MEMORANDUM

TO: Power Committee Members

FROM: Daniel Hua and Massoud Jourabchi

SUBJECT: 2021 Plan Climate Scenario Load Forecasts

BACKGROUND:

Presenter: Daniel Hua and Massoud Jourabchi

Summary: Staff will update Power Committee Members on the new regional climate scenario load forecasts for the 2021 Power Plan. The new load forecasts were calculated from a new load methodology that was developed to correct problems observed in the previous set of climate loads presented at the Resource Adequacy Advisory Committee meeting in June 2020. These new loads have reasonable daily and monthly shapes and peak magnitudes when compared to recent historical observed loads.

Relevance: Load forecast is an essential building block of the Resource Plan.
Climate Scenario Loads For the 2021 Power Plan

August 10, 2020

Outline

- Review of the previous set of climate scenario loads presented during RAAC June 2020
  - Comparison with historical loads
  - Comparison with RA-2024 loads

- New load methodology

- New climate scenario loads
  - Comparisons with historical loads
Review of the *Previous* set of Climate Scenario Loads Presented at the RAAC in June 2020

The *Previous* Set of Climate Scenario Loads for June RAAC (I)

- The loads used in the preliminary resource adequacy studies for the 3 selected climate scenarios for the 2021 Power Plan:
  - CanESM2_BCSD
  - CCSM4_BCSD
  - CNRM-CM5_MACA

- for the operating year 2024 were:
  - of medium economic forecast
  - had the effects of the 7th Plan EE targets and hourly shapes (with magnitude of 1,570 aMW)
  - and DSI
The *Previous* Set of Climate Scenario Loads for June RAAC (II)

- For comparison with other types of loads, for each of the 3 climate scenario, use the 10-year time-period: 2020 – 2029
- In aggregate, there are 30-years of loads from the 3 climate scenarios

Comparisons with Historical Observed Loads (2002 - 2017) - PNUCC
Interpreting Box-and-Whiskers Plot

The interpretations of the upper and lower whiskers

Comparison with Historical Observed Loads (2002 – 2017) - PNUCC (I)
Comparison with Historical Observed Loads (2002 - 2017) - PNUCC (II)

Historical winter peaks (2002 - 2017)

Jan load went past 34,000 MW in 2017, Feb went past 33,000 in 2014

What is happening to Nov/Dec? All values are below historical whiskers.

March 2019 load peak above 30,000

Three 2024 CC winter peaks


Historical summer peaks (2002 - 2017)

Jul/Aug loads on median -1,250 to -1,500 MW higher than historical max
Comparisons with Medium Economic Forecast For the RA-2024 Loads
(with 1998 - 2017 Temperatures)

Regional Temperature

- The regional temperature used in load forecast modeling,

\[ T_{region} = a \times T_{Seattle} + b \times T_{Portland} + c \times T_{Spokane} + d \times T_{Boise} + \text{constant} \]

is a weighted sum of the temperatures of four cities: Seattle, Portland, Spokane and Boise

- the weights, \( a, b, c, d \), and \( \text{constant} \) vary by month
- For example, for Jan to Apr,
  - \( a = 0.49, b = 0.26, c = 0.22, d = 0.06, \text{constant} = -2.54 \)
Climate Scenario (2020 – 2029) and Historical Jan Temperatures (1988 – 2017)

Comparison with Jan RA-2024 Loads
Climate Scenario (2020 – 2029) and Historical Mar Temperatures (1988 – 2017)

Comparison with Mar RA-2024 Loads
New Hourly Load Forecast Methodology

Simplified Flow Chart for Load Methodology

- Long-Term Model
  - Monthly HDDs, CDDs
  - Average Monthly Loads
  - Hourly Normal Temperatures

- Short-Term Model
  - Hourly Temperatures
  - Hourly Loads

HDD = heating degree days, CDD = cooling degree days
Changes in Short-Term Model

- **Key economic driver:**
  
  Previous Methodology: monthly averaged loads from long-term model
  
  New Methodology: future regional employment for 2020 – 2050*

- **Normal temperatures**
  
  Previous Methodology: climate scenario temperatures 2020 - 2050
  
  New Methodology: historical observed temperatures 1948 - 2017

* Source for employment projections: Global Insight 2018

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**Average Annual Regional Employment* Forecast (1000s)**

*Regional employment was used as economic driver for STM across all CC scenarios. LTM uses a variety of economic drivers, such as number of residences, commercial square footage, industrial output, population.

