Systematic Evaluation of Distribution-Level Load Flexibility: A Large-Scale Experimental Approach

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Introduction

DR Program Descriptions & Motivation for Project

- **Smart Energy Program (SEP):** Operates through temporary thermostat adjustments (4 degree max.) which reduce AC usage & lowers electric demand during events; Approx. 89,204 customers in 2026
- **Summer Discount Plan (SDP):** Operates through installation of a remote-controlled device on the participant's air conditioning unit; During events, this device turns off or cycles the A/C unit; Approx. 137,212 res. & 5,769 non-res. customers in 2026
- **Data to inform Ex Ante growing more sparse** - Fewer events that didn't cover full 4-9 pm or 5-10 pm RA windows
- **However, SCE prefers to avoid customer fatigue**…too many events or events that are too long
- Also of note, **distribution value is highly concentrated**, and resources are available to dispatch at granular levels

DSA Developed an Op. Plan, where SCE could Explore Distribution-Level Dispatch & Enhance Ex Ante Models

- **Random subset of customers**; Others were "controls"
- **Temp. thresholds** were enabled to call events – Very Hot & Hot Days; Room for CAISO emergency events
- Roughly 10 groups per program; **Each group represented ~ 10% of total program pop.,** limiting customer fatigue (Dispatch was historically at territory-level or sublap-level)
- **Events spanned 1-4 hours**; ~ 10 events per program
- **Participants split into groups of A-Banks, B-Banks**
  - Note that A-Banks & B-Banks are groups of transformers within substations at different voltage levels. A-banks are at a higher voltage level and SCE has ~ 40 within its territory. B-Banks are at a lower voltage level and SCE has ~ 850 within its territory.

Unlocking Distribution-Level Demand Response

Research Questions

- Can DR be dispatched at **system/distribution levels**?
- Do **distribution events** drive real load reduction?

Approach

- 20 events across 2 DR programs
- **Randomized groups** (distribution level)
- Varied time, duration, weather conditions

