Northwest **Power** and **Conservation** Council

June 4, 2019

MEMORANDUM

TO: **Power Committee Members**

FROM: **Massoud Jourabchi, Manager Economic Analysis**

SUBJECT: **Forecast Load with Price Effects and Forecast Load with Frozen Efficiency, Climate Change impacts on load forecasting**

<u>BACKGROUND:</u>

Presenter: Massoud Jourabchi

Summary: In preparation for the 2021 Power Plan, staff will be providing the Power Committee a series of presentations on different aspects to developing the Plan. In this presentation, I will provide an overview of the methods used in Council's long-term load forecasting. I will present the analytical steps to create load forecast from consumer perspective Price-effect load forecast, and Frozen-efficiency load forecast used in Council's resource planning process. I will also be discussing how climate change is anticipated to impact loads.

Relevance: A 20-year load forecast is a fundamental component of the power plan and is required by the Northwest Power Act.

Workplan: A.3.1. Develop Base Load Forecast: Price Effects & Frozen Efficiency Forecast for 2021 Power Plan

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Load Forecasting Price-effect, Frozen Efficiency and Climate Change Impacts on Loads

Massoud Jourabchi

June 2019

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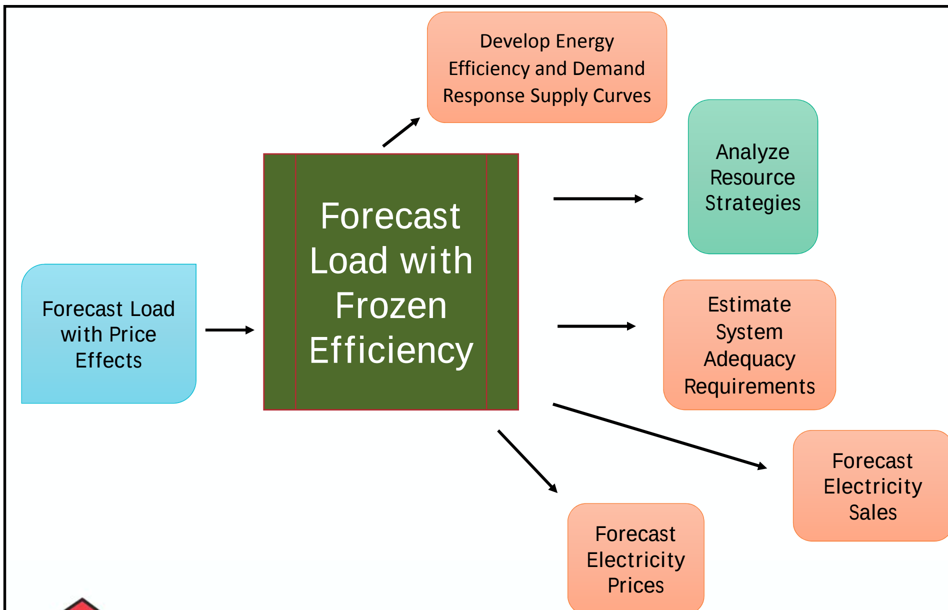
FOR A SECURE & AFFORDABLE ENERGY FUTURE



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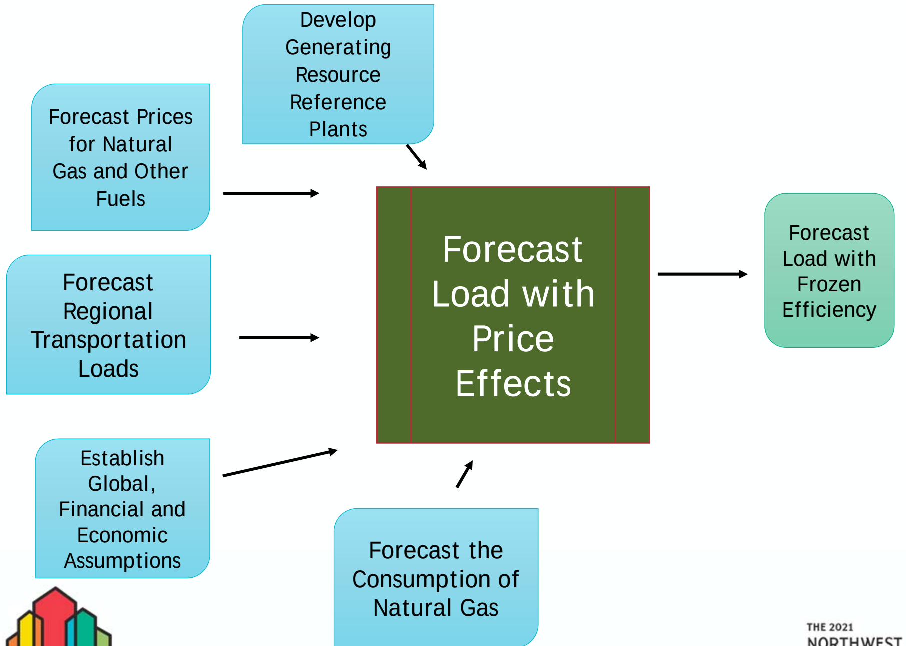

In this presentation

- Why we need to do a long-term load forecast.
- What does it entail.
- What are different type of forecasts
  - Price-effect (Consumer perspective)
  - Frozen efficiency (for use in power planning)
- Why we need to incorporate Climate Change in our modeling
- How Climate Change impacts loads
  - Direct effects- through change in temperatures
  - Indirect effects- by changing economic drivers of the forecast
- Selection Criteria for selecting Global Climate Change models

Why we do it?

