

FRAMEWORK FOR QUANTIFYING FLEXIBLE LOAD AT THE DISTRIBUTION LEVEL

AEIC-WLRA CONFERENCE



Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS



TODAY'S AGENDA

- Background
- Tool methodology
 - Objective
 - Conceptual Approach
 - Input development
- Tool overview
- Demo



PACIFIC GAS & ELECTRIC



PG&E Territory

- 70,000 sq. mile service territory
- 26,000 employees
- Services 16+ million customers
- 5.5 million electric service accounts
- 4.5 million natural gas accounts
- 108,000 circuit miles of electric distribution lines
- 18,000 circuit miles of electric transmission lines
- 3,000+ feeders, 800+ substations, 16 distinct planning areas

Flexible Loads Landscape

- The California Energy Commission (CEC) adopted a statewide goal of 7,000 MW of load shifting or load flexibility by 2030
- 1 in 7 of all electric vehicles in the US is in PG&E's service area
- 1 in 5 of all solar rooftops in the US is in PG&E's service area

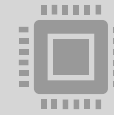


OBJECTIVES AND VALUE DRIVERS

VALUE DRIVERS

- The electricity industry is experiencing rapid technological change, particularly with distributed energy resources, connected loads, and electrification
- The California Energy Commission (CEC) adopted a statewide goal of 7,000 MW of load shifting or load flexibility by 2030
- Need to understand needs and flexible loads at specific grid locations
- Ability to compare flexible loads with other resource options
- Plan for the future, not the past

OBJECTIVES



Quantify flexible loads at specific grid locations



Model the cost of acquisition for flexible loads



Integrate flexible loads into planning (program, distribution, system)



TAKING A PHASED APPROACH

(1) Standardize buildings, end use load profiles, and segmentation

- What are the counts and loads by building type, customer segment, and climate zone?
- What is the magnitude of flexible loads by building type and location?
- How would flexible loads evolve?
- What share of flexible end uses can be shifted or reduced?
- How do the flexible loads vary by building type, customer segment, and sublap?

Tool to establish a common set of load profiles and the ability to identify and quantify flexible loads

(2) Developing granular flexible supply curves

- How likely are customer to adopt flexible load technologies?
- How likely are they to participate in programs?
- Is the customer and flexible load tech combination cost-effective?
- Where does the combination of customers and/or technology stack in the flexible load supply curve?

Tool to estimate achievable potential at a granular level and to produce supply curves

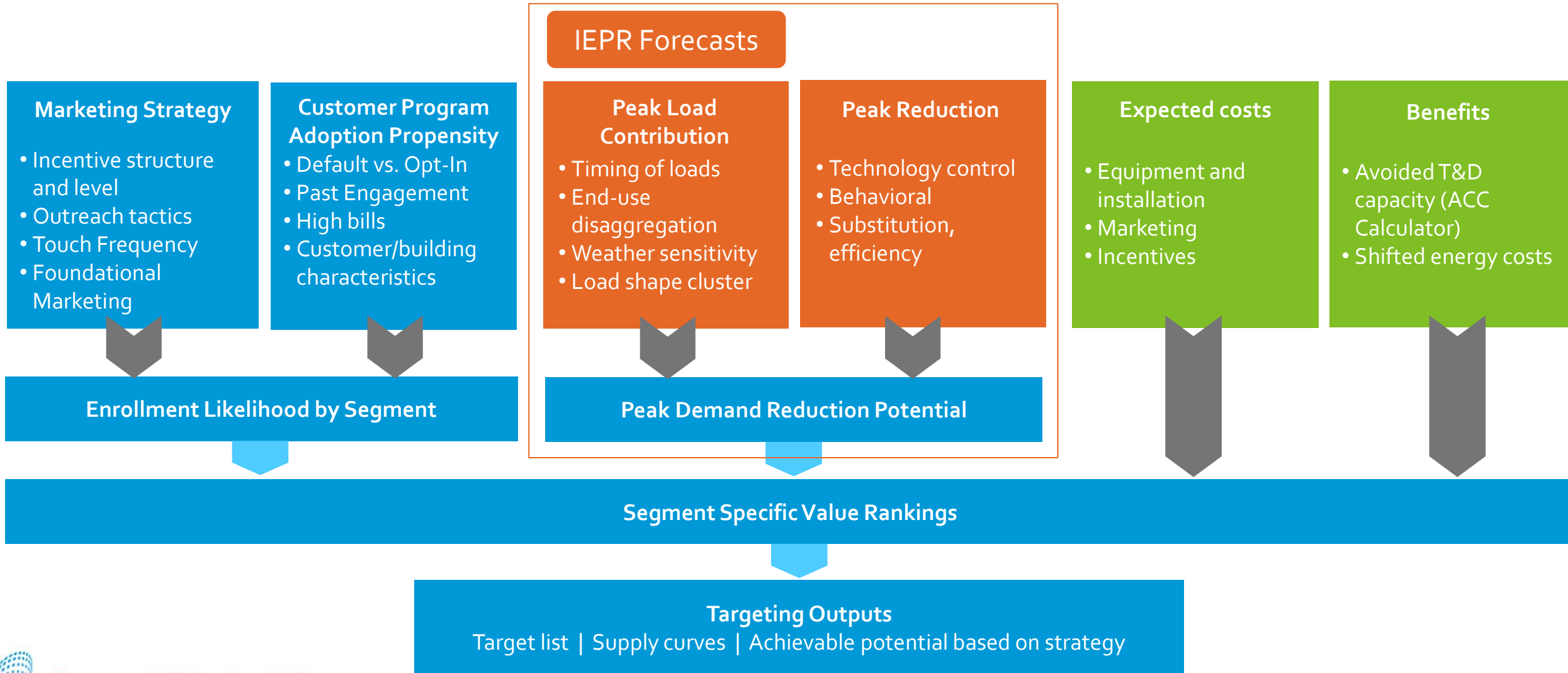
(3) Optimizing the mix and dispatch of flexible load resources

- What is the right portfolio mix of resources?
 - ✓ To manage loads at a specific location?
 - ✓ To maximize benefits?
- What is the right dispatch strategy for resources that can be scheduled/dispatched?

Resource mix and dispatch optimization module



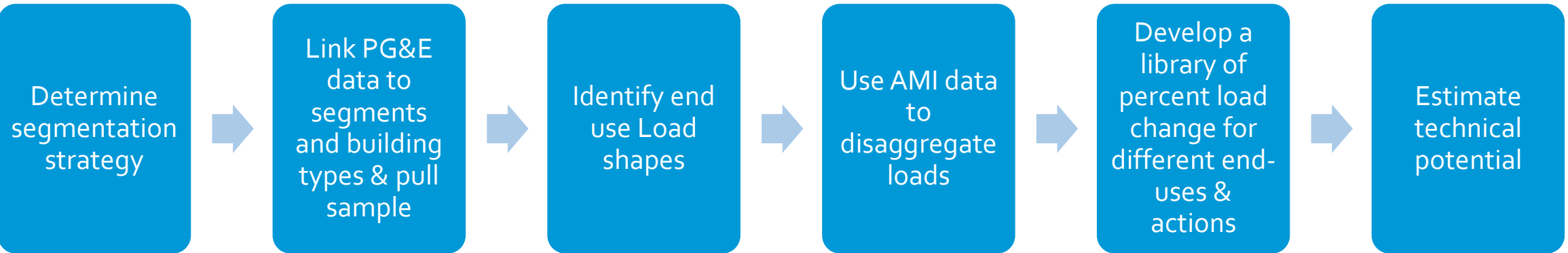
CONCEPTUAL FRAMEWORK



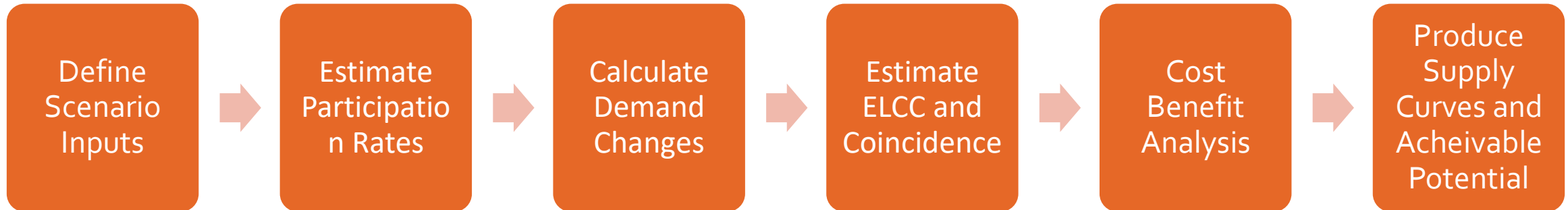
TECHNICAL POTENTIAL METHODOLOGY

INPUT DEVELOPMENT

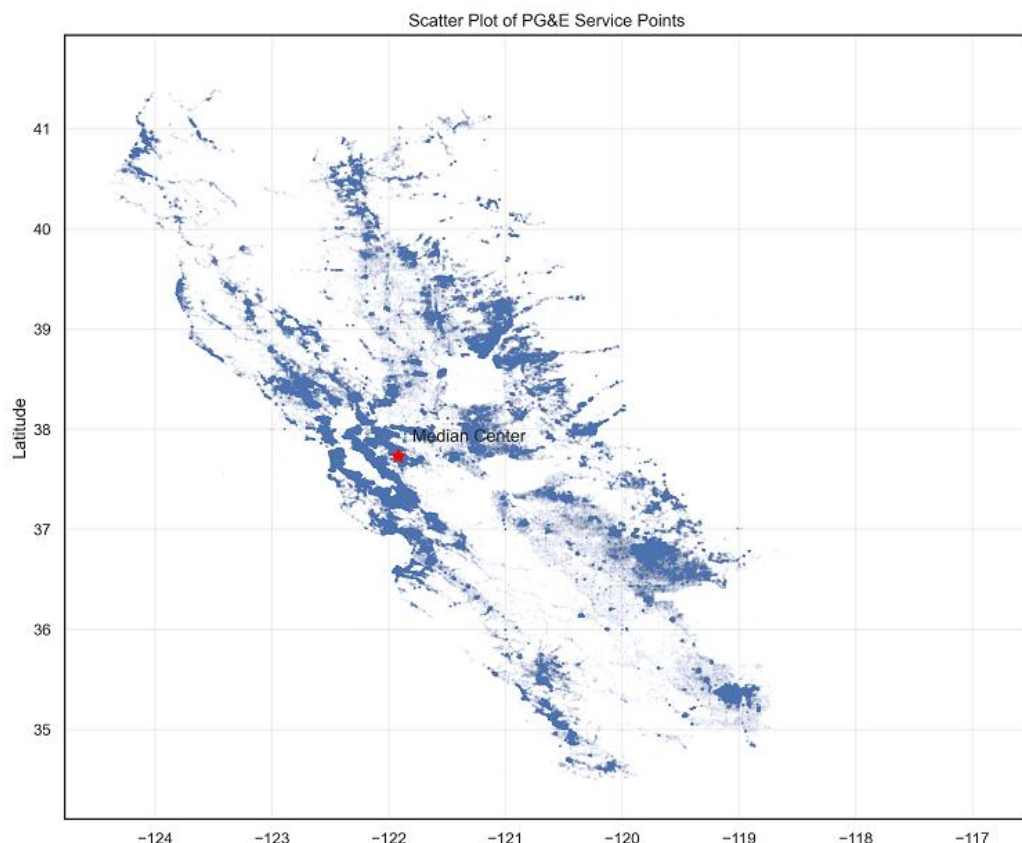
Technical Potential



Achievable Potential



DEVELOPING SEGMENTATION – HOW DID WE DECIDE TO CAPTURE A DIVERSE CUSTOMER BASE?



