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10/26/21

Ms. Kim Herb
Utility Strategy & Planning Manager
Oregon Public Utility Commission
kim.herb@puc.oregon.gov

Dear Ms. Herb,

Cascade Natural Gas Corporation appreciates the opportunity to submit comment as part of UM 2178, the Natural Gas Fact Finding. Our comments pertain to the discussion around Regulatory Tools which took place during Workshop #4b on October 12, 2021.

During the last two workshops associated with this Fact Finding, the Regulatory Assistance Project (RAP) has been tasked with sharing their perspective on resources available to pursue decarbonization. We appreciate the opportunity to hear RAP's perspective on additional regulatory mechanisms to achieve GHG emissions reductions. However, we are concerned that some pathways identified by RAP appear to be based on unexamined presuppositions regarding the exclusive viability of electrification as the sole tool for achieving decarbonization. We believe this premature conclusion may inadvertently limit pathways to decarbonization by centering prescriptive solutions over more dynamic pathways to GHG emissions reductions.

The Fact Finding provides the LDCs and our regulators an opportunity to understand the potential impacts associated with LDC's compliance with emission reduction targets resulting from the Governor's Executive Order 20-04. It is important to consider the multiple pathways, and associated impacts of various decarbonization strategies, and the method of achieving those reductions should be allowed to remain dynamic. This means designing regulatory tools that allow flexibility in the utilities' approach to decarbonization, and award innovation. However, during the discussion on October 12, options listed during breakout conversations as points of discussion focused disproportionately on electrification. Prompts to encourage stakeholder response demonstrated a leaning towards discontinuation of fuel neutrality, and migration of natural gas customers towards electrification. RAP also expressed positions that appear predisposed toward electrification as the primary means by which the State's GHG emissions goals may be accomplished.

We are concerned that a narrowed definition of decarbonization to be exclusively synonymous with electrification would likewise result in narrowed regulatory tools that may not be best cost, nor equitably mitigate potential harm to natural gas consumers, resource adequacy, and the economy as a whole.

Many of the ratemaking tools identified by RAP, such as updating customer contributions to line extensions, accelerated depreciation, and changes to energy efficiency incentives suggest a binary approach to decarbonization in which the continuation of gas infrastructure and gas services by LDCs is assumed to be in inherent opposition to the cost-effective reduction of GHG emissions. However, independent analysis has suggested that gaseous fuels paired with robust energy efficiency, and limited/strategically targeted electrification provides a stronger, more economically viable strategy for decarbonization in the State of Oregon.

As part of their engagement in the Department of Environmental Quality (DEQ)'s Rulemaking Advisory Committee (RAC), the Rural Service Providers contracted with Guidehouse to perform analysis on the modeling performed by the DEQ, as well as to examine an additional modeling scenario that considered the application of low-carbon fuels paired with aggressive energy efficiency, to achieve the State's decarbonization goals.

The memo, which has been submitted as an attachment to our comments, concluded that "a singular focus on electrification of end uses as the primary means to reduce GHG will lead to resource constraint issues and will require material investments in new infrastructure to generate, transmit, and distribute electricity to meet the increased electric demand resulting from electrification activities." The analysis also estimated that the low carbon fuels scenario would be 25% more cost effective on a dollars-per-ton basis than the DEQ-modeled high-electrification scenarios.

Cascade encourages the PUC to consider this independent analysis as they examine the cost impacts associated with decarbonization. We also recommend Guidehouse be provided an opportunity to share these findings as part of a future workshop to ensure that multiple pathways and perspectives are considered in addition to those offered by RAP's electrification-centered leanings.

As part of the discussion on October 12, the PUC also raised several questions of stakeholders which have been addressed below.

What customer impacts related to Oregon's natural gas decarbonization efforts do you think are most important for the Commission to address?

Cascade believes it is important for demonstrable and cost-effective GHG emissions reductions to result from the State's natural gas decarbonization efforts. Such reductions should be achieved based on a least-cost, least-impact basis for Oregon's ratepayers. Least cost pathways are best supported by ensuring that multiple fuel and technology pathways are available to achieving GHG emissions reductions. Regulated entities and ratepayers should be empowered to invest in decarbonization strategies that are best-cost for their operations, and are solely focused on resultant emissions reductions, rather than favoring a particular fuel or technology. This allows Oregon homes and businesses that have come to rely on gaseous fuels to continue to do so, while ensuring that regulatory tools are available to incentivize decarbonization of pipeline gas. An all-of-the-above approach to decarbonization would also support continued resource

adequacy which is essential to avoiding brownouts and adverse impacts to health and safety resulting from no-heat situations and extreme weather events.

How can existing planning processes be utilized or expanded to incorporate changing circumstances?

The existing planning process can be leveraged to consider the avoided cost of carbon. Negative discount rates can also be applied to empower natural gas utilities to pursue expanded energy efficiency in partnership with the Energy Trust of Oregon, and to expand investments in gas decarbonization technologies, carbon sequestration, renewable natural gas, and pursuit of hydrogen development. This allows flexibility for pipeline fuel suppliers to decarbonize our systems in the same way electric utilities have been empowered to decarbonize their wires through the use of solar, wind, and hydroelectric resources. Zero, or negative discount rates will help move this process forward by recognizing that investments in the decarbonization of the gas pipeline yield long term benefits for the climate.

What can be done within the existing framework to integrate with electric planning (e.g., timing of planning efforts, information exchange, requirements to cross-reference information, requirement for input from gas/electric utilities?)

As the analysis performed by Guidehouse suggests, it will be important that a realistic assessment of GHG emissions for both the gas and electric sector be considered as regulatory tools are developed in support of best-cost decarbonization pathways. For example, the electrification of building heat and transportation end uses would increase emissions from electricity generation through 2040, the deadline for the power sector to comply with emissions targets from HB 2021. This should be taken into consideration as regulatory pathways and tools are considered.

What needs to be changed or added to develop a more integrated planning approach?

Cascade encourages the PUC to consider establishing additional workshops as part of the IRP process to ensure planning explores the emissions impact of the total energy system and not just the utility. These workshops would allow stakeholders to determine the best approach to utilize IRPs to incorporate consideration of emissions impact and costs of a wide variety of decarbonization pathways. IRP planning will have to move beyond traditional least cost, least risk metrics, and these additional workshops may require modification of the current IRP process timeline to include expanded discussion of decarbonization pathways beyond a direction narrowly focused on a single fuel or technology.

What programmatic tools would you recommend that the Commission implement immediately, near-term, and long-term to facilitate meeting climate goals with least risk to customers? Why would you prioritize these tools over others?

Cascade encourages the PUC to support the Energy Trust of Oregon in its continued pursuit of fuel and technology neutral energy efficiency opportunities. The PUC should consider allowing additional monies to be directed towards the pursuit of renewable natural gas placed into the pipe to offset geologic gas for Oregon ratepayers, as well as the inclusion of tools and resources for achieving GHG emissions reductions for transport customers. Opportunities could further be identified in partnership with DEQ to ensure pathways for carbon sequestration and voluntary offset development.

What ratemaking tools would you recommend that the Commission implement immediately, near-term, and long-term to facilitate meeting climate goals with least cost to customers? Why would you prioritize these tools over others?

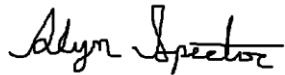
The Commission should immediately allow for the recovery of energy efficiency and other gas-decarbonization strategies for transport customers, support the design of a cost-test methodology that takes the avoided cost of GHG emissions into account in order to support the LDCs in meeting compliance with the Climate Protection Program.

What information is missing from the discussion so far?

As stated earlier, Cascade believes that it is essential for conversations around decarbonization strategies to be approached in a manner that meets the needs of all ratepayers and does not favor a specific approach or technology. Instead, tools should allow flexibility so that GHG emissions can be reduced in regionally and economically appropriate ways that support continued resource adequacy and energy resiliency. GHG emissions reductions should be quantifiable, verifiable, and approached in a manner that minimizes unintended consequences or economic harm.

We thank you again for the opportunity to submit comment on UM 2178 and look forward to the opportunity for Guidehouse to present on their findings as a part of this essential Fact Finding.

Respectfully Submitted

A handwritten signature in black ink that reads "Alyn Spector". The signature is written in a cursive, flowing style.

Alyn Spector
Energy Efficiency Policy Manager
Cascade Natural Gas Corporation



Analysis of Oregon's Cap-and-Reduce Program GHG Emissions Reductions

Provided to:

**Avista Corporation and
Cascade Natural Gas Corporation**

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Disclaimer

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This memo describes modeling that Guidehouse conducted to understand how the adoption of different greenhouse gas emissions reduction technologies could affect statewide energy use and greenhouse gas emissions in Oregon. This memo also presents Guidehouse's estimate of the total statewide capital expenditure that would be required to implement emissions reduction technologies in different scenarios. The analysis presented does not examine health or economic impacts of program policies, the banking or trading of compliance instruments, or the purchase of alternative compliance instruments such as Community Climate Investment credits.

Guidehouse

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Executive Summary

In response to Governor Brown's Executive Order 20-04, the Oregon Department of Environmental Quality (DEQ), with support from the Oregon Environmental Quality Commission (EQC), has engaged stakeholders and the public in the development of a cap-and-reduce program to regulate greenhouse gas (GHG) emissions from natural gas utilities, fuel providers, and industry sources. The DEQ has stated three goals for the cap-and-reduce program: to reduce GHG emissions, contain costs, and promote equity. This analysis focuses on two of the program's three goals: the GHG emissions reductions mandated by EO 20-04 and the capital cost of investments required to achieve those reductions. This memo describes the results of Guidehouse's independent modeling (under contract to Avista Utilities and Cascade Natural Gas) to understand the economywide energy and emissions impacts and the capital investment requirements of decarbonization measures that would achieve the program's goals.

Background

The DEQ and its contractor used modeling tools to forecast the impacts that a cap-and-reduce program may have on GHG emissions, public health, and the economy. The DEQ modeled a Reference Case that forecasts future conditions based on existing regulations prior to adoption of a cap-and-reduce program. The DEQ also modeled program options in four policy scenarios and compared the scenario outcomes to the Reference Case to inform its rulemaking. DEQ's contractor presented summary assumptions and results of this modeling activity to DEQ's Rulemaking Advisory Committee (RAC) during a series of monthly RAC meetings from January to July 2021. During the final RAC meeting on July 8, 2021, the DEQ presented a fiscal impact statement that described the direct and indirect costs of compliance with the proposed rules, including administrative, reporting, and recordkeeping costs, as well as projected costs per ton of emissions reduced. DEQ's fiscal impact statement did not address the capital investments that would be required under different scenarios.

Among other RAC stakeholders, Avista and Cascade have raised concerns regarding DEQ's limited modeling, which considered electrification as the only pathway to compliance with the CPP, while ignoring resource adequacy concerns and emerging technologies (such as hydrogen). Stakeholders are also concerned that:

- DEQ's draft regulations do not consider GHG emissions associated with electric generation since the DEQ does not have purview over electric utilities.
- The scenarios modeled by DEQ assume a high degree of electrification, which would lead to resource constraint issues and shift GHG emissions to unregulated sources.
- DEQ's scenario modeling does not account for emissions leakage¹ to the electric sector that result from electrification of building heat, industrial processes, and transportation.

A singular focus on electrification of end uses as the primary means to reduce GHG will lead to resource constraint issues and will require material investments in new infrastructure to generate, transmit, and distribute electricity to meet the increased electric demand resulting from electrification activities. This memo examines several of DEQ's analytical assumptions that could limit future decarbonization measures and cause unintended consequences.