- Basically because it is required by the power act. Act language requires Council to produce a load forecast of at least 20 year horizon.
- It is to be developed through an open and transparent process.
- We use advisory committees to vet our assumptions.
- Forecast is used internally to develop Resource Plan.
- Forecast is also used externally by various bodies, state regulatory agencies, independent consultants, and utilities.

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What does entail

- Many, Many, Many details.
- Model that we use to generate the 20 year forecast, is a bean-counting enduse model with extensive policy assessment capabilities.
- It generates forecast of demand at sub-aggregated level for each state, for each month, across a wide range of fuels (more than just electricity), for wide range of enduses and technologies.
- Since a picture is worth 2,000 words, here is a picture of the process used in load forecasting

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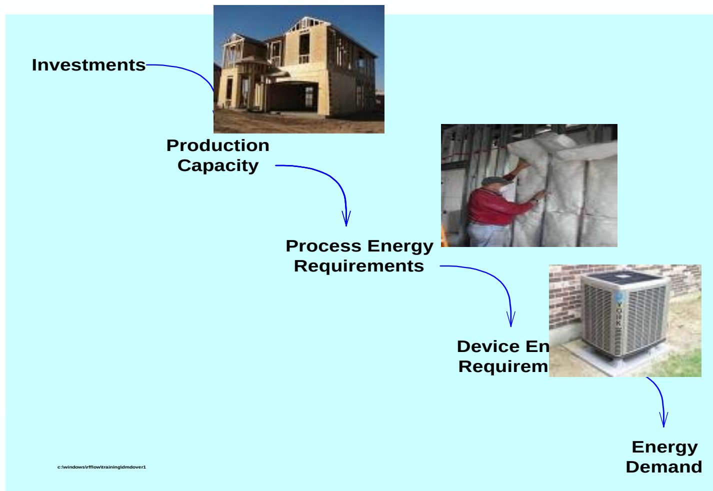
Tracking Energy Demand



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Now imagine we do this for

- For Four states, 3 residential building types, 17 commercial buildings, over 20 industrial sectors, many many modes of transportation. and for many enduses.
- For example for residential sector we forecast demand for space heating, space cooling, water heating, lighting, cooking, clothes washing, clothes drying, dishwashing, water heating, TVs, other electronic devices, etc.)
- We also follow and forecast demand for different technologies for each enduse.
- For example, heat pump water heaters as well as storage water heaters. We track multiple types of space conditioning technologies (heat pumps, ductless heat pumps, central AC, room AC).
- Because consumers have options of choice of fuels, we also need to track and forecast across fuels (electricity, natural gas, oil wood, and behind-the-meter solar). These fuels compete with each other on price and efficiency.

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Where do we start?

- Track 1: Economic Drivers
- Track 2: retail prices for fuels.
- Track 3: technology characteristics and costs
- The information from these 3 tracks give an starting forecast.
- We then have to vet model results. Best way is look at history. We look back t0 1985-2016 for demand by fuel, by state, by sector.
- From surveys and market research data we obtain data on market share of different fuels and technologies across sectors for the four states.
- We also bring in data on weather conditions. Cooling and heating requirements for temperature sensitive loads need to be taken into account. We bring in monthly temperatures, because temperatures impact energy requirement.
- Same heat pump may show higher levels of heating demand if the winter in a given year was colder than previous year. So we need to incorporate that into our analytics.
- Methodology used for estimating demand for energy starts with consumer choice.
  - There are price or cost attributes and non-price attributes that lead to consumer choice. We simulate consumer decision based on costs and then compare it to what actually consumer chose. The difference is treated as non-price effect.
- By now you would think we are out of the wood. But that is not the end of the road.

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Going from Consumer Demand for Energy to utilities generation requirements or Loads

- Demand for energy (we talked about in the last slide) is measured behind-the-meter, consumer site
- Load is measured at generator, bus-bar. Typically the difference between Demand and Load is Transmission and Distribution losses
- So we need more data

Track 4- For each enduse and sector we translate monthly demand for energy to monthly loads using hourly enduse load profiles.

Track 5- We bring in hourly system load profile.

We then map hourly loads for each enduse to hourly system load. This tells us how much each enduse contributes to system peak, average and minimum load, on a monthly basis.

Once we have vetted the demand for energy and load for each year and for each month in historic period. We can forecast future demand and loads by state, by enduse and by technology by sector.

Now our first forecast is called Price-effect forecast, because it is from a consumer perspective.

We produce two other types of forecasts. Will get to those late.