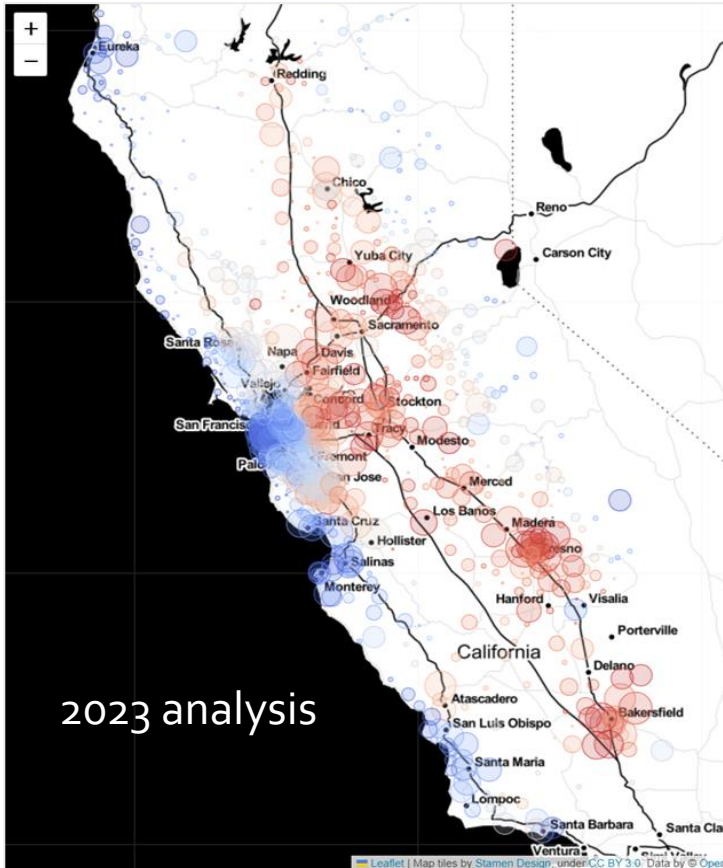
smalloffice-< 20 kW-PGSB	336
mediumoffice-20-200kW-PGSB	336
Other-< 20 kW-PGSB	312
Single Family Detached-4 - 2000-<3000-newer-PGSB	288
fullservicerestaurant-< 20 kW-PGSB	264
...	...
Multifamily 5+ Units-5 - Over 3000-<1950-PGSB	24
Multifamily 5+ Units-5 - Over 3000-1990-2000-PGSB	24
school-200-500kW-PGSB	24
Multifamily 5+ Units-4 - 2000-<3000-1990-2000-PGSB	24
Multifamily 2-4 Units-1 - Under 1000-newer-PGSB	24

- PG&E has a very wide and diverse customer base
 - Any segmentation needs to capture geographic diversity, temporal or weather diversity, and customer diversity
 - We linked PG&E customers to property data to view our catalogue of options
- Residential Customers are segmented by:
 - Location (sublap)
 - Building Type
 - Year built
 - Size of home
- Non-Residential Customers are segmented by:
 - Location (sublap)
 - Industry
 - Customer size (Demand)
- Result: ~3000 customer segments

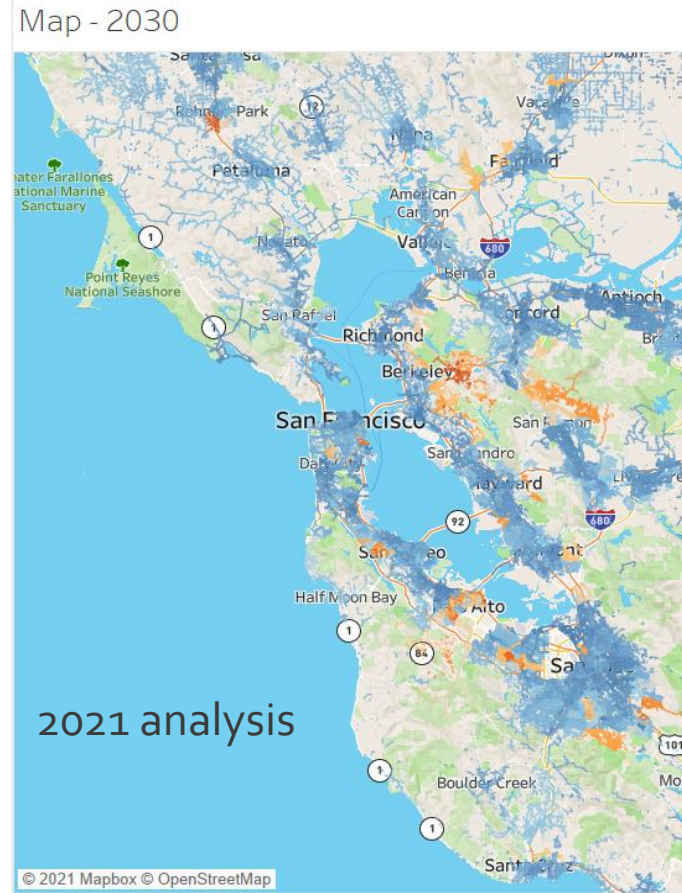


IDENTIFY SITES AND PROPENSITIES FOR SOLAR/STORAGE, ELECTRIC VEHICLES, AC, AND HEAT PUMPS

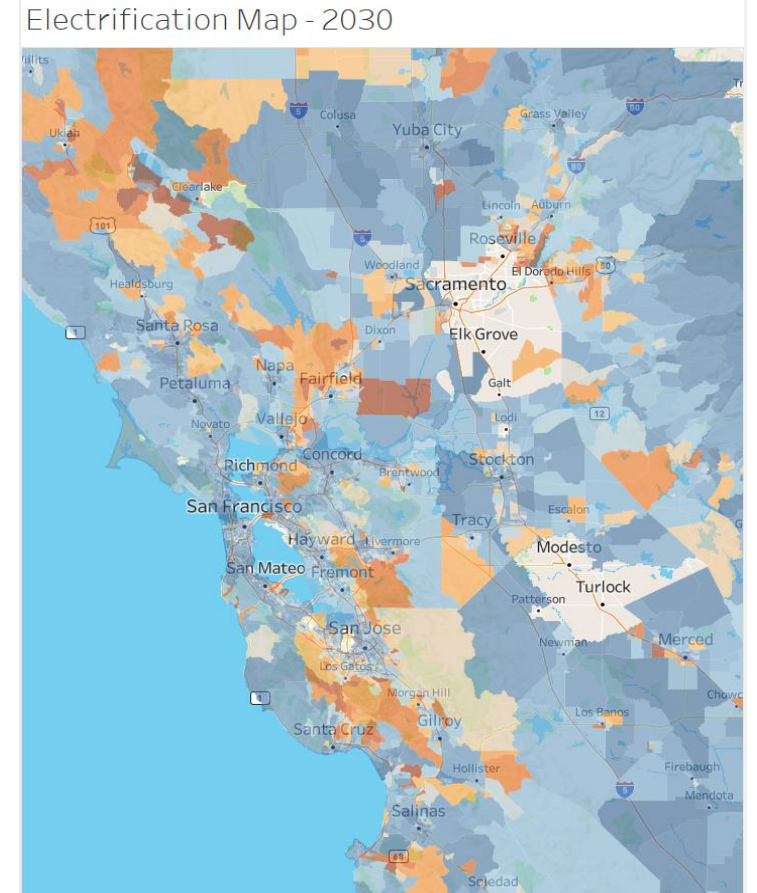
AC Loads for 4.8M Res Customers



EV adoption propensities



Heat pump adoption propensities



Rely on PG&E customer characteristics plus prior

IDENTIFYING PROPENSITIES

- A propensity score helps estimate adoption probability and distinguish early/late adopters

● Starting point (coefficient)

