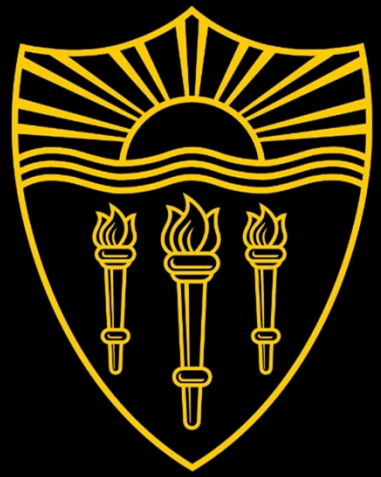


CAISO Flex Alerts: How responsive are residential customers to voluntary demand response events?

McKenna Peplinski
Advisor: Kelly T. Sanders

Sanders Sustainable Systems Group

January 16, 2024

USC Viterbi School of Engineering
Sonny Astani Department of Civil and Environmental Engineering

Climate change and extreme heat pose threats to grid reliability

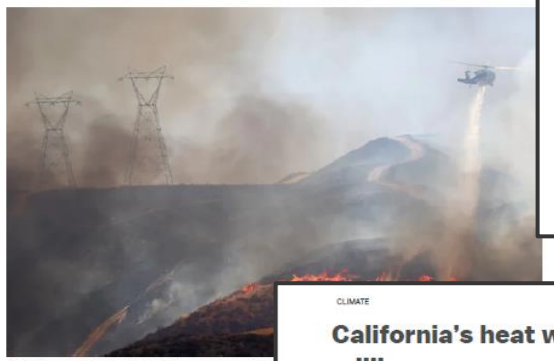
E&E NEWS

CLIMATE CHANGE

A Climate-Fueled Heat Wave Tests California's Power Grid

Officials are urging California residents to curtail their energy use as the state faces this summer's highest chance of outages during record-breaking temperatures

By Anne C. Mulkern, E&E News on September 6, 2022



Firefighters drop water on the Route Fire near Castaic, Calif., legislation as extreme heat grips California. Credit: Mario Tan

Los Angeles Times

CALIFORNIA

More rolling blackouts ordered in California amid power shortages and searing heat

The Washington Post

Democracy Dies in Darkness

How extreme heat is straining California's electrical grid

By Derek Hawkins

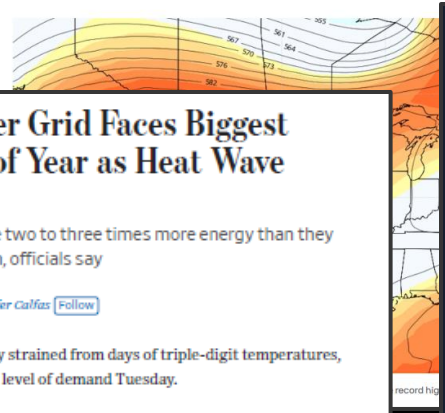
June 17, 2021 at 10:03 p.m. EDT

kouts in California, soaring temperatures are once

duce their energy use as triple-digit heat seared the reaking temperature records in some places. The "flex Operator so far in 2021 and comes days before the

Heat wave in West breaks records, threatens California grid

Andrew Freedman, author of Axios Generate



record hig

U.S.

California Power Grid Faces Biggest Blackout Risk of Year as Heat Wave Intensifies

Residents need to conserve two to three times more energy than they have been to keep power on, officials say

By Alyssa Lukpat Follow and Jennifer Calfas Follow

Updated Sept. 6, 2022 5:37 pm ET

California's power grid, already strained from days of triple-digit temperatures, faced a nearly record-breaking level of demand Tuesday.

The California Independent System Operator, which provides electricity to most of the state, issued an emergency alert for the afternoon and evening, expecting energy deficiencies as a heat wave in the U.S. West was forecast to peak in some places.

CLIMATE

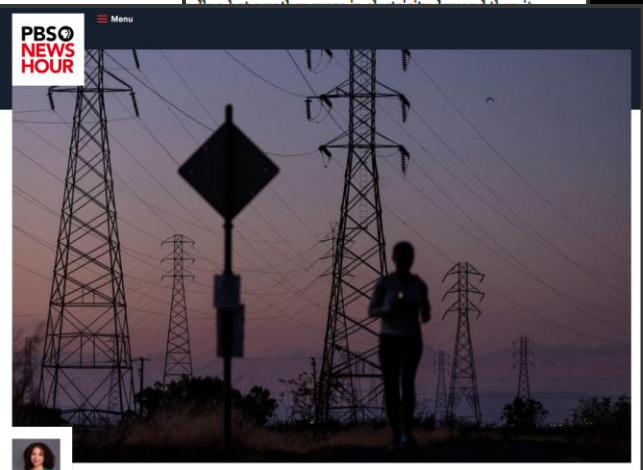
California's heat wave caused rolling blackouts for millions

Up to 4 million people were hit by "load interruptions" after power reserves fell below a critical threshold.

By Zeeshan Aleem | @ZeeshanAleem | Aug 15, 2020, 2:40pm EDT

PBS NEWS HOUR

Menu



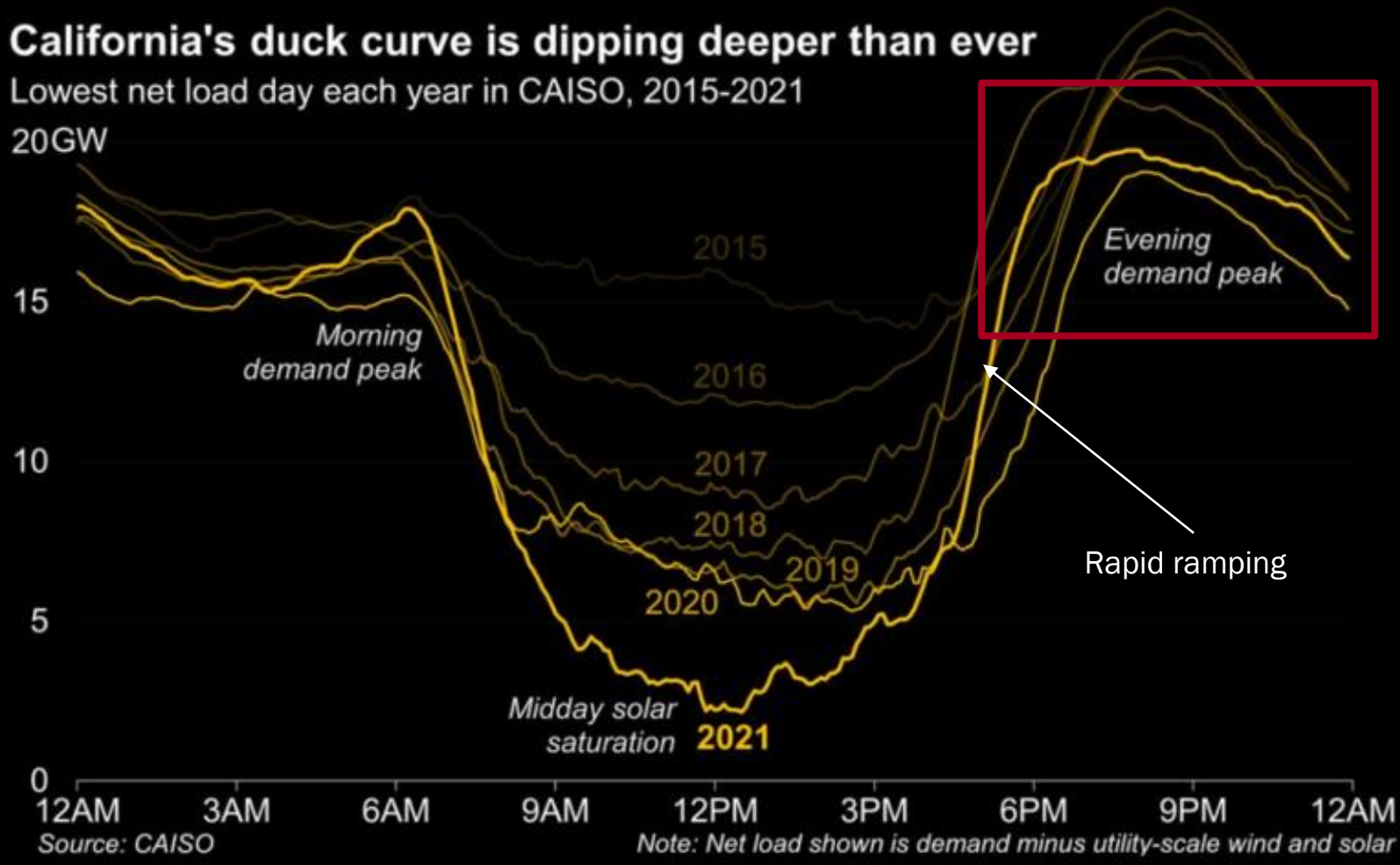
By Jenna Cohen

California's electricity demand breaks all-time record during severe heat wave

Share

Nation Sep 9, 2022 5:33 PM EDT

Growing variable renewable energy complicates the balance between supply and demand



@BPBartholomew April 26, 2023

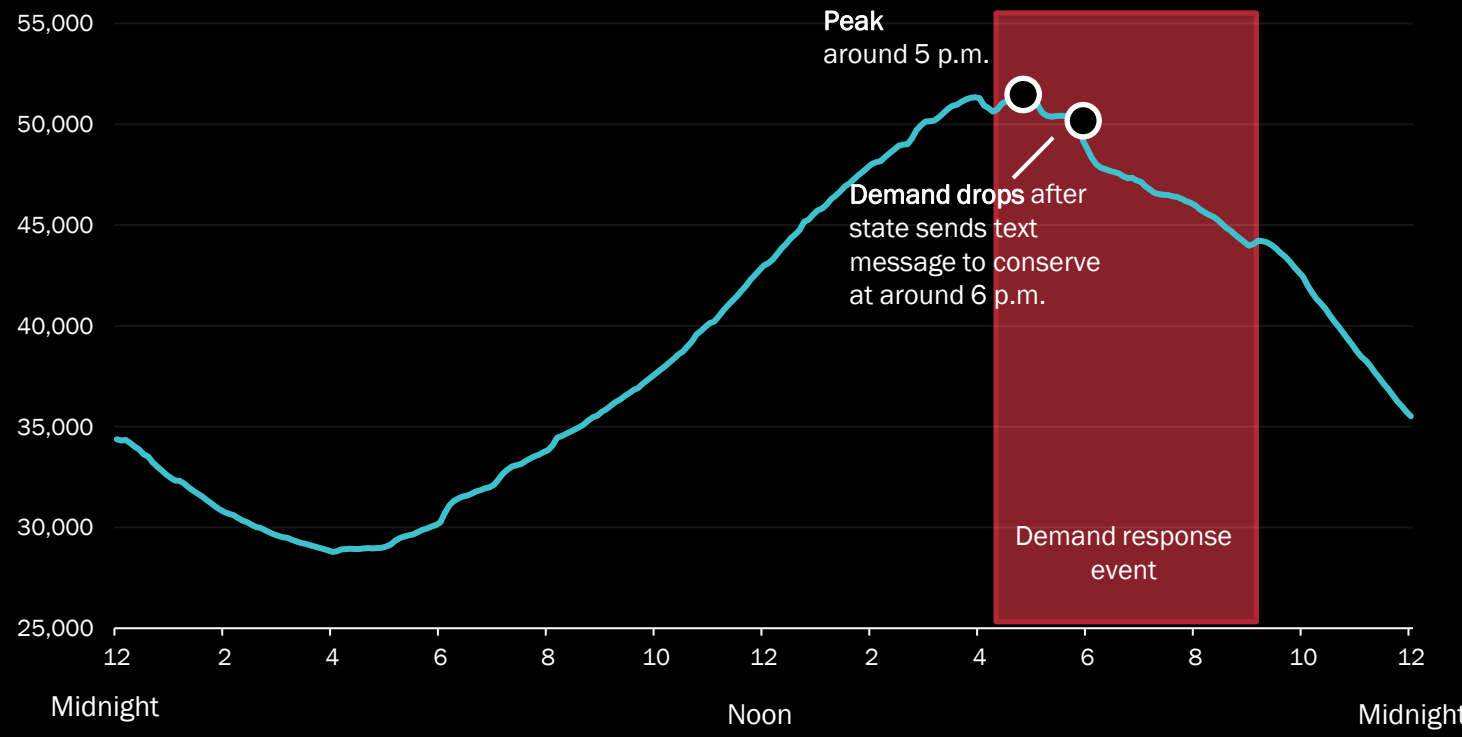
Flex Alerts can help alleviate strain placed on the grid during emergency grid events

- Voluntary, demand response (DR) program implemented by CA Independent System Operator (CAISO)
- Issued when demand threatens to exceed supply, typically on hot summer afternoons
- Customers asked to reduce their demand during the “Flex Period” without incentive

Flex Alerts can help alleviate strain placed on the grid during emergency grid events

CAISO HOURLY ELECTRIC DEMAND 9/6/22

During an extreme heat even in September 2022, the state's electrical usage reached a "demand response event"



Source: CAISO

Analyses of the effectiveness of Flex Alerts are limited

Very few studies on voluntary demand response programs that offer no financial incentive like Flex Alerts

Most Flex Alert analyses use systemwide or utility data with no insight into how participation varies

Difficult to quantify the efficacy of demand response programs without a ground truth

Are voluntary demand response programs effective at shedding load during emergency grid events?

