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Description:	5B. Nick Fugate, CEC
Filer:	Raquel Kravitz
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Climate Change Impacts on the Hourly Demand Forecast

Nick Fugate, Energy Assessments

Overview

1. Review current use of climate analysis/data within the CEC's peak and hourly forecasts
2. Identify potential uses for climate tools beyond current practice
3. Provide an update on staff efforts to re-estimate the hourly consumption profile
4. Identify challenges – seeking stakeholder discussion/feedback

Constructing the Hourly Forecast

1. Apply a base "consumption" profile to the annual "consumption" forecast
2. Adjust hourly consumption using profiles for:
   - Hourly climate impacts
   - Electric vehicle charging
   - Behind-the-meter PV generation and storage
   - "Additional Achievable" efficiency and electrification
3. Calibrate to a weather-normal peak estimate

Weather-Normal Peak

Method

Objective: Estimate what base-year peak load would have been given weather that is characteristic of “normal” peak load conditions

1. Create a counterfactual hourly system load history
   - Begin with observed CAISO loads
   - Remove demand response impacts
   - Remove LESR/HYBD charge load
2. Create models to predict system load (using historical data)
   - Models are specific to TAC and hour of the day
3. Simulate daily peaks over a distribution of weather patterns (using climate-informed data products)
4. Take the maximum simulated value for each year and examine the distribution

Process Flow (Prior to CED 2023)

Historical Load
- Hourly System Load
- Demand Response Impact Estimates

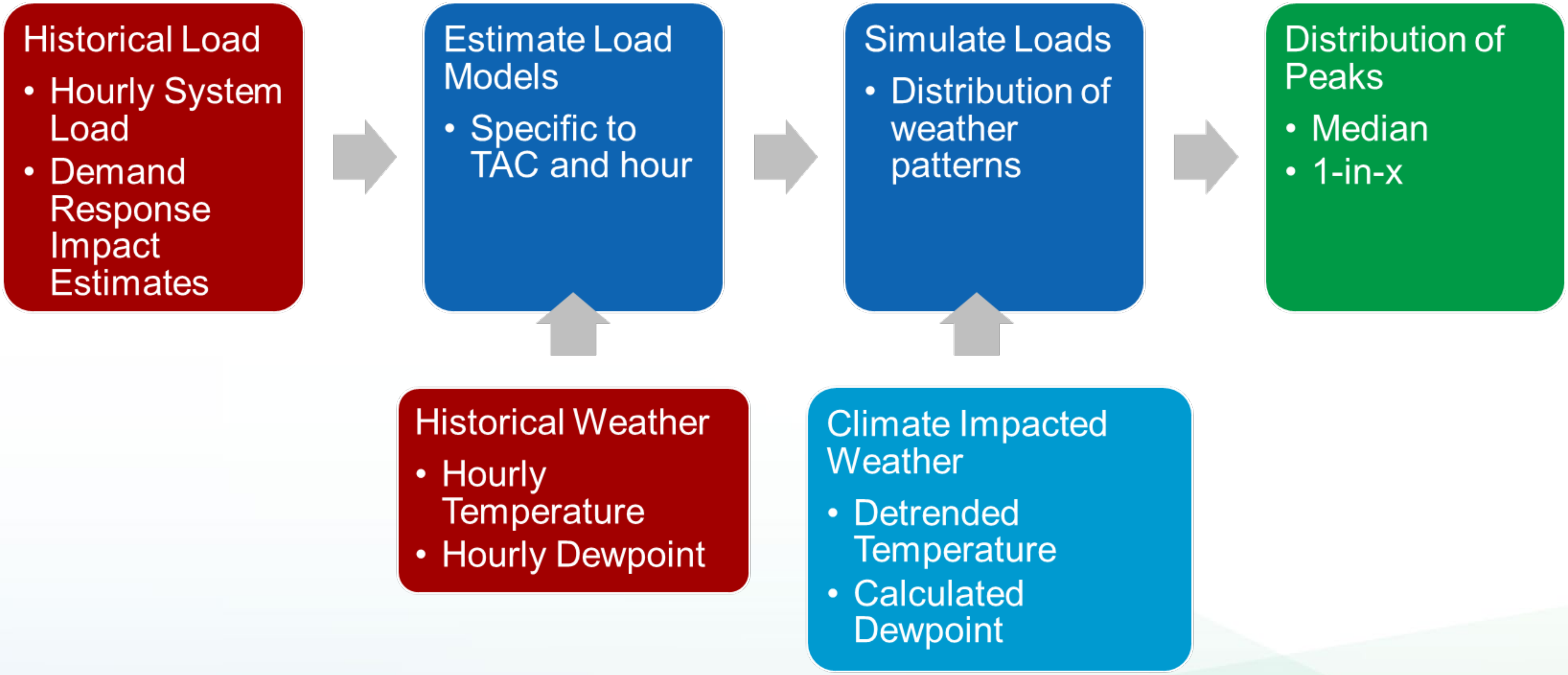
Estimate Load Models
- Specific to TAC and hour

Historical Weather
- Hourly Temperature
- Hourly Dewpoint

Simulate Loads
- Distribution of weather patterns

Distribution of Peaks
- Median
- 1-in-x

Process Flow (Current)

