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

December 6, 2016

MEMORANDUM

TO: **Power Committee**

FROM: **Massoud Jourabchi**

SUBJECT: **Load Forecasting Methodology Primer**

BACKGROUND:

Presenter: Massoud Jourabchi

Summary: load forecasting is a cornerstone of power planning activities at the Council. In this presentation an overview of two types of forecasting approaches discussed and pros and cons of each method is evaluated.

Relevance: long-term load forecast is used in development of the Power Plan, while shorter- term forecast is used in Resource Adequacy analysis.

Work plan: B.3.2. Continue enhancement of Council's forecasting models for fuel supply and demand and prices

Background: A technical background paper on the methodology for short-term model is provided council's website. Following link provides access to this technical paper.
http://www.nwcouncil.org/media/7150695/development-of-short-term-demand-forecasting-model-and-its-application-to-resource-adequacy-2014-version.pdf

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A primer on Load Forecasting

Massoud Jourabchi

December 2016

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In Today's Presentation

- Types of load forecasts
  - Purpose
  - Forecasting horizon
  - Periodicity
- Medium to long-term forecast
  - Econometric
  - Enduse simulation
- Medium to short-term forecasts
  - Statistical methods
    - Regression
      - Time-series
      - Cross-sectional

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Load Forecasting methodology will depend on the purpose

- Enduse Simulation modeling
  - Suitable for long-term
    - 5 years and beyond
    - Forecasting and Policy analysis
    - Changing structural relationships
- Econometric modeling
  - Suitable for medium-term
    - (3-5 years forecasting horizon)
    - Static structural relationships

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Major Factors Influencing Forecast

- Structural relationship - Longer-term factors
  - Population Growth
  - Economic Activities
  - Energy Prices
  - Technology Choices
  - Codes and Standards
  - Socio-economic Trend
  - Long-term weather patterns and trends
- Medium-term factors
  - Daily and hourly weather patterns
  - Employment, Income

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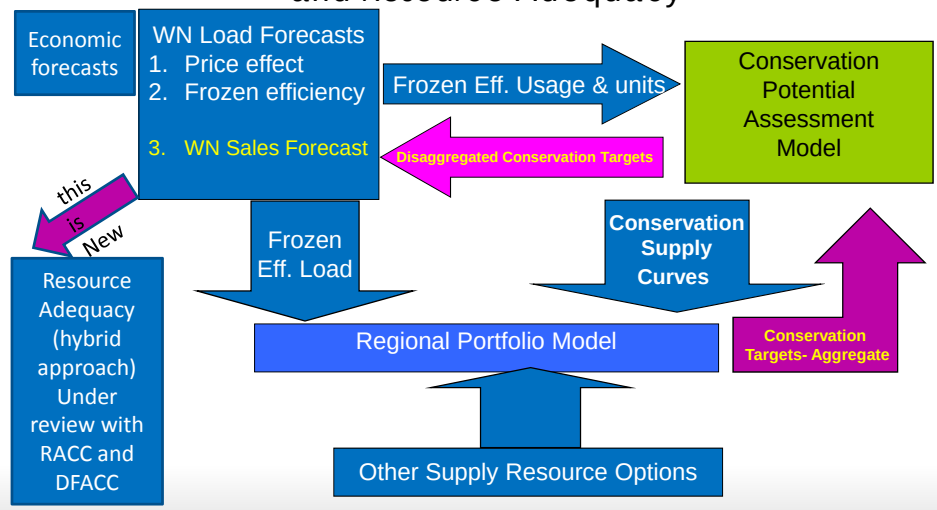
Council's Load Forecasting Tools

- Long-term using Energy2020, an all fuel, all sectors, state level, monthly simulation forecasting model.
- Short-term model (using in-house developed econometric models) daily and hourly forecast of regional loads under various weather patterns.

Load Forecast

Conservation, Resource Planning and Resource Adequacy



Basic Building Blocks of long-term 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

Number of Units (A)

- Driven by the economic forecast
  - Population and demographic forecast
  - Number of Existing home and their square footage
  - Number of New homes (Single, Multi, Manuf.)
  - Square footage of existing commercial buildings
  - Square footage of new commercial buildings
  - Level of production/employment from industrial, agricultural and mining firms
  - Income of residential sector
- Number of units are tracked using stock turnover logic.
- Source of information: (Global Insight and in-house analysis)
- Review: by State economists and Demand Forecasting Advisory Committee
- Can be updated fully every 5 years.
- Typically there is a 2-3 year lag in data sets.

