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OREGON STATE ENERGY STRATEGY

CETI TECHNICAL APPROACH DOCUMENT

Before undertaking technical modeling in support of the Oregon Energy Strategy, ODOE's technical consultants, the Clean Energy Transition Institute Oregon Energy Strategy Team—which includes the Clean Energy Transition Institute, Evolved Energy Research, Sylvan Energy Analytics, and Rockcress Consulting (CETI-OES Team) — presented this Technical Approach document outlining its proposed approach to producing energy pathways modeling and complementary analyses in support of the Oregon Energy Strategy.

ODOE is now publishing this Technical Approach document as a resource and reference point for members of the public interested in the design of the technical modeling undertaken to inform the Energy Strategy. It includes minor edits and annotations made by ODOE and the CETI-OES Team to reflect how the technical modeling was conducted for the Oregon Energy Strategy, but otherwise retains the language and voice used in the original proposal.

Energy Pathways Modeling Technical Approach

Submitted by the Clean Energy Transition Institute and Evolved Energy Research to the Oregon Department of Energy to inform modeling for an Oregon Energy Strategy

Clean Energy
Transition Institute

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II. Introduction

Energy Pathways Modeling Technical Approach presents the methodology for the technical approach that the Clean Energy Transition Institute Oregon Energy Strategy Team (CETI-OES Team), including Evolved Energy Research, Sylvan Energy Analytics, and Rockcress Consulting, developed to model energy pathways to achieve greenhouse gas emissions reductions under current Oregon policy[1] from the present until 2050.

This document starts by clarifying what energy pathways modeling is and what it is not; explains the five intertwined deep decarbonization pillars; and describes the least-cost, optimization modeling approach that the CETI-OES Team will engage in with the Oregon Department of Energy (ODOE) and its public engagement process throughout the development of the Oregon Energy Strategy.

A. Energy Pathways Modeling

Energy pathways modeling calculates the energy needed to power an economy while meeting policy targets, such as a greenhouse gas emissions target, and the least-cost way to provide that energy with efficiency, clean electricity, electrification, clean fuels, and carbon sequestration. Energy pathways modeling includes detailed electricity sector modeling integrated with optimization of the supply of liquid and gaseous fuels from an economy-wide perspective.

Knowing the future that current policy goals aim to achieve guides our investigation of the steps that might best reach those goals over the next 25 years. Energy pathways modeling takes a backcasting approach to inform near-term decision-making, answering the question: what are the ways that the state might achieve a given emission reduction goal? Examining a variety of different scenarios using a backcasting framework can help understand the pros, cons, and trade-offs among different pathways, policies, and strategies.

Figure 1 below visually describes the backcasting approach, setting A—the target to achieve—and then "backcasting" to B—the baseline today—to calculate mathematically what it would take to achieve A. With the framework that the backcasting exercise provides, policymakers develop C—strategies and solutions to get on the path to that future goal and determine D—near-term priorities to get on the path, knowing that adjustments will be required along the way as technologies change and new information is received.

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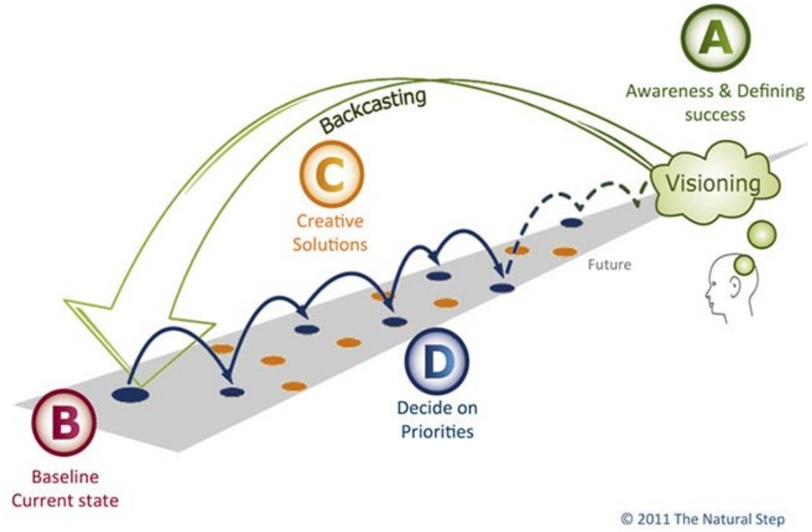
[1] The model must solve to meet Oregon's anchor climate and clean energy goals: Executive Order 20-04 (80 percent economy-wide reduction in greenhouse gas emissions by 2050); HB 2021 (100 percent clean electricity for the state's largest investor-owned electric utilities and electricity service suppliers), and the Climate Protection Program (90 percent reduction in greenhouse gas emissions from fuels by 2050). This is a requirement of HB 3630, which directs ODOE to develop the energy strategy and identify optimized pathways to achieving the state's energy policy objectives.

Figure 1. What is Backcasting?[2]



It is critical to understand what energy pathways modeling is and how it differs from other types of energy and economic modeling, in particular electricity sector modeling. Key characteristics of energy pathways modeling include:

- Energy pathways modeling is ***least-cost, energy system optimization*** that matches least-cost energy resources to energy demand. Energy demand is forecast from a current starting point through 2050.
    - Drivers of change in energy service demand, such as population and industrial activity, are combined with assumptions about how energy-consuming technologies will evolve over time.[3]
- All emissions—whether from fossil fuel combustion to produce electricity or fossil fuel use in buildings, industry, or transportation (planes, vehicles, or shipping)—are **counted and modeled together** and are reduced over time to achieve a chosen greenhouse gas emissions target.
    - The practical implication of this economy-wide, all-emission reduction approach is that end uses will vie for clean energy resources in the future in ways they do not today. Energy pathways modeling helps planners understand the trade-offs involved in allocating clean energy supply from different resources to different uses.

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[2] Backcasting Partners. https://www.backcastpartners.com/what-is-backcasting/

[3] For example, population growth may drive greater service demand for electric lighting. At the same time, substituting LED bulbs for incandescent and fluorescent will reduce the energy needed to provide lighting service. Forecasted energy demands across the economy result in demand for different forms of energy to be met by the supply side, such as electricity, gasoline, diesel, jet fuel, fuel oil, and others. Supply-side modeling determines the best infrastructure investments and system operations to supply all forms of energy reliably, subject to resource availability and policy.

- Energy pathways modeling is ***integrated and holistic*** and indicates future energy supply across a particular geographic area.
    - To identify pathways for Oregon, the future energy supply includes ***all energy resources***—electricity, gaseous, and liquid fuels— supplying the 11 Western states.
    - Energy pathways modeling includes detailed electricity sector modeling ***integrated with fuels***, but is ***not*** focused on only one state or a single utility service territory in isolation.
- Energy pathways modeling encompasses ***every sector*** of the region's economy that uses energy.
    - Energy pathways modeling includes demand for all forms of energy, across all energy consuming sectors – buildings, industry, agriculture, and transportation not just the electricity sector.

Including fuel switching among electricity, liquid, and gaseous fuels is critical to identifying least-cost pathways to a decarbonized future. For this reason, we model the electricity sector as well as liquid and gaseous fuels and their interaction with electricity. This concept is often the hardest to understand for energy modelers familiar with modeling either electricity or fuels because planning across energy resources to meet decarbonization targets has not been a primary focus to date.

Energy pathways modeling is complementary to and not a replacement for integrated resource planning (IRP) modeling, such as production simulation and loss-of-load probability modeling, that electric utilities perform.

- **Not a loss-of-load probability model**: Energy pathways modeling is not loss-of-load probability modeling; dedicated loss-of-load probability modeling in utility planning is still a necessary part of resource planning for a reliable system. Energy pathways modeling approximates reliability needs, including rules of thumb for capacity needs and energy-limited resources that include generator and transmission outage rates, load forecast error, availability of renewable resources, and energy storage contributions. Reliability requirements in the model adapt in each model year to account for the quantity and location of renewable resources built by the model, the size and flexibility of load, and the type of transmission and generation resources constructed.
- **Not nodal production simulation or electricity market modeling**: Energy pathways modeling includes detailed hourly electricity sector operations and constraints, capturing the dynamics of the electricity system and the value of different potential energy resource investments. However, it uses a zonal transmission model and aggregates hydro system operational constraints based on historical hydro capabilities.[4] Electricity system planners use more detailed models of operations for short-term planning. Energy pathways models are not electricity market models. Electricity sector dispatch is based on least-cost operations and investments in the physical electricity system and does not consider contracts, day-ahead or hour-ahead bids and bidding behavior, tariffs, or other market structures. It is therefore complementary to, and does not replace, the role of short-term market modeling.
- **Not a forecast:** The future is uncertain and grows more uncertain the further we venture forward from the present day. Energy pathways modeling helps to inform near-term decision making in the

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[4] For the Oregon Energy Strategy, the CETI-OES Team used updated hydro data from the Pacific Northwest Power Supply Adequacy Assessment for 2029.

> face of that uncertainty, not by forecasting the future, but by suggesting the best way forward across multiple potential futures. By examining different scenarios for how the future might play out, we can examine trade-offs between different strategies and inform near-term decisions to best navigate uncertainty. Energy pathways modeling informs decision making now, recognizing that planning will continue in the future with updated information, new technologies, and new policy. It is therefore concerned with informing near-term decisions in the context of future goals with what we currently understand about how technologies, prices, loads, and other elements of energy demand and supply will change over time.

Before delving into the specific Technical Approach that the CETI-OES Team takes to produce energy pathways modeling results to guide Oregon policymakers in developing an energy strategy, it is important to understand the fundamental concept of the five deep decarbonization pillars.

B. Five Pillars of Deep Decarbonization

There is no one pathway to deep decarbonization and energy pathways modeling is designed to demonstrate a variety of different combinations of energy resources that can meet a desired emissions target. Regardless of the pathway, however, there are five intertwined pillars of deep decarbonization as Figure 2 illustrates, showing the final results of the Net-Zero Northwest Energy Pathways (NZNW) study.[5] While the results of the Oregon Energy Strategy will be different, the themes represented by the results of the NZNW study reflect findings that are consistent across numerous other studies that have explored economy-wide pathways to decarbonization.[6]

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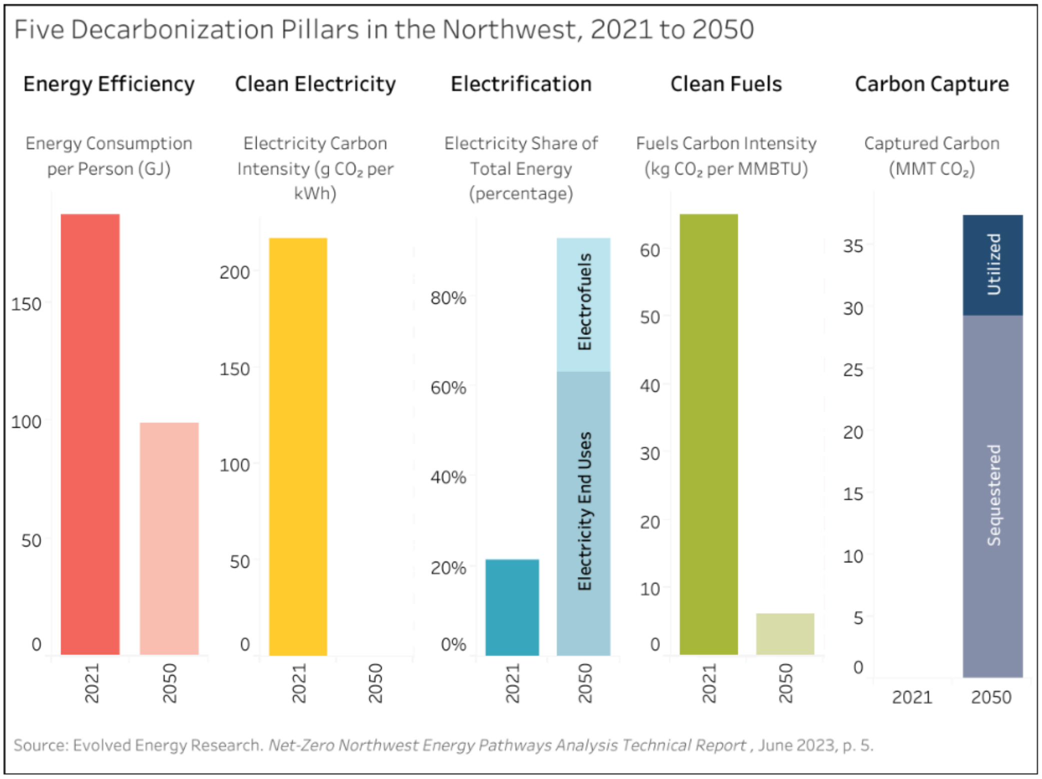
[5] *Net-Zero Northwest: Technical and Economic Pathways to 2050 (NZNW).* Clean Energy Transition Institute. June 2023. With the NZNW study, Evolved Energy Research examined low-cost energy pathways for how the Northwest could achieve economy-wide net-zero emissions by 2050.

