February 7, 2023

MEMORANDUM

TO: Council Members

FROM: John Ollis, Manager of Planning and Analysis

SUBJECT: Annual Wholesale Electricity Price Forecast

BACKGROUND:

Presenter: John Ollis, Dor Hirsh Bar Gai

Summary: This presentation will review the process used to create the market price forecast and the underlying buildout information for different policy scenarios. Then, it will discuss how those policies/buildouts are projected to affect prices and avoided market emissions rates in the region over the next 20 years.

Relevance: Wholesale power markets outside the region were highlighted as a key data point to monitor coming out of the 2021 Power Plan in which policy changes throughout the western states impacted not just wholesale power markets in the long term, but also in the short term. This update will revisit some of the Power Plan market study findings and track any major changes in the updated study results.

While not required by the Power Act to be updated regularly, revisiting this price and avoided emissions rate analysis on an annual basis will provide an important data point on the wholesale power markets to inform our Mid-Term Assessment. This study has historically provided high value to stakeholders, who use it for several purposes such as vetting their own price forecasts for resource planning or providing avoided market emissions rate guidance for state agencies developing building codes.
Background: The Council has periodically updated its wholesale electricity price study using the AURORA model to help inform Council staff and regional stakeholder analysis. The Council relies on the System Analysis Advisory Committee to help provide expert feedback on market fundamentals and power system modeling assumptions related to the market price study.

The Council’s forecast is a fundamentals-based forecast that reflects actual power system operation, relationships of supply and demand for, and transmission of electricity. In addition, underlying a wholesale electricity price forecast in this region would be an understanding of the operating characteristics of future and existing supply and demand-side resources, as well as unit commitment, ancillary services, fuel prices, hydro, wind and solar conditions. The AURORA software captures many of these characteristics of the power system well and has a periodically updated WECC database, and thus, AURORA has been the Council’s wholesale market electricity price forecasting model.

Due to significant clean and RPS policies and less dependence on new baseload generation to meet growing loads, the market price forecast studies from the 2021 Power Plan scenarios consistently showed extremely large buildouts of new resources, especially solar generation outside the region. These buildouts implied a persistence of market fundamentals that seemed to be just emerging at the time of the plan’s development, like significant renewable generation curtailment and negative pricing mid-day. This market update is another early look at how the plan work compares to current market behavior and highlights some of the data sources the staff uses to monitor this behavior for reference.

More Info: Presentation of draft results relating to buildouts to inform the adequacy assessment work

August 31st SAAC Meeting

August 10th SAAC Meeting

July 27th SAAC/RAAC Meeting

Wholesale Power Price Forecast from the 2021 Plan
Market Price Study, Results and Analysis

Dor Hirsh Bar Gai/John Ollis
February 14, 2023
Power Committee
Discussion Today

- WECC buildouts scenario results and analysis review
- Using buildouts to determine wholesale market prices and avoided emissions rates under different scenarios and conditions
- Identifying market risks to monitor
- Improvements for the future
Why Do We Look at the Whole West-wide Market?

1. **Economics**
   - Even though we only plan for the region, the economics of every regional resource decision depends not just on the regional market fundamentals/policies but on the market fundamentals/policies throughout the WECC.

2. **Adequacy**
   - Even though regional adequacy depends primarily on regional resources, understanding what resources might be available outside the region during stressful times is also important for keeping rates down.
Review: Market Study Use Cases

**WECC-wide Resource Buildouts**
- Used to build market supply at different price bins in adequacy and plan needs assessments.

**Prices and Avoided Emissions Rates Studies**
- Used in regional capital expansion in the plan to understand market prices and emissions.
- Used by regional stakeholders as input into, or vetting for, their planning processes.
Market Price Scenarios

Scenarios
Helped RAAC frame market risk in 2027 time period and vetted by SAAC as useful for understanding prices

- Buildout Scenarios:
  - Baseline
  - Limited Markets (no PRMs)
  - High WECC Demand (Increased electrification)
  - Persistent Global Instability (Build limitations and high gas prices)
  - Organized Market (One PRM, wheeling rate)
  - Emissions Price (Universal Carbon Price)
  - No Gas Build Limits (No limits on gas plant builds)
### Review Buildouts Information

