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Base Load Modeling Update & Preliminary Results

Load Forecast Committee

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Acronyms

ASOS	Automated Surface Observing System	**EIA**	Energy Information Administration
ARA	Annual reconfiguration auction	**EV**	Electric Vehicle
AEO	EIA's Annual Energy Outlook	**GCM**	Global Climate Model
CDD	Cooling degree day	**FCM**	Forward Capacity Market
CELT	Capacity, Energy, Load, and Transmission	**HDD**	Heating degree day
COP	Coefficient of performance	**HP**	Heat pump
DER	Distributed energy resource	**ICR**	Installed Capacity Requirement
ECMWF	European Center for Medium-Range Weather Forecasts	**IPSL**	Institut Pierre-Simon Laplace (Climate Modelling Center)
EPRI	Electric Power Research Institute	**LFC**	Load Forecast Committee
ERA5	ECMWF Reanalysis Version 5	**SAE**	Statistically-adjusted end-use
EE	Energy efficiency	**SSP**	Shared Socioeconomic Pathway

Objective

- As discussed at the September 27th LFC presentation on Forecast Modeling, CELT 2025 will include hourly base load models and forecasts
- This presentation provides an update on ISO's base load modeling efforts and a preliminary mockup of CELT 2024 using the new hourly forecast methodology
  - Additional details on base load modeling
  - Model validation
  - Benchmarking of preliminary results to CELT 2024

BASE LOAD MODELING UPDATE

Base Load Forecast Modeling for CELT 2025

- The methodology used to develop the base load forecast is entirely new and is the focus of this section of the presentation
- ISO recently finished developing the overall modeling methodology, but is still working to further refine some inputs and model variables

Base Load Forecast

- Statistically modeled based on historical load reconstituted for BTM PV
- Is combined with electrification forecasts to yield the gross and net load forecasts

DER (BTM PV) Forecast

- Adoption forecasting based on NREL's dGen™ tool
- Demand reductions derived using zonal, historical hourly capacity factors

Heat Pump Forecast

- Adoption forecast along possible heating pathways
- Demand derived from simulated weather-dependent building heating needs and HP coefficient of performance (COP) curves

Electric Vehicle Forecast

- Policy-based adoption forecast (5 vehicle types)
- Demand derived from weather-sensitive battery efficiency curves and daily charging profiles

Base Load Modeling Elements

- Key elements of the new methodology used for the CELT 2025 base load modeling include:

Re-defining Gross Load

- $Load_{Gross} = Load_{Net} + \ BTM\ PV$
- Forward looking impacts of EE are captured with SAE drivers included as inputs to the model

Model Structure

- A daily energy model that feeds 24 individual hourly models, resulting in an hourly forecast

Temporal Granularity

- Modeling will now include all hours to produce an hourly forecast that extends 20+ years

Model Architecture

- Combination of linear regression and neural networks
- Model training period of ~9-10 years

Hierarchical Forecasting

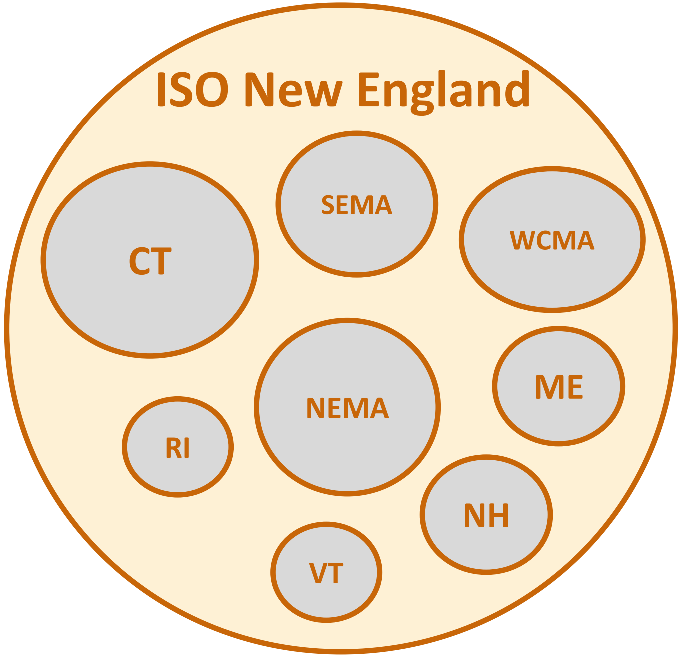
- Each load zone will be modeled separately, where the regional forecast results directly from the sum of the zones

Expanded Features

- More than 25 weather features
- More than 40 calendar features

Hierarchical Forecasting Approach

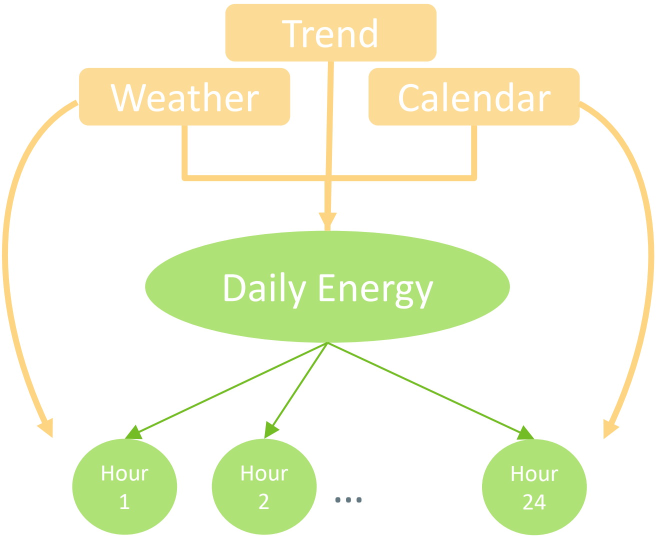
- The new methodology uses a hierarchical approach
  - All modeling is performed at the zonal level
  - ISO-NE forecast is a sum of zonal forecasts
- This approach provides a framework to understand the zonal contributions to coincident load behavior, based on the spatial diversity of weather and load characteristics across the region
  - New capabilities to derive non-coincident load characteristics for each zone



