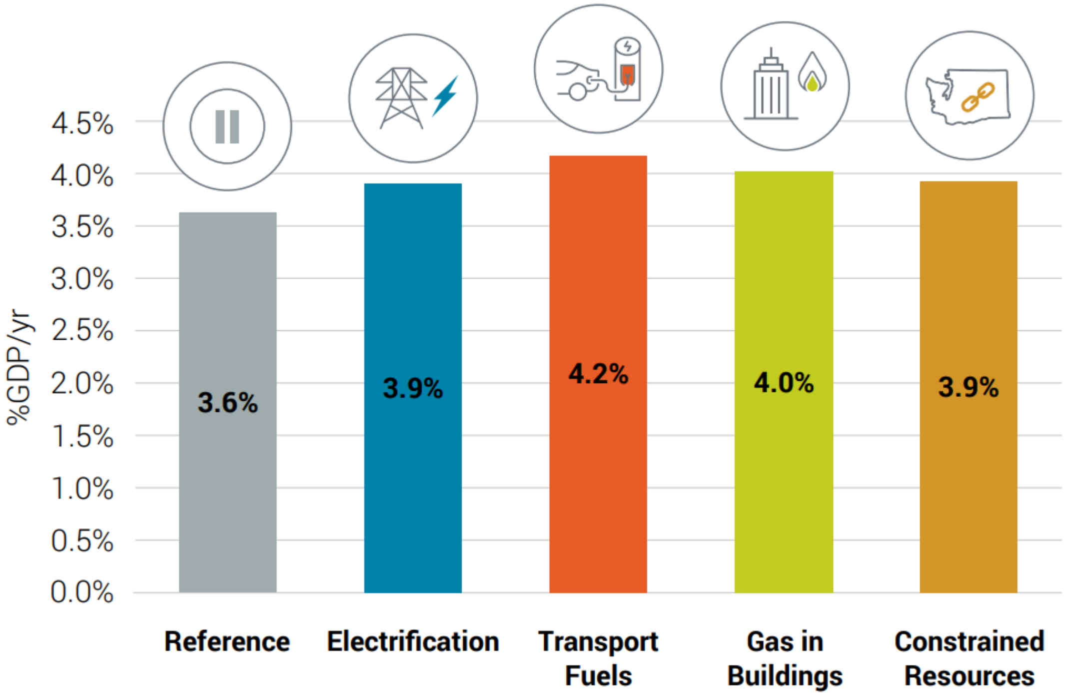
* *WH stands for water heater and PHS for pumped hydro storage, which reflect other sensitivity analyses performed by Evolved Energy Research, but are not applicable to this topic.*

Costs

Studies found that scenarios with higher levels of electrification generally had lower costs than scenarios that relied more heavily on zero-carbon fuels like hydrogen and synthetic biofuels. Figure 12 below reflects annual energy spending in Washington State, represented as a percentage of Gross Domestic Product over the 2020 – 2050 timeframe. The blue bar represents the anticipated costs for a high electrification decarbonization scenario compared to the reference case – it is the lowest cost of the different scenarios. This contrasts with the “Transport Fuels” scenario, which is the highest cost to decarbonize because vehicles and buildings require more zero-carbon fuel alternatives.

[iv] Curtailment is the reduction of output of a renewable resource below what it could have otherwise produced.[52]

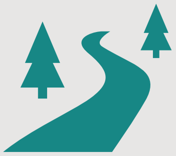
Figure 12: Average Annual Energy Expenditures in Washington 2021 State Energy Strategy[54]



- **Oregon Clean Energy Pathways Analysis**: "Rapid adoption of electric vehicles, electric appliances, and electric space/water heating enable lower cost economy-wide decarbonization by 2050."[55]
- **Washington 2021 State Energy Strategy**: "The Transport Fuels Scenario, where fewer vehicles are electrified or transition to hydrogen, requires more clean fuels, which drives higher costs."[56]
- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "Widespread transportation electrification (100% of light-duty, 60% of medium-duty, and 40% of heavy-duty vehicles in the study's Central Case) will be crucial to reduce emissions at least cost and avoid using either scarce biofuel supplies or relatively expensive electric fuels for transport."[31]

While adoption of new technology can be expensive, transitioning to fuels produced in-state like electricity or biofuels can lower overall transportation expenditures by reducing Oregon's dependence on imported fossil fuels. Electricity use could also reduce transportation fuel price volatility for Oregonians, allowing businesses and families to better budget for these costs.[33] See the Consumer Energy Cost Drivers 101 for more information.

Funding Roadways



Oregon finances state highways on the principle of cost responsibility – the idea that road users should pay for their share of road costs. Currently, drivers pay for roads when they pay for gas; the state assesses a tax on each gallon of fuel sold. These tax revenues go into the State Highway Fund, which pays for state highway, county road, and city street construction and maintenance. As zero emission vehicles, which don't run on gas, become a greater portion of the passenger vehicle fleet, annual fuel tax revenues are likely to decline. Yet, the roads still need to be maintained. The Oregon Department of Transportation is exploring an alternative method for funding roadway maintenance and construction that could solve this problem. The OReGO program charges a tax on mileage instead of at the pump, allowing ZEV owners who opt in to the program to pay 1.8 cents per mile.[57]

Equity

In addition to the challenges outlined above, pathways to decarbonize the transportation sector need to consider equity. Electrification strategies should ensure that the benefits are felt in every corner of the state and shared by all drivers, communities, and businesses. Policies should be intentionally designed to avoid exacerbating historical inequities. This is particularly important as Oregon moves forward with electrification, for which the availability and accessibility of both vehicles and charging infrastructure are critical.

- **Washington 2021 State Energy Strategy**: "Experience tells us and data confirm that the costs and benefits of our energy future will not be shared equitably without intentional action. Policy makers must embed equity, resiliency and inclusivity into policy design and implementation."[58]

Charging Availability

While home electricity supplies have been designed to accommodate standard appliances, some homes – particularly older ones – may require electrical upgrades to accommodate an EV. Some upgrades can be expensive, particularly if a new electrical panel is required. People who live in homes that don't have garages or driveways may need alternative charging options. Some electric utilities are providing outlets on streetlights and utility poles where EV owners can access charging near their homes.[59] [60] Other options for these consumers include public or workplace charging.

About 38 percent of Oregonians do not have access to home charging because they live in multi-unit buildings.[61] Oregon's commercial building code requires new multi-unit dwellings to be EV-ready, but it may be expensive for existing building owners to bring charging to their residents, and some apartment buildings do not have associated parking lots. Public charging options are not yet available everywhere in Oregon, and generally electric fuel at public chargers costs more than residential electricity rates. Workplace charging offers the convenience of charging during the workday, but employers may not want to bear the costs of installing the infrastructure.

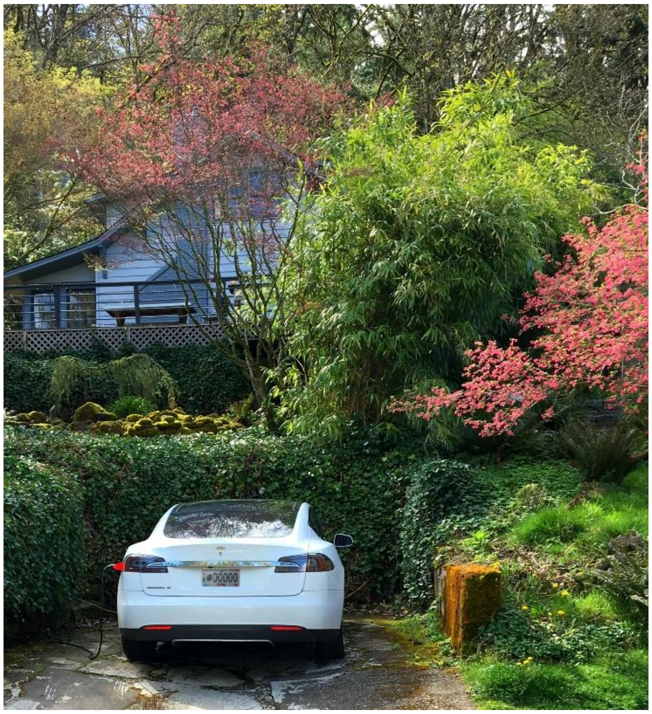
About 38% of Oregonians do not have access to home charging because they live in multi-unit buildings.