Fuel Efficiency Choices (B)

- Trade-off between high up-front costs and high operating cost.
- Three different efficiency decisions for new purchases are tracked in the model
  - Efficiency consumers select (market condition)
  - Efficiency with standards (regulatory condition)
  - Greater of the consumer selected efficiency or standards

  This implies that standards will be effective as long as it is above consumer choice.
- Efficiency of stock of appliances is tracked as stock is turned over.
- Source of information: Various sources and studies (LBL, DOE,…)
- Review process : Demand Forecast Advisory Group and In-house
- Can be updated every five years.
- Typically there is a 2-3 year lag in data sets depending on timing for Residential or Commercial Building Stock Assessments, or Industrial assessments.

Fuel Choice (C)

Customer trading off one fuel for another on the basis of relative cost of fuels. Cost factors considered include:

- Capital Cost
- Operation and maintenance cost
- Non-price factors such as customer preference for one fuel over another

- Fuel-switching decision

Source of Information:
- Historic retail fuel prices,
- National and regional survey of customer choices (RBSA,CBSA,IFSA others)
- Calibration demand to 1985-2012 (for the 7th plan)

Review process: Demand Forecast Advisory Group
- Can be updated every 5 years or as regional surveys become available.

Momentum Savings

- It reflects rapidly changing markets
- If we were able to annually update:
  - **Number of Units (A)**
  - **Fuel efficiency choices (B)**
  - **Fuel choice (C)**
  - **Conservation baseline**
- Momentum savings would be zero.
- Momentum savings have short life. Only between forecast updates.

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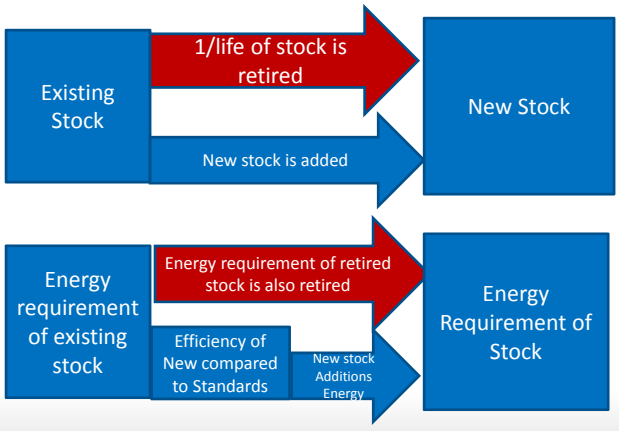
Stock and Energy Requirements Turns over annually



life of processes and devices varies by Enduse, Technology, and sector

Retirement rates are consistent with RTF.

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Illustrative Example
Demand from Water Heating in New Homes

Electric water heaters demand in new homes is calculated as:

A. Number of new single family homes: 20,000/year
B. Baseline Electricity Efficiency: 0.90 Energy Factor = 3600 kWh/year
C. Market share of electric: 69%

- Electricity Demand for water heating added per year
- 20,000*.69*3600 ~ 49,680 MWH ~ 5.67 aMW
- Every year, number of appliances, their efficiency and energy requirements are tracked using stock turnover logic.

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Economic Drivers

Economic Category	Driver
Residential	Number of households and square footage
Commercial	Square footage
Industrial	Gross state product/employment
Passenger	Personal income
Freight	Gross state product
Off Road	Gross state product

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Examples of Economic Sectors
Residential, Commercial, Transportation

Residential

- Single Family
- Multi Family
- Manufactured Homes

Commercial

- Large Office
- Medium Office
- Small Office
- Big Box-Retail
- Small Box-Retail
- High End-Retail
- Anchor-Retail
- K-12
- University
- Warehouse
- Supermarket
- Minimart
- Restaurant
- Lodging
- Hospital
- Elder care
- Assembly
- Other

Transportation

- Passenger
- Freight
- Air Passenger
- Air Freight
- Off Road

Economic Sectors
Industrial

- Food & Tobacco
- Textiles
- Apparel
- Lumber
- Furniture
- Paper
- Printing
- Chemicals
- Petroleum Products
- Rubber
- Leather
- Stone, Clay, etc.
- Aluminum
- Other Primary Metals
- Fabricated Metals
- Machines & Computer
- Electric Equipment
- Transport Equipment
- Other Manufacturing
- Data Centers
- Agriculture

