June 1, 2023

Incorporating Climate Change in California's Energy Demand Forecast

Outline

1. **EPIC- and Gas R&D-funded climate change research**

   Providing open, quality-controlled climate and weather data for climate-informed planning

2. **2023 IEPR forecast priorities**

   Near-term opportunities to better capture climate in 2023 CED

3. **Longer-term recommendations**

   Moving forward with sustained collaboration among climate scientists, energy researchers, and state agency staff, supported by EPIC funding

Part 1

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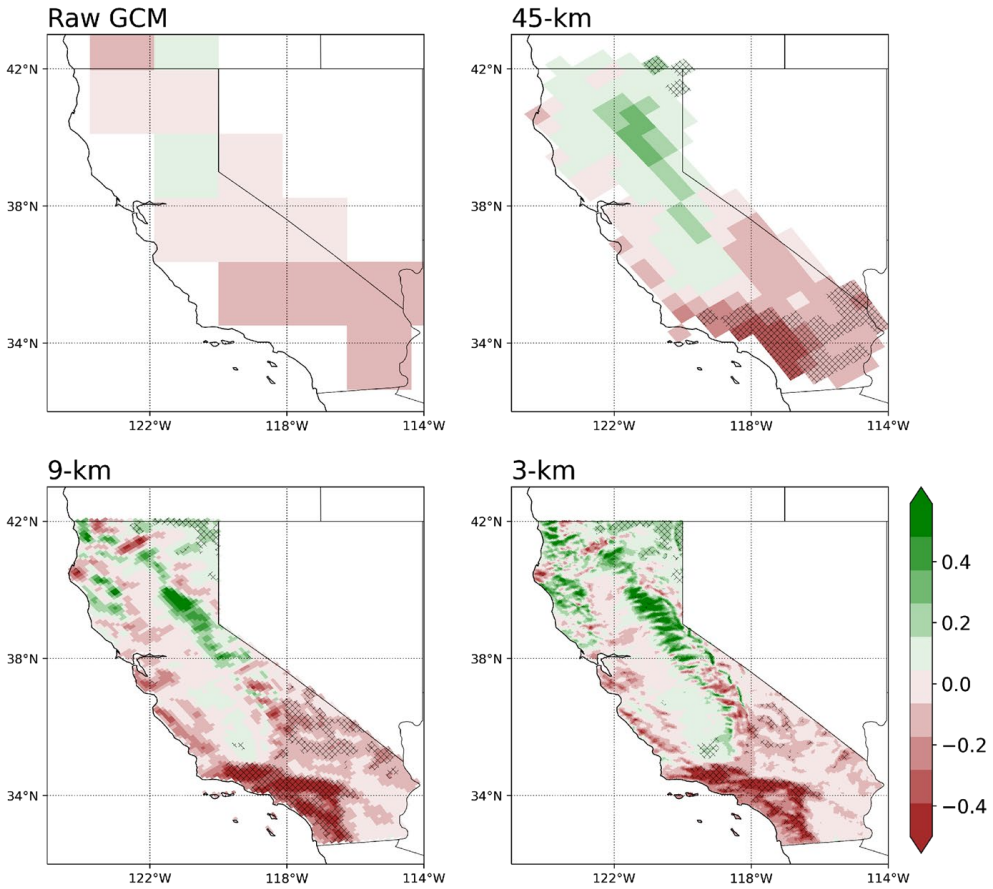
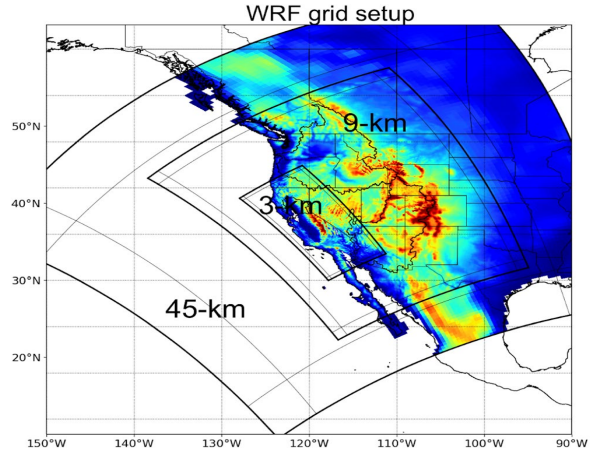
CEC's Climate Research Supports Energy Sector Adaptation and Planning