↑ Home owner

↑ Larger House

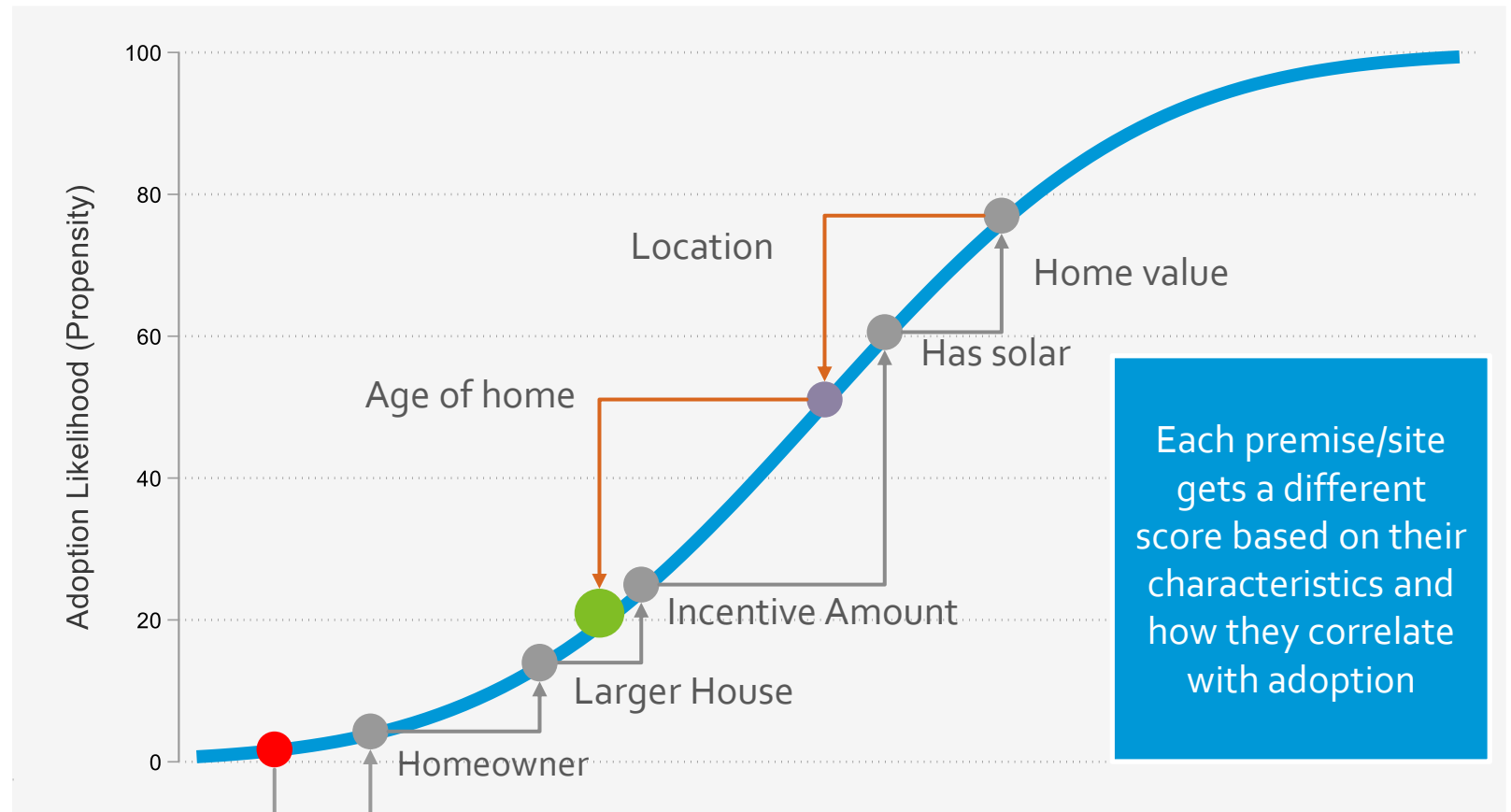
↑ Incentive amount

↑ Has solar

↑ Home value

↓ Location

↓ Age of home



END-USE DISAGGREGATION: SAMPLING AMI DATA

- Needed a large enough sample to be representative of the population
 - Large C&I customer loads were very influential on the system load: we census these guys
 - Smaller customers we assume that a 1% or floor of 100 customer is representative
 - If there are less than 100 customers in a segment, we pull the entire segment
- Resulted in pulling over 300,000 of the 5.5 million customers AMI data for the year of 2022

Pull out & census the large customers (500 kW and up)

Take a 1% fractional sample of a segment with a floor of 100 meters/premises per stratum/segment

Recombine the large customers

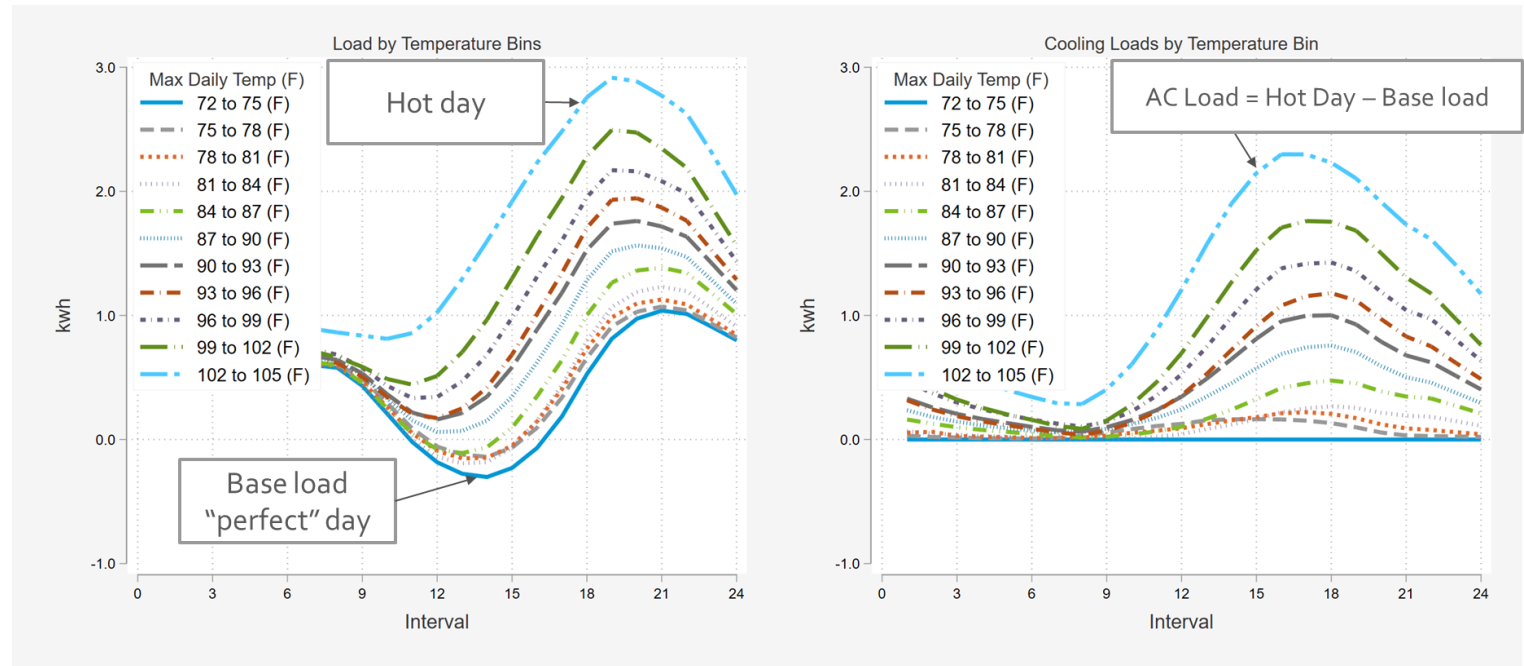
Calculate Population weights



DISAGGREGATE AMI DATA INTO END USES

- Implement end-use disaggregation for each customer segment based on large samples of AMI data, appliance saturation surveys, and end-use data
- Use site level estimated cooling/heating
- Rely on NREL end use profiles by county for other profiles
- Incorporate additional custom profiles (e.g., EVs')

Cooling Load Disaggregation (Illustrative)



LOAD DISAGGREGATION & DETERMINING END USES

Residential Load Shapes & Sources

End use	Candidate source	Flexible and sizeable?
Battery Storage	PG&E Tesla and LG data	Y
Clothes Dryer	NREL	Y
Clothes Washer	NREL	Y
Cooling	PG&E AC load estimates	Y
Dishwasher	NREL	Y
Heating	NREL	Y
Hot Tub Heater	NREL	Y
Hot Tub Pump	NREL	Y
Pool Pump	NREL	Y
Heat pumps	?	Y
Electric Vehicles	EV Lite Pro	Y
Water Systems – Water heaters	PG&E WatterSaver	Y
Well Pump	NREL	Y
Whole Building	PG&E AMI	Y
Bath Fan	NREL	
Ceiling Fan	NREL	
Cooking Range	NREL	
Ext Holiday Light	NREL	
Exterior Lighting	NREL	
Extra Refrigerator	NREL	
Fans Cooling	NREL	
Fans Heating	NREL	
Freezer	NREL	
Garage Lighting	NREL	
House Fan	NREL	
Interior Lighting	NREL	
Plug Loads	NREL	
Pool Heater	NREL	
PV (Solar)	PG&E Tesla /sunrun data	
Range Fan	NREL	
Recirc Pump	NREL	
Refrigerator	NREL	

Non-Residential Load Shapes & Sources

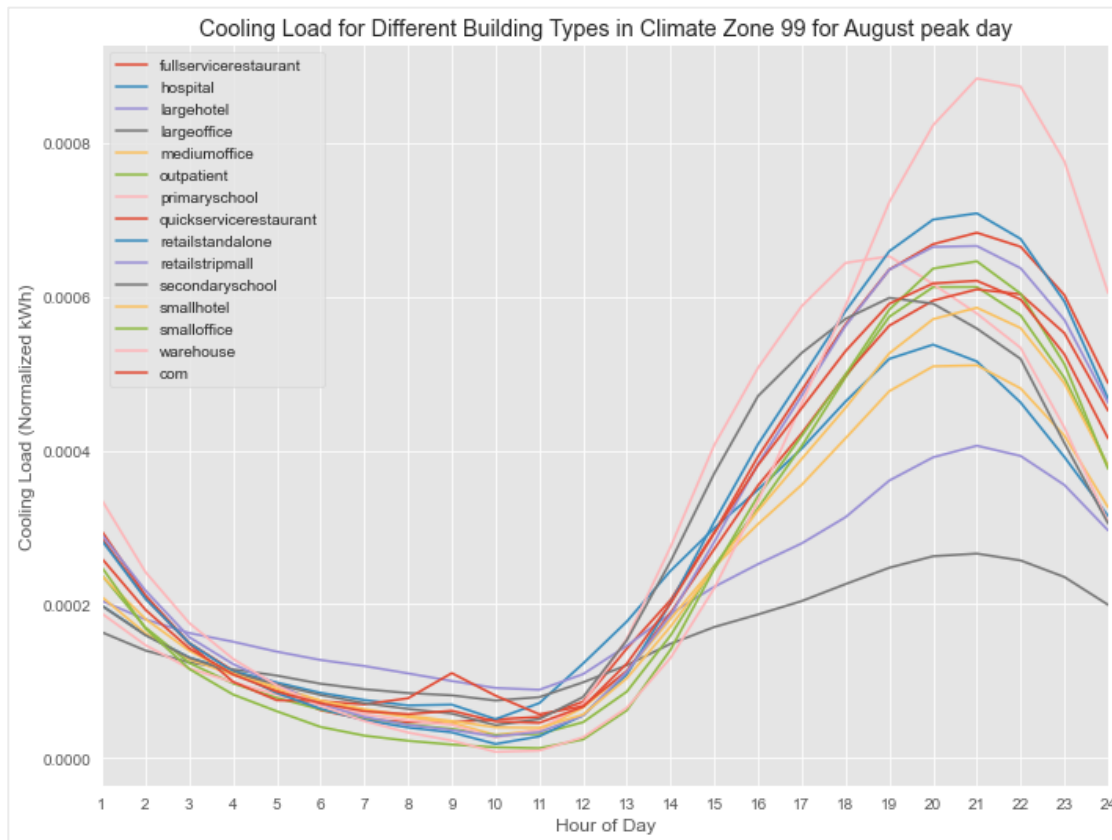
End use	Candidate source	Flexible and sizeable?
Battery Storage	PG&E Tesla and LG data	Y
PV (Solar)	PG&E Tesla /sunrun data	
Exterior Lighting	NREL	Y
Interior Lighting	NREL	Y
Fans	NREL	Y
Heat Recovery	NREL	
Heat Rejection	NREL	
Heating	NREL	Y
Interior Equipment	NREL	Y
Interior Lighting	NREL	Y
Pumps	NREL	Y
Refrigeration	NREL	
Water Systems	NREL/PG&E AMI	Y
Whole Building	PG&E AMI	Y
EV Charging	EV Lite Pro	

