Electric Price Forecast

This update summarizes the electric price forecast assumptions and results Puget Sound Energy (PSE) will use as a basis for the company's 2023 Electric Progress Report (EPR). The levelized nominal power price for the 2023 EPR is $44.18/MWh. This document provides additional details on the information reviewed during the Integrated Resource Plan (IRP) webinar PSE hosted on March 22, 2022, concerning the Climate Commitment Act and assumptions for our 2023 EPR.

Introduction

The Resource Planning team at PSE developed this electric price forecast as part of our 2023 EPR. In this context, *electric price* is not the rate charged to customers but PSE's price to purchase or sell 1 MW of power on the wholesale market, given the prevailing economic conditions. Electric price is an essential input to EPR analysis since market purchases comprise a substantial portion of PSE's existing resource portfolio.

To create wholesale electric price assumptions, the Resource Planning team at PSE performed two Western Electricity Coordinating Council (WECC)-wide modeling runs using AURORA software, an hourly chronological price forecasting model based on market fundamentals.

- The first AURORA model run identifies the capacity expansion needed to meet regional loads. AURORA looks at loads and peak demand plus a planning margin and then identifies the lowest cost resource(s) to ensure all the modeled zones are balanced.
- The second AURORA model run produces hourly power prices. A complete simulation across the entire WECC region produces electric prices for all 34 zones shown in Figure 1. The lines and arrows in the diagram indicate transmission links between zones and their transmission capacity noted in megawatts.

Figure 1 illustrates the AURORA system diagram, and Figure 2 shows PSE's process to create wholesale market electric prices using AURORA, as described.

The AURORA model produces electric price forecasts for each zone included in the model's topology. The Mid-Columbia Hub (Mid-C) electric prices are then calculated in post-processing as the demand-weighted average of the zones which compose the Pacific Northwest. The Pacific Northwest zones are Avista, Bonneville Power Administration (BPA), Chelan County Public Utility District (PUD), Douglas County PUD, Grant County PUD, PacifCorp West, Portland General Electric, Puget Sound Energy, Seattle City Light, and Tacoma Power.

Figure 1: AURORA System Diagram

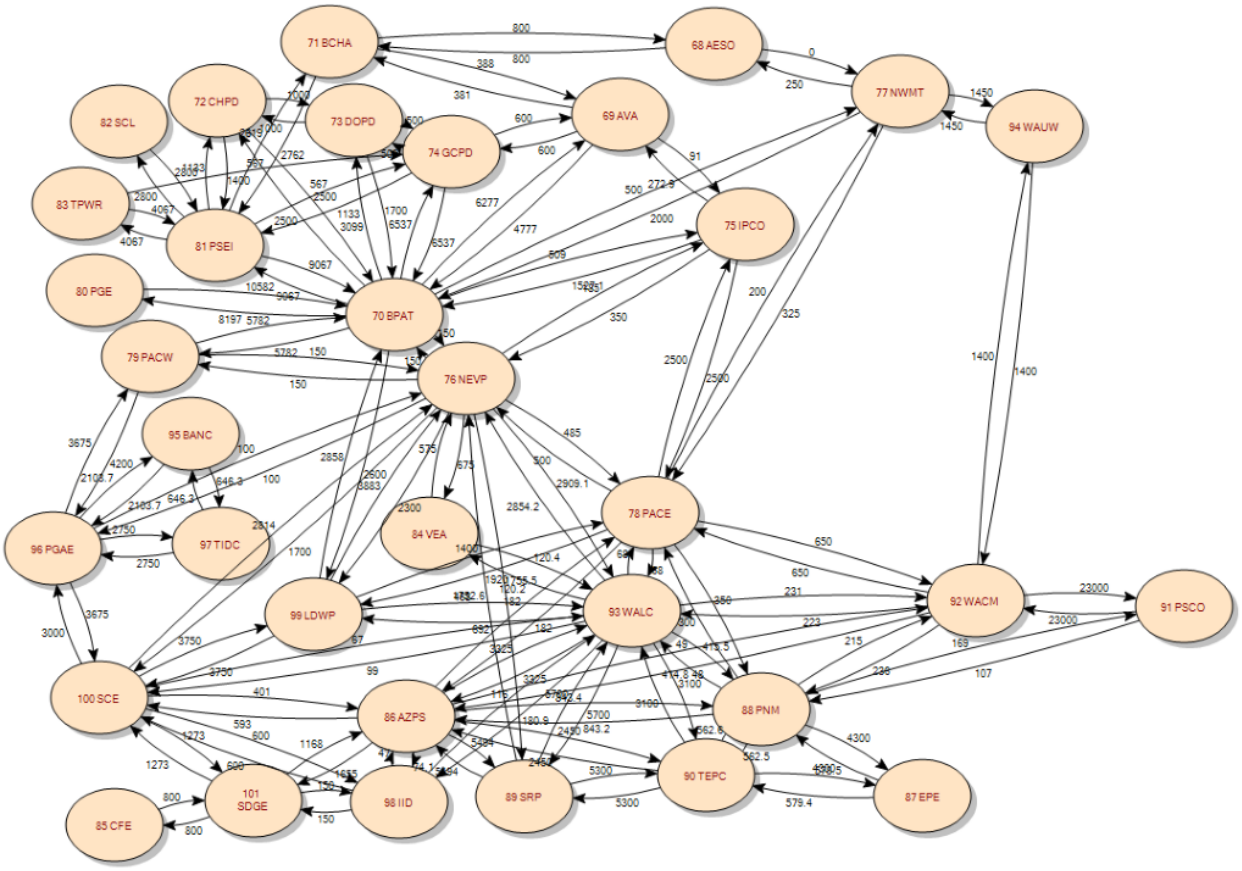
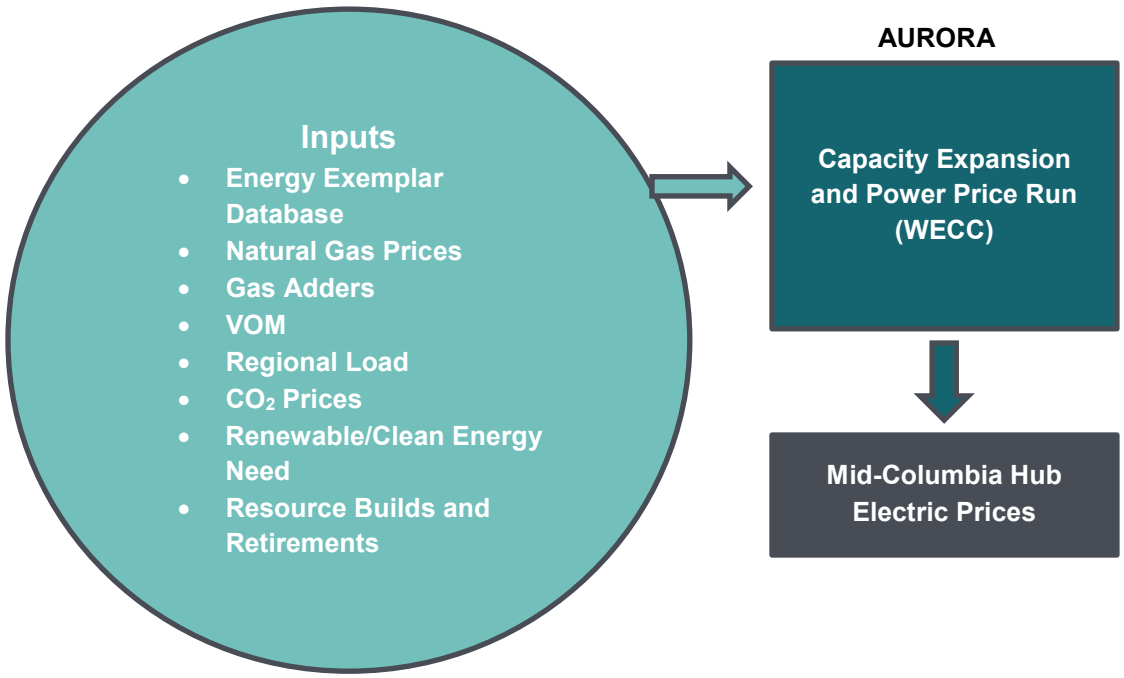