- CEC-funded climate scenarios & data: foundational to CA's Climate Change Assessments
- CPUC's Decision 19-10-054* on Phase 1 of Adaptation Rulemaking, issued Nov. 2019:
  - Anchors acceptable data to California's Climate Change Assessments
  - Directs IOUs to Cal-Adapt as a source of data and tools
  - Establishes criteria for acceptability of additional data or models.
  - Sets expectations of adequate granularity (p. 54): "*Climate data should provide the geographical and temporal resolution required for the research or planning at hand*."
- IOUs have used data on Cal-Adapt (https://cal-adapt.org/) for vulnerability assessments & to support adaptation efforts.**
- Publicly available data on Cal-Adapt: used by stakeholders beyond energy sector, recognized by legislation and guidance, used by government agencies.**

Advancing High-Resolution Climate Projections





Figures: (*left*) Raw Global Climate Model outputs are downscaled to provide 3 km spatial resolution over CA. (*above*) Limited model runs are available for much larger domains that include the vast majority of WECC. ***Source***: UCLA, EPC-20-006

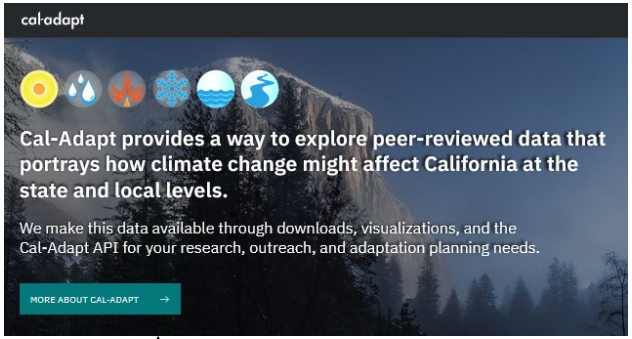
Data Products to Support Climate-Informed Planning

EPIC & PIER-funded data portray evolution of weather-related variability, extremes, uncertainty.

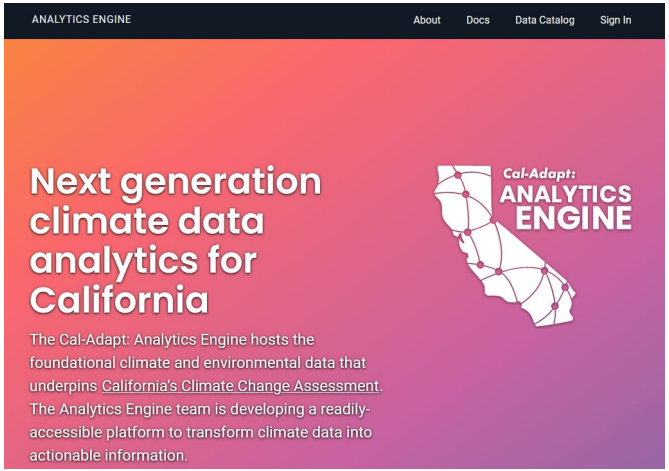
Downscaled climate data and analytics support:

- ✓ **Anticipating novel extremes** without analogues in the historical record (duration, magnitude, frequency, timing/seasonality, spatial extent)
- ✓ **Uncertainty analyses** that account for multiple possible futures
- ✓ **Stochastic** and **scenario-driven analyses**
- ✓ Analyses of **correlated extremes**
- ✓ **Median conditions** as well as **1-in-x extremes**
- ✓ Both **long-term** (e.g., drought) and **short-term** (e.g., heat waves, cold snaps) extremes

Data Products Available through an Expanding Cal-Adapt Enterprise



Analytics engine
- ~ 2.5 Pb data



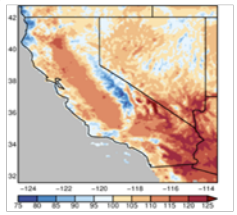
Interactive web application
- ~ 10 Tb data

Observation platform
(QC'd historical data)

Figure: An expanding Cal-Adapt enterprise is working to seamlessly integrate web tools, climate projections, continuously updated historical observed data, and analytics transform rich data resources into modeling inputs and other forms of energy resilience support.