1. To what extent have Flex Alerts reduced generation system ramping and residential sector demand during Flex Alert hours?
2. Can we identify the factors (e.g., daily maximum temperature, weekend-weekday scheduling, and frequency of alerts) that affect responsiveness?
3. What subpopulations are most responsive to FAs?

High resolution smart meter dataset used to evaluate how responsive customers were on Flex Alert days

Years: 2015-2016, 2018-2020

Hourly Load Data

Hourly smart meter data from ~200,000 households in SCE AND hourly demand for all of SCE

Flex Alert History

Summary of all issued Flex Alerts, retrieved from CAISO's Grid Emergency History Report

Socioeconomics

Census tract level socioeconomic indicators from CalEnviroScreen 3.0

Weather Data

Hourly temperatures from CIMIS, NOAA, and EPA weather stations

We define two new metrics to evaluate the success of Flex Alerts

Because there is no ground truth for what demand would have been in the absence of a Flex Alert, we define a reference electricity scenario.

"Comparable days"

Reference scenario to estimate hourly electricity demand in the absence of the Flex Alert

1. Occurred in two weeks leading up to or after Flex Alert
2. Same day type (e.g., weekday or weekend)
3. Not classified as a Flex Alert day
4. 3 hottest days based on daily max temperature

Demand on FA day

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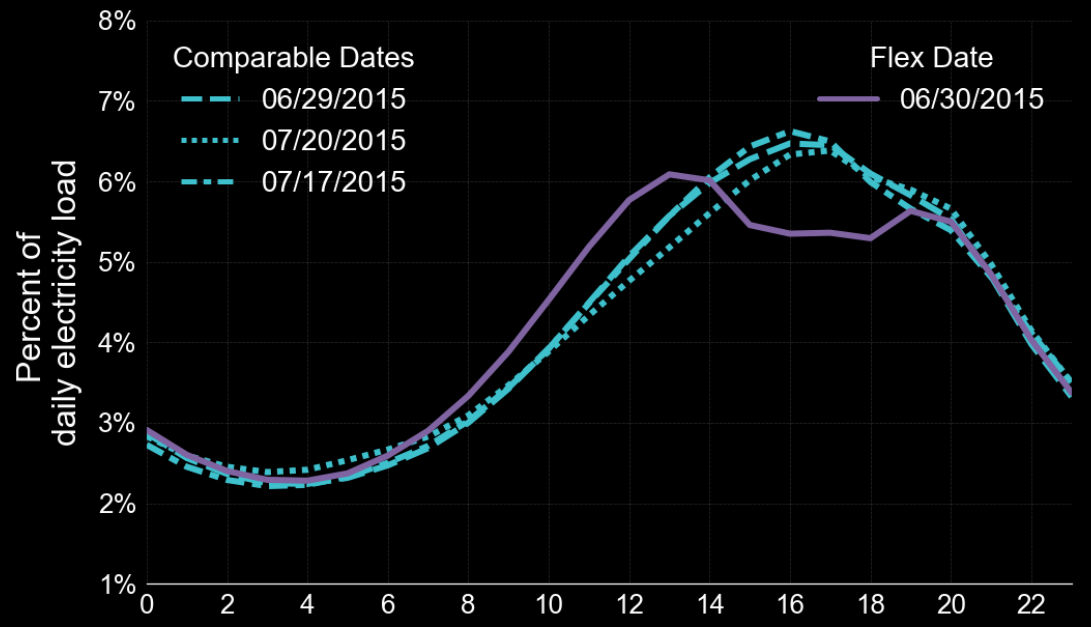
Demand on FA day

Load profile on Flex Alert day & its comparable dates



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"Comparable days" ⟹ "Reference electricity demand"

Estimate of the electricity demand on the Flex Alert day had the Flex Alert *not* been issued

Equal to: the average electricity demand of each customer in each hour of the Flex Alert on each of the three comparable days

Demand on FA day

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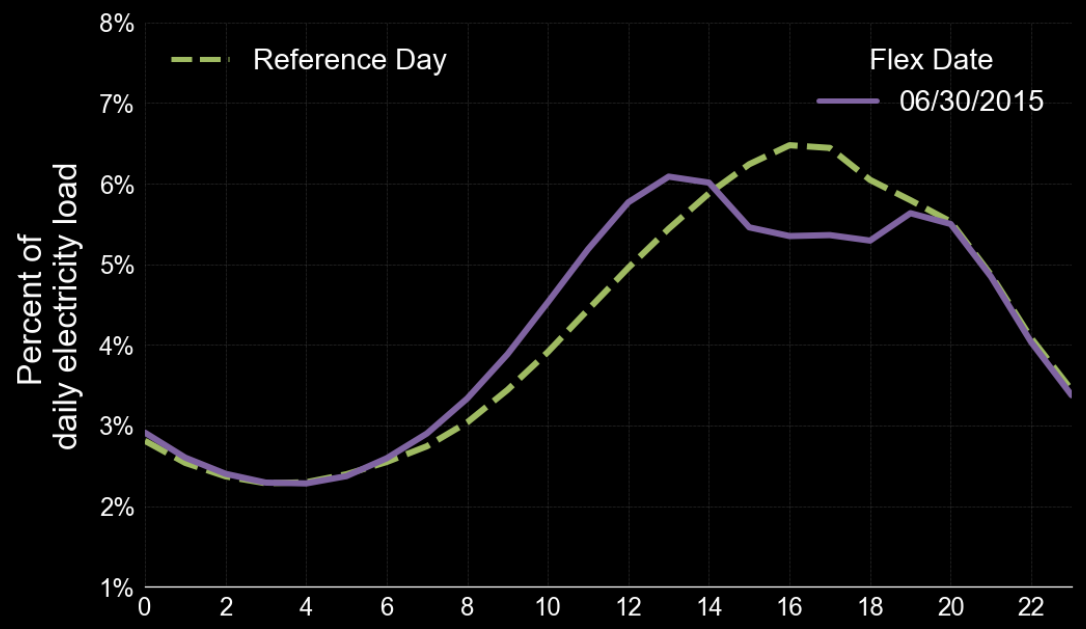
Demand on FA day

Load profile on Flex Alert day & its reference day



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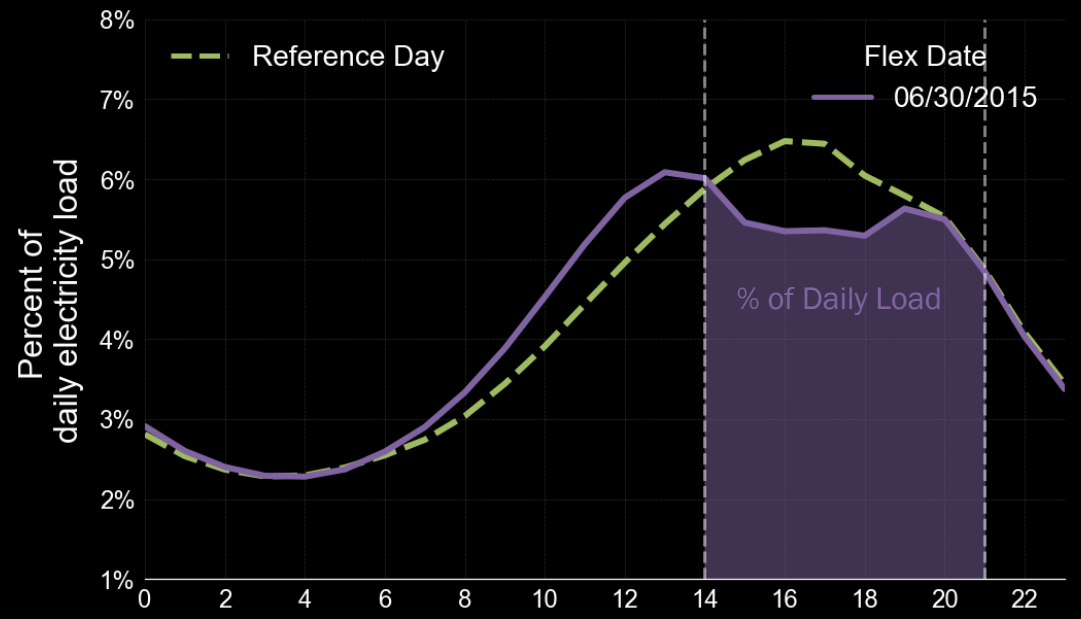
"Comparable days" ⟹ "Reference electricity demand"

Demand on FA day

"Flex Period Response"
Estimates how much demand was shifted away from the Flex Alert period



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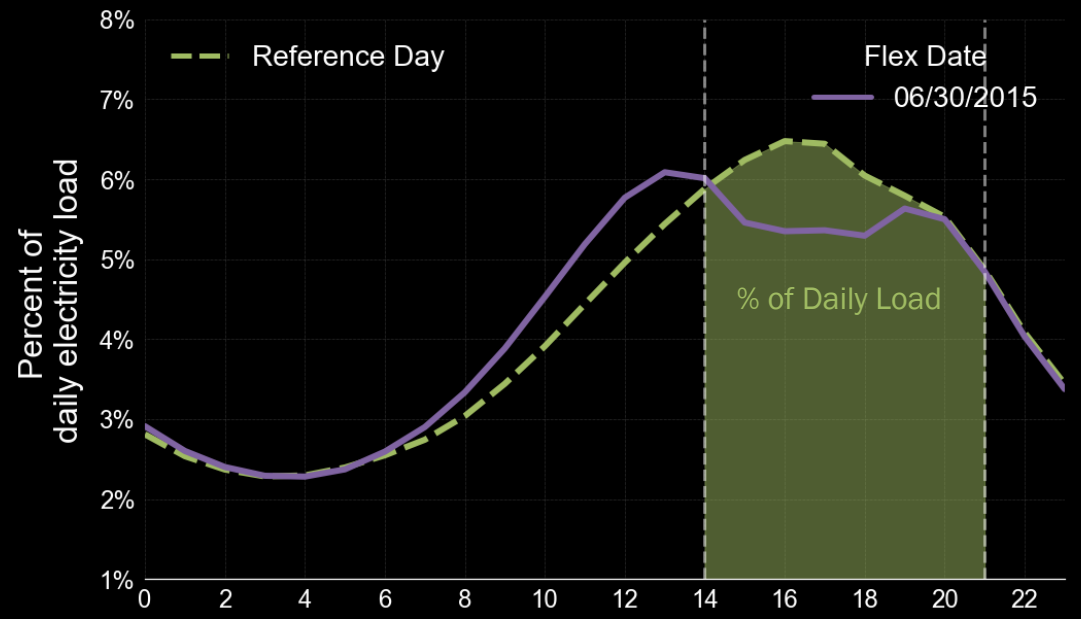
"Comparable days" ⟹ "Reference electricity demand"

"Reference electricity demand" + Demand on FA day

"Flex Period Response"
Estimates how much demand was shifted away from the Flex Alert period



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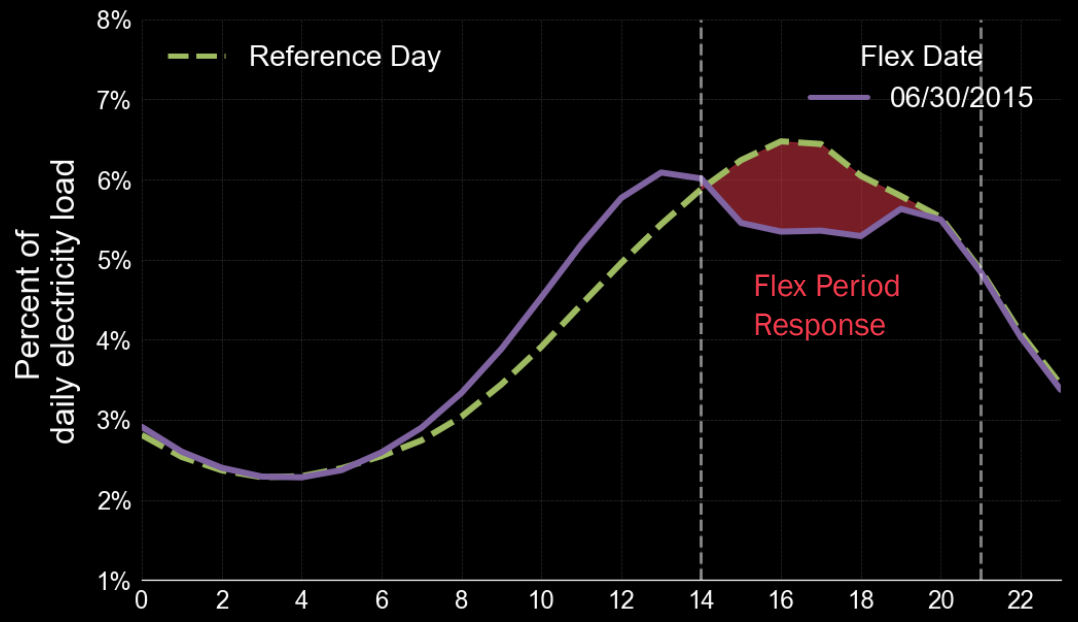