[6] *See e.g.* SoCalGas. (2021). Role of Clean Fuels and Gas Infrastructure in Achieving California's Net Zero Climate Goals (p. Ch. 2, 23-24). https://www.socalgas.com/sites/default/files/2021- 10/Roles_Clean_Fuels_Full_Report.pdf; California-China Climate Initiative & Energy and Environmental Economics (E3). (2021). Pathways Toward Carbon Neutrality: A Review of Recent Mid-Century Deep Decarbonization Studies for the United States (p. Table 1, 4-5). https://ccci.berkeley.edu/sites/default/files/GTZ-US-2021-FINAL-July13.pdf; Subin, Z. (2019). The Role of Electricity in Decarbonizing California's Energy System (p. Slide 11). https://www.ethree.com/wp-content/uploads/2019/10/The-Role-of-Electricity-in-DecarbonizingCalifornia%E2%80%99s-Energy-System-CEC-Workshop-24-Sept-2019.pdf.

Figure 2. Five Decarbonization Pillars[7]



Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, p. 5.

Starting from the left with the rose/pink bars, we see **energy efficiency**, which is an essential bedrock decarbonization strategy because the less energy you need, the less you need to produce. If efficiency decreases energy produced with fossil fuels, you reduce carbon emissions right away. Requiring less energy also eases strain on the overall system to meet demand. The figure shows that when modeling a net-zero emissions by 2050 target for the Northwest, energy consumption per person was reduced nearly in half.

The next pillar of decarbonization in gold/yellow is **clean electricity**, which is electricity produced with renewable energy (onshore/offshore wind, solar, geothermal, tidal) or a non-emitting power producer, such as nuclear, instead of coal or natural gas. The figure shows the carbon intensity of electricity use decrease to zero by 2050 in the NZNW analysis.

Because clean electricity is a lynchpin decarbonization strategy, electricity demand will grow significantly over the coming decades as the economy shifts to electricity to power many uses tomorrow that currently use fossil fuels, such as internal combustion engines and natural gas furnaces or propane stoves, and the like. This is evident in the blue bars under **electrification,** which show electricity use doubling from 2021 to 2050.

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[7] *Five Decarbonization Pillars, Net-Zero Northwest: Technical and Economic Pathways to 2050. June 2023. Clean Energy Transition Institute & Net-Zero Northwest Technical Report (Evolved_NZNW_Energy_Technical Report_06-2023). June 2023. p. 5.*

Not all energy end-uses can be electrified due to a variety of factors, including how much weight or space an electric battery might require for a long-duration activity such as aviation, marine shipping, long-haul trucking, or in the case of industrial processes, high temperature requirements. For these uses, we will need **clean fuels**, which are fuels with low or zero associated emissions such as hydrogen or ammonia produced with renewable energy. The green bars show a significant drop in the carbon intensity of fuels from 2021 to 2050.

Finally, there are uses that can be neither electrified nor converted to low-carbon fuels and for those we must rely on **carbon capture** to sequester emissions or use captured carbon to produce clean synthetic fuels. These strategies are reflected in the purple bars in Figure 2. Carbon can also be captured today at the smokestack and prevented from being emitted into the atmosphere. It is hoped that in the future, technological advances will make it possible to capture carbon from the atmosphere in a process called direct air capture or (DAC).

Capturing carbon emissions is an emerging two-pronged decarbonization strategy: 1-it keeps carbon from being emitted into the atmosphere, or removes it from the atmosphere, *and* 2-the carbon can be used as a feedstock to produce synthetic fuels.

III. Technical Approach

The CETI-OES *Energy Pathways Modeling Technical Approach* (Technical Approach) is designed to produce energy pathways that will enable Oregonians to understand what the state's future energy systems could look like as the state decarbonizes over time. The modeling results can help the state make informed decisions today in crafting an energy strategy that will put the state on the most cost-effective path to reducing greenhouse gas emissions while providing insights to help navigate risks, uncertainties, and trade-offs. The Technical Approach:

- Analyzes near-term policies and strategies in the context of Oregon's greenhouse gas reduction targets and other objectives;
- Educates policymakers on choices and risks that the state faces in developing an energy strategy;
- Conveys the magnitude of, and trade-offs between, actions that would achieve the state's energy goals;
- Illuminates dead-end strategies; and
- Informs near-term energy strategy decisions, aligned with Oregon's priorities, and compliant with state laws, policies, and greenhouse gas reduction targets.

These are the principles that guide the Technical Approach:

- **Benchmarking:** Ensuring that the current energy system developed as the basis for modeling draws upon the best available local information, represents present energy demands, electricity resources, near-term investment schedules, and incorporates existing energy policies.
- **Backcasting:** Guiding state policymakers to make informed decisions in the context of long-term goals and in the face of uncertainty, and not just simulating outcomes of existing market structures and regulatory systems over time; identifying decisions, investments, and system operations in future years that will best meet the state's objectives.
- **Unbiased Analytics:** Relying on public and verifiable sources that are technology- and solution-agnostic and responsive to public engagement; crafting questions with the most accurate and least biased assumptions; and learning what the modeling and public engagement tell us.
- **Responsiveness to Input:** Designing the analysis to be responsive to the broad array of input provided through a public engagement process.
- **Actionability:** Ensuring that the pathways clearly show the consequences of potential near-term policy and planning decisions in the context of the state's long-term objectives.

The Technical Approach uses a scenario modeling methodology guided by "What if?" research questions that pose potential energy futures based on what we know today. It starts with choosing a geographical region within which to model, an emissions reduction target to achieve by 2050, and interim targets along the way. Current clean energy policies are also input into the model as part of the baseline starting point.

In conjunction with ODOE and public engagement, the CETI-OES Team inputs the most Oregon-relevant and up-to-date energy data for the geographical area chosen to be examined and makes assumptions about how quickly different end uses would become decarbonized. Then, with ODOE and public participants, the modelers develop a Reference Scenario that reflects assumptions aiming to define a least-cost pathway to an affordable, reliable, low-carbon future that aligns with state energy objectives.

The model uses scenarios that investigate a series of “What if?” research questions that modify the Reference Scenario assumptions to test the impact of those modifications on pathways to achieve energy policy goals and cost. The modeling results offer pathways of investments and energy systems over time that achieve emission reduction targets.

The methodology for the Technical Approach is as follows:

Model Foundation

- Geographical Region Selection
- Emissions Target Incorporation
- Current Policy Assessment
- Data Approach in conjunction with ODOE subject matter experts
- Assumptions Development in conjunction with data holders
- Data Tables and Data Library

Research Questions

- Reference Scenario Development
- “What if” Scenarios Development

Modeling and Results

- Modeling Process
- Understanding Results

Approach to Understanding Effects of Pathways on Oregonians and Addressing Equity Considerations

- Representative Households & Energy Wallet
- Geospatial Mapping
- Economic and Employment Effects
- Health Impacts

Approach to Additional Cross-Cutting Issues

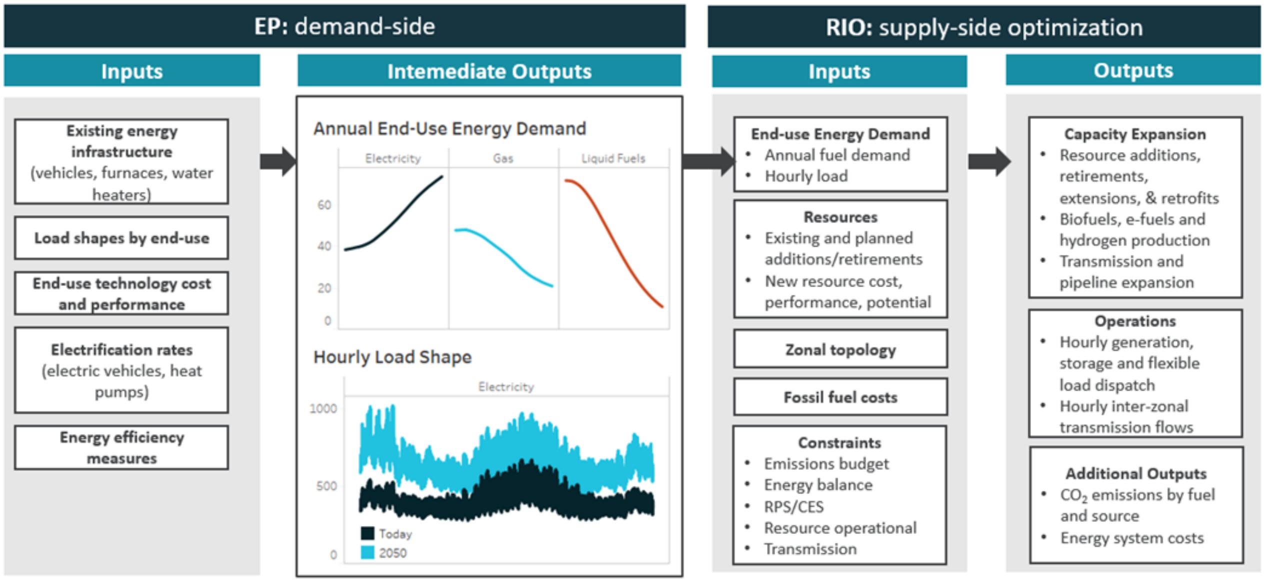
- Land Use and Natural Resource Impacts
- Reliability, Resiliency, and Energy Security

Each of these is discussed in order in the following pages.

IV. Model Foundation

Evolved Energy Research (Evolved) uses two modeling tools for its energy pathways deep decarbonization modeling: (1) a bottom-up energy demand model called **EnergyPATHWAYS (EP)**, and (2) the **Regional Investment and Operations (RIO)** model, an economy-wide optimal capacity expansion model that includes detailed hourly electricity system operations and constraints.[8] Evolved integrates scenario planning on the demand-side and optimizes the supply-side, incorporating load flexibility within the supply optimization. Figure 3 below illustrates the role each tool plays in the modeling framework.