Figure 2: PSE IRP Modeling Process for AURORA Wholesale Electric Price Forecast



2021 Integrated Resource Plan

Puget Sound Energy filed the 2021 IRP in April 2021. We used inputs and assumptions from the Energy Exemplar 2018 database for AURORA price forecast modeling for that 2021 IRP. We then incorporated updates such as regional demand, natural gas prices, resource assumptions, renewable portfolio standard (RPS) needs, and resource retirements and builds. The 20-year levelized nominal power price in the Mid-C scenario for the 2021 IRP was $23.37/MWh. Details of the inputs and assumptions for the AURORA database are available for review in the 2021 IRP[1].

Modeling Power Prices for the 2023 Electric Progress Report

The electric price forecast for the 2023 EPR retains the fundamentals-based approach of forecasting wholesale electric prices while incorporating significant changes to some methodologies and input assumptions from the 2021 IRP process. Methodology changes include:

- Incorporate the impacts of climate change on demand and hydro assumptions.
- Expand renewable portfolio and clean energy standards to include non-binding clean energy policies set by municipalities and utilities.
- Include Washington State carbon pricing to reflect the impact of the Climate Commitment Act.

This report documents all methodology and input assumption changes from the 2021 IRP.

Model Framework Updates

The electric price model for PSE's 2023 EPR includes two significant changes to the modeling framework from the 2021 IRP, updated AURORA software, and the WECC database updates.

AURORA Version 14.1

We updated the AURORA software from version 13.4, which we used for the 2021 IRP, to version 14.1 for the 2023 EPR. AURORA version 14.1 includes several changes that make it easier to use and allow greater modeling flexibility. AURORA enhancements include:

- Updates to the storage logic and limits on charging and generating in the same hour when a storage method has a minimum generation constraint.
- New scripting functions.

[1] PSE | 2021 IRP

Energy Exemplar WECC Zonal Database version 1.0.1

We updated the AURORA input database from the WECC 2018 database to the WECC 2020 database for the 2023 EPR. As a result of these changes, the WECC 2020 database:

- Introduces battery energy storage systems as a new resource option.
- Updates generic resource costs.
- Updates transmission assumptions.
- Moves to a default 34-zone system topology that models each balancing authority in the WECC as a unique zone, a change from the 16-zone system topology previously used.
- Modifies the structure of fuel price adders for increased flexibility.
- Limits the addition of new natural gas-fired power plants to years before 2030 across the WECC.

These changes result in a materially different starting point for the 2023 EPR and provide differing pathways for determining the solution in the long-term capacity expansion simulation from previous electric price models. More granular system topology gained by moving from a 16-zone to a 34-zone system better represents the transmission constraints between balancing authorities across the WECC. Limitations on natural gas builds and the addition of storage as a new resource option provide more cost-effective decarbonization pathways to meet growing clean energy policy targets.