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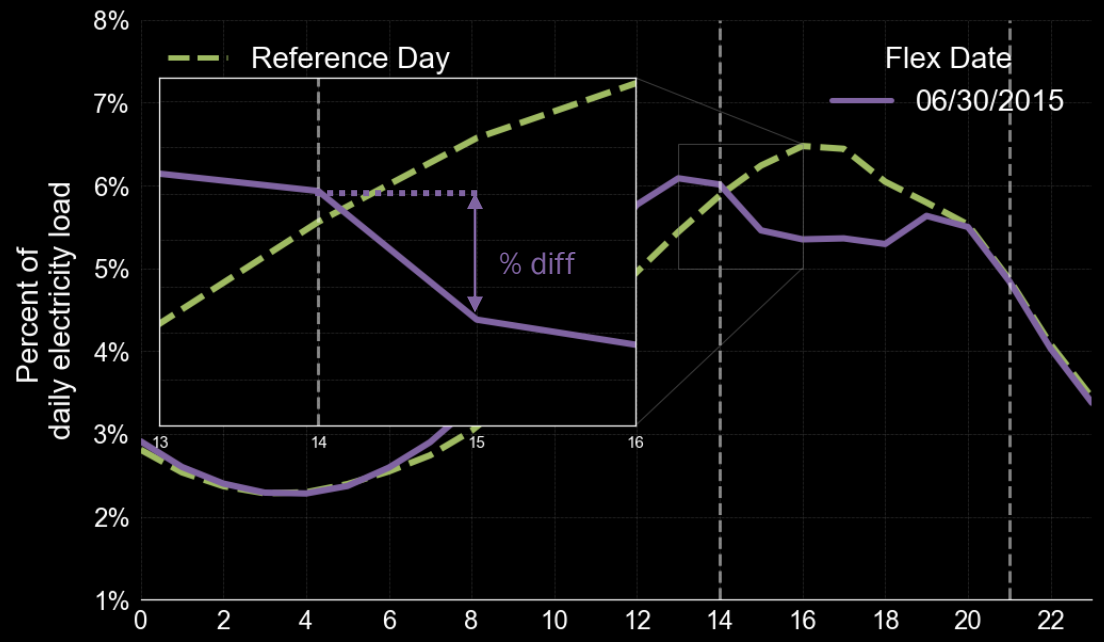
Because there is no ground truth for what demand would have been in the absence of a Flex Alert, we define a reference electricity scenario.

"Comparable days" ⟹ "Reference electricity demand"

"Reference electricity demand" + Demand on FA day → "Ramping Response"

"Ramping Response"
Estimates changes in demand during the first hour of the Flex Alert period



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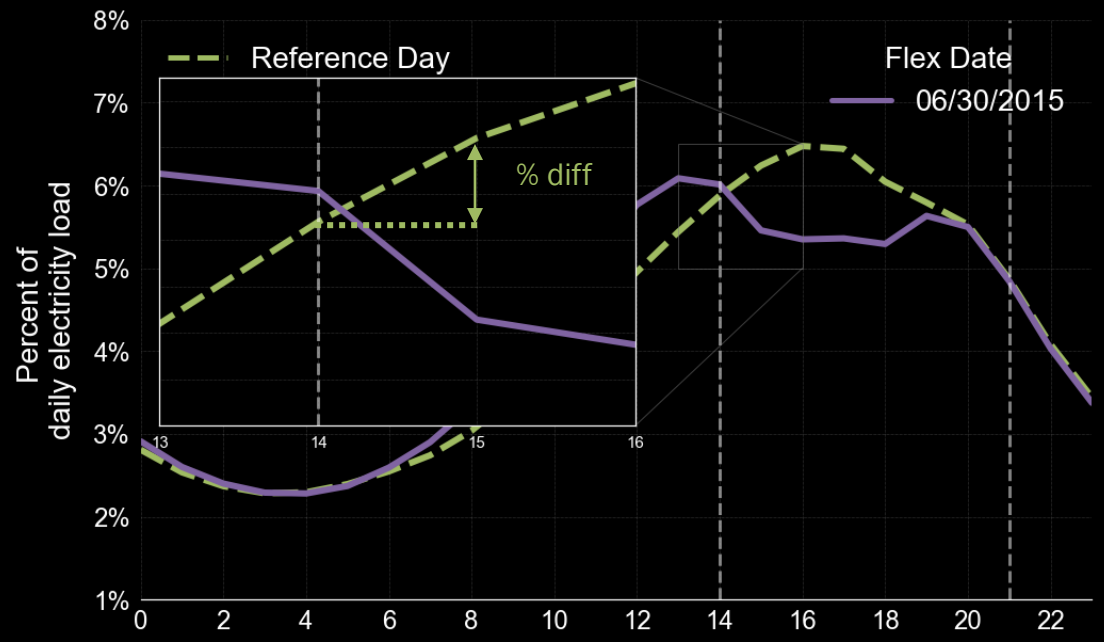

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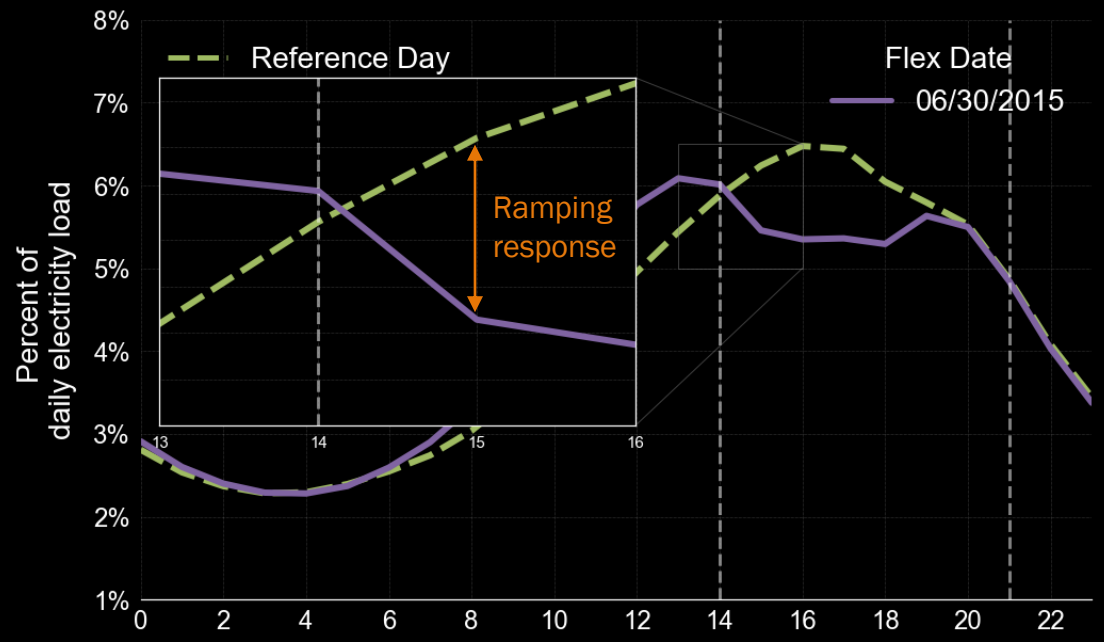
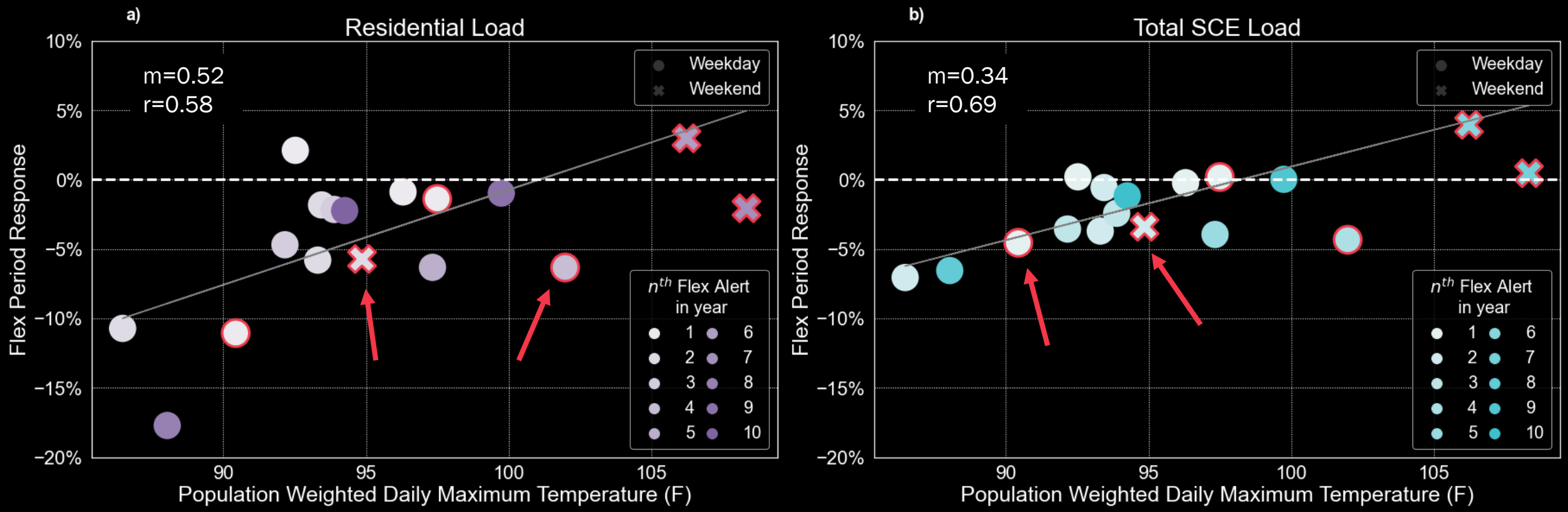


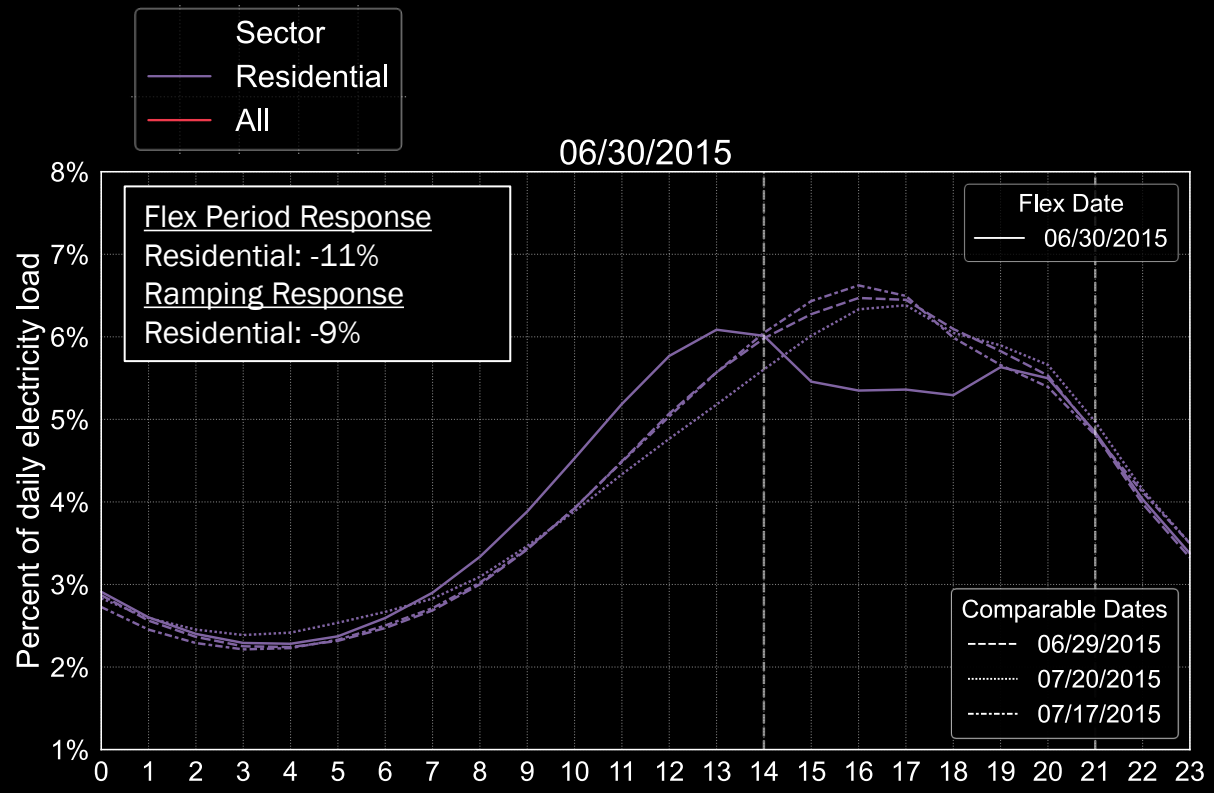
"Ramping Response"
Estimates changes in demand during the first hour of the Flex Alert period