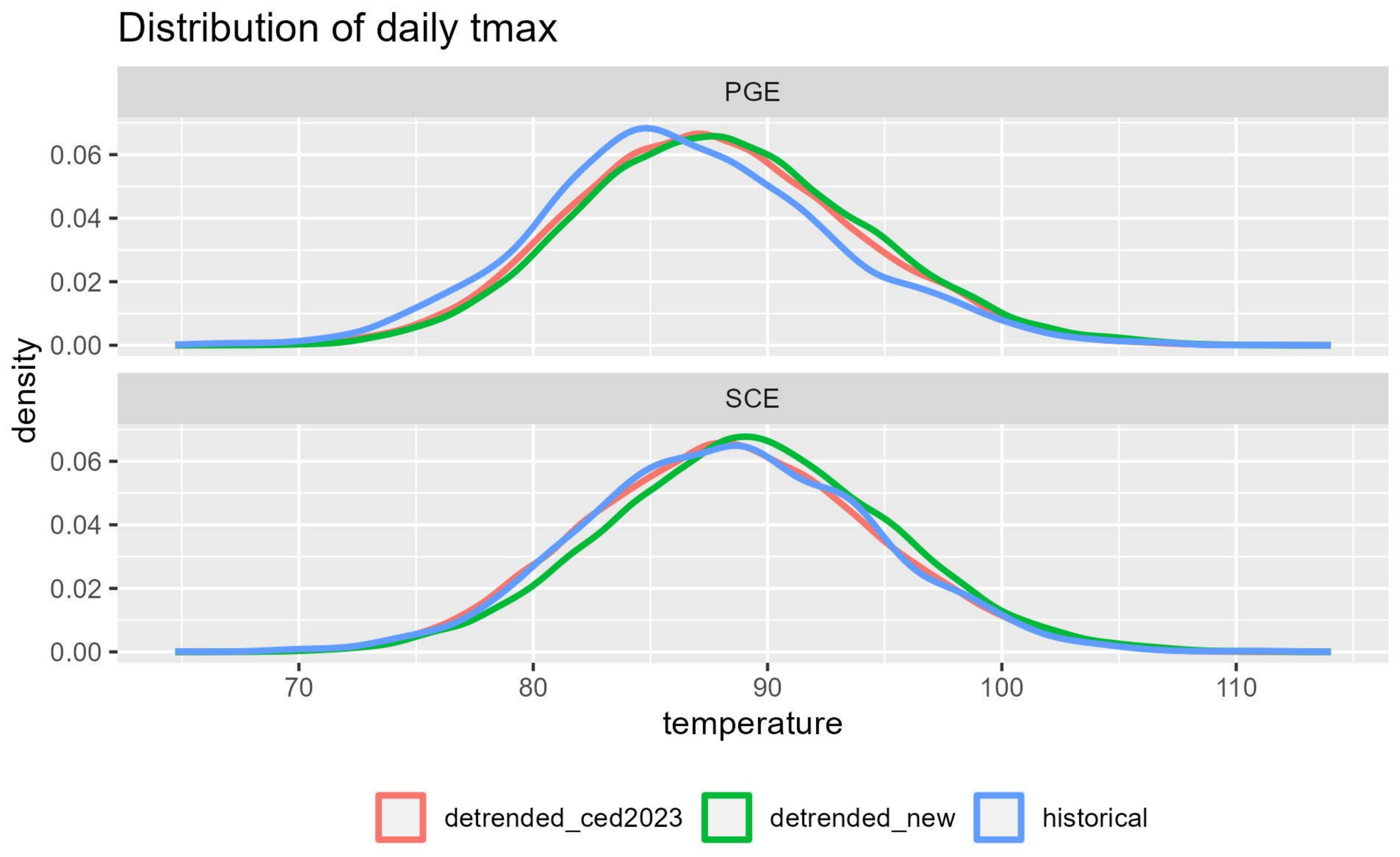


Updates

- Staff are not currently considering methodological changes to the peak normalization process
- For CED 2024 – consider the use of newly available WRF data sets
  - Temperatures further processed into detrended libraries
- Specific considerations include:
  - Continued use of calculated dewpoint library
  - New data sets are generally warmer, with implications for base-year peak estimate
- Staff will conduct and compare analyses with both data sets