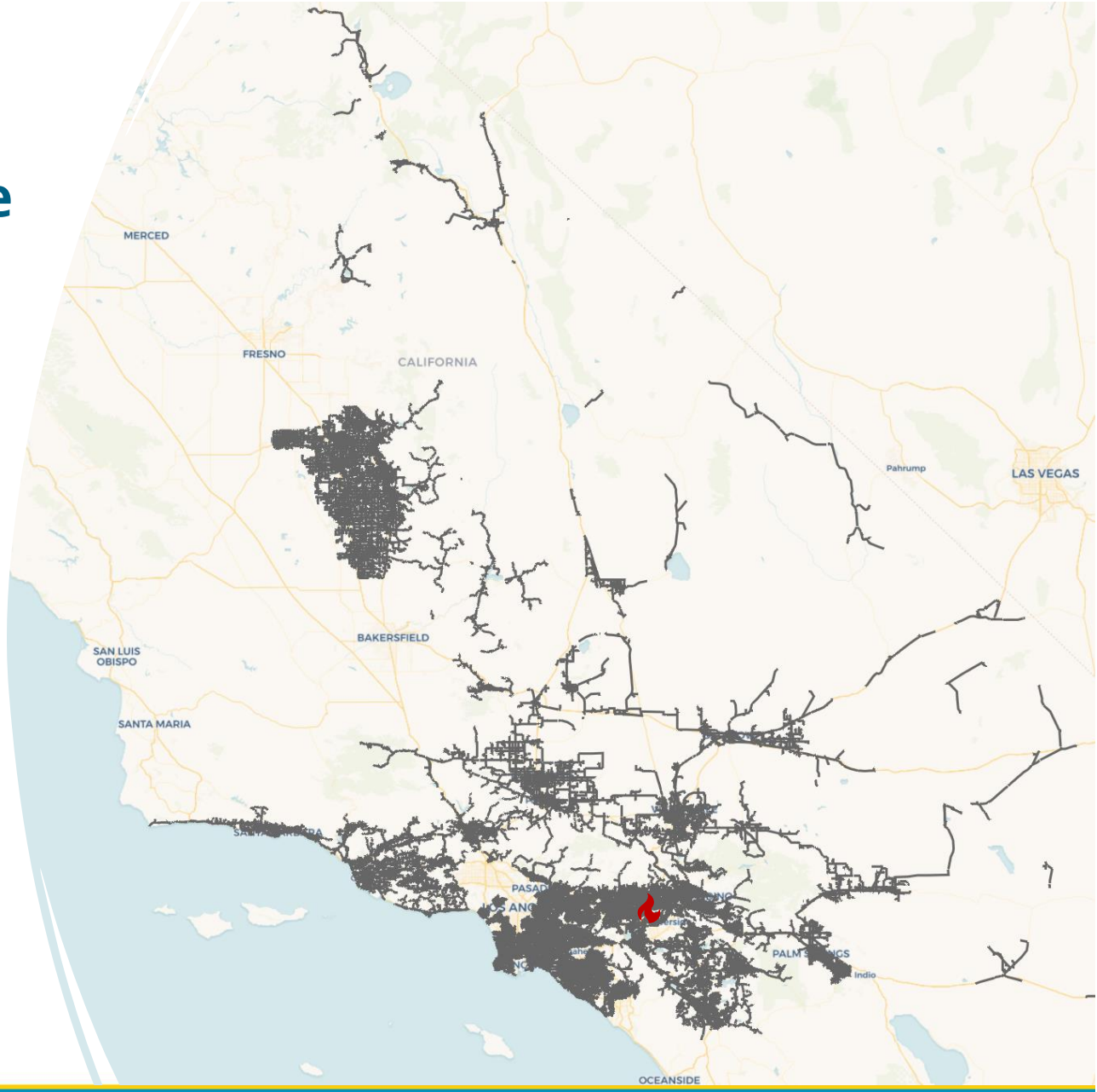
Findings

- **Reliable dispatch** at distribution level
- **Hotter weather → higher reductions**
- **Diminishing impact** over event duration
- **Concentrated results** in key substations

Distribution-level relief is becoming increasingly necessary, as shown by the Mira Loma localized emergency (September 2024).

Meanwhile, demand response events are becoming less frequent.

SCE and Demand Side Analytics (DSA) engaged in system level testing to test feasibility and measure distribution-level impact.



Demand Response has the capability to provide load relief for Transmission & Distribution operations

Load relief needs are heavily concentrated

Distribution value is concentrated in:

- Highly loaded locations
- Areas where growth is occurring

Capturing distribution value requires the ability to dispatch the resources:

- At the right location
- At the right times
- On the right days

Demand Response resources are available to dispatch at granular levels

Experimental Design

- Define groups at the A-Bank / B-Bank level
  - A-Bank
  - B-Bank
- Stratify bank groups by size and randomly assign one group of each size to one of 10 testing groups

Group	Number of Banks	Number of Bank Groups	Customer Count
1	43	10	9,096
2	61	10	8,464
3	45	10	8,003
4	49	10	8,360
5	51	10	8,516
6	63	10	8,284
7	39	10	8,594
8	48	10	8,071
9	39	10	8,844
10	33	9	9,155
Average	**47**	**10**	**8,539**
Total	**471**	**99**	**85,387**