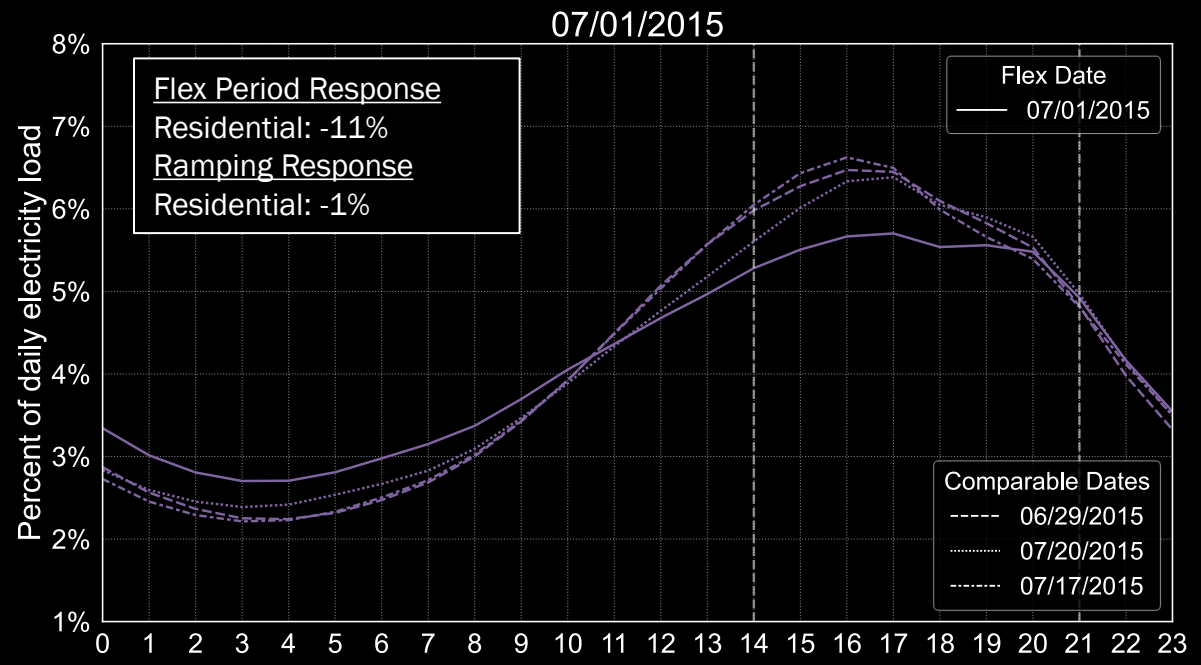
Residential load and total SCE load were more likely to reduce demand on days with relatively cooler temperatures

17 Flex Alerts

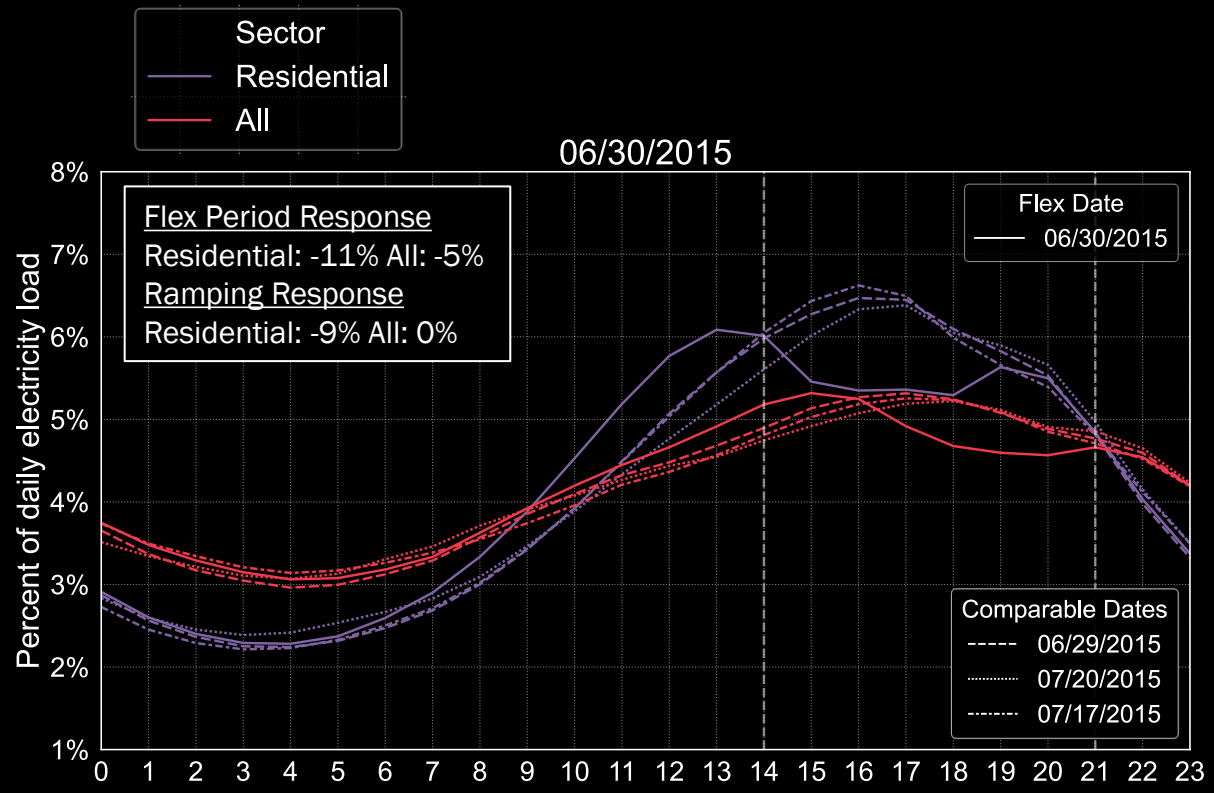


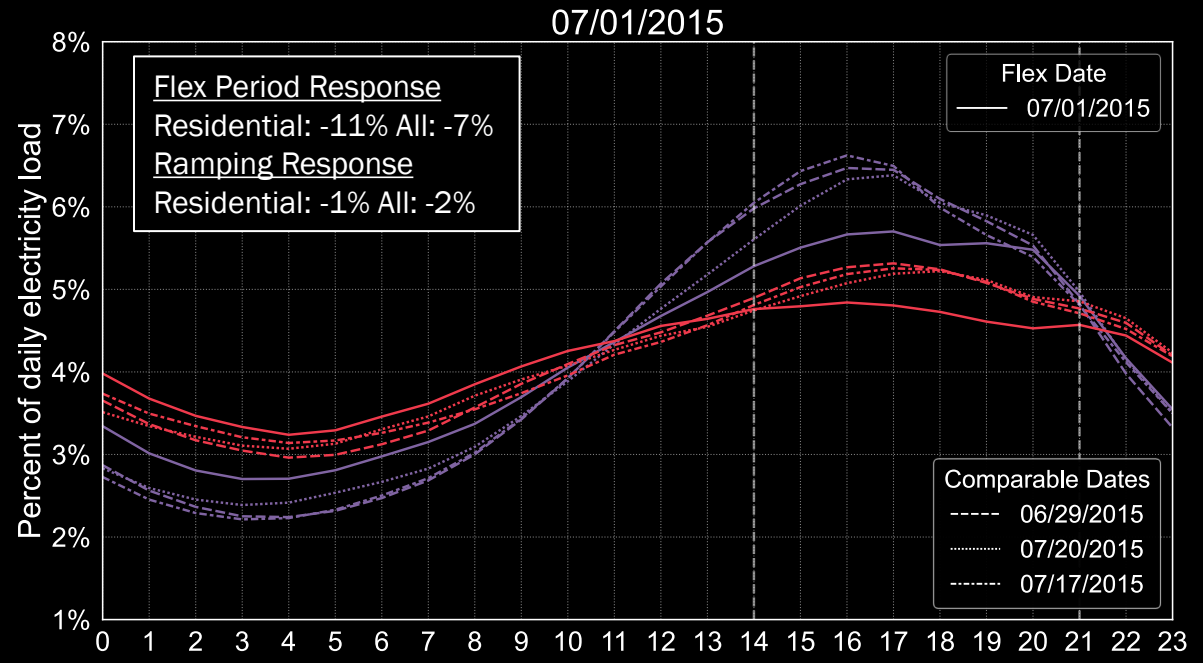
Shape of the response varies across effective Flex Alert days (i.e., large magnitude, negative Flex Period Response)





Residential demand response participation has significant potential to reduce peak electricity demand