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Baseline</th>
<th>Persistent Global Instability</th>
<th>High WECC Demand – West Coast</th>
<th>High Emissions Price</th>
<th>No Gas Build Limits</th>
<th>Limited Markets</th>
<th>Organized Markets</th>
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<td>Meets Reserve Margins</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes*</td>
<td>Yes</td>
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<td>Meets Policies</td>
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<td>Annual System Cost in 2045 (2016 $)</td>
<td>50 billion 83% Fixed 17% Variable</td>
<td>53 billion 75% Fixed 25% Variable</td>
<td>68 billion 81% Fixed 19% Variable</td>
<td>72 billion 61% Fixed 39% Variable</td>
<td>42 billion 46% Fixed 54% Variable</td>
<td>40 billion 46% Fixed 54% Variable</td>
<td>44 billion 66% Fixed 34% Variable</td>
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</table>

* This scenario has operational issues and would likely require different policy pricing for more consistency
** This scenario relies more heavily on expensive demand side resources. Likely needs larger reserve margin.
Annual System Investments (in 2016 dollars)
High-Level Observations

- Policies are pushing towards lower variable cost, higher fixed cost system investments.
- These investments create a natural hedge against fuel price volatility.
- Existing thermal plant use shifts from baseload to assisting in grid services and ramping.
- Existing hydro and renewable plant use maximized for meeting policies.
Wholesale Power Prices

Annual, Monthly, Hourly Price Results
Used in Council and stakeholder power planning
Review of Price Study Methodology

- Simulate hourly market prices and avoided emissions rate forecast in AURORA over 30 regional hydro/load/wind conditions for multiple scenarios
- Mid-Columbia (Mid-C) Prices are the average of GCPUD, CCPUD and DCPUD zonal prices
Significant Annual Price Uncertainty Depends Mostly on Policy

1. Annual Mid-C prices have been fairly stable annually in recent history with variation closely tied to fuel price variability.

2. Investments in lower variable cost resources like renewable generation will likely reduce correlation with fuel prices in the long run but create more volatile wholesale market prices based on availability of fuel.

3. Depending on policies, future market structure and subsequent investment pace wholesale price trajectory may vary drastically.
Since the zero emissions, low production cost resource expansion (and subsequent generation) outstrips growth of load during most periods, we expect emissions and prices to steadily fall.
Monthly Variation Will Still Depend Heavily on Hydro Condition

- Consistent with previous studies, Mid-C prices show greater dependency on hydro condition during the winter, spring and early summer depending on runoff.
Hourly Prices Summary

- In general, hourly prices show increasing wholesale price volatility in the winter within a decade and increasing volatility in the summer by the end of the study in most hours of the day.
- Most scenarios show continued price pressure around morning ramps in winter and evening ramps in summer and winter.
- Spring and Fall prices offer additional perspectives to consider to complement the analysis (see extra slides).
How to Interpret Box-and-Whisker Plots

An Example Boxplot and Distribution Statistics

Upper Outlier
Upper Extreme
75th Percentile < Baseline
50th Percentile
25th Percentile
minimum
up to 1.5 x (IQR)
IQR
Baseline

Little overlap; Prices likely > Baseline
Comparable bottom range, higher price volatility likely
Similar price likely
Narrower volatility, lower upper range higher lower range

Compared to Other Scenario

Central 50% of baseline hourly distribution (25th-75th percentiles)
<table>
<thead>
<tr>
<th></th>
<th>2023</th>
<th>2033</th>
<th>2042</th>
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</thead>
<tbody>
<tr>
<td><strong>Winter</strong></td>
<td>Price differences from the baseline observed mostly during the ramp hours*</td>
<td>Baseline, global instability, and emission price increased negative pricing during day and night</td>
<td>Almost entirely negative pricing under baseline and emission price, but only likely in under global instability and high WECC with higher volatility</td>
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<tr>
<td></td>
<td>Global Instability higher volatility and prices than high WECC</td>
<td>Daytime price reductions across scenarios</td>
<td>High WECC demand likely most expensive</td>
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<tr>
<td></td>
<td>Emission price most expensive</td>
<td>High WECC demand narrow price distribution</td>
<td>Emission price likely cheapest except ramps</td>
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<tr>
<td><strong>Summer</strong></td>
<td>Price differences observed mostly during evening ramp hours*</td>
<td>Increased volatility during ramp of high WECC demand, but lower prices during the day.</td>
<td>High WECC demand increased prices during ramp hours, but lower during the day.</td>
</tr>
<tr>
<td></td>
<td>Persistent Global instability likely higher prices than High WECC demand</td>
<td>Increased global instability prices.</td>
<td>Global instability shows increased volatility.</td>
</tr>
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<td></td>
<td>Emission price most expensive</td>
<td>Reduction of morning ramp prices under emission price, including negative pricing</td>
<td>Emission price scenario low day and ramping prices, but higher night prices</td>
</tr>
</tbody>
</table>