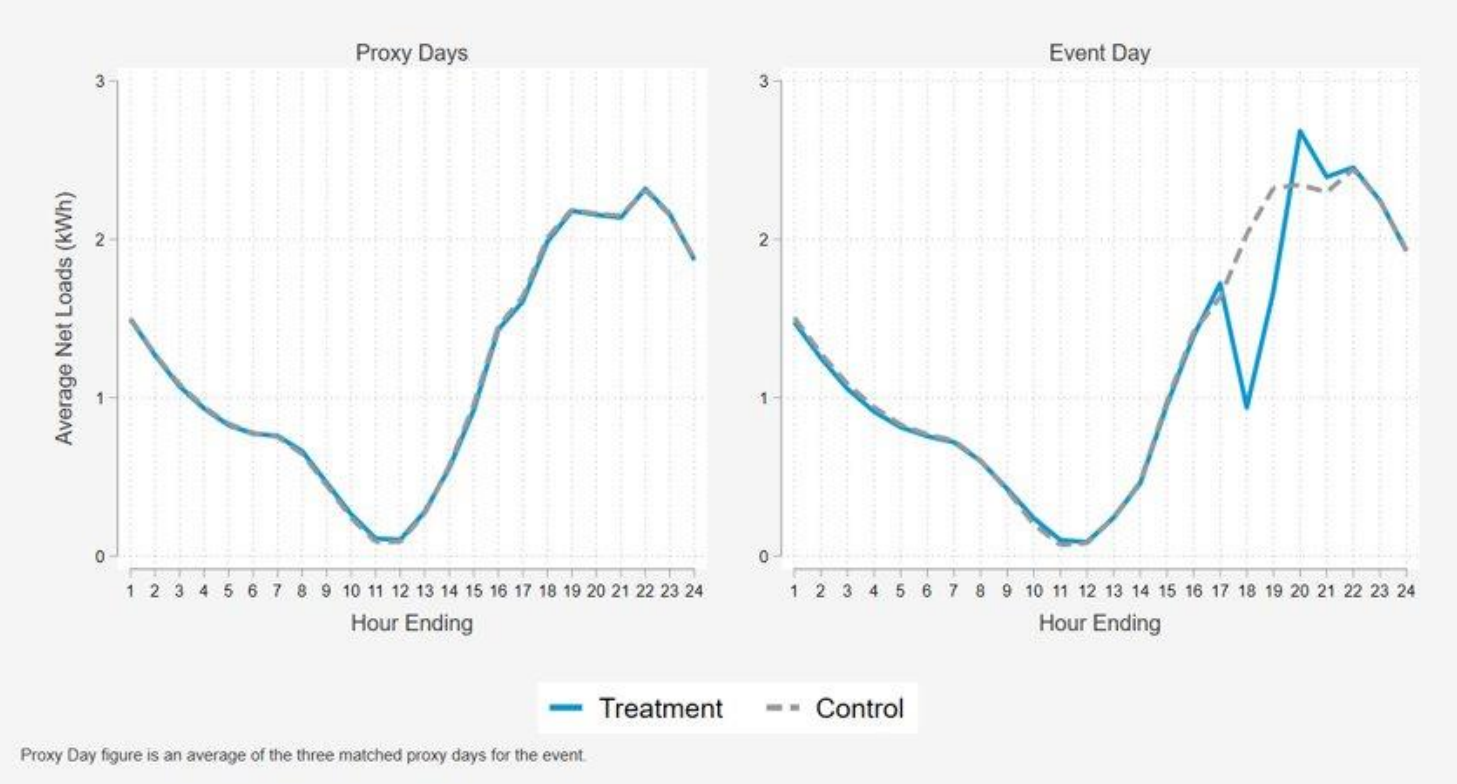
Condition Monitoring by DSA allowed for Variation in Weather, Event Start/End Time, and Duration across Events

- Incorporated daily weather forecasting to dynamically evaluate conditions and strategically time events
- Ran systematic event tests under varying heat conditions (hot and very hot), using different durations and start/end times to cover the full event window
- Considered customer fatigue when designing program

SEP Option						Hourly Coverage					Customer Dispatch		
Event	Weather	Test Element	Event Start	Event End	Group(s) dispatched	HE17	HE18	HE19	HE20	HE21	2 Hour Event	3 Hour Event	4 Hour Event
1	Very hot	Event start - 4 PM	4:00 PM	7:00 PM	1	1	1	1	0	0	0	1	0
2	Very hot	Event start - 5 PM	5:00 PM	8:00 PM	2	0	1	1	1	0	0	1	0
3	Very hot	Event start - 6 PM	6:00 PM	9:00 PM	4	0	0	1	1	1	0	1	0
4	Very hot	Event duration - 4 hour	4:00 PM	8:00 PM	3	1	1	1	1	0	0	0	1
5	Very hot	Event duration - 4 hour	5:00 PM	9:00 PM	5	0	1	1	1	1	0	0	1
6	Very hot	Event duration - 2 hour	5:00 PM	7:00 PM	6	0	1	1	0	0	1	0	0
7	Very hot	Event duration - 2 hour	7:00 PM	9:00 PM	7	0	0	0	1	1	1	0	0
8	Hot	Event start - 5 PM	5:00 PM	8:00 PM	8	0	1	1	1	0	0	1	0
9	Hot	Event start - 6 PM	6:00 PM	9:00 PM	9	0	0	1	1	1	0	1	0
10	Hot	Event duration - 4 hour	4:00 PM	8:00 PM	10	1	1	1	1	0	0	0	1