Ongoing Research at the Nexus of Climate Science and Energy System Planning

Climate Projections, Scenarios, & Analytics



Development of Climate Projections

Cal-Adapt Analytics Engine

Research to Support a Climate Resilient Transition

Climate-Informed Zero-Carbon Generation Capacity Modeling (Eagle Rock Analytics)

Climate-Informed Load Forecasting & Electric Grid Modeling (E3)

Advancing California's Electricity Resource Planning Tools to Assess & Improve Climate Resilience (Lumen)

Key elements of ongoing state-funded research to support climate-informed planning

Past and projected climate

- Develop high-resolution (3 km × 3 km) climate projections and hydrologic scenarios (Q1-Q3 2023)
- Reconstruct historical climate at high resolution (hourly, 2 km × 2 km)
- Characterize climate trends of interest, compound events
- Quality-controlled, open-access historical station data to support demand forecast (Q1 2023)
- WECC-wide, near-real time, quality-controlled open historical station data (Q4 2023)

Wildfire https://pyregence.org/

- Future climate fire risk scenarios (Q2/Q3 2024)
- Open and free, real-time fire risk and spread modeling
- Wildfire science advancements: extreme weather, fuel mapping, fire behavior

Key elements of ongoing state-funded research to support climate-informed planning, *continued*

Cal-Adapt Analytics Engine http://analytics.cal-adapt.org/

- Analytics to support use of projected HDDs and CDDs in demand forecasting (Q1 2023)
- Provision of projected 8760 weather profiles as a basis for “weather-normal” and 1-in-x (Q1 2023)
- Help transform large data into inputs & insights, working with energy stakeholders

Key elements of ongoing state-funded research to support climate-informed planning, *continued 2*

Climate-Informed Generation Capacity Modeling (Eagle Rock Analytics)

- Leverage high-resolution (3 km × 3 km), hourly WECC-wide climate projections to deliver 8760 profiles of generation capacity for solar and wind (Q3 2023)
- Leverage hydrological projections to inform projected generation capacity
- Evaluate changes in zero-carbon generation resources individually
- Assess correlations between zero-carbon generation resource availability (e.g., during extremes)
- Work with energy stakeholders and EPIC-funded research to deliver data products that support further modeling and research

Key elements of ongoing state-funded research to support climate-informed planning, *continued 3*

Climate-Informed Load Forecasting & Electric Grid Modeling (E3)

- Parameterize climate impacts for model inputs (future weather years, load, generation, ELCC, capacity expansion and reliability)
- Update the California PATHWAYS, Renewable Energy Solutions (RESOLVE), and Renewable Energy Capacity Planning (RECAP) models to facilitate modeling of climate scenarios and capture WECC-wide impacts
- Use current modeling framework (deterministic) with parameterized climate impacts to understand climate impacts on SB 100 resource portfolios and reliability
- Assess performance of electricity system resource portfolios under extreme, compound & cascading climate scenarios (2025)

Key elements of ongoing state-funded research to support climate-informed planning, *continued 4*

Climate-Informed Load Forecasting & Electric Grid Modeling (E3), *continued*

- Develop novel (stochastic) modeling functionality for the electric sector capacity and resource adequacy models (RESOLVE & RECAP) to incorporate and optimize for uncertainty around climate-related trends and extremes, variability, technology costs and learning rates (Q1 2024)
- The stochastic analyses will explore several approaches to balance uncertainty risk and costs of resource portfolios that can be used to inform grid expansion best practices and reliability planning targets

Key elements of ongoing state-funded research to support climate-informed planning, *continued 5*

Advancing California's Electricity Resource Planning Tools to Assess and Improve Climate Resilience (Lumen Energy Strategy)