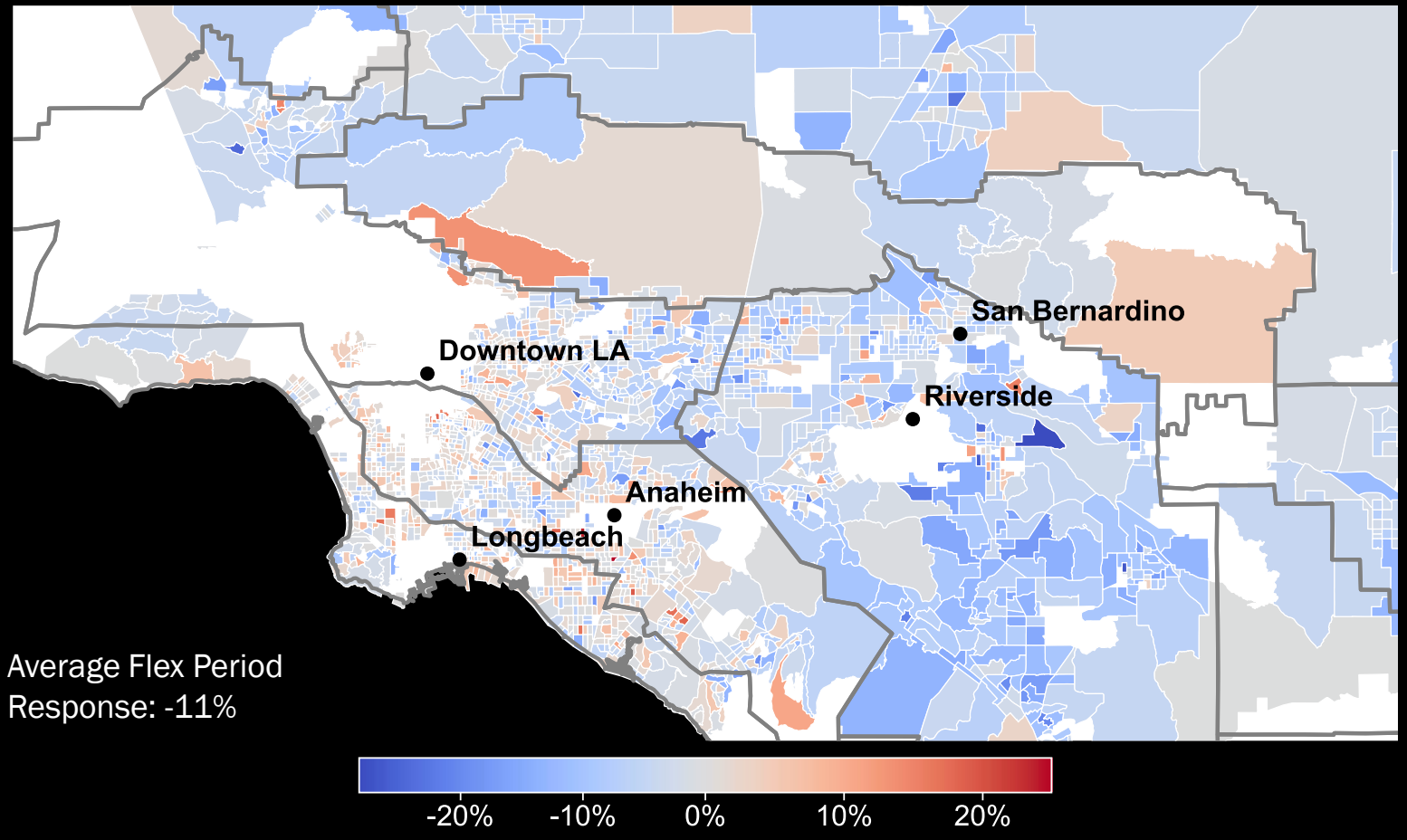




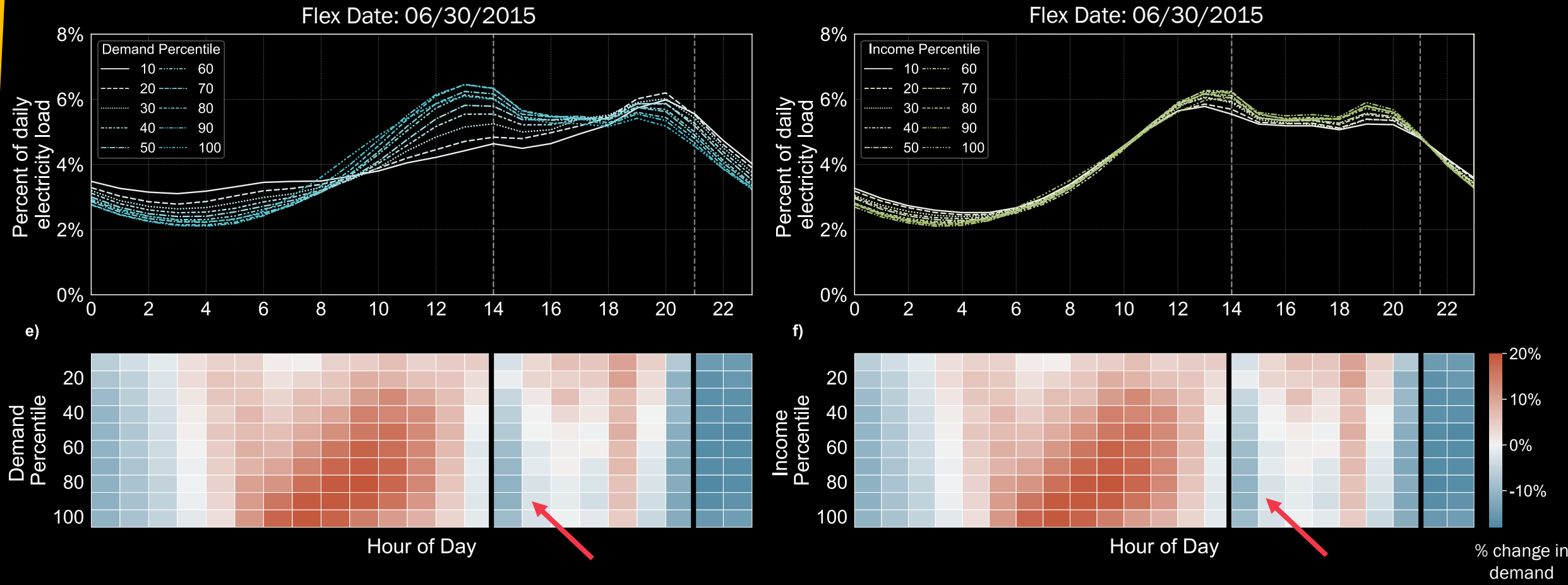
The response to Flex Alerts across residential customers is not uniform

Flex Period Response by census tract

Flex Date: 06/30/2015



Higher income, higher demand customers have larger demand reductions during Flex Alert hours than low income, low demand



Conclusions

- Flex Period responses of -11% (residential load) and -7% (total SCE load) show that unincentivized, voluntary DR programs can help to maintain grid reliability
- High demand, high income households have more demand flexibility
- Inconsistent response levels make it difficult to predict how much additional DR capacity can be gained
- A well-designed DR program should be optimized to engage customers with the most flexibility while still providing benefits to the grid and offering overall electricity cost reductions

McKenna Peplinski

PhD Candidate

peplinsk@usc.edu

“Residential electricity demand on CAISO Flex Alert days: A case study of voluntary emergency demand response programs”
in review at EREN

Sanders Sustainable Systems Group

Visit us at: s3research.usc.edu

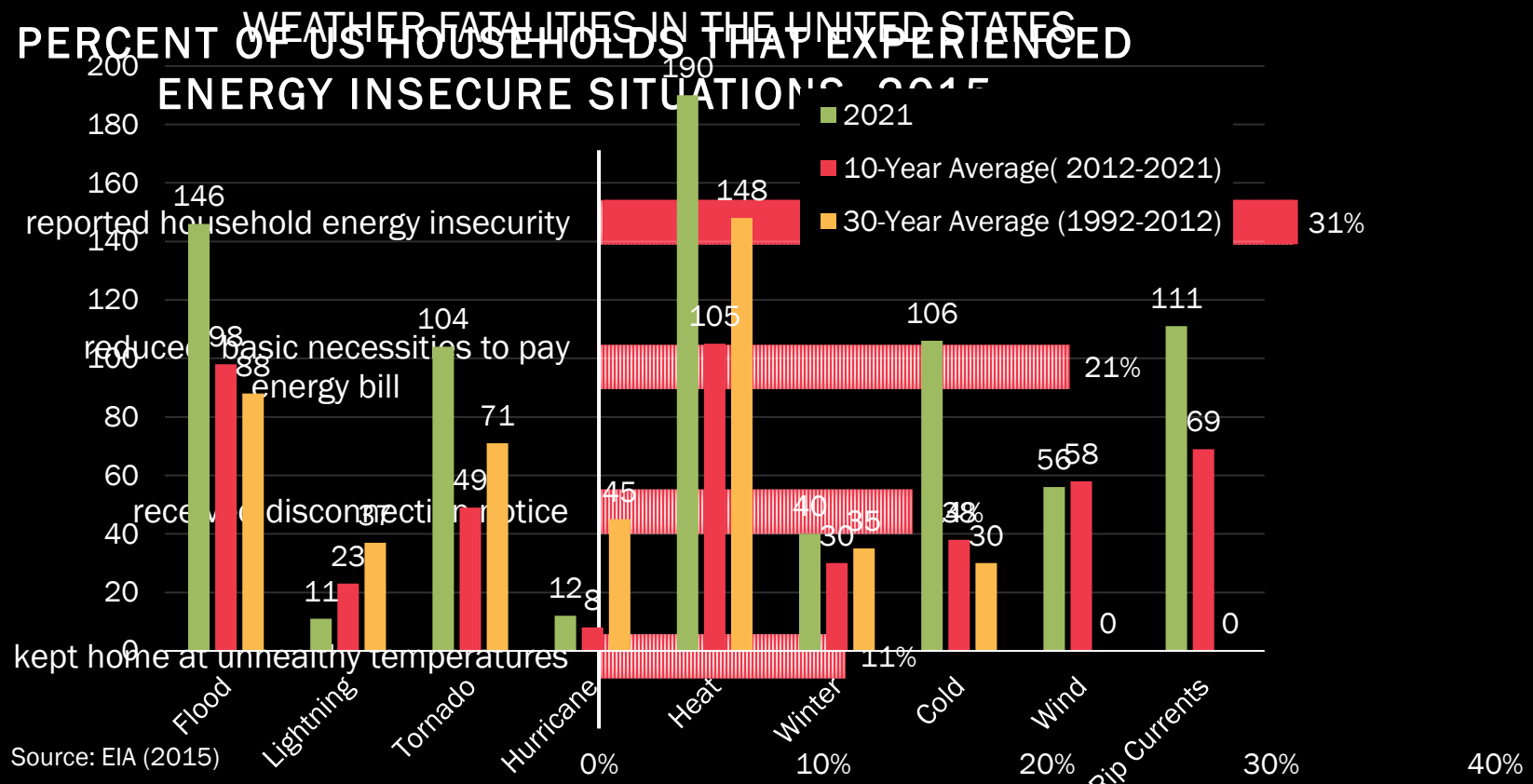
Acknowledgements

Dr. Kelly Sanders & S3 Lab Members

Funding

NSF Career

Certain communities will be more vulnerable to future warming and heat stress



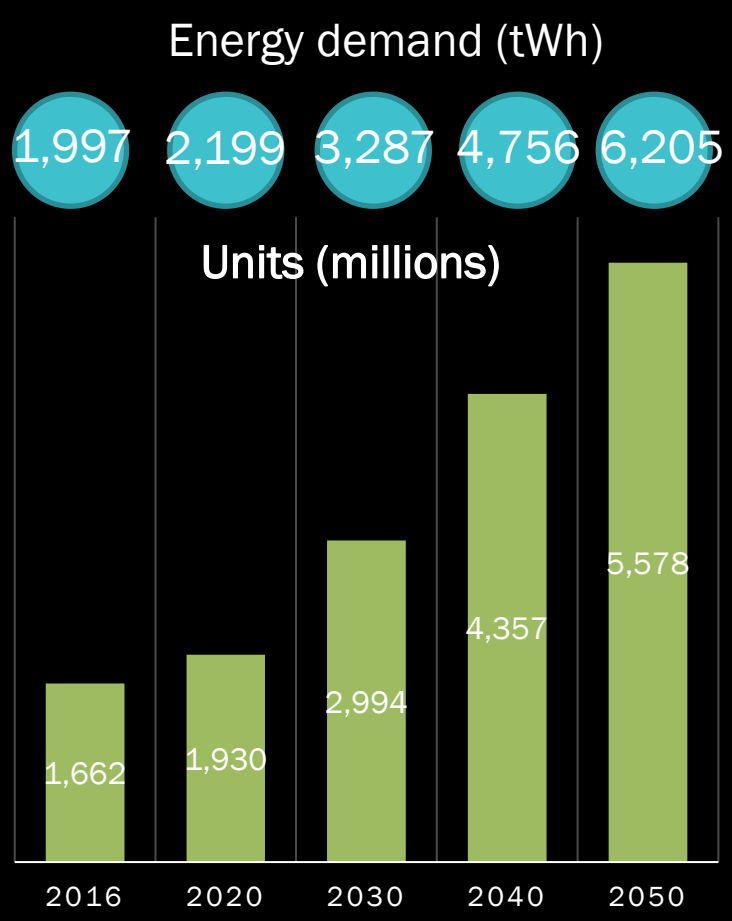
Source: EIA (2015)

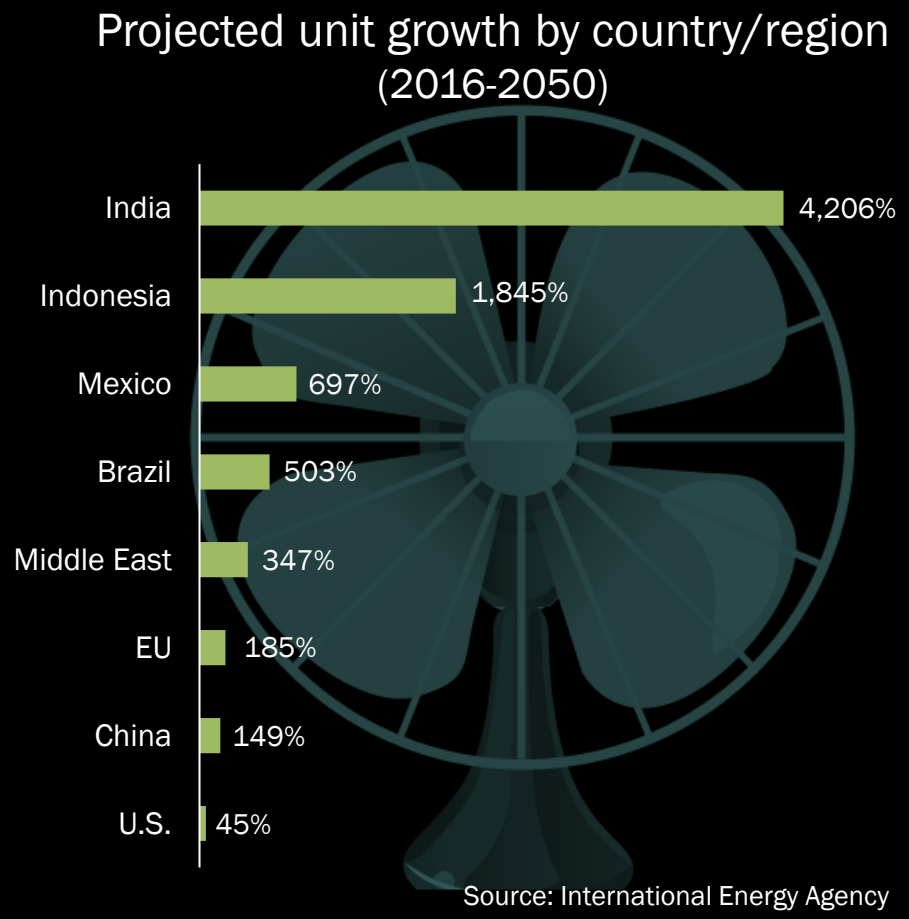
Source: EIA (2015)