The Resource Planning team at Puget Sound Energy made the following changes and updates to the WECC database:

1. Adjusted clean energy policies
   1.1. Modeled clean energy policies
2. Updated natural gas prices
3. Added climate change impacts
   3.1. Updated the regional demand forecast based on climate change impacts
   3.2. Updated the hydro forecast based on climate change impacts
4. Added Climate Commitment Act (CCA) impacts

Clean Energy Policies

Clean energy policies are shaping the resource generation landscape of the WECC. For this electric price forecast, clean energy policies include a range of different targets such as:

- Renewable portfolio standards
- Statewide clean energy goals
- Municipal clean energy goals and mandates
- Utility-set clean energy targets

These new targets depart from previous IRPs where we only modeled legislatively binding state policies (i.e., renewable portfolio standards). We include these other clean energy targets in PSE's 2023 EPR to reflect their actual

impact on planning and implementing energy in the WECC. Puget Sound Energy's 2023 EPR includes clean energy policies after the work performed by the Northwest Power and Conservation Council's (NPCC) 2021 Power Plan.

Modeling Clean Energy Policies

Puget Sound Energy's 2023 EPR features two modeling changes to reflect better the clean energy policies across the WECC.

Sourcing Includes Out of State Resources

In previous IRP cycles, we modeled clean energy targets by state consistent with methodology in the Northwest Power and Conservation Council (NPCC) Seventh Power Plan. This approach meant we had to add qualifying clean resources to the specific state which set the clean energy target. For example, a unit of Washington wind power would need to be constructed in the state to fulfill a portion of the Washington renewable energy target. This requirement is an unrealistic assumption because it limits utilities from sourcing energy from regions with better wind or solar resources than their home state. The NPCC realized this shortcoming and updated their methodology in the 2021 Power Plan to allow utilities to source clean resources beyond their state's boundaries. We adopted a similar methodology for the electric price forecast in this EPR. The new methodology set a WECC-wide clean energy target composed of all the clean energy targets for states across the region. We then adjusted the NPCC methodology and carved out a small subset for the states of Washington and Oregon to ensure we met these states' policies more precisely.

Clean Energy Targets Include Existing and New Resources

In previous IRP cycles, PSE set clean energy targets only for new resources. This method subtracted contributions from existing resource generation from the total clean energy target, and only new resources counted toward meeting the clean energy target. This methodology required extensive accounting of clean energy contributions from existing resources outside the AURORA model, which may have understated the contribution of the existing clean energy resources. In the 2023 EPR, we included existing and new resources in the modeled total clean energy target. We tagged both existing and new resources to contribute to the target. This approach allowed more precise accounting and better representation of all resources using AURORA's dispatch logic.

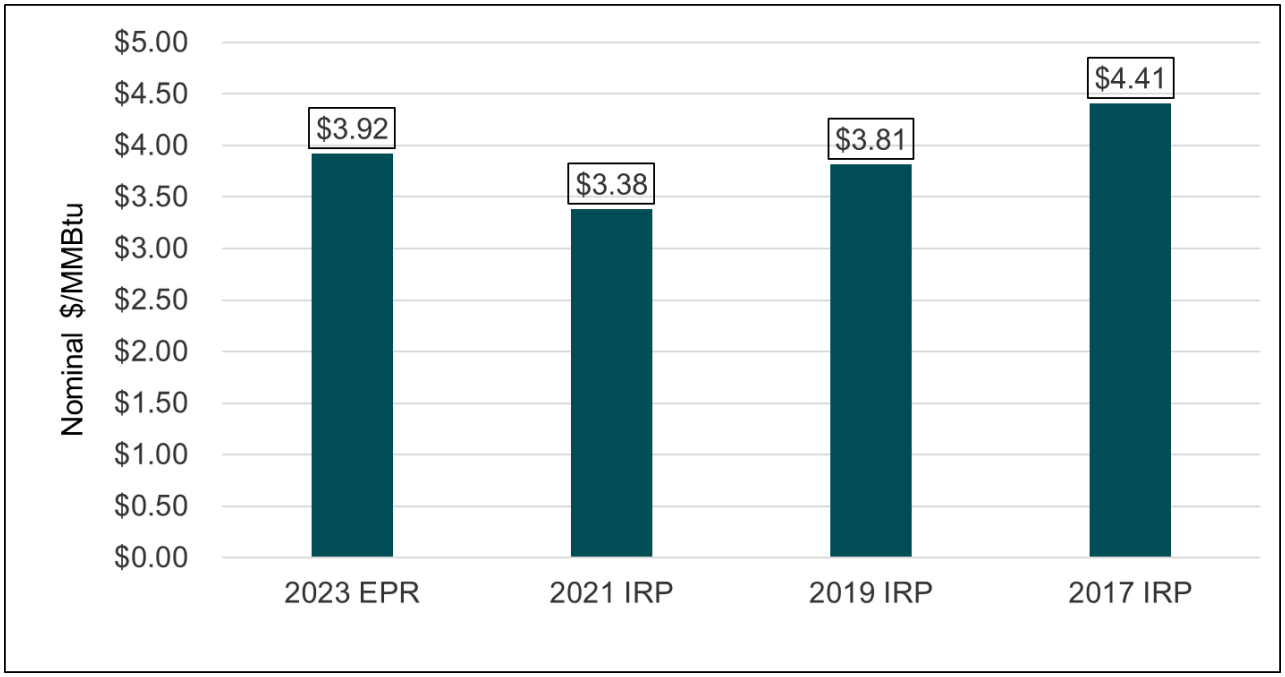
Both changes are consistent with methodologies used by the NPCC in their electric price forecast AURORA model. We calculated clean energy targets using regulations, goals, and policies described in the NPCC 2021 Power Plan supplemental material[2]. PSE updated the NPCC clean policy targets for recent developments in Oregon and Montana regulations. Oregon adopted a 100 percent clean energy target by 2040 for investor-owned utilities, and Montana repealed its 15 percent renewable portfolio standard.