Figure 3. High-level representation of Evolved Energy Research's modeling framework[9]



A. EnergyPATHWAYS Model

The EP model will simulate a detailed bottom-up representation of all energy-consuming technologies in Oregon (e.g., number of water heaters, air conditioning units, gasoline vehicles, electric vehicles, etc.) and how they will change over time based on sales assumptions. EP develops a comprehensive picture of electricity and fuel demands across 80 subsectors of the economy (see Figure 4). Sales assumptions of demand-side technologies can be specified by year or follow S-curve adoption logic that simulates market emergence, market growth, and market maturity.

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[8] For comprehensive documentation of Evolved's modeling approach, please see Annual Decarbonization Perspective (ADP) 2023.

[9] *Net-Zero Northwest Technical Report (Evolved_NZNW_Energy_Technical Report_06-2023). June 2023. p. 263.*

Figure 4. Examples of sub-sectors that Evolved Energy Research models on the demand side.[10]

Residential Sector
- Air-conditioning
- Space heating
- Water heating
- Lighting
- Cooking
- Dishwashing
- Freezing
- Refrigeration
- Clothes washing
- Clothes drying

Commercial Sector
- Air-conditioning
- Space heating
- Water heating
- Ventilation
- Lighting
- Cooking
- Refrigeration

Industrial Sector
- Boilers
- Process heat
- Space heating
- Curing
- Drying
- Machine drives
- Additional subsectors (e.g., machinery, cement)

Transportation Sector
- Light-duty autos
- Light-duty trucks
- Medium-duty vehicles
- Heavy-duty vehicles
- Transit buses
- Aviation
- Marine vessels

For the Oregon Energy Strategy, sales share assumptions will be inputted considering other studies done in the state and region on technology adoption, input from ODOE and public participants, and the CETI-OES Team's experience looking at sales targets that would achieve clean energy and emissions targets at lowest cost in Oregon and other regions.

B. Regional Investment and Operations (RIO) Model

Once EP develops a picture of energy demands across the economy by subsector and year using scenario assumptions built with ODOE and public participants, RIO optimizes supply-side investment and operational decisions to serve those energy demands reliably. Electricity operations are modeled on an hourly timescale, ensuring that electricity sector investments are subject to operating and reliability constraints.

Electricity sector modeling includes commercial and emerging technologies; transmission constraints and transmission expansion; flexible loads; energy storage (long and short duration); demand response and load shifting; distributed energy resources; economic curtailment of renewables; simulation of operations across multiple weather years and hydro years; reliability requirements; optimal build and operations of electric fuel production; carbon capture; and many other features.

The electricity sector modeling integrates with optimization of fuels supply, which includes primary energy supply of oil, natural gas, and biomass; and fuels conversion infrastructure, including refining, bio-refining, hydrogen production, Fischer-Tropsch hydrocarbon synthesis, Haber-Bosch ammonia production, and others.

Table 1 gives examples of the energy resources that can be represented in the capacity expansion modeling, both in electricity and fuels production. This list is not exhaustive, and any resources identified by ODOE and public participants as important to the analysis can be incorporated into the model as the data and assumptions are calibrated in advance of the modeling.

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[10] Kick-off presentation to Oregon Department of Energy (ODOE) Oregon Energy Strategy Working Groups, July 30, 2024, slide 13.

Table 1. Examples of energy resources the model can build as part of an optimal portfolio

Resource Categories	Examples
Biomass/Biomass Conversion	Biomass supply curves: existing woody and waste, new woody/herbaceous/waste, corn ethanol land displacement, anaerobic digestion feedstocks (landfill gas-LFG, water resource recovery facilities, food waste, manure). Conversion technologies: Fischer-Tropsch, pyrolysis, BECCS H_2, cellulosic ethanol, corn ethanol, biochar
Direct Air Capture (DAC)	DAC for synthetic hydrocarbon production (e-fuels), DAC for geologic sequestration, differentiated by technology (solid sorbent, or liquid solvent) and efficiency by climate zone
Distributed Energy Resources (DERs)	Flexible end-use loads (electric vehicles, water heating, space heating, air conditioning, appliance loads), rooftop solar, distributed storage
Dispatchable Hydroelectric	Reservoir hydro, on-stream pumped hydro
Electricity Storage	Li-Ion, Flow batteries, long duration energy storage (LDES), pumped hydro, thermal storage
Electricity Transmission & Distribution Infrastructure	Distribution upgrades, generator interties, existing corridor upgrades, new AC and DC corridors
Geologic Sequestration	Enhanced oil recovery (EOR), onshore saline, offshore saline
Hydrogen Production	Electrolysis, bioenergy w/ carbon capture and storage (BECCS) H_2, SMR, SMR w/ CC, high-temp electrolysis, autothermal reforming (ATR) w/ CC
Hydrogen Storage	Aboveground tanks, underground pipes, salt cavern storage
Industrial Decarbonization Solutions	Industrial carbon capture, solar thermal heat, dual-fuel boilers, differentiation between heat grades of industrial processes with different options for fuel switching, hydrogen, thermal energy storage, cement and lime retrofit and new build options including efficiency improvements, alternative fuels, direct separation carbon capture and storage (CCS), integrated CCS, and oxyfuel, iron and steel options including direct reduced iron (DRI), electric arc furnace (EAF), and CCS
Pipelines	Ammonia, hydrogen, CO_2
Thermal Power Plants	Gas combustion turbine (CT), combined cycle gas turbine (CCGT), coal, coal w/ carbon capture (CC), gas w/ CC, gas w/ CC (Allam), biomass, biomass w/ CC, biomass w/ CC (Allam), gas and coal CC retrofits, small modular reactor (SMR) and Gen IV nuclear, repowering of brownfield sites with incentives
Utility-Scale Renewables	Solar PV, onshore wind, offshore wind, geothermal
Zero-Carbon Fuel Synthesis	Ammonia, synthetic hydrocarbons (refined and unrefined), methanol
Zero Emission Vehicles	Light-duty, medium-duty, heavy-duty, and bus vehicle types

The model also includes detailed and updated policy representation of clean electricity standards; emissions targets; resource qualification to achieve policy goals; renewable energy credits; production tax credits; investment tax credits; and tax code clean resource accounting mechanisms. The Inflation Reduction Act (IRA) incentives are incorporated into the model, including accounting mechanisms for tax code updates, such as hourly matching, additionality, and deliverability requirements for hydrogen producers to receive the full hydrogen production tax credit.

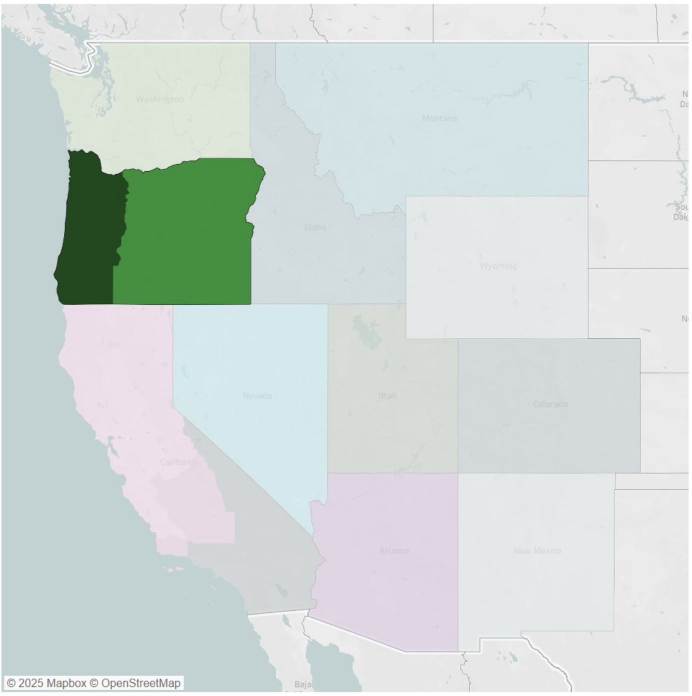
The model also incorporates state-level non-CO_2 and land-sink supply curves. Economy-wide emissions accounting includes emissions from non-combustion sources, such as agriculture and industrial processes. **The model incorporates the potential and cost to reduce these emissions, weighing those solutions against energy system emissions reductions in the optimization.** As with many features in RIO, this functionality is optional and depending on ODOE and public feedback, the model can incorporate state projections of non-CO_2 emissions reductions in these sectors instead.

Finally, RIO offers different ways to constrain the rate of resource builds such as: future build rates pegged to historical build rates; limits on developed land area; or supply curves representing slower maximum builds early on as supply chains scale up, workforces are trained, and siting and permitting processes are reformed.

C. Geographical Region Selection

Oregon does not exist in a vacuum but instead is a vital part of an increasingly dynamic energy system of 11 Western states as seen in Figure 5. Clean energy advances in other Western states impact the availability and cost of solutions here. Hence the Technical Approach will model Oregon in the context of the 11 Western states, with California represented as two zones, Oregon represented as two zones, each other Western State modeled as one zone per state, and the rest of the US as a single zone.

Figure 5. Model Geography[11]



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[11] *Net-Zero Northwest Technical Report (Evolved_NZNW_Energy_Technical Report_06-2023). June 2023. p. 275.*

Advantages of this approach include:

- Contextualizing the energy decisions Oregon makes as operating as part of a larger energy system
- Accounting for competition for fuels including biomass, renewables, and renewably-derived hydrogen
- Balancing the electricity system over a large and diverse region, operating as if there were a single balancing authority
- Capturing transmission lines and pipeline flow and build constraints
- Enabling region-wide, least-cost resource, load, and temporal diversity to meet the regional economy's energy needs while achieving a net-zero emissions target

Decarbonization modeling suggests that in a deeply decarbonized future we will live in a world where a variety of different electricity resources will be on the grid at different times of the day and year. Examples of these resources could include solar from California, Arizona, New Mexico, Nevada, and Colorado; offshore wind from California and Oregon; inland wind from Montana, Utah, and Wyoming; potentially nuclear in Idaho and Utah; and hydroelectricity from the Northwest. These clean electricity resources could support a wide range of technologies to power a much broader set of end-uses than is currently the case today.

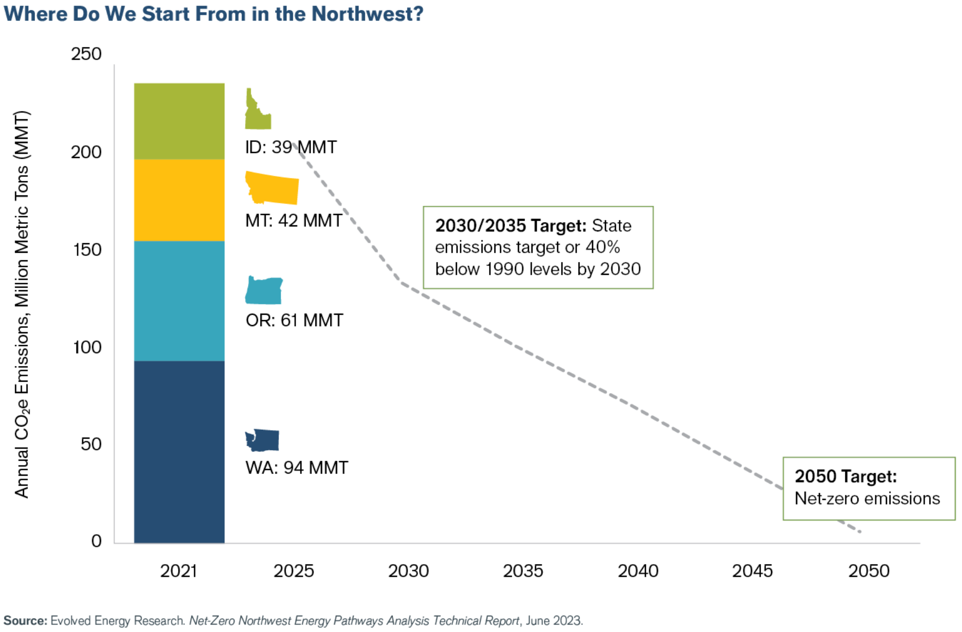
In addition to modeling Oregon in the context of the other 10 Western states, the model can also investigate regions within a state. During the initial review of the technical and data approach, transmission constraints within the state are identified as important to capture. Therefore, the Technical Approach will model Oregon as two zones: Western and Eastern Oregon.