The global demand for AC is growing rapidly

DEMAND FOR AIR CONDITIONING AND ENERGY

Number of AC units worldwide and corresponding energy demand



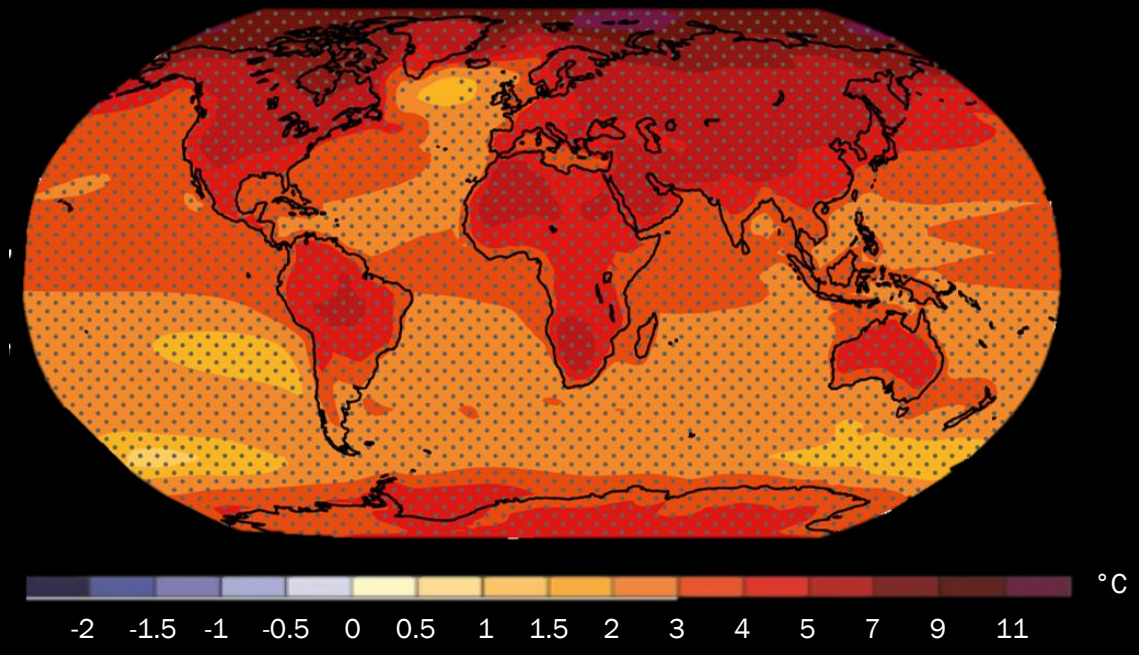


Source: International Energy Agency

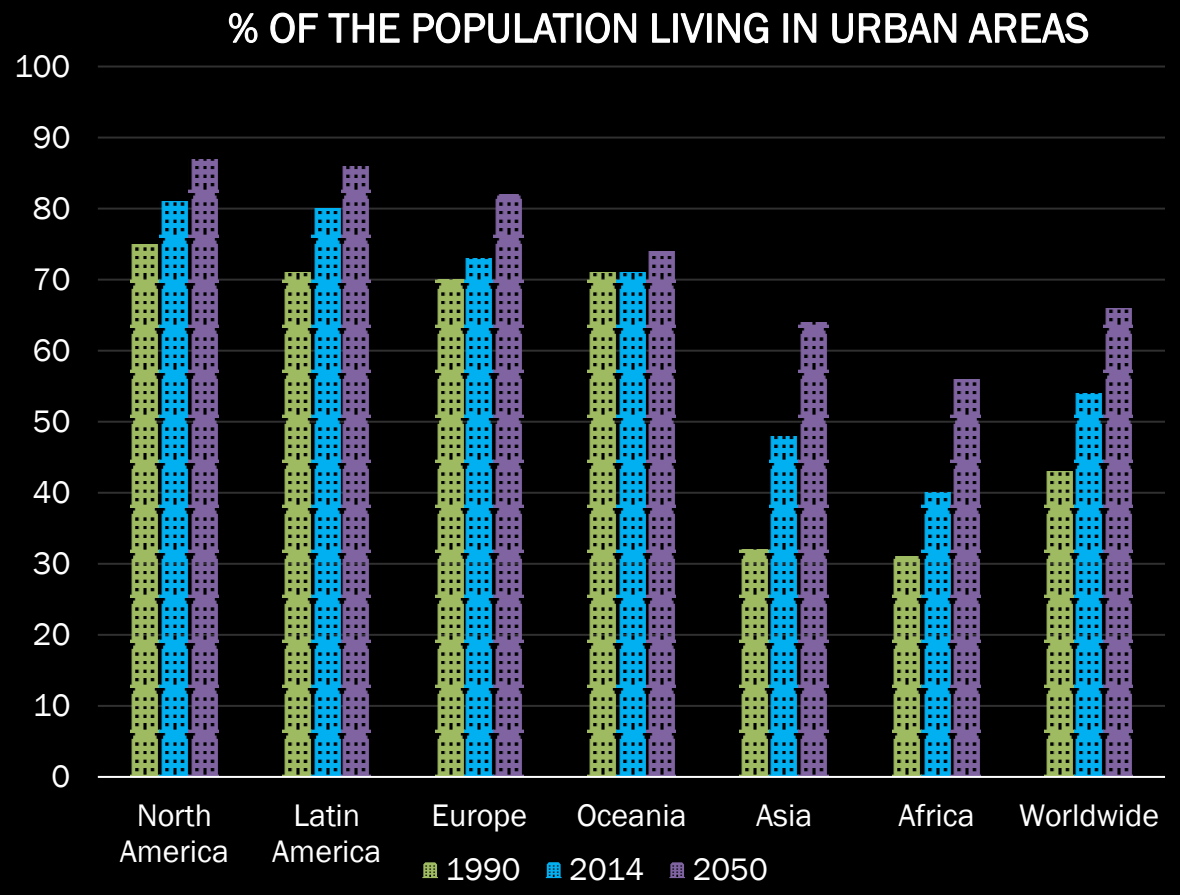
- Higher incomes and living standards increase AC demand
- Global electricity demand for cooling expected to triple by 2050 (EIA 2018)
- Will be 2nd largest source of global electricity demand

Climate change and urbanization are changing how we consume energy

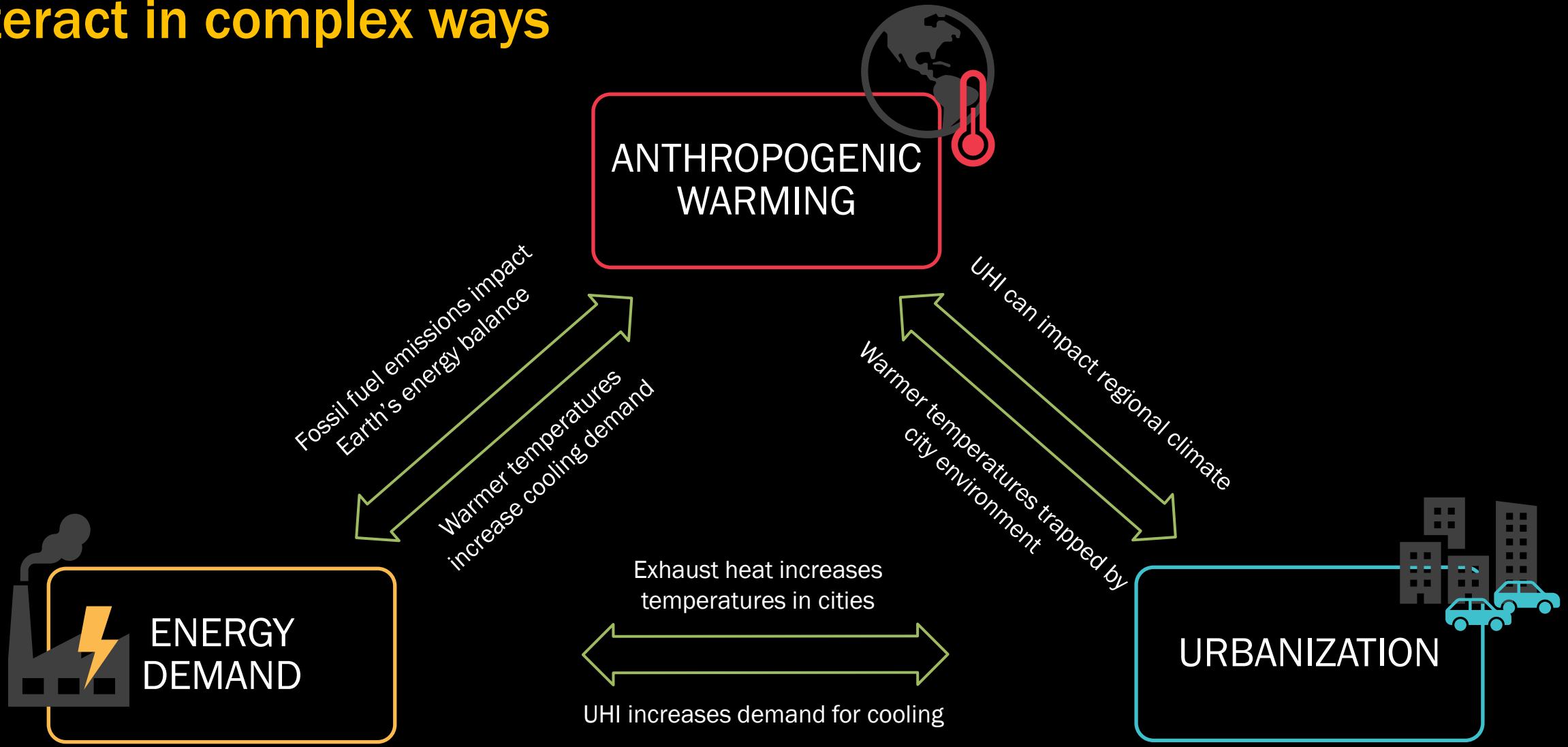
CHANGE IN AVERAGE SURFACE TEMPERATURE,
RCP 8.5 (1986-2005 to 2081-2100)