Use Utility built shapes where available: AC, Solar, EV, Storage, HP, HPWH
 Fill in base loads with NREL Comstock and Restock Load Shapes

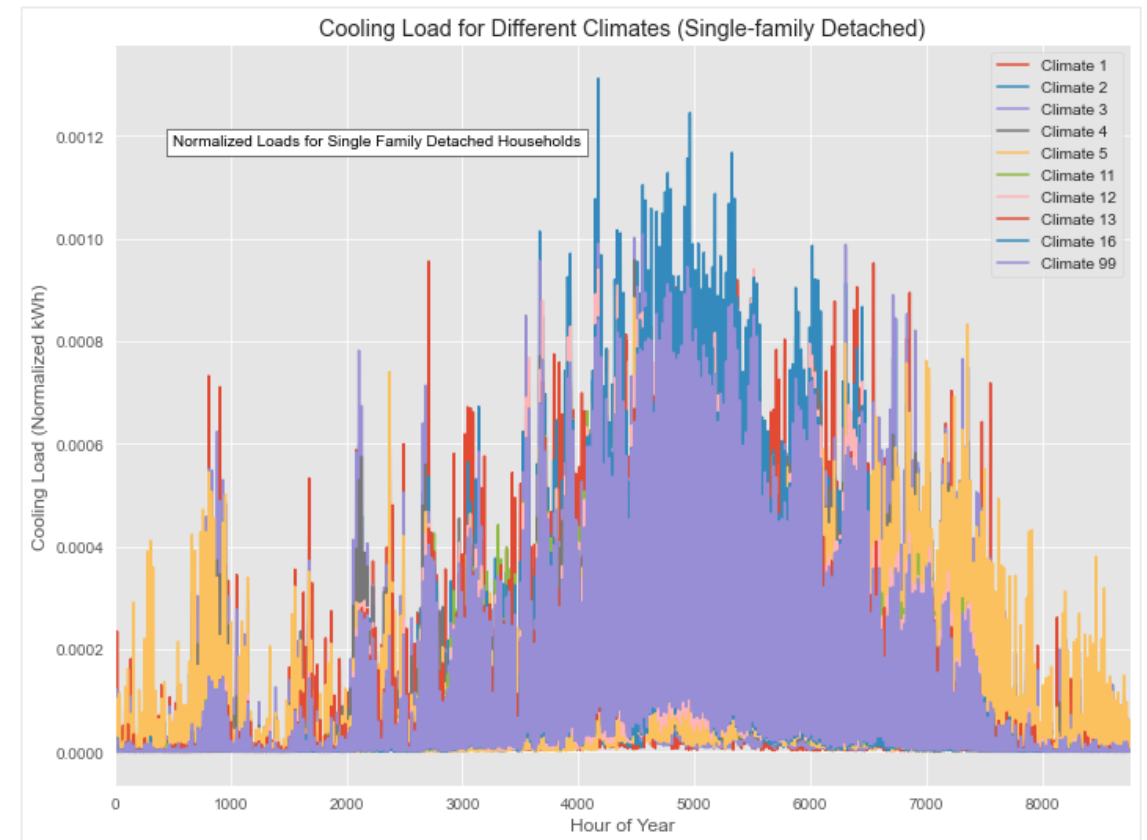


NREL END USE LOAD SHAPES VARY BY LOCATION AND BUILDING TYPES

Cooling Load Shapes by Building Types

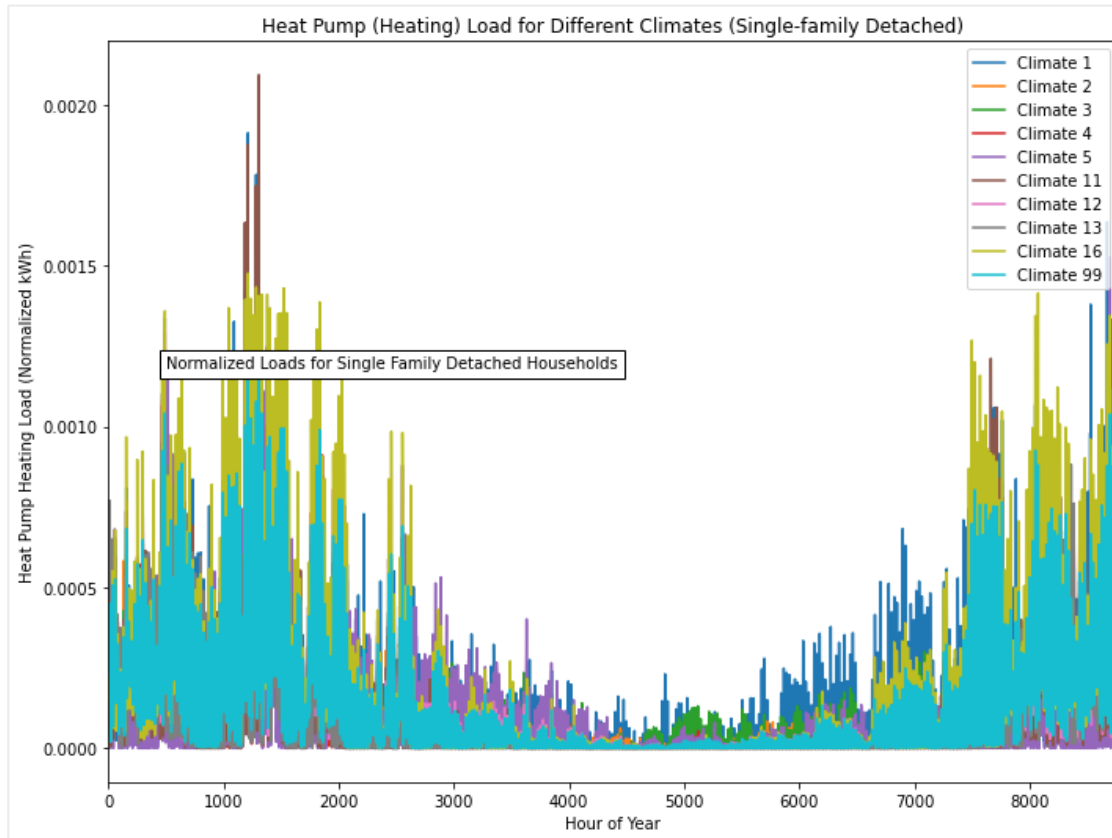


Cooling Loadshapes by Climate Zones

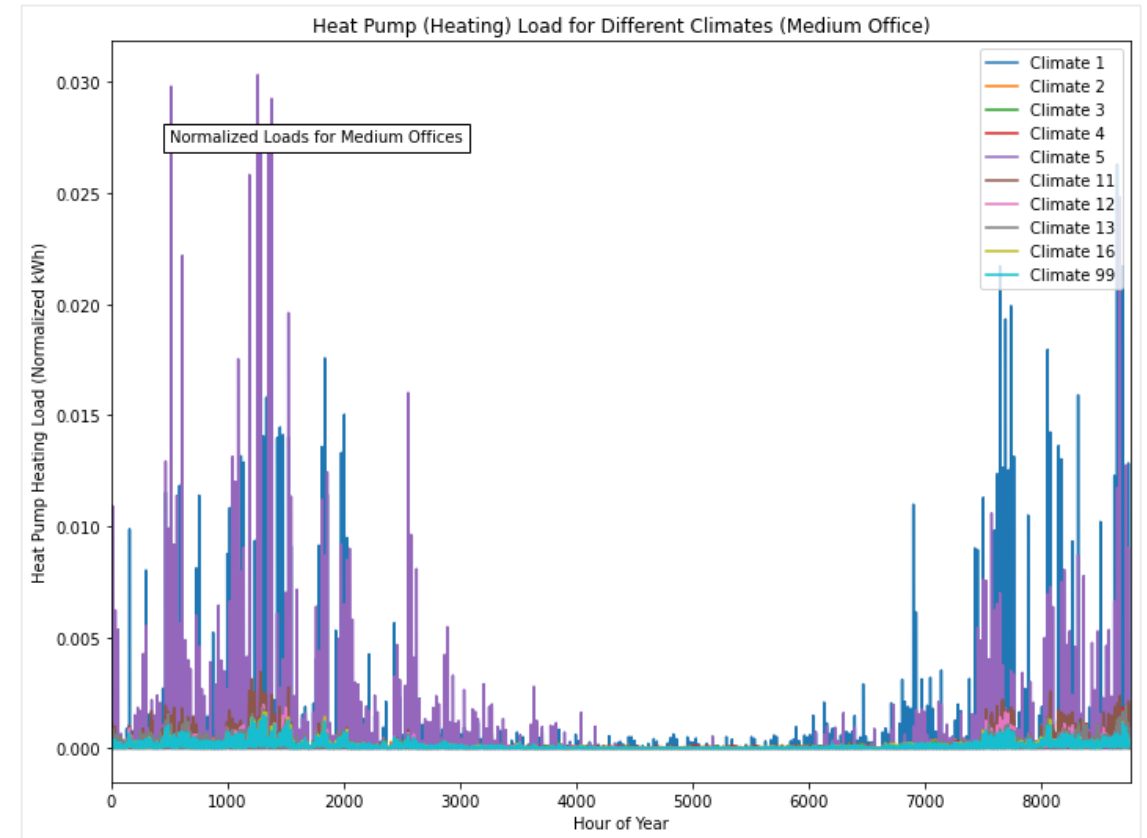


NREL HEATING 8760 SHAPES EXAMPLE

Residential



Non-Residential



LOAD DISAGGREGATION PROCESS

- Load NREL shapes: Pull in ResStock and ComStock normalized shapes
- Match to each customer merging on building type, sublap, peak type
- Scale by gross load:
 - Multiply every normalized end-use share by customers hourly gross disaggregation load as well as end-use saturation
 - This process distributes total consumption across end-uses while conserving the hourly total