[2] 2021 Power Plan Supporting Material Site Map (nwcouncil.org)

Gas Prices

The Resource Planning team at PSE updated the long-term gas prices in the 2023 EPR to the most recent Wood Mackenzie forecasts and current forward market prices. We used the Spring 2022 Wood Mackenzie Forecast, published in May 2022. The forecast shows an increase in long-term gas prices compared to the estimates used in the 2021 IRP, shown in Figure 3.

Figure 1: Levelized Natural Gas Price for the Sumas Gas Hub for Recent IRP Processes



Climate Change

For the first time, PSE's 2023 EPR includes the influence of climate change on demand and hydro conditions in the Pacific Northwest. We adapted inputs incorporating climate change from the NPCC's 2021 Power Plan analysis. As the basis for their analysis, the NPCC evaluated 19 climate change scenarios developed by the River Management Joint Operating Committee (RMJOC), Part II[3], and selected three scenarios that represented a range of possible climate outcomes. PSE adopted these same three climate change scenarios:

- CanESM2_RCP85_BCSD_VIC_P1; coded as "A"
- CCSM4_RCP85_BCSD_VIP_P1; coded as "C"
- CNRM-CM5_RCP85_MACA_VIC_P3; coded as "G"

The three climate change scenarios we adopted uniquely impact the Pacific Northwest (PNW) load and hydro input assumptions. Incorporating these disparate impacts into a single deterministic forecast presented significant modeling

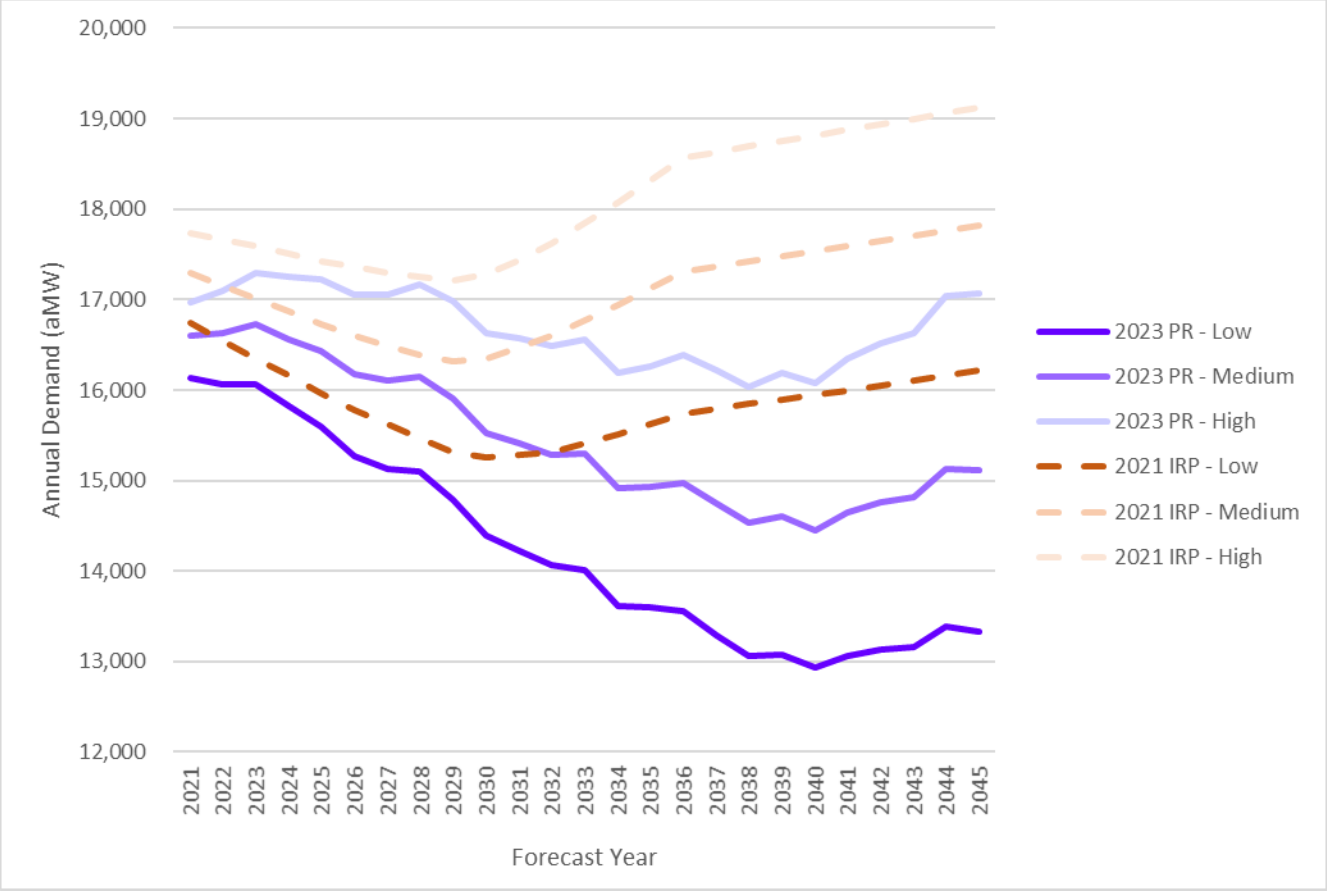
[3] Climate and hydrology datasets for RMJOC long-term planning studies: Second edition (RMJOC-II) - Technical Reports - USACE Digital Library (oclc.org)