End Uses
Residential, Commercial, Industrial

Residential Enduses

- Space Heating (by tech)
- Water Heating (by tech)
- Cooking (by fuel)
- Refrigeration(freezer)
- Lighting
- Air Conditioning (room, central)
- Misc.
  - Home electronics, etc

Commercial Enduses

- Space Heating
- Water Heating
- Other Substitutables
- Refrigeration
- Lighting
- Air Conditioning
- Other Non-Substitutables

Industrial Enduses

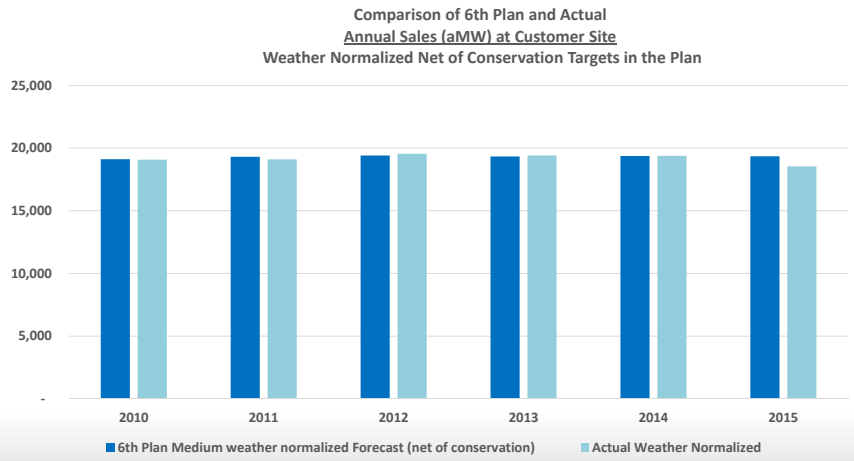
- Process Heat
- Motors
- Other Substitutables
- Miscellaneous
- Off-Road

Scope of Long-term Model
(using simulation modeling)

- Designed to provide a range of 20year forward looks for use in:
  - Conservation and Demand Response Assessment
  - Regional Portfolio Model (to select future resources for the region)
- Resolution for the forecasts is monthly, by state, enduse
- Past monthly temperature profiles are used for temperature sensitive loads (Space Conditioning, water heating)
- Forecast load assumes normal weather in the future.
- Produces three different Load forecasts (Price effect, Frozen-efficiency and Sales*)
- Quarterly Frozen-efficiency forecast is provided to RPM for resource selection.
- Sales forecast* is Frozen-efficiency loads net of energy efficiency targets
- Annual sector and enduse level conservation targets (EE) are incorporated into the Frozen-efficiency model.
- It incorporates impact of future codes and standards as well as rooftop solar/battery.
- It can incorporate impact of future policies.

*- although labeled "sales" forecast, it is a forecast of loads (at the generator busbar)

How accurately has the Long-term model forecasted energy sales?



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Test of Accuracy of Energy Forecasts from LTM

	2010	2011	2012	2013	2014	2015
6th Plan Medium weather normalized forecast of Sales at Customer Site (net of conservation) (aMW)	19,109	19,300	19,400	19,331	19,363	19,342
Actual Weather Normalized (aMW)	19,077	19,100	19,544	19,409	19,377	18,539
Difference in forecasts (aMW)	(31)	201	(144)	(78)	(14)	803
Difference as percent of Actual	-0.2%	1.1%	-0.7%	-0.4%	-0.1%	4.3% *

- Load forecast for 2010 used actual sales data for 2008.
- * Conservation targets for the 6th plan during this period was about 1500 aMW whereas actual conservation achieved is over 1700 aMW.

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Comparison of the Three Energy Forecasts from the 7th Plan analysis (aMW)

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 EE)	Low	20,611	19,720	18,632	-0.5%
Sales (FE net EE)	High	21,257	21,006	21,909	0.2%

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.

