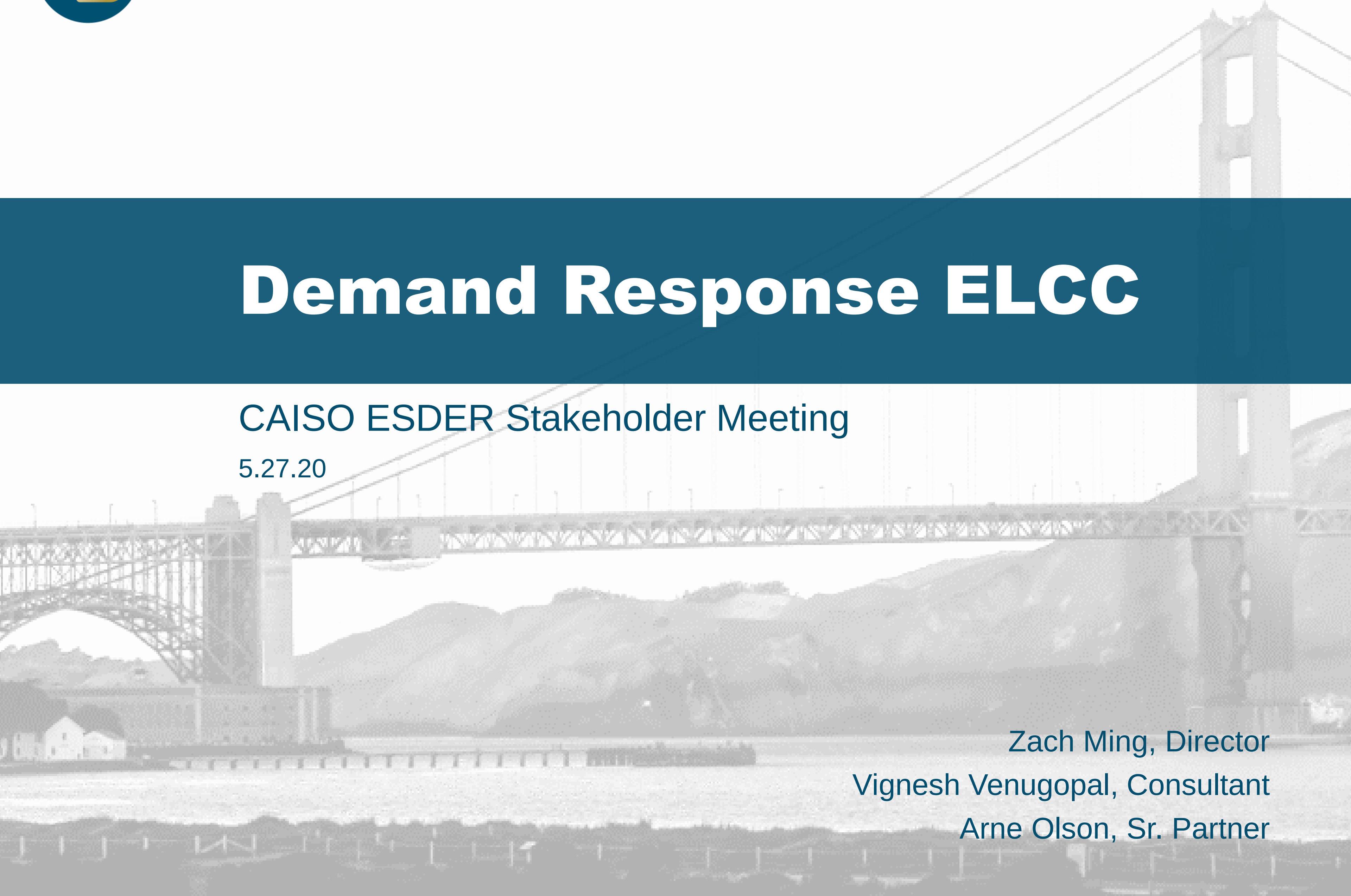
Energy+Environmental Economics



Demand Response ELCC

CAISO ESDER Stakeholder Meeting

5.27.20

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Overview

Background

- California has a unique approach to capacity procurement, where the CPUC administers a Resource Adequacy (RA) program to ensure sufficient resources to maintain an acceptable standard of reliability, but the CAISO retains ultimate responsibility for the reliable operation of the electricity system
- The CAISO wants to ensure DR is properly valued in the Resource Adequacy program

Project

- The CAISO retained E3 to investigate the reliability contribution of DR relative to its capacity value in the CPUC administered RA program
- To the extent that DR is overvalued, the CAISO asked E3 to suggest solutions to issue
- E3 provided technical analysis to support the CAISO in this effort

Disclaimer required by the California Public Utilities Commission

This report has been prepared by E3 for the California Independent System Operator (CAISO). This report is separate from and unrelated to any work E3 is doing for the California Public Utilities Commission. While E3 provided technical support to CAISO preparation of this presentation, E3 does not endorse any specific policy or regulatory measures as a result of this analysis. The California Public Utilities Commission did not participate in this project and does not endorse the conclusions presented in this report.