¹ DEQ defines "leakage" as the shifting of GHG emissions outside of Oregon or outside the scope of the program's regulation. DEQ (2020) "GHG Emissions Program 2021 Rulemaking: Background Brief" <https://www.oregon.gov/deq/Regulations/rulemaking/RuleDocuments/ghgcr2021KeyTerms.pdf>

Independent Modeling

Given DEQ does not have jurisdiction over all relevant energy market participants, Avista and Cascade contracted with Guidehouse to develop a transparent model that examines the economywide energy use and emissions impacts of the proposed cap-and-reduce program, as well as the statewide capital investments required to deploy emissions reducing technology. This analysis is not intended to serve as a substitute for a transparent and thorough analysis from DEQ. We used publicly available data to develop a Guidehouse Reference Case forecast. This forecast assumes that policies in place as of August 1, 2021 (including Oregon's House Bill 2021) remain in force and that no new policies are implemented to reduce GHG emissions. A comparison of the DEQ and Guidehouse Reference Case results confirms that the fundamental assumptions of Guidehouse's model are aligned with DEQ's model.

Guidehouse modeled the emissions outcomes of four policy scenarios presented by DEQ and one additional Low-Carbon Fuel scenario developed by Avista & Cascade that is focused on deployment of emerging technologies such as RNG and hydrogen. Each scenario is defined by a GHG emissions reduction target and an array of GHG reduction interventions that are deployed to reduce GHG emissions. Table 1 summarizes the GHG reduction technologies assumed in each scenario. The Guidehouse model introduces these emissions reduction technologies as interventions to the Guidehouse Reference Case, and the model calculates the collective energy and emissions impacts and the CAPEX requirements of each scenario's technology mix. For this analysis, Guidehouse used an electric generation mix forecast from the Guidehouse Spring 2021 Reference Case, which assumes a high penetration of renewables at levels exceeding current renewable portfolio standards (RPS), as well as some amount of gas-fired generation to maintain system resilience and meet peaking needs.

Table 1. Policy Scenario Summary

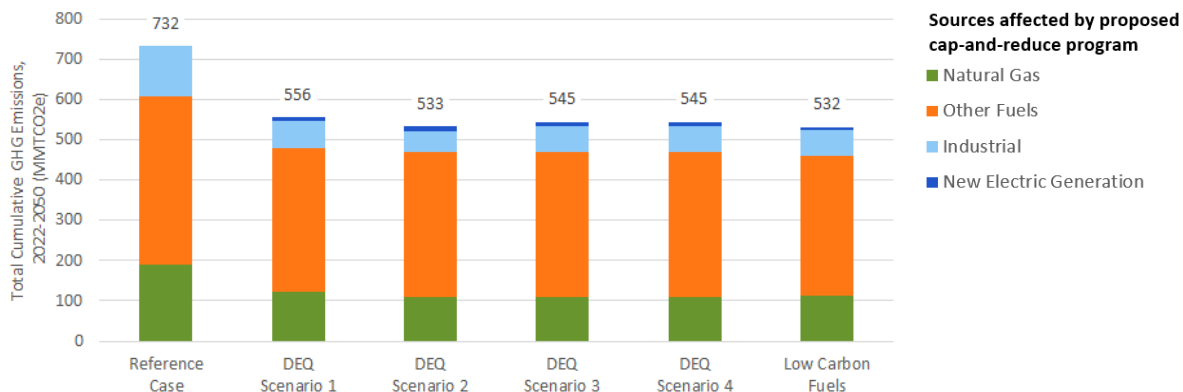
	DEQ Scenario 1	DEQ Scenario 2	DEQ Scenario 3	DEQ Scenario 4	Low-Carbon Fuel Scenario (developed by Avista & Cascade)
GHG emission cap	80% by 2050	80% by 2050	90% by 2050	90% by 2050	80% by 2050
Trading allowance	Allows trading	Limited trading	Allows trading	Allows trading	Allows trading
Alternative compliance instrument allowance	Up to 25%	Up to 5%	Up to 25%	Up to 20%	Up to 25%
Hydrogen (H ₂) technologies modeled	None	None	None	None	H ₂ -enriched natural gas (HENG), and industrial H ₂
Renewable natural gas (RNG) portion of gas supply	Moderate	High	High	High	High
Energy efficiency improvements in all sectors	Low	Low	Low	Low	High
Electrification of building heat and hot water	High	Very High	Very High	Very High	Moderate
Transport electrification beyond SB.1044 goals	Moderate	Moderate	Moderate	Moderate	Moderate
Electrification of industrial processes	Moderate	Moderate	Moderate	Moderate	Low

Figure 1 presents the cumulative GHG emissions for each of the five scenarios from sources that the cap-and-reduce program would regulate over the 2022-2050 period. Note that this figure does not account for any emissions reductions that may be achieved through the use of Community Climate Investments, since the actual projects and timeline of the proposed CCI program are currently not well defined. The dark blue bars on the chart show the increase in electric sector GHG emissions resulting from electrification activities.

Figure 2 presents the portion of total 2050 energy use from each fuel type for the five scenarios considered. These figures illustrate that:

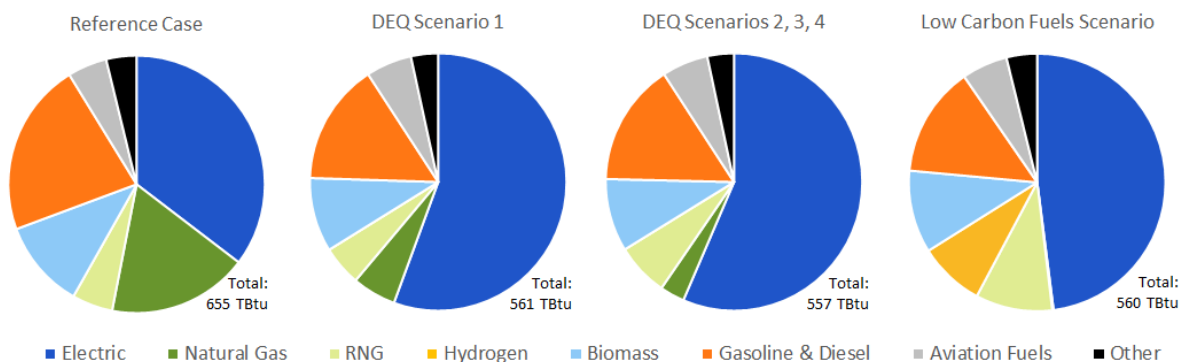
- DEQ Scenarios 2, 3, and 4 arrive at the same mix of energy sources in 2050 since they contain nearly identical assumptions regarding GHG reduction technologies.
- DEQ Scenario 1 results in the highest cumulative emissions for the 2022-2050 period, in part because it assumes the lowest level of RNG development.
- The Low Carbon Fuels scenario provides the greatest reduction in cumulative GHG emissions by applying energy efficiency, low carbon gas technologies, and moderate electrification.
- The Low Carbon Fuels scenario shows that in 2050, the demand for gaseous fuels can be mostly met by RNG and hydrogen. This is in part because natural gas consumption is forecast to decline due to energy efficiency and electrification measures.

Figure 1. Cumulative 2022-2050 GHG Emissions from Sources Affected by Cap-and-Reduce Program



Source: Guidehouse analysis

Figure 2. Total 2050 Energy Use by Source, for Four Policy Scenarios



Source: Guidehouse analysis

Table 2. Cumulative State-wide CAPEX per Ton Emissions Reduction, 2022-2050, Incremental to Reference Case

	DEQ Policy Scenario 1	DEQ Policy Scenarios 2, 3, 4	Low Carbon Fuels Scenario
Scenario Summary	High Electrification	Very High Electrification	Moderate Electrification, EE, RNG, Hydrogen
Total Cumulative CAPEX Above Reference Case, 2022 to 2050 (\$B)	\$40.5 B	\$41.9 B	\$29.9 B
Total CO2e Reductions versus Ref. Case (MMTCO2e)	177 MMT	199 MMT	201 MMT
Total CAPEX Cost per Ton CO2e Reduced (\$/ton)	\$229 / ton	\$211 / ton	\$149 / ton

Guidehouse modeled the capital costs associated with each technology in this analysis and estimated the total CAPEX “price tag” for the state to deploy technologies sufficient to achieve the GHG reductions described in Figure 1. The purpose of this cost analysis is to compare the total cost and the cost effectiveness of different policy scenarios at a high level. As summarized in Table 2, the Low Carbon Fuels scenario would lead to more GHG reductions at a lower CAPEX. Guidehouse estimates that the Low Carbon Fuels scenario would be 25% more cost effective on a dollars-per-ton basis than the four scenarios that DEQ modeled.

Conclusions and Recommendations

The cap-and-reduce program proposed by DEQ would impact emissions and costs in sectors outside the scope of the program. The electrification of gas- and fuel-powered end uses would displace emissions from fuel providers (in scope) to electric generators (out of scope). Emissions leakage to the power sector may decline in later years as the power sector decarbonizes. Electrification will also lead to increases in peak electric demand, requiring investments in new capacity to generate, transmit, store, and distribute electricity. DEQ’s analysis of the cap-and-reduce program has not described the emissions or cost impacts that the program would have on the electric sector. At present, the Oregon Public Utilities Commission (OPUC) is conducting a fact finding process to analyze the potential natural gas utility bill impacts that may result from limiting GHG emissions of regulated natural gas utilities under the DEQ’s Climate Protection Program and to identify appropriate regulatory tools to mitigate potential customer impacts.

- **Recommendation:** To fully understand the potential impacts of DEQ’s Climate Protection Program, the OPUC should analyze the emissions and cost impacts that the proposed cap-and-reduce program would have on the broader energy system, rather than limiting their analysis to entities that would be covered by the program.

There are various pathways to decarbonization, and Guidehouse modeling shows that a pathway that uses low carbon fuels that complement energy efficiency and electrification deliver more cost-effective GHG reductions and achieve deeper decarbonization targets.

- **Recommendation:** The DEQ should maintain the flexibility of available compliance options in the draft rules available for direct emissions reductions from covered parties and expand the compliance options to include verifiable offsets and carbon sequestration.

Meeting the statewide goals of EO 20-04 will require emissions reduction from sectors of the energy economy for the proposed scope of the cap-and-reduce program. The proposed

Community Climate Investment (CCI) program² provides an avenue for investment in GHG reductions strategies in these sectors. There are opportunities for interventions to reduce GHG emissions in the non-energy residential, commercial, and agricultural sectors of the economy, for instance through improved wastewater management, improved refrigerant handling, and conservation tillage.

- **Recommendation:** Alternative compliance mechanisms such as CCIs should encourage innovation from regulated sectors and should incentivize a broad range of approaches to GHG reductions. Until the power sector is fully decarbonized, CCI entities should prioritize interventions that **eliminate emissions** over actions, such as electrification, that displace emissions to sectors outside the scope of the cap-and-reduce program.

The low-carbon fuels scenario that Guidehouse modeled emphasizes the delivery of low carbon gas through deployment of technologies (such as hydrogen) and, compared to the scenarios modeled by DEQ, the low-carbon fuels scenario resulted in greater reductions in economywide GHG emissions.

- **Recommendation:** The OPUC should consider a policy scenario in which emerging low carbon fuel technologies are a viable option used to deliver GHG emissions reduction with minimal impacts to the electric sector.