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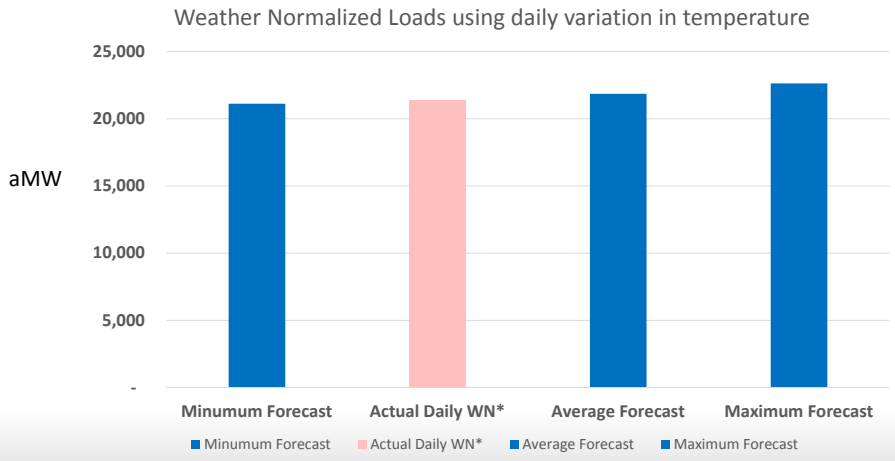
Comparison of forecast and actual for Q4 2015



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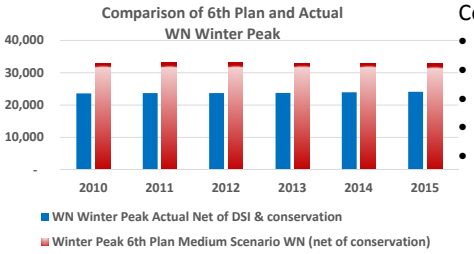
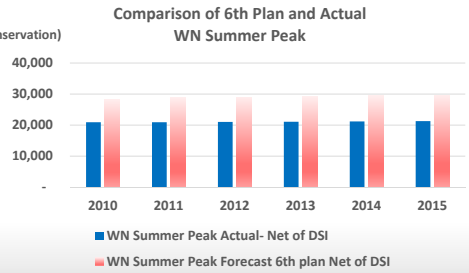
LTM projected higher single hour peak loads



Contributing Factors

- Vintage of data (3-5 years in the past)
- Treatment of temperature (annual vs hourly)
- Temperature Normalization process
- Conservation acquisition levels
- EE Impact on peak loads



A more detailed model incorporating impact of weather patterns and aggregate load shape of the system is needed.

Scope of Short-Term Model (Daily and Hourly)

- An econometric model
- It does not know, explicitly, about future codes, standards or conservation
- Suitable to produce regional hourly forecast with 3 years forecast horizon.
- It does not make a forecast of future weather profiles but instead uses past daily and hourly regional temperatures in creating future hourly loads.
- It creates daily load forecast based on past observed weather patterns of 1929-2015.
- It can also create hourly load forecast based on observed hourly weather patterns of 1995-2015.
- Uses regional employment as the one key economic driver.

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Structural relationships in Short-term model

$$L = f(S, W, DE, I)$$

Where :

L = net average hourly or daily electricity load in the region (net of DSI)
S = variables depicting seasonal variations in load (weekday, weekend, holidays)
W = weather variables generated via a regression model,(Normal and deviation from normal)
DE = demographic and economic variables, (Employment)
I = indicator or dummy variables. (1998 recession, 2001 energy crisis)

Decomposition of the Effects

1. **Loads under "normal" temperatures**
2. **Loads due to temperature deviation from normal**

What is "normal" temperature and impact of temperature on loads will depend on the level of aggregation of temperature data (Annual, Monthly, Daily, Hourly) as level of disaggregation increases accuracy in measuring impact of the weather increases