Finding #1: Granular Randomization can be a powerful tool

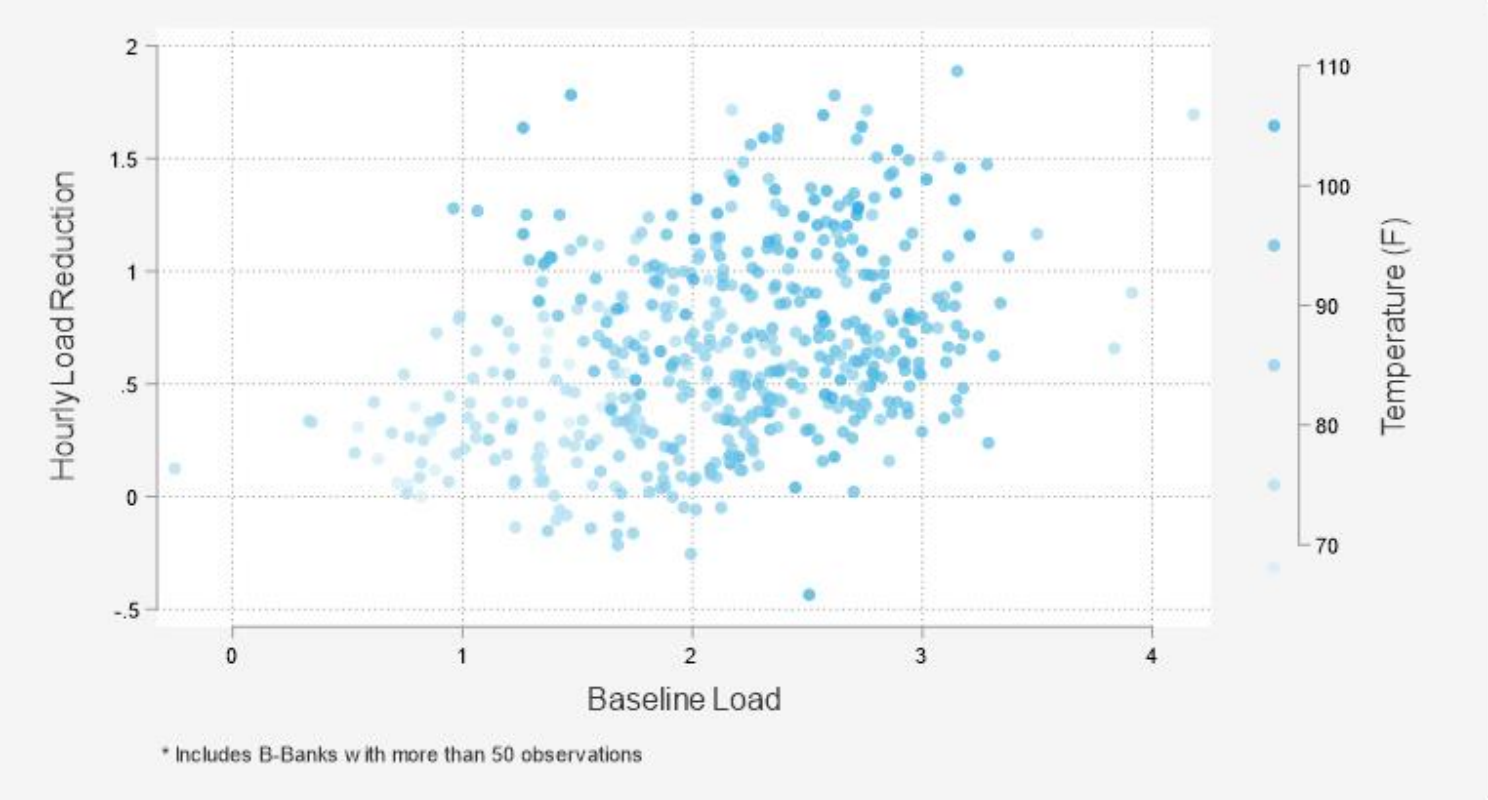
Observed Average Loads on August 6th and Matched Proxy Days for SEP Program[1]



- Control and treatment customers have identical loads on proxy days due to randomization and can be used to provide an unbiased estimation of impacts on the event day
- **Randomized non-dispatched program participants provide an ideal control group for analyzing each event, controlling for unobservable characteristics better than a matched control group**