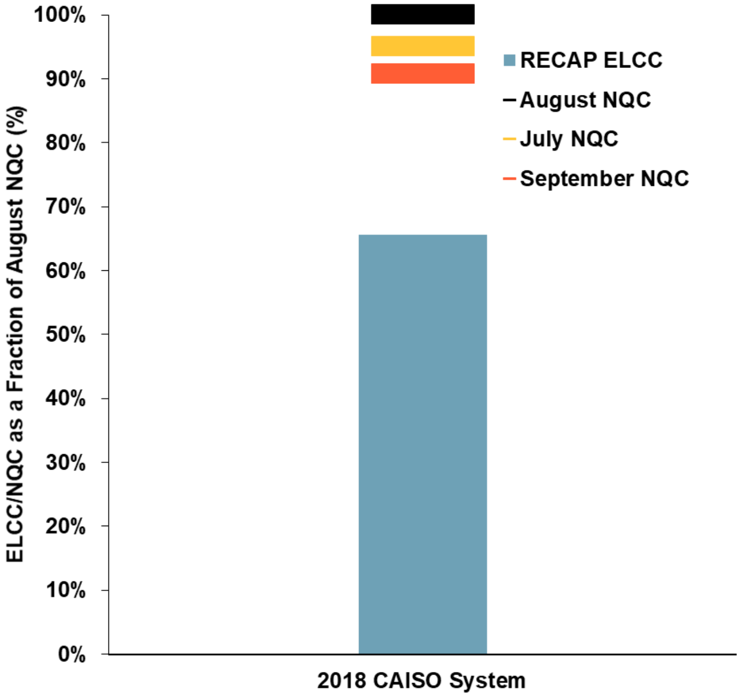
Outline

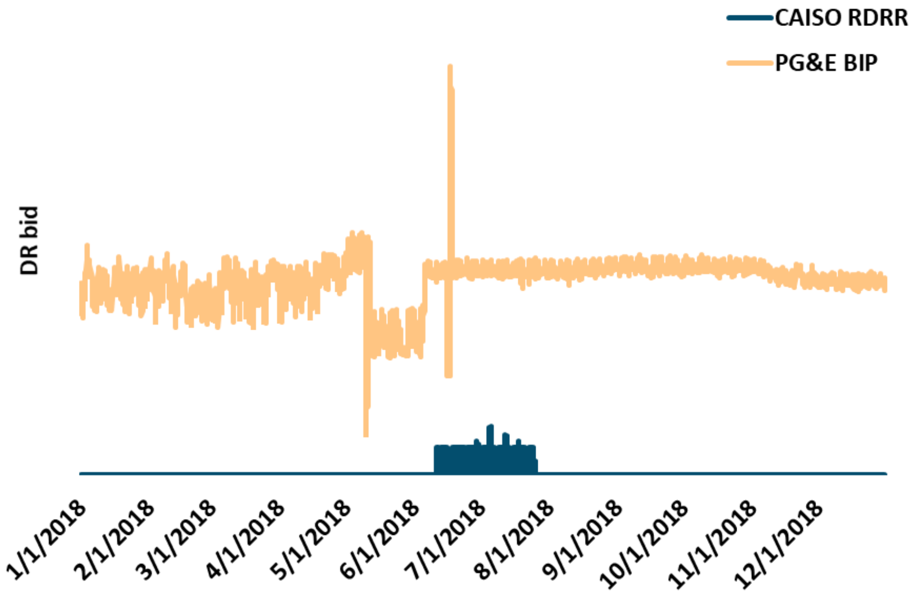
- Refresher on March 3 CAISO stakeholder meeting presentation
- Background on ELCC
- Performance of Existing DR
- Characteristics of DR Needed for ELCC
  - Time availability
  - # of calls / duration of calls
  - Penetration of DR
- Incorporating DR ELCC into Existing CPUC RA Framework
- Questions

Acronyms

Acronym	Name	Description
API	Agricultural and Pumping Interruptible	DR program to suspend agricultural pumping
BIP	Base Interruptible Program	Participants are offered capacity credits for reducing their demand up to a pre-determined level in response to an event call
CBP	Capacity Bidding Program	DR program where aggregators work on behalf of utilities to enroll customers, arrange for load reduction, receive and transfer notices and payments
DR	Demand Response	Reductions in customer load that serve to reduce the need for traditional resources
ELCC	Effective Load Carrying Capability	Equivalent perfect capacity measurement of an intermittent or energy-limited resource, such as DR
LCA	Local Capacity Area	Transmission constrained load pocket for which minimum capacity needs are identified for reliability
LIP	Load Impact Protocol	Protocols prescribed by the CPUC for accurate and consistent measuring (and forecasting) of DR program performance
LOLP	Loss of Load Probability	Probability of a load shedding event due to insufficient generation to meet load + reserve requirements
NQC	Net Qualifying Capacity	A resource's contribution toward meeting RA after testing, verification, and accounting for performance and deliverability restrictions
PDR	Proxy Demand Response	Resources that can be bid into the CAISO market as both economic day-ahead and real-time markets providing energy, spin, non-spin, and residual unit commitment services
PRM	Planning Reserve Margin	Capacity in excess of median peak load forecast needed fore reliability
RA	Resource Adequacy	Resource capacity needed for reliability
RDRR	Reliability Demand Response Resource	Resources that can be bid into CAISO market as supply in both economic day-ahead and real-time markets dispatched for reliability services
SAC	Smart AC Cycling	Direct air conditioner load control program offered by PG&E
SDP	Summer Discount Plan	Direct air conditioner load control program offered by SCE
SubLAP	Sub-Load Aggregation Point	Defined by CAISO as relatively continuous geographical areas that do not include significant transmission constraints within the area