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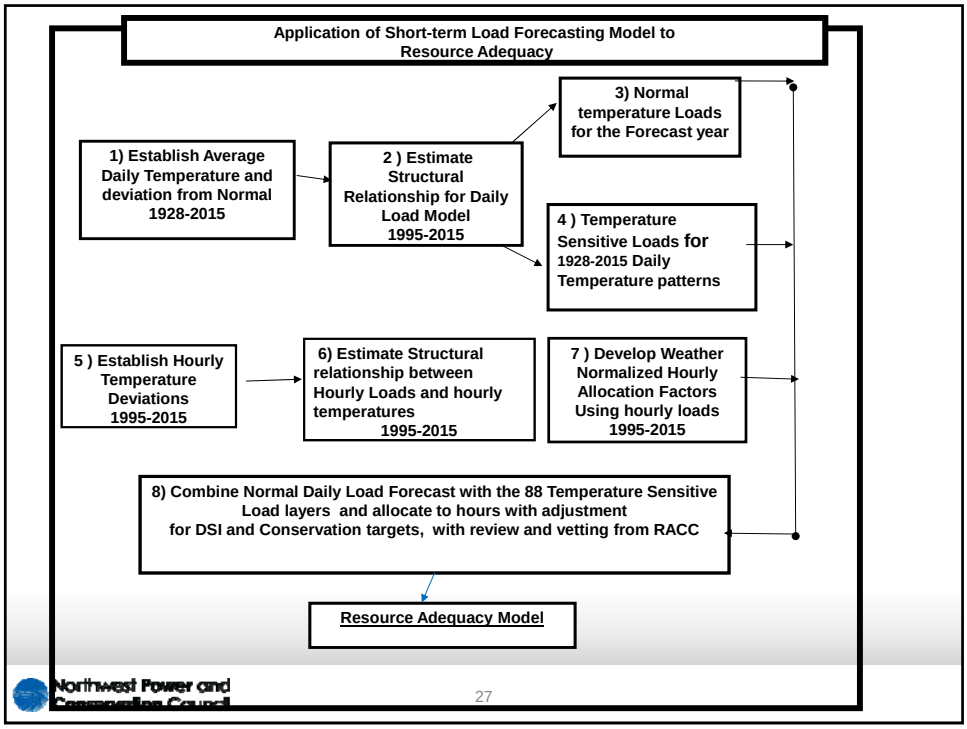


Test of accuracy of Daily and Hourly models

- We tested the accuracy of our short-term Daily and Hourly model, using 2015 observed loads
- Annual Energy
- Summer peak
- Winter peak

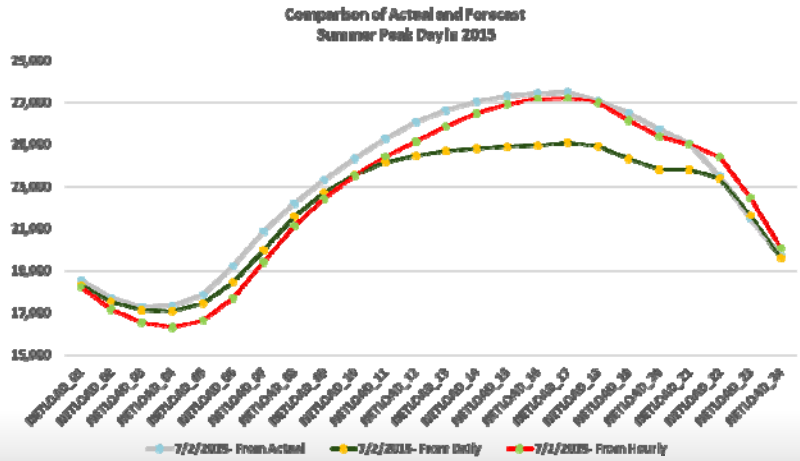
Test of Accuracy of Daily and Hourly Short-term Models (Annual Energy)

	Daily model	Hourly model
2013	2.4%	3.4%
2014	2.7%	3.6%
2015	5.0%	5.6%

2015 Summer Peak

- Summer peak load of 27487 MW occurred on July 2, 2015 at 5 PM.
- Daily model under-estimated peak load by about 8.7%.
- Hourly model under-estimated peak load by about 1%.
- For hour 18, which is typically used as a system peak hour, the hourly model under-estimated by 0.02%.