Source for employment projections: Global Insight 2018

subject to change / Draft to final / Covid-19 impact.
Comparing New Climate Scenario with Historical Monthly-Averaged Loads

New Climate Scenario Monthly Averaged Weather-Normalized Loads

- As a check on continuity near the year 2020,
  - Compare the 3 climate scenario monthly-averaged loads (from the long term model) with historical monthly-averaged loads
  - For the climate scenario loads (weather-normalized), use the just the first few forecast years: 2020 - 2024
  - For historical loads, use the 10-year historical time period: 2009 – 2018
  - use historical net-of DSI loads
Climate Model Weather-Normalized and Historical Monthly Averaged Loads

Comparing New Climate Scenario with Historical Hourly Loads
**New Climate Scenario Loads**

- To validate the new climate hourly loads, use the operating year **2024** and compare with historical hourly loads
  - Compare climate scenario loads (*medium economic forecast*) with historical observed loads
  - For the climate scenarios, use temperatures for the 10-year time-period: **2020 – 2029**
  - For simplicity, use *frozen-efficiency* and *net-of DSI* loads for climate scenarios
  - For historical loads, take the 10-year time period from **2009** to **2018** to match the 10-year climate scenario time-period
  - And use historical observed *net-of DSI* loads

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**Monthly Climate Scenario (2020 -2029) and Historical (2009 – 2018) Temperatures**

Distributions of Aggregated Climate Scenario (2020 - 2029) and Historical (2009 - 2018) Hourly Regional Temperatures by Month
Monthly Climate Scenario (with 2020 -2029 Temp)
Loads for 2024 and Historical (with 2009 - 2018 Temp)

Monthly Climate Scenario 2024 (2020 - 2029 Temps) and Historical (2009 - 2018) Peak Loads
Comparing Climate and Historical Hourly Temperatures and Loads by Month

Climate and Historical Temperatures

- **Maximum** and **minimum hourly** regional temperatures for the **aggregated** climate scenarios
  - CanESM2_BCSD
  - CCSM4_BCSD
  - CNRM-CM5_MACA

  for 2020 – 2029 are plotted for each month

- **Maximum** and **minimum hourly** regional temperatures for 2009 – 2018 are plotted for each month

- Plot maximum and minimum hourly temperatures as envelopes
Climate and Historical Observed Loads

- **Maximum and minimum hourly** regional loads for 2024 (*medium economic forecast, frozen efficiency, net of DSI*) for the aggregated climate scenarios:
  - CanESM2_BCSD
  - CCSM4_BCSD
  - CNRM-CM5_MACA

  with **2020 – 2029 temperatures** are plotted for each month

- **Maximum and minimum hourly** historical observed loads *(net of DSI)* for 2009 – 2018 are plotted for each month

- Plot maximum and minimum loads as envelopes

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**Jan Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures**

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 1

*Graph showing temperature data for different climate scenarios and historical data.*
**July Climate Scenario 2020 - 2029 and Historical 2009 - 2018 Temperatures**

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 7

**July Climate Scenario (2020 -2029 Temp) Loads for 2024 and Historical (2009 - 2018)**

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 7
**July Climate Scenario (2020 - 2029 Temp)**

* loads for 2024 and historical (2009 - 2018)

* Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 7

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**Questions?**
Methodology: Weather Normalized Loads

- **Using 1995-2018 historical observed** temperature and load data, we estimate the following equation.