Refresher on March 3 CAISO ESDER Meeting



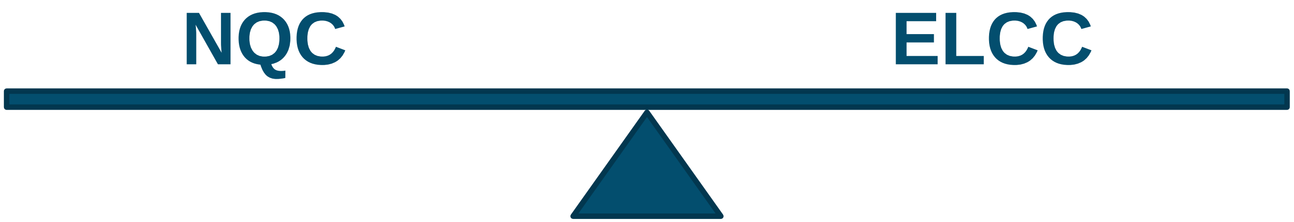


Established disconnect between ELCC and NQC

Provided E3 thoughts on how to match CAISO and utility DR bid data as well as techniques to extend this data over multiple historic weather years. Both points were addressed with the 2019 data.

Key Questions to Answer

1) How are demand response programs performing today, relative to what they are being credited for?



NQC

ELCC

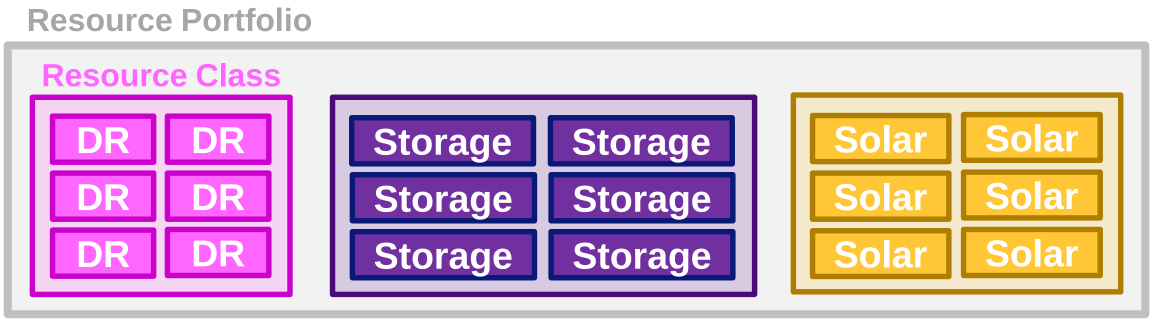
2) What characteristics of demand response are needed today and in the future?

hrs/call

availability

# of calls/yr

3) How should a resource adequacy program be designed to allocate and credit both DR in aggregate and individual DR programs?