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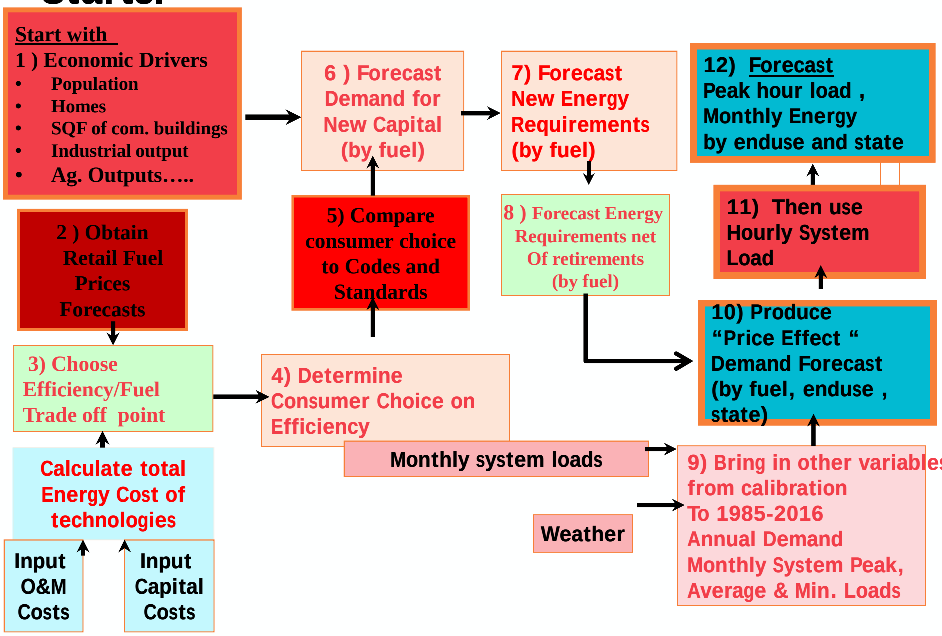
A Picture of How Price-effect Load Forecast Starts.



Basic Building Blocks of Long-term Demand Forecasting Model

For each enduse in each sector consumption is determined in part by:

- Number of Units (A)
- Fuel efficiency choices (B)
- Fuel choice (C)

Energy use by an enduse = A * B * C

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Number of Units (A)

- Driven by the economic forecast
  - Population
  - Number of Existing home
  - Number of New Homes (Single, Multi, Manuf.)
  - Square footage of existing commercial buildings
  - Square footage of new commercial buildings
  - Level of production from industrial, agricultural and mining firms
- Source of information: Global Insight and in-house analysis
- Review process: State economists and Demand Forecast Advisory Committee

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Fuel Efficiency Choices (B)

- An important consumer choice is between increased efficiency and higher capital cost
  - It involves a trade-off between potentially higher up-front costs and lower operating costs
  - For Example, if a very high efficiency water heater is purchased, the capital cost will be large, but the future operating costs will be lower
- Source of information: various sources and studies (LBL, DOE, ...)
- Review process: Demand Forecast Advisory Committee

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Fuel Choice (C)

- When customers trade one fuel for another on the basis of relative cost of fuels, factors considered include:
  - Capital Cost
  - Operation and maintenance cost
  - Non-price factors such as customer preference for one fuel over another
- Source of information: Historic fuel prices, National and regional survey of customer choices, Calibration demand to 1985-2016
- Review process: Demand Forecast Advisory Committee

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Illustrative Example Demand from Water Heating in New Homes

Electric water heaters demand in new homes is calculated as:

- Number of new single family homes: 20,000/yr
- Baseline Electricity Efficiency: 0.90 Energy Factor = 3600 kWh/yr
- Market share of electric: 69%
- Electricity Demand for water heating added per year
- 20,000*.69*3600 ~ 49,680 MWH ~ 5.67 MWa

Similar approach is used for existing homes. Existing homes are tracked over-time and the energy use is reduced each year based on the physical life of the device (i.e., as existing units fail, they are replaced units meeting federal minimum efficiency standards).

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Alternative Load Forecast Concepts

- Three different but related load forecasts are produced for use in the Council's resource planning process. The first of these forecasts is called a "price-effect" demand forecast, which is the forecast that has been presented up to this point.
- The price-effect forecast reflects customers' choices in response to electricity and fuel prices and technology costs, without any new conservation resources. However, expected savings from existing and approved codes and standards are incorporated in the price-effect forecast, consequently reducing the forecast and removing the potential from the new conservation supply curves.
- To eliminate double-counting the conservation potential, the load-forecasting model produces another long-term forecast, labeled Frozen-Efficiency forecast.

Frozen Efficiency Load Forecast

- **Frozen-Efficiency (FE) demand forecast,** assumes that the efficiency level is fixed or frozen at the base year of the plan (in the case of the 7th Plan, base year is 2015). For example, if a new refrigerator in 2015 uses 300 kilowatt hours of electricity per year, in the FE forecast this level of consumption is held constant over the planning horizon. However, if there is a known federal standard that takes effect at a future point in time (e.g., 2022), which is expected to lower the electricity consumption of a new refrigerator to 250 kilowatt hours per year then post-2022 a new refrigerator's consumption is reduced to this new lower level in the FE demand forecast.
- In this way, the difference in consumption, 50 kilowatt hours, is treated as a reduction in demand rather than considered as a future conservation potential. This forecast approach attempts to eliminate the double-counting of conservation savings, since estimates of remaining conservation potential use the same baseline consumption as the demand forecast. That is, the frozen technical-efficiency levels are the conservation supply model's starting point. Frozen-efficiency load forecasts are inputs to the Regional Portfolio Model for use in resource strategy analysis.