Identify Representative peak Days: Summer, winter, local, and minimum load

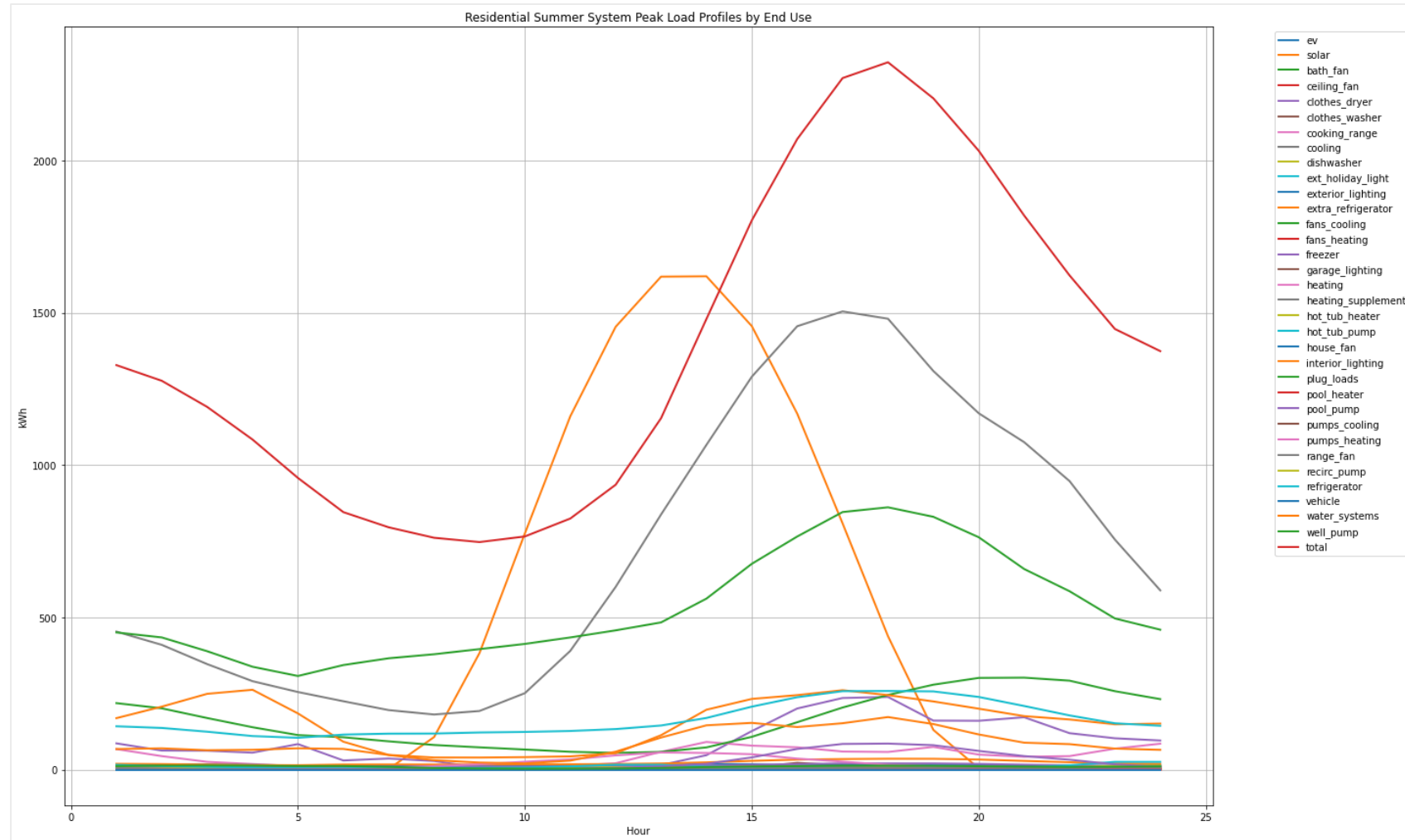
Back out BTM DERs: Add solar & battery back, subtract EV load

Apply NREL end-use shares: Scale the gross load into end uses

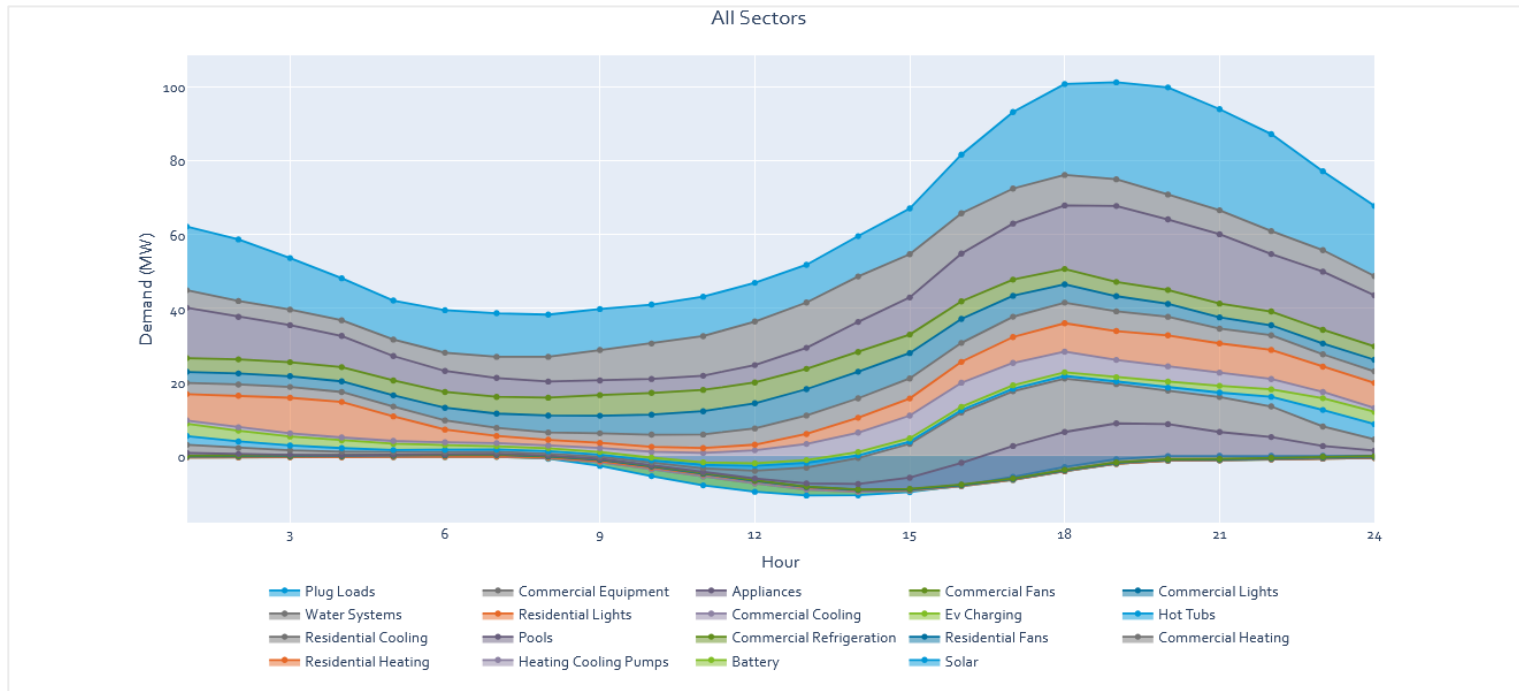
Aggregate by segment



LOAD DISAGGREGATION RESULTS IN HOURLY LOAD PROFILES FOR A GIVEN SEGMENT



OUR SEGMENTATION & HOURLY PROFILES GIVE US A METHODOLOGY TO BUILD BACK UP END USE LOADS AT THE DISTRIBUTION LEVEL



- For each Feeder we have:
 - A Year (For Forecasts)
 - A Peak Type
 - A mix of Segments
 - The number of customers in a segment
 - The amount of customer expected to adopt a technology
- Multiplying the segment counts in a feeder to the load profile gives us the end-use make up for a Feeder, Substation, Sublap all the way up to the System



DEVELOP LIBRARY OF % REDUCTIONS BY END USE

Example for RTP conjoint study

Day Shifting	Residential (General, PV, & DR)	Residential EV	Residential PV+ES	Small and Medium Business (General, PV, & DR)	Agricultural (General, PV, & DR)
Behavioral Shift (Top 10 Days)	PG&E SmartRate	PG&E SmartRate	PG&E SmartRate	PG&E Peak Day Pricing	PG&E Peak Day Pricing
Behavioral Shift (Daily)	PG&E Opt-in TOU Pilots	SDG&E EV TOU	SDG&E EV TOU	PG&E Peak Day Pricing	PG&E Peak Day Pricing
Automated Response (Scaled based on whether moderate or substantial)	PG&E SmartAC BYOT (TOU + Event Impacts)	PG&E EV ADR Study	PG&E Tesla VPP Study	SDG&E Small Commercial CPP and Commercial Technology Deployment Program	SCE Agricultural Pumping Interruptible Program

- Pull PG&E specific data from various:
 - ✓ Program evaluations
 - ✓ Emerging tech pilots
- Supplement with other California data available
- Supplement with data from outside of California



ESTIMATE TECHNICAL POTENTIAL

$$\text{Technical Potential} = \sum_{seg=1}^n \sum_{use=1}^n \left[\begin{array}{l} \text{Number of} \\ \text{sites with end} \\ \text{use equipment} \end{array} \right] \times \left[\begin{array}{l} \text{End use} \\ \text{equipment load} \\ \text{coincident with} \\ \text{selected hours} \end{array} \right] \times \left[\begin{array}{l} \% \text{ reduction (or} \\ \text{shift) in end use} \\ \text{equipment load} \end{array} \right]$$

- Does not include adoptions rates (Phase II)
- Does not include costs or benefit cost screening (Phase II)

HOW DO WE USE THIS?

TOOL FUNCTIONALITY

1

Select specific building types, sublap, and/or customer segments

2

Visualize the load profiles and changes in load profiles

3

Identify the flexible loads and the technical capacity to reduce or shift loads (ignoring participation & cost-effectiveness)

4

Identify the cost-effective achievable potential

5

View Supply Curves and the Achievable Capacity of Demand Management Scenarios

6

Create Demand Management Scenarios for Achievable Potential

7

Add, update, and create specific interventions that reduce, or shift loads to the library