- Provide climate-informed inputs for consideration by demand forecasting (e.g., weather normal and 1-in-x weather variants) (Q2-Q4 2023)
- Explore use of additional weather variables to capture climate-sensitivity of demand
- Explore possible refinements of explanatory models used in the demand forecast to better capture load patterns and peaks
- Establish conceptual framework for resilience in the context of grid planning, in collaboration with CPUC, California ISO, and energy utility staff
- Build a probabilistic loss-of-load model, synergized with existing planning models, to evaluate resource portfolio scenarios with respect to grid resilience framework established earlier
- Contribute to long-term resource planning

Climate Data and Analysis Working Group (C-DAWG)

The Climate Data and Analysis Working Group (C-DAWG) is a forum for technical discussion regarding issues at the nexus of climate change and California's energy system. It informs planning and execution of applied research that supports development of climate projections, wildfire and hydrologic scenarios, quality-controlled historical weather data, and analyses that contribute to a resilient transition to a 100% clean energy system.

Goal

C-DAWG's goal is to promote sustained technical exchange and collaboration between climate science researchers, energy system researchers and technical experts, technology innovators, and state agency staff to facilitate high-impact research and knowledge transfer that directly supports energy sector resilience as California transitions to a 100% clean energy system.

Expand All

Ongoing CEC-funded Climate Research +

Past CEC-funded Climate Research (since 2018) +

CONTACT

Climate Data and Analysis working Group

916-776-0824

RELATED LINKS

Meetings and Documents

Demand Analysis Working Group (DAWG)

California's Fourth Climate Change Assessment

Cal-Adapt

SUBSCRIBE

Climate Data and Analysis Working Group (C-DAWG)

Email *

Email

Part 2

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Innovation: Localization of downscaled projections

- Cal-Adapt Analytics Engine provides analytical capacity to "localize" gridded projections to nearby meteorological stations in California and in the broader WECC domain
- Localized data readily integrate with existing frameworks (i.e., use of historical station data)
- Importantly, this provides for continually updating of both the historical record of weather variants and approaches to ensuring that projected weather variants are localized/calibrated to evolving variability observed in the climate system

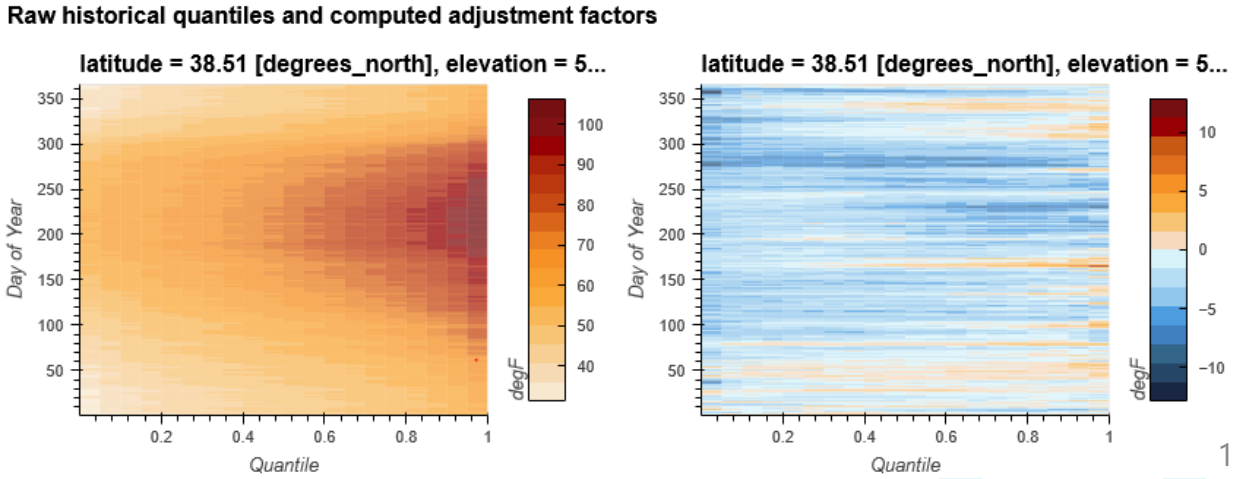

Figure: (*left*) Historical observed data, by quantile and day of year. (*right*) Adjustment factors for calibrating model output to historical variability.
Source: Eagle Rock Analytics, EPC-20-007