D. Emissions Target Development

A critical early step in energy pathways decarbonization modeling involves selecting a deep decarbonization target that will provide the end point for the analysis, where the energy pathways decarbonization modeling will show different pathways for how to get to that point.

Figure 6 shows the net-zero target modeled in the Net-Zero Northwest Technical and Economic Analysis plotted against the starting point of emissions for the four Northwest states in 2021. That analysis used 1990 as the baseline year for all Northwest states, drawing from each state's emissions inventory. The emissions modeling includes both carbon dioxide (CO_2) and non-CO_2 emissions.

Figure 6. Where do we start from in the Northwest?[12]



Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023.

E. Current Policy Assessment

Another early step in the modeling process is to align the analysis with Oregon's policies and leverage recent work from state agencies and regional organizations where possible. The modeling is grounded in Oregon's anchor clean energy policies, as well as an understanding of recent utility IRPs and Clean Energy Plans (CEPs). It has a specific focus on aligning near-term assumptions and actions and on business-as-usual expectations for energy efficiency, electrification, and other load growth, including new large technology sector loads, such as for data centers or new and/or automated manufacturing. The team reviews utility distribution system plans (DSPs), transportation electrification plans (TEPs), flexible load plans, and information from the Energy Trust of Oregon and the Northwest Energy Efficiency Alliance.

In addition to reviewing recent utility plans, the CETI-OES Team reviews Oregon energy policies and documents how the modeling accounts for these policies and associated regulations. This review involves all policy documents identified by ODOE and public participants, including but not limited to: HB 3630 (2023); HB 2021 (2021); SB 1547 (2016); relevant rulemakings; the Department of Environmental Quality's (DEQ) CFP rules; Executive Order 20-04; DEQ's CPP rulemaking; and the "Climate Package" from the 2023 Legislative Session.

Finally, the CETI-OES Team reviews program design elements and requirements for regional programs in which Oregon utilities already participates or could participate in the future, including the Western Resource Adequacy Program (WRAP), CAISO's Extended Day-Ahead Market (EDAM) and Western Energy Imbalance Market (WEIM), and SPP's Markets+ and Western Energy Imbalance Service (WEIS).

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[12] *Net-Zero Northwest Energy Pathways-Emissions. June 2023, p. 2.*

We examine the various regional transmission planning organizations and efforts, including the Western Transmission Expansion Coalition (WestTEC) to determine key dependencies between Oregon's Energy Strategy and regional transmission planning efforts. The overarching goal of this policy assessment is to ensure that the Oregon Energy Strategy complements and informs existing processes and does not attempt to recreate or supplant them.

F. Data Approach

The Data Approach is designed to manage, collect, and coordinate data for use in modeling the pathways for the Oregon Energy Strategy. Data collection included multiple meetings with dataholders and engaged community members throughout the state. The starting point is Evolved's comprehensive, regularly updated economy-wide database that incorporates national and regional studies with high geographical resolution for technology stocks; technology cost and performance; built infrastructure and resource potential; and high temporal resolution for electricity loads by end-use and for renewable (wind and solar) generation profiles.

Evolved's EP model leverages many of the same input files used to populate the National Energy Modeling System (NEMS) that the United States Energy Information Agency (EIA) deploys to forecast the Annual Energy Outlook. Where possible, Oregon-specific data sources are substituted in place of this data.

Examples of local data sources to draw from include recent utility Integrated Resource Plans, IRP updates, Clean Energy Plans, Distribution System Plans, and Transportation Electrification Plans. The team will review recent relevant work to identify potential data and scenarios for incorporation into the analysis, including, at a minimum, the following ODOE reports: the 2022 Biennial Energy Report;[13] 2023 Biennial Zero Emission Vehicle Report; 2023 Cooling Needs Study; 2022 Small-Scale Renewable Energy Projects Study; 2021 Regional Transmission Organization Study; 2022 Floating Offshore Wind Study; and the 2024 Oregon Energy Security Plan. The team reviews recent reports from the Oregon Climate Action Commission, including the Oregon Climate Action Roadmap to 2030.

To gain a broader regional perspective, we also review the Northwest Power and Conservation Council's 2021 Northwest Power Plan, and follow key developments as the Council develops the next plan; the Bonneville Power Administration (BPA) White Book; the Pacific Northwest Utilities Conference Committee (PNUCC)'s2024 Northwest Regional Forecast; and the Columbia River Inter-Tribal Fish Commission Energy Vision for the Columbia River Basin.

1. Demand Side: Economy-Wide Energy Demands

The EP model uses information about Oregon by county, such as population and square footage, to downscale these national-level databases (that are sometimes at the state level but often at the census division level) and obtain an estimate for state-level technology stocks, service demands, and energy demands.

The CETI-OES Team uses the EIA's State Energy Data System (SEDS) to benchmark the energy demands that are built bottom-up from the EP stock representation, and finetune the downscaling to match Oregon-specific energy demands. Where possible, the downscaled national study data is replaced with local demand data from

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[13] To the extent possible, the CETI-OES Team incorporated data being developed for the 2024 Biennial Energy Report into the modeling.

Oregon- or region-specific studies. This is our approach to addressing data gaps between national and local data.

By downscaling national studies at state or census division granularity, we have complete coverage of energy demands across the economy. This overcomes any data gaps in Oregon-specific studies. The national studies have a complete data framework into which we can plug in updates from Oregon-specific studies. In addition, the Technical Approach considers energy demands in states outside of Oregon to produce a realistic Oregon Energy Strategy because Oregon's electricity and fuels supply is integrated into larger energy systems.

The analysis must model the competition for resources, resource and load diversity, policies in other regions, and resource potentials outside of Oregon to understand the challenges of decarbonizing the state's economy. The EP database contains that information for all states at a high level of granularity and specificity.

A further factor is that these national datasets include forecasts of service demand growth, population growth,[14] and industrial activity, reflecting regional forecasts of economic and population growth. Additionally, the impact of global warming on energy demand is reflected through changes in heating degree days and cooling degree days.

The U.S. energy economy is separated into 80 energy-using demand subsectors in the EP model (see Figure 4 above). Subsectors, such as residential space heating, refer to energy use associated with the delivery of an energy service.[15]

2. Supply Side: Energy Supply Chains

On the supply side, the RIO model includes a representation of the current energy systems—including electricity transmission and generation and fuel supply and delivery networks—and captures the potential for investment in energy supply chains in the future to meet Oregon's and the larger region's energy needs. It also includes a multitude of other inputs, such as emissions factors and emissions constraints, land use and land-use constraints, and non-CO_2 emissions reduction supply curves.

In modeling the supply side, the analysis again starts from national studies of regional resources, such as those from the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the National Renewable Energy Lab. A comprehensive list of sources for all inputs to the RIO model is available in the technical documentation of Evolved's ADP 2023 Technical Documentation (p. 60-66).

Evolved's generator database includes up-to-date generator locations, capacity, and cost. Where possible, these will be updated with local sources, particularly the utility IRPs that incorporate investment pipelines to capture accurate near-term resource additions. The model also represents shares of out-of-state generation, such as from wind and coal plants, delivered to Oregon loads.

For resource and transmission potentials for the Western United States, Evolved uses *The Nature Conservancy (TNC) Power of Place – West study* (*PoP-West*), where resource potentials use detailed GIS mapping of

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[14] For the Oregon Energy Strategy modeling, state-specific population growth forecasts were identified and used in place of downscaled national data.

[15] Evolved's ADP 2023 Technical Documentation (p. 52-60) offers a detailed description of the methods EP uses to project energy-service demand, energy demand, and the costs and emissions associated with the performance of that service, as well as tables referencing the data sources for all economy subsectors.

sensitive land areas. The *PoP-West* study produced three exclusion levels corresponding to environmental and social impact scores.

- Level 1 included legally protected areas, including national parks, wildlife refuges, marine sanctuaries, and military training areas, and excluded biomass feedstocks from conservation lands.
- Level 2 added administratively protected areas, including critical habitats, priority habitat management areas, tribal lands, and wetlands. Purpose-grown biomass crop cultivation was limited to the land currently cultivated for corn used for corn ethanol.
- Level 3 added land areas of high conservation value, including those with social, economic, or cultural value, including prime farmland, important bird areas, big game habitat, and TNC ecologically core areas.

As part of *PoP-West* and subsequent studies, Evolved has redeveloped its solar and wind hourly production shapes and capacity factors using high geographic granularity insolation and wind forecast data. This data can be redeveloped for any past weather years that ODOE and public participants wish to include in the analysis for Oregon. *PoP-West* also includes detailed consideration of existing transmission and expansion opportunities at a state level, factoring topographical and land use characteristics into feasibility, potential, and cost of transmission expansion. The analysis uses this West-wide resource for transmission and expansion opportunities, incorporating updates to Oregon interties with data from utility IRPs.

The analysis uses the latest emissions inventory developed by the Oregon DEQ for target-setting and benchmarking of today's emissions from the model against the most recent emissions inventory year.

G. Assumptions Development

Along with managing, collecting, and coordinating data for use in the pathways modeling, we engage with ODOE, public participants, and Working Groups to develop assumptions that feed into the model.

The modeling includes assumptions about policy (e.g., Oregon's HB 2021 targets for 2030, 2035, and 2040), the supply side (e.g., whether nuclear qualifies as a clean resource in the modeling), and the demand side (e.g., future sales shares of electric vehicles, heat pumps, and other technologies). Evolved has developed these assumptions based on reputable sources, and these are then further refined through public engagement. See Table 2 and Table 3 below for example lists of policy, supply-side, and demand-side assumptions from the Net-Zero Northwest study.[16]

Example of policy and supply-side assumptions in the Net-Zero Northwest Core Case:

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[16] The final scenarios and assumptions modeled for the Oregon Energy Strategy are available at [Oregon-Energy-Strategy-Modeling-Assumptions-Sources.pdf]().