Businesses interested in electrifying their fleets may face high costs for charging infrastructure, including the cost to purchase and install charging equipment and potentially to upgrade electricity delivery to the site. Slow fleet turnover can also be a barrier for businesses; when a diesel vehicle reaches the end of its useful lifetime, buying an electric model may be significantly more expensive than a new diesel model. Once purchased, trucks can remain in service for more than two decades, which means vehicle electrification actions are needed in the next decade to achieve a significant fleet turnover by 2050.[30]

The type of charger available is likely to become a bigger issue as certain electric vehicle models proliferate. Today there are three charging standards for fast charging EVs (CCS, Tesla, and CHAdeMO) and two standards for Level 2 charging (Tesla and J1772). CHAdeMO, which supports many older models of EVs, including the popular Nissan LEAF, is rapidly becoming an obsolete standard in the U.S.[62] CHAdeMO chargers are necessary to support these vehicles until they cycle out of the fleet. Many of the early low-cost EVs use CHAdeMO, so availability of this charging platform may be particularly critical for low-income drivers.

Vehicle Availability

Although state and federal incentives can bring the cost of some EVs close to parity with gasoline vehicles, costs are still high.[63] Low-income households are more likely to purchase a used vehicle.[64] Nearly three-quarters of 2021 U.S. passenger vehicles sales were used vehicles.[65] [66] However, with demand exceeding supply for used EVs, there is indication that used car prices are also trending higher.[67] Electric vehicles are anticipated to reach cost parity across all vehicle classes by the mid-2020s, but policies to address the higher costs, like the state's EV rebates, can be helpful until this occurs.[68]



A potential unintended consequence of passenger vehicle electrification is that older gasoline vehicles may ultimately end up in environmental justice[v] and low-income communities, exacerbating current inequities. As more Oregonians buy electric cars, used gasoline vehicles may become a lower-cost option for Oregonians with low incomes. Many low-income communities are in areas that are disproportionately affected by poor air quality resulting from local transportation emissions. Concentration of gasoline vehicles in these communities will slow local air quality improvements that will result from electric vehicle adoption.

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[v] Environmental justice communities include communities of color, communities experiencing lower incomes, tribal communities, rural communities, coastal communities, communities with limited infrastructure and other communities traditionally underrepresented in public processes and adversely harmed by environmental and health hazards, including seniors, youth, and persons with disabilities.[69]

Policy Considerations for Oregon

Most of the studies reviewed for this brief conclude that there are three major pathways to decarbonize the transportation sector:

1. Electrify as many vehicles as possible as soon as possible.
2. Use lower-carbon liquid fuel alternatives for vehicles that cannot be electrified in the near-term.
3. Plan for zero-carbon liquid fuel alternatives to decarbonize vehicles that cannot be electrified.

Each strategy has trade-offs that must be weighed. There is also an opportunity to build a more equitable transportation system from the ground up. Energy transitions have not historically benefitted everyone. Often, key benefits are out of reach for those who are most in need due to high up-front costs of new technologies or geographic disparities. Inequitable access to the benefits of electric vehicles already exists: cost savings are highest for Oregonians who can charge their vehicles at home, and investments in charging infrastructure in low-income or rural communities often lag because the economics don't pencil out soon enough.[70] [71] Policies may be needed to address these issues and other equity considerations.

There is an opportunity to build a more equitable transportation system from the ground up.

A transition to clean transportation requires thoughtful deliberation and robust engagement with industry, communities, drivers, and governments. The following questions could help frame transportation decarbonization policy discussions.

Electrify as many vehicles as possible as soon as possible:

- Is the market trajectory of passenger zero-emission vehicle sales, coupled with existing programs and policies, sufficient to achieve the state's greenhouse gas emissions goals, or are additional policies necessary to transition the fleet by 2050?
- Is Oregon's used ZEV market sufficient to ensure affordable vehicles are widely available in the state?
- How can Oregon support timely charging infrastructure development sufficient to meet anticipated battery electric vehicle adoption rates?
- What options are there to provide charging for electric drivers who can't charge at home? Are incentives necessary? What are the most cost-effective and convenient alternatives to at-home charging? Is there a role for workplace charging or centralized charging depots?
- What policy levers exist to make ZEVs available in environmental justice communities?
- How can the state use its resources to support chargers for passenger vehicles along travel routes? Should the state consider the use of state-owned lands, resources, and operations for public charger installations? If so, what policies or policy changes are needed?
- How can the state address the high up-front costs for businesses interested in electrifying their medium- and heavy-duty fleets? Is there a need to design programs specifically for small businesses?

- What policies or policy changes are needed to ensure sufficient revenue is collected to fund Oregon's roads and bridges?
- How can the state work with utilities to ensure sufficient electricity is available and take advantage of opportunities for transportation electrification to benefit the electric grid?

Use lower-carbon fuel alternatives for vehicles that cannot be electrified in the near-term:

- What options does the state have to facilitate the availability of renewable diesel, and other lower-carbon liquid fuel alternatives, in all parts of Oregon?
- What is the optimal use of limited supplies of lower-carbon liquid alternative fuels to support decarbonization?
- How can state policies help balance the need to support lower-carbon liquid alternative fuels in the next few decades while preparing for an economy where the demand for these fuels may ultimately diminish?
- Should the state prioritize the development of in-state production to support a clean transportation sector in Oregon?

Plan for zero-carbon liquid fuel alternatives to decarbonize vehicles that cannot be electrified:

- What fuel options enable Oregon to retain more transportation fuel-related dollars in the state?
- What are neighboring states considering for zero-fuel development? How much influence could they have on future fuel decisions in Oregon?
- What role should the state play in supporting the production of biofuel feedstock crops and the development of biofuel and clean hydrogen production facilities?
- Are there opportunities to use existing infrastructure to support zero-carbon fuel development? For example, could gas stations be repurposed to provide clean hydrogen?
- As Oregon moves toward a 100 percent clean electric grid, what options exist to develop zero-emission fuel production operations that can act as flexible demand to help optimize grid management?

Conclusion

As identified previously in this policy brief series, there is an emerging consensus in technical studies that energy efficiency, electrification of end uses, decarbonization of the electric sector, and the development of low-carbon fuels are necessary strategies to achieve a decarbonized energy future. The studies were equally consistent in the strategies needed to reduce emissions in the transportation sector. While there are challenges in navigating this transition for transportation in Oregon, it's necessary to make these changes to meet our state's energy goals – ideally with the thoughtful deliberation and balanced approach of a statewide energy strategy charting the course.

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Policy Brief: Charting a Course for Oregon's Energy Future

Part V: Pathway Trade-Offs

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

Other briefs in this series describe common strategies identified in recent studies to achieve clean energy and climate change policy objectives. These strategies include pathways to meet those targets by taking different actions across the electricity, natural gas, and transportation sectors. This brief focuses on how those different pathways will require intentional consideration of trade-offs – in terms of total costs, effects on disadvantaged communities, land use impacts, and more – as investments are made to deploy needed clean energy projects to achieve Oregon's mid-century policy objectives, including HB 2021 and the Oregon Department of Environmental Quality's Climate Protection Program.