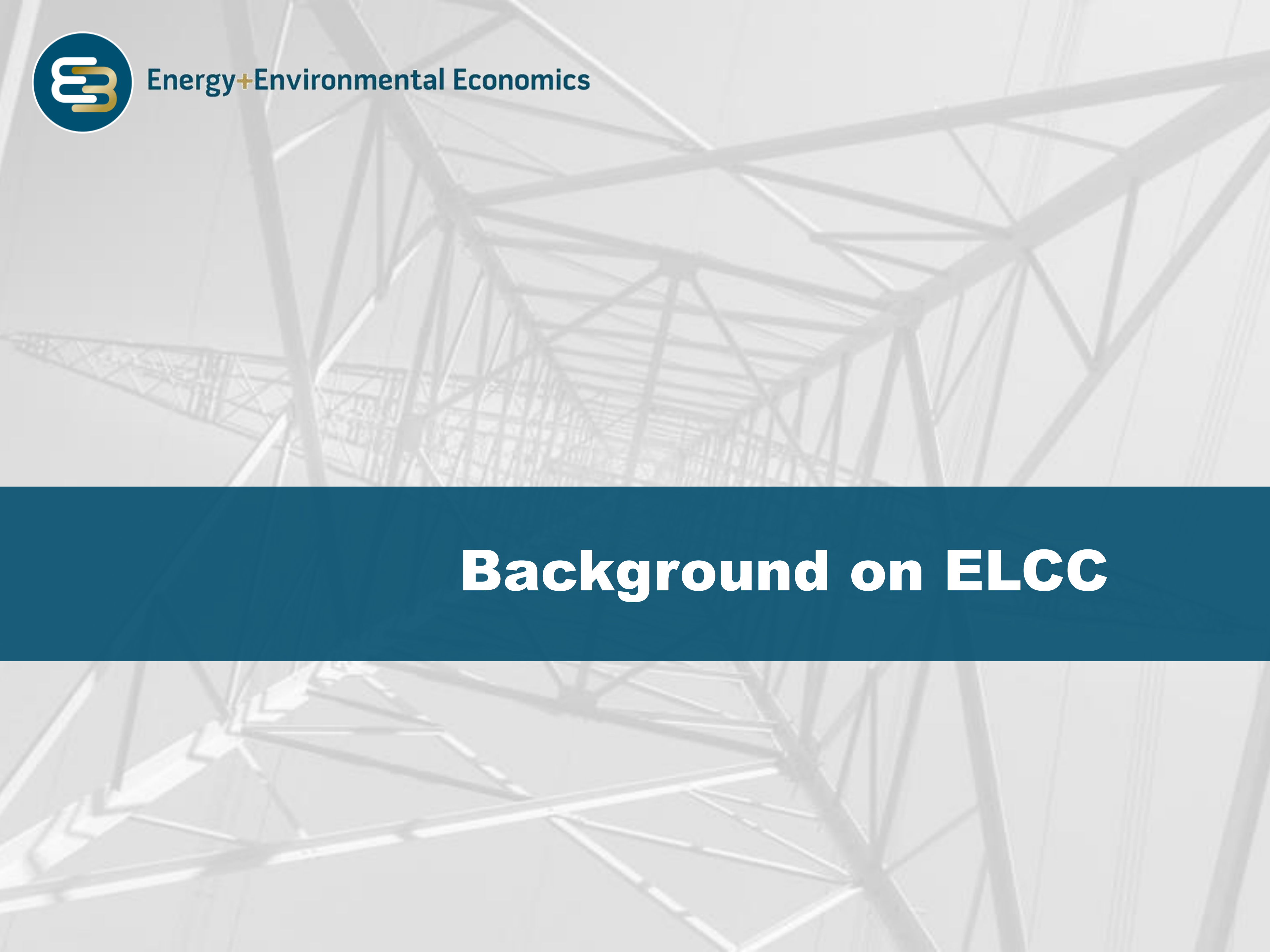
Resource Portfolio

Resource Class

DR	DR
DR	DR
DR	DR

Storage	Storage
Storage	Storage
Storage	Storage

Solar	Solar
Solar	Solar
Solar	Solar



Background on ELCC

Effective Load Carrying Capability (ELCC)

- **Effective Load Carrying Capability (ELCC) is a measure of the amount of equivalent perfect capacity that can be provided by an intermittent or energy-limited resource**
  - **Intermittent resources:** wind, solar
  - **Energy-limited resources:** storage, demand response
- **Industry has begun to shift toward ELCC as best practice, and the CPUC has been at the leading edge of this trend**

1. **Calibrate existing system to target LOLE standard**

   If necessary, add or remove "perfect capacity" to achieve target standard

2. **Add desired resource to portfolio**

   Addition of new source of generation will decrease LOLE relative to measurement in Step 1

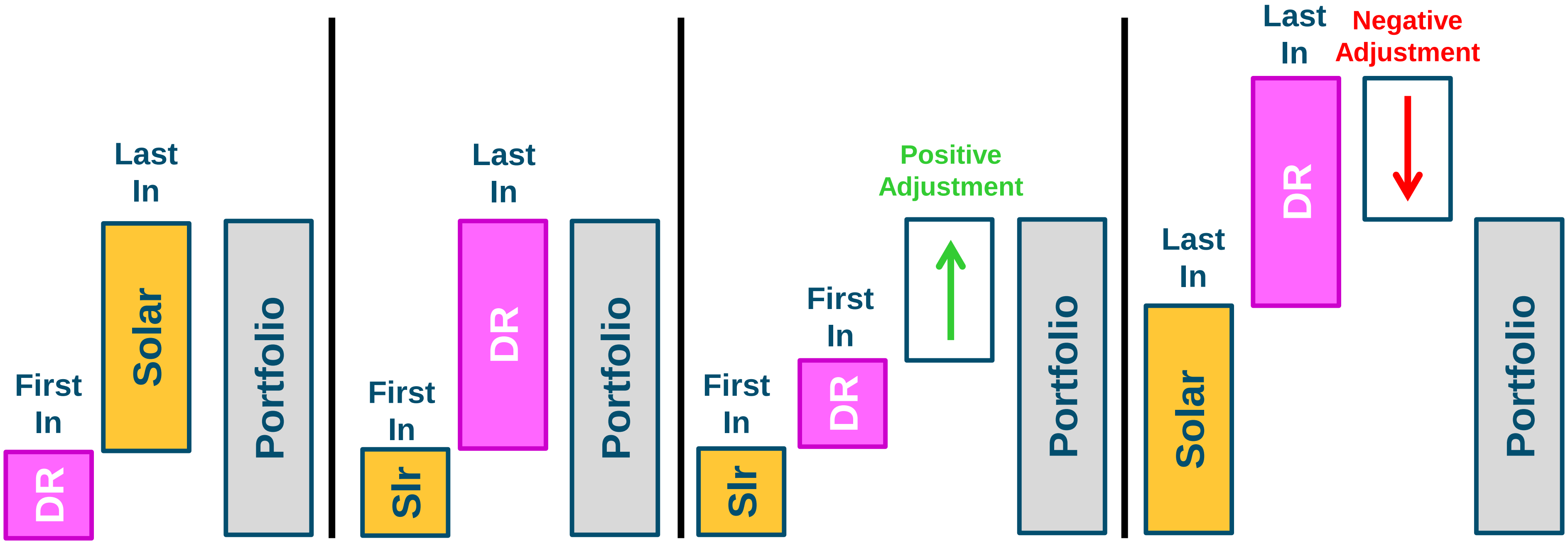
3. **Remove perfect capacity until target LOLE is restored**