challenges. Therefore, the base electric price forecast averaged the effects of each climate change scenario to develop a single climate change case, which retains trends present in all three climate change scenarios.

Regional Demand Forecast

For the electric price modeling, the PSE Resource Planning team used the regional demand from the NPCC 2021 Power Plan. Figure 4 reflects the PNW regional demand forecast change from the 2021 IRP to the 2023 EPR. The demand forecast includes energy efficiency in all cases.

Figure 2: Annual Average Regional Demand for the Pacific Northwest, 2023 Electric Progress Report and 2021 IRP



Climate Change Regional Demand Forecast

We incorporated the climate change regional demand forecast created by the NPCC for the 2021 Power Plan in the electric price forecast for this EPR. The regional demand forecast is presented seasonally in Figure 5, with each year of the forecast as a separate line; darker lines represent years earlier in the planning horizon and lighter lines later in the planning horizon. We provided selected data from the 2021 IRP regional demand forecast for reference.

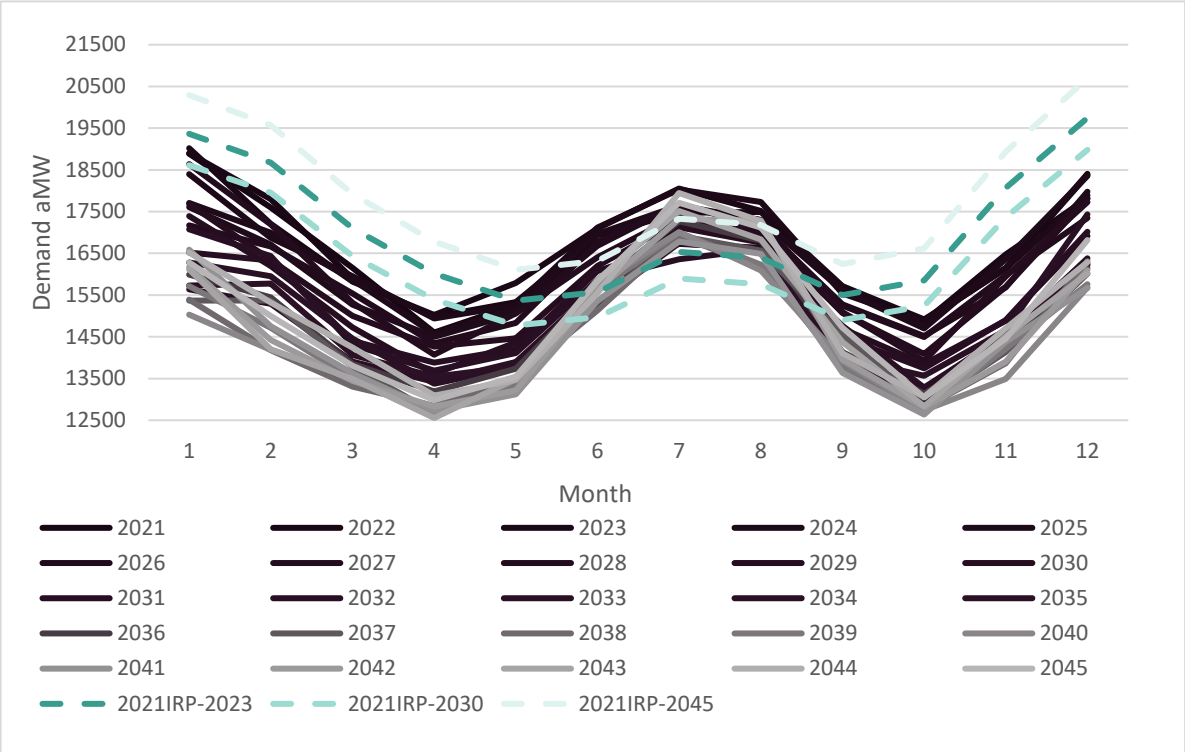
The climate change regional demand forecast shows a trend of warming winters and summers that translates to lower demand in the winter than we modeled in the 2021 IRP and increased demand in the summer.

Climate Change Hydro Forecast

We adapted the climate change hydro forecast from the regional demand forecast created by the NPCC for the 2021 Power Plan. The hydro forecast represents an average of all three climate change scenarios and an average of the hydro conditions for the 30-year timespan of the climate change scenarios. We calculated hydro capacity based on expected hydro output from the GENESYS[4] regional resource adequacy model using streamflow data representative of the climate change scenarios.