\[
\log (L) = \alpha + \beta S + \gamma C + \delta \log (Emp) + \theta I + \mu + \omega \log (\Delta T)
\]

where:
- \(L\): is the log of net hourly load for electricity.
- \(S, C\): are a set of Fourier sine and cosine series capturing seasonal and trends.
- \(\Delta T\): Deviations from “normal/mean” temperatures.
- \(Emp\): is seasonally adjusted monthly employment (history).
- \(I\): are the indicator or dummy variables,
- \(\mu\): is the error term of the regression model

- **Parsing Loads: Weather Normalized and Temp. Sensitivity Multiplier**

We take Coefficients from above equation to estimate WN and TSM

\[
\text{WN load} = \alpha + \beta S + \gamma C + \delta \log (Emp) + \theta I + \mu
\]

where \(Emp\) is forecast for 2020-2049 period. This provides a forecast void of temperature deviations from Normal, but it includes impact of normal temps.
New Methodology: Temperature Sensitivity Multipliers

- To forecast loads that are sensitive to temperature variations, we need to incorporate coefficients from temperature deviations in the load equation using the coefficient from

\[ TSM = \omega \log(\Delta T) \text{ where:} \]

- \( \omega \) is set of coefficients showing relationship between hourly load and \( \Delta t \).
- \( \Delta T \) is (Climate Change temperature forecast from CC models) minus (Deviation from Normal historical temperatures).

- Note that in the past RA analysis, \( \Delta T \) had come from historic observed temperatures. For example for RA-2024, normal temperature calculated from 1948 – 2017, and deviations from normal temperature calculated for 1948 – 2017 hourly temperatures.

- However for 2021 Plan/future RA, we are using future temperatures from CC models to develop TSM. This shift to future temps. is a new methodology and has implication for future RA analysis. It increases uncertainty of the load forecast.

- Normal temperature calculated from historical observed 1948 – 2018 temperatures. But deviations from normal temperature calculated from climate temperatures from 2020 - 2049.
CCSM4 Loads for 2024 for February and March Show a Jump due to jump in Heating Degree Days

<table>
<thead>
<tr>
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<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
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<tbody>
<tr>
<td>Oregon HDD January</td>
<td>805</td>
<td>591</td>
<td>662</td>
<td>659</td>
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<tr>
<td>Oregon HDD February</td>
<td>681</td>
<td>616</td>
<td>536</td>
<td>715</td>
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<td>Oregon HDD March</td>
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<td>Washington HDD January</td>
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<tr>
<td>Washington HDD February</td>
<td>718</td>
<td>659</td>
<td>569</td>
<td>752</td>
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<tr>
<td>Washington HDD March</td>
<td>574</td>
<td>582</td>
<td>689</td>
<td>882</td>
</tr>
</tbody>
</table>
Climate Model Weather-Normalized and Historical Monthly Averaged Loads (A)

Low Economic Forecast Climate Model Weather-Normalized and Historical Monthly Averaged Loads

Climate Model: Low Economic Forecasts

Year

Climate Model Weather-Normalized and Historical Monthly Averaged Loads (B)

Medium Economic Forecast Climate Model Weather-Normalized and Historical Monthly Averaged Loads

Climate Model: Medium Economic Forecasts

Year
Climate Model Weather-Normalized and Historical Monthly Averaged Loads (C)

Climate Model: High Economic Forecasts
Monthly Climate Scenario (2020 - 2029) and Historical (2009 - 2018) Temperatures

Distributions of (2020 - 2029) Climate Scenario and Historical (2009 - 2018) Hourly Regional Temperatures by Month

Monthly Climate Scenario (with 2020 - 2029 Temp) Loads for 2024 and Historical (with 2009 - 2018 Temp)

Distributions of Climate Scenario (2020 - 2029) and Historical Observed (2009 - 2018) Loads by Month
Monthly Climate Scenario 2024 (2020 – 2029 Temps) and Historical (2009 - 2018) Peak Loads

Distributions of Climate Scenario (2020 - 2029) and Historical Observed (2009 - 2018) Peak Loads by Month

Loads [MW]

Month

Model:
- CanESM2_7_4_2020
- CGCM4_7_4_2020
- CNRM-CM5_7_4_2020
- Hist
Jan Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 1