Table 2. Net-Zero Northwest Policy and Supply-Side Assumptions[17]

Policy or Supply	Core Case Assumptions
Clean Electricity Policy	State-by-state clean electricity policy. Oregon: 100% clean electricity by 2040; Washington: CETA, 100% clean by 2045, coal retirements by 2025
Economy-Wide GHG Policy	State targets by 2030 (or 40% below 1990 for those without them), net-zero by 2050
Clean Resource Qualification	Renewables and 100% clean fuels, nuclear, fossil gas with carbon capture.
Inflation Reduction Act (IRA) Incentives	Supply-side incentives included for hydrogen production, renewable electricity generation, battery storage, carbon sequestration, clean fuels, and nuclear.
Resource Availability	TNC renewable resource potential; TNC new transmission supply curves; 4th generation and SMR nuclear not permitted in Oregon or California. New gas build not permitted in Oregon.
Fuels	AEO Reference fuel prices; sequestration potential across the West where geologic formations exist; clean fuels have zero emissions associated with them, so sequestration credit is left in state of origin. Oregon and Washington low-carbon fuel standards incorporated
Land sink	Supply curve of land sink measures
Non-energy emissions	Non-energy emissions abatement curve

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[17] *Net-Zero Northwest Technical Report (Evolved_NZNW_Energy_Technical Report_06-2023). June 2023. p. 250*

Example of Demand-side Assumptions in the Net-Zero Northwest Core Case are below in Table 3:

Table 3. Net-Zero Northwest Demand-Side Assumptions.[18]

Assumption Type	Core Case Assumptions
Energy Service Demand	Annual Energy Outlook (AEO) 2022
Buildings: Electrification	Fully electrified appliance sales by 2035
Buildings: Tech Energy Efficiency	Sales of high efficiency technology: 100% in 2035 High efficiency building shell sales: 100% by 2035
Transportation: Light-Duty Vehicles	100% ZEV sales by 2035
Transportation: Medium and Heavy-Duty Vehicles	HDV long-haul: 50% hydrogen, 50% electric sales by 2045. HDV short-haul: 100% electric sales by 2045. MDV: 100% electric sales by 2035
Industry	Generic efficiency improvements over AEO of 1% a year; fuel switching measures; 1.5% a year efficiency improvement in aviation. Process heat storage opportunities
Distributed Energy Resource Schedule	State-by-state rooftop solar schedule, 75% of light duty vehicle load and 10% of heating and cooling load is flexible by 2050

Engaging with ODOE, dataholders, and Working Groups involves sharing a working PowerPoint document, collaborating on Excel spreadsheets, and eliciting feedback on alternative sources of data for each input or assumption that better fit the needs of the Oregon Energy Strategy. We ensure transparency in the data and assumptions underpinning the analysis by specifying the inputs and assumptions defining the analysis, recording revisions made to those assumptions, and documenting changes through draft, revised, and final stages of development. Consistent with the research questions described below, this engagement process focuses first on developing assumptions for a Reference Scenario and then assumptions for "What if" scenarios.

Figure 7 below shows an example of a PowerPoint slide showing draft Transportation assumptions. In the Research Questions section below, we describe the role of assumptions in developing the Reference Scenario and additional "What if" scenarios.

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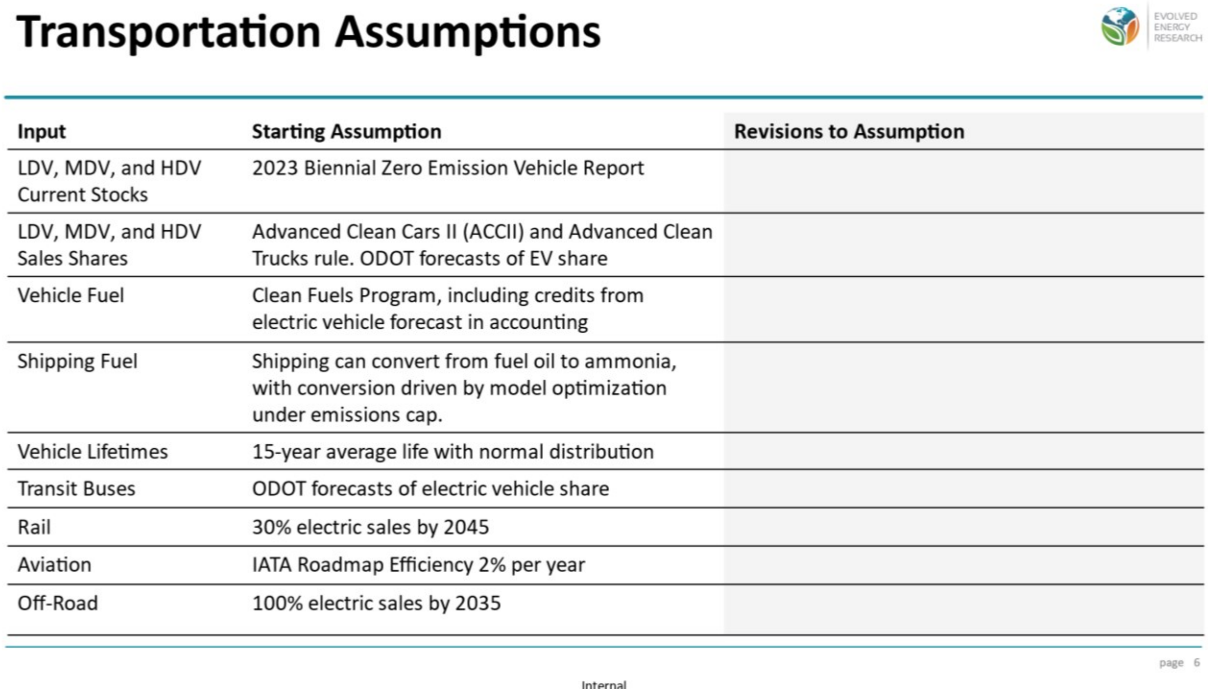
[18] *Net-Zero Northwest Technical Report. Evolved_NZNW_Energy_Technical Report_06-2023. June 2023. p. 251.*

Figure 7. Example Data/Assumptions PowerPoint slide for Transportation.



Transportation Assumptions

EVOLVED ENERGY RESEARCH

Input	Starting Assumption	Revisions to Assumption
LDV, MDV, and HDV Current Stocks	2023 Biennial Zero Emission Vehicle Report	
LDV, MDV, and HDV Sales Shares	Advanced Clean Cars II (ACCII) and Advanced Clean Trucks rule. ODOT forecasts of EV share	
Vehicle Fuel	Clean Fuels Program, including credits from electric vehicle forecast in accounting	
Shipping Fuel	Shipping can convert from fuel oil to ammonia, with conversion driven by model optimization under emissions cap.	
Vehicle Lifetimes	15-year average life with normal distribution	
Transit Buses	ODOT forecasts of electric vehicle share	
Rail	30% electric sales by 2045	
Aviation	IATA Roadmap Efficiency 2% per year	
Off-Road	100% electric sales by 2035	

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Internal

H. Data Tables and Data Library

All data used in the model and assumptions developed with input is kept in a living document in PowerPoint format that describes all sources and assumptions, starting point data sources, assumptions, and revisions made to them. We include how feedback was incorporated or why it was not included. For example, a participant may recommend including an emerging resource that does not have sufficient publicly available data to incorporate into the model. This forms the basis for the final Data Library, delivered in a format agreed upon with ODOE through the process of finalizing the Data and Assumptions Approach.

This living document can be used in meetings with ODOE, community members, and Working Groups to easily interrogate a particular data source or assumption so that it can be approved or refined. It includes current data sources, those that describe the future and assumptions developed with ODOE and participants in the process that describe each of the scenarios designed to answer the study's research questions.

This living document also contains assumptions slides for each scenario, designed to answer the research questions posed in the Final Technical Approach. These scenario-specific assumptions show the starting assumption and revisions to those assumptions throughout the modeling development process.

V. Research Questions

The analysis employs a scenario modeling approach. Scenarios are developed by asking "What if?" research questions that represent potential future uncertainties due to factors outside of decision-maker control or alternative state priorities that shift future policies. Examples include uncertainties in future technological development; siting and permitting challenges; consumer trends and behavior; federal and local policies; regional and global fuel supply conditions; and different state policy objectives that change the trade-offs between outcomes – such as developing local jobs or limiting environmental impacts. Identifying and analyzing the uncertainties represented by these questions is key to the success of the Oregon Energy Strategy.

The CETI-OES Team investigates these "What if?" research questions by modeling scenarios that use a set of inputs—developed in consultation with ODOE and public engagement—and produce pathways of investments and operations of energy systems over time that achieve state targets.

A single scenario may provide useful information to inform multiple research questions. For example, a scenario that limits development of renewable resources, clean energy technologies, and/or transmission in Oregon would provide answers to both uncertainty—and policy-related research questions such as "*What if development of new clean energy resources and/or transmission lines is delayed or limited because of unforeseen siting and permitting challenges?*" But the same scenario could address the policy-related research question, "*What if stronger environmental regulation limits deployment of renewable and clean resources in Oregon?*" that prioritizes state objectives differently, emphasizing local environmental stewardship.

Some of the most interesting findings from pathways analysis come from comparisons between scenarios. In the above example question about siting and permitting challenges, the cost impact, feasibility challenges, different investment decisions, and environmental impacts from reduced siting and permitting would only be apparent when compared to a scenario that has less constrained siting and permitting. The comparison would inform policy making by showing trade-offs between taking one course versus another. It also shows what choices remain common across scenarios, regardless of uncertainties or state priorities. These so-called "least regrets" choices would be the basis for policy-making recommendations.

The Technical Approach therefore starts from a common set of assumptions about demand- and supply-side technology availability and potential, the evolution of the demand side, and the actions of surrounding states. These assumptions form a Reference Scenario whose definition will be developed in consultation with ODOE and the public and will be the basis for common comparison with other scenarios to answer agreed upon research questions.

The CETI-OES Team will model a Reference Scenario and six additional scenarios to support recommendations in the Oregon Energy Strategy. The Technical Approach involves working with ODOE and the public to determine the most pressing questions, uncertainties, and state priorities that will provide the most valuable information to policymakers.

For each scenario, the study will report a wide range of metrics, including annual energy demand across energy types and sectors, investments in energy supply infrastructure, demand-side investments, overall cost of the energy system, greenhouse gas emissions by source and by subsector across the state, and others, allowing comparison across scenarios of the trade-offs between pathways.

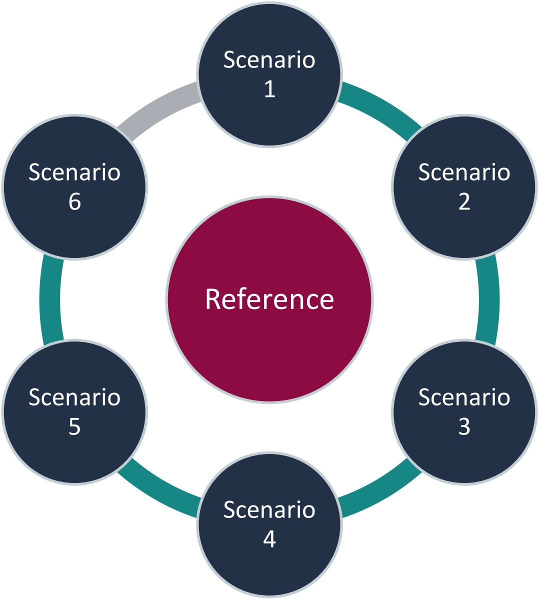
The comparison across scenarios and to the Reference Scenario reveals the relative impacts of different policies, potential uncertainties, and prioritized objectives on Oregon's most effective pathways to meeting its future goals, including near-, medium-, and long-term infrastructure investments. Knowing these impacts can help policymakers evaluate policies that prioritize different state objectives, such as job growth, economic development, environmental justice, environmental impact, health impacts, risk mitigation, and broader economic costs and benefits. The results of these scenario investigations will inform development of the Oregon Energy Strategy.

A. Reference Scenario Development

The analysis starts with a common set of data for demand- and supply-side technology availability and potential, the evolution of the demand side, clean energy emissions targets and policy, and the targets and investments of surrounding states. These assumptions form a Reference Scenario, whose definition will be developed in consultation with ODOE and the public, and against which all other scenarios will be compared by varying assumptions to answer the agreed-upon "What if" questions.

For example, if the analysis were to investigate the question, *"What if developing new clean energy resources and/or transmission lines is delayed or limited compared to the assumptions in the Reference Scenario?",* the modeling would hold all data inputs and assumptions developed for the Reference Scenario constant other than the rate and/or potential to site and permit new generation and transmission. This would allow reviewers to see the different results between scenarios that changing data inputs and assumptions caused. Figure 8 offers an example of how four different scenarios could answer different "What if" questions.