Source: IPCC 2014

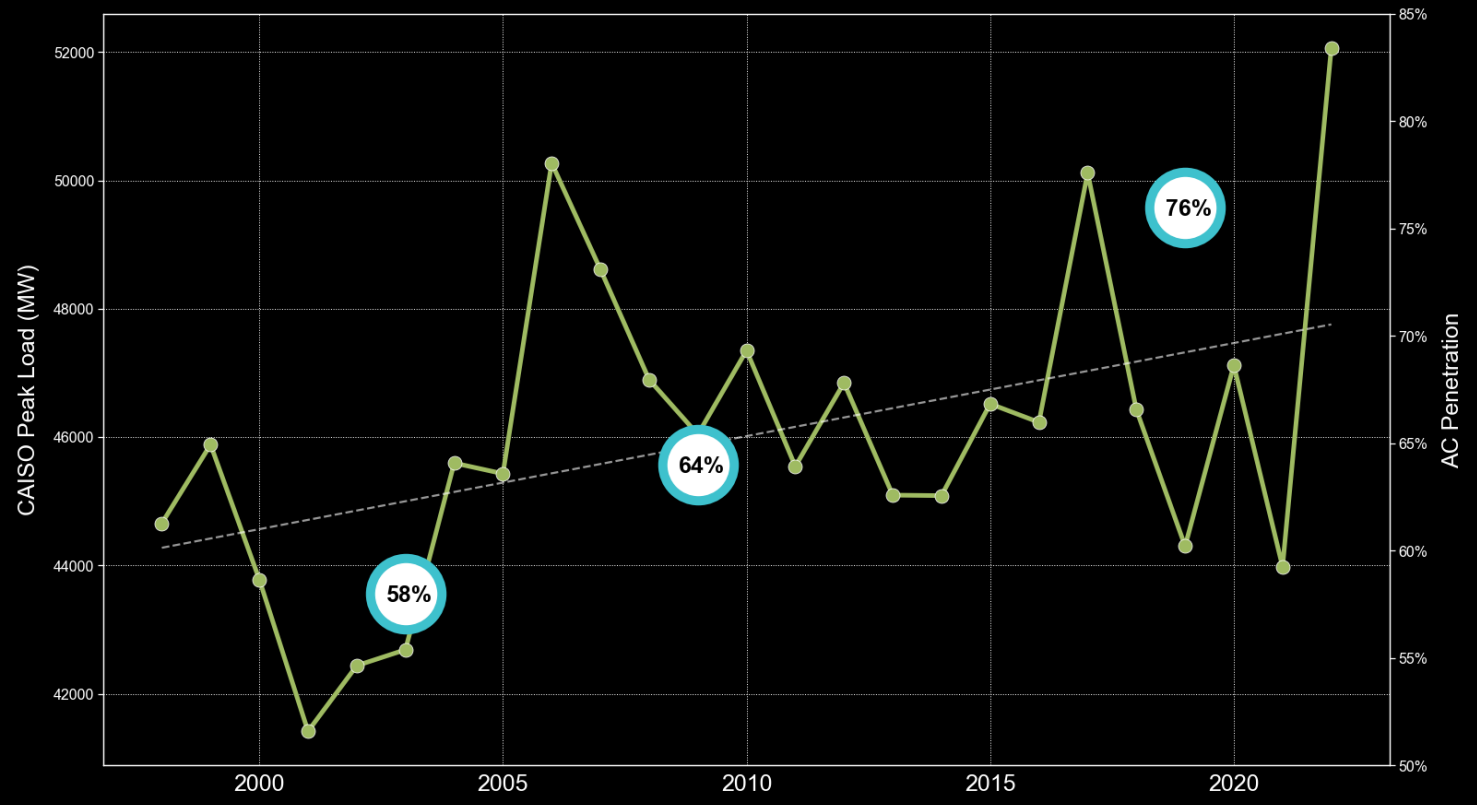


Anthropogenic warming, urbanization, and energy demand interact in complex ways

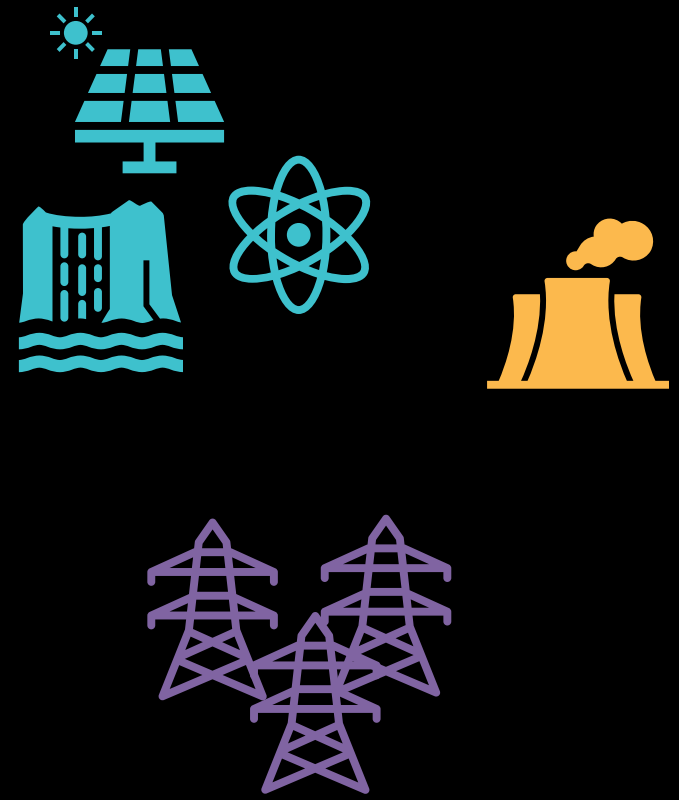


Demand for cooling strains grid resources, amidst other stressors

CAISO Peak Load (MW) from 1998-2022 and AC Penetration in CA



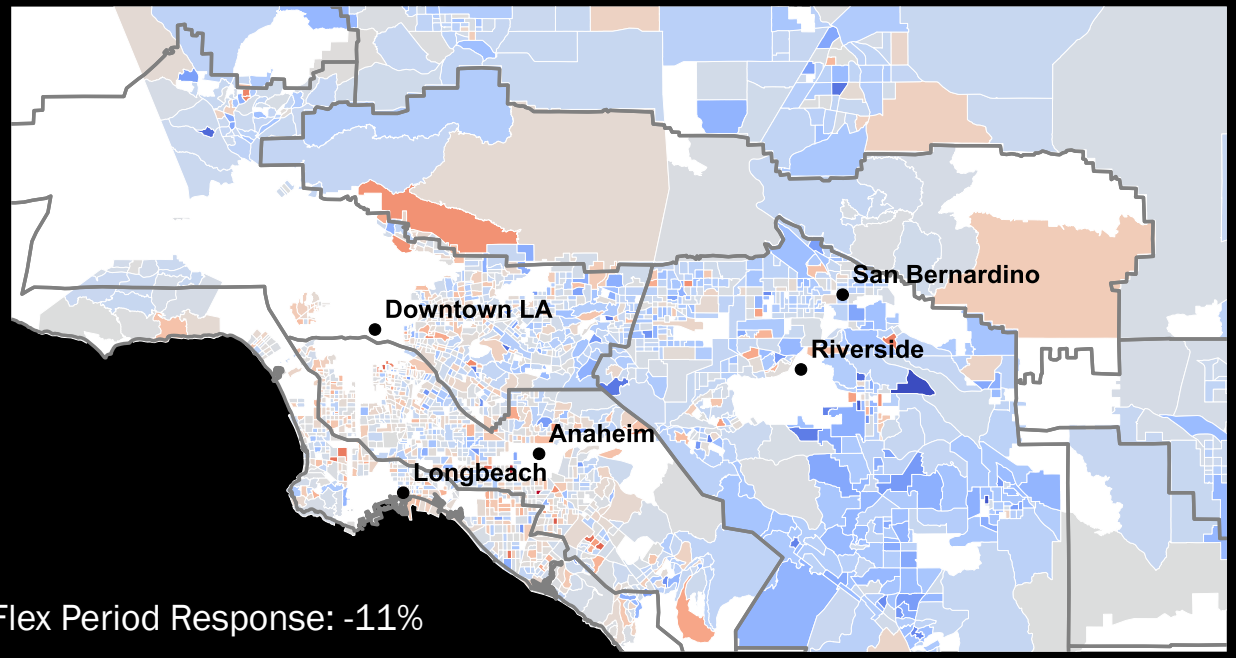
Extreme heat → reduced efficiency and transmission losses



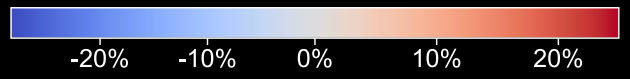
The response to Flex Alerts across residential customers is not uniform

Flex Period Response by census tract on two Flex Alert days

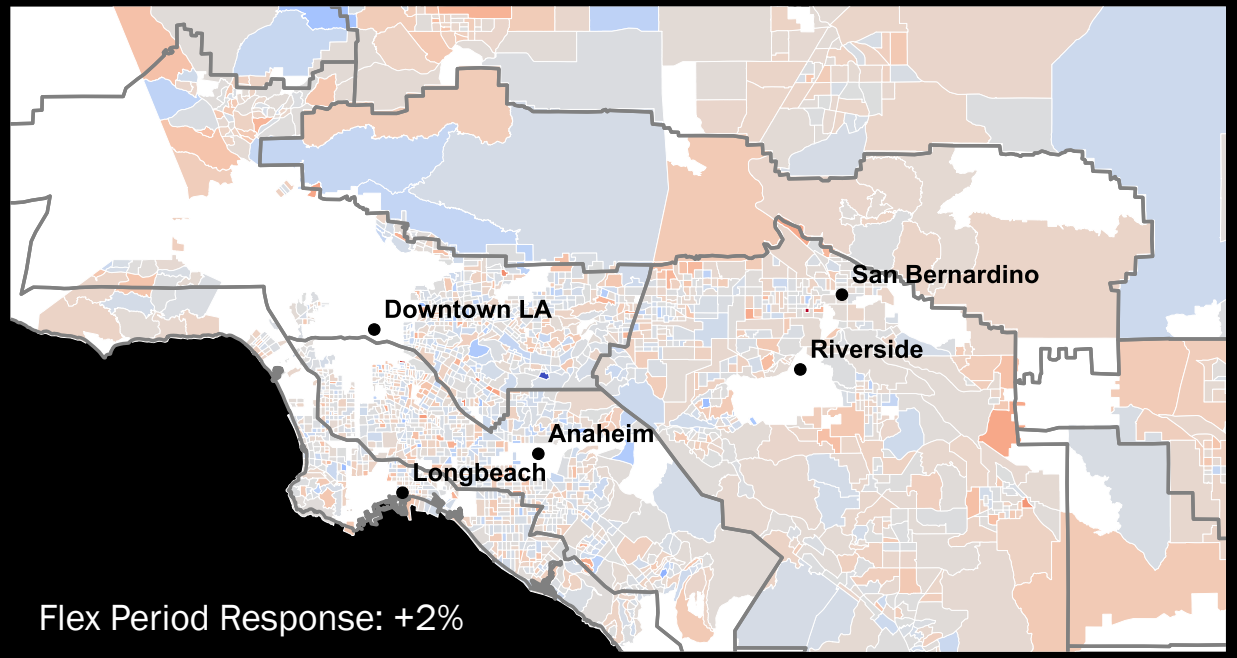
Flex Date: 06/30/2015



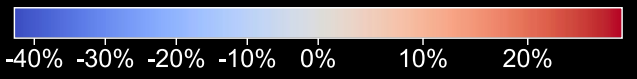
Flex Period Response: -11%



Flex Date: 06/11/2019



Flex Period Response: +2%



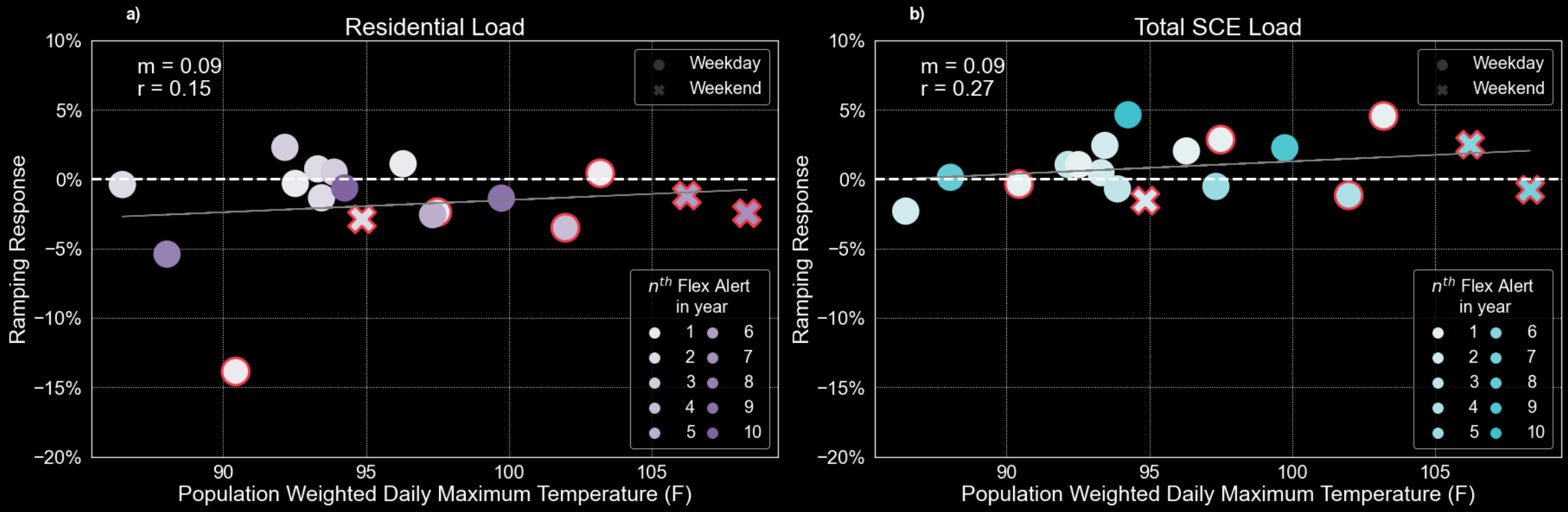
Power Saver Rewards Pilot

- CPUC approved the Power Saver Rewards program in 2021 which offers financial incentives for customers that enroll in the program and reduce demand on Flex Alert Days
- SCE, PG&E, SDGE offer the program
- $2 per kWh of energy below typical usage
- “SDG&E retains sole discretion for the calculation of the incremental load reduction”
- Cannot be a participant of other energy saving incentive programs
- Some customers were automatically enrolled including CARE and FERA customers