* Emission Price scenario an exception
Central 50% of baseline hourly distribution (25th-75th percentiles)

Difference between baseline and Emission Price scenarios: almost no overlap; Emission Price > Baseline

Difference between baseline and Persistent Global Instability scenarios: little overlap; Global instability likely to be higher throughout the day

Difference between baseline and High WECC Demand scenarios: A lot of overlap; High WECC Demand prices likely to be similar, with narrower range, except during morning ramp
Central 50% of baseline hourly distribution (25th-75th percentiles)

Daytime price drop
Ramp increase

Comparable daytime prices to baseline
Higher night prices
Negative pricing
Baseline and Emission Price likely experience negative pricing most hours of the day except ramps.

High WECC Demand: Increased price volatility and highest prices throughout the day.

Global Instability: Comparable daytime prices, higher prices and volatility in ramps and night.
Central 50% of baseline hourly distribution (25th-75th percentiles)

2023 Summer Mid-C Hourly Price Distribution

- **Baseline**: Lower night prices, similar morning ramp and day prices
- **Emissions Price**: Similar hourly price shape but substantially higher
- **High Westside Demand**: Minimal changes from baseline
- **Persistent Global Instability**: Likely more expensive from baseline
Consistent prices throughout the day except evening ramp, higher price volatility

Price and volatility increases in morning and evening ramps, price drop in the later day hours

Reduction of morning ramp prices with increased volatility

Price and volatility increases during ramp and day hours

Central 50% of baseline hourly distribution (25th-75th percentiles)
Ramps slightly more expensive than night prices, stable day prices.

Most expensive and volatile night hours, but later morning ramps, day, and early evening ramps comparable to baseline.

Higher ramps prices, but smaller price volatility in the negative pricing during the day and early evening, more expensive night prices from baseline.

Increased price and volatility throughout the day.
Trends in Hourly Periods in comparison to baseline

- **2023:**
  - Emission Price scenario experiences most expensive prices
  - Persisted Global Instability shows higher prices throughout the day than baseline and High WECC Demand
  - Increased summer evening ramp and day prices

- **2033**
  - Increased winter volatility but higher summer prices
  - Baseline and Global Instability increased winter volatility, High WECC Demand mostly during the day hours
  - Emission price scenario with wide winter price volatility

- **2042:**
  - Winter and summer negative pricing under the Baseline, seasonal negative pricing for High WECC Demand, Global Instability, and Emission Price
  - Under Emission Price, winter sees narrow prices, and increased volatility in the summer, especially during the night
Summer prices expected to be higher during day, evening ramp and night hours

2023 Winter-Summer Mid-C Hourly Price Distribution

- **Baseline**
- **High Westside Demand**
- **Persistent Global Instability**
- **Emissions Price**

**Highest prices**

Comparative:
- **Comparable**
- **Higher than baseline and High WECC Demand**

Prices [$/(MWh)]

Hourly Periods:
- Night
- Mor
- Rmp
- Day
- Eve
- Rmp

Winter
Summer
Substantial winter price volatility compared to narrow distribution of summer prices

Increased summer volatility during ramps and day

Negative pricing in winter

Morning, ramps, and night volatility encompass other scenarios
Seasonal volatility depending on scenario

Winter generally more volatile under High WECC demand and Persistent Global Instability

Negative pricing during winter likely throughout the full day, party under summer

Substantial summer volatility during the night, and ramp hours
Avoided Market Emissions Rates

Used in power planning for Council and regional stakeholders, state agencies for building codes, energy efficiency planners etc.
What is the Avoided Emissions Rate?