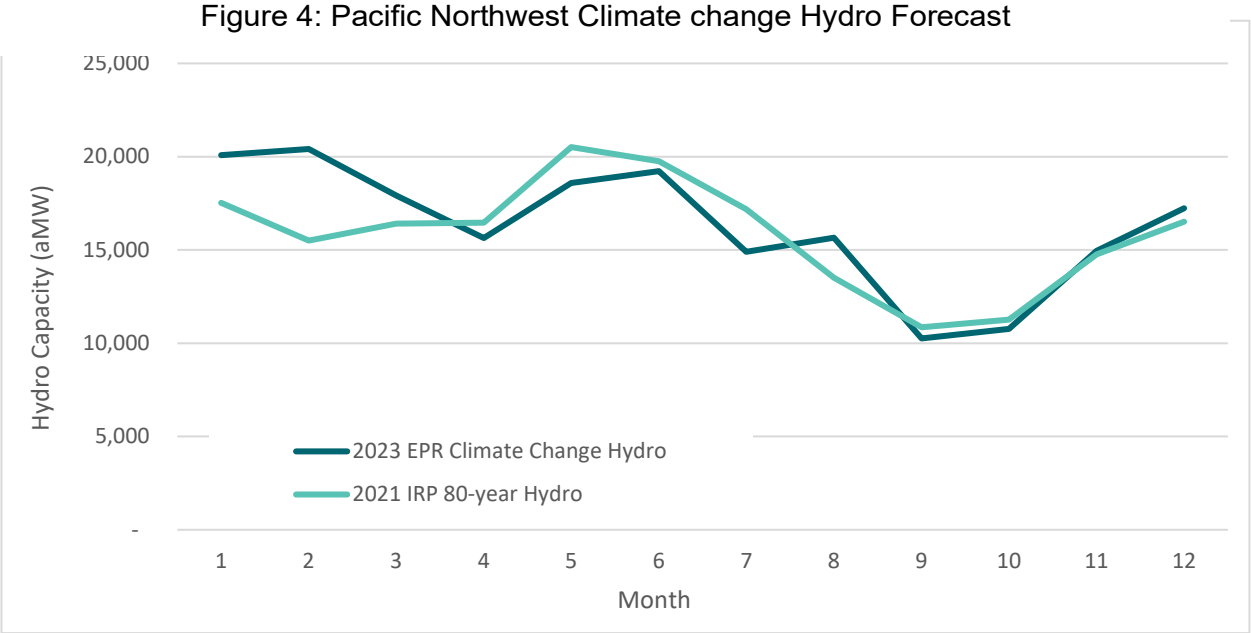
We held the average hydro forecast fixed for all the modeled years. Figure 6 presents the climate change hydro forecast compared to the 80-year historic hydro average forecast we used in the 2021 IRP. The forecasts are similar, but the climate change forecast trends toward more hydro generation in the winter and less generation for the remainder of the year.

Figure 3: Seasonal Regional Demand for the Pacific Northwest, 2023 Electric Progress Report and 2021 IRP



[4] GENESYS Model (nwcouncil.org)

Figure 4: Pacific Northwest Climate change Hydro Forecast



Climate Commitment Act

The Washington State legislature passed the Climate Commitment Act (CCA) in 2021, which goes into effect in 2023. The CCA is a cap and invest bill that places a declining limit on the quantity of greenhouse gas emissions generated within Washington State and establishes a marketplace to trade allowances of permitted emissions.

The resulting market establishes an opportunity cost for emitting greenhouse gases. We added a price to greenhouse gas emissions for emitting resources within Washington State to model this opportunity cost in the electric price forecast. We only added an emission price to Washington emitting resources to ensure the model does not impact dispatch of resources outside Washington State that are not subject to the rule.

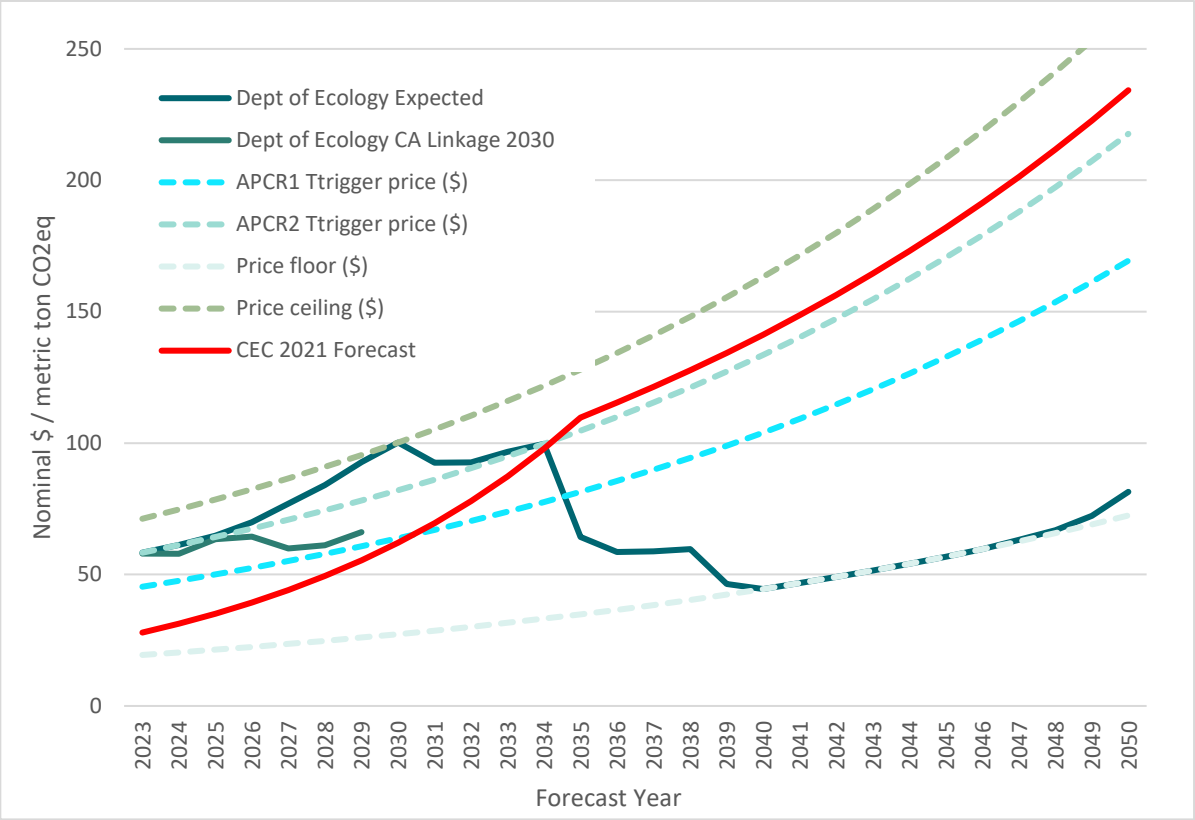
To accurately reflect all costs imposed by the CCA, we will add a hurdle rate on market purchases to the PSE portfolio model to account for unspecified market purchases using the CCA price forecast at the unspecified market emission rate of 0.437 metric tons of CO_{2eq} per MWh (RCW 19.405.070).