   Removal of perfect capacity results in increase in LOLE until original target is met

A resource's ELCC is equal to the amount of perfect capacity removed from the system in Step 3

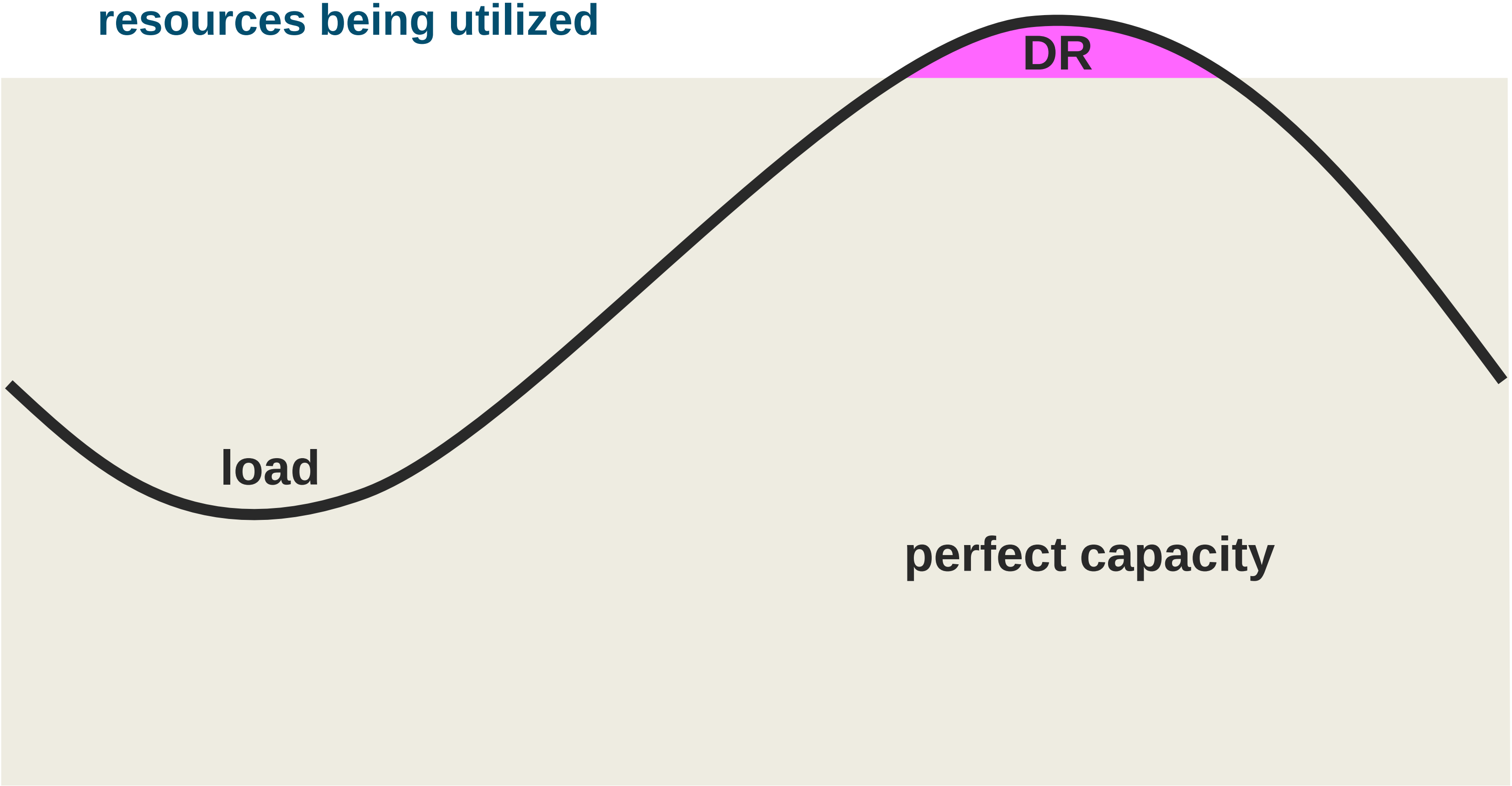
Measuring ELCC

- **There are multiple approaches to measuring the ELCC of a resource(s)**
  - **Portfolio ELCC:** measures the combined ELCC of all intermittent and energy-limited resources on the system
  - **First-In ELCC:** measures the marginal ELCC of a resource as if it were the only intermittent or energy-limited resource on the system, thus ignoring interactive effects
  - **Last-In ELCC:** measures the marginal ELCC of a resource after all other intermittent or energy-limited resources have been added to the system, capturing all interactive effects with other resources