Distribution of Daily Max Temp

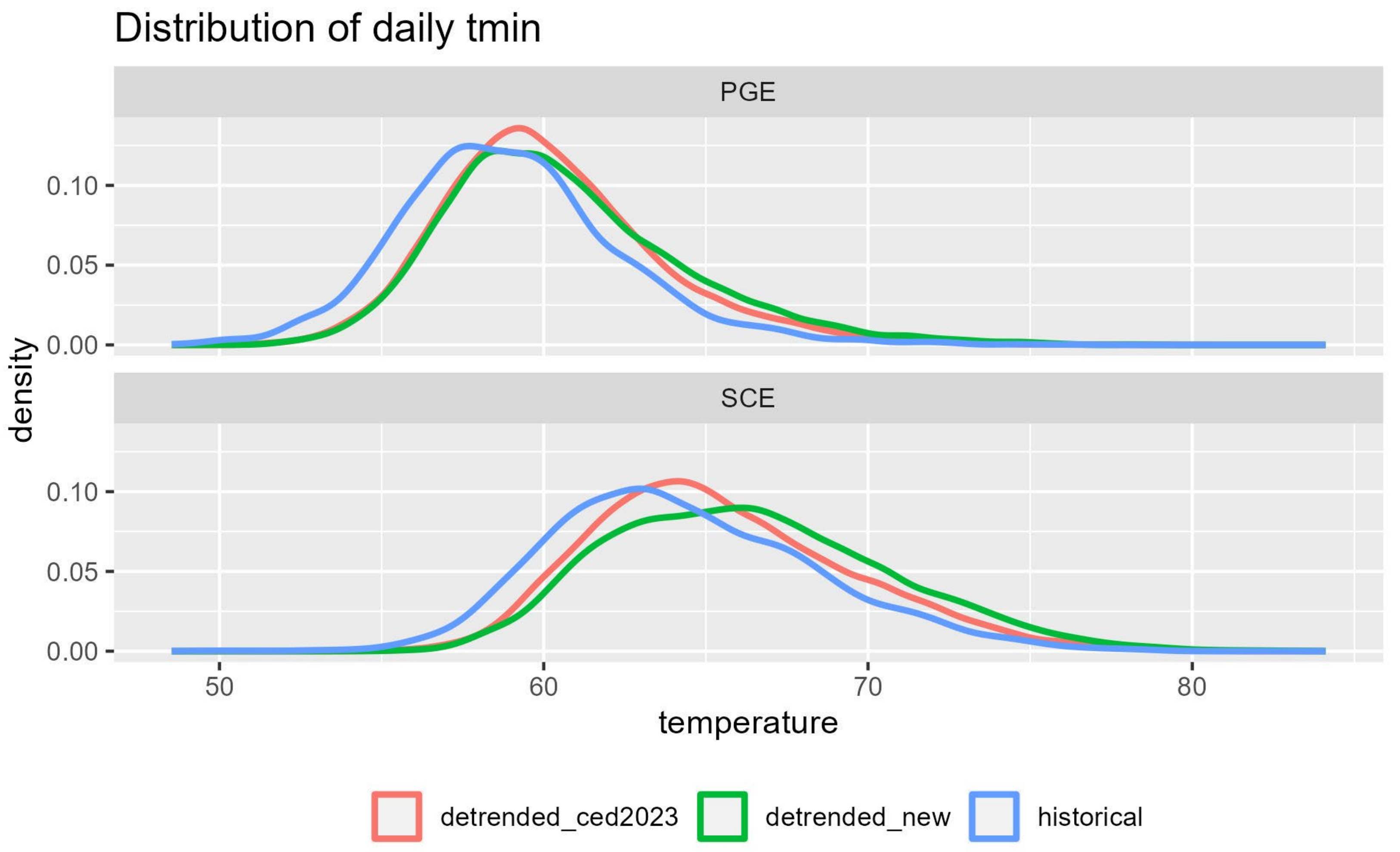
- Shows distribution of summer daily maximum temperatures
- Compares latest 30-year historical record to detrended temperature series (centered on 2023)
- New temperature libraries are generally warmer



Source: CEC Staff

Distribution of Daily Min Temp

- Shows distribution of summer daily minimum temperature
- New detrended temperature library shows larger increases in daily minimum temperatures relative to CED 2023
- Minimum temperatures begin to exceed historical range



Source: CEC Staff

Hourly Climate Impacts

Method

Objective: Construct a profile representing expected incremental load changes resulting from average hourly temperature increases over time

1. Construct a counterfactual hourly consumption history
    - Add BTM PV generation to counterfactual system load
2. Estimate hourly load elasticities to temperature
3. Calculate average % change in hourly temperature
4. Calculate average % change in hourly consumption

Process Flow (Current)

Historical Data

- Hourly system load
- Demand response impact estimates
- Hourly temperature

Estimate Load Elasticity to Temperature

- Specific to TAC, month, hour of day
- Separate estimates for weekdays and weekends

% Change in Consumption

- Apply to consumption profile to create climate change profile

Climate Change Profile

- Incremental impacts relative to base hourly consumption profile

Climate Impacted Weather

- Detrended hourly temperature

% Change in Temperature

- Specific to TAC, month, hour of day
- Apply load elasticities to estimate % change in consumption