Model Architecture

25 Models For Each Zone

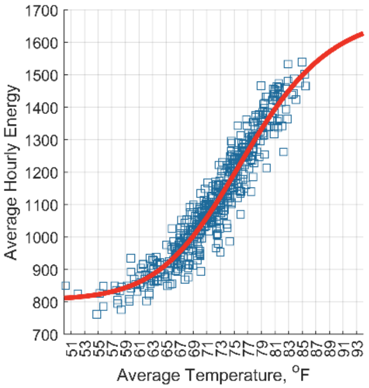
- Linear regression daily energy model
  - About 25 weather features, including transformations of dry bulb, dew point, wet bulb, wind speed, cloud cover, and some interactions between variables
    - Groups of weather variables for each season
  - More than 40 calendar features, including day of week, monthly, monthly “walk” variables, various holiday binaries
  - Three trend variables
    - Xheat is interacted with heating season weather variables
    - Xcool is interacted with cooling season weather variables
    - Xother is interacted with calendar variables
- 24 hourly neural network models
  - Ingests output of daily energy model
  - 13-15 weather variables, depending on hour of day
  - Mostly similar (~40) calendar variables as daily energy model
- Models are trained on 9-10 years of historical data

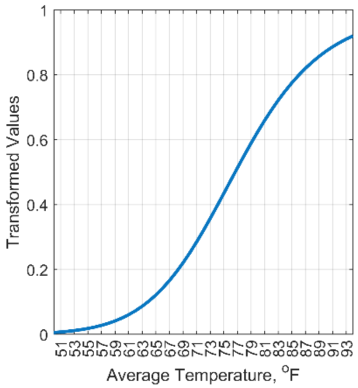


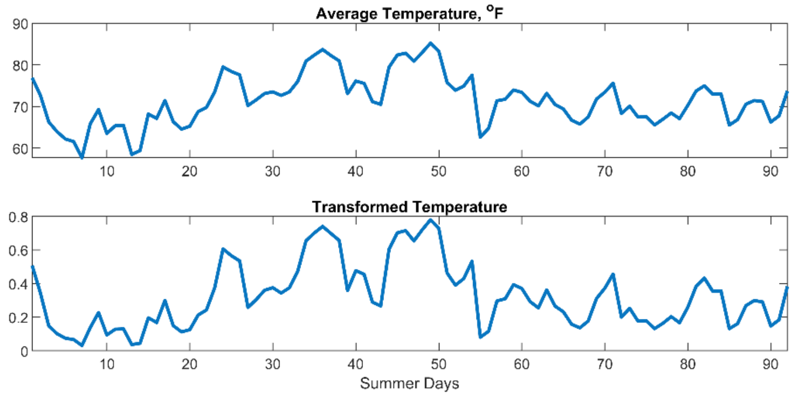
Daily Energy Modeling

Sigmoidal Transform of Temperature

- ISO is using a new sigmoidal transform of dry bulb temperature in its daily energy modeling that captures the nonlinear relationship between temperature and load during the cooling season
  - The magnitude of increased cooling demand per degree of temperature increase changes as it gets hotter
- This transformation leads to improved summer load modeling, and ensures it captures the "saturation" effects on demand during the hottest days
  - As weather becomes very hot, most A/C units are already on, leading to reduced increases in cooling demand per degree of additional temperature increase







Model Validation

CELT 2013 Backcasts

- ISO performed backcasting associated with a CELT 2013 vintage of models, and evaluated summer and winter daily peak accuracy
  - Models were trained on data from 2004-2012
  - Hourly backcasts (*a.k.a.*, ex-post forecasts) were generated based on actual weather and historical trend variables from 2013-2023 (11 years)
- Results are shown on the next slide
- Note that the performance of the resulting annual energy was discussed on slide 19 of today's presentation on trend variables

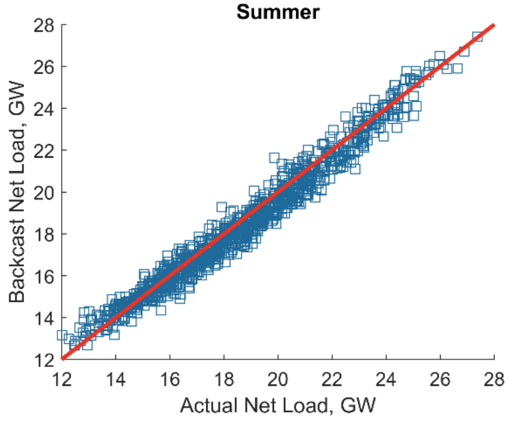
Model Validation

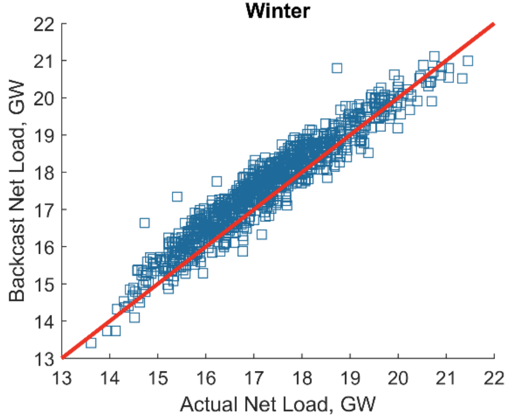
CELT 2013 Validation Results

- Backcast results for both sets of seasonal peaks yielded good accuracy, even for peak days occurring 6-10 years beyond the model training period

Mean Absolute Percent Error (MAPE)

Peak Days	Summer (n = 1,012)	Winter (n = 991)
All Peaks	2.50%	2.62%
Highest 100 Peaks	1.79%	1.46%
Highest 25 Peaks	1.84%	1.42%
Highest 10 Peaks	1.10%	1.83%