Figure 8. Scenario Analysis: Common Set of Assumptions.[19]



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[19] Net-Zero Northwest Technical Report *(Evolved_NZNW_Energy_Technical Report_06-2023). June 2023. p. 248.*

B. “What if” Scenarios Development

A key step in the modeling process is determining what the most important questions are for ODOE and the public to explore with the five scenarios beyond the Reference Scenario. The following is a list of the kinds of research questions the analysis could answer.

- What if developing new clean energy resources and/or transmission lines is delayed or limited because of unforeseen siting and permitting challenges? What if stronger environmental regulations limit deployment of renewable and clean resources in Oregon?
- What if consumer adoption of technologies like heat pumps and EVs occurs more slowly than expected due to supply chain issues, challenges accessing incentives, or delays in charging infrastructure deployment?
- What if transmission expansion to access resources outside of Oregon is harder than expected? What if in-state resource development is supported to promote growth in the economy and jobs in particular areas of the state?
- What if hydrogen pipelines and other clean fuel delivery systems cannot be constructed between Oregon and other states? What if Oregon chooses to promote clean fuels development in-state for economic development and jobs growth?
- What if the cost, performance, or availability of emerging technologies, like long duration storage, offshore wind, and hydrogen, do not align with expectations?
- What if expansion of the technology sector leads to rapid load growth in Oregon?
- What if distributed energy resource adoption were accelerated due to customer benefits?

As a further example, Table 4 shows the summary of the seven “What if?” Scenarios that the Net-Zero Northwest analysis explored in relation to the Core Case.[20]

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[20] The final scenarios and assumptions modeled for the Oregon Energy Strategy are available at Oregon-Energy-Strategy-Modeling-Assumptions-Sources.pdf.

Table 4. Net-Zero Northwest Core and What-if Scenarios: Policy and Supply-Side Assumptions.[21]

Scenario	Summary	Key Questions Investigated
Core Case	Assumes all states hit net-zero target by 2050; 2030 emission targets in states where they exist & 40% in states where not	What resources must be built to meet clean energy demand for different energy sectors in the Northwest by 2030 and 2050?
Accelerated/ Constrained Transmission	Varies transmission expansion potential in six scenarios	What is the impact of accelerated or constrained transmission expansion across the Western grid?
Gas vs. Electrification in Buildings	Examines the relative costs of preserving or eliminating gas infrastructure over time	How does decarbonizing gas compare with electrification as a decarbonization strategy in buildings?
Role of Distributed Energy Resources	Four scenarios varying levels of DERs (rooftop solar and customer appliance flexible load)	What role can distributed energy resources (DERs) play in a decarbonization strategy?
Pace of Transportation Electrification	Two scenarios that vary the pace of transportation electrification	What is the impact of the pace of transportation electrification on the overall cost of decarbonization for the Northwest?
Clean Fuels Trade-offs	Explores the impact of technology pricing options for biofuels, synthetic fuels, and hydrogen	What are the trade-offs between clean fuels, including biofuels and synthetic fuels/hydrogen?
Emissions Impacts on Health Metrics	Determines changes in criteria pollutants and their impact on health metrics	What is the impact on health metrics in the Northwest if criteria pollutants are reduced as a result of decarbonization?
Oregon Offshore Wind Targets	Investigates the impact on investment decisions if Oregon were to target offshore wind builds of 3 GW by 2030, 5 GW by 2035, and 10 GW by 2050	How does Oregon offshore wind targets impact decarbonization costs and strategy?

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[21] Net-Zero Northwest Technical Report *(Evolved_NZNW_Energy_Technical Report_06-2023). June 2023. p. 252.*

VI. Modeling and Results

A. Modeling Process

Following the development of the assumptions that define the Reference Scenario and the "What If" scenarios, we model the pathways of each scenario. The modeling process includes separate demand-side and supply-side steps as demonstrated in the Evolved Energy Research Deep Decarbonization Pathways Modeling infographic (see Figure 9).

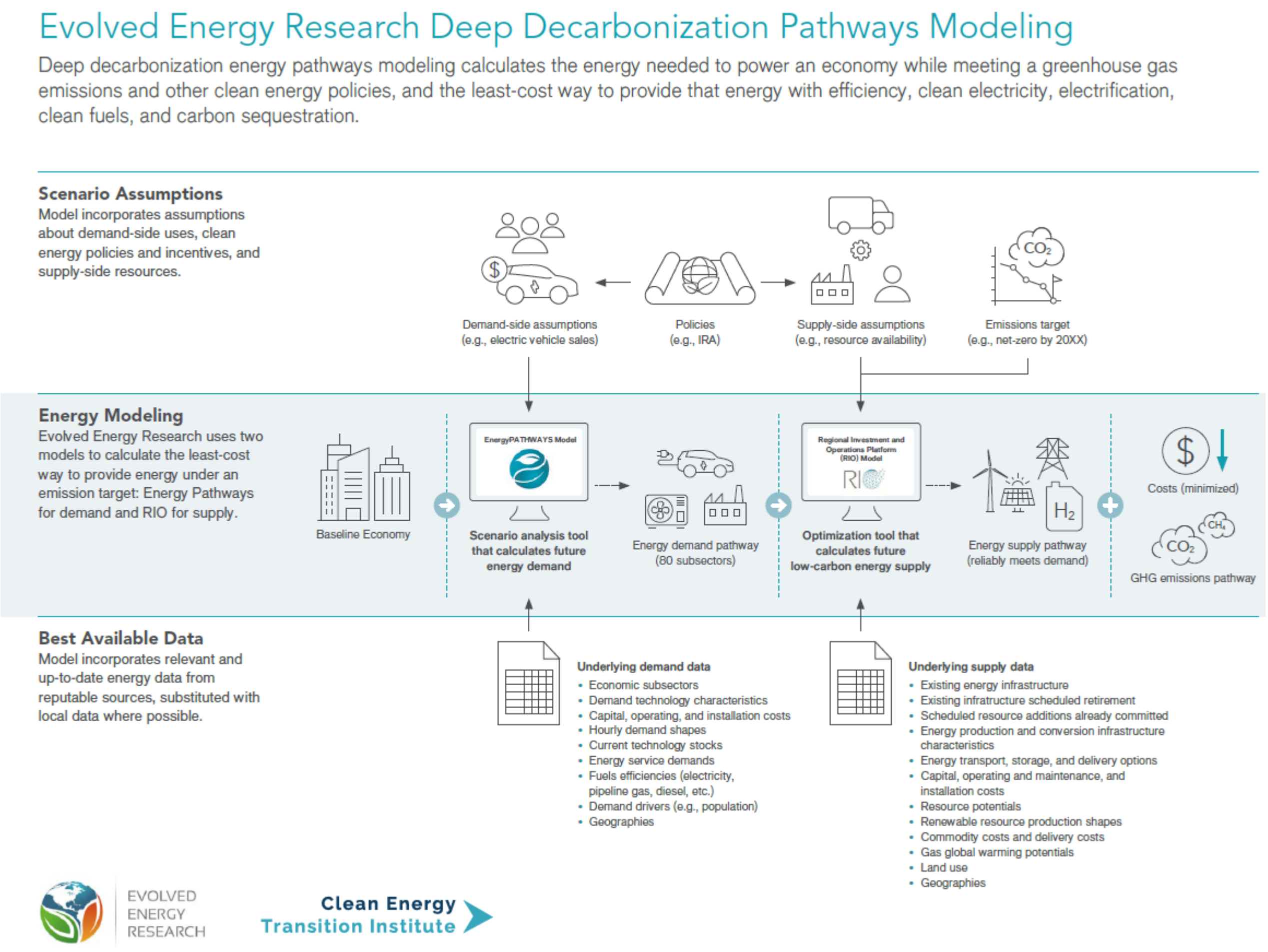
The demand-side modeling in EnergyPATHWAYS will include Oregon-specific data sources and assumptions finalized during development of the Reference Scenario with ODOE, the Advisory Groups, the Working Groups, and the public listening sessions. The EnergyPATHWAYS demand-side modeling will calculate the stock rollover or the impact of technology changes across 80 subsectors of the economy to simulate how energy demands evolve. Outputs will include sales, stocks, energy demand, service demand, costs, and hourly demand shapes across subsectors and in aggregate. These provide inputs into the next step of the process, the supply side.

The supply-side modeling in RIO will take the aggregate demand for all types of energy from EnergyPATHWAYS as inputs. The assumptions for each scenario developed with ODOE and public input will be set up in the RIO model and each scenario will be run to investigate the "What if" questions selected for the study.

The RIO step, as described in previous sections, determines the least-cost set of investments, finding the answers to what, when, where, how much, and how are they operated. The results of the scenarios will be summarized in graphical form, as described below in Understanding Results.

Both modeling steps form draft results for review with ODOE. We will solicit feedback at this stage and revise the inputs of the scenarios to ensure that we are best answering the selected "What if" questions. Depending on the results and feedback from ODOE, the scenarios may go through another revision before finalizing.

Figure 9. Evolved Energy Research Deep Decarbonization Pathways Modeling Infographic



Evolved Energy Research Deep Decarbonization Pathways Modeling

Deep decarbonization energy pathways modeling calculates the energy needed to power an economy while meeting a greenhouse gas emissions and other clean energy policies, and the least-cost way to provide that energy with efficiency, clean electricity, electrification, clean fuels, and carbon sequestration.

Scenario Assumptions
Model incorporates assumptions about demand-side uses, clean energy policies and incentives, and supply-side resources.

Energy Modeling
Evolved Energy Research uses two models to calculate the least-cost way to provide energy under an emission target: Energy Pathways for demand and RIO for supply.

Best Available Data
Model incorporates relevant and up-to-date energy data from reputable sources, substituted with local data where possible.

Underlying demand data
- Economic subsectors
- Demand technology characteristics
- Capital, operating, and installation costs
- Hourly demand shapes
- Current technology stocks
- Energy service demands
- Fuels efficiencies (electricity, pipeline gas, diesel, etc.)
- Demand drivers (e.g., population)
- Geographies

Underlying supply data
- Existing energy infrastructure
- Existing infratructure scheduled retirement
- Scheduled resource additions already committed
- Energy production and conversion infrastructure characteristics
- Energy transport, storage, and delivery options
- Capital, operating and maintenance, and installation costs
- Resource potentials
- Renewable resource production shapes
- Commodity costs and delivery costs
- Gas global warming potentials
- Land use
- Geographies

B. Understanding Results

The modeling process produces results presented as figures in a PowerPoint presentation that show how Oregon's energy system could change to achieve the modeled emissions targets. These figures—all of which present annual results for five-year increments between the baseline year and 2050—include but are not limited to:

- Sales shares, stock, and energy demand of light-duty, medium-duty, and heavy-duty vehicles; residential and commercial space heating; and residential and commercial water heating
- Energy demand by fuel (hydrogen, biomass, electricity, diesel blend, pipeline gas blend, etc.) and sector (residential, commercial, agriculture, transportation, productive)
- Electricity demand by sector (residential, commercial, agriculture, transportation, productive)
- Electricity generation capacity by source (onshore wind, solar, hydro, gas, coal, etc.)

- Electricity balance: generation by source (onshore wind, solar, hydro, gas, coal, etc.) and consumption by end use (direct end-use, electrolysis, direct air capture, etc.)
- Liquid and gaseous fuel demand by use (direct end-use petroleum refining, power generation, hydrogen boilers) and supply by source (hydrogen, biofuel, fossil fuel, etc.)
- Hydrogen demand by use (petroleum refining, hydrogen end-use, Fischer-Tropsch fuel production, etc.) and supply by source (steam methane reforming, electrolysis, etc.)
- Electricity transmission intertie capacity maps
- Demand for captured carbon (Fischer-Tropsch fuel production, CO_2 sequestration) and supply (direct air capture, bio-gasification with carbon capture, cement and lime carbon capture, etc.)
- Emissions by greenhouse gas and source (F-gases, N_2O, CH_4, CO_2-oil, CO_2-natural gas, CO_2-coal, etc.)