Consumption Profile

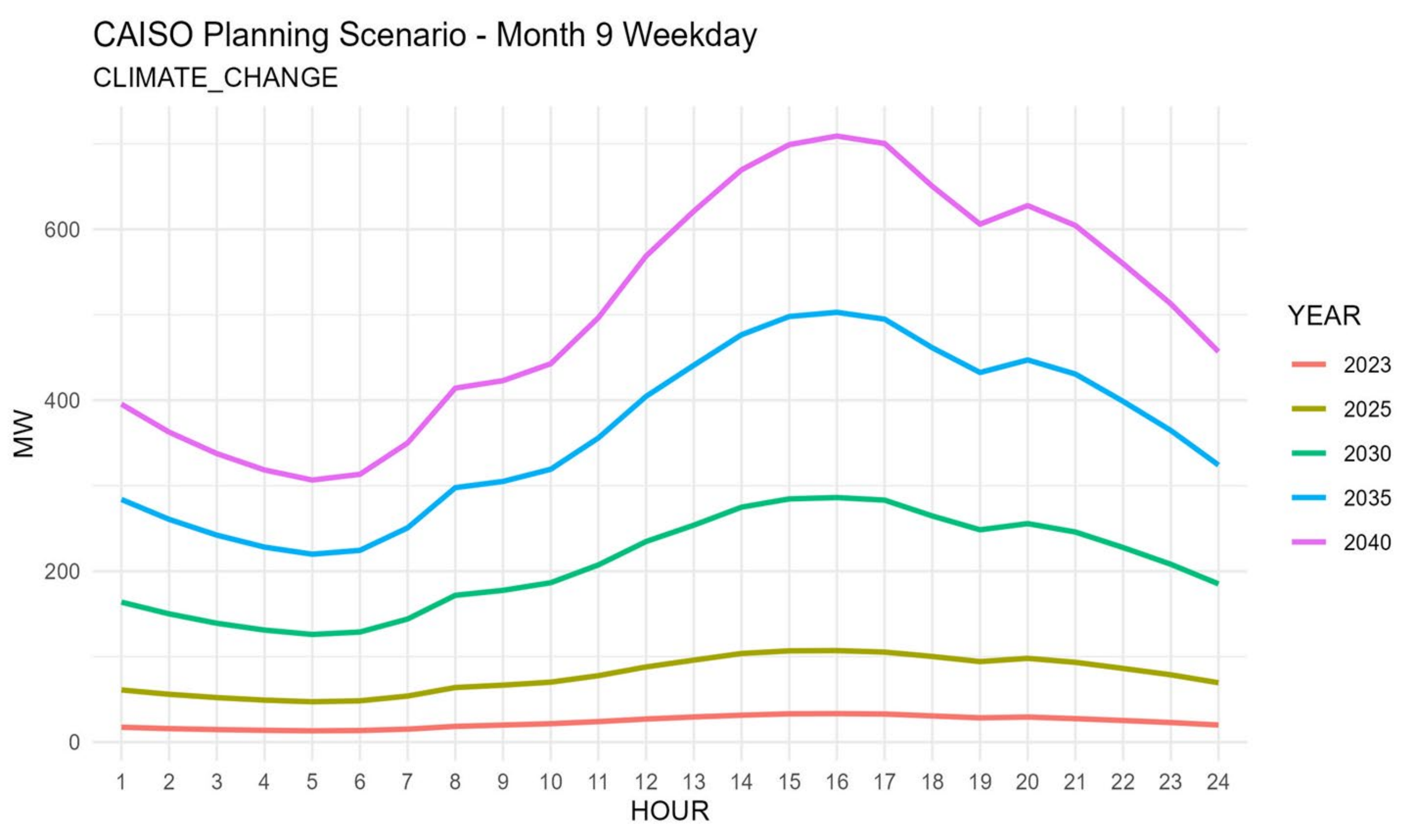
- Developed in a separate process with the same load data and historical weather

Annual Energy Impacts

- Estimated with annual models
- Used to scale hourly profile
- Specific to heating and cooling

Hourly Climate Change Profile

- Current process creates one relatively static profile
- Increasing magnitude reflects growing consumption and increasing average temperatures
- Average changes do not reflect varying rate of change across different temperature quantiles



Source: CEC Staff

Updates

- Staff are not currently considering methodological changes to this process
- For CED 2024 – consider the use of newly available WRF data sets

Future Considerations:

- Staff are considering a more direct use of climate data to develop hourly consumption profiles
- Embedding climate-impacted weather into the base consumption profile would eliminate the need for an incremental modifier
- Conceptually, this approach would better support the development of profiles to support stochastic reliability modeling

Consumption Profile

Method

<u>Objective</u>: Construct a base hourly consumption profile reflecting reasonable expectations around weather

1. Construct a counterfactual hourly consumption history
2. Build regression models for each territory and hour of day
    - Models predict consumption ratios as a function of weather and calendar variables
3. Ratios are simulated using varying weather/calendar patterns
4. Ratios are rank-ordered and medians selected by rank
5. Median ratios are assigned to the forecast calendar according to rank

Calendar Assignment

- Initially, calendar ranks were established with a single “average” historical load pattern
  - “Average” historical years will have extreme events/months
  - Historical years look “average” in one territory but not another
- More recently, ranks were constructed by averaging many historical load patterns across “day-type” (first Tuesday in May, for example)
  1. Average historical load ratios by day-type and hour, then rank days in each month
  2. Average historical days in a month by rank of peak hour
  3. Assign levels from (2) to day-ranks from (1)

Need for an Updated Profile

- By CED 2019, the addition of substantial levels of BTM PV complicated the process of reconstituting historical consumption
  - Counterfactual loads would "spike" when actual generation was misaligned with the assumed generation profile
  - Evolving load patterns complicated the "averaging" process used for calendar assignment
- CED 2020 through CED 2022 left the base consumption profile unadjusted
  - Timing of daily peaks misaligned with historical observations
  - Daily ramps exceeded recent historical levels

Model Re-estimation (CED 2023)

- For CED 2023, staff re-estimated the base consumption profile
  - Recently procured metered PV generation data used to reconstitute consumption
  - Calendarization step averaged across simulated load patterns rather than historical patterns
  - Revised profiles showed some improvement regarding peak timing and daily ramps
  - Raised other concerns around coincidence and timing of annual peak

Process Flow (Current)