The studies characterized in the earlier briefs in this series illustrate how these aggressive policies can be achieved, but they also reveal the multitude of pathways available to do so. Oregon has the opportunity at this juncture to consider the technical findings and explore the range of trade-offs for different pathways. In so doing, the state can engage with the public to identify an intentional pathway for Oregon that optimally balances these trade-offs.

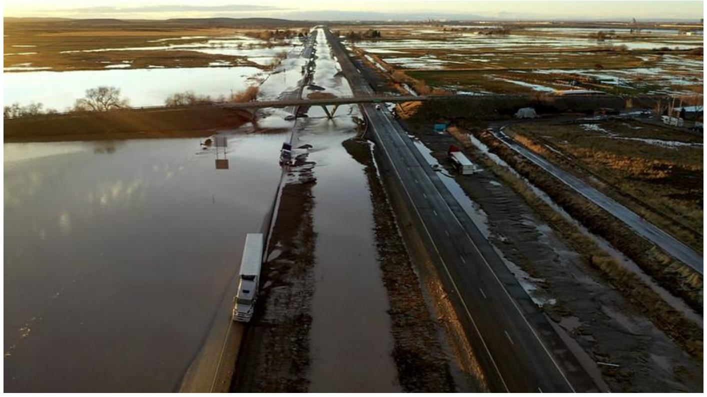
Key Considerations in the Transition to Clean Energy

What are the risks in continuing the status quo and not meeting our greenhouse gas reduction policy targets in time?

First, it is important to acknowledge the option of maintaining the status quo. While Oregon has adopted aggressive policy targets to address climate change, significant investments – many involving complex processes and decision-making with long development timelines – are required to ensure sufficient clean energy is in place to meet those requirements. Continuing to emit greenhouse gas emissions from energy infrastructure will exacerbate the real risk that communities across Oregon, and the world, will continue to experience worsening effects resulting from climate change. While action by Oregonians alone will not stop climate change, it is important the state does its part to reduce emissions and support people through the energy transition. The IPCC's Sixth Assessment Report includes five scenarios that consider how humanity will respond, or not, to climate change and what effects may result – including inundation of coastal communities on a regular basis, significant drop in global food production, far more extreme heat, and more devastating flooding.[1]

USEPA recently published an analysis that focuses on the disproportionate and unequal risks that climate change is projected to have on communities that are least able to anticipate, cope with, and recover from the adverse climate change effects.[2] For example:

Flooding:



In early 2020, severe flooding closed Interstate-84 in north-central Oregon for several days. Photo: Oregon Department of Transportation

- "Areas with both high flood exposure and high social vulnerability **occur predominantly in rural areas**. . ."
- "**Hispanic and Latino individuals are also 50 percent more likely** to live in coastal areas with the highest projected increases in traffic delays from climate driven changes in high-tide flooding."
- "**[I]ndividuals in . . . socially vulnerable groups . . . [are more likely to live]** in areas where the highest percentage of land is projected to be inundated due to sea level rise."

Increased Mortality Rates:

- "**Black and African American individuals are 40 percent more likely** than non-Black and non-African American individuals to currently live in areas with the highest projected increases in mortality rates due to climate-driven changes in extreme temperatures."

Childhood Asthma Diagnoses:

- "**Black and African American individuals are 34 percent more likely** to live in areas with the highest projected increases in childhood asthma diagnoses due to climate-driven changes in particulate air pollution."
- "**[I]ndividuals in . . . socially vulnerable groups are approximately 15 percent more likely** to currently live in areas with the highest projected increases in childhood asthma diagnoses due to climate-driven increases in particulate air pollution."

Labor Impacts:

- "**Hispanic and Latino individuals are 43 percent more likely** than non-Hispanic and non-Latino individuals to currently live in areas with the highest projected labor hour losses in weather-exposed industries due to climate-driven increases in high-temperature days."
- "**Those with low income or no high school diploma are approximately 25 percent more likely** than non-low-income individuals and those with a high school diploma to currently live in areas with the highest projected losses of labor hours due to increases in high-temperature days with 2°C of global warming."

Oregon communities already experience the effects and costs of climate change. The Oregon Health Authority's *2020 Climate and Health in Oregon* report found that climate change is negatively affecting Oregon's natural and human environments and intensifying public health crises in the state.[3] For example, between 2015 and 2020, Oregon set several ominous records that were exacerbated by climate change:[3]

- **High temperatures:** The single hottest year in state history occurred in 2015 and three others (2016, 2018, and 2020) over that timespan all rank in the top 10 hottest years on record. Since the publication of the OHA Report, 2021 also ranked in the top 10 hottest years on record.[4]

> "A new study finds the Pacific Northwest's extreme heat wave last summer was a freak event that should only happen once in 10,000 years and **it was even hotter because of climate change**. Records were broken across the region in June of 2021, as temperatures soared as high as 118 degrees Fahrenheit. . . Hundreds of people died across the Northwest, and at least 96 people died in Oregon."
>
> — *Pacific Northwest heat wave was a freak, 10,000-year event, study finds.* OPB (September 2022)[5]

- **Snowpack:** The lowest snowpack ever recorded in the state was in 2015.
- **Wildfire:** The most severe wildfire seasons in modern history have occurred since 2015, including the 2020 wildfire season that burned more than 1 million acres and destroyed or severely damaged more than 4,000 homes. By comparison, Oregon's next most severe wildfire year, 2015, saw 56 residences lost to conflagration fires. Not only do wildfires harm communities, they also result in harmful air pollution, exacerbate climate change by emitting greenhouse gas emissions, and impact wildlife habitat.[6]
- **Water Supply:** The municipal drinking water system for the City of Salem was contaminated with cyanotoxins (2018) resulting from algal blooms.

> "Scientists are anticipating even **more harmful algal blooms with the warmer water temperatures that come with climate change**."
>
> — *Researchers identify toxin that tainted Salem's drinking water in 2018.* OPB (June 2022)[7]

- **Disasters:** Areas of the state were declared national disaster areas multiple times for damage caused by extreme storms, floods, and landslides (2016, 2017, 2019, 2020).
- **Drought:** Drought emergency declarations were issued in 25 of 36 counties in the state in 2015. Meanwhile, 11 counties declared drought emergencies again in 2018 and then 15 counties did so yet again in 2020.

OHA's report also found that climate change affects each community differently and requires the state to acknowledge and address racial and economic inequities in Oregon. It also found that Oregonians working on the frontlines, including those working outdoors in smoke and extreme heat, are at increased risk of illness and death.[3] For example, OHA found that farmworkers in Oregon (the majority of whom are Latino and Latina immigrants) are "particularly vulnerable" to the cumulative effects of climate change, which can exacerbate existing disparities.[3]

As identified in the previous briefs in this series, recent studies find that the current pace and scale of clean energy deployment needs to accelerate in Oregon and across the world in the years and decades ahead in order to reduce these types of risks.

Trade-Offs in Focus: Achieving Clean Energy and Climate Policy Goals

Policy Goal: Reducing greenhouse gas emissions and producing clean electricity

Key Policy Question: What are the trade-offs involved with failing to achieve the state's clean energy and climate change policies?

Framing the Trade-Offs: Maintaining the status quo trajectory of the world's energy systems would continue reliance on resources that emit greenhouse gas emissions. While Oregon has made progress in reducing emissions, more can be done to accelerate progress. The adverse effects of unmitigated climate change on the health and well-being of humanity and on natural ecosystems are well documented, some of which have been described above.