In a decarbonized future, pipeline networks could continue to support the reliability and resiliency of Oregon's broader energy system by transporting and distributing low carbon gas and hydrogen. These fuels can support decarbonization of hard-to-electrify uses such as heavy duty transportation and high temperature industrial processes. Guidehouse has previously analyzed and reported how the gas system contributes to US energy system resilience.³ DEQ's analysis of policy alternatives does not account for the benefit that pipeline networks and storage solutions provide as an energy source that complements intermittent renewable generation resources.

- **Recommendation:** Analysis of regulatory alternatives conducted by the OPUC should consider the reliability and resilience benefits of maintaining diverse energy delivery systems, including the pipeline infrastructure and storage network.

² The CCI program proposed by DEQ would provide an alternate compliance pathway for covered entities, whereby covered entities could purchase credits from non-profit CCI entities and the CCI entities would use the proceeds from these sales to fund projects that reduce GHG emissions.

³ American Gas Foundation (2021). "Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience" Available at: <https://gasfoundation.org/2021/01/13/building-a-resilient-energy-future/>

Introduction

In response to Governor Brown's Executive Order 20-04, the Oregon Department of Environmental Quality (DEQ) has engaged stakeholders and the public in the development of a cap-and-reduce program to regulate greenhouse gas (GHG) emissions from gas utilities, fuel providers, and industry sources. The DEQ stated three goals for the cap-and-reduce program: to reduce GHG emissions, contain costs, and promote equity. This memo describes the methodology and results of Guidehouse's independent modeling (under contract to Avista and Cascade) to understand the economywide energy and emissions impacts and capital investment requirements of the proposed program. This analysis focuses on two of the program's three goals: the GHG emissions reductions mandated by EO 20-04 and the capital investments that would be needed to achieve them.

DEQ's Modeling Efforts to Date

The DEQ convened a rulemaking advisory committee (RAC) to provide diverse perspectives on policy proposals including fiscal, environmental justice, public health, and economic impacts. At the RAC's second meeting on February 17, 2021, DEQ's contractor presented the Reference Case results, projecting emissions from different sectors through 2050 in the absence of a cap-and-reduce program. DEQ's contractor presented initial GHG emissions results from three policy scenarios at the third RAC meeting (March 18, 2021) and presented revised emissions results at the fourth RAC meeting (April 22, 2021). These policy scenario presentations showed emissions from entities that would be regulated under the cap-and-reduce program; but DEQ's results do not show how the program's activities could affect emissions from sectors outside of the program, such as the electric sector. DEQ has also stated that their modeling does not consider emerging GHG reduction technologies such as carbon capture and sequestration or hydrogen.

During the final RAC meeting on July 8, 2021, the DEQ presented a fiscal impact statement that described the direct and indirect costs of compliance with the proposed rules, but DEQ's fiscal analysis did not address the capital investments that would be required under different scenarios.

RAC Stakeholder Questions

Among other RAC stakeholders, Avista and Cascade have raised questions about the DEQ's singular focus on electrification in its modeled policy scenarios. Specifically, stakeholders have noted that:

- The electrification of building heat and transportation end uses would increase emissions from electricity generation through 2040, when the power sector must eliminate GHG emissions to comply with emission targets from Oregon House Bill 2021 (HB.2021).
- The DEQ appears to consider electrification as the default approach that a CCI program would use to reduce GHG emissions.
- The DEQ's policy scenario results (as presented to the RAC) do not account for emissions that would be transferred to the electric sector due to electrification, and the DEQ's fiscal impact analysis does not account for the capital costs associated with electrification.
- A high degree of electrification will lead to resource constraint issues and will require large investments in infrastructure to generation, transmit, and distribute electricity.

Avista and Cascade believe that an exclusive focus on electrification as the primary decarbonization solution will result in leakage⁴ or displaced emissions from the natural gas and other fuels sectors to the electric generation sector. As a result, electrification-focused policies risk falling short of delivering economywide emissions reductions in the ways presented by DEQ's modeling results.

To date, DEQ has not presented scenario results regarding the amount of emissions leakage from regulated entities to the electric sector. Nor has DEQ described the capital investment requirements and full cycle emissions that would be needed to meet the increased electric demand from high levels of electrification. This memo provides a thorough view of economywide emissions and costs to help readers understand the program's potential impact on emissions from regulated entities and emissions from sectors outside of the program's scope.

Independent Statewide Emissions Modeling

Avista and Cascade contracted with Guidehouse to develop a transparent model that examines the economywide energy use, emissions, and capital cost impacts of six potential pathways for Oregon, with various decarbonization measures that can be deployed to meet the cap-and-reduce program's targets:

- A Reference Case forecast of emissions in the absence of a cap-and-reduce program
- Four policy scenarios developed and presented by DEQ
- A low carbon fuel policy scenario that allows deployment of technologies such as hydrogen-enriched natural gas (HENG) and local supply of industrial green hydrogen

This modeling effort intends to understand how the adoption of different GHG reduction technologies could affect economywide emissions and statewide investment requirements in Oregon. Taking an economywide perspective enables consideration of the emissions and cost impacts to sectors such as power generation, which are outside the scope of the proposed program. The analysis presented here does not examine the program's health impacts, the operating expenses or fuel costs associated with GHG reduction measures, the banking or trading of compliance instruments, the purchase of alternative compliance instruments such as CCI credits, or unintended consequences such as the cost of retiring stranded assets. These points are important considerations that policy makers should consider in addition to the analysis presented here.

Methodology

Guidehouse created an independent model to forecast the energy use, emissions, and capital investment requirements associated with the Reference Case and policy scenarios, using technology assumptions presented by the DEQ. These assumptions include Oregon-specific, Oregon-adjacent, and Federal policies that impact the future energy mix, energy landscape, and emission sources, including utility programs.⁵ Guidehouse's economywide model forecasts changes in energy consumption through 2050 across all sectors of the economy, by fuel type and by end use. The model accounts for fuel used upstream to generate electricity and energy

⁴ The DEQ has defined leakage as the shifting of emissions or business to outside of Oregon or outside the scope of the program's regulation.

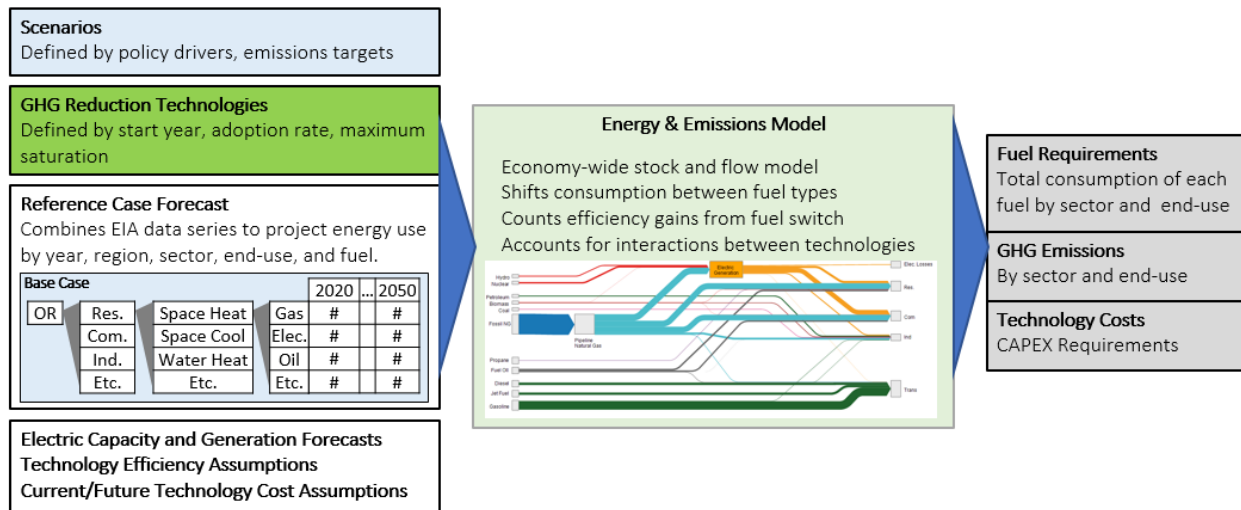
<https://www.oregon.gov/deq/Regulations/rulemaking/RuleDocuments/ghgcr2021KeyTerms.pdf>

⁵ The DEQ's assumptions regarding adoption of GHG emissions technologies are provided in a presentation titled, "Modeling Study: Assumptions and Background," available at:

<https://www.oregon.gov/deq/Regulations/rulemaking/RuleDocuments/ghgcrModAssumptions.pdf>

used downstream by customers. Figure 3 provides a schematic of Guidehouse's energy and emissions model.

Figure 3. Schematic of Guidehouse Energy and Emissions Model



Updates to Methodology

On May 24, 2021, Avista and Cascade provided DEQ and the RAC members with a memorandum describing an earlier version of this analysis that was conducted in April 2021, prior to DEQ's development of policy scenario 4, prior to DEQ's release of detailed assumption data, and prior to Oregon's enactment of HB.2021. Guidehouse has updated the analysis described herein to account for these new developments, with the following changes:

- A fourth DEQ scenario has been added to the analysis to model the scenario DEQ introduced in the RAC meeting on May 25, 2021
- The input assumptions for GHG reduction technologies have been aligned to the assumptions that DEQ provided in response to a public records request from the Northwest Gas Association
- The electric generation mix forecast has been updated to model power sector emissions assuming that the power sector meets the decarbonization targets set forth in HB.2021

Reference Case Methodology

Guidehouse used publicly available data to develop a Guidehouse Reference Case forecast, which assumes that policies in place on August 1, 2021 remain in force and no new policies are implemented to reduce GHG emissions. The Reference Case begins with 2018 energy consumption data by sector and by fuel, reported by the US Energy Information Administration's (EIA's) State Energy Data System (SEDS).

Guidehouse referenced the EIA's *Annual Energy Outlook (AEO) 2021* forecasts for the Pacific region to project energy consumption by sector and by fuel type through 2050. For the residential and commercial sectors, Guidehouse estimated the amount of energy consumed for different end uses (e.g., space heating, water heating) based on end use consumption estimates in EIA's Residential Energy Consumption Survey (RECS) and EIA's Commercial Building Energy Consumption Survey (CBECS).

For the power generation sector, Guidehouse estimated the future electric generation mix using the Guidehouse Spring 2021 Reference Case forecast, with the added assumption that natural gas electric generators will begin implementing carbon capture and storage (CCS) technologies in 2030 to reduce their carbon emissions to comply with House Bill 2021 targets.⁶ The Guidehouse reference case forecast approximates a world with high penetration of renewables at levels exceeding current RPS and some amount of gas-fired generation to maintain system reliability and meet peaking needs.

Policy Scenario Methodology

Guidehouse modeled the emissions outcomes of the four policy scenarios presented by DEQ and one additional policy scenario focused on low carbon gas deployment. Each scenario is defined by a GHG emissions reduction target and an array of GHG reduction interventions that are deployed to reduce GHG emissions. Guidehouse's model introduces these emissions reduction technologies as deviations from the Guidehouse Reference Case. The model calculates the collective energy and emissions impacts and CAPEX requirements of each scenario's technology bundle.

On June 18, 2021, DEQ provided a spreadsheet file containing detailed assumptions used to model the four policy scenarios that DEQ considered for this rulemaking.⁷ Using the data and information provided by DEQ, Guidehouse developed policy scenario assumptions to replicate the policy scenarios used in DEQ's model. The four DEQ scenarios examine various approaches to the cap-and-reduce program, with different GHG emissions trajectories and different limitations on compliance mechanisms like CCIs and trading. However, the DEQ scenarios show little variation in the technologies that would be deployed to achieve GHG reductions. All four DEQ scenarios assume a high or very high degree of building electrification, a moderate amount of transportation and industrial process electrification, a low amount of energy efficiency improvement, and a moderate supply of RNG. None of DEQ's scenarios consider the deployment of emerging technologies such as hydrogen, either blended in pipeline gas (as HENG) or supplied as a pure fuel. Table 3 summarizes these assumptions.