PRELIMINARY RESULTS & BENCHMARKING

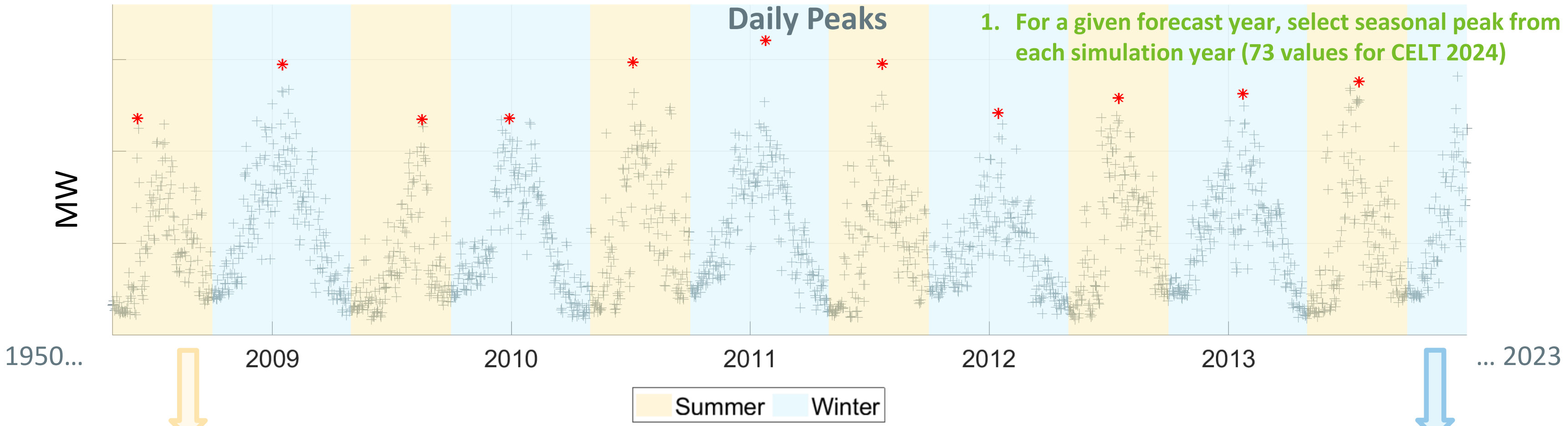
Mockup of CELT 2024 Using New Methodology

Calculation of Seasonal Peaks

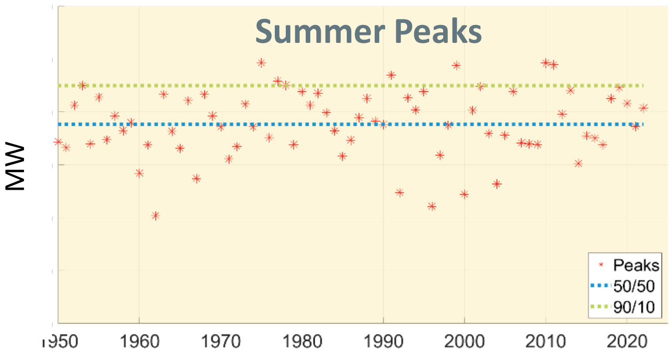
Review

- For each forecast year of the forecast horizon, seasonal peaks are derived from all seasonal peaks calculated within 73 years of simulated hourly loads
  - 50th and 90th percentiles are calculated from all 73 resulting seasonal peaks
    - Summer months: May-Sept
    - Winter months: Nov-Mar
- Using this method, the likelihood of a seasonal peak at any given threshold magnitude aligns with its expected return period
  - "50/50" forecast has a 50% probability of being exceeded in any season
  - "90/10" forecast has a 10% probability of being exceeded in any season
- These likelihoods are true ***on average*** over the span of many years
  - However, there is a chance that multiple "50/50", or even "90/10", peaks can occur within a single season

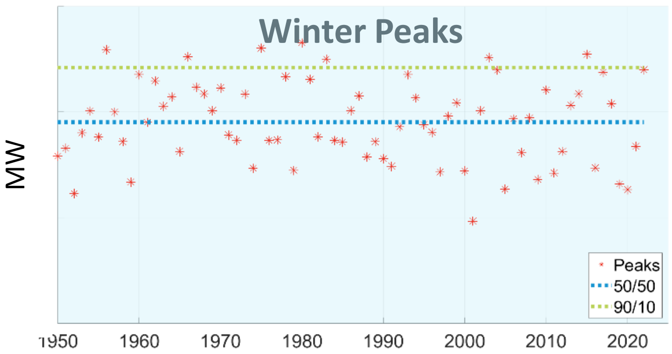
Review: Example Calculation of Seasonal Peaks