The primary alternative to the status quo, as outlined in this series of briefs, requires accelerating the clean energy transition in Oregon to reduce the state's contribution to climate change. This will require significant investment in clean energy and all development pathways will involve some degree of adverse impacts. The state has an opportunity to identify an intentional approach to deploying clean energy to ensure that Oregon reduces its emissions while balancing the respective trade-offs involved in a way that is optimized for Oregonians.

? *In the clean energy transition, how can Oregon lower overall costs, balance benefits, and mitigate rather than exacerbate energy burdens?*

The clean energy transition requires building significant new infrastructure to power homes, businesses, and modes of transportation – and customers will ultimately pay for the associated costs through utility bills, fuel costs, and the embedded cost of energy in goods and services. While the costs of clean energy generating technologies have fallen dramatically and the fuel itself – such as the sun and the wind – is free, there are still substantial costs associated with the necessary infrastructure to transition to a clean energy economy. As described in the introduction to this policy brief series, several studies show that the capital investments required to support the clean energy transition – such as investments to deploy renewables and to purchase EVs – will be largely offset by reductions in expenditures elsewhere in the economy. For example, the *Washington State Energy Strategy* found that savings from avoided purchases of gasoline and, to a lesser extent, natural gas, can substantially offset the costs of increased expenses in the electric sector and on clean fuels.[8]

One of the four pillars of decarbonization identified in the studies arguably has fewer trade-offs than the others in most cases: energy efficiency. For example, using a more efficient electric appliance results in lower energy consumption and thereby reduces the need for the development of additional power plants and the associated impact to the environment. Investments in energy efficiency also tend to result in a direct reduction in customer energy bills. In recent years, savings from energy efficiency in the Pacific Northwest have slowed.[9] Importantly, the studies reviewed for this policy brief series identify a need to redouble efforts to invest in energy efficiency to help mitigate the scale of the buildout of clean energy resources that will be required to achieve aggressive mid-century policy targets. For more information on the evolution of evaluating the cost-effectiveness of energy efficiency investments, see the Policy Brief on Co-Benefits of Energy Efficiency.

In some cases, the most energy efficient pathway to achieving decarbonization goals may require using more electricity.

In some cases, however, the most energy efficient pathway to achieving decarbonization goals may require using more electricity. Electrification of end uses will lead to an increase in electricity use. But this transition in the transportation sector – from vehicles that use gasoline or diesel in internal combustion engines to vehicles powered by electric drive trains – will be more energy efficient. As referenced in the introduction to this policy brief series, the *Oregon Clean Pathways* study found that converting light-duty vehicles in Oregon from gasoline powered internal combustion engines to electric would cut energy consumption (on a Btu basis) by more than half.[10]

Analyses of household energy burden focus on the high energy bills that challenge income-constrained U.S. households. Energy burden refers to the portion of a household's income spent on electricity, natural gas, and other home heating fuels – a household that spends more than 6 percent of its income on energy is considered energy-burdened.[11] Energy burden analyses rarely consider the cost of transportation energy, which is unfortunate given that a broader energy scope would likely spotlight even larger affordability challenges and would lay a foundation for projecting the positive impacts on energy burden that would likely result from expanding the market share of electric light-duty vehicles.[12] For example, the average price for a gallon of gasoline in Oregon in 2022 has been about $4.50/gallon, while the equivalent cost for charging a similar model of EV is $0.81.[i] Assuming the average number of miles driven per year, that would equate to a savings of $2,084 per year.[13]

There are also costly health consequences associated with the energy infrastructure that is typical in affordable housing in the U.S. Outdated space conditioning equipment and poorly insulated roofs, walls, and foundations characterize this building stock, all of which can cause or exacerbate the health problems of occupants. Exposure to carbon monoxide poisoning and other indoor air pollution, in addition to higher energy costs, can result from inefficient, unvented, and poorly serviced heating equipment. Other health issues include lead exposure, thermal discomfort, and aggravation of respiratory problems such as asthma. Respiratory illnesses and thermal discomfort are also associated with older HVAC systems. Living with energy insecurity represents the consequences of stressors, fears, and even mental health related to the inability to pay energy bills and the real potential of disconnection of electricity and gas heating utility services. These effects are amplified for groups vulnerable to additional underlying health issues combined with financial limitations.[12] As described in the policy brief on the Co-benefits of Energy Efficiency, targeted energy efficiency investments, if done right, can not only reduce energy burden but help mitigate some of these other challenges.

Targeted energy efficiency investments, if done right, can reduce energy burden and help mitigate other challenges.

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[i] Assumes gasoline and electric vehicle models are similar and driving habits are the same.

The Oregon Department of Energy offers rebates for solar and solar plus storage projects.

Policies and programs to subsidize improvements in energy efficiency and investments in renewable energy include rebates and credits for smart thermostats, efficient appliances, and tax credits for rooftop solar systems. However, such subsidies are often inaccessible to low-income households – they are not "inclusive" – due to affordability barriers and limited tax liability against which tax credits can be credited.[12] Nationwide, residential rooftop solar systems have been installed disproportionately on owner-occupied, single-family housing owned by middle- and upper-income families.[14] Because they have less disposable income, low-income households often find it more difficult to invest in on-site solar energy. In addition, these same customers are more likely to live in older housing, which often makes their rooftops less suitable for hosting solar. Federal solar tax credits have historically[ii] been a poor fit for households that do not have large tax liabilities.[12] Oregon's solar tax credit programs were discontinued several years ago, and a solar and storage rebate is now available in the state to help address this tax liability incentive issue.[iii]

Cost is another input to consider when evaluating clean energy pathways – including how much the processes and timeline to build those resources would cost – and how those costs are ultimately passed down to Oregonians through utility bills and fuel costs over time. Large-scale renewable energy projects can take advantage of economies of scale and can be sited in locations with the strongest resources and optimal transmission access. This can help deliver the lowest cost renewable power, to the benefit of all utility ratepayers, regardless of income or proximity to the project. For example, the 120 MW Jackpot Holdings solar development near Twin Falls, Idaho is contracted to deliver energy to Idaho Power for less than 2.2 cents per kWh, which is below conventional avoided cost rates for Northwest utilities.[15] However, large-scale energy facilities can have negative effects on natural resources and the communities in which they are sited, and the benefits don't necessarily accrue to the most affected communities.

An alternative to large-scale renewable energy development are small-scale and community-based renewable projects.

An alternative to large-scale renewable energy development are small-scale and community-based renewable projects. In addition to delivering clean energy, these projects also have the potential to deliver additional co-benefits, including local energy resilience and economic development in communities. In Oregon, there are financial incentives to support small-scale projects with local community benefits.[iii] The Community Renewable Energy Grant

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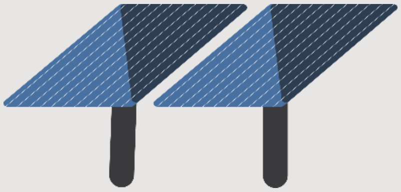
[ii] The Inflation Reduction Act of 2022 (H.R. 5376) made changes to the federal tax credit, including extending the credit to participants of community solar projects, and making the tax credit refundable to tax exempt entities, which may increase low and moderate-income participation in the program.

[iii] Learn about Oregon Department of Energy incentive programs: www.oregon.gov/energy/Incentives

Program administered by the Oregon Department of Energy provides construction grants of up to $1 million to support small-scale community projects with an emphasis on such projects that deliver local energy resilience benefits. The program is designed to support the development of many valuable community-based projects.[iv]

ODOE Community Renewable Energy Grant Program



In October 2022, the Oregon Department of Energy selected 21 recipients for a total of $12 million in Community Renewable Energy Grant Program dollars for the first round of funding.[16] The program supports planning and construction of renewable energy or energy resilience projects for Tribes, public bodies, and consumer-owned utilities. ODOE will make additional rounds of funding available through 2024.