With input from Avista and Cascade, Guidehouse developed an alternate scenario that emphasizes energy efficiency and development of low carbon fuels, and that assumes a lesser degree of building heat and industrial process electrification compared to DEQ's scenarios. These assumptions are also included in Table 3.

Appendices to this memo include a list of referenced data sources and further modeling details.

⁶ Guidehouse uses a fundamentals-based market modeling approach to forecast the average generation mix of electricity generated in Oregon. Guidehouse forecasted these values for the 2020-2045 period using a proprietary capacity expansion model and PROMOD, a commercially available software model. Guidehouse used linear extrapolation based on prior 10 years to estimate the generation mix in the years 2046-2050.

Oregon's House Bill 2021 was signed into law July 19, 2021, and it established GHG emissions reduction targets for the state's two large utilities, Portland General Electric (PGE) and Pacific Power. The law requires these utilities to reduce GHG emissions 80% by 2030, 90% by 2035, and 100% by 2040, relative to a baseline of average annual emissions over 2010-2012.

⁷ A spreadsheet file titled "DEQ-ICF-GHGanalysis-2021.06.17.xlsx" was provided by DEQ via email to RAC participants.

Table 3. Policy Scenario Assumptions

	DEQ Policy Scenarios*				Low-Carbon Fuel** (developed by Avista & Cascade)
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	
Policy Scenario Definition					
GHG Cap	80% by 2050	80% by 2050	90% by 2050	80% by 2050	80% by 2050
Trading allowance	Allows trading	Limited trading	Allows trading	Allows trading	Allows trading
CCI use allowed	Up to 25%	Up to 5%	Up to 25%	Up to 20%	Up to 25%
Includes hydrogen technologies?	No	No	No	No	Yes
GHG Reduction Technologies					
Building Heat Electrification	High (83% of load)	Very High (90% of load)	Very High (90% of load)	Very High (88% of load)	Moderate (38% of load)
Building Hot Water Electrification	High (83% of load)	Very High (90% of load)	Very High (90% of load)	Very High (88% of load)	Moderate (39% of load)
Cumulative Efficiency Improvements over Reference Case	1% load reduction	1% load reduction	1% load reduction	1% load reduction	10% load reduction
Cooking Electrification	83% of gas load	90% of gas load	90% of gas load	88% of load	60% of gas load
Transport Electrification Beyond SB1044	49% of gasoline use 44% of diesel use				
RNG Supply	28 bcf/year	36 bcf/year	36 bcf/year	38 bcf/year	54 bcf/year
	50% of gas supply	75% of gas supply	75% of gas supply	75% of gas supply	84% of gas supply
	39% of potential	51% of potential	51% of potential	54% of potential	75% of potential
Hydrogen-enriched Natural Gas (HENG)	None	None	None	None	5% of gas supply, by energy
Industrial Process Electrification	44% of gas load	44% of gas load	44% of gas load	44% of gas load	15% of gas load
Industrial Local Green Hydrogen	None	None	None	None	75% of gas energy

* Guidehouse developed GHG technology assumptions for the DEQ policy scenarios based on examination of the scenario-specific data in the spreadsheet file "DEQ-ICF-GHGanalysis-2021.06.17.xlsx" that DEQ provided via email to RAC participants.

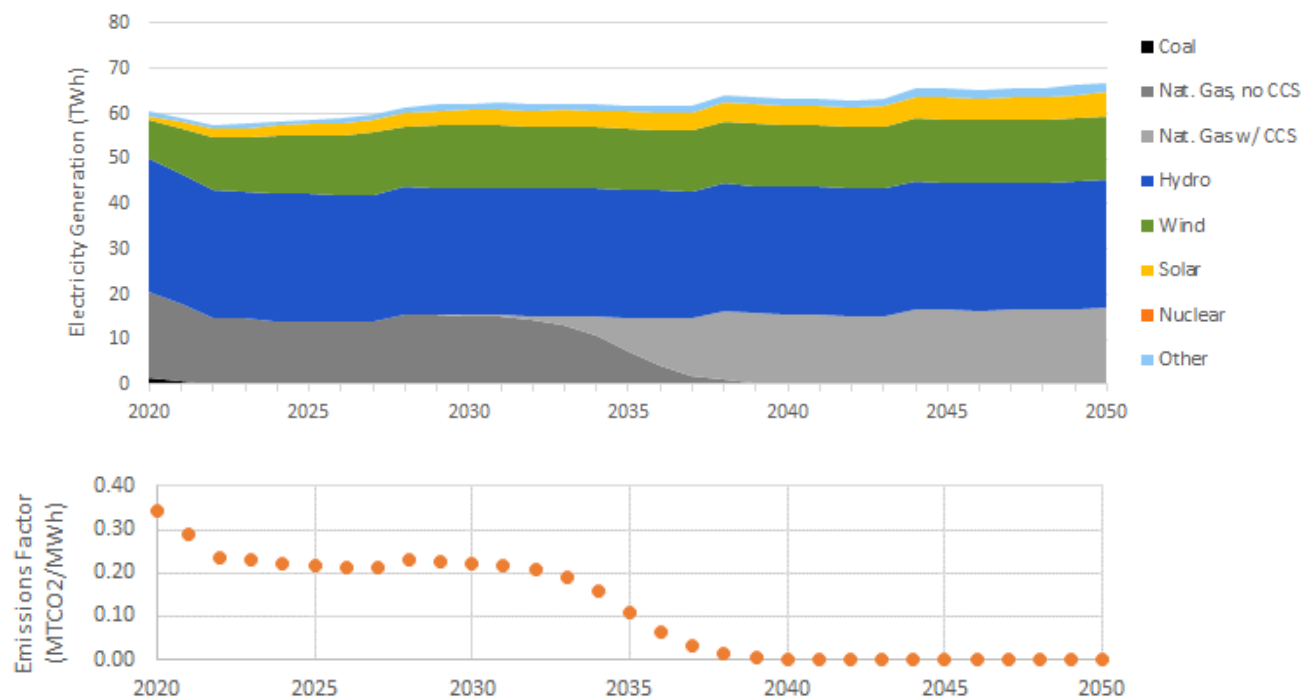
** Guidehouse developed GHG technology assumptions for the Low-Carbon Gas scenario based on our understanding of various gas technologies (detailed in Appendix B) and based on the "medium electrification" levels described in Table 1 of NREL (2021) "Electrification Futures Study: Scenarios of Power System Evolution and Infrastructure Development for the United States," available at: <https://www.nrel.gov/docs/fy21osti/72330.pdf>

Electric Sector Emissions

The emissions forecasts depicted in this memo are highly sensitive to assumptions regarding the electric sector generation mix and its evolution over the course of the study period. Oregon's House Bill 2021 (HB.2021) was signed into law July 19, 2021, and it established GHG emissions reduction targets for the state's two large utilities, Portland General Electric (PGE) and Pacific Power. The law requires these utilities to reduce GHG emissions 80% by 2030, 90% by 2035, and 100% by 2040, relative to a baseline of average annual emissions over 2010-2012.

This analysis forecasts the electric generation mix using the Guidehouse Spring 2021 Reference Case, with the added assumption that natural gas electric generators will begin implementing carbon capture and storage (CCS) technologies in 2030 to reduce GHG emissions and comply with HB.2021.⁸ The Guidehouse Spring 2021 Reference Case forecast approximates a world with high penetration of renewables at levels exceeding current RPS and some amount of gas-fired generation to maintain system reliability and meet peaking needs.

Figure 4. Electric Generation Mix and Emissions Factor Forecast, Guidehouse Spring 2021 Reference Case plus Carbon Capture



Source: Guidehouse Analysis

⁸ Guidehouse uses a fundamentals-based market modeling approach to forecast the average generation mix of electricity generated in Oregon. Guidehouse forecasted these values for the 2020-2045 period using a proprietary capacity expansion model and PROMOD, a commercially available software model. Guidehouse used linear extrapolation based on prior 10 years to estimate the generation mix in the years 2046-2050.

Emissions Modeling Results

This section details the results of Guidehouse's modeling of a Reference Case and five policy scenarios.

Reference Case Modeling Results

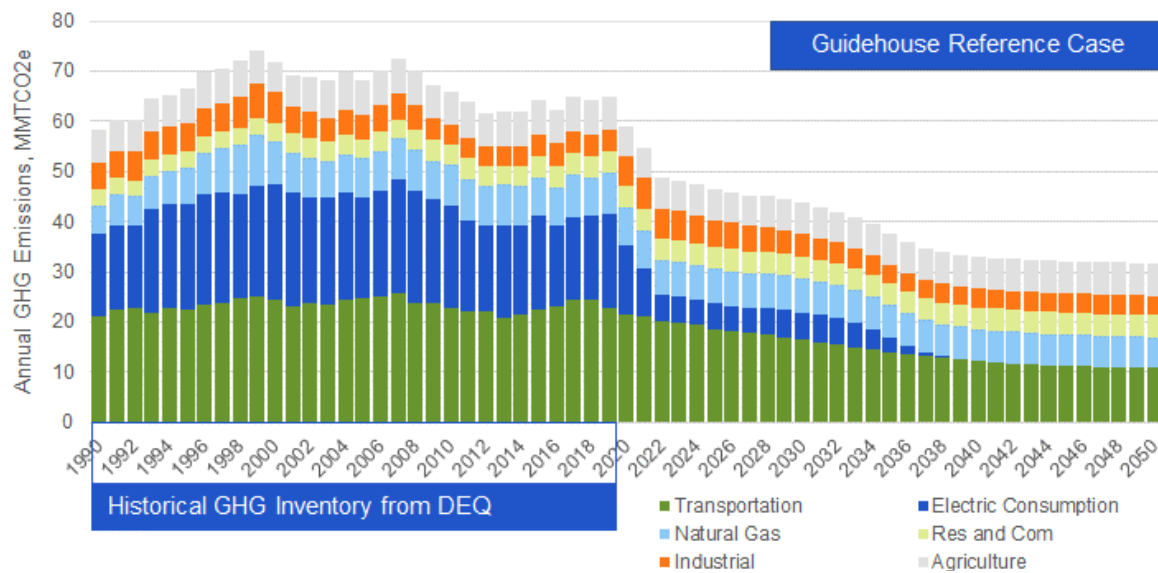
Guidehouse modeled a Reference Case that forecasts future emissions based on regulations in force as of August 1, 2021, including regulations with future compliance dates. The Guidehouse team aligned historical emissions estimates prior to 2019 with emissions estimates published by the DEQ.⁹ Figure 5 presents emissions forecasts through 2050 for the Guidehouse Reference Case. The following trends are evident:

- Transportation emissions decrease due to requirements of the Oregon Clean Fuels Program, increased stringency of federal CAFE standards, and Senate Bill 1044 (SB.1044) requirements for zero emissions vehicle adoption.
- Natural gas emissions decrease due to RNG adoption requirements in SB.98 and utility-driven improvements to energy efficiency (referenced from utility IRP plans).
- Industrial emissions decrease due to US AIM Act requirements for reduced emissions of hydrofluorocarbons (HFCs).
- Electric sector emissions decrease due to Oregon's shift away from coal-fired generation, increased generation from renewable sources, and utility-driven improvements to energy efficiency (referenced from IRP plans). Electric sector emissions decrease to zero over the 2030-2040 period, as electric generators come into compliance with HB.2021 emissions targets.
- Emissions from residential, commercial, and agriculture sectors remain stable.