Innovation: Develop detrended library of weather variants that reflect changing climate

- Leverages climate models to improve demand normalization process and support projections of future electric demand
- Adjusts for long-term climate trends, centering each weather variant on the year in question
- Yields a suite of climate-informed weather variants to estimate normal and 1 in-x demand

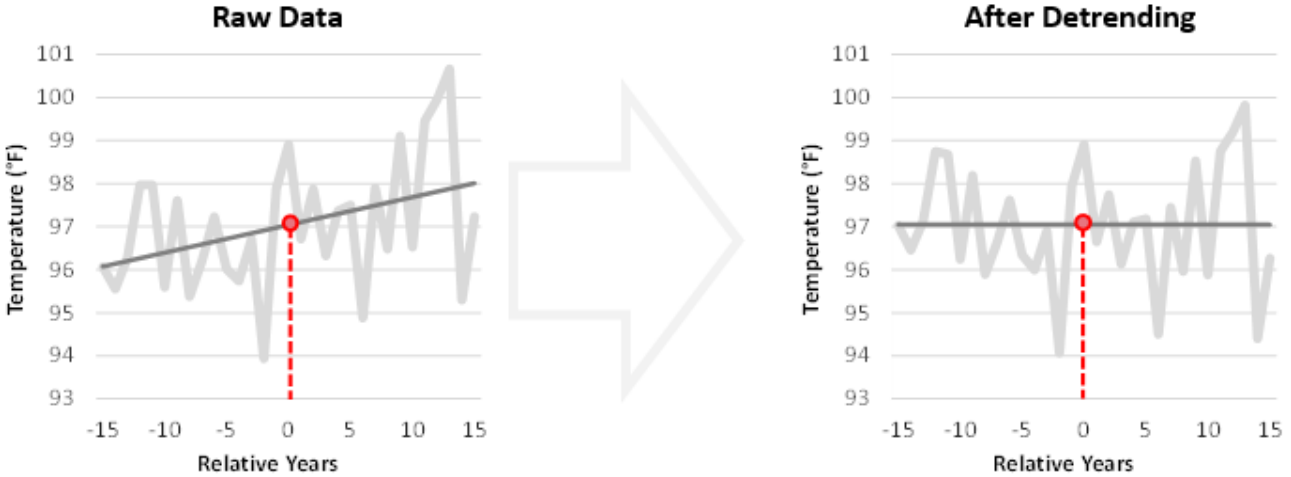

Figure: Example to illustrate detrending of temperatures. ***Source***: Lumen Energy Strategy, EPC-22-001

Proposed change #1: Integrate projected climate into CDDs, HDDs

Recommendation: Use localized, detrended weather variants to portray changes in cooling and heating degree days, drawing on data from Cal-Adapt Analytics Engine.

Key attributes:

- Brings next-generation climate projections into CED in a manner that is anchored to continually updated historical data.
- Localizes climate model output to respective weather stations based on transparent, quality-controlled historical observations.

Proposed change #2: Use new detrended library of weather variants for peak weather normalization, 1-in-x

Recommendation: Use localized, detrended weather variants as inputs to the peak normalization model, which serves as the anchor point for the weather-normal peak demand forecast and 1-in-x variations.

Key Attributes:

- Leverages a suite of climate models, increasing the ensemble on which statistics are drawn.
- Supports planning for emerging, novel weather patterns that are anticipated by the best available climate science but may not have analogues in the historical record.
- Rather than assuming a static ratio between the 1-in-2 and 1-in-x peaks for all forecast years based on the base year's ratio, allows this ratio to change over the forecast period.

Proposed change #3: Apply a detrended library of 8760 weather variants for hourly weather normalization, 1-in-x

Recommendation: Use localized, detrended weather variants as inputs for the Hourly Load Model in a manner that preserves realistic inter- and intra-daily autocorrelations.