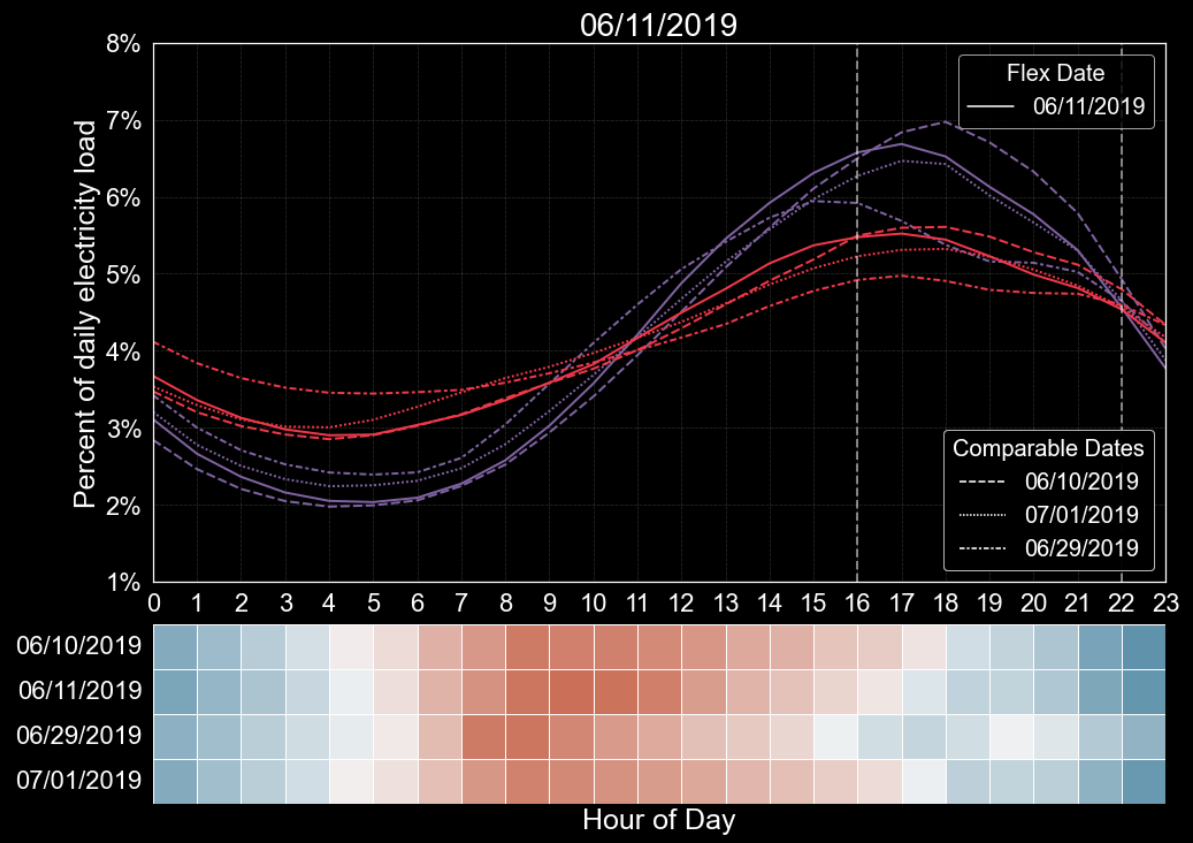
No observable fatigue in response over consecutive Flex Alert days

Flex Period response of the residential and total SCE load

Ramping response is less correlated with temperature than the Flex Period response

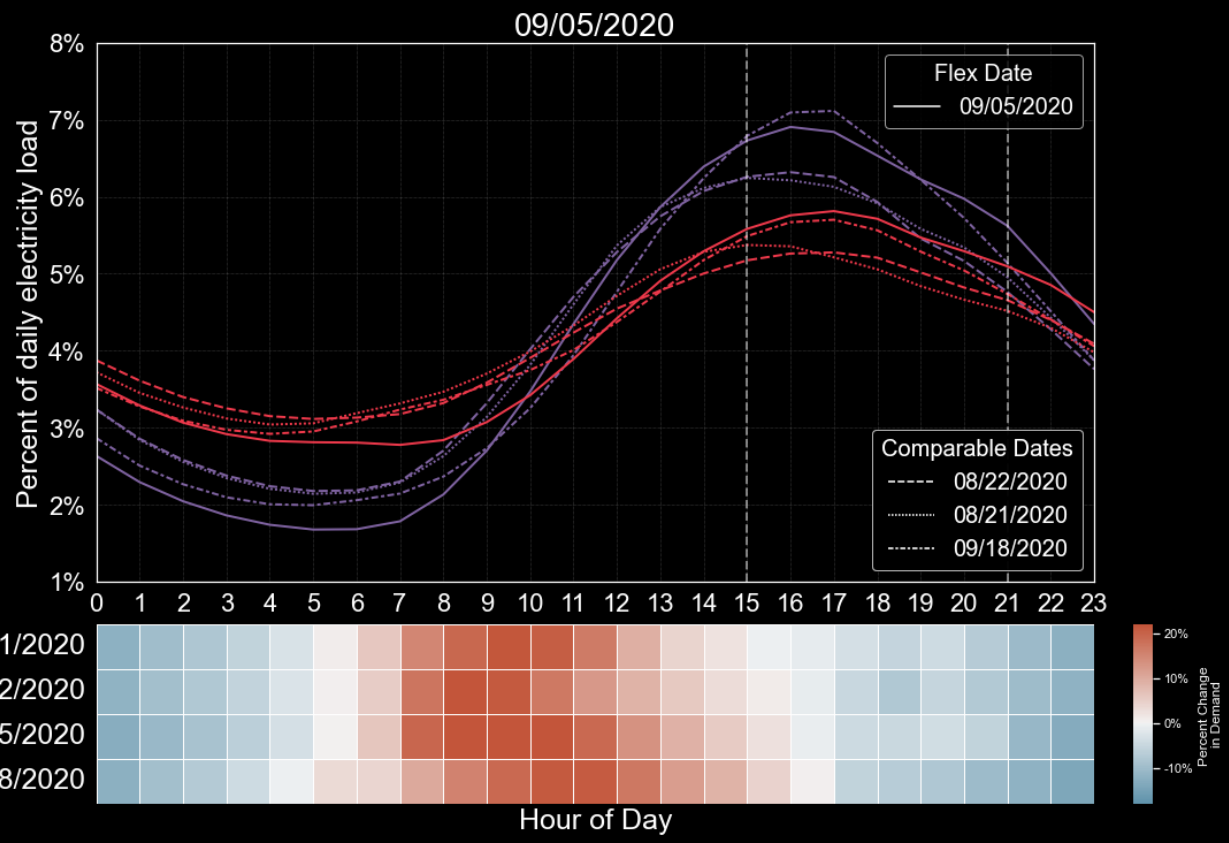


Flex Period response was on average positive on certain Flex Alert days



Residential
Flex Period Response: +2%
Ramping Response: 0%

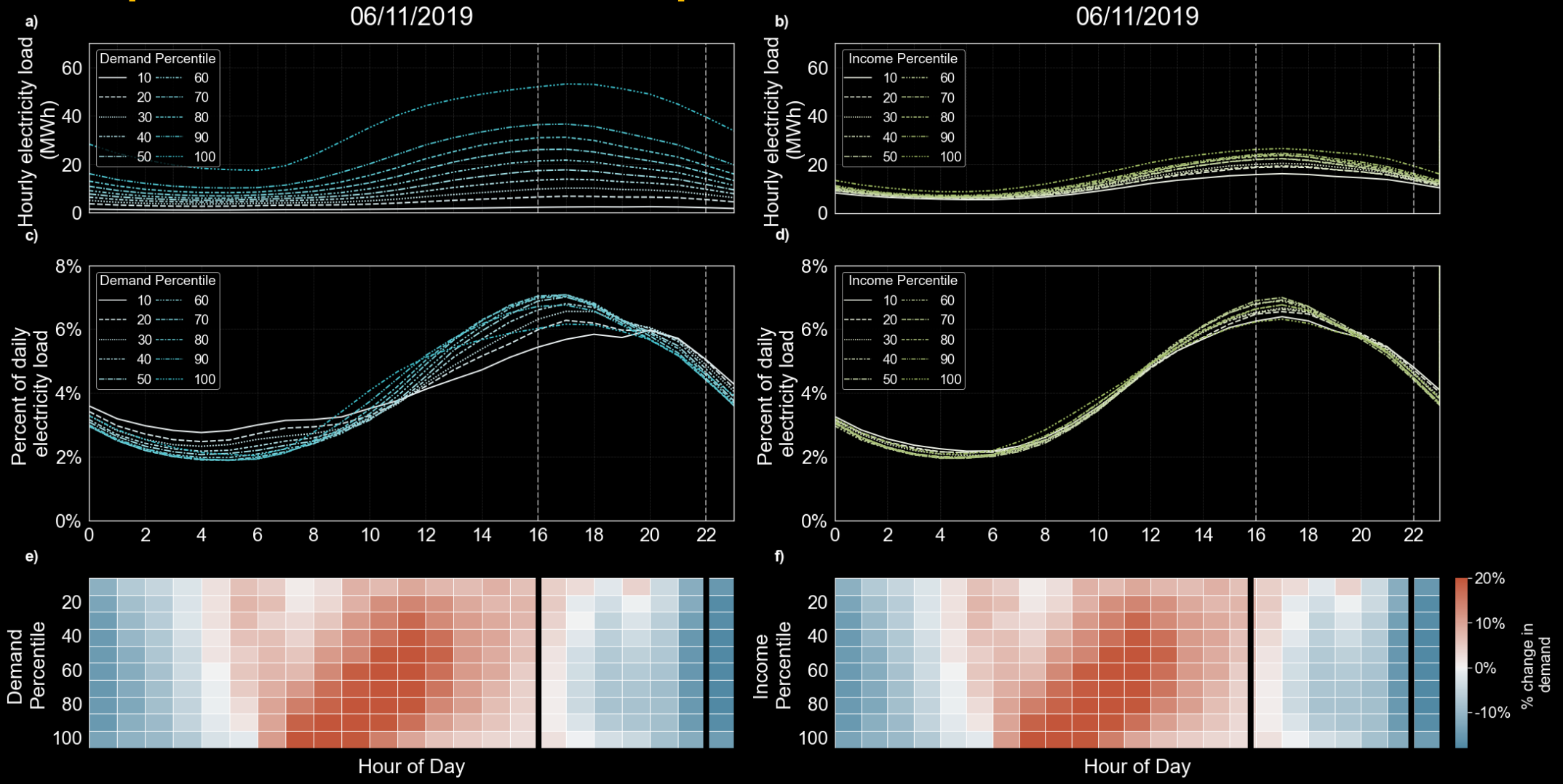
Total SCE
Flex Period Response: +1%
Ramping Response: 0%



Residential
Flex Period Response: +2%
Ramping Response: -2%

Total SCE
Flex Period Response: +2%
Ramping Response: +4%

High income and high demand customers are more responsive on days that overall had positive Flex Period Responses



Ramping and Flex Period Responses

			Residential SCE Load		Total SCE Load	
Date	Day of Week	Daily Max Temp (F)	Ramping Response	Flex Period Response	Ramping Response	Flex Period Response
6/30/2015	Tuesday	90.4	-9%	-11%	0%	-5%
7/1/2015	Wednesday	86.5	-1%	-11%	-2%	-7%
7/27/2016	Wednesday	93.3	-2%	-6%	0%	-4%
7/28/2016	Thursday	92.2	-1%	-5%	1%	-4%
7/24/2018	Tuesday	96.3	1%	-1%	2%	0%
7/25/2018	Wednesday	93.4	1%	-2%	2%	-1%
6/11/2019	Tuesday	92.5	0%	2%	1%	0%
8/14/2020	Friday	97.5	0%	-1%	3%	0%
8/16/2020	Sunday	94.9	-3%	-6%	-2%	-3%
8/17/2020	Monday	93.9	-1%	-2%	-1%	-2%
8/18/2020	Tuesday	102	-2%	-6%	-1%	-4%
8/19/2020	Wednesday	97.3	-1%	-6%	-1%	-4%
9/5/2020	Saturday	106.2	-2%	3%	2%	4%
9/6/2020	Sunday	108.3	-3%	-2%	-1%	0%
9/7/2020*	Monday	88	-7%	-18%	0%	-7%
10/1/2020	Thursday	99.7	-1%	-1%	2%	0%
10/15/2020	Thursday	94.2	1%	-2%	5%	-1%
Average response			-2%	-4%	1%	-2%
Median response			-1%	-2%	0%	-2%
Slope of response metric to temperature metric			0.01	0.69	0.01	0.53
r value of response metric to temperature metric			0.14	0.38	0.27	0.37

*Flex Alert fell on a federal holiday

We define two new metrics to evaluate the success of Flex Alerts

Because there is no ground truth for what demand would have been in the absence of a Flex Alert, we define a reference electricity scenario.