Jan Climate Scenario (2020 - 2029 Temp)
 Loads for 2024 and Historical (2009 – 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 1
Feb Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 2

Feb Climate Scenario (2020 -2029 Temp)
Loads for 2024 and Historical (2009 – 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 2
Mar Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures
Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 3

Mar Climate Scenario (2020 -2029 Temp)
Loads for 2024 and Historical (2009 – 2018)
Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 3
Apr Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 4

Temperature [°F]

Date

Apr-02 Apr-04 Apr-06 Apr-08 Apr-10 Apr-12 Apr-14 Apr-16

Apr-18 Apr-20 Apr-22 Apr-24 Apr-26 Apr-28 Apr-30

Apr-1

Model: Aggregated Climate Scenarios Hist

Medium Economic Forecasts

Apr Climate Scenario (2020 -2029 Temp)
Loads for 2024 and Historical (2009 – 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 4

Loads [MW]

Date

Apr-02 Apr-04 Apr-06 Apr-08 Apr-10 Apr-12 Apr-14 Apr-16

Apr-18 Apr-20 Apr-22 Apr-24 Apr-26 Apr-28 Apr-30

Apr-1

Model: Aggregated Climate Scenarios Hist
May Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 5

Week 1

Week 2

Week 3

Week 4

Date
Temperature [°F]

May-02 May-04 May-06 May-08 May-09 May-11 May-13 May-15

May-16 May-18 May-20 May-22 May-23 May-25 May-27 May-29

Load [MW]

May-02 May-04 May-06 May-08 May-09 May-11 May-13 May-15

May-16 May-18 May-20 May-22 May-23 May-25 May-27 May-29

Medium Economic Forecasts

Model: Aggregated Climate Scenarios Hist
**Jun** Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 6

![Temperature Graph](Image)

**Jun** Climate Scenario (2020 -2029 Temp)

Loads for 2024 and Historical (2009 – 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 6

![Load Graph](Image)
Aug Climate Scenario 2020 - 2029 and Historical 2009 - 2018 Temperatures

Aug Climate Scenario (2020 - 2029 Temp) Loads for 2024 and Historical (2009 - 2018)
**Sep** Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 9

![Graph](image)

Medium Economic Forecasts

Model: Red Aggregated Climate Scenarios, Gray Hist.
**Oct** Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 10

**Oct** Climate Scenario (2020 - 2029 Temp) Loads for 2024 and Historical (2009 – 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 10
**Nov** Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 11

**Nov** Climate Scenario (2020 -2029 Temp)

Loads for 2024 and Historical (2009 - 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 11
Dec Climate Scenario 2020 - 2029 and Historical 2009 – 2018 Temperatures

Agg Climate Scenarios (2020 - 2029) and Historical Temperatures (2009 - 2018) for Month 12

Dec Climate Scenario (2020 - 2029 Temp) Loads for 2024 and Historical (2009 – 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 12
Climate (High and Low Economic Forecasts) vs Historical Hourly Loads by Month

Jan Climate Scenario (2020 - 2029 Temp)
Loads for 2024 and Historical (2009 - 2018)
Apr Climate Scenario (2020 -2029 Temp) 
Loads for 2024 and Historical (2009 – 2018)

May Climate Scenario (2020 -2029 Temp) 
Loads for 2024 and Historical (2009 – 2018)
Aug Climate Scenario (2020 - 2029 Temp)  
Loads for 2024 and Historical (2009 - 2018)

Sep Climate Scenario 2020 - 2029 and  
Historical 2009 - 2018 Temperatures
Oct Climate Scenario (2020 - 2029 Temp)
Loads for 2024 and Historical (2009 – 2018)

Nov Climate Scenario (2020 - 2029 Temp)
Loads for 2024 and Historical (2009 – 2018)
Dec Climate Scenario (2020 - 2029 Temp)

Loads for 2024 and Historical (2009 - 2018)

Agg Climate Scenarios (2020 - 2029) and Historical Observed (2009 - 2018) for Month 12