More information on the projects selected: https://tinyurl.com/C-REP-Round1

Trade-Offs in Focus: Minimizing Energy Burden

Policy Goal: Minimize energy burden

Key Policy Question: How do different clean energy deployment pathways affect energy burdened, low-income Oregonians? Can some pathways minimize those burdens more or less than others?

Framing the Trade-Offs: Supporting the development of small-scale and community-based projects within low-income and disadvantaged communities could help to promote local economic development and support other community benefits (e.g., resilience) within those communities. This strategy may result in higher overall costs, however, as these projects likely would not benefit as much from economies of scale or be able to site in optimal locations with regard to resource quality and transmission access.

Policies could also be designed to support the development of the least-cost portfolio of renewables – including any associated transmission development and siting and permitting support – to deliver the lowest cost clean energy to maintain lower electricity rates for all utility ratepayers. Pursuing a strategy that results in the lowest electric rates, particularly given the expected increase in the reliance on electricity to meet more consumer energy demands in the future (such as from EVs), could help to alleviate energy burdens on low-income Oregonians. This type of strategy may miss opportunities to provide non-energy or co-benefits to those same communities.

[iv] For more information on the benefits and opportunities associated with small-scale and community-based renewable energy projects, see ODOE's 2022 study on Small-Scale and Community-Based Renewable Energy Projects: www.oregon.gov/energy/Data-and-Reports/Pages/SSREP-Study.aspx

What are the considerations in workforce, supply chain, and innovation through continued research and development?

The energy sector is a capital- and workforce-intensive industry. As identified elsewhere in this brief, significant investment will be required to deploy clean energy in the years ahead to achieve policy goals. Different clean energy pathways will have different effects on issues related to workforce, supply chain considerations, and the potential need for research and development to support innovative solutions.

In recent years, workforce and supply chain issues have created problems for a range of industries, including in the electricity, transportation, and natural gas sectors. Given the scale and pace of the clean energy development necessary – and not just in Oregon, but also in other regions of the country at the same time – these issues could become a bigger challenge in the years ahead. See the Policy Brief on Local Energy Perspectives on Workforce and Supply Chain for more.

The USDOE *Solar Futures* study found that continued technological progress in solar – as well as wind, energy storage, and other technologies – is critical to achieving cost-effective grid decarbonization and greater economy-wide decarbonization. Continued research and development is key to keeping these technologies on current or accelerated cost-reduction trajectories. For example, a 60 percent reduction in PV energy costs by 2030 could be achieved via improvements in photovoltaic efficiency and lifetime energy yield. Further advances are also needed in areas including energy storage, load flexibility, generation flexibility, and inverter-based resource capabilities for providing grid services. With the requisite improvements, solar technologies may proliferate in novel configurations associated with agriculture, waterbodies, buildings, and other parts of the built environment.[17] The anticipated growth in solar deployment will yield broad economic benefits in the form of jobs and workforce development. The solar industry already employs around 230,000 people in the United States, and with the level of growth envisioned in the *Solar Futures* study's scenarios, it could employ 500,000 to 1,500,000 people by 2035.[17]

There are also significant differences in the supply chains, and the potential susceptibility of those supply chains to disruption, associated with the development of different types of clean energy resources. For example, most solar PV modules in recent years have been manufactured in Asia and imported into the United States.[18] Other clean energy technologies may be more readily manufactured domestically, or even in state. And in some cases, this may be a necessity. Floating offshore wind turbines, given their immense scale, must be manufactured near a port for final deployment into the ocean.[19]

Trade-Offs in Focus: Supply Chain

Policy Goal: Achieving clean energy and climate policies while minimizing susceptibility to supply chain disruptions

Key Policy Question: Are some pathways to achieving mid-century policy goals more conducive than others to avoiding supply chain disruptions of the type that have plagued the global economy in the last several years?

Framing the Trade-Offs: Supporting policies that drive a buildout of a single type of clean energy technology (e.g., solar PV), even if that path may offer the least-cost option, could make Oregon's energy sector more dependent on global imports more susceptible to supply chain disruptions.

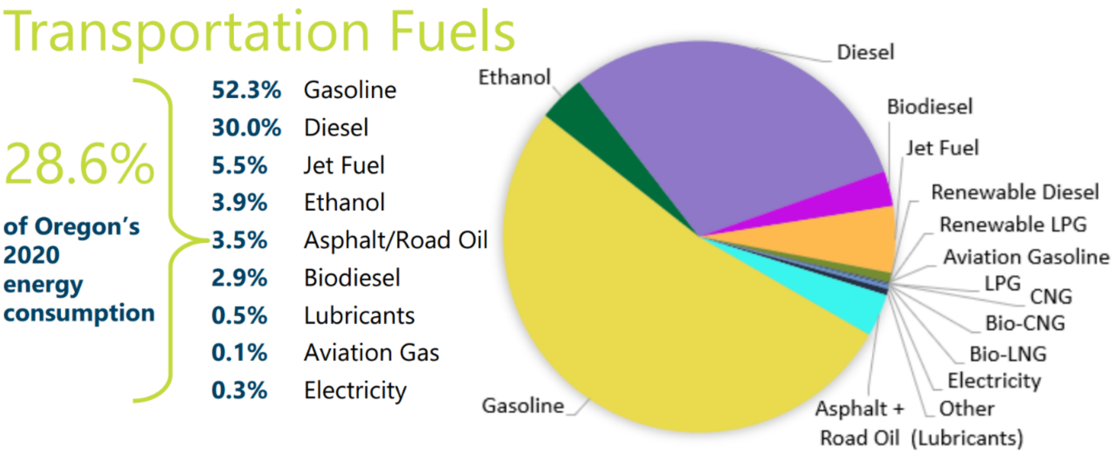
Developing an intentional strategy that relies upon a diverse portfolio of clean energy resources (e.g., solar, offshore wind, hydropower, robust transmission buildout, etc.), even if it may not be the least-cost option, could help mitigate the risks of supply chain disruptions disproportionately impacting one technology more than another. Sourcing certain technologies, like solar PV panels, from domestic manufacturers could also help to mitigate these concerns.

All energy resources and related infrastructure incur some level of adverse effects and trade-offs: what are they and how can we avoid, minimize, mitigate, and compensate for them?

The development of any energy resource comes with some associated trade-offs. Below are some examples of the types of broad trade-offs that must be considered as investments in clean energy are made to meet mid-century policy targets. It is important to acknowledge these trade-offs and to understand how these trade-offs may adversely and inequitably affect certain communities, depending on the type and location of the resource being developed.

Transportation Sector Examples

The transportation sector includes personal, passenger, and commercial vehicles, both on and off the roads, plus airplanes, boats, barges, ships, and trains. As of 2022, nearly all transportation fuels are imported from out-of-state for consumption in Oregon. Currently the transportation sector primarily uses gasoline and diesel, while the studies reviewed find the need to rapidly transition to electrification and low-carbon fuels, like renewable hydrogen, to achieve mid-century policy targets.