Comparison and Range of the Two Energy Forecasts from the 7th Plan analysis (aMW)

Forecast	Economic Scenario *	2016	2021	2035	AAGR 2016-2035
Price-effect	Low	20,783	21,115	22,916	0.5%
Price-effect	High	21,427	22,395	26,073	1.0%
Frozen Efficiency	Low	20,781	21,117	22,976	0.5%
Frozen Efficiency	High	21,436	22,466	26,620	1.1%

By 2021, delta between Frozen Efficiency and Price-effect forecasts is between 2-71 aMW depending on the scenario.
By 2035 the delta increases to 60-550 aMW
However, by 2021 the forecasts will be updated.
*- in the 7th Plan report we did not show medium range of forecast, to highlight range of uncertainty.

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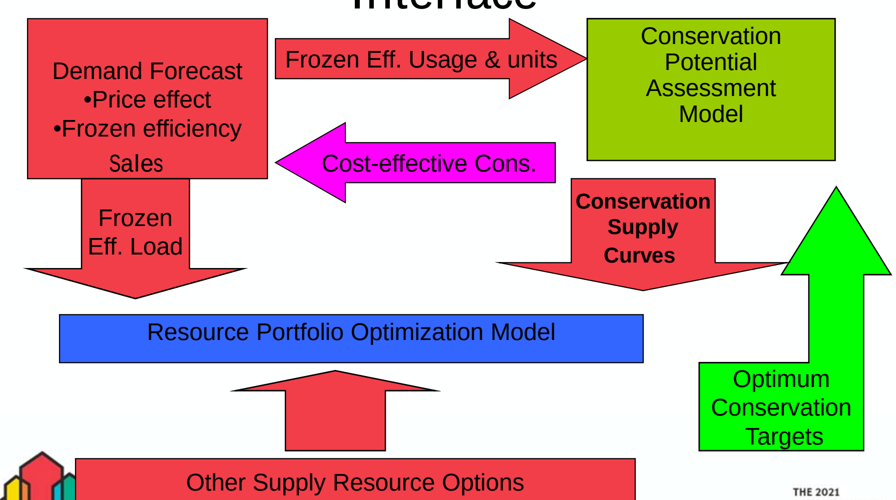
Demand forecast and Conservation Interface



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Once Conservation Targets are determined we now can produce the Third Forecast

Forecast	Scenario	2016	2021	2035	AAGR 2016-2035
Price-effect	Low	20,783	21,115	22,916	0.5%
Price-effect	High	21,427	22,395	26,073	1.0%
Frozen Efficiency	Low	20,781	21,117	22,976	0.5%
Frozen Efficiency	High	21,436	22,466	26,620	1.1%
Sales (FE net of EE)	Low	20,611	19,720	18,632	-0.5%
Sales (FE net of EE)	High	21,257	21,006	21,909	0.2%

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Incorporating impact of temperature variations

- Currently Long-term TM model is producing loads under normal weather.
- LTM is being modified to accommodate deviations from normal temperature, to simulate impact of extreme weather events of the past or forecasted climate change trends.
- Dr. Rupp presented background on what a General Circulation Model (GCM) is and the range of forecasts for temperature and precipitation.
- Next we briefly present where Climate Change (cc) would impact power planning process. I will then focus on some preliminary forecasts of loads under different climate change models.

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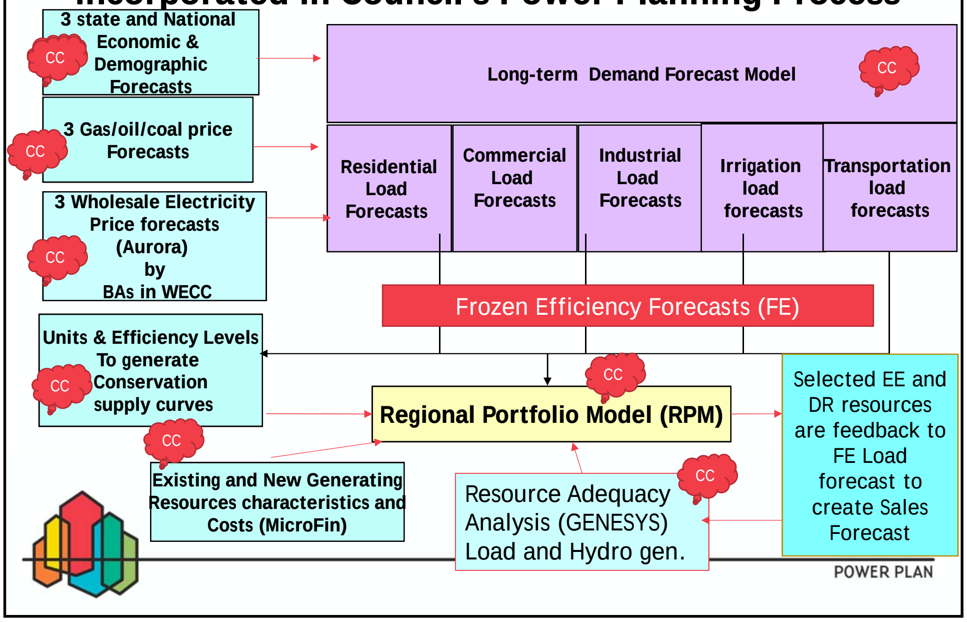
Where impact of climate change would be incorporated in Council's Power Planning Process



How are impacts of Climate Change incorporated into these base forecasts

- There is no explicit accounting of direct or indirect impact of CC included in the base economic forecasts.
- How climate change impacts future will depends on many factors.
  - Factors outside societal control (example, weather events, change in temperatures and precipitating)
  - Factors within societal control (impact of economy, mitigation, adaptation policies)
- Direct (out of our control) impacts of climate change can be layered into the base economic forecasts through changing cooling and heating requirement.
- Indirect impacts (within our control) such as mitigation, adaptation and migration will be included in to the analysis through modification to base economic drivers- to the degree these impacts can be quantified.
- We will be discussing the indirect impacts in later presentations.