1. For a given forecast year, select seasonal peak from each simulation year (73 values for CELT 2024)



2. Calculate 50th and 90th percentiles from resulting peaks
3. Repeat for each forecast year

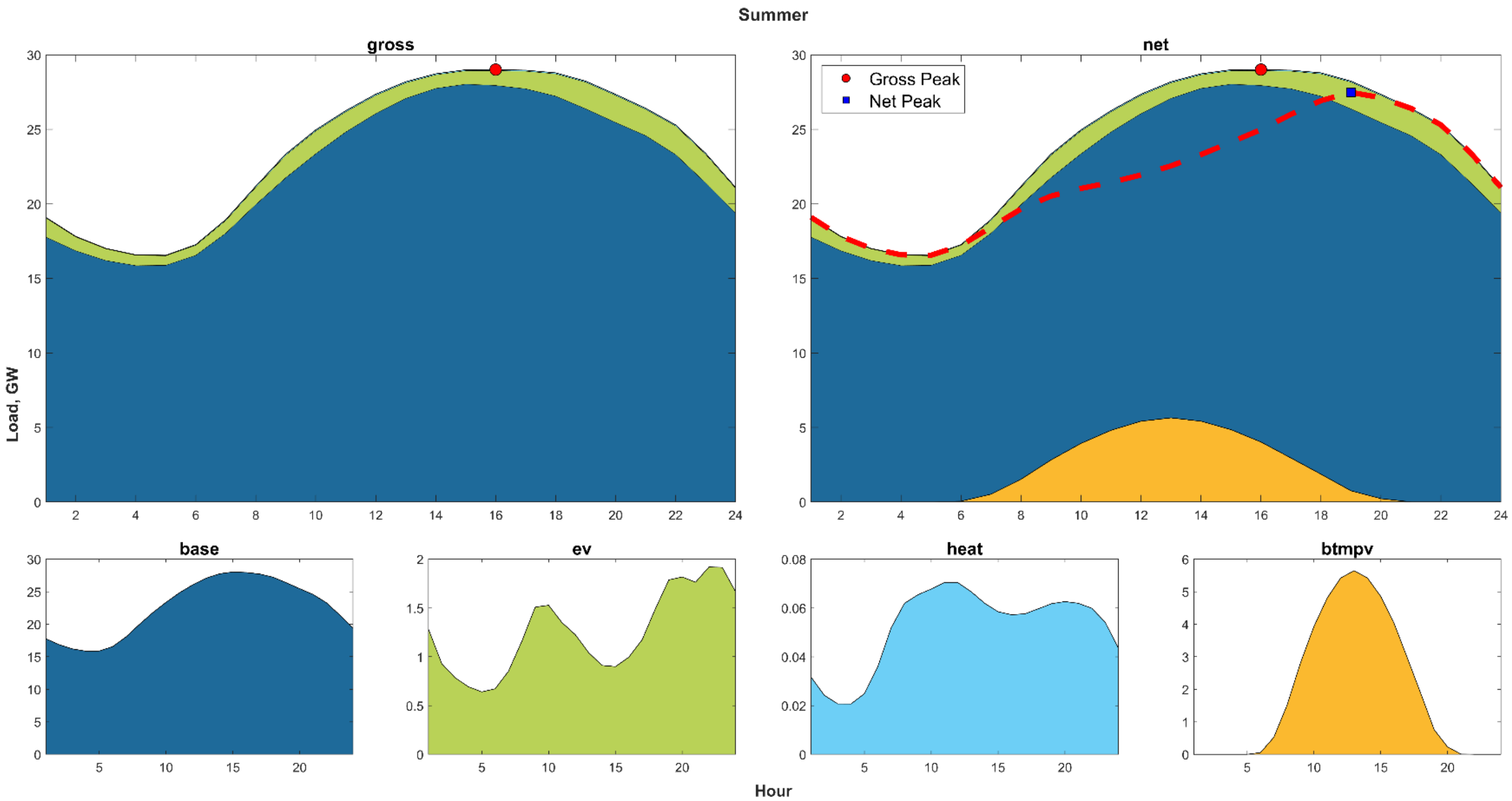


Seasonal Peak Calculations

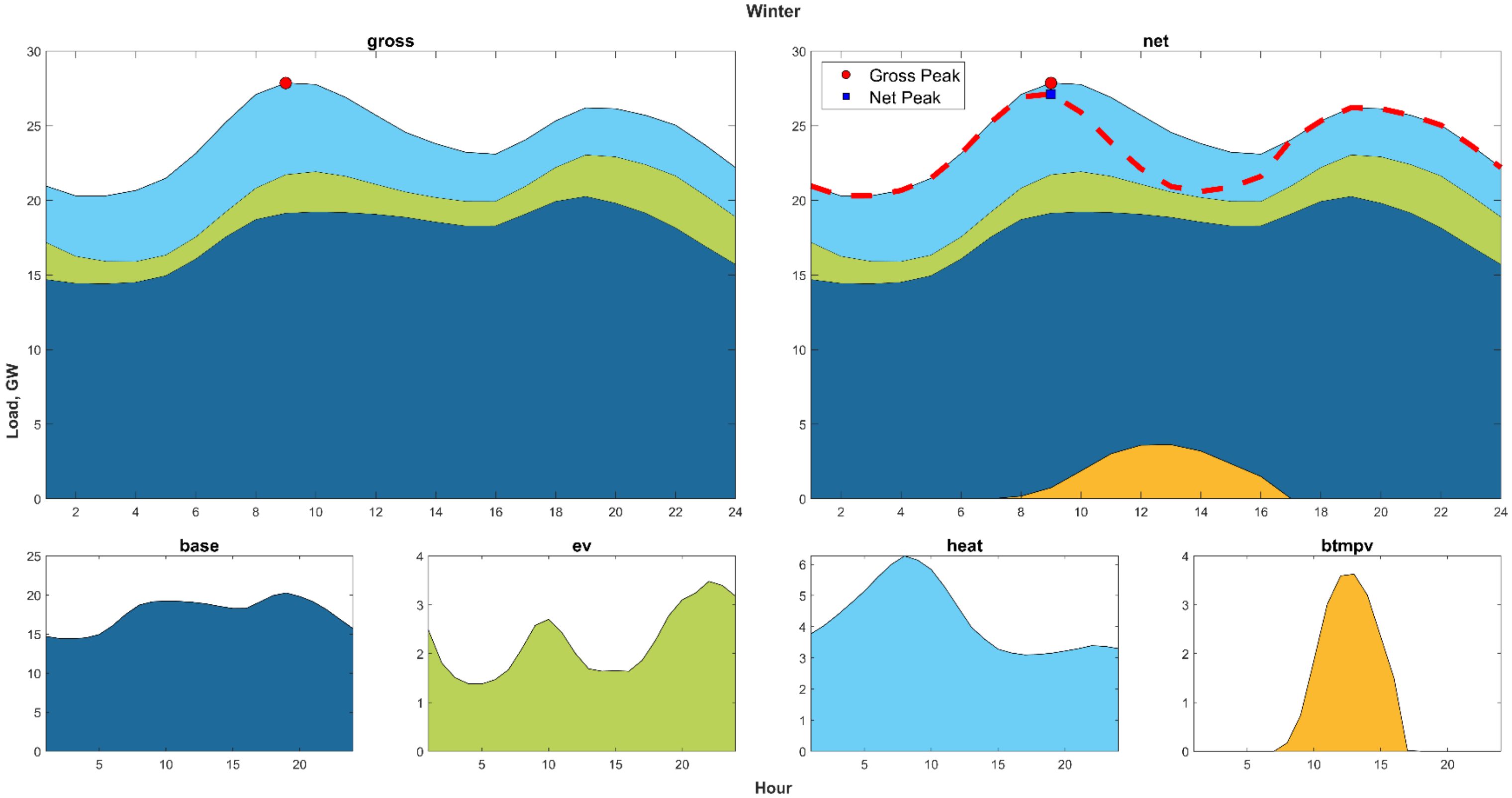
Examples of Combining 4 Load Components

- Examples of how the forecast results of each of the 4 load components are combined into a seasonal peak are shown on the following two slides:
  - Summer weather day: June 29, 2021
  - Winter weather day: January 24, 2011
  - Both slides are associated with a mockup of CELT 2024 results using the new methodology for forecast year 2032
- This process is repeated for all 73 seasons of the weather simulation period, resulting in a distribution of 73 seasonal peak values