Oregon's HB.2021 had not been enacted when DEQ presented their Reference Case results at the third RAC meeting on March 18, 2021, so DEQ's Reference Case did not account for the impacts of HB.2021 on electric sector emissions. Aside from accounting for the impacts of HB.2021, the fundamental assumptions of Guidehouse's model are aligned with DEQ's model.

⁹ Oregon Dept. of Environmental Quality (DEQ). "Oregon Greenhouse Gas Sector-Based Inventory Data." Available at: <https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx>

Figure 5. Guidehouse and DEQ Forecasts of Reference Case Greenhouse Gas Emissions,¹⁰ MMTCO₂e



Source: Guidehouse analysis

Policy Scenario Modeling Results

Guidehouse modeled the emissions outcomes of five policy scenarios (Figure 6). In Figure 6, solid bars represent GHG emissions affected by the cap-and-reduce program. The program will directly regulate gas utilities (green bars), non-natural gas fuel suppliers (orange), and industrial emitters (light blue). Although the program will not regulate the electric sector, the electrification measures implemented to meet the program's requirements will increase electricity consumption and lead to an incremental increase in electric sector emissions (dark blue bars).

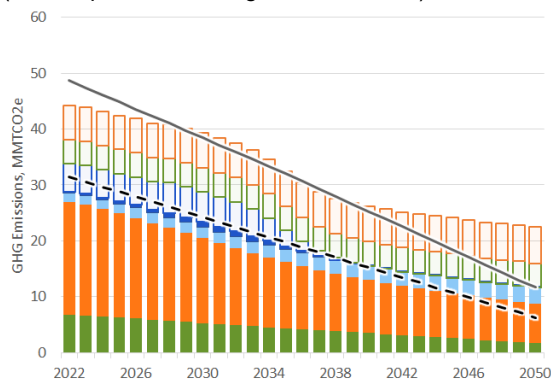
The hollow bars in Figure 6 represent GHG emissions that will not be affected by the cap-and-reduce program. These include non-energy emissions from the residential and commercial sectors (hollow green, including emissions from wastewater, landfills, refrigerants), from agricultural activity (hollow orange), and from electric generation unaffected by the program (hollow blue). The dashed lines represent the GHG limits for activities covered by the cap-and-reduce program; the solid lines represent statewide GHG emissions limits prescribed by EO 20-04.

¹⁰ Consumption of electricity and natural gas from all sectors are included in the "Electric Consumption" and "Natural Gas" categories. The "Industrial" category represents process emissions. The "Residential and Commercial" category represents emissions from delivered fuels, landfills, wastewater, and other non-energy sources.

Figure 6. Annual GHG Emissions Forecasts by Category for Five Policy Scenarios

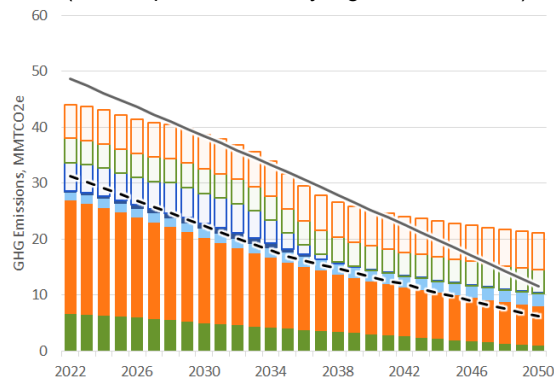
DEQ Policy Scenario 1

(80% cap, 25% CCI, high electrification)



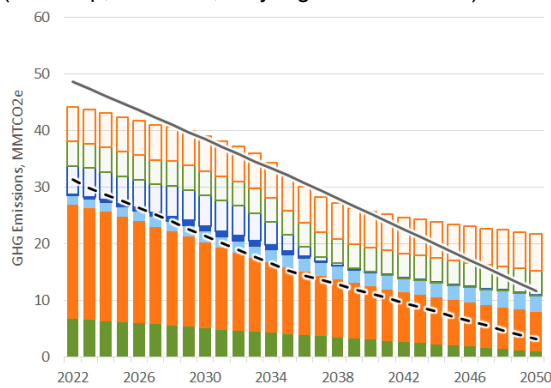
DEQ Policy Scenario 2

(80% cap, 5% CCI, very high electrification)



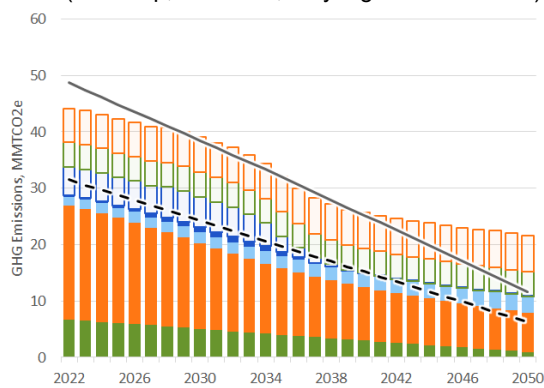
DEQ Policy Scenario 3

(90% cap, 25% CCI, very high electrification)



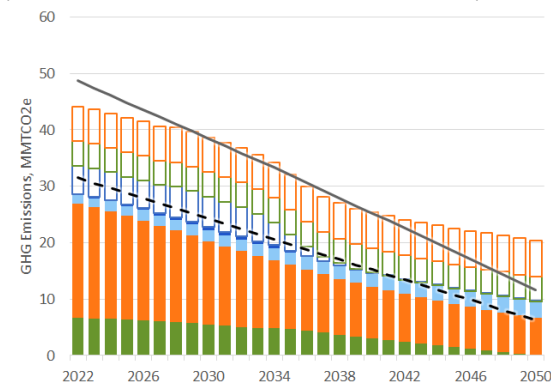
DEQ Policy Scenario 4

(80% cap, 20% CCI, very high electrification)



Low Carbon Fuels Scenario

(80% cap, 20% CCI, moderate electrification)



Affected by proposed cap-and-reduce program

Natural Gas

Other Fuels

Industrial

Incremental Scenario Elec. Gen

Not affected by proposed cap-and-reduce program

Reference Case Electric Gen

Residential & Commercial

Agriculture

Cap-and-Reduce Program Cap

EO 20-04 Total State Cap

Note: Guidehouse's modeling assumes that Oregon's electric generation mix evolves as shown in Figure 4. Regardless of cap-and-reduce program activities, Oregon's average electric emissions factor is projected to decrease due to the retirement of coal generating facilities, the installation of new renewable capacity, and the decarbonization of fuel-fired generation facilities, as required by Oregon HB.2021. Guidehouse projects the emissions factor for electric generation will decrease from 0.54 lbs CO₂/kWh in 2022 to 0.00 lbs CO₂/kWh for 2040-2050.

Source: Guidehouse analysis

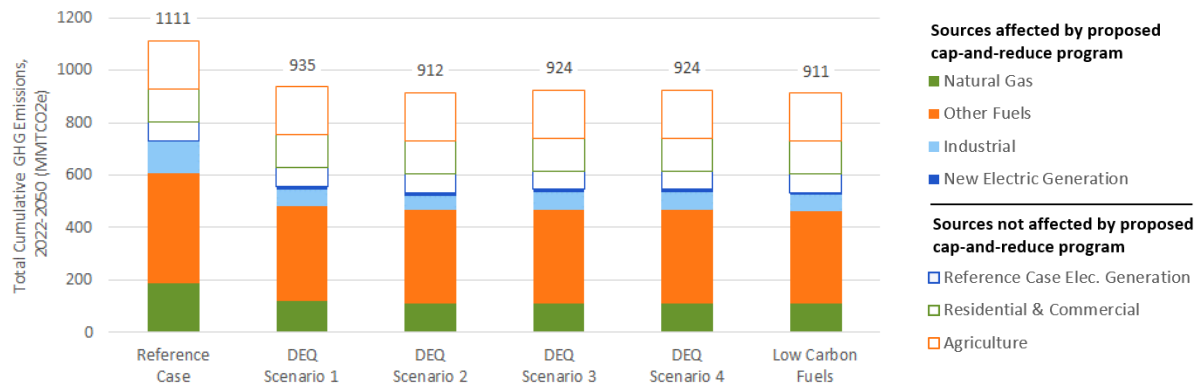
Although none of the policy scenarios achieve the statewide emissions targets (solid line) established by EO 20-04, there are differences between the scenarios; stakeholders need to understand the potential outcomes and the relationships that drive them. Several findings are evident from the policy scenario results in Figure 6:

- In the four DEQ policy scenarios, natural gas emissions are not fully eliminated because DEQ's analysis assumes that half of industrial natural gas customers' consumption will not be affected by electrification, efficiency, or fuel switching. In contrast, the Low Carbon Fuels scenario provides a pathway that reduces natural gas emissions to near zero in all sectors using a combination of RNG, hydrogen, electrification, and energy efficiency.
- In the Low Carbon Fuels scenario, GHG emissions from gas utilities are reduced to almost zero using a combination of energy efficiency, electrification, and low carbon fuels such as renewable natural gas (RNG) and hydrogen. The Low Carbon Fuels scenario depicts a compliance pathway that allows utilities to eliminate GHG emissions with minimal impact to electric generation emissions. This pathway was not considered in DEQ's analysis.
- The high levels of electrification activities modeled in all DEQ policy scenarios will greatly reduce GHG emissions from gas utilities. However, as the solid blue bars in Figure 6 illustrate, these emissions are not fully eliminated from the economy until the electric sector is fully decarbonized in 2040. In the first 15 years of the program, the electrification activities forecasted by DEQ would displace emissions from the gas sector to the electric sector, which is outside the scope of the cap-and-reduce program.
- Policy scenario 3 has a high emissions target of 90% reduction by 2050 and, as the DEQ noted in presentations at the third and fourth RAC meetings, it is unlikely that the GHG reduction technologies being considered can achieve a 90% reduction target.
- In all five scenarios, the actual GHG emissions from regulated sectors in 2050 exceed the cap-and-reduce program's GHG emissions cap. Depending on the program design, regulated entities may be allowed to use flexibility mechanisms such as emissions banking and alternative compliance instruments to meet the emissions cap in 2050.

While this analysis assumes that non-energy emissions (agriculture, wastewater) are relatively stable, new programs and policies may be developed to reduce non-energy emissions in the future.

Figure 7 shows the cumulative GHG emissions by sector over the course of the 2022-2050 study period for each of the five scenarios. Note that this figure does not account for any emissions reductions that may be achieved through the use of Community Climate Investments, since the actual projects and timeline of the proposed CCI program are currently not well defined. The four DEQ policy scenarios show very similar outcomes in terms of cumulative total emissions. This is an expected result, since DEQ considered nearly the same set of technology interventions for each scenario. Of the five scenarios considered, the Low Carbon Fuels scenario results in the lowest cumulative emissions over the study period, largely due to emissions reductions achieved through energy efficiency and displacement of fossil natural gas with RNG and hydrogen.