8

Export & visualize results



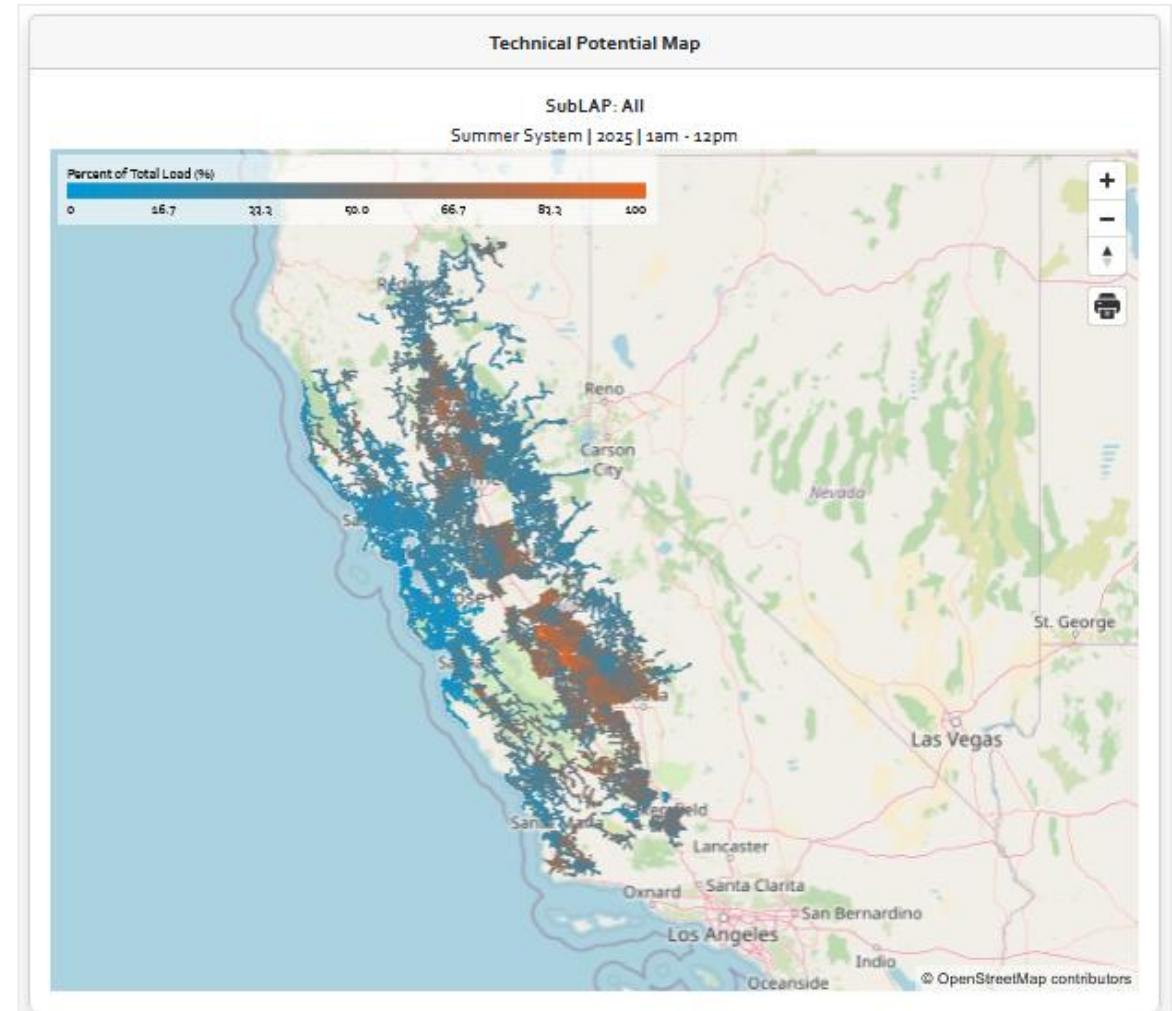
FLEXIBLE LOAD TOOL MODEL OVERVIEW

■ Purpose

- Catalog and model current and future load flexibility opportunities
- Model expected costs for acquiring flexible load and quantify the amount

■ Key Functions

- Comprehensive evaluation of achievable flexible load capacity across technologies, customer segments, and locations
- Scenario modeling and supply curve generation depending on inputs
- Granular analysis from system level down to specific circuits and customer segments



KEY QUESTIONS THE FLEXIBLE LOAD TOOL ANSWERS

What are the counts and loads by customer segment, and location?

What is the magnitude of flexible loads at a location by customer segment and building type?

How would flexible loads evolve as electrification increases?

By how much can the flexible demand be reduced?

How likely are customer to adopt flexible load technologies?

How likely are specific customer segments to participate in programs, and how do incentives and marketing intensity impact participation?

Is the customer and flexible load tech combination cost-effective?

Which specific customer segments or interventions are more cost-effective?

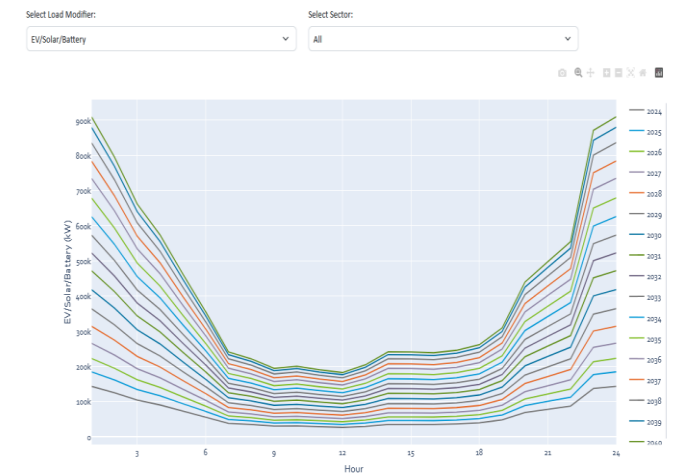
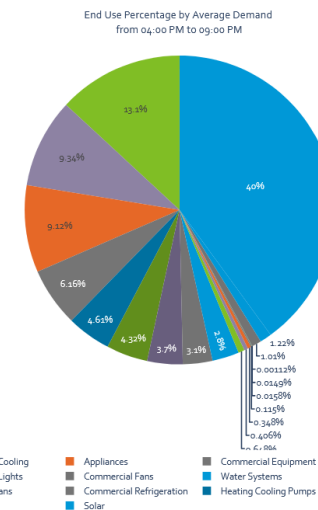
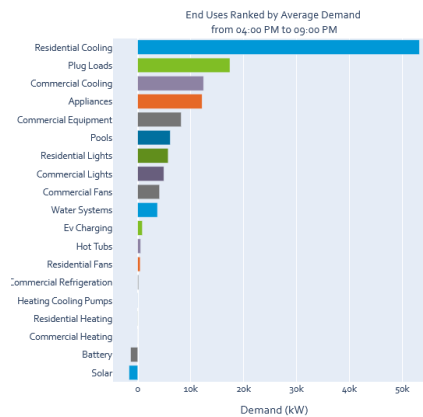
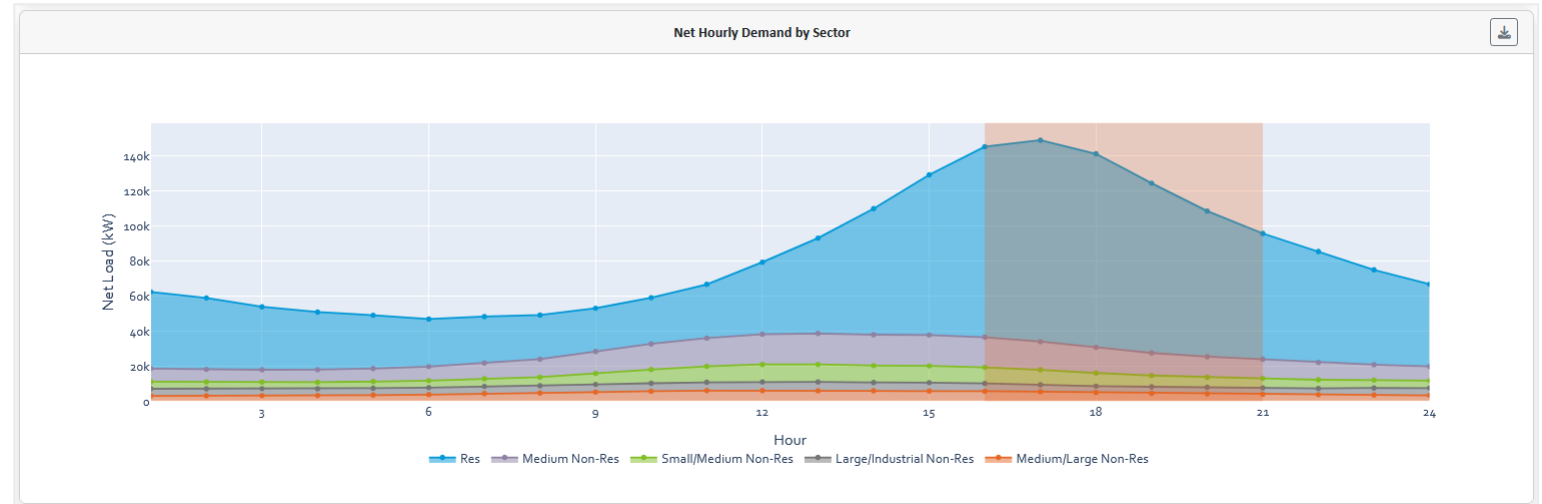
Where does the combination of customers and/or technology stack in the flexible load supply curve?

What is the cost to achieve different levels of flexible load targets?