Example 2032 Summer Seasonal Peak Day, ISONE



Example 2032 Winter Seasonal Peak Day, ISONE

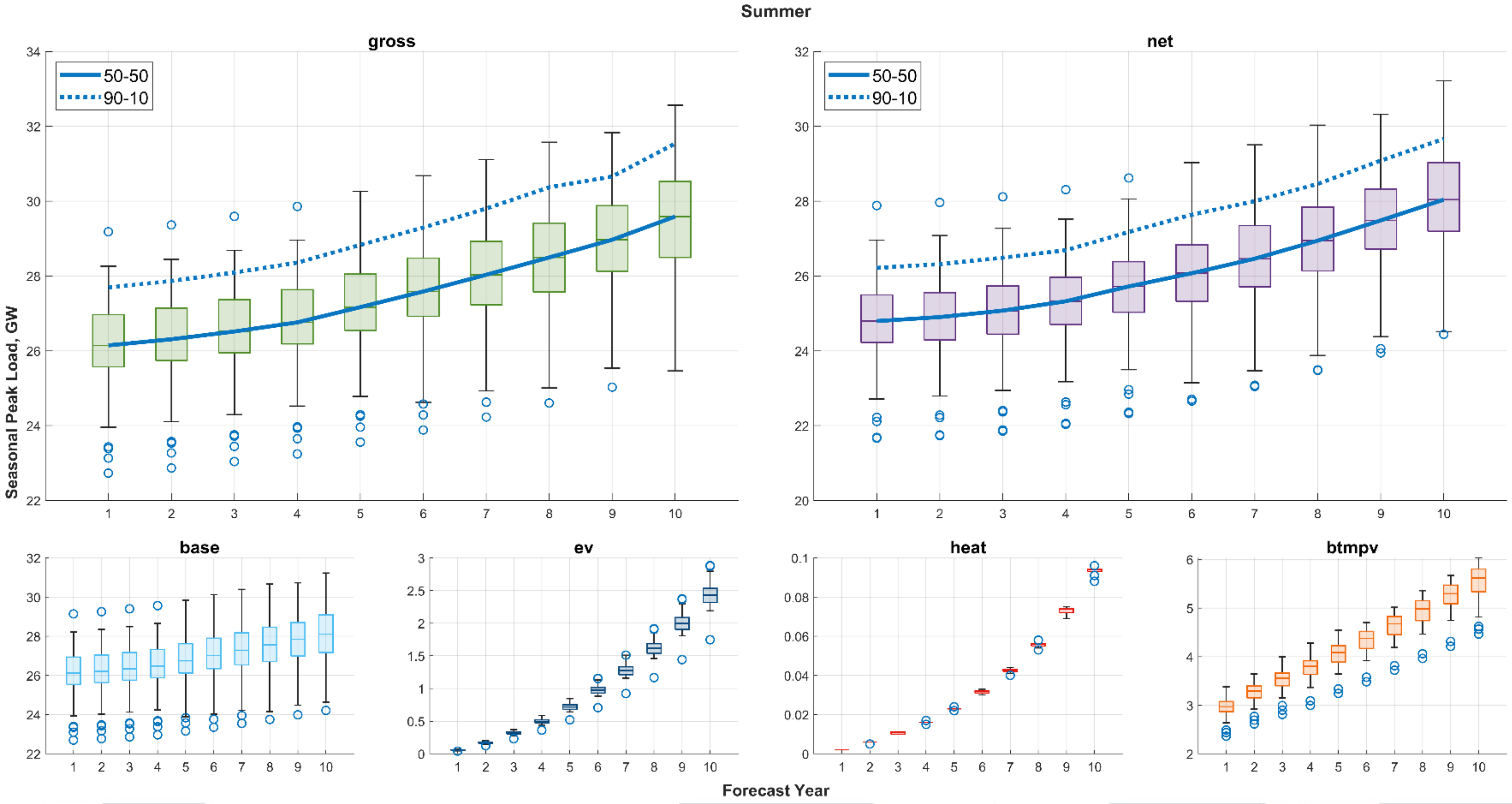


Seasonal Peak Distributions

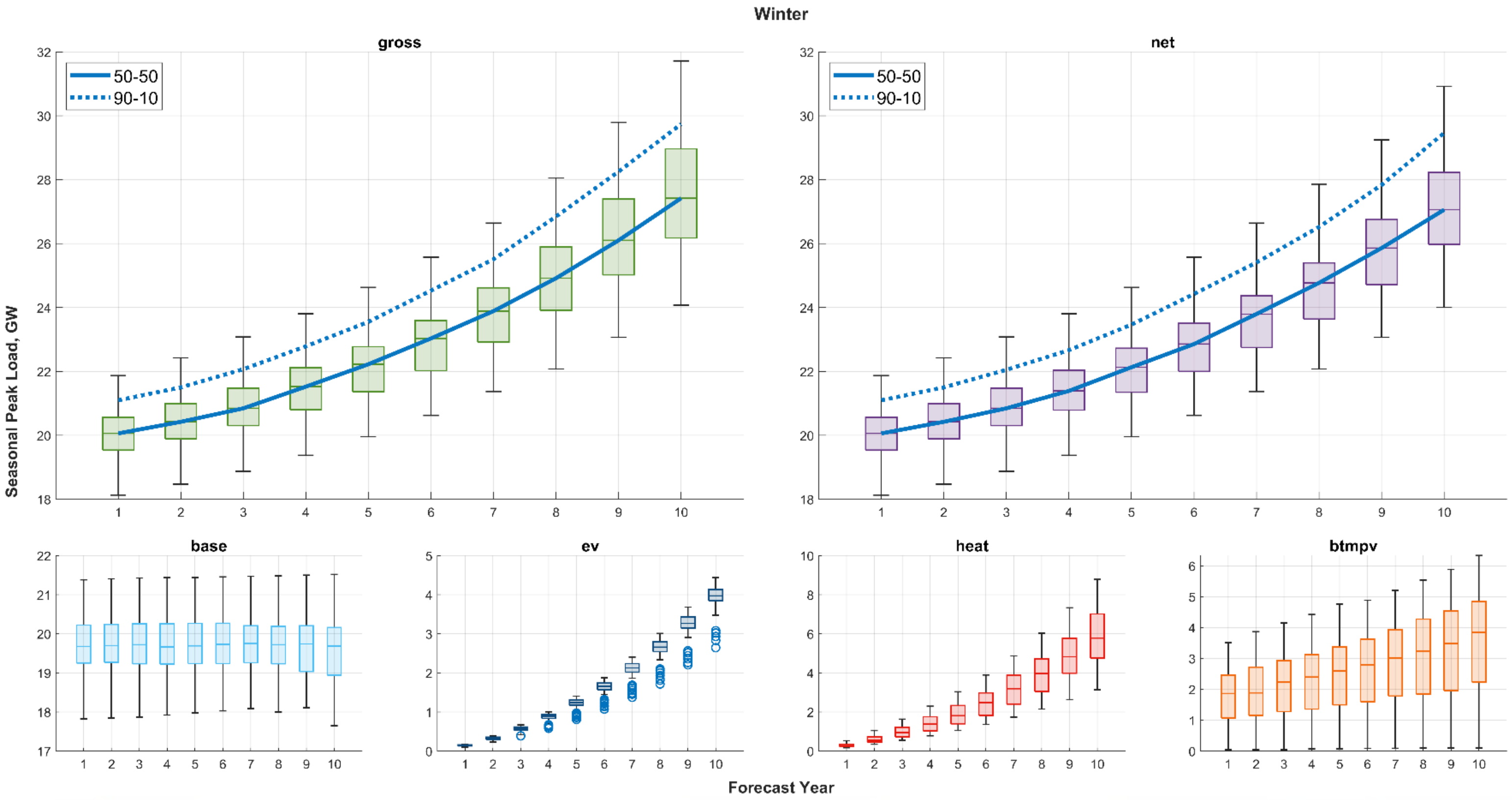
Distributions of Gross and Net Peaks and Load Components