Historical Load
- Hourly System Load
- Demand Response Impact Estimates

Estimate Hourly Load Models
- Predicts consumption load ratio
- Specific to TAC and hour

Distribution of 8760 Load Patterns
- Simulated using a variety of weather patterns

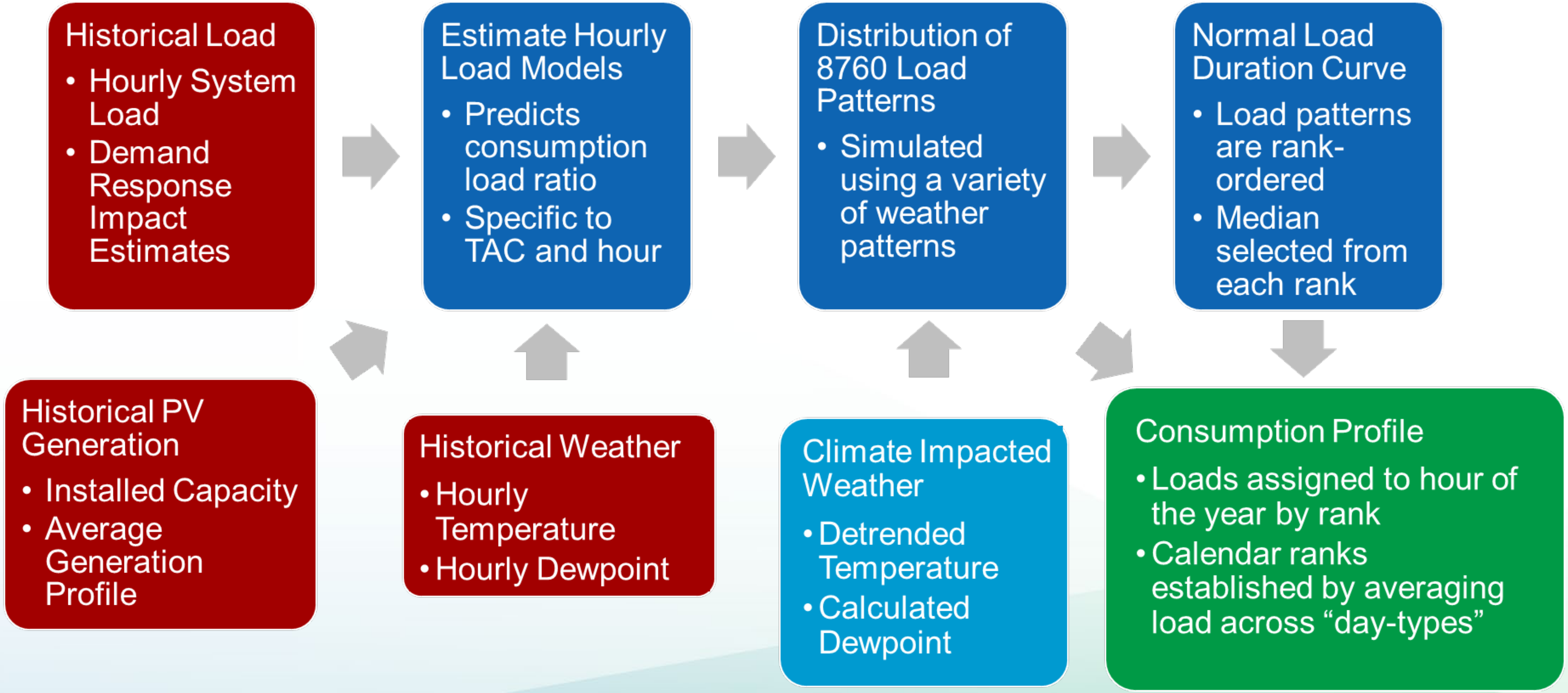
Normal Load Duration Curve
- Load patterns are rank-ordered
- Median selected from each rank

Historical PV Generation
- Installed Capacity
- Average Generation Profile

Historical Weather
- Hourly Temperature
- Hourly Dewpoint

Consumption Profile
- Loads assigned to hour of the year by rank
- Calendar ranks established by averaging load across “day-types”

Process Flow (Proposed)



Updates

- For CED 2024, staff will re-estimate the base consumption profile using the current methodology
- Staff are working to identify and resolve issues with this process and improve model performance

Future Considerations:

- Explore direct use of climate data in the hourly load model
  - Embed climate change impacts within the consumption profile
  - Simulated consumption profiles would reflect climate trends and novel weather patterns

CAISO Historical BTM PV Capacity Factors

- **Data Procurement:** In 2023, CEC procured a large sample of BTM PV generation data
- Annual capacity factors calculated from new vendor data are 3-4% points lower than CED 2023
- Monthly average capacity factors were calculated from 2018-2022
  - Monthly average factors from vendor data are 2-5% points lower than CED 2023