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What are climate change models?

- There are numerous General Circulation Models/Global Climate Change Models or GCMs. They use different approaches to simulate impact of change in quantity and timing of future temperature, precipitation events.
- GCMs are global but they are downscales to desired geographies and they are bias corrected
- For the Northwest, and for Council's planning purposes we have access to 10 GCM's at four locations (Boise, Spokane, PDX and SeaTac).
- For each location daily minimum and maximum temperatures for 1950-2099 are available from each GCM.
- These temperatures are used to develop monthly and hourly temperature profiles.
- For hydro availability, daily precipitations forecasts are converted to flow at different locations. RMJOC is currently producing these forecasted flows.
- Same GCM needs to be used for load and hydro analysis.

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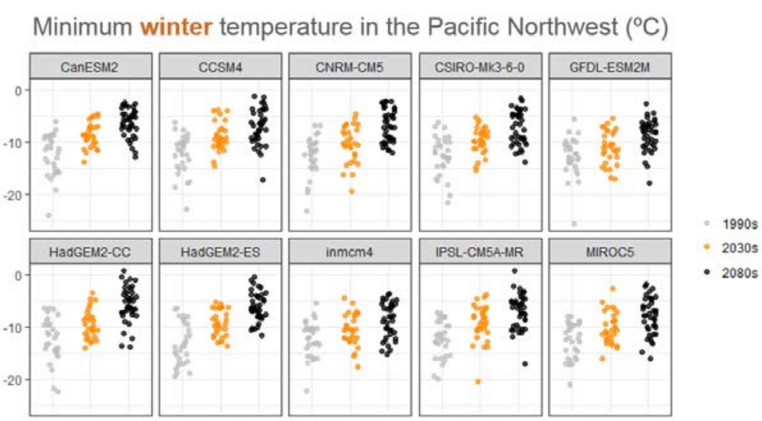
All GCMs forecast warmer winters



Source: RMJOC2 projected air temperatures for a range of atmospheric models

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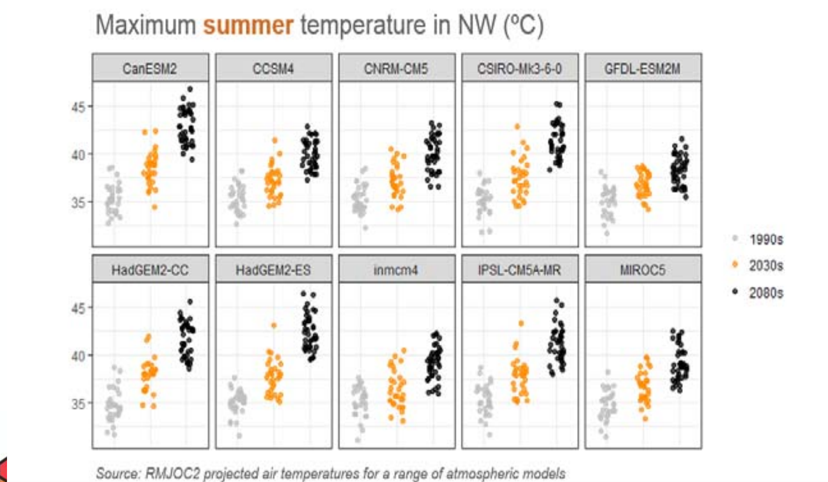
All GCMs forecast hotter summers



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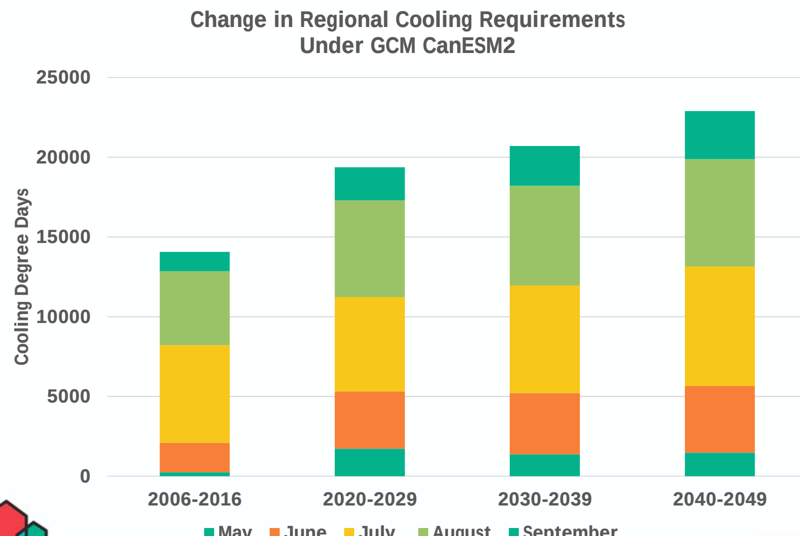
Earlier and Later Cooling