“First-In” ELCC

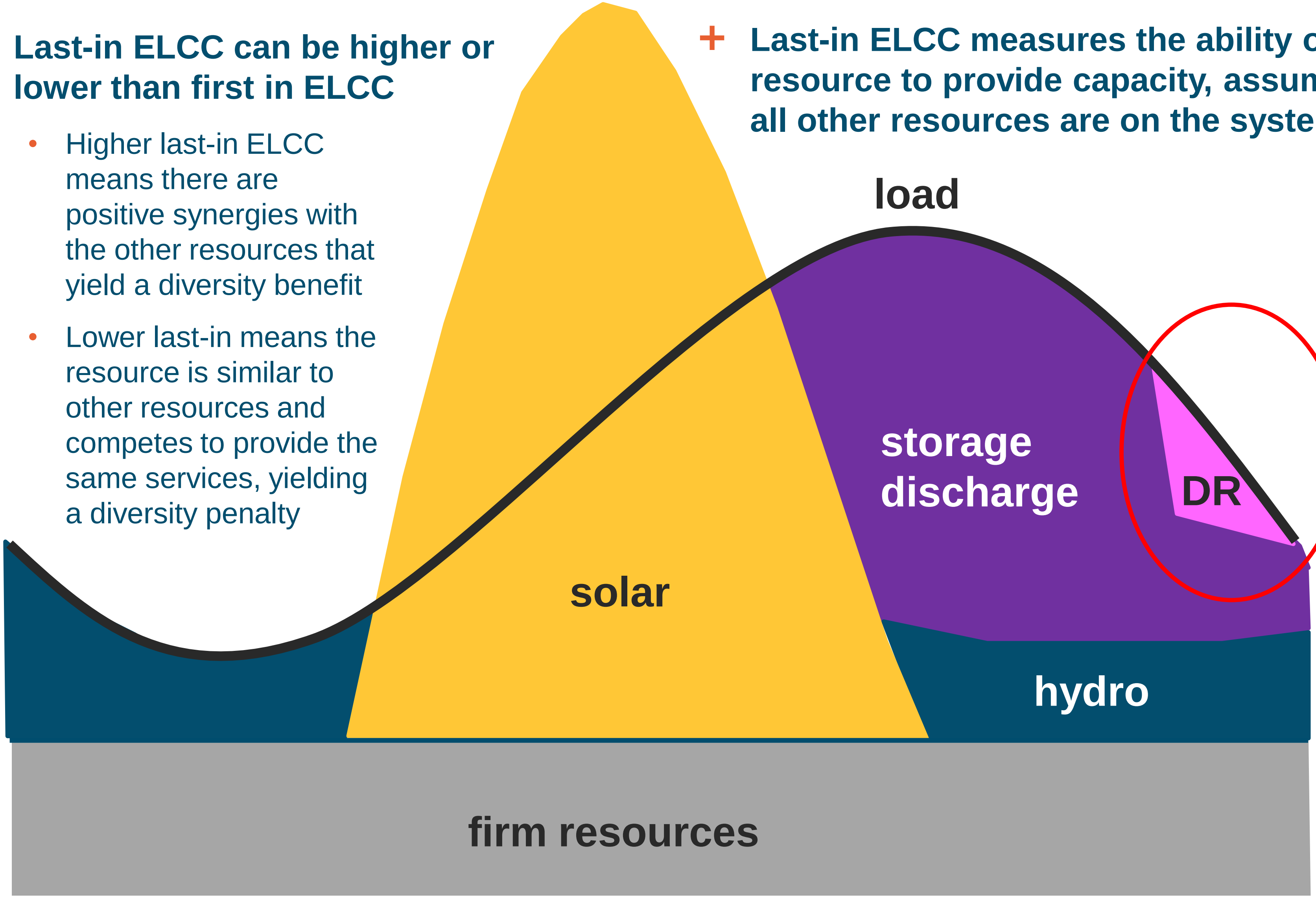
- First-in ELCC measures the ability of a resource to provide capacity, absent any other resource on the system
- This measures the ability of a resource to “clip the peak” and is often analogous to how many industry participants imagine capacity resources being utilized



"Last-In" ELCC

- **Last-in ELCC can be higher or lower than first in ELCC**
  - Higher last-in ELCC means there are positive synergies with the other resources that yield a diversity benefit
  - Lower last-in means the resource is similar to other resources and competes to provide the same services, yielding a diversity penalty