Together, the final set of figures for the Reference Scenario shows what resources must be built to meet energy demand for different sectors in Oregon to meet the modeled emissions targets.

Comparing results from the Reference Scenario to those from the other scenarios will reveal the relative impacts of whichever assumption was modified. For example, one could compare the annual energy demand from the Reference Scenario to a scenario investigating the impact of slower electric vehicle (EV) adoption. The Reference Scenario would likely show lower overall energy demand due to the efficiency gains from fuel switching to electricity earlier.

With the same two scenarios, one could also compare results for fuel supply and demand and see the additional amount of fuel (coming from lower-carbon sources over time) required by a slower transition to EVs. One could also compare the cost impacts of the slower EV transition scenario to those of the Reference Scenario and find higher costs from investment related to clean fuels production.

Comparing results across scenarios leads to an understanding of trade-offs and can help policymakers evaluate policies that prioritize different state objectives. The results of these scenario investigations will inform development of the Oregon Energy Strategy.

VII. Approach to Complementary Analyses

Energy pathways modeling is the primary tool used in the Technical Approach, but models have analytical limits for quantifying certain considerations including equity, energy burden, and employment effects. The CETI-OES Team therefore uses additional qualitative and mapping analyses to supplement the technical modeling and provide additional information to help guide discussions with the public.

Working in collaboration with ODOE and the public, we evolve our process over time, being responsive to feedback where feasible. We actively participate in the engagement process to identify opportunities to quantify key metrics. We describe our approach to addressing priority considerations specified in ODOE's Statement of Work and HB 3630 through quantitative and qualitative analysis in the following sections.

The CETI-OES Team is aware that multiple forums are discussing community benefits in the context of HB 2021 compliance, including with IRPs and CEPs, and Utility Community Benefits & Impacts Advisory Groups (CBIAGs). We intend to provide analysis that draws from, supplements, and expands upon this work. To inform our analysis, we will review the most recent developments in these dockets and discussions, and we will consider the input provided by the Energy Advocates in OPUC Docket UM 2225.

We are also aware of ongoing work in this space that could inform Oregon's approach to incorporating community benefits more thoughtfully into energy planning and will bring those insights into the process as they are helpful.

A. Equity, Energy Burden, and Affordability

1. Household Vignettes with "Energy Wallet" Analysis

As electricity grows as a share of overall delivered energy, electricity bills will increase. However, bills for other forms of fuel will decrease at the same time. It is critical to determine the impact this change will have on the average customer and on low income/disadvantaged community customers. The study looks at the entire "energy wallet" of customers as their usage shifts between petroleum, electricity, and natural gas.

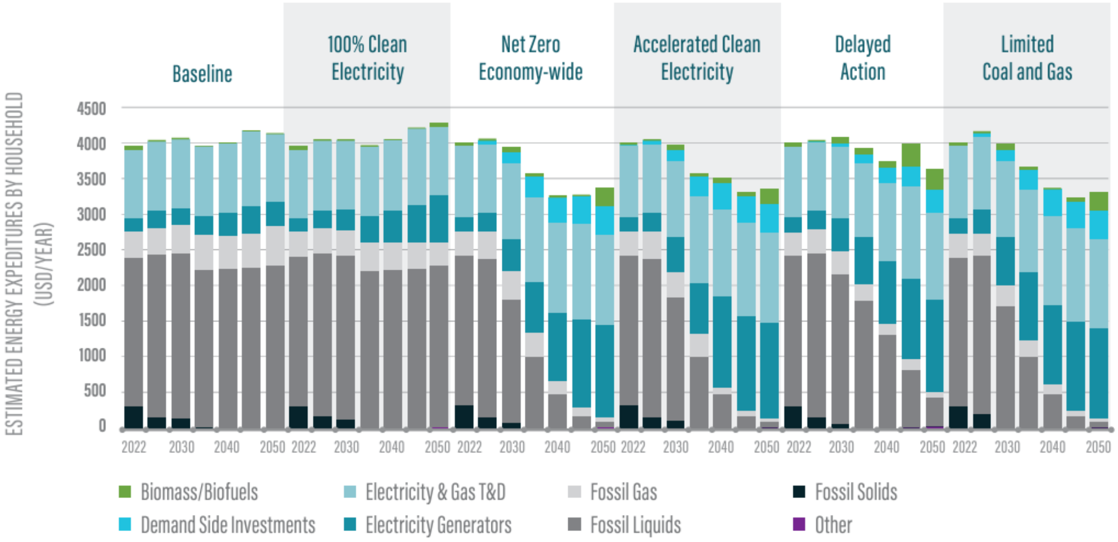
To provide policymakers with a more tangible understanding of the implications of each scenario on individual Oregonians, the CETI-OES Team works through the public engagement process to develop household vignettes that represent five customer groups in Oregon.

These customers are defined by their energy consumption and their present energy bills for all forms of energy they consume, such as electricity, gas, and gasoline. Depending on the customer groups selected for the analysis, their consumption and energy spending may differ. For example, a rural customer may drive more miles and use more gasoline than a metropolitan customer. Outputs from the modeling informing the customer vignettes include how much it costs to produce and deliver the energy they consume through 2050.

The following figures show an example of estimated bill analysis from Evolved's Achieving 100% Clean Energy in Wisconsin study. Estimated bills are calculated by applying percentage changes in the cost of serving customer energy needs to present-day energy bills for electricity, gas, gasoline, and diesel.

Figure 10 shows the change in estimated energy expenditures for average customer consumption in Wisconsin over time. Figure 11 shows how household energy costs in the state are impacted by the year an EV is purchased, something that low-income customers are forecast to do later than other customers. This shows both the equity challenge of electrification and the benefits of measures (such as IRA incentives) that help low-income customers pay for large capital investments.

Figure 10. Estimated Annual Household Energy Expenditures.[22]



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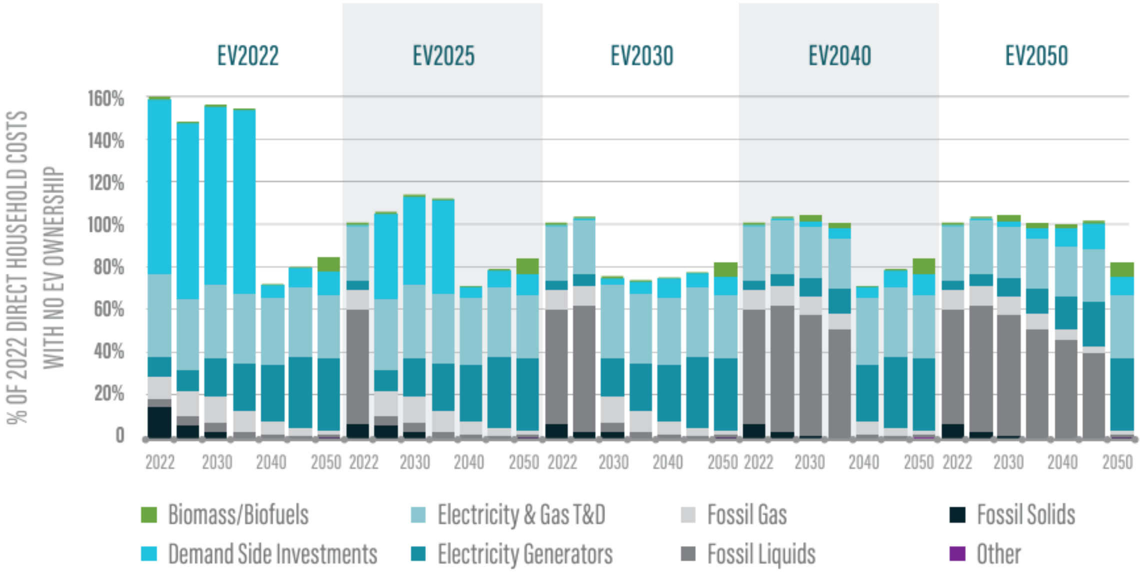
[22] *Achieving 100% Clean Energy in Wisconsin*, 2022

Figure 11. Direct Household Energy Costs and EV Purchase Year[23]



We provide a similar analysis for Oregon, where we estimate energy expenditures by household between now and 2050 for five customer groups across the Reference Scenario and one additional scenario, as well as look at the impact on customer costs of the timing of clean energy technology adoption for the Reference Scenario. We use gross household income for these customers to determine energy burden and how it changes over time.

2. Geo-Spatial Mapping with Equity Overlays

In addition, the CETI-OES Team develops geo-spatial mapping with equity overlays that could be used to identify communities with environmental, resiliency, community well-being, economic, and equity vulnerabilities (see Figure 12) as required under Oregon's Clean Energy Plans (CEPs).

These maps will use a similar methodology to the interactive ArcGIS maps created for CETI's Community-Defined Decarbonization report, which used publicly available datasets to understand community-level energy inequities and their relationship to socioeconomic disparities (e.g., the community-level relationship between poverty level, manufactured homes, energy burden, access to internet and personal vehicles, and eligibility for state weatherization assistance). We also pair the geo-spatial mapping with the analysis from household vignettes (described above) to show where the archetypal customer groups are located throughout Oregon.

Figure 12. Map showing proportion of individuals in communities living at or below the federal poverty line, paired with average energy burden.[24]

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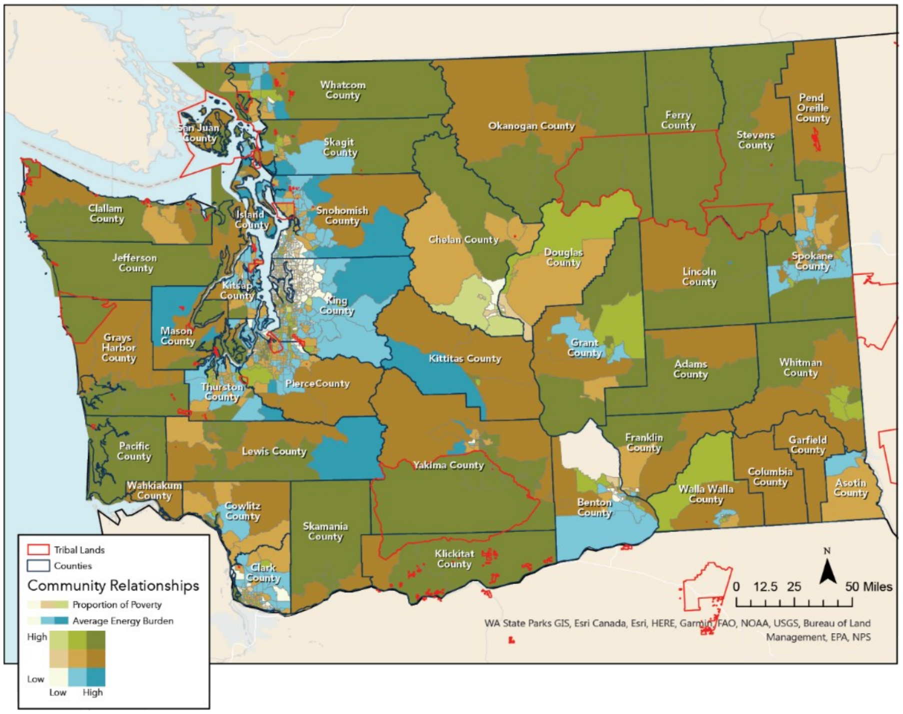
[23] Ibid.