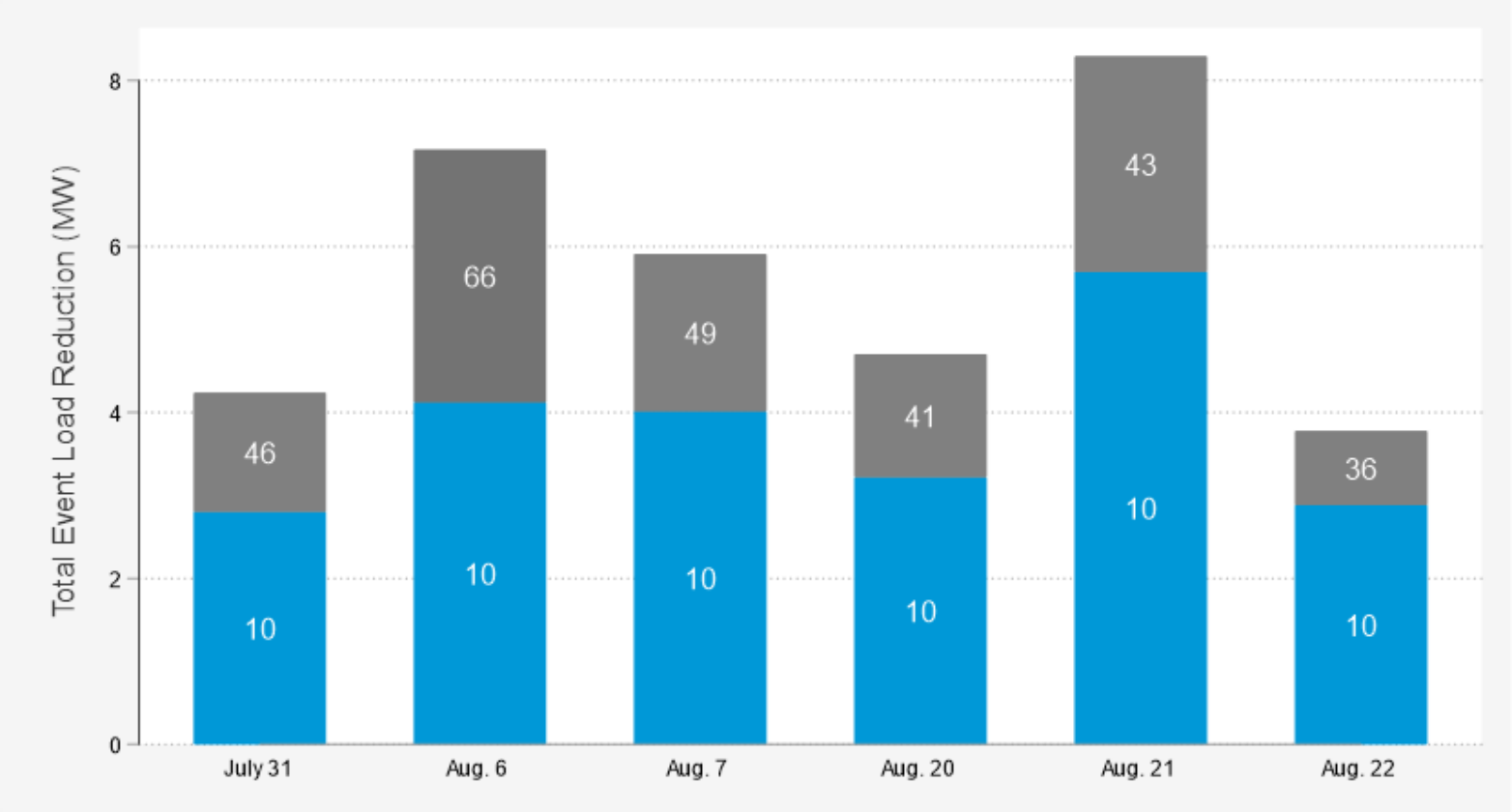
[1] Images are actual loads with no modeling.

Finding #2: Hotter temperatures are associated with higher loads and greater reductions



- For SEP, B-Bank level dispatching provides very granular data on load reductions and loads across a wide range of temperatures
  - Event temperatures range from 66F to 106F
- As expected, load and participants' ability to reduce load during events increases as temperatures increase
- Findings are consistent with SDP