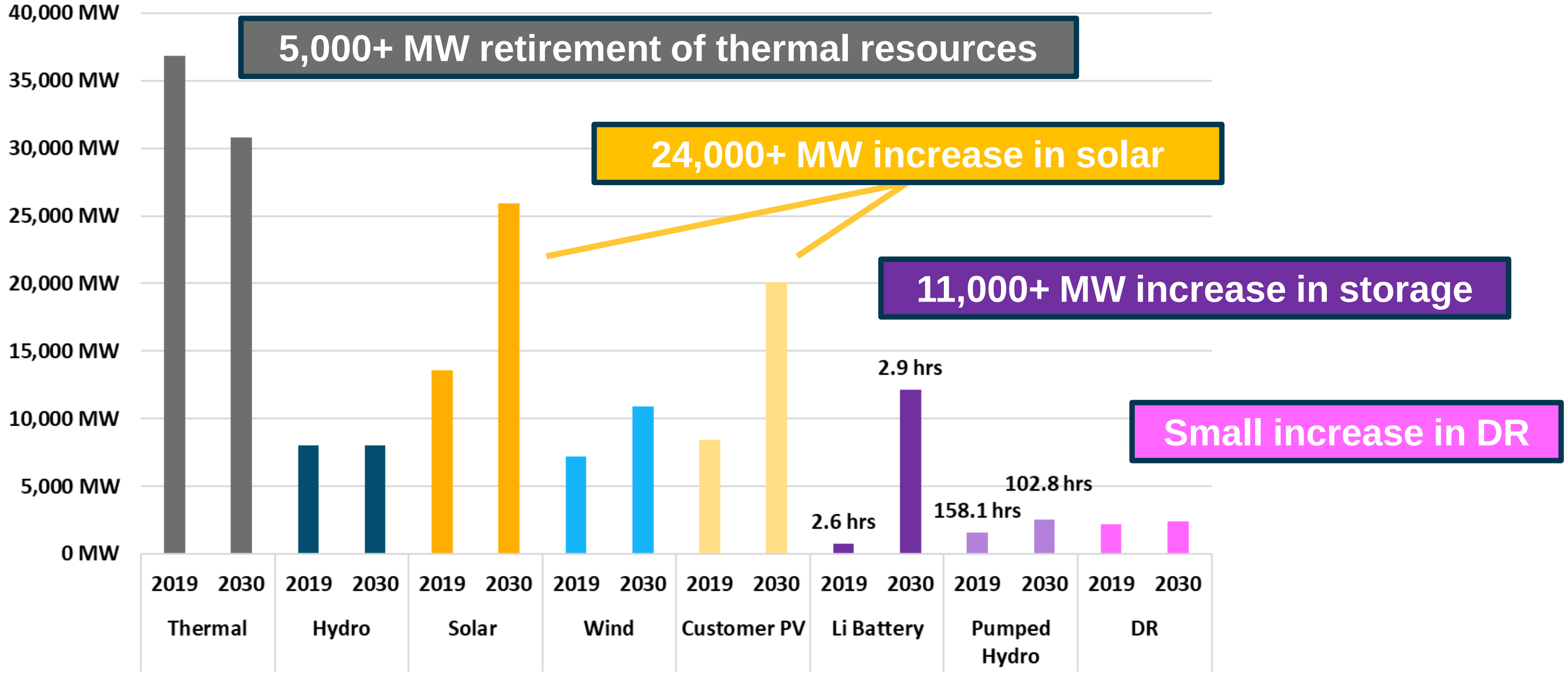
- **Last-in ELCC measures the ability of a resource to provide capacity, assuming all other resources are on the system**



Today (2019) vs. Future (2030)

- E3 analyzed the value of DR to the CAISO system today (2019) and the future (2030) to assess how coming changes to the electricity system might impact value
- Primary changes are on the resource side (shown below) with modest changes to loads (49 GW 2019 peak load vs 53 GW 2030 peak load)