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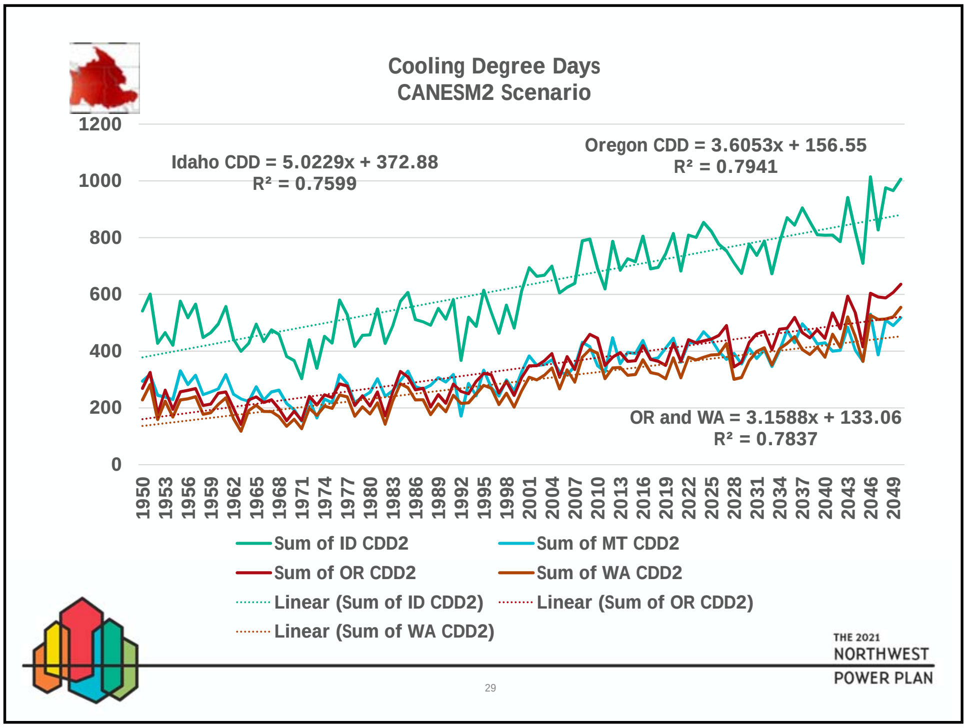
Cooling Degree Days
CANESM2 Scenario
Idaho CDD = 5.0229x + 372.88
R² = 0.7599
Oregon CDD = 3.6053x + 156.55
R² = 0.7941
OR and WA = 3.1588x + 133.06
R² = 0.7837
Sum of ID CDD2
Sum of MT CDD2
Sum of OR CDD2
Sum of WA CDD2
Linear (Sum of ID CDD2)
Linear (Sum of OR CDD2)
Linear (Sum of WA CDD2)
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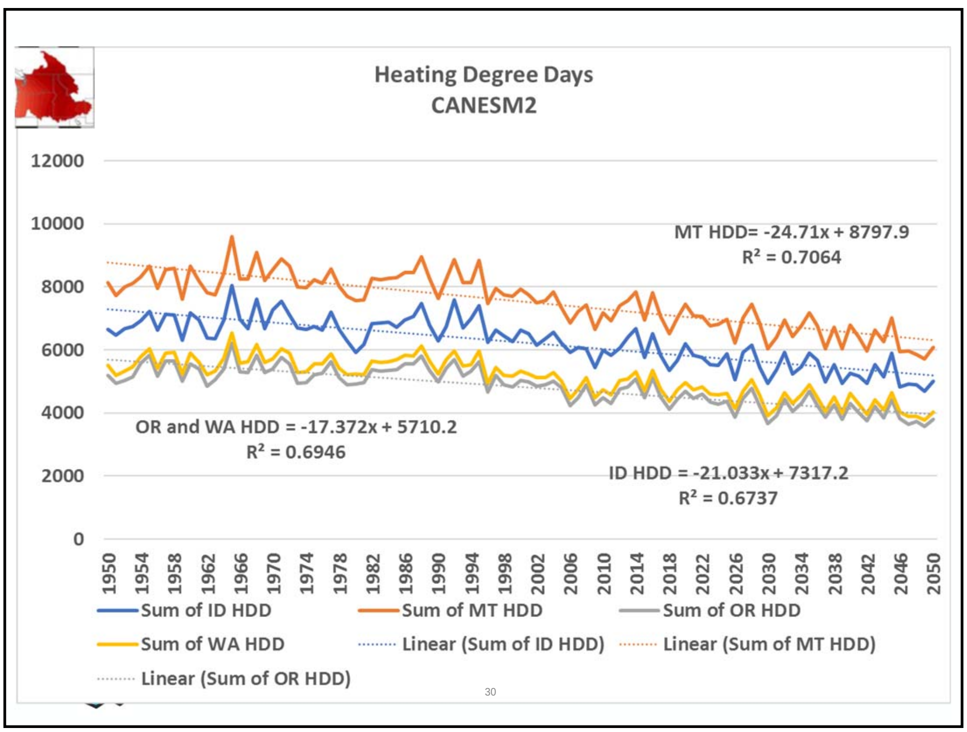
Heating Degree Days
CANESM2
MT HDD= -24.71x + 8797.9
R² = 0.7064
OR and WA HDD = -17.372x + 5710.2
R² = 0.6946
ID HDD = -21.033x + 7317.2
R² = 0.6737
Sum of ID HDD
Sum of MT HDD
Sum of OR HDD
Sum of WA HDD
Linear (Sum of ID HDD)
Linear (Sum of MT HDD)
Linear (Sum of OR HDD)
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Going from temperature increases to increase in Peak Loads