Figure 7. Cumulative GHG Emissions Forecasts by Category for Five Policy Scenarios, 2022-2050



Source: Guidehouse analysis

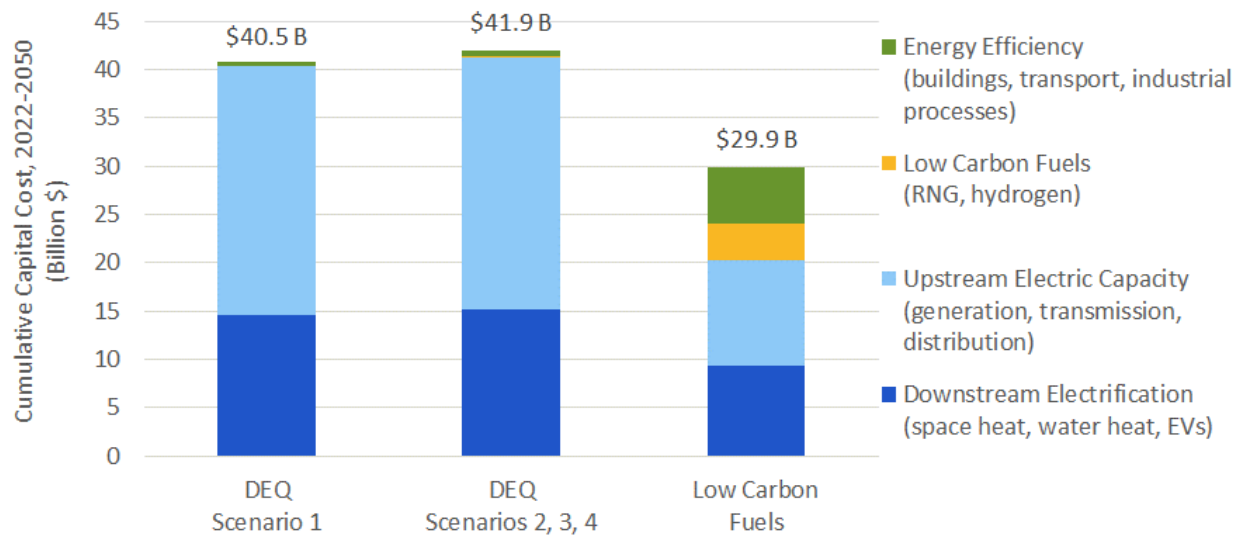
Cost Modeling Results

The GHG reduction technologies modeled in this analysis will incur capital costs across the state of Oregon. For instance, the electrification of buildings requires the purchase and installation of electric-powered heating equipment, as well as the development of new upstream electric capacity to provide electricity. As another example, the development of RNG resources requires investment in plants to collect, clean, and transfer biomethane. Guidehouse modeled the capital costs associated with each technology in this analysis and estimated the total CAPEX “price tag” for the state to deploy technologies sufficient to achieve the GHG reductions described in the prior section. The purpose of this cost analysis is to compare the total cost and the cost effectiveness of different policy scenarios at a high level. This analysis does not explore operating costs, customer energy costs, levelized costs of energy, rebates, or incentives. These factors are omitted because they depend entirely on future state and federal policy decisions whose outcomes are unclear.

Figure 8 shows the cumulative statewide costs of different scenarios from 2022 to 2050, reported in nominal 2021 dollars. All costs are incremental relative to the Reference Case scenario. Guidehouse offers the following observations:

- DEQ scenarios 2, 3, and 4 have nearly the same estimated CAPEX since DEQ assumed nearly identical technology inputs for these scenarios.
- The DEQ scenarios have very high costs for upstream and downstream electrification, driven by the DEQ assumption that 80-90% of buildings will be electrified by 2050.
- The Low Carbon Fuels scenario would cost about 30% less than the DEQ scenarios, driven by its moderate level of building electrification (about 38% of buildings electrified).
- The Reference Case for this analysis assumes that sufficient RNG resources are developed to meet the requirements of SB.98. For the DEQ policy scenarios, the incremental CAPEX for low carbon fuels is near zero, since DEQ’s scenarios do not include hydrogen and assume little development of RNG beyond SB.98 requirements.
- The cost of energy efficiency is very low in the DEQ scenarios since these scenarios assume only a 1% efficiency improvement for buildings and industry over the 2022-2050 period. Energy efficiency costs are higher in the Low Carbon Fuels scenario since it assumes efficiency improvements of 10% for buildings, industry, and transportation.

Figure 8. Cumulative Statewide CAPEX, 2022-2050, Incremental to Reference Case



Source: Guidehouse analysis

Table 4 compares the cost effectiveness of the different scenarios by combining the cumulative CAPEX costs described in this section with the cumulative emissions reductions described in the prior section. The cumulative CAPEX is divided by the cumulative emissions savings to estimate the capital cost per ton of emissions reduced. Table 4 shows that the Low Carbon Fuels scenario would reduce more total emissions at a lower cost and is 25% more cost effective on a dollars-per-ton basis than the four scenarios that DEQ modeled.

Table 4. Cumulative State-wide CAPEX per Ton Emissions Reduction, 2022-2050, Incremental to Reference Case

	DEQ Scenario 1	DEQ Scenarios 2, 3, 4	Low Carbon Fuels
	High Electrification	Very High Electrification	Moderate Electrification, EE, RNG, Hydrogen
Emissions Reduction Intervention Category	Cumulative Statewide CAPEX, to 2050 (\$ Billion)		
Energy Efficiency (buildings, transport, industry)	0.5	0.5	5.9
Low Carbon Fuels (RNG, HENG, hydrogen)	-0.3*	0.2	3.7
Downstream Electrification (space & water heat, EVs)	14.6	15.1	9.3
Upstream Electric Capacity (generation, T&D)	25.7	26.1	11.0
Total Cumulative CAPEX, to 2050 (\$B)	\$40.5 B	\$41.9 B	\$29.9 B
Sector	Cumulative CO₂e Emissions, 2022-2050 (MMTCO₂e)		
Transportation	358	358	348
Electric Sector	82	82	78
Natural Gas	122	111	112
Other (Industrial, Ag., Res & Com)	373	362	373
Total CO₂e Emissions, 2022-2050 (MMTCO₂e)	935 MMT	913 MMT	911 MMT
Total CO₂e Reductions versus Ref. Case (MMTCO₂e)	177 MMT	199 MMT	201 MMT
Total CAPEX Cost per Ton CO₂e Reduced	\$229 / ton	\$211 / ton	\$149 / ton

* DEQ Scenario 1 assumes less deployment of RNG than the Reference Case, so DEQ Scenario 1 shows negative incremental CAPEX (i.e., cost saving) for RNG compared to the Reference Case.

Conclusions

The cap-and-reduce program proposed by DEQ would impact emissions and costs in sectors outside the scope of the program. The electrification of gas- and fuel-powered end uses would displace emissions from fuel providers (in scope) to electric generators (out of scope). Emissions leakage to the power sector may decline in later years as the power sector decarbonizes. Electrification will also lead to increases in peak electric demand, requiring investments in new capacity to generate, transmit, store, and distribute electricity. DEQ's analysis of the cap-and-reduce program has not described the emissions or cost impacts that the program would have on the electric sector. At present, the Oregon Public Utilities Commission (OPUC) is conducting a fact finding process to analyze the potential natural gas utility bill impacts that may result from limiting GHG emissions of regulated natural gas utilities under the DEQ's Climate Protection Program and to identify appropriate regulatory tools to mitigate potential customer impacts.

- **Recommendation:** To fully understand the potential impacts of DEQ's Climate Protection Program, the OPUC should analyze the emissions and cost impacts that the proposed cap-and-reduce program would have on the broader energy system, rather than limiting their analysis to entities that would be covered by the program.

There are various pathways to decarbonization, and Guidehouse modeling shows that a pathway that uses low carbon fuels that complement energy efficiency and electrification deliver more cost-effective GHG reductions and achieve deeper decarbonization targets.

- **Recommendation:** The DEQ should maintain the flexibility of available compliance options in the draft rules available for direct emissions reductions from covered parties and expand the compliance options to include verifiable offsets and carbon sequestration.

Meeting the statewide goals of EO 20-04 will require emissions reduction from sectors of the energy economy for the proposed scope of the cap-and-reduce program. The proposed Community Climate Investment (CCI) program¹¹ provides an avenue for investment in GHG reductions strategies in these sectors. There are opportunities for interventions to reduce GHG emissions in the non-energy residential, commercial, and agricultural sectors of the economy, for instance through improved wastewater management, improved refrigerant handling, and conservation tillage.

- **Recommendation:** Alternative compliance mechanisms such as CCIs should encourage innovation from regulated sectors and should incentivize a broad range of approaches to GHG reductions. Until the power sector is fully decarbonized, CCI entities should prioritize interventions that **eliminate emissions** over actions, such as electrification, that displace emissions to sectors outside the scope of the cap-and-reduce program.

The low-carbon fuels scenario that Guidehouse modeled emphasizes the delivery of low carbon gas through deployment of technologies (such as hydrogen) and, compared to the scenarios modeled by DEQ, the low-carbon fuels scenario resulted in greater reductions in economywide GHG emissions.

- **Recommendation:** The OPUC should consider a policy scenario in which emerging low carbon fuel technologies are a viable option used to deliver GHG emissions reduction with minimal impacts to the electric sector.

In a decarbonized future, pipeline networks could continue to support the reliability and resiliency of Oregon's broader energy system by transporting and distributing low carbon gas and hydrogen. These fuels can support decarbonization of hard-to-electrify uses such as heavy duty transportation and high temperature industrial processes. Guidehouse has previously analyzed and reported how the gas system contributes to US energy system resilience.¹² DEQ's analysis of policy alternatives does not account for the benefit that pipeline networks and storage solutions provide as an energy source that complements intermittent renewable generation resources.

¹¹ The CCI program proposed by DEQ would provide an alternate compliance pathway for covered entities, whereby covered entities could purchase credits from non-profit CCI entities and the CCI entities would use the proceeds from these sales to fund projects that reduce GHG emissions.

¹² American Gas Foundation (2021). "Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience" Available at: <https://gasfoundation.org/2021/01/13/building-a-resilient-energy-future/>

- **Recommendation:** Analysis of regulatory alternatives conducted by the OPUC should consider the reliability and resilience benefits of maintaining diverse energy delivery systems, including the pipeline infrastructure and storage network.

Additional Considerations

Achieving the interim and mid-century GHG emissions reduction goals established by EO 20-04 will require a swift and equitable transformation of the energy sector that balances resiliency, climate justice, and economics. The pipeline infrastructure, low carbon fuels and storage systems should play an integral role in this decarbonization effort:

- **Providing a complementary asset to battery storage.** The substantial growth in energy production from wind and solar PV that is necessary to achieve Oregon's climate goals requires dispatchable electrons via cost-effective infrastructure. Biomass and low carbon gas can be leveraged as energy carriers to expand storage options in times of excess electricity production where chemical batteries are not enough, especially over longer periods of time when current seasonal or long duration battery storage technology would be prohibitively expensive.
- **Providing a pathway to decarbonize high temperature industrial processes.** Full electrification of high temperature industrial processes is currently infeasible. Combustion of low carbon gases (such as RNG and green or blue hydrogen) can effectively meet these heating needs while reducing GHG emissions in the process.¹³
- **Mitigating the growth in electric peak demand.** Gas-fired and dual-fuel (i.e., heat pump systems with gas-fired backup heat) heating systems contribute less to electric peak demand in the winter months than whole-home, electric-powered air-source heat pumps. This is because, at low temperatures, gas-fired and dual-fuel systems rely on non-electric sources of heat energy.
- **Ensuring the reliability and resiliency of the energy system.** In a decarbonized future, gas infrastructure will continue to support a broader energy system reliability and resiliency when it is used to transport and distribute low carbon gas and hydrogen.