- The resulting CELT 2024 seasonal peak distributions are shown on the following two slides, along with distributions of demand impacts associated with the 4 load components on seasonal peak days
- The values shown were derived as follows:
  - Gross - maximum winter/summer load for each simulation year
  - Net - maximum winter/summer load for each simulation year
  - Base - maximum hourly value on the <u>gross</u> peak day in each simulation year
  - EV - maximum hourly value on the <u>gross</u> peak day in each simulation year
  - Heat - maximum hourly value on <u>gross</u> peak day in each simulation year
  - BTMPV - maximum hourly value on the <u>net</u> peak day in each simulation year

Summer Seasonal Peak Distributions, ISONE



Winter Seasonal Peak Distributions, ISONE

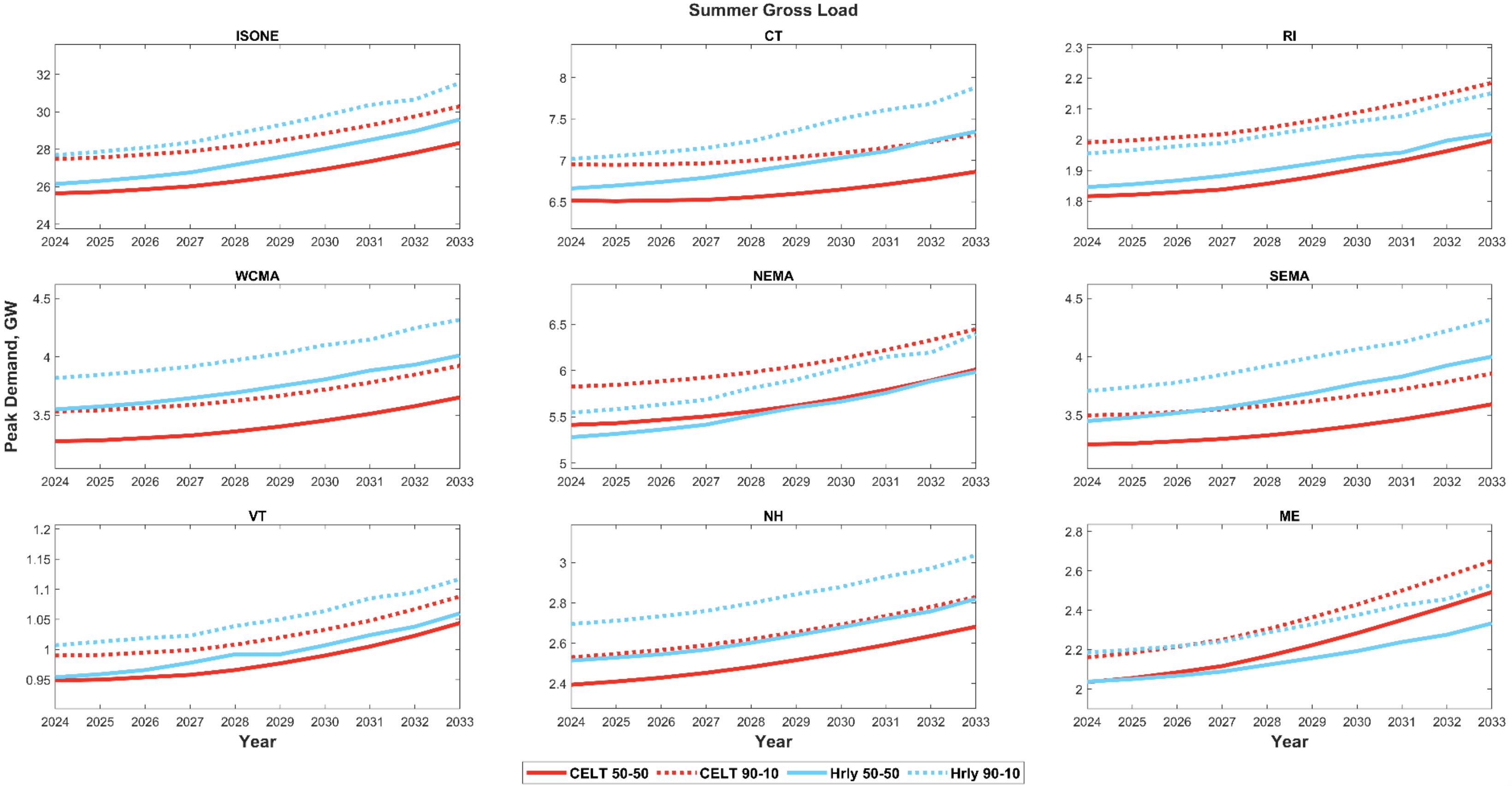


Benchmarking

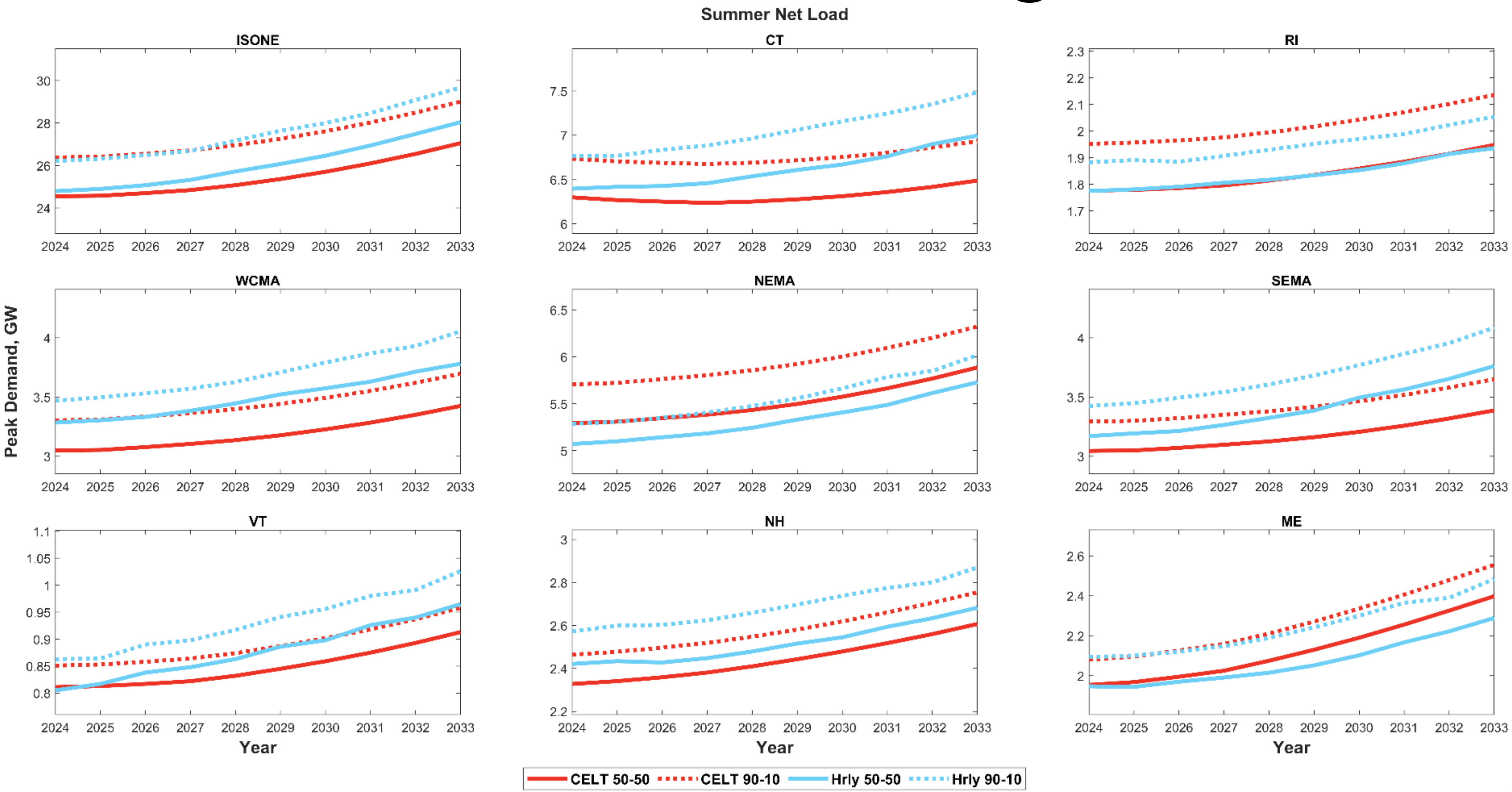
CELT 2024: Existing and New Methodology

- The following slides illustrate a comparison of gross and net seasonal peaks for the region and all 8 zones
  - Existing 50-50 and 90-10 forecasts are shown in red
  - Preliminary results from new hourly methodology are shown in blue