EXISTING TOOL MODULES

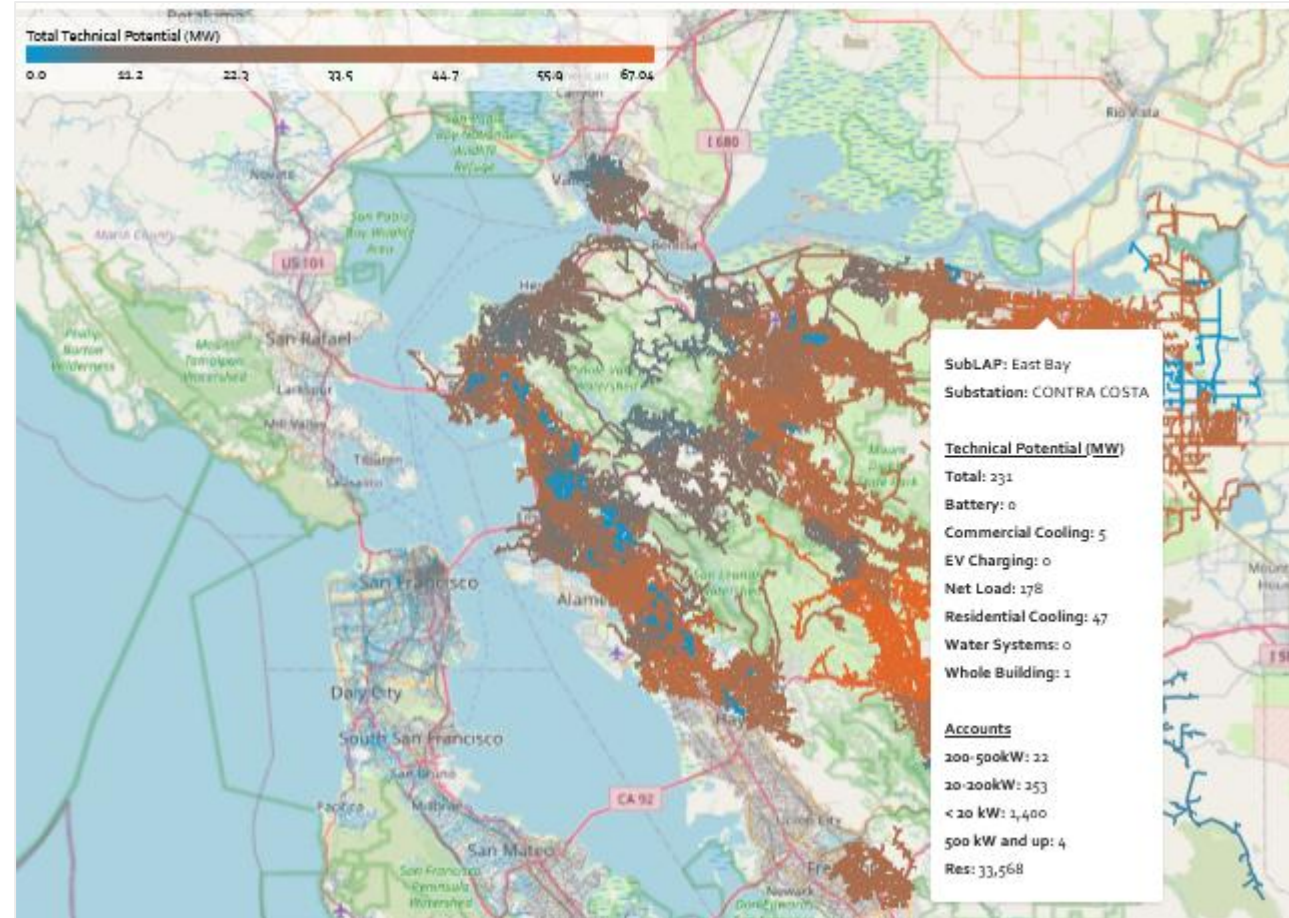
LOAD AND CUSTOMER MIX – LOAD COMPOSITION AT A GEOGRAPHIC LOCATION

- Useful for understanding load patterns within a selected location – system, sublap, substation, or feeder – for the year, season, and hour selected
- Which customer (rate) classes are contributing to the location's peak?
- Which end-uses are contributing to the location's peak?
- How are end-uses projected to evolve at the location?



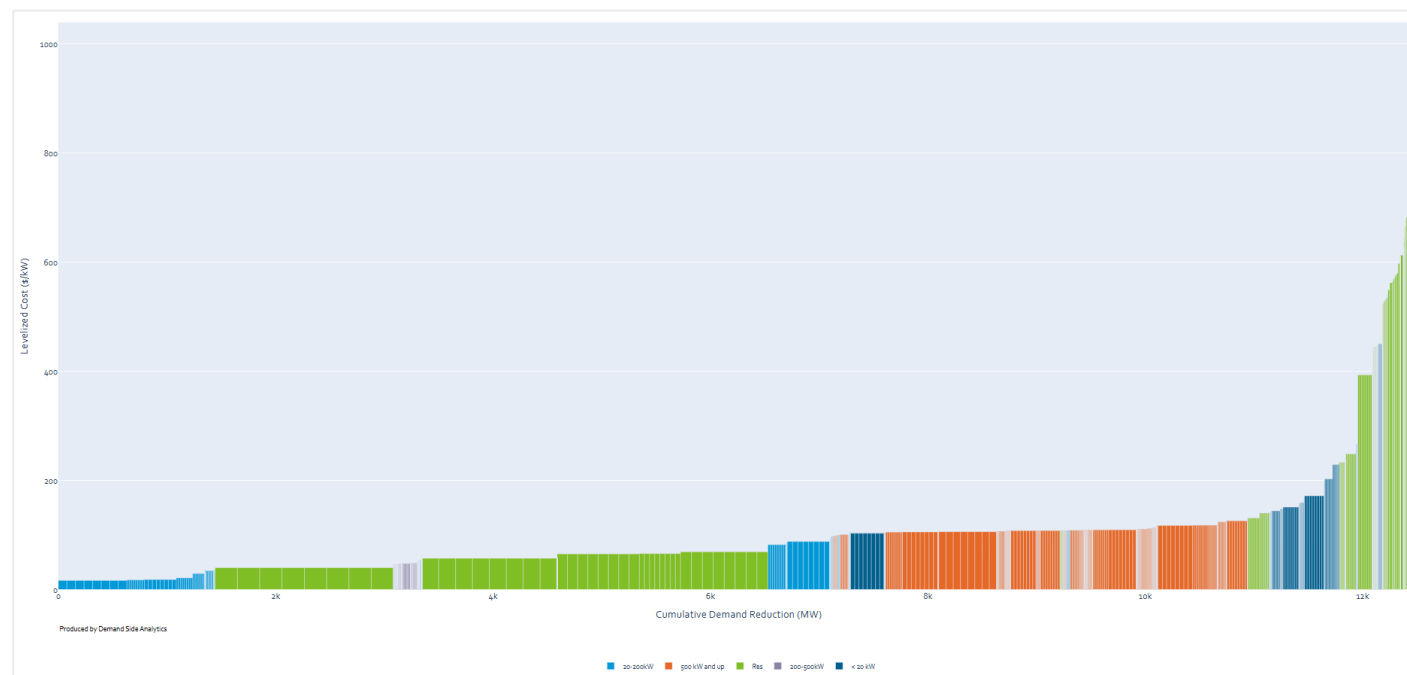
TECHNICAL POTENTIAL VIEWER

- Identifies the locations a lot of connected flexible loads
- Shows biggest opportunities for energy reductions based on DER penetration, absent participation and costs
- Combines both geographic and quantitative data for easy visualization



ACHIEVABLE POTENTIAL VIEWER – VIEW DR PORTFOLIO ECONOMICS BASED ON CONFIGURED SCENARIO

- Helps identify 'hotspots' for flexible loads
- Factors in participation propensities, marketing intensity, and cost-effectiveness
- Visualize Flexible Load Supply curves at the selected location
- Identify the most cost-effective segments and technologies
- Calculated levelized costs of distribution and generation capacity
- Allows for cost comparisons with between resources and customer segments
- View results using different benefit cost tests (e.g., societal, utility, ratepayer)



Sector ^	Technology	Enrolled	Participation %	Nameplate MW	System MW	Distribution MW	Cost	Benefit	Net Benefit	BCR
Non-Res	AG non-pump C&I	0	25%	0.00	0.01	0.00	3,879	10,853	6,973	2.80
Non-Res	Aggregator Program - General	61	7%	1.01	0.81	0.86	566,100	1,134,498	568,398	2.00
Non-Res	Aggregator Program - Hotels, Offices & Finance	46	3%	0.35	0.29	0.30	200,571	401,177	200,605	2.00
Non-Res	Aggregator Program - Manufacturing, Pumps, Utilities & Warehouses	1,795	16%	30.60	27.51	26.01	17,181,345	37,708,360	20,527,015	2.19
Non-Res	Aggregator Program - Retail	112	9%	3.28	3.04	2.79	1,825,641	4,121,811	2,296,170	2.26
Non-Res	Commercial AC 30% Cycling	65,091	43%	243.09	219.25	206.63	48,194,286	417,646,082	369,451,796	8.67
Non-Res	Manufacturing & Warehousing C&I	4	50%	0.56	0.91	0.47	736,483	1,140,358	403,875	1.55
Res	Residential Thermostat 4 degree offset	517,733	27%	644.83	548.08	548.10	358,472,785	1,060,083,056	701,610,271	2.96

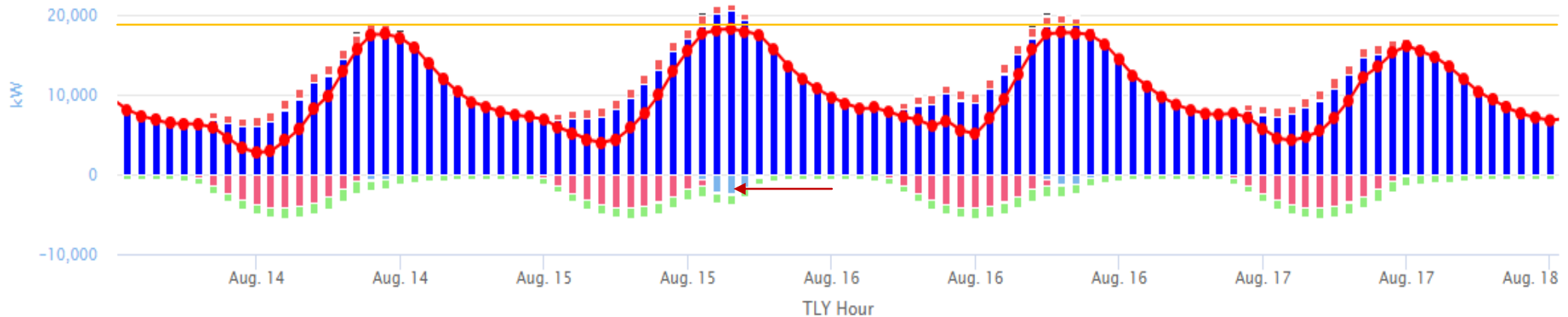
Showing 1 to 8 of 8 entries

Previous 1 Next



NEXT STEPS: INTEGRATING LOAD FLEXIBILITY INTO DPP

- **Integrate Load Flexibility into the PG&E Distribution Planning Process**
 - What is the load flexibility capability and how does it vary by hour?
- **Allow cost comparisons between wires solutions and flexible loads**
 - Compare load flex at different budgets



● New Growth: New Residential
● Spatial: Battery Storage Residential
● Spatial: EV S5 Residential L2
● Base