This study did not analyze these issues in depth since they are treated in prior studies, including Guidehouse's *2020 Gas Decarbonisation Pathways* study¹⁴ and the American Gas Foundation's 2021 study on *Building a Resilient Energy Future*.¹⁵

¹³ European Commission Joint Research Centre (2020). "Global Energy and Climate Outlook 2019: Electrification for the low-carbon transition." p.50. Available at:

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC119619/kjna30053enn_geco2019.pdf

¹⁴ Guidehouse (2020). "Gas Decarbonisation Pathways 2020-2025." Available at:

<https://gasforclimate2050.eu/publications/>

¹⁵ American Gas Foundation (2021). "Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience" Available at: <https://gasfoundation.org/2021/01/13/building-a-resilient-energy-future/>

Appendix A: Data Sources

Table 6 lists the main data sources referenced in Guidehouse's modeling of the Reference Case and policy scenarios. The table contains hyperlinks to the source data and describes how data from each source was used. Table 6 also notes which data sources were also referenced in the DEQ's modeling, based on information provided by DEQ.

Table 5. Referenced Data Sources

Source Consulted	Nature of Use	Sector	Used by DEQ?
Oregon Greenhouse Gas Sector-Based Inventory	To obtain OR's historic emissions by sector (1990-2018)	All	Yes
EIA State Energy Data System (SEDS)	To obtain baseline energy use in OR by fuel type and sector	All	Yes
EIA Annual Energy Outlook (AEO)	To obtain % change in fuel use each year from SEDS baseline for Reference Case to 2050 – used Northwest Power Pool	All	Yes
NREL Electrification Futures Study	To inform the level of end use electrification assumed to occur by 2050. Informs cost of electrifying space heating and hot water end uses.	All	Yes
Integrated Resource Plans for Avista, Cascade, NW Natural, PacifiCorp, Portland General Electric, and Puget Sound Energy	Compared load forecasts to EIA AEO forecasts; gathered projected savings from energy efficiency measures	All	Yes
EIA Residential Energy Consumption Survey (RECS)	To calculate % energy consumption by fuel type and end use in the Pacific Region	Residential	Not stated
EIA Commercial Buildings Energy Consumption Survey (CBECS)	To calculate % energy consumption by fuel type and end use in the Pacific Region	Commercial	Not stated
Argonne National Laboratory's VISION 2020 Model	To inform growth projections of state vehicle registrations	Transportation	Yes
EIA State Electricity Profiles	To obtain OR's generation mix, present day, in-line with Electricity Mix in Oregon	Electricity	Not stated directly
EPA SIT Agriculture Module	To affirm historical emissions numbers from DEQ GHG inventory	Agriculture	Yes
EPA SIT Projections Tool	Default settings used to obtain projection data for Reference Case to 2050	Agriculture	Yes

Source Consulted	Nature of Use	Sector	Used by DEQ?
McKinsey & Company (2018) "Decarbonization of industrial sectors: the next frontier"	Informed the portion of industrial energy consumption that may be replaced by hydrogen fuel	Industrial	Yes
ICF (2019), "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment"	Provides statewide potential RNG production capacity	Natural Gas	Yes
International Renewable Energy Agency (IRENA, 2020), "Renewable Power Generation Costs in 2019"	Informs costs of developing new solar and wind power generation capacity	Electricity	No
Guidehouse (2020), "Market Data: Energy Storage Pricing Trends"	Informs cost of energy storage infrastructure that is assumed to support deployment of intermittent electric sources.	Electricity	No
International Energy Agency (IEA, 2015), "Technology Roadmap - Hydrogen and Fuel Cells"	Informs cost of hydrogen deployment and production.	Electricity	No
CSIRO Energy (2016), "Cost assessment of hydrogen production from PV & electrolysis"	Informs cost of hydrogen deployment and production.	Electricity	No

Appendix B: Sector- and Technology-Specific Methodology

This appendix describes the methodology and assumptions for individual sectors and technologies in the energy and emissions model.

Residential and Commercial Electrification

In 2018, 40% of homes in Oregon used fossil fuels as their primary heating source, well below the US average of 57%.¹⁶ Technologies available today can be used to fully electrify the heating and hot water needs of Oregon's buildings. However, the electrification of end uses served by fuels will shift consumption and GHG emissions to the electric sector and will require substantial expenditures by consumers to purchase and install electric heating equipment. Guidehouse tested whether a more selective approach to building electrification can meet the cap-and-reduce program's targets with a lesser degree of electrification.

Guidehouse focused on three technologies to electrify buildings' heating needs:

- **Electric air-source heat pumps** (ASHPs) provide space heating and space cooling by using electricity to move heat from the outdoor space to the indoor space and vice versa. Recent advances in cold climate ASHP technology make it possible to use heat pumps for space heating when outdoor ambient temperatures are as low as -13°F.¹⁷ With these systems, most buildings in Oregon could feasibly electrify their heating needs, albeit with high installation costs.
- **Heat pump water heaters** (HPWHs) use electricity to transfer heat from ambient air to a stored water tank and are an energy efficient alternative to electric resistance water heaters and fuel-fired water heaters. The adoption of HPWHs has been limited by a variety of factors, including cost, product availability, and installation constraints. Guidehouse projects that the market for HPWHs will overcome these barriers and that many Oregon buildings will use HPWH technology for water heating by 2050.
- **Electric cooking equipment** is capable of displacing conventional fuel-fired cooking equipment. In the Pacific West region (including Oregon), about 23% natural gas consumed by commercial buildings is used for cooking purposes.¹⁸

Fuel-fired appliances and electric appliances have inherently different energy efficiency ratings. When modeling electrification interventions, Guidehouse accounted for the changes in energy efficiency. Guidehouse also assumed that equipment energy efficiency improves over time, due to replacement of older less efficient appliances and to improvements in appliance technology. Table 7 presents Guidehouse's assumptions regarding the efficiency of different end uses and energy sources at the start and end years of the modeling period. These values reflect the

¹⁶ US Energy Information Administration (2021). "State Profile and Energy Estimates: Oregon." Available at: <https://www.eia.gov/state/data.php?sid=OR#ConsumptionExpenditures>

¹⁷ A sample of heat pump products capable of continuous operation at -13°F include Daikin's Aurora, Mitsubishi's Hyper-Heat, Fujitsu's Halcyon, and Lennox's MLA product lines.

<https://daikincomfort.com/go/aurora/>

<https://www.mitsubishicomfort.com/benefits/hyper-heating>

<https://www.fujitsugeneral.com/us/residential/technology/xlth-low-temp-heating.html>

<https://www.lennox.com/products/heating-cooling/mini-split-systems/mla>

¹⁸ EIA (2012). Commercial Buildings Energy Consumption Survey. Table E7. Natural gas consumption and conditional energy intensities by end use. Available at:

<https://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/e7.pdf>

assumption that non-condensing gas-fired equipment will gradually be replaced by high-efficiency condensing gas equipment and that electric resistance heating will gradually be replaced by electric heat pumps.

Table 6. Energy Efficiency Assumptions by Sector, End Use, and Energy Source

Sector and End Use	Energy Source	2020	2050
Residential Space Heat	Electric	128%	260%
	Natural Gas	82%	94%
Residential Water Heat	Electric	150%	330%
	Natural Gas	58%	80%
Commercial Space Heat	Electric	161%	360%
	Natural Gas	83%	88%
Commercial Water Heat	Electric	150%	332%
	Natural Gas	59%	75%

Source: Guidehouse analysis

Energy Efficiency Measures

Energy efficiency can reduce energy-related carbon emissions by decreasing the amount of energy consumption needed to accomplish a given task (e.g., heat a home, transport cargo, etc.). Our analysis assumes that some amount of energy efficiency will be deployed in the Reference Case, as utilities continue their rebate programs, building codes improve over time, and federal automobile efficiency standards become more stringent. The Reference Case for this analysis is based on the EIA's *Annual Energy Outlook 2021*, and the EIA provides estimates of energy intensity by sector and end use in 2020 and 2050.¹⁹ Guidehouse's analysis uses EIA's proportional change in energy intensity as a proxy for energy efficiency improvement in the Reference Case.

The measures included in the Guidehouse model assume that efficiency measures implemented in the policy scenario cases could achieve greater efficiency reductions than those included in the Reference Case. Guidehouse referenced projected reductions in energy loads from the IRPs published by electric and gas utilities operating in Oregon. Each utility's IRP stated that energy efficiency would impact overall load growth over the IRP period, though the magnitude of energy efficiency reductions was different for each utility.

The spreadsheet model that DEQ provided to RAC participants on June 18, 2021 included an assumption that energy consumption from buildings would decrease by 1% due to energy efficiency improvements. Guidehouse examined the calculations from DEQ and confirmed that DEQ modeled a 1% decrease in load over the 2022-2050 period and not decrease of 1% per annum. Guidehouse used the 1% efficiency improvement assumption in its modeling of DEQ policy scenarios. In contrast, Guidehouse modeled the Low Carbon Fuels scenario assuming that energy efficiency measures could reduce building and transportation loads to levels 10% lower than the reference case by 2050.

¹⁹ EIA (2021). *Annual Energy Outlook 2021 with projections to 2050: Chart library*. pp. 9, 33, 42-43, 48. Available at: <https://www.eia.gov/outlooks/aeo/pdf/00%20AEO2021%20Chart%20Library.pdf>

Transportation Sector Modeling

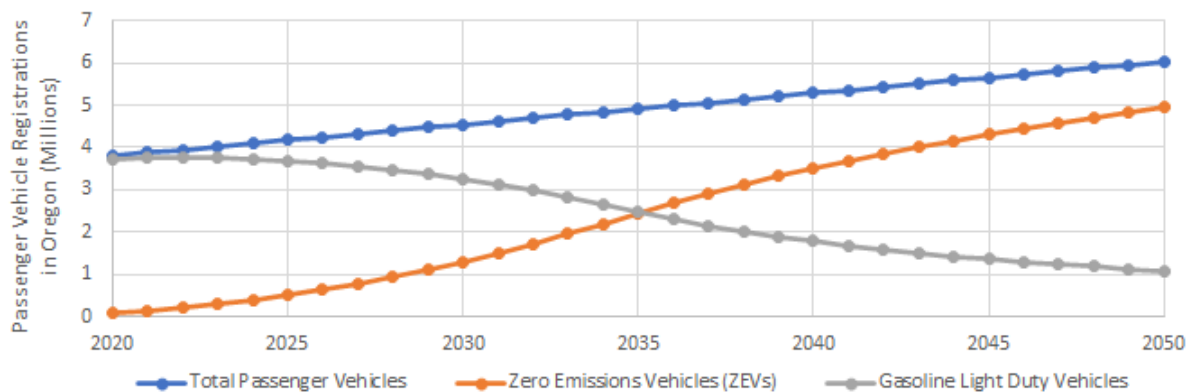
The Guidehouse Reference Case for transportation sector emissions is based on Oregon's current transportation sector energy use from EIA SEDS and on the EIA's *Annual Energy Outlook* projections of transportation sector growth in the Pacific region. Guidehouse adapted the EIA's outlook to account for local laws and regulations including Oregon's SB 1044 and Oregon's Clean Fuels Program.

Vehicle Electrification

Oregon's SB 1044 sets targets for zero emissions vehicle (ZEV) adoption in the state.²⁰ Per SB 1044, Oregon must target the registration of 250,000 ZEVs by 2025, and ZEVs should account for 25% of total vehicle registrations in Oregon by 2030. To model the expected impacts of SB 1044 on the transportation sector's energy consumption, Guidehouse assumed the targets in SB 1044 are met.