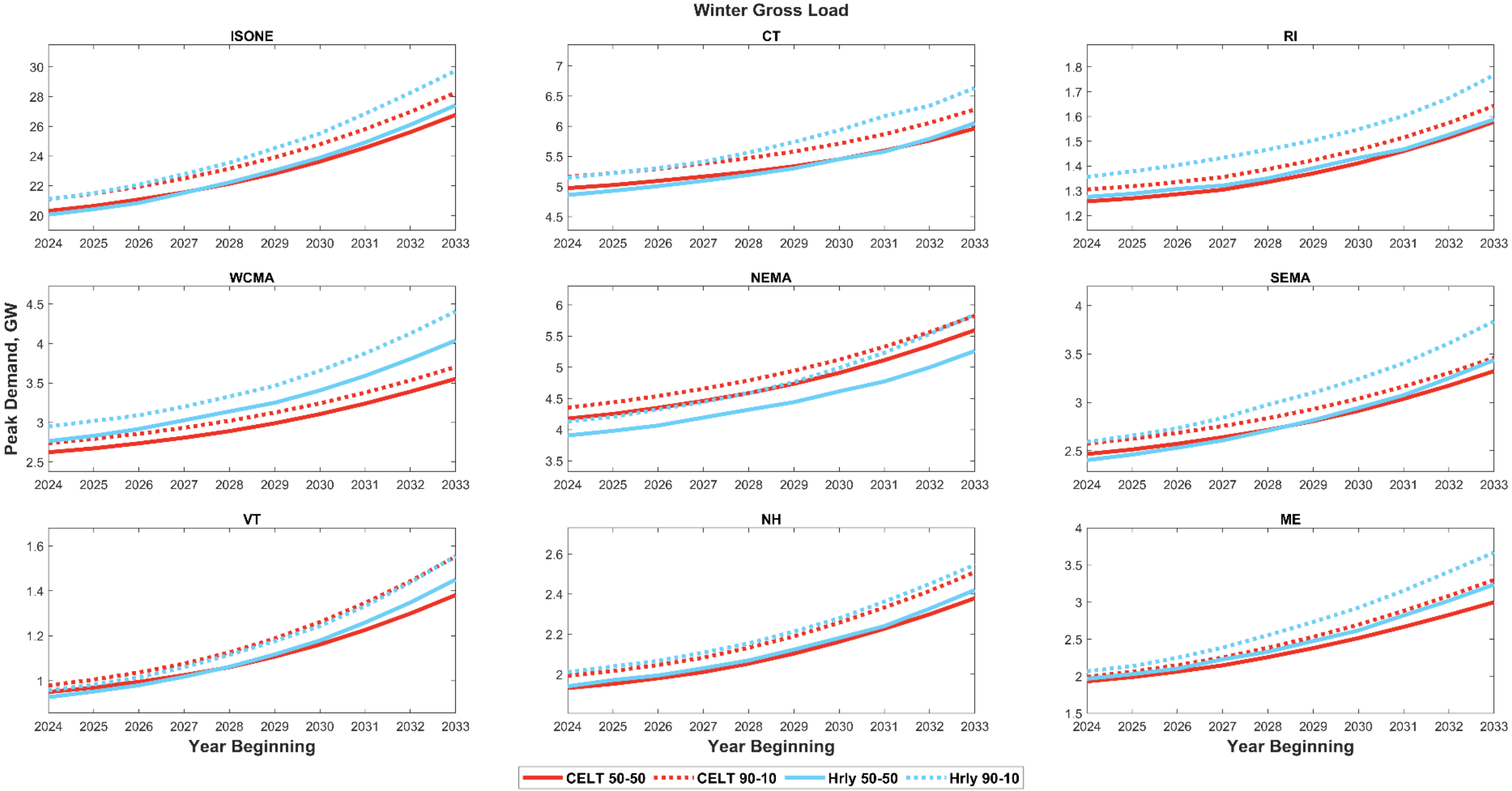
Summer Gross Peak Benchmarking



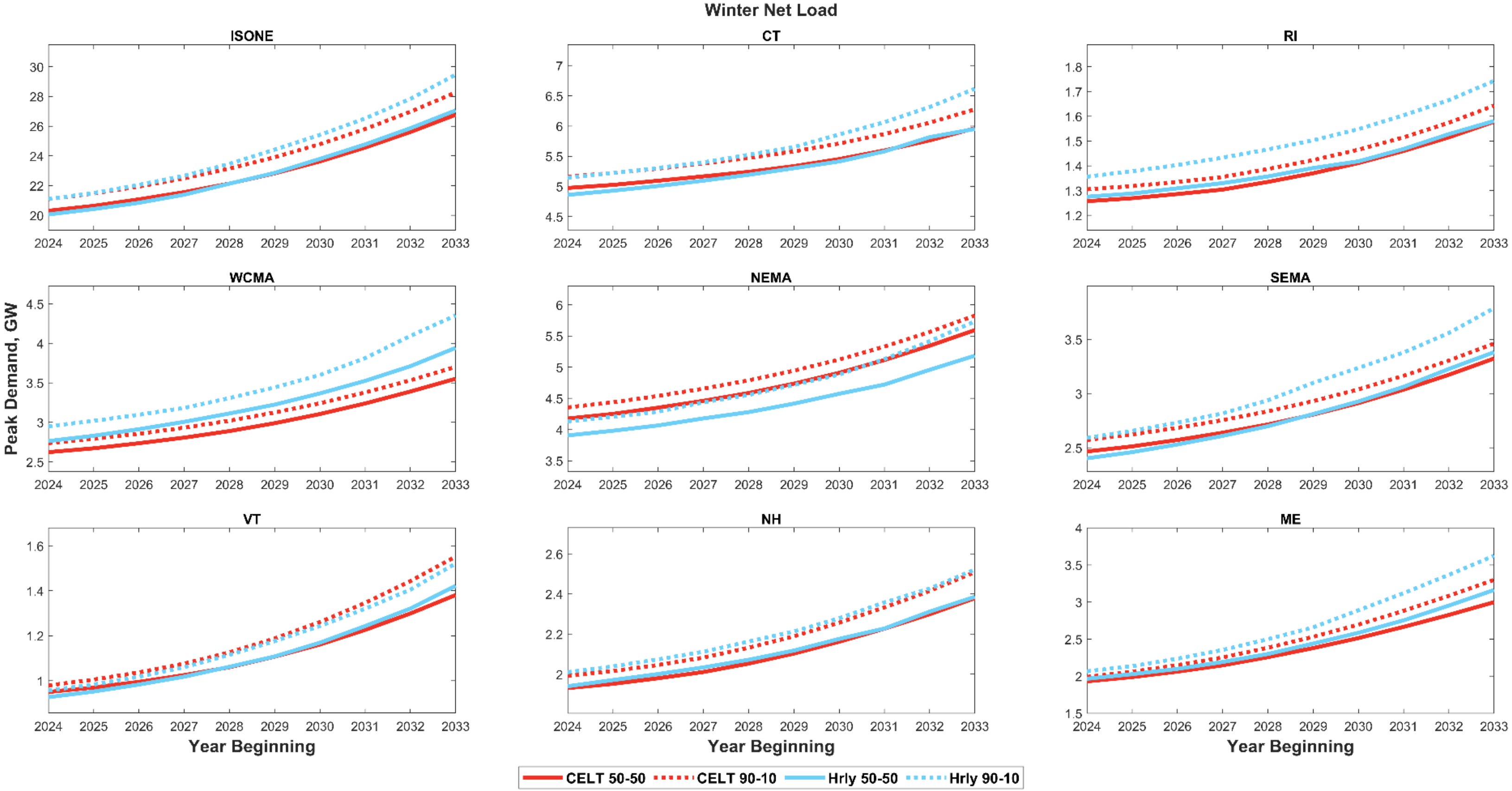
Summer Net Peak Benchmarking



Winter Gross Peak Benchmarking



Winter Net Peak Benchmarking



Observations

- Summer peak forecasts increase as part of the new methodology, with 50/50 peaks exhibiting more of an increase than 90/10 peaks
  - Climate data reflects hotter, more frequent summer peak weather
- The new methodology yields more summer demand growth
  - Attributable to both the use of climate data, and the increasing trend of XCool, which is associated with expectations of greater cooling demand over time
- Winter peak forecasts stay about the same in the near-term with the new methodology, but then end up higher than the existing methodology
  - Despite somewhat warmer climate data, increased winter peak forecasts are attributable to the new methodology's ability to capture the growing prevalence of morning peaks that are missed by the existing methodology

Next Steps

- ISO will continue refining and further validating its base load modeling
- Updates will be shared at the February 21, 2025 LFC meeting

Questions