Figure 7 presents the emission prices considered in the electric price forecast. The Washington State Department of Ecology's expected prices represent the predicted emission price, assuming no linkage to the California carbon market. The Resource Planning team at PSE suggests that linkage to the California carbon market is the most likely scenario and has adopted a hybrid scheme that begins with pricing at the rate specified by the Department of Ecology California Linkage 2030[5] case, then transitions to the California Energy Commission (CEC) 2021 Integrated Energy Policy Report[6] allowance price forecast for the remainder of the modeling horizon.

[5] Preliminary Regulatory Analyses for Chapter173-446 WAC, Climate Commitment Act Program

[6] 2021 Integrated Energy Policy Report (ca.gov)

Figure 5: Climate Commitment Act Emission Prices



Electric Price Forecast Results

Figure 8 compares the annual average Mid-C wholesale electric price from the 2017 IRP to the 2023 EPR and the historic Mid-C wholesale electric price. Several factors contribute to the increase in electric prices from the 2021 IRP to the 2023 EPR:

1. **Natural gas prices**
   Natural gas prices increased between the 2021 IRP and the 2023 EPR, particularly in the near term, increasing electric prices.

2. **Transmission constraints**
   In the 2023 EPR, we modeled the WECC as a 34-zone system instead of the 16-zone system modeled in the 2021 IRP. The increased number of zones increases transmission links within the model and increases wheeling costs as electricity is transported between zones, resulting in higher electricity prices.

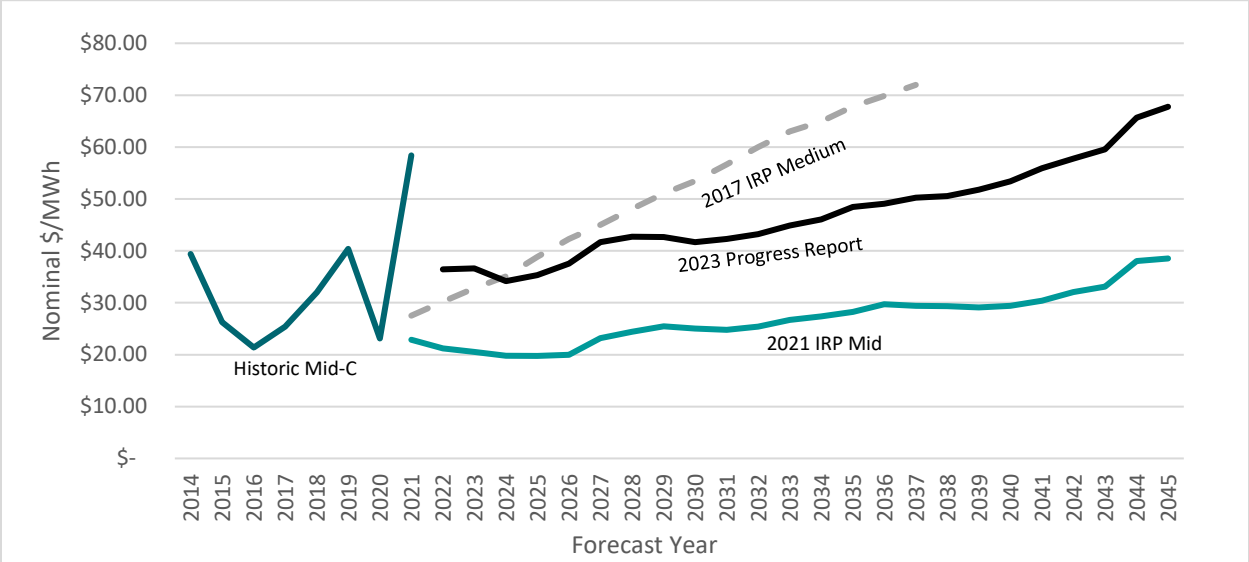
3. **Clean energy need modeling**
   Clean energy requirements accounted for existing and new resources in the 2023 EPR, whereas in the 2021 IRP, only new resources contributed to the clean energy targets. The method used in the 2021 IRP may have understated the contribution of existing resources and, therefore, overbuilt new solar resources, which resulted in excess hours with low-cost power, artificially driving prices lower. The method we used in the

2023 EPR resulted in fewer renewable energy additions to the WECC, which results in a tighter energy market and higher prices.