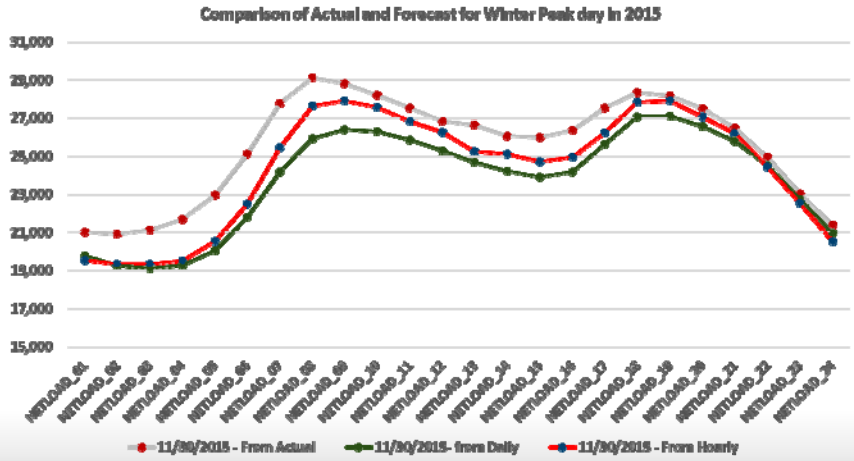
Test of accuracy of STM



2015 Winter Peak

- Winter peak load of 29120 MW occurred in November 30th 2015. The winter peak had the typical double hump.
- Morning peak load occurred at 8 AM and afternoon peak at 6 PM.
- Daily model under-estimated morning winter peak by about 11% and the afternoon peak by about 4.5%.
- Hourly model forecast also under-estimated morning peak by 5% and afternoon peak by 1.7%.

Test of accuracy of STM



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Test of Accuracy of STM

- Short-term model seems to do a better job of forecasting peaks than the LTM.
- For Resource Adequacy purposes use of STM is appropriate. However, the STM needs to incorporate impact of future codes, federal standards and conservation targets.
- For this purpose we are testing a hybrid approach.

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Differences between LTM and STM Forecasting tools used in the Council

	LTM	STM
Purpose	Produce 20 year forecast to be used in Conservation supply assessment, tracking enduse efficiency. Can test impact of future policies	3-5 year forward look, used for Resource Adequacy application. Focus on peak and energy.
Methodology differences	Enduse Simulation modeling. Produces 3 different forecasts, Explicitly models impact of future codes and standards, other trends.	Econometric modeling, Embedded Energy Efficiency, no explicit knowledge of future policies, codes/standards.
Incorporating impact of temperature on load	Uses monthly temperature profiles. For the forecast period uses Normal weather. Can simulate impact of change in weather patterns to a limited degree.	Explicit account of past daily and hourly temperature conditions More suitable for incorporating future weather patterns.
Periodicity	Monthly	Hourly and daily
Data update	Every 5 years, by sector, enduse, technology, by state	Annual, region-wide
Geographic detail	State and regional level	Regional level

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Combining the models

- To capture impact of future policies, such as codes and standards, or behind the meter distributed generation, we have combined the long-term and short-term model.
- Monthly energy forecast from the long-term model is provided to the short-term model to forecast hourly loads under past temperature profiles.

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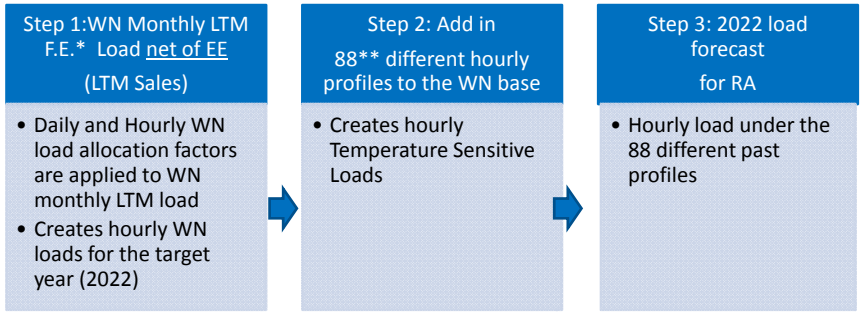
Hybrid Approach

This approach replaces the WN loads (step 3) from STM with the WN loads from monthly LTM Sales forecast. For example for 2022 forecast



*WN loads from the LTM can only be fully updated every 5 years, as part of Power Plan. For RA application we can update the temperature, economic drivers, natural gas prices of the LTM every year. EE amount will not be updated for RA analysis.
**- 1928 through 2014, as of 2015.

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Summary

- Load forecasting methodology and analysis will depend on the purpose of the forecast.
- LTM using simulation modeling is more suitable for evolving conditions.
- STM using econometric approach is more suitable for near-term applications with more static conditions.
- Hybrid approach brings these two approaches together for RA purposes.

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Questions?