● Spatial: Heat Pump
● Spatial: Photovoltaic
● Spatial: EV S5 Workplace L2

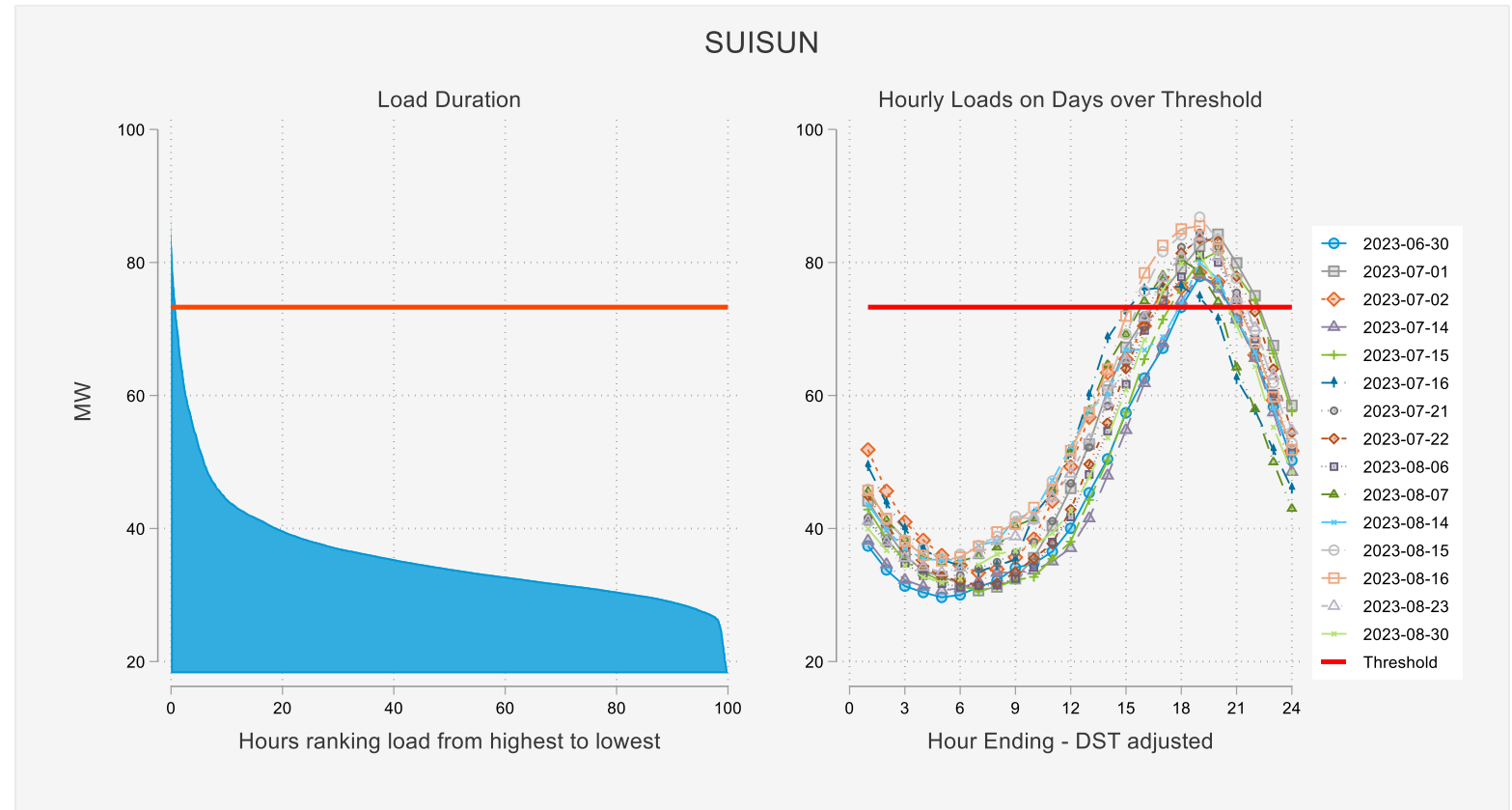
● Spatial: Energy Efficiency
● Spatial: EV S5 Public L2
● **Load Management**

Goal is to essentially add a new “Load Management” load shape to the forecast at the asset level



MORE NEXT STEPS

- Integrate Load Flexibility into Distribution Planning
 - What is the load flexibility capability?
 - How does it vary by hour?
- Allow cost comparisons between wires solutions and flexible loads
 - What is the amount of load flexibility that can be delivered at different budgets at the location?



Illustrative Example

ACTIVITY #1: OBJECTIVES

1

Identify an area with a considerable amount of controllable load

2

Understand the mix of customer and loads at the location

3

Understand the achievable potential

4

Identify the interventions that are most cost-effective

5

Identify customer segments that are most cost-effective



QUESTIONS?



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APPENDIX

DEMO ACTIVITY 1: LOOKING AT TECHNICAL POTENTIAL FROM SUBLAP TO FEEDER & IDENTIFYING END USES

GOAL: Identify Areas with a considerable amount of controllable load using the Technical Potential Dashboard

- Use the technical potential viewer and navigate through the maps to identify a few locations of interest
 - Where is technical potential concentrated?
 - What is the technical potential reduction for a given location?
 - What hours are those loads flexible?
 - What technologies are flexible based on the given scenario? Are there any geographic constraints of the substation?

GOAL: Identify the load make-up of locations of interest using the Disaggregation Module

- Use the Disaggregation Module and select key locations of interest
 - What are the largest loads at locational level?
 - What segments are responsible for the load make-up of a location?
 - Are the largest loads in a location flexible? How are those loads flexible?
 - What is the Forecast of DERs at that location?



DEMO ACTIVITY #2: ACHIEVABLE POTENTIAL

GOAL: Identify Areas with a considerable amount of controllable load using the Technical Potential Dashboard

- Use the Achievable Potential Dashboard to evaluate supply curves
 - What is the main cost test of interest?
 - What are the metrics of focus? Distribution benefit? System Benefit?
 - What is the levelized cost for different technologies?
 - What technologies are cost effective? What segments are cost effective?
 - How does cost effectiveness differ based on different locations?

CONFIGURING SCENARIOS AND DETERMINING ACHIEVABLE POTENTIAL

CONFIGURE SCENARIOS WHICH DEFINES THE OUTPUT OF TECHNICAL AND ACHIEVABLE POTENTIAL MODELS

- Limited to specific users
- Defines scenario conditions for portfolio
 - What is included in the portfolio? For example, include managed charging, but not V2G.
 - For each intervention, define applicable customer segments
 - Set specific peak windows to calculate resource capacity
 - Define the avoided costs and financial inputs (inflation and discount rates)
 - Define marketing intensity and costs

Actions for: [TEST SCENARIO 1](#) [+ Add Action](#)

Action Type	Action	End Use	Sector	Building Types	Expected Dispatch Hours	Attrition Rate (%)	Rank	Actions
Event Action	BTM 4-hour Battery Existing	Battery	Residential	Mobile Home, Multifamily 2-4 Units and 3 more...	240	11.0%	5	Edit Delete
Event Action	EV Charging Load Curtailment	EV_Charging	Residential	Mobile Home, Multifamily 2-4 Units and 3 more...	100	11.0%	6	Edit Delete
Event Action	AG Pump Interrupt	Water_Systems	Commercial	agriculture pumps	20	11.0%	8	Edit Delete
CI DR Program	AG Pump C&I	Commercial & Industrial	Industrial	agriculture pumps	4	11.0%	10	Edit Delete
CI DR Program	Hotels, Offices & Finance C&I	Commercial & Industrial	Industrial	largehotel, largeoffice and 4 more...	4	11.0%	9	Edit Delete
CI DR Program	AG non-pump C&I	Commercial & Industrial	Industrial	agriculture nonpumps	4	11.0%	11	Edit Delete

Configuration Parameters

[Save All Parameters](#)

All configuration parameters below are required for each scenario. Please fill in all values before saving.

Peak Window Start (Hour Ending):

17

Peak Window End (Hour Ending):

21

Discount Rate:

0.08

Inflation Rate:

0.03

Calculate Attrition:

Benefit Cost Analysis

Distribution Rate (\$ per kW):

0.16

Include Attrition:

TRUE

Attrition Rate (If ACC):

0.0

Peak Type:

Summer System



MARKETING AND OUTREACH DESIGN

- Input into the Configure Scenario Module
 - Determines the intensity of marketing for different Customer segments
- Determine cost inputs and marketing channels for reaching customers
- Build realistic enrollment projections based on mass marketing strategy

Recruitment Costs

All Scenarios

Apply

Search...

+ Add New Cost

Show

10

entries

Search:

ID	Scenario ID	Sector	Recruitment Mode	Cost Per Attempt (\$)	Cumulative Attempts	Last Updated	Actions
13	1	Residential	In App	\$0.01	3.00	N/A	<div><div></div><div></div></div>
12	1	Large C&I	Email	\$0.01	3.00	2025-04-30 17:03	<div><div></div><div></div></div>
11	1	Large C&I	Direct Mail	\$1.00	0.00	2025-04-30 17:03	<div><div></div><div></div></div>
10	1	Large C&I	Phone	\$2.50	1.00	N/A	<div><div></div><div></div></div>
9	1	Large C&I	Door-to-door or In Person	\$200.00	1.00	N/A	<div><div></div><div></div></div>
8	1	Commercial	Email	\$0.01	3.00	N/A	<div><div></div><div></div></div>
7	1	Commercial	Direct Mail	\$1.00	3.00	N/A	<div><div></div><div></div></div>
5	1	Commercial	Door-to-door or In Person	\$50.00	1.00	N/A	<div><div></div><div></div></div>
4	1	Residential	Email	\$0.01	3.00	N/A	<div><div></div><div></div></div>
3	1	Residential	Direct Mail	\$1.00	3.00	N/A	<div><div></div><div></div></div>

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LIBRARY OF EVENT AND DAILY SHIFTING ACTIONS – WITH ADD, UPDATE, AND DELETE CAPABILITIES

- The Event and Daily Shifting Actions pages allow users to build interventions
- Interventions can be either:
 - Event or Daily Shifting based: Set event, pre-event and pos-event impact multipliers
- Set incentives to accurately model costs for each load action
- Allows user to test the action at either the sublap or per-premise level



FOR LARGE COMMERCIAL & INDUSTRIAL THE FLEXIBLE LOADS ARE BAED ON ELASTICITIES

- Elasticity is simply the demand change associated with a change in price (or incentive)
- Annual incentive are converted to and effective kWh value
- Calculate load changes in real-time time based on:
 - Annual incentive
 - Expected hours of dispatch
 - Current retail prices (\$/kWh)
 - Price elasticity (sensitivity)
- Easy to benchmark across different customer segments
- Adjustments to parameters instantly show feedback
- Create tailored programs for high-flexibility customers vs. Low flexibility customers

Show	10	entries	Search programs...			
Name	Building Type	Participation	Incentive	Effective Price	Load Change	Actions
AG non-pump C&I	All	100.0%	\$144.00/kW	\$12.00/kWh	-24.60%	✎ ✖
AG Pump C&I	agriculture pumps	100.0%	\$144.00/kW	\$9.60/kWh	-36.89%	✎ ✖
Aggregator Program - General	All	100.0%	\$60.00/kW	\$2.50/kWh	-7.03%	✎ ✖
Aggregator Program - Hotels, Offices & Finance	largehotel	100.0%	\$60.00/kW	\$2.50/kWh	-2.69%	✎ ✖
Aggregator Program - Manufacturing, Pumps, Utilities & Warehouses	manufacturing	100.0%	\$60.00/kW	\$2.50/kWh	-16.40%	✎ ✖
Aggregator Program - Retail	retailstandalone	100.0%	\$60.00/kW	\$6.00/kWh	-9.48%	✎ ✖
Hotels, Offices & Finance C&I	largeoffice	100.0%	\$144.00/kW	\$36.00/kWh	-42.21%	✎ ✖
Large C&I Retail	retailstandalone	100.0%	\$144.00/kW	\$18.00/kWh	-28.49%	✎ ✖
Manufacturing & Warehousing C&I	warehouse	100.0%	\$144.00/kW	\$7.20/kWh	-49.70%	✎ ✖
Other C&I	school	100.0%	\$144.00/kW	\$18.00/kWh	-5.93%	✎ ✖
Showing 1 to 10 of 10 entries						Previous 1 Next