While decarbonizing the transportation sector will reduce the negative effects associated with petroleum use, there are also challenges associated with the low-carbon alternatives, including the extraction of lithium for EV batteries, the need to develop more renewable generating capacity to fuel electric cars or produce renewable hydrogen, the charging and fueling infrastructure to support new technologies, and the affordability of these new technologies for some customers. Examples include:

- **Renewable hydrogen** is an option for decarbonizing the transportation sector sited in the studies reviewed. As an end-use technology, the use of hydrogen has some unique appeal for the transportation sector, as customers would be able to travel a similar distance on a tank of fuel and could refuel in a similar amount of time compared to gasoline cars. But new infrastructure would be required to produce, store, and deliver renewable hydrogen at-scale to fuel a substantial portion of the transportation sector.[v] For example, a significant amount of renewable electricity would be necessary to power the electrolyzers to produce renewable hydrogen, and, as discussed below, there are trade-offs involved with the large-scale buildout of renewables.
- **Lithium-ion batteries** are used to power electric cars, as well as to store grid-scale electricity – and they are also used in smartphones and laptops. In the U.S. alone, stationary battery energy storage (to support renewable energy generation) is expected to grow from 523 megawatts annually to 7.3 gigawatts in 2025, and U.S. roads are projected to see 46 million passenger electric vehicles (EV) by 2035.[20] Critical minerals (e.g., cobalt, lithium, nickel, graphite, manganese) used in batteries are finite and mined in only a few regions around the world. Moreover, these minerals are often found and refined in countries with less stringent environmental, labor, and public health regulations. The demand for graphite, lithium, and cobalt is expected to increase by nearly 500 percent by 2050 with the potential for shortages of some minerals by the end of this decade if current trends for mobile and stationary batteries persist.[20] Lithium can be extracted through open-pit mining, like many other minerals, as well as methods that involve taking superheated, mineral-rich brine found underground and pumping it up to the Earth's surface. Lithium is extracted from that brine and then the brine is reinjected back into the earth. Both of these methods have large land footprints, are often very water intensive, and can create contamination and waste. Right now, most of the commercially harvested lithium comes from Australia and some countries in South America, namely Chile. Some companies have explored a method of extraction that involves geothermal energy that could have less environmental impact. The California Energy Commission estimates that there's enough lithium in the Salton Sea area to meet all of the United States' projected future demand and 40 percent of the world's demand, and there are at least 10 geothermal plants and lithium extraction projects in progress there.[21] Also, extending the useful life of batteries through reuse and recycling lowers lifecycle environmental impacts by reducing energy output and the costs of obtaining, transporting and refining virgin materials required to manufacture new batteries.[20] There are also efforts underway to develop novel battery technologies that avoid or minimize the use of rare earth minerals and instead rely on more abundant materials.

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[v] For more information, see the Oregon Department of Energy's *2022 Renewable Hydrogen Report* (Available November 15, 2022): https://tinyurl.com/ODOE-Studies

Trade-Offs in Focus: Zero-Emission Vehicles

Policy Goal: Reducing greenhouse gas emissions in the transportation sector by accelerating a transition to zero emission vehicles

Key Policy Question: How much will electric vehicles with lithium-based batteries drive the decarbonization of the transportation sector?

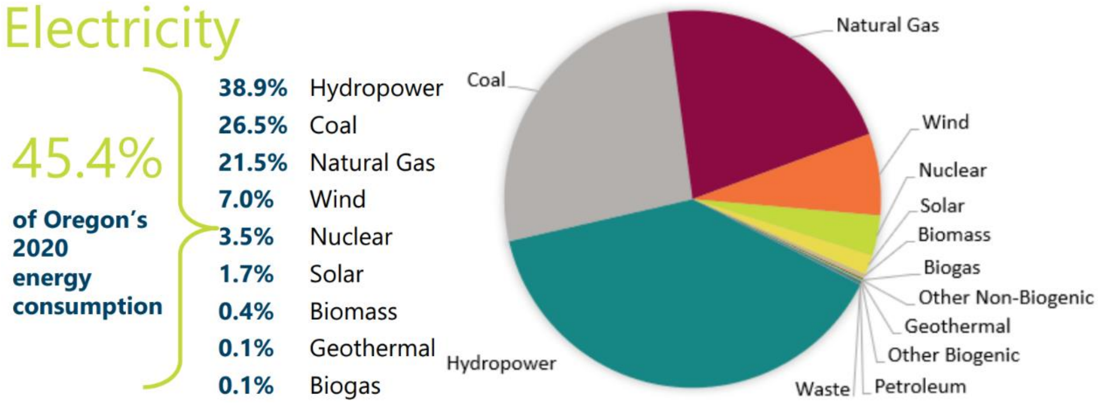
Framing the Trade-Offs: Decarbonizing the transportation sector is a critical component of achieving mid-century clean energy and climate policies, but the options for doing so involve potential adverse effects.

For example, policies to support current electric vehicle technology—which is becoming significantly more cost effective—will require the mining of large volumes of lithium. As with other zero-emission vehicle technologies, these adverse effects will be mitigated in some ways by a reduced need to extract petroleum products and a reduction in GHG emissions associated with fossil-fuel powered vehicles, but localized impacts will likely be distributed unevenly.

As an alternative, policies could support additional research and development of other alternative zero-emission vehicles (such as EVs with innovative batteries that avoid the need to mine for lithium and other rare earth minerals, or production of low-carbon fuels like renewable hydrogen), but these technologies may be more expensive and/or lack commercial viability on the timeline required to achieve policy objectives. These technologies will also have other potential adverse effects, such as the need to develop additional renewable generation (along with the associated land use and fish and wildlife impacts) to produce renewable hydrogen.

Electricity Sector Examples

The electricity Oregonians use comes from facilities located in the state and across the western United States. Some of the in-state facilities also import fuel from out-of-state, which is the case with natural gas plants. The largest source of electricity comes from the hydroelectric dams on the Columbia River and its tributaries. As of 2022, solar and wind facilities make up a relatively small percentage of the electricity that Oregonians consume on an annual basis. But their contribution, particularly from solar, has grown in recent years as costs have fallen over the last decade. As discussed earlier, the studies reviewed find the need to deploy substantial amounts of new wind and solar capacity in the years and decades ahead. While these renewable energy resources do not emit greenhouse gas emissions, they do have other negative effects that policymakers should consider



38.9%	Hydropower
26.5%	Coal
21.5%	Natural Gas
7.0%	Wind
3.5%	Nuclear
1.7%	Solar
0.4%	Biomass
0.1%	Geothermal
0.1%	Biogas

when evaluating tradeoffs associated with the clean energy transition. Examples of the negative effects of clean energy generation resources include:

- **Hydropower** is the largest existing energy resource in the region – and it is carbon free. However, there are significant and documented fish and wildlife impacts, particularly for threatened salmon and steelhead species within the Columbia River Basin. In some places, like the Grand Coulee and Chief Joseph dams in northeast Washington, fish passage is impossible, and the native salmon populations upriver from those dams have been eliminated. The remainder of the federal dams on the Columbia and Snake Rivers – including those along Oregon's border – have fish passage structures that allow returning adult salmon to pass over the dams, but these dams still take a toll, such as when juvenile salmon and steelhead pass through the powerhouse at these hydropower projects. These fish species can also suffer adverse effects in the warmer, slower moving waters impounded behind these hydropower projects. And they can fall prey to predators like sea lions and certain avian species, which have thrived in the conditions the dams created. Fish biologists have also identified that the stressors placed on these fish that survive passage through multiple reservoirs and dams can have adverse effects on longer-term survival.[22] Many Tribal Nations in the Pacific Northwest signed treaties in the 1850s with the U.S. government ceding land. A critical element of those treaties was preservation of the rights for Tribal Nations to continue to fish and to gather foods as they always have since time immemorial. They preserved the right to fish on Tribal lands and at usual and accustomed places, which has been interpreted over the years as the need to have sufficient fish in the rivers for Tribes to be able to catch, in order to honor those treaty rights.[23] At the same time, electricity marketed from the Bonneville Power Administration from the federal hydropower system can provide as much as 22,000 MW of carbon-free power,[24] and in recent years has provided about 40 percent of the electricity that Oregonians consume on an annual basis. This provides an important, existing base of carbon-free power for the Pacific Northwest, which results in the region having among the cleanest electricity mix in the United States. The climate benefits of this clean electricity are also important for the survival of salmon, which are threatened by decreasing freshwater flows and increases in temperature associated with climate change.[25]
- **Solar** facilities can occupy a large amount of land and can have adverse effects on natural and cultural resources. Large-scale projects in Oregon also tend to be concentrated in the eastern portions of the state. It takes approximately 6 acres of land to support 1 MW of ground mounted solar PV, which would mean 500 MW of solar would require about 3,000 acres (or 4.7 square miles). A 500 MW solar facility would produce approximately 140 aMW of energy output annually, assuming a 28 percent capacity factor.[26] And while rooftop solar can avoid these land use impacts and make a meaningful contribution, there are limitations on how much those systems can contribute to the scale of the need identified in the studies reviewed. For more information, see the excerpts from the *LA100* study included in the Electricity section of this Policy Brief. There are also concerns with the energy used in the production of PV panels, particularly when manufactured in countries that still use significant quantities of coal power.