- The goal is to develop the amount of emissions that are avoided by reducing 1 kWh of load in the NW at any time.
  - In the recent past, this could be determined by the most expensive unit online (almost always coal or gas) assuming it was serving the last kWh of load in any hour.
  - Since many of the expensive generators are now being used for reserves or grid services, the methodology identifying the most expensive unit serving the last kWh is less accurate than before.
- In the past 5 or 6 years, staff and the System Analysis Advisory Committee have developed a different technique for estimating the “market” or “marginal” emission rate.
Avoided Emissions Rate Methodology

The avoided emissions rate over the output changed in the WECC from the flat drop of 1000 MW is

$$\frac{Emissions_{1000} - Emissions_0}{Output_{1000} - Output_0} = X \text{ lbs/kWh}$$

Variable Definition:
1. $Emissions_{1000}$ is the emissions in the WECC with 1000 MW less load in PNW run
2. $Emissions_0$ is the emissions in the WECC in the base run
3. $Output_{1000}$ is the output in the WECC with 1000 MW less load in PNW run
4. $Output_0$ is the emissions in the WECC in the base run

Expect to be lower due to hydro runoff timing
Expect to be higher due to WECC peak need
Avoided Emissions Rates Drivers Part 1

Baseline
Avoided CO2e Emissions Rate in lbs per kWh by Quarter

High WECC Demand
Avoided CO2e Emissions Rate in lbs per kWh by Quarter

Emissions rate of CCCT

Higher demand keeps avoided emissions rates higher in general
Avoided Emissions Rates Drivers Part 2

Baseline
Avoided CO2e Emissions Rate in lbs per kWh by Quarter

Persistent Global Instability
Avoided CO2e Emissions Rate in lbs per kWh by Quarter

Emissions rate of CCCT

Higher gas prices, inefficient builds keeps emissions rates higher during summer evenings and nights.
Avoided Emissions Rates Drivers Part 3

Baseline
Avoided CO2e Emissions Rate in lbs per kWh by Quarter

Emissions Price
Avoided CO2e Emissions Rate in lbs per kWh by Quarter

Emissions rate of CCCT

Emissions pricing lowers emissions rates in general

Northwest Power and Conservation Council
Monitoring Risks During the Energy Transition

- Rate/effectiveness of fixed cost investment lowering production costs and emissions
- Rate of increase and timing of price volatility
- Adoption of enabling market structures and/or policies
Analytical Work Before Next Assessment

- Improve transmission assumptions
  - Significant modeling issues with large renewable buildouts and constrained transmission

- Improve understanding of market structure and policy assumptions
  - Significant uncertainty on end state of WECC markets
Questions

John Ollis
jollis@nwcouncil.org

Dor Hirsh Bar Gai
dhirshbargai@nwcouncil.org
Extra Slides
Observations By Scenario – Energy Transition

- A **Persistent Global Instability** scenario in slightly slower and less optimized early builds which leads to slightly higher prices, emissions and system costs.
  - Higher gas prices keep wholesale costs high, but like the baseline overall price volatility seems to increase near the end of this decade.
  - Prices stay higher than the baseline given the higher price of gas.

- The **High Westside Demand** scenario shows an increase in wholesale prices and system costs by the end of the study.
  - Less negative pricing by end of study due to increased demand.
  - Lower prices in the evening ramp and day due to significantly larger buildout in the PNW than in other scenarios.
Observations By Scenario – Energy Transition

- The **Emissions Price** scenario results in a sharp decline of production costs across the regions (until stabilizing in 2030) due to rapid growth of renewables; but production costs relatively high to all scenarios due to emissions pricing.
  - Trading out existing resource usage
  - Prices stay relatively high given the cost of emitting resource dispatch

- An **Organized Market** scenario reduced the buildout pressure in CA by increasing build in Canada, Mountain West and PNW
  - Early increase in wholesale prices due to leveraging more heavily on efficiencies existing system which causes more higher priced resources to be utilized more often to defer fixed cost investment
  - Recall that due to lower and more efficient build of clean energy resources to maintain reserve margins this scenario had lower system costs in general
Observations By Scenario – Traditional Investment