- Although climatic trends suggest warmer winters and hotter summers, the day-to-day weather patterns will include some cold winters or cold summers.
- To forecast impact on peak loads, we calculated monthly heating and cooling degree days for each state for each year for 10 GCMs. Then these cooling and heating degree days were provided to long-term forecast model. We will present the results later. For now
- We provide an example, of annual variations for two GCMs
- Although the year designation in GCMs may not map to calendar years, over all the years we see the upward trend in cooling and downward trend in heating requirement.

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Variations in Peak Load Forecast* Across the decades and GCMs

- The summary table showed the maximum peak load from preliminary forecast of loads.
- We follow winter and summer peak loads on a decadal basis for all GCMs in the following charts.
- Winter peak load variations is reduced overtime while
- Summer peak load variations increases.

- All the results shown are preliminary and subject to change.

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Peak loads projections over the next three decades (Preliminary)*

	2020-2029 Winter Peak	2030-2039 Winter Peak	2040-2049 Winter Peak	2020-2029 Summer Peak	2030-2039 Summer Peak	2040-2049 Summer Peak
1- CanESM2	34,407	35,306	37,803	31,403	34,834	36,323
2- CCSM4	34,624	36,031	37,351	31,180	33,955	37,583
3- CNRM	34,417	35,906	38,062	31,267	33,333	39,337
4-CSIRO	35,969	37,213	40,586	32,653	36,919	40,380
5- GDFL	35,136	37,117	40,510	33,557	36,057	41,485
6- HadGEM2-CC	34,078	36,268	38,203	31,512	32,699	35,873
7 -HadGEM2-ES	34,449	35,952	38,231	30,964	32,849	37,536
8-inmcm4	33,826	35,421	37,722	32,591	35,027	40,444
9 - IPSL-CM5-MR	35,236	37,435	40,166	33,119	35,012	42,143
10-Miroc5	35,592	36,200	37,689	31,768	33,271	38,795

	2020-2029 Winter Peak	2030-2039 Winter Peak	2040-2049 Winter Peak	2020-2029 Summer Peak	2030-2039 Summer Peak	2040-2049 Summer Peak
Highest Peak Load	35,969	37,435	40,586	33,557	36,919	42,143
GCM	4-CSIRO	9 - IPSL-CM5-MR	4-CSIRO	5- GDFL	4-CSIRO	9 - IPSL-CM5-MR

Summer Peak Load range across GCMs for (2020-2029) ~2000 MW
Summer Peak Load range across GCMs for (2030-2039) ~4000 MW
Summer Peak Load range across GCMs for (2040-2049) ~7000 MW

* - These forecasts do not include indirect impact of CC and are subject to change as load forecasting model is finalized. Also note that we are taking the load forecast to 2049,but the Resource Plan would only use the first 20 years of the forecast.

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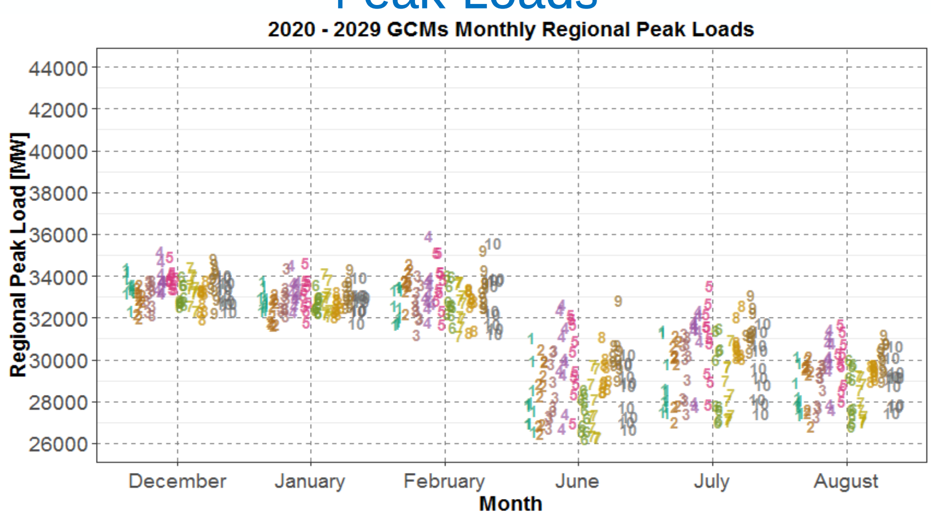
2020-2029 GCMs Winter & Summer Peak Loads