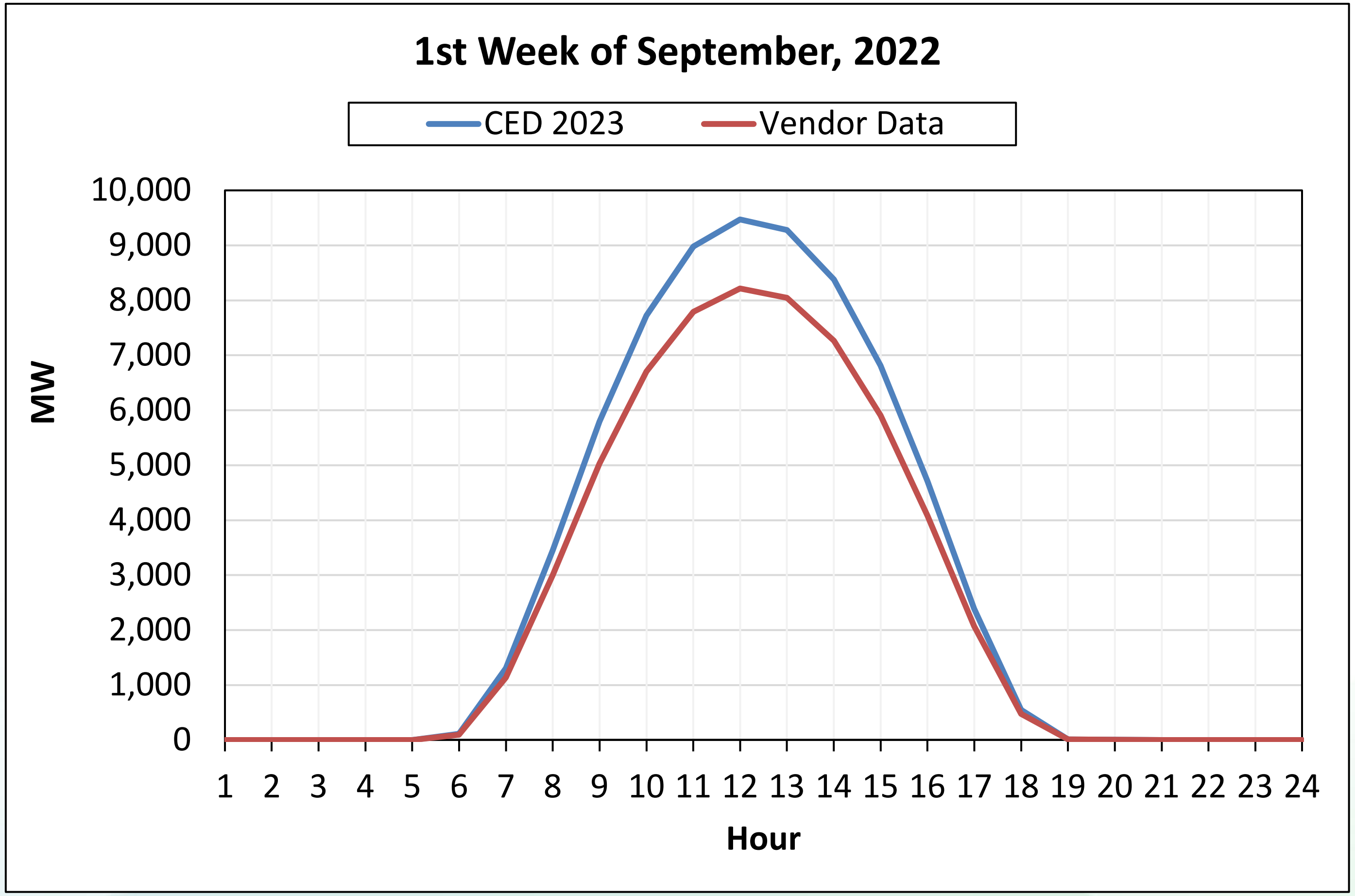
		Year				
pa	**source**	**2018**	**2019**	**2020**	**2021**	**2022**
CAISO	CED 2023	21%	20%	21%	21%	22%
CAISO	Vendor Data	18%	17%	18%	18%	18%

			Month										
pa	**source**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CAISO	CED 2023	13%	18%	21%	26%	27%	29%	28%	26%	22%	18%	14%	11%
CAISO	Vendor Data	11%	16%	18%	22%	23%	24%	24%	22%	18%	16%	12%	9%

CAISO Historical Average Hourly BTM PV Generation

- Over 13 GW of BTM PV in 2022 contributed to generation estimates
- On average, the daily maximum generation estimate using vendor data is ~1,260MW lower than CED 2023
- Less counterfactual “consumption” during hours of high PV generation

	Source	
Hour	CED 2023	Vendor Data
1	0	0
2	0	0
3	0	0
4	0	0
5	2	1
6	111	97
7	1,307	1,138
8	3,456	3,005
9	5,791	5,030
10	7,723	6,703
11	8,979	7,791
12	9,473	8,218
13	9,279	8,047
14	8,378	7,264
15	6,813	5,907
16	4,706	4,081
17	2,389	2,071
18	550	475
19	12	10
20	5	4
21	0	0
22	0	0
23	0	0
24	0	0



Source: CEC Staff

QFER Sales vs CAISO EMS

- Staff applies transmission and distribution loss factors to scale load measured at the customer meter to load measured at the CAISO generation level
- Table shows the ratio of CAISO EMS totals to QFER utility sales data as well as assumed CED loss factors
- In 2022, the ratio of system load to sales is significantly higher than the assumed loss factor
- Resolving this discrepancy will mitigate the need to “stretch” the PG&E hourly profile