Guidehouse forecast the growth in total state passenger vehicle registrations based on trends observed in Oregon's historical vehicle registrations²¹ and nationwide forecasts included in Argonne National Laboratory's VISION model (Figure 9).²² Guidehouse used a stock turnover calculation to estimate how the shares of ZEV and gasoline-powered passenger vehicles changes over time through 2050. Based on these forecasts, the energy and emissions model includes a fuel switching calculation to estimate the amount of energy use that shifts from gasoline to electricity, accounting for the difference in energy efficiency of gasoline- and electric-powered vehicle types.

Figure 9. Forecast of Oregon Passenger Vehicle Registrations by Fuel Type in Guidehouse Reference Case



Source: Guidehouse analysis

Clean Fuels Program

Oregon's Clean Fuels Program requires reduction in the carbon intensity of gasoline and diesel beginning in 2015.²³ Guidehouse modeled the effects of this program as adjustments to the

²⁰ Oregon State Legislature (2019). "SB 1044 Enrolled." Available at:

<https://olis.oregonlegislature.gov/liz/2019R1/Downloads/MeasureDocument/SB1044/Enrolled>

²¹ Oregon Department of Transportation (2020). "Oregon DMV Vehicle Registration Statistics." Available at:

https://www.oregon.gov/odot/DMV/Pages/News/vehicle_stats.aspx

²² Argonne National Lab (2020). "VISION Model." Available at: <https://www.anl.gov/es/vision-model>

²³ Oregon Department of Environmental Quality. "Oregon Clean Fuels Program Overview." Available at:

<https://www.oregon.gov/deq/ghgp/cfp/Pages/CFP-Overview.aspx>

emissions factors for gasoline and diesel fuels over time, using emissions factors provided by the DEQ, as Table 8 lists.

Table 7. Oregon Clean Fuel Standards for Gasoline and Diesel Fuels

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025 and beyond
Percent Reduction from 2015 Baseline (%)	0.25	0.50	1.00	1.50	2.50	3.50	5.00	6.50	8.00	10.00
Gasoline Emissions Factor (gCO ₂ e/MJ)	98.37	98.13	97.66	96.59	95.61	94.63	93.15	91.68	90.21	88.25
Diesel Emissions Factor (gCO ₂ e/MJ)	99.39	99.14	98.61	97.26	96.27	95.29	93.81	92.32	90.84	88.87

Source: Oregon DEQ

Transportation Sector Efficiency

Guidehouse also assumed that transportation sector efficiency may be improved so that transportation energy loads decrease relative to the Guidehouse Reference Case. The catchall assumption for transportation efficiency includes measures such as improvements to urban planning, traffic management, and public transit, though the analysis did not model these opportunities individually.

Renewable Natural Gas

RNG is a gaseous fuel with lower carbon intensity and similar operational and performance characteristics to natural gas, and RNG can reduce GHG emissions in applications that use natural gas and other fossil fuels. RNG reduces systemwide GHG emissions by avoiding the release of methane into the atmosphere from the natural breakdown of organic materials. Combusted natural gas has a much lower carbon intensity than pure methane when released to the atmosphere; eliminating methane emissions provides the majority of avoided GHG emissions. The specific carbon intensity of RNG is a complex calculation that depends on feedstock, production technology, and location, among other factors.

RNG or biomethane can be produced through several production technologies, including landfill gas collection, anaerobic digestion, and thermal gasification systems. Common RNG feedstocks include landfill gases, livestock waste, food waste, agricultural residues, and woody biomass. RNG facilities can use the produced gas onsite for electricity generation, boiler heating, and transportation refueling, or facilities can inject the RNG into the natural gas grid for use by gas utility customers. When distributed to these end use customers, RNG can reduce the GHG emissions of gas appliances in buildings, gas-fired combined heat and power systems at industrial sites, or through compressed natural gas vehicle fleets. RNG is a valuable low carbon resource for applications that are difficult or expensive to electrify.

Table 9 highlights the RNG production potentials for each feedstock assumed for Oregon, along with the applicable emissions rates. In recent years, RNG development has increased in support of federal and state decarbonization goals in the transportation and gas utility sectors. Oregon has an estimated in-state RNG production technical potential of roughly 27.7 trillion Btu

per year from available landfill, animal manure, wastewater treatment, and food waste resources through anaerobic digestion technologies. In future years, thermal gasification production technologies could increase in-state RNG technical potential by about 44.8 trillion Btu per year using available agricultural residues, forest residue, municipal solid waste resources, and energy crops. In 2018, Oregon consumed 271 trillion Btu of natural gas.²⁴ Our analysis assumes that the state's total natural gas consumption will decline over time due to efficiency improvements and electrification measures, while the state's total RNG potential will remain stable.

As the final column of Table 9 illustrates, the emissions factor of RNG can vary depending on the source of the gas, since some sources capture greenhouse gases that would otherwise be vented to the atmosphere. Guidehouse adopted the assumption used in DEQ's modeling that RNG is a zero emissions fuel source.

Table 8. Estimated RNG Production Potential and Emissions Rates for Oregon

Process	Feedstock	Potential (Trillion Btu/Year)				Emissions Rate (lbs CO ₂ e per MMBtu)**
		Low	High	Average High-Technical	Technical	
Anaerobic Digestion	Landfill gas	6.24	10.19	12.80	15.41	21.0
	Animal manure	1.96	3.93	5.23	6.54	-124.0
	Water resource recovery facilities	0.29	0.41	0.72	1.03	16.6
	Food waste	0.14	0.25	2.47	4.70	-9.9
Thermal Gasification	Agricultural waste	1.06	2.65	7.34	12.03	12.3
	Forestry and forest product residue	2.16	4.32	7.70	11.08	10.4
	Energy crops	0.00	0.00	0.00	0.00	9.7
	Municipal solid waste	1.16	8.66	15.18	21.70	6.4
Total		13.02	30.41	51.45	72.48	

** Emissions rates are based on relevant Low Carbon Fuel Standard projects; data available at: <https://www2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities>

Source: Low, High, and Technical potentials from ICF (2019), "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment." The ICF report claims that the provided potentials are conservative, so Guidehouse calculated an average of the High and Technical cases from ICF (2019).

Hydrogen-Enriched Natural Gas (HENG)

In sectors currently using natural gas and other fossil fuels, hydrogen offers another low carbon gas solution to reduce GHG emissions. Hydrogen can be produced through electrolysis using dedicated renewable generation or curtailed renewable generation systems (power-to-gas or green hydrogen) and through natural gas reformation with carbon capture (blue hydrogen). It can be blended into existing natural gas pipelines using HENG. If implemented with low

²⁴ US Energy Information Administration. State Energy Data System, Table C1. Available at: https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_1.html&sid=OR

concentrations, this strategy appears to be viable without increasing risks in end use devices (such as household appliances and heating equipment), overall public safety, or the durability and integrity of the existing natural gas pipeline network. Guidehouse research and interviews with heating technology experts indicate that hydrogen may be blended with natural gas at a maximum concentration of 15% hydrogen by volume, which could displace about 5% of natural gas supplied in HENG pipelines.^{25,26} HENG technology is unlikely to be available beyond the pilot scale until 2030.

The Guidehouse energy and emissions model assumes in policy scenario 4 that utilities begin blending hydrogen in the gas supply in 2035 and that hydrogen has displaced 5% of natural gas deliveries by 2050. Blending hydrogen into delivered gas has the effect of reducing the emissions factor of delivered gas by about 5%.

Industrial Sector Process Emissions

The Guidehouse model estimates two values for industrial sector GHG emissions: (1) the total GHG emissions from all industrial activity in Oregon, and (2) the total GHG emissions from industrial activity that would be regulated by the cap-and-reduce program.

In the Reference Case forecast, total industrial GHG emissions from all industrial activity is referenced from forecasts provided by the US Environmental Protection Agency's State Inventory Tool (SIT).²⁷ The SIT model reports CO₂, N₂O, and other emissions based on historical industry activity and forecasts of industrial growth through 2050. The SIT tool was last updated prior to passage of the US AIM Act, which requires an 85% reduction in hydrofluorocarbon (HFC) emissions by 2035. To reflect the impact of the AIM Act, the Guidehouse model assumes a linear reduction in HFC emissions beginning with 0% HFC reduction in 2021 and ramping to 85% HFC reduction in 2035.

In the policy scenario forecasts, consideration of industrial GHG emissions is limited to facilities that would be regulated under a cap-and-reduce program. During RAC meetings, the DEQ has stated that the cap-and-reduce program's regulations of industrial emissions will likely be limited to stationary sources producing over 25,000 MTCO₂e of process-related GHG emissions per year. The DEQ reports GHG emissions from facilities holding air quality permits,²⁸ but these reports do not separate process emissions from emissions due to combustion of natural gas and delivered fuels. Thus, from the data publicly available, Guidehouse was unable to validate the DEQ's estimates of industrial process emissions from facilities that would be regulated by the program. Because of this limitation, Guidehouse used values for regulated industrial process emissions as reported in DEQ's presentation of initial results from DEQ's modeling study.²⁹

²⁵ GRTgaz et al. (2019). "Technical and economic conditions for injecting hydrogen into natural gas networks." Available at: <http://www.grtgaz.com/fileadmin/plaquettes/en/2019/Technical-economic-conditions-for-injecting-hydrogen-into-natural-gas-networks-report2019.pdf>

²⁶ Melaina, Antonio and Penev (2013). "Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues." Available at: <https://www.nrel.gov/docs/fy13osti/51995.pdf>

²⁷ Available at: <https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool>

²⁸ See: <https://www.oregon.gov/deq/eq/programs/Pages/GHG-Emissions.aspx>

²⁹ Available at: <https://www.oregon.gov/deq/Regulations/rulemaking/RuleDocuments/ghgcrRefPolResults.pdf>

Industrial Local Green Hydrogen

Green hydrogen is a term used to describe hydrogen that is separated from water and converted to a viable fuel source through a renewables-powered electrolysis process. Recent studies that have demonstrated the feasibility of using green hydrogen in the steel industry³⁰ and the cement-making process.³¹ Separate from the HENG strategy described previously, hydrogen may be delivered to customers through dedicated distribution systems designed for 100% hydrogen gas, known as hydrogen clusters or districts. For policy scenario 4, Guidehouse's energy and emissions model calculates the impacts associated with switching a portion of the industrial sector's energy consumption from pipeline gas sources to locally produced hydrogen. Assumptions regarding the amount of industrial energy consumption that may be replaced by hydrogen were informed by a third party analysis of industrial sector decarbonization.³²

³⁰ See, for instance, Hybrit Steel in Sweden, at: <http://www.hybritdevelopment.com/>; Voestalpine Hydrogen Production Facility in Austria, at: <https://www.voestalpine.com/group/en/media/press-releases/2019-11-11-h2future-worlds-largest-green-hydrogen-pilot-facility-successfully-commences-operation/>; Thyssenkrupp Steel Europe's partnership for green hydrogen production, at: <https://www.thyssenkrupp.com/en/newsroom/press-releases/pressdetailpage/green-hydrogen-for-steel-production--rwe-and-thyssenkrupp-plan-partnership-82841>;

³¹ Doyle, Amanda (2019). "Producing cement using electrolysis". Available at:

<https://www.thechemicalengineer.com/news/producing-cement-using-electrolysis/>

³² McKinsey & Company (2018). "Decarbonization of industrial sectors: the next frontier" Available at:

<https://www.mckinsey.com/~media/mckinsey/business%20functions/sustainability/our%20insights/how%20industry%20can%20move%20toward%20a%20low%20carbon%20future/decarbonization-of-industrial-sectors-the-next-frontier.pdf>