- The **No Gas Build Limits** scenario looks much more like the traditional market paradigm with production costs and fixed costs at parity.
  - Emissions and market emissions rates are slightly reduced due to investment in efficient gas investment, but not enough to meet policy targets.
  - Prices stay stable with more efficient gas plants replacing older less efficient gas plants
- The **Limited Markets** scenario had the least investment but was also the least adequate and close to meeting policies.
  - Overall increases in prices and emissions throughout time
  - By late 2020’s prices during peak seasons are extremely high for a sustained period.
Scenario Description Review: Limited Markets

- Removed planning reserve margins
  - Implemented by setting operating pool planning reserve margins to -99 in AURORA
- All other inputs the same as the baseline
Scenario Description Review: High WECC Demand

- High electrification Pacific NW, California, BC and Alberta
  - High demand only in those areas, baseline forecast elsewhere
  - All other inputs the same as the baseline, except updating policy targets (in MWhs)
Scenario Description Review:
Persistent Global Instability

- Changed ramping limitations of resources to be slower initially but the nearer to 2030 converge to the normal ramp rate.
  - Implemented by changing maximum annual new additions on short duration storage, solar and wind generation until 2030.
  - Other resource ramps unchanged due to online date or previous restrictions
  - All other inputs the same as the baseline
Scenario Description Review: High Social Cost of Carbon

- Significantly higher carbon price
  - Universal SCC across the region
    - $162 (2020) - $260 (2045)
  - All other settings the same as the Baseline

Response to literature and National Academies findings to reevaluate current SCC values

Social Cost of Carbon @ 2012 $ value
Scenario Description Review: Organized Market

- Simulate WECC as a “perfect” coordinated/cooperated market
  - Single zone and reserve pool (18%).
  - Unified wheeling costs set to $0
  - All other settings the same as the Baseline
Scenario Description Review:
No Gas Build Limits

- Remove gas build limitations to test if policies were relaxed
  - Leave build rates and totals at default
  - Allow gas builds in all zones
**Review:**

*Three climate change data sets selected to encompass the range of hydro and load variation*

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<th>Hydro Year 2030s</th>
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<th>Summertime CDD</th>
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We will be looking at power prices over 30 different climate change sets and weather conditions...
## Solar and Solar Plus Storage Build Comparisons

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline</th>
<th>Global Instability</th>
<th>Limited Demand</th>
<th>High Demand West*</th>
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## Battery and Pumped Storage Build Comparisons

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## Wind and Gas Build Comparisons

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## Offshore Wind and Proxy Clean Build Comparisons

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Largest 2027 Build for reference
Observations

- Most scenarios have around 30% curtailment of renewables or hydro by the end of the study except WECC High Demand West Coast (24%), Limited Markets (15%) and Organized Market (21%)

- Most scenarios have decreasing thermal plant capacity factors from around 40% at beginning of the study to 25% to 33%, but the Limited Markets scenario thermal plant capacity factors go up to over 50%.
2023 Fall Mid-C Hourly Price Distribution

- **Baseline**
  - Prices [$/MWh]
  - Central 50% of baseline hourly distribution (25th-75th percentiles)

- **Emissions Price**
  - Prices [$/MWh]
  - Hour

- **High Westside Demand**
  - Prices [$/MWh]

- **Persistent Global Instability**
  - Prices [$/MWh]
  - Hour

Northwest Power and Conservation Council
Central 50% of baseline hourly distribution (25th-75th percentiles)
Central 50% of baseline hourly distribution (25th-75th percentiles)
Central 50% of baseline hourly distribution (25th-75th percentiles)
Central 50% of baseline hourly distribution (25th-75th percentiles)
50% of baseline hourly distribution (25th-75th percentiles)
Avoided Emissions Rates Drivers Part 4

Baseline

Avoided CO2e Emissions Rate in lbs per kWh by Quarter

No Gas Build Limits

Avoided CO2e Emissions Rate in lbs per kWh by Quarter

Emissions rate of CCCT
Limited Markets
Persistent Global Instability

Energy Load Resource Balance (aMW)

RPS/Clean Policies versus Capability in aMW
High West Coast Demand
High Social Cost of Carbon

Energy Load Resource Balance

RPS/Clean Policies versus Capability in aMW

Northwest Power and Conservation Council