[24] *Source: Clean Energy Transition Institute, Community-Defined Decarbonization: Reflecting Rural and Tribal Desires for an Equitable Clean Energy Transition in Washington (2022)*



WA State Parks GIS, Esri Canada, Esri, HERE, Garmin, FAO, NOAA, USGS, Bureau of Land Management, EPA, NPS

As the CETI-OES Team engages the public through ODOE's facilitated process, we refine our process to ensure energy metrics that communities identify and prioritize are considered and that public participants are part of the decision-making process. Additionally, the CETI-OES Team may use data from national mapping efforts, such as the Council on Environmental Quality's EJ Screen and Greenlink Analytics' Greenlink Equity Map.

The Team is also aware of Oregon's Environmental Justice Mapping efforts under HB 4077 (2022) and will coordinate where possible.

B. Employment Effects

The CETI-OES Team, including CETI partner BW Research Partnership, analyzes the employment effects of the Energy Strategy pathways modeling outlined above. The Employment Analysis estimates: a) the initial employment outputs and secondary employment outputs[25] for the Oregon Energy Strategy Reference Scenario for Oregon State, Eastern Oregon, and Western Oregon; b) the initial employment outputs for all additional scenarios modeled for Oregon State only.

CETI commissioned BW Research Partnership to conduct an and employment analysis in Oregon as part of the *Net-Zero Northwest* study using inputs from Evolved's energy pathways modeling, which can be reviewed as an example of a similar Employment Analysis per Figure 13 and the linked source below.

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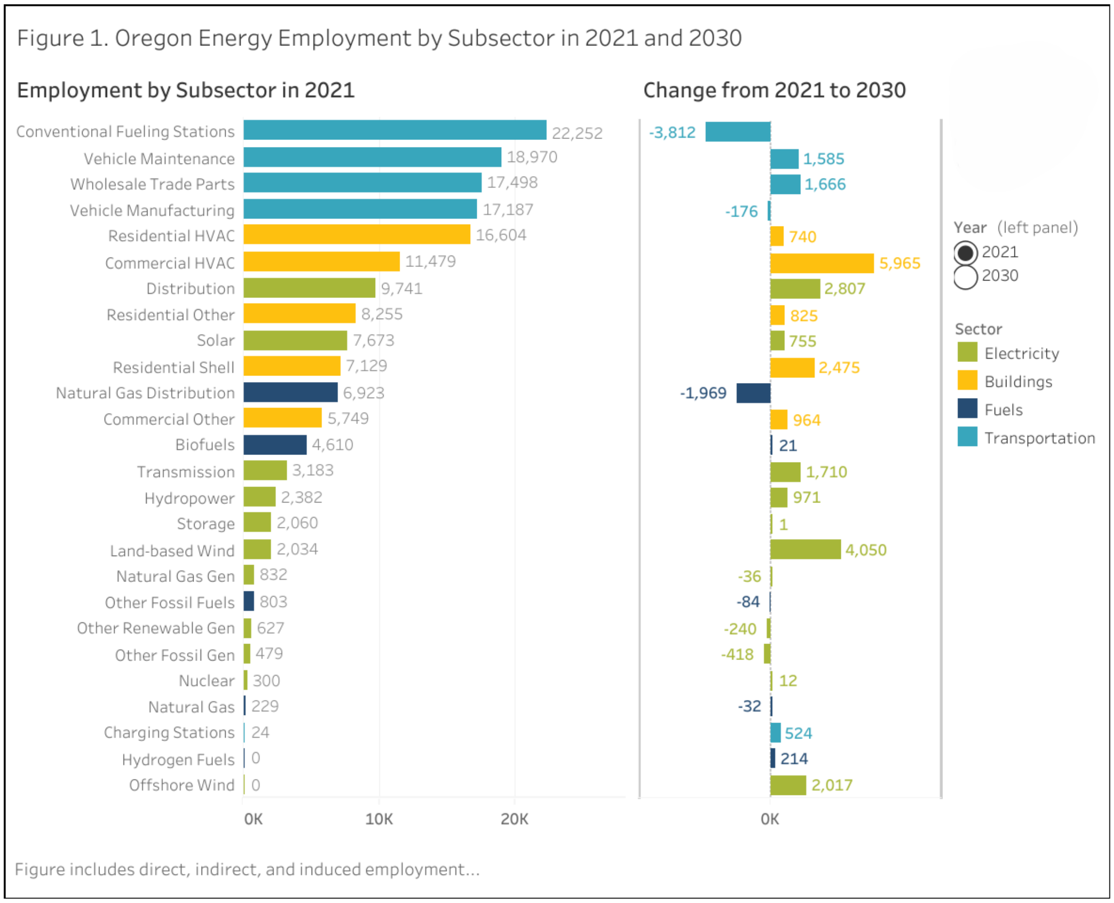
[25] For a description of secondary employment outputs, refer to the NZNW Workforce Analysis Technical Report at slides 5 and 7.

Figure 13. Oregon energy employment on the path to net-zero emissions.[26]



C. Health Impacts

Evolved's modeling toolkit directly interfaces with the EPA COBRA model, allowing us to determine the benefits of reduced pollutant emissions on public health outcomes due to reduced emissions from factory smokestacks as well as vehicle tailpipes. We will use this integration to calculate the benefits of GHG reduction measures over business-as-usual, reporting metrics such as reduced mortalities, days of work lost, and hospital admissions, and convert those to economic benefits. Figure 14 shows the impact on health metrics in the Northwest from our recent Net-Zero Northwest project.

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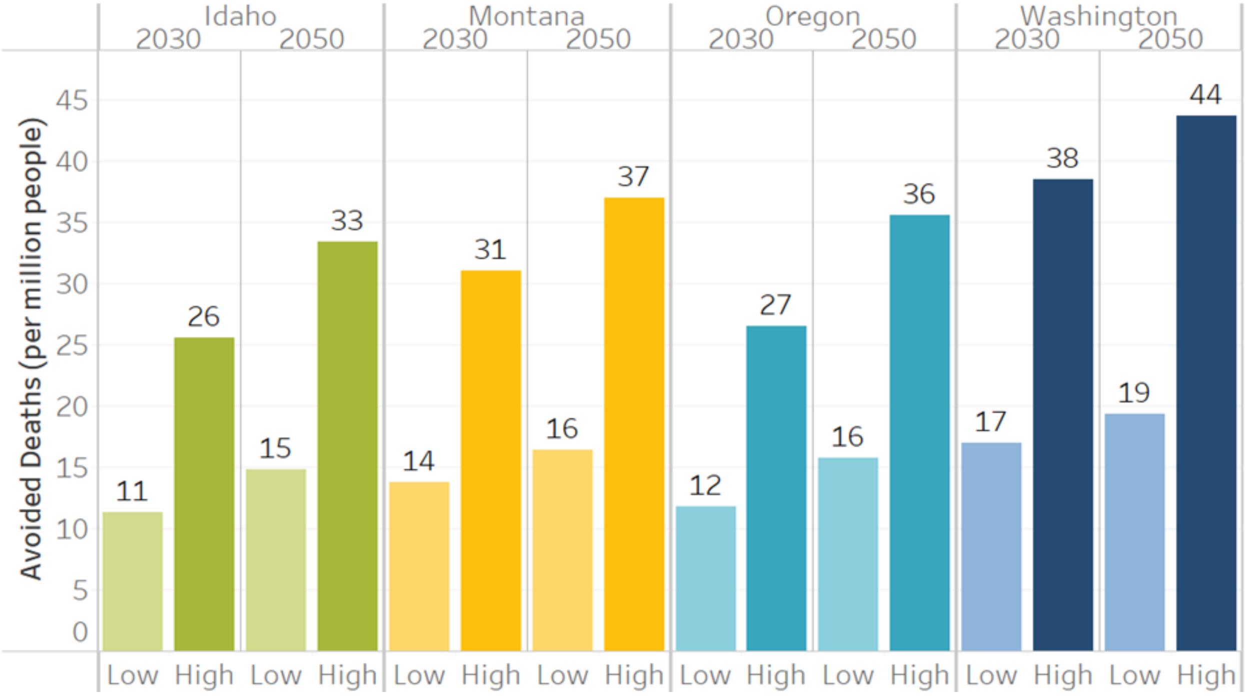
[26] *Source: BW Research Partnership. CETI Net-Zero Northwest Workforce Regional and State Analysis, March 2024.*

Figure 14. Impact on Health Metrics in the Northwest.[27]



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[27] *Source: Net Zero Northwest-Health, 2023.*

D. Land Use and Natural Resource Impacts

A decarbonized world requires a significant quantity of renewables, transmission, and pipelines to move energy to load centers. Many studies forecast electric loads will double or more between now and 2050. This brings up questions about land use and challenges around siting and permitting and impact on natural lands, tribal territories, and other protected areas.

Resource potentials used in Evolved's modeling that we will draw upon incorporate land use development restrictions by using GIS land use layering, thus restricting development on the most sensitive land areas. Even so, land impacts will be considerable. Limiting the potential for siting and permitting these resources in Oregon and other regions in the West is an option for scenario design that could simulate greater challenges to siting and permitting resources.

We will quantify the area of land used for resource development in each of the scenarios and qualitatively discuss the challenges that may be encountered in building on that land area. This discussion will include a literature review of studies that have considered these challenges in depth, the risks associated with not being able to build out resources (supported by our modeling, depending on what scenarios ODOE and the public determine to be most important), and potential strategies that could mitigate these challenges. Resources and topic areas of particular focus will be informed by feedback from ODOE and the public.

E. Reliability, Resiliency, and Energy Security

Energy pathways modeling approximates reliability needs, including rules of thumb for capacity needs and energy-limited resources that include generator and transmission outage rates, load forecast error, availability of renewable resources, and energy storage contributions. Reliability requirements in the model adapt in each model year to account for the quantity and location of renewable resources built by the model, the size and flexibility of load, and the type of transmission and generation resources constructed. For each scenario, the study will explore the performance of the energy system under a set of extreme weather and hydro conditions. RIO uses historical weather years and hydro years to capture the underlying weather impacts on future load, wind, solar, and hydro, and uses dynamic reliability requirements across all modeled hours to ensure enough capacity is built. For hydro, we typically include a low, average, and high hydro year. Extreme weather is therefore incorporated into the capacity expansion, and we will show how electricity and natural gas demands are met on an hourly basis over the course of the most challenging reliability events.

For the Reference Scenario, we will run the portfolio developed in RIO with standard production simulation using our Emporium model, benchmarked by outside venders against PLEXOS (a production simulation software designed for energy market analysis) and found to have similar results. We will run six historical weather years with low, average, and high hydro conditions for a total of 18 years of conditions. Emporium expands upon the already powerful hourly electricity model in RIO by simulating 8760-hour system operations and dispatching generators in the region individually, constrained by their operating characteristics.

By running historical weather years with future demand and supply portfolios, we can evaluate the risk of reliability challenges. These insights will not supplant the role of utilities in planning their systems for reliability and affordability but may help utilities develop more consistent planning scenarios and will provide additional visibility for policymakers, regulators, and the community into cross-fuel and cross-sectoral decisions and system interactions that are currently opaque.

In addition to running historical weather years, the modeling accounts for several climate factors. For the Oregon Energy Strategy, the modeling incorporated forecasts from the Northwest Power and Conservation Council about impacts of climate change on hydro, including low, medium, and high hydro years along with the frequency with which those years occur. The model also includes variations in heat pump efficiencies by climate zones. Finally, data inputs into the model also account for future cooling demand days (CDD) and heating demand days (HDD). To do this, the model draws linear regressions from historical statewide (i.e., specific to Oregon) HDD and CDD trends from NOAA data to project future service demand.