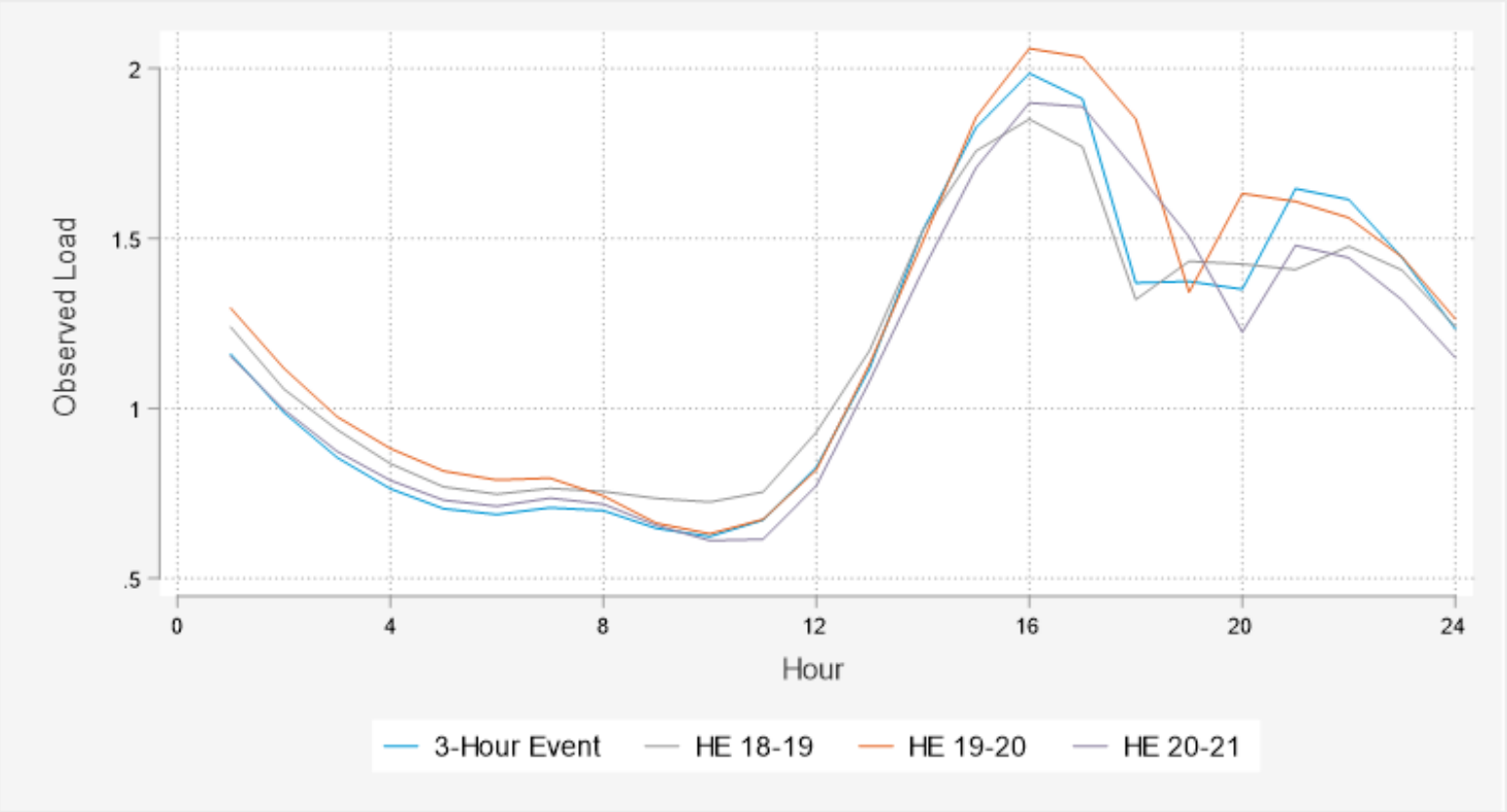
Finding #3: B-Bank Potential is Highly concentrated