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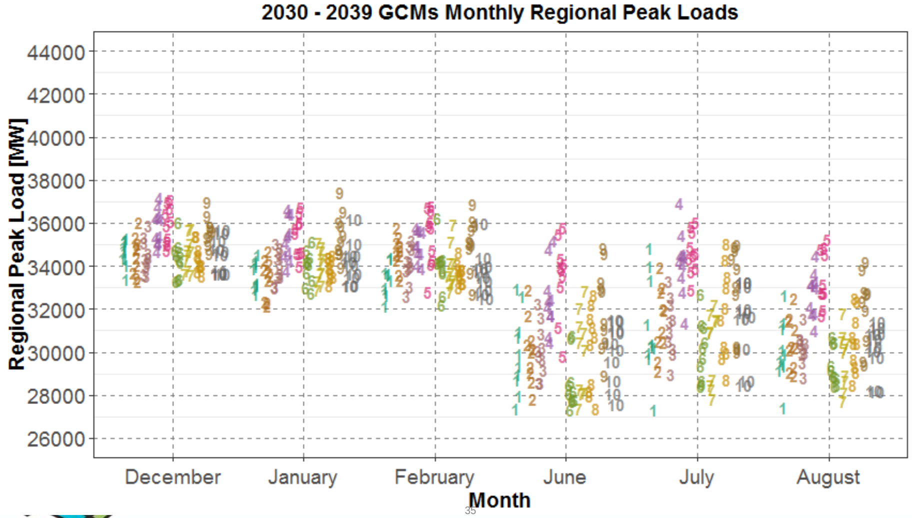
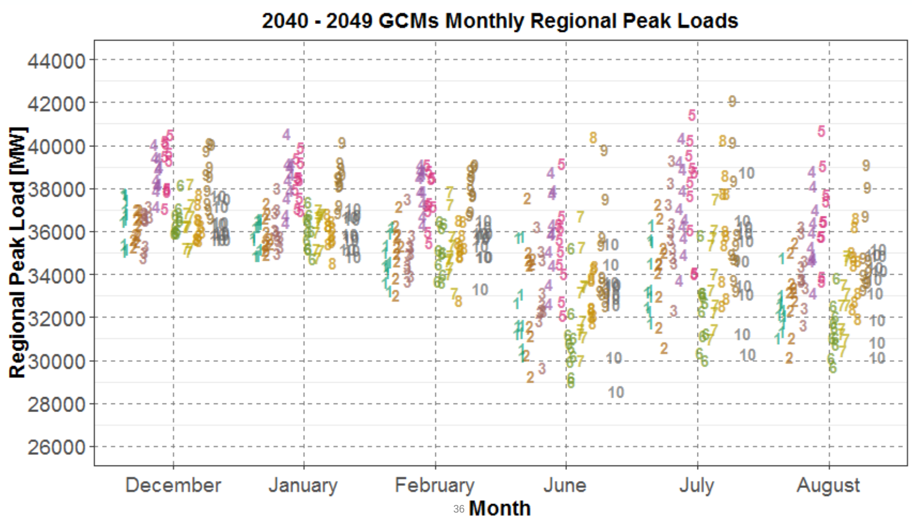
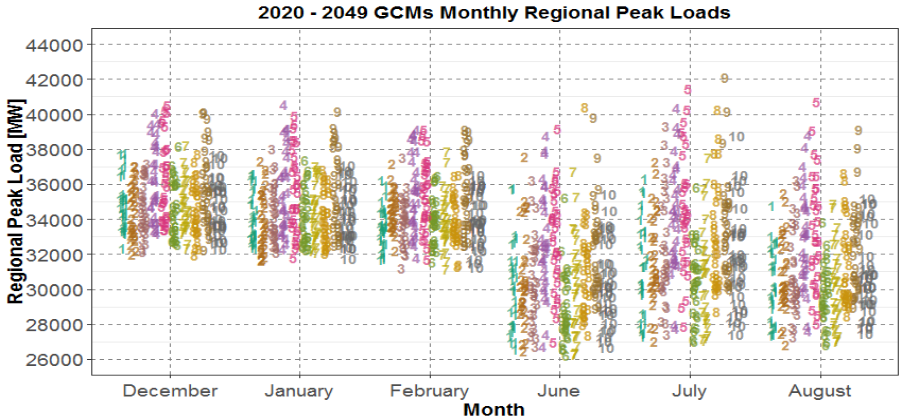
2030-2039 GCMs Winter & Summer Peak Loads



2040-2049 GCMs Winter & Summer Peak Loads



2020-2049 GCMs Winter & Summer Peak Loads



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Range of Load forecasts under different economic drivers and climate change models

- To cover the full range of economic and climate change models, we would need to produce 30 different frozen efficiency load forecast.
- Clearly that is not practical.
- So we need to select a reasonable number of forecast.
- However, at this point, a Key deciding factor, range of hydro generation, is not available.
- In the next slide we present the current selection criteria.

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Criteria to Select GCMs

GCM selected should have good representation of:

- **Historic regional temperatures and precipitation**
- **Past Atmospheric Rivers events**
- **Past 5-year drought events**
- **Change in summer temperature**
- **Change in winter temperature**
- **Future hydro-generation**

Once hydro-generation data is made available to Council staff, we can take the next step of selecting the GCMs.

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Incorporating Indirect Impacts of Climate Change on Loads

- In addition to change in cooling and heating requirements there are additional indirect impacts of CC. These impact include:
- Increase Saturation rate of AC
- Change in economic drivers
  - Population
  - Gross State Product
- We have brought recommended change in AC saturation rates and propose changes in population and gross state product. We will be bringing to you these indirect impacts later in the year as we synthesis feedback from advisory committees.

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Questions?

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