4. **Storage**

Storage resources (e.g., batteries) were not available in the 2021 IRP electric price model, which resulted in overbuilding of wind and solar resources to provide non-emitting capacity. Overbuilt wind and solar resources lead to lower wholesale electric prices as more hours can be filled with zero-cost power from these renewable resources. We added storage as an available resource in the 2023 EPR, which allows for load/generation shifting and a dramatic reduction in the number of renewable resources required to meet the load. This scenario creates a tighter market driving up wholesale electric prices overall. Storage can help reduce very high prices through arbitrage and load/generation shifts resulting in more moderate average prices.

Figure 6: Mid-C Wholesale Electric Price Annual Average Price Forecast Over Time



Despite the addition of storage resources, volatility is still present in the wholesale electric price results for the 2023 EPR. Price volatility results from the substantial buildout of renewable resources across the WECC.

Figure 9 shows electric price volatility over a day for each month of the year. Strong morning and evening peaks are present throughout the modeling horizon and will become particularly extreme in the summer months by 2045.

Figure 10 presents volatility across all hours of each year of the modeling horizon. Price spikes become increasingly common in the latter years of the analysis.

Figure 7: Daily Price Volatility by Month for the Years 2023, 2030, and 2045

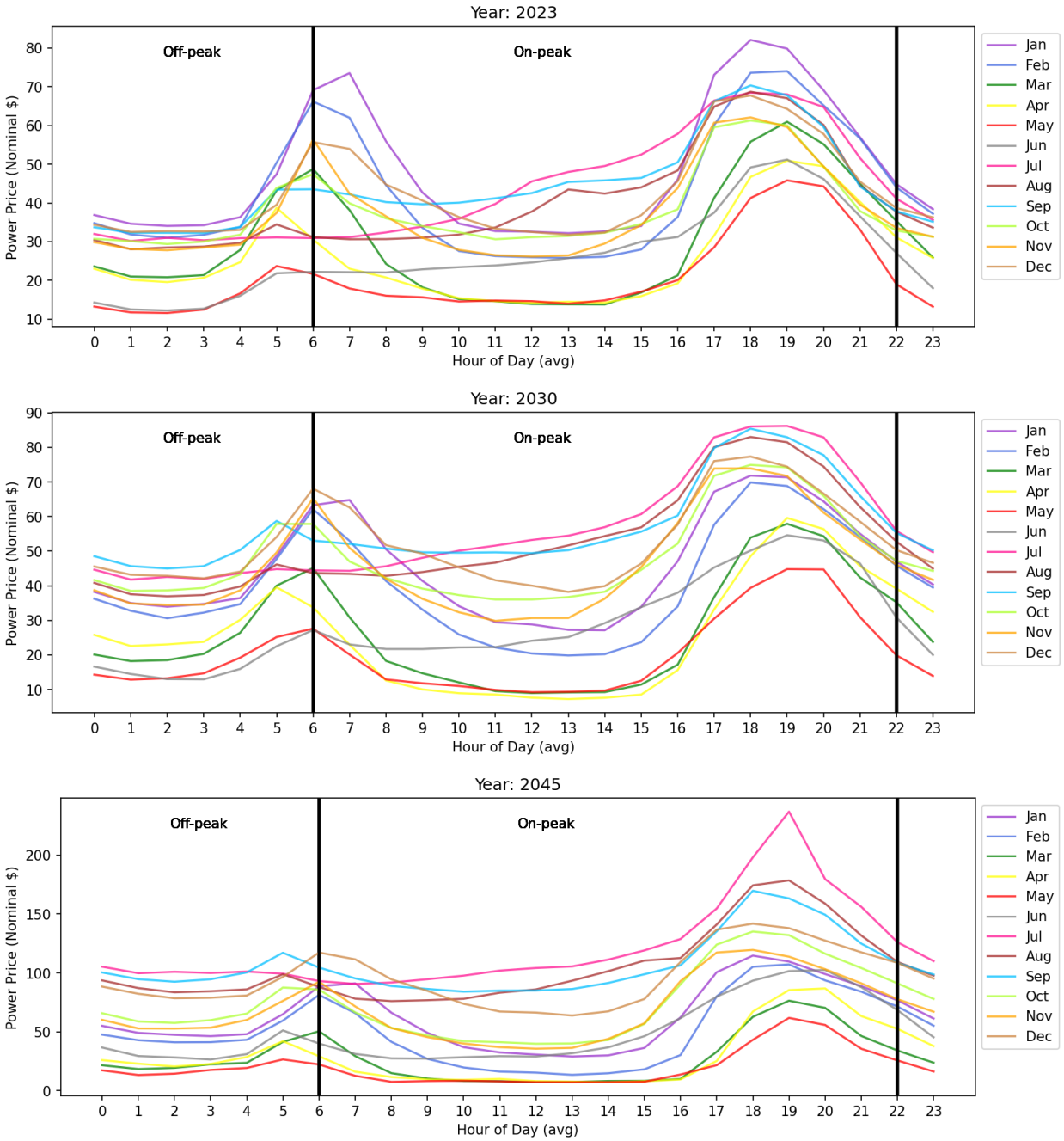


Figure 8: Hourly Electric Prices Over the Modeling Horizon