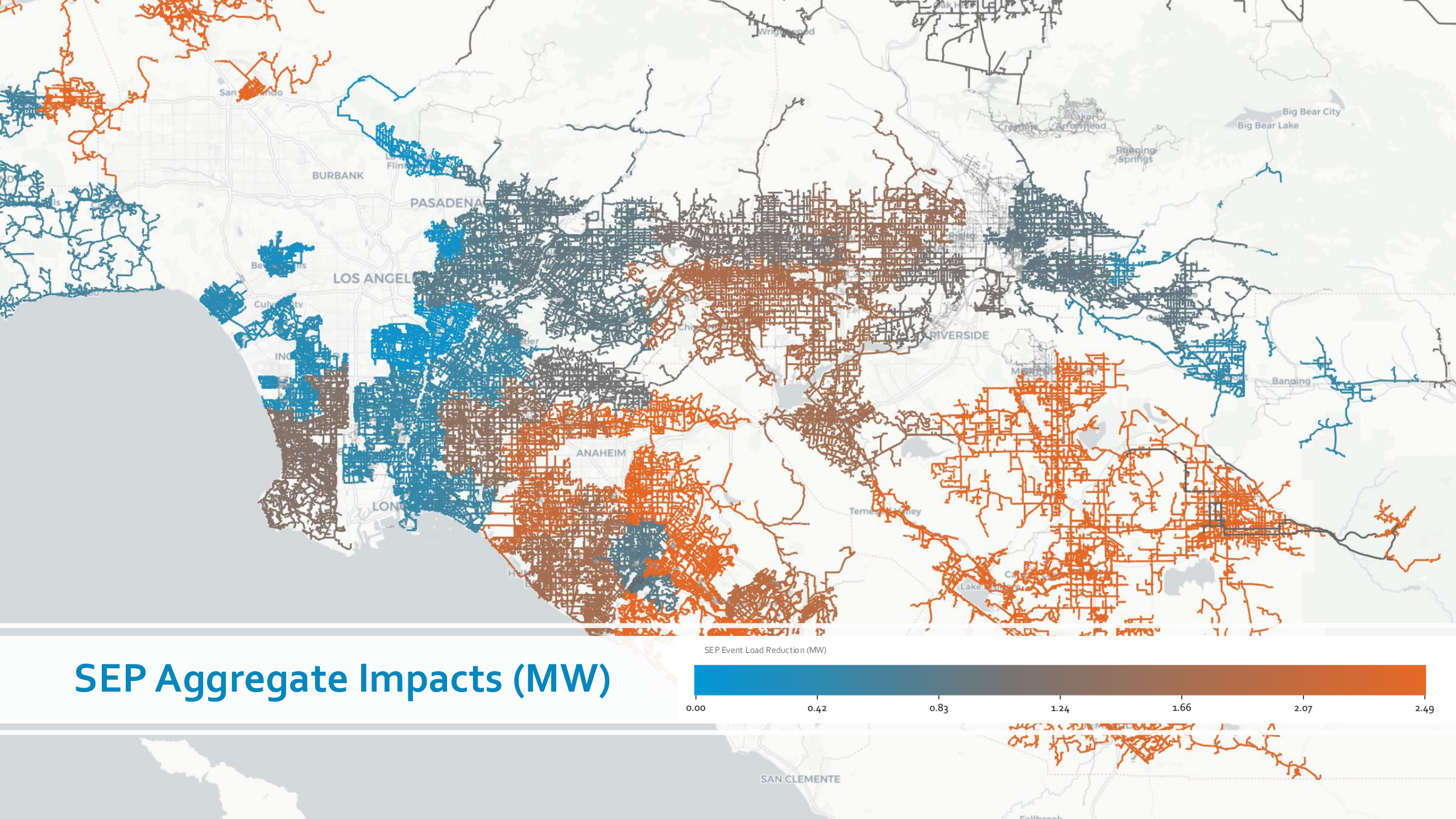
The top 10 B-Banks consistently provide more than half of the load reductions.

Event	Top 10 B-Banks	
	Percent of Customers	Percent of Load Reduction
July 31	60.6%	66.2%
August 6	50.2%	57.5%
August 7	64.4%	68.0%
August 20	54.1%	68.5%
August 21	61.7%	68.7%
August 22	69.2%	76.4%

Finding #4: Side-By-Side Testing



- September 17th dispatched four unique SDP events
  - Three 1-hour events
  - One 3-hour event
- Although four different groups of customers were dispatched, events delivered similar load reductions regardless of duration
  - A/C cycling programs are agnostic of thermostat setpoints

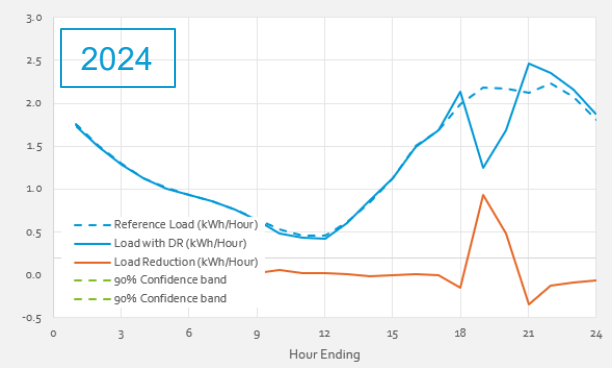


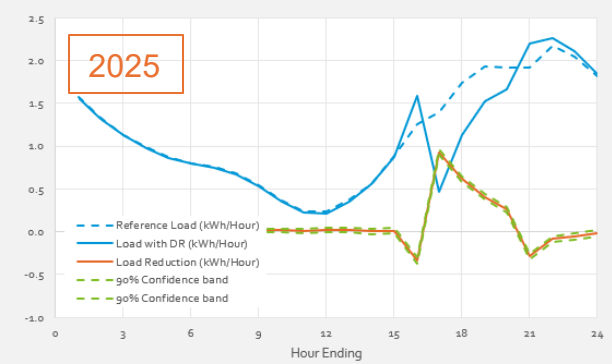
SEP Aggregate Impacts (MW)