	SDGE	SCE	PGE
2016	6.1%	9.6%	9.2%
2017	8.0%	12.6%	9.3%
2018	8.4%	10.8%	10.1%
2019	8.8%	9.5%	8.4%
2020	8.7%	7.2%	11.2%
2021	7.6%	8.3%	12.5%
2022	9.0%	8.4%	13.1%
CED Assumed:	8.2%	6.8%	9.1%

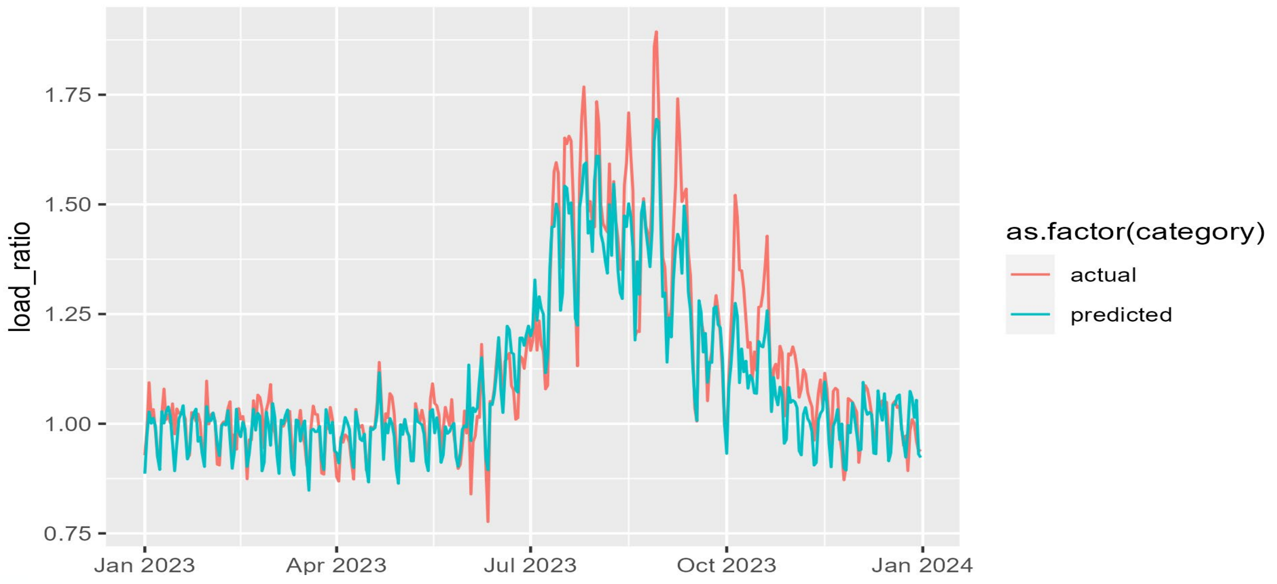
Increasing Temperature Response

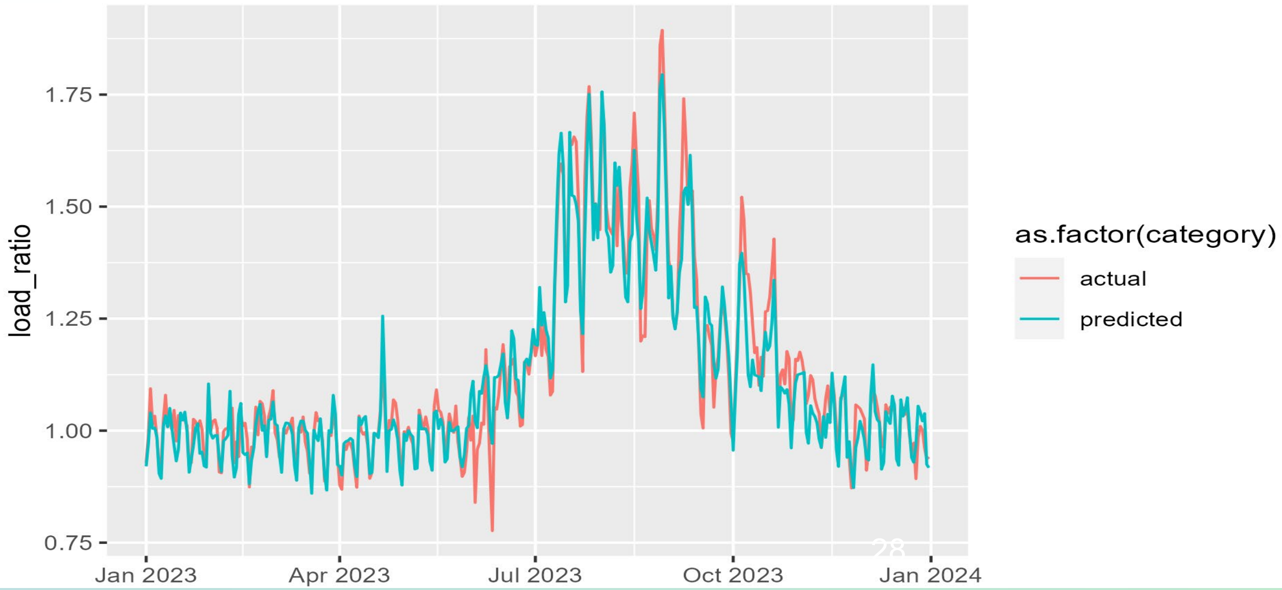
- Staff observed that CED 2023 model fit in the high temperature range progressively worsened with each subsequent year from 2016 to 2022
- The table here shows percent change in load for each percent increase in temperature (above 70 degrees, hour 16)
- The increasing trend exists across hours 15 – 18, presumably a response to increased saturation of air conditioning