Key Attributes:

- Redefines "normal" as an 8760 *chronological* load ratio shape consistent with a plausible weather outcome—rather than as a normal level of demand within an hour and season.
- Enables analysis of average & extreme conditions that reflect the range of potential outcomes now and in the future.
- By preserving temporal coherence, provides a foundation for more realistic exploration of supply and demand volatilities, including at peak periods
- Again, supports planning for emerging, novel weather patterns that are anticipated by the best available climate science but may not have analogues in the historical record.

Explore use of additional weather variables and metrics to capture climate-sensitivity of demand

Explore weather variables and data that may improve explanatory power of models associated with CED, including:

- Changes to CDD/HDD metrics (e.g., incorporate hourly data, variables beyond temperature)
- Weather variables that may be linked more closely to consumer behavior (e.g., heat index or web bulb temperature instead of Max631 dry bulb temperature, solar irradiance as an alternative/counterpart to cloud cover for characterization of PV)
- Changes to the selection of weather stations used for historical analyses, consideration of aggregation across weather stations and/or use of gridded weather/climate data to capture regions and trends of relevance
- Further evaluation of weather patterns within and across days that are associated with periods of grid stress

Part 3

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EPIC collaborations to improve demand forecasting in future cycles

Opportunities:

- Leverage AMI data to illuminate composition of demand and impacts of load modifiers[1]
- Explore possible refinements of explanatory models to better capture load patterns and peaks[1]
- Improve portrayal of climate change impacts on sectoral models (residential/commercial,[2] agriculture, industrial)
- Continue improving individual load modifier profiles (under normal and extreme conditions) and improve representation of dynamic interactions across load modifiers

1. Proposed AMI data analysis and potential refinements to HLM under consideration through EPC-22-001 with Lumen Energy Strategy, LLC.
2. Ongoing work with E3 (EPC-21-041) will develop quantitative relationships between temperature and load, informed by expectations of increased AC penetration, increased plug loads (e.g., fans), changing weather patterns, evolution and roll-over of technology, and demographic trends.

EPIC collaborations to improve demand forecasting in future cycles

Opportunities:

- Parameterizations of climate impacts on demand for use in load forecasting and analysis of load shapes, capacity expansion modeling, and reliability assessments[3]
  - Physically consistent data (e.g., enable analysis of correlations between variables)[4]
  - Data that can support stochastic analyses, stress tests

3. Through EPC-21-041, E3 expects to deliver quantitative relationships between temperature and load in the fourth quarter of 2023.
4. Through ongoing EPIC work, Eagle Rock Analytics, Inc. (EPC-21-037) will leverage physically consistent, high-resolution climate models to explore projected changes in spatial and temporal distribution of hourly solar and wind resources, as well as hydroelectric resources.

Why CEC is advancing climate-informed forecasting based on downscaled data products

Key data attributes

- ✓ Based on the latest climate science projections and methods
- ✓ Represents a **range of future climate outcomes** and **warming levels**
- ✓ Spatial and temporal granularities that can inform demand forecasting at the sub-planning area (down to 3 km) and hourly level, as well as renewable generation
- ✓ **Based on open process**, publicly available
- ✓ Used as basis for extensive research and planning

Downscaled climate data and analytics support:

- ✓ **Localized projections** for integration with approaches that currently rely on historical data
- ✓ **Anticipating novel extremes** without analogues in the historical record (duration, magnitude, frequency, timing/seasonality, spatial extent)
- ✓ **Uncertainty analyses** that account for multiple possible futures
- ✓ **Stochastic** and **scenario-driven analyses**
- ✓ Analyses of **correlated extremes**

Thank you!

Material from Michael Mastrandrea, Susan Wilhelm, and Mithra Moezzi (2023) *Recommended Improvements to Incorporating Climate Change in California's Energy Demand Forecast (draft).* With support from CEC Agreement 800-20-005, Work Authorization 1981.005-003.

With thanks to EPIC Recipients Lumen Energy Strategy, LLC and Eagle Rock Analytics, Inc. for contributions and Energy Assessments Division colleagues for ongoing collaboration.