Siting Snapshot

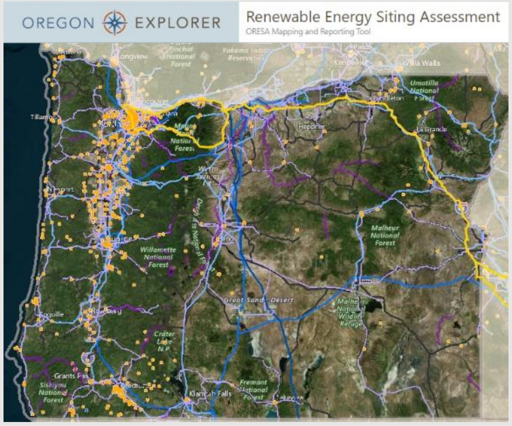
Oregon's Energy Facility Siting Council, which is staffed by the Oregon Department of Energy, has established requirements for what happens to both land where facilities are sited and equipment like wind turbines and solar panels when they are decommissioned.

During the application process, the Council ensures that project developers have the expertise to not only construct and operate a project, but also retire the facility and restore a site to a useful, non-hazardous condition. It is also requires that a certificate holder retire the facility if construction or operation is permanently ceased.

In order to prevent a certificate holder from getting out of this obligation later, the Council also requires a bond or letter of credit to be in effect at all times until the facility is retired. The Council determines the amount for that bond or letter of credit, called the retirement cost. For example, the largest permitted solar project in Oregon, the Obsidian Solar Center, has a retirement cost of $28.3 million to ensure that resources are available to restore the site.

One frequently asked question involves what happens to wind turbines, solar panels, and batteries when they are no longer operational. Oregon Revised Statutes direct the Energy Facility Siting Council to adopt standards for the reduction of solid waste. The Council requires a materials analysis during the application process and has a waste minimization standard. The Council also recommends conditions that applicants must agree to, including – as applicable – the development of a project solar panel recycling plan, a requirement to use reused or recycled wind turbines to the extent practicable, or annual reporting on the quantities of removed wind turbine components and how they were disposed.

Oregon Renewable Energy Siting Assessment (ORESA)



A thoughtful approach to deploying renewable energy sources at the scale required to achieve policy goals should seek to minimize or avoid conflicts, and will require close coordination and careful consideration of a wide range of factors. Published in June 2022, the Oregon Renewable Energy Siting Assessment project developed a comprehensive, online Mapping and Reporting Tool and report to explore and better understand the opportunities and constraints of future renewable energy development in Oregon. This project confirmed that there is enough renewable energy potential in the state to meet Oregon's energy and climate goals, while acknowledging that there are tradeoffs related to impacts and benefits with development that need to be evaluated through sustainable and responsible processes. In the tool, users can interact with more than 250 spatial datasets and explore key themes from the report related to energy planning, military coordination, siting and permitting, and inter-agency collaboration, coordination, and community engagement.[27] Learn more, read the report, and access the tool online: www.tinyurl.com/ORESA

- **Wind** projects have been deployed on land in Oregon for decades, with more than 3,500 MW of capacity installed as of 2022. Siting and permitting the development of these projects required avoiding, minimizing, and mitigating adverse effects on existing land uses and wildlife, such as bird strikes. Meanwhile, Oregon has access to one of the strongest offshore wind resources in the world – a large ocean area located in federal waters off its southern coast – where floating offshore wind projects could be deployed. There is strong interest in the potential to develop this resource to contribute to Oregon and the region's clean energy goals, with exploratory activities and studies currently in process.[28] Offshore wind projects, if deployed at scale, could occupy large areas of the ocean off Oregon's southern coast, with the potential for adverse effects on fisheries and other existing industries that rely on the ocean. On the other hand, because offshore winds are stronger, more consistent, and more abundant than land-based winds, developing this resource could make a critical contribution to achieving mid-century clean energy policies, while also offsetting the need to develop other clean technologies on land and creating significant new economic development opportunities for coastal Oregon. According to NREL, one square mile of ocean can accommodate approximately 7.5 MW of installed offshore wind capacity.[29] As a result, a 500 MW offshore wind project would require approximately 65 square miles of space in ocean and could generate about 250 aMW of energy output (assuming 50 percent capacity factor[30]).

Trade-Offs in Focus: Natural Resource Impacts of Clean Energy Generation

Policy Goal: Achieving Oregon's statutory target of 100 percent clean electricity by 2040, while also supporting more zero-emission vehicles

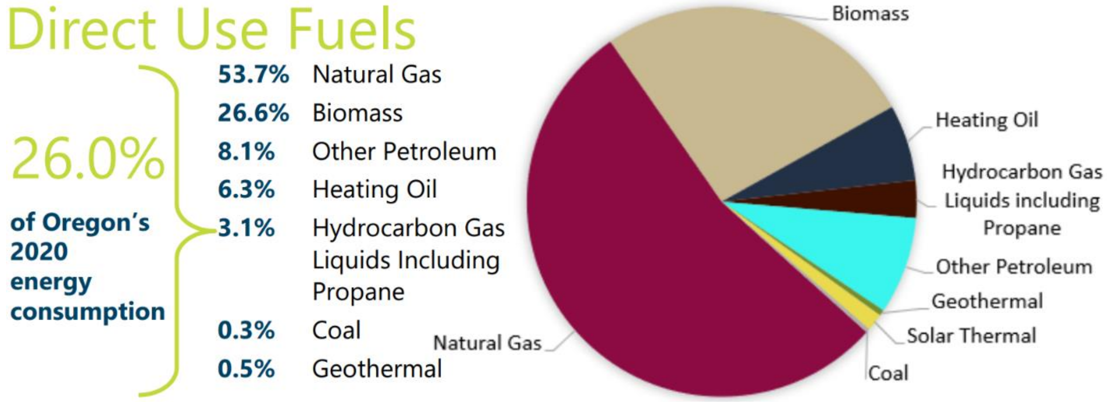
Key Policy Question: A portfolio of clean electricity resources will be required to achieve mid-century clean energy and climate policies. Can the state identify an optimal portfolio design that balances the trade-offs associated with the scale of clean energy development necessary to achieve policies?