Ex Post Average Event Day | 2024 vs. 2025 Comparison (SEP)

2024 78,771 avg. participants

Hour Ending	Reference Load (kWh/Hour)	Load with DR (kWh/Hour)	Load Reduction (kWh/Hour)	% Load Reduction	Avg Temp (°F, Site-Weighted)
1	1.76	1.74	0.02	1%	75.71
2	1.50	1.49	0.00	0%	74.56
3	1.29	1.29	0.00	0%	73.73
4	1.13	1.13	0.00	0%	72.56
5	1.02	1.01	0.01	1%	71.82
6	0.94	0.93	0.00	0%	71.19
7	0.86	0.86	0.00	0%	70.72
8	0.76	0.76	0.01	1%	70.77
9	0.65	0.63	0.02	3%	72.23
10	0.53	0.48	0.05	10%	74.74
11	0.46	0.44	0.02	4%	77.56
12	0.45	0.43	0.03	6%	80.30
13	0.61	0.60	0.01	2%	82.80
14	0.85	0.87	-0.02	-2%	84.89
15	1.12	1.12	0.00	0%	86.53
16	1.50	1.49	0.01	0%	87.78
17	1.68	1.69	-0.01	0%	88.13
18	1.99	2.13	-0.15	-7%	86.83
19	2.18	1.25	0.93	43%	85.35
20	2.17	1.68	0.49	22%	83.16
21	2.12	2.47	-0.35	-16%	79.98
22	2.23	2.36	-0.12	-6%	76.86
23	2.07	2.16	-0.08	-4%	75.09
24	1.81	1.87	-0.06	-4%	73.81





2025 7,764 avg. participants

Hour Ending	Reference Load (kWh/Hour)	Load with DR (kWh/Hour)	Load Reduction (kWh/Hour)	% Load Reduction	Avg Temp (°F, Site-Weighted)
1	1.57	1.56	0.02	1%	73.65
2	1.33	1.32	0.02	1%	72.30
3	1.13	1.13	0.00	0%	71.36
4	0.99	0.98	0.01	1%	70.43
5	0.87	0.86	0.01	2%	69.73
6	0.80	0.79	0.01	1%	69.20
7	0.76	0.75	0.01	2%	68.43
8	0.68	0.67	0.01	2%	68.25
9	0.54	0.52	0.02	3%	70.16
10	0.36	0.35	0.01	4%	73.36
11	0.23	0.22	0.01	4%	76.27
12	0.23	0.21	0.02	8%	79.31
13	0.37	0.35	0.02	6%	82.27
14	0.56	0.55	0.00	0%	84.85
15	0.88	0.88	0.01	1%	86.24
16	1.25	1.59	-0.34	-27%	86.65
17	1.40	0.47	0.93	66%	86.49
18	1.74	1.13	0.61	35%	85.37
19	1.93	1.52	0.41	21%	83.77
20	1.92	1.67	0.26	13%	81.93
21	1.91	2.20	-0.29	-15%	78.75
22	2.17	2.26	-0.09	-4%	76.38
23	2.05	2.10	-0.06	-3%	75.07
24	1.81	1.83	-0.02	-1%	73.91

Key Takeaways

- **Strengthened confidence in granular dispatch for dist. level events**
  - Tested a variety of event formats tailored to different temperature ranges, which increased understanding of future events/impacts
  - Potential load reduction is highly concentrated in select A & B Banks
- **Randomized Controlled Trial successful, gold standard for DR interventions**
  - Random groups of customers (10% of pop.) were dispatched during events, and the other 90% were modeled as controls
  - Results comparable to "non-participant" control groups methodology used in years past; And much less data collection was needed
- **SCE to continue to focus on granular event dispatch when applicable**
  - Gran. Dispatches - High potential in system reliability moving forward
  - Well-designed granular dispatches can be deployed to update datasets and bolster ex ante models at any time

Thank You!

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