	SDGE	SCE	PGE
2016	2.1%	2.1%	2.0%
2017	2.3%	2.2%	2.1%
2018	2.3%	2.3%	2.0%
2019	2.2%	2.2%	2.2%
2020	2.9%	2.5%	2.0%
2021	2.9%	2.5%	2.2%
2022	3.4%	2.4%	2.2%
2023	3.5%	2.4%	2.3%

Increasing Temperature Response

- Increasing temperature response can be accounted for in the model
- These charts show out-of-sample predictions for SDG&E hour 16 in year 2023
- Top: CED 2023 vintage model estimated with 2016-2022 weather/load data underpredicts at high temperatures
- Bottom: Interacting temperature with a yearly index significantly improves performance

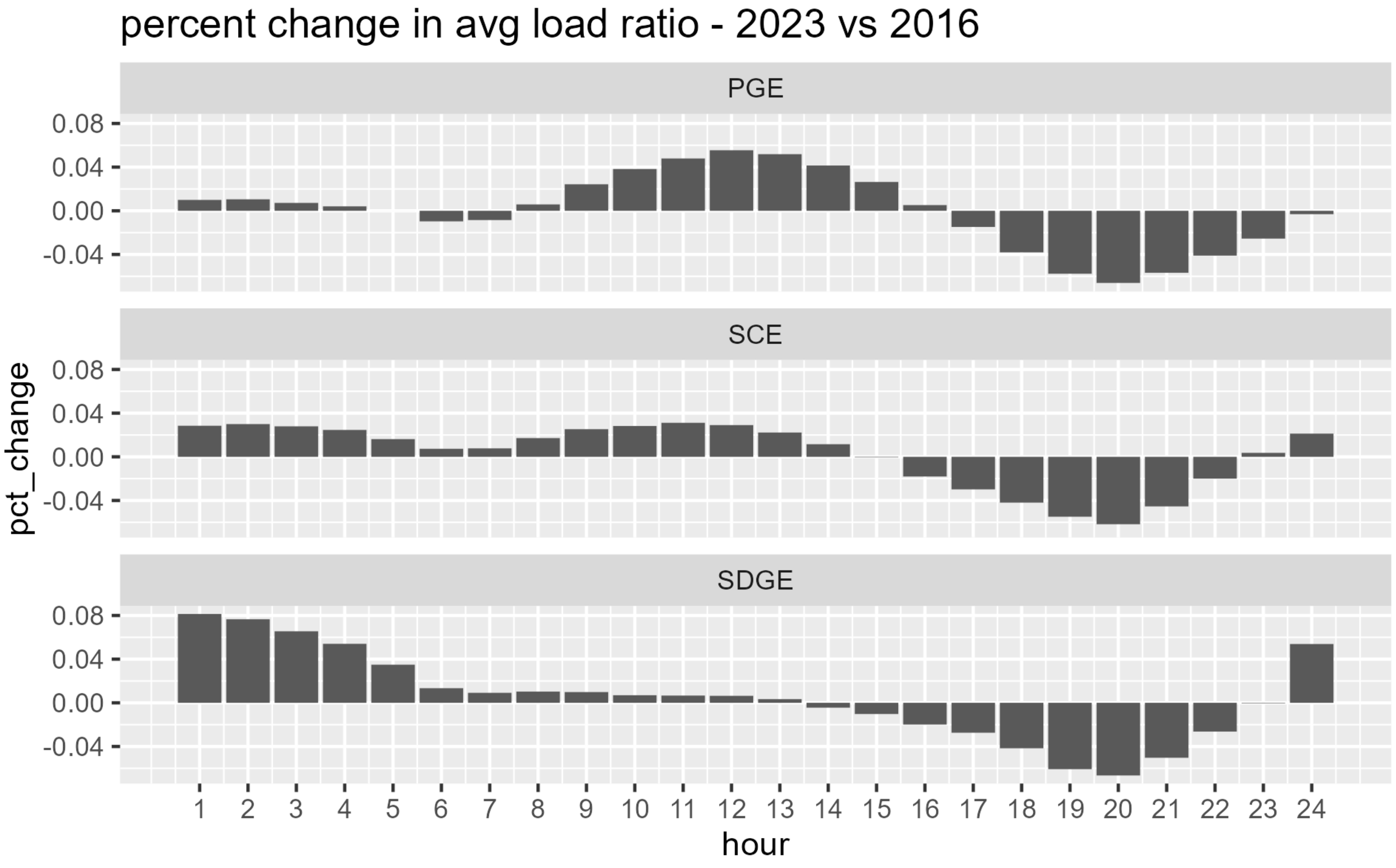




Source: CEC Staff

Evolving Load Pattern

- Other trends exist that were not robustly captured in the CED 2023 vintage models
- Load has shifted away from the peak window across all territories and to the mid-day and early morning hours
- CED battery and electric vehicle charging profiles reflect similar characteristic patterns



Source: CEC Staff

Thank you

Email:
Nicholas.Fugate@energy.ca.gov