Framing the Trade-Offs: The existing hydropower resource is immense in scale and is the primary reason that the state currently has some of the cleanest electricity in the nation. But there exist few opportunities to develop new hydropower resources at-scale. Additionally, some in the region have advocated exploring a pathway that would lead to removal of the four Lower Snake River Dams,[31] which account for approximately 1,000 aMW of clean energy annually in the region, to restore threatened salmon and steelhead species within the Columbia River Basin. While this could help to restore fish populations, it would result in the loss of a valuable, flexible carbon-free power resource that would need to be replaced with other carbon-free resources that also have potential adverse effects on the natural environment and wildlife.

As noted above, solar resources can occupy a significant amount of land. The studies reviewed to develop this series of briefs finds that tens of gigawatts of new wind and solar capacity is likely to be needed in Oregon to achieve policy goals. To put this land use footprint in perspective, the Oregon Zoo occupies 64 acres, which means that an area that size that is suitable for hosting solar could accommodate approximately 10 MW of installed solar capacity. It would require a land area 100 times the size of the Oregon Zoo to accommodate 1 GW of solar capacity.

Developing the state's offshore wind resource offers a potentially valuable tool to minimize the land use impacts of solar and the adverse effects of the hydropower system on threatened salmon and steelhead. However, the development of offshore wind resources will also incur trade-offs. As noted above, large areas of coastal waters would be required for developing this resource at scale and this development has the potential to harm fish, marine life, and other ocean users.

Natural Gas Sector Examples



Direct use fuels include fuel oil and natural gas that is used to heat homes and commercial spaces, fuels used for other residential purposes, such as gas stoves, and fuels used directly in industrial processes. The primary direct fuel used in Oregon is natural gas. Electric utilities will need to phase out the use of fossil gas in the generation of electricity to comply with HB 2021. Meanwhile, pursuant to Oregon's Climate Protection Program, natural gas utilities will need to develop strategies to reduce carbon emissions from their gas supply by 90 percent from an average of 2017-2019 levels in the decades ahead (by 2050). This is reflected in NW Natural's *Vision 2050* which was reviewed as part of this policy brief series. Most studies reviewed point to electrification as a primary means of decarbonizing current natural gas end uses. In addition, the use of renewable natural gas (such as captured methane from wastewater treatment plants or from dairy farms) or renewable hydrogen produced from wind and solar powered electricity have also been identified as pathways available for decarbonizing this supply of gas for direct-use applications.[vi]

Trade-Offs in Focus: Decarbonization of the Natural Gas Sector

Policy Goal: Reducing emissions from the direct use of natural gas

Key Policy Question: Can Oregon identify an optimally balanced pathway to decarbonize the natural gas sector?

Framing the Trade-Offs: Pathways are available for developing low-carbon fuels (like RNG and RH2) at scale that could use existing gas infrastructure to supply clean energy to Oregonians.

[vi] For more information on potential feedstocks, see ODOE's 2018 RNG Inventory Report and 2022 Renewable Hydrogen Report (coming November 15, 2022): www.tinyurl.com/ODOE-Studies

This would have the advantage of leveraging existing investments in gas infrastructure to deliver large volumes of clean energy to customers to replace the direct use of natural gas, such as for space and water heating applications. That said, there are challenges associated with the production of these low-carbon fuels at scale. For example, a significant amount of additional renewable electricity generation would need to be developed to produce large volumes of renewable hydrogen. There are significant trade-offs involved with the scale of renewables buildout anticipated to decarbonize the electric sector already which would be exacerbated by needing to develop even more renewables to produce renewable hydrogen. One of the drivers of this has to do with the efficiency losses that would occur when converting renewable electricity to hydrogen using an electrolyzer, a technology whose efficiency ranges from about 50 percent to 80 percent depending on type and size.

Electrification of current direct-use natural gas applications, meanwhile, is another potential pathway to decarbonization of the sector. While this would also require the development of additional renewable generating capacity, the renewable electricity generated could be used directly by electric end-use appliances without having to first be converted into hydrogen, thereby avoiding the costs and efficiency losses of that conversion process. On the other hand, electrification of these end-uses would require new investments in electric end-use appliances to replace existing gas appliances and has the potential to result in substantial stranded assets in the form of existing gas infrastructure.

Conclusions and Considerations to Chart a Path Forward

The studies reviewed as part of this policy brief series identify that there is no single pathway to achieving the state's clean energy and climate policies, but rather there are multiple pathways – each with its own unique cost profile and associated trade-offs for Oregon's natural resources and its people. This brief focuses on select examples of these types of tradeoffs facing the state as it charts its path to achieving mid-century policy objectives. A combination of regulation and standards to *require* specific actions as well as programs and incentives to *encourage* other actions could help resolve some of these policy choices.

The state would be well-served to engage a broad group of stakeholders to design intentional technical analysis that is responsive to the interests of Oregonians to identify Oregon-specific pathways to achieving mid-century clean energy and climate policies. This type of analysis and intentional planning to understand the potential tradeoffs of different pathways can help the state to minimize or mitigate potential adverse effects, while maximizing community and economic benefits across the state. It would also provide a critical foundation for development of a comprehensive state energy strategy that best positions Oregon to achieve its policy goals in a manner that is optimized for Oregonians. Such a strategy could be developed to address the types of core questions identified throughout this policy brief series, including:

- **Equity.** How can Oregon identify a pathway to 2050 that centers the concerns of historically marginalized communities?

- **Land Use.** How can Oregon identify a pathway to 2050 that balances the different land use and wildlife effects of clean energy developments?
- **Cost:** How can Oregon identify policy solutions to help mitigate the costs of the clean energy transition across sectors and type of customer, particularly for the state's most energy-burdened residents?
- **Resilience:** How can Oregon identify a pathway to 2050 that balances the scale and total cost of the clean energy transition with a secondary objective of seeking to improve community energy resilience across the state?
- **Fuel Choice:** How can Oregon identify a pathway to 2050 that balances maintenance of existing gas infrastructure with an increasing electrification of end uses?
- **Regionalization:** How can Oregon identify a pathway to 2050 that balances interests in developing in-state clean energy resources with the benefits that might accrue from increased regionalization?

Several states have conducted this type of analysis to inform the development of energy strategies that can guide investment, regulation, and project development in the energy sector. For example:

- **Wisconsin** developed and published a clean energy plan in April 2022.[32] It provides a framework to help ensure that Wisconsin businesses, communities, and people are well-positioned to share in the work of this plan and to take advantage of the large influx of federal dollars for clean energy and environmental justice initiatives. The Wisconsin plan objectives include all electricity consumed within the state to be 100 percent carbon-free by 2050, reducing the disproportionate impacts of energy generation and use on low-income communities and communities of color, and improving reliability and affordability of the energy system (among others). The Wisconsin plan identifies areas where further analysis will be needed to inform new legislation, programs, or changes in policies and procedure, while also identifying core strategies and actions, including: accelerating clean energy deployment, maximizing energy efficiency, modernizing buildings, supporting transportation innovation, prioritizing equity, and fast-tracking workforce development.
- **Washington** developed and published a state energy strategy – one of the studies reviewed for this policy brief series – that offers a blueprint for how the state can nearly eliminate the use of fossil fuels by 2050 while continuing to maintain and grow a prosperous economy.[33] It is informed by detailed technical analysis and modeling and covers transportation, buildings, industry/workforce, equity, electricity, and decarbonization modeling. The strategy identifies key actions in the following areas: communities, transportation, buildings, and industry.

Oregon policymakers have responded to the clear and present risks of climate change by committing the state to transition its economy away from fossil fuels and toward clean energy. Achieving these policy commitments will require substantial new investments by 2050, as identified by the studies reviewed for this policy brief series. The state has an opportunity over the next several years to engage stakeholders to develop an intentional strategy for how Oregon can accelerate this transition in a way that is equitable, that considers the respective of trade-offs between different clean energy pathways, and that defines a path forward for Oregonians.

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