2019 and 2030 CAISO Resource Portfolio



5,000+ MW retirement of thermal resources

24,000+ MW increase in solar

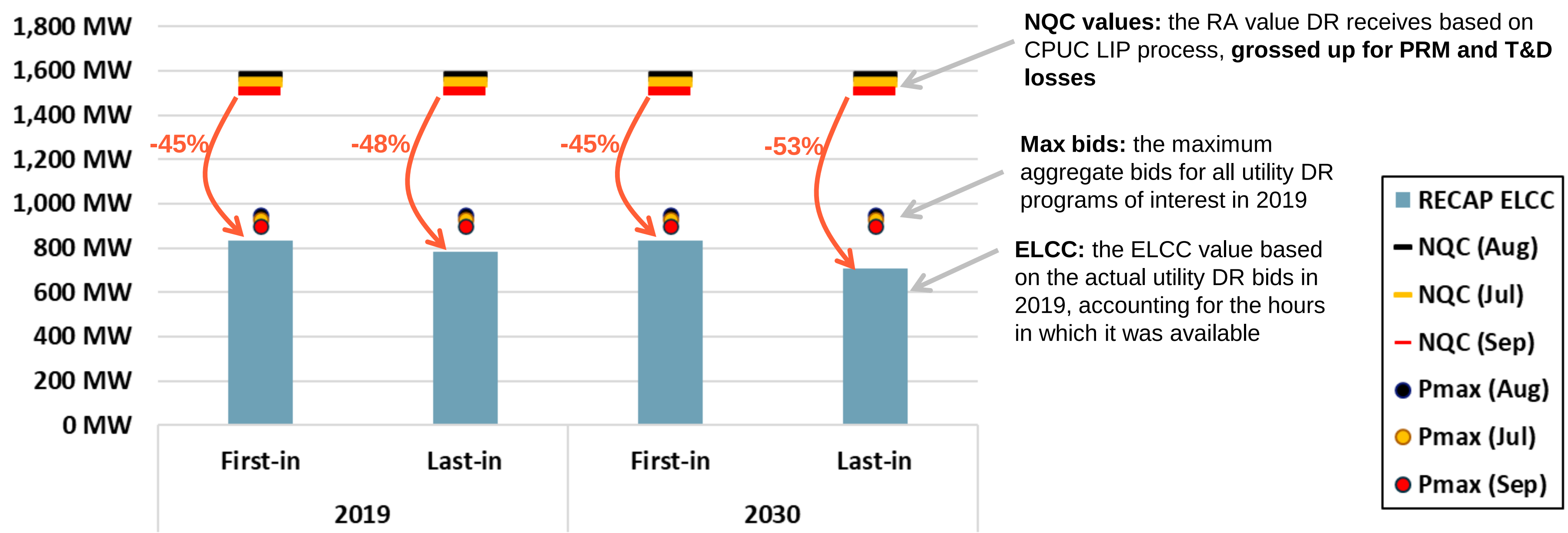
11,000+ MW increase in storage

Small increase in DR

Source: CPUC Integrated Resource Plan (IRP) Reference System Plan (RSP)

Performance of Existing PG&E and SCE event-based DR Programs

- **Demand response (DR) resource adequacy qualifying capacity is currently calculated using the load impact protocols (LIP), which are performed by the utilities under the oversight of the CPUC**
  - LIP uses regression and other techniques to estimate the availability of demand response during peak load hours
- **E3 has analysis suggests that LIP overvalues the capacity contribution DR relative to ELCC by 40%+ for two reasons:**
  1) DR does not bid into the CAISO market, in aggregate, at levels equal to its NQC value
  2) The times when DR is bid are either not at optimal times or not for long enough to earn full ELCC value



NQC values: the RA value DR receives based on CPUC LIP process, **grossed up for PRM and T&D losses**

Max bids: the maximum aggregate bids for all utility DR programs of interest in 2019

ELCC: the ELCC value based on the actual utility DR bids in 2019, accounting for the hours in which it was available

Load impacts are grossed up for transmission and distribution losses, as also the 15% PRM, owing to demand response being a demand reduction measure

$NQC = LI * 1.15\,(PRM) * T\&D\ loss\ factor$[1]

Load impacts for the year 2019 are referenced from the CPUC's RA Compliance documents[2]

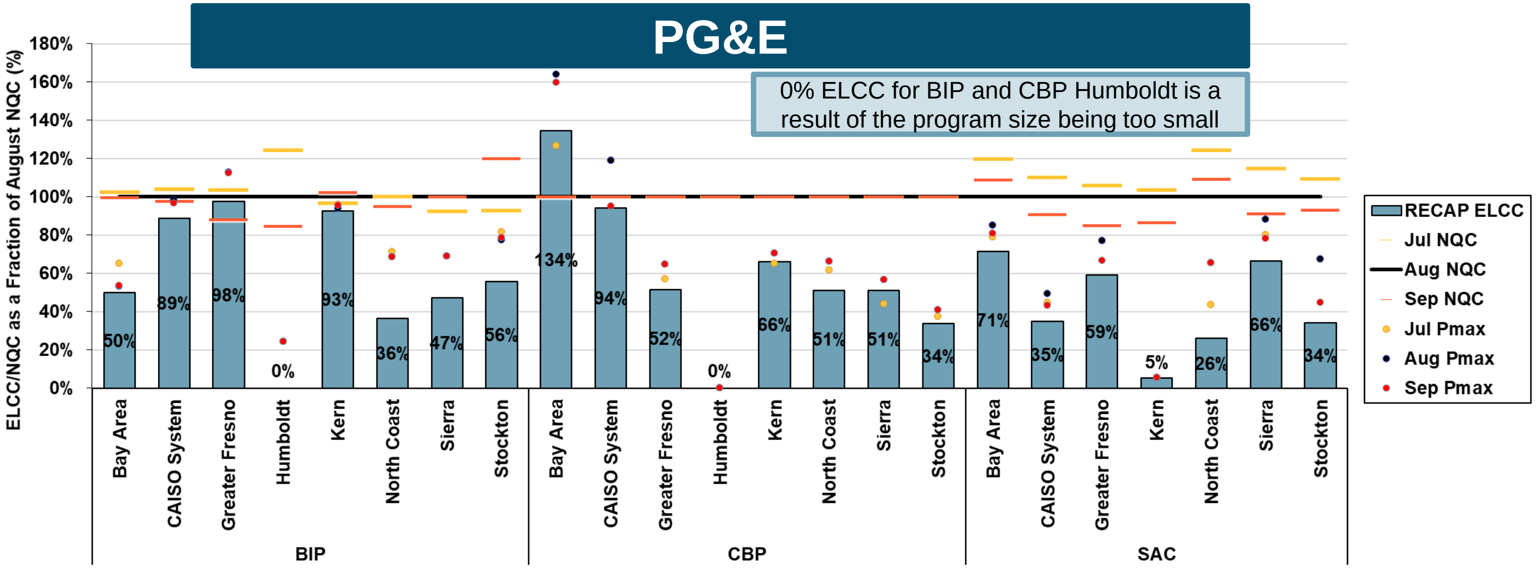
Load impacts are defined on an LCA level from 1 pm to 6 pm, Apr to Oct, and from 4 pm to 9 pm in the rest of the year, both with and without line losses

[1] CPUC 2019 RA Guide

[2] CPUC 2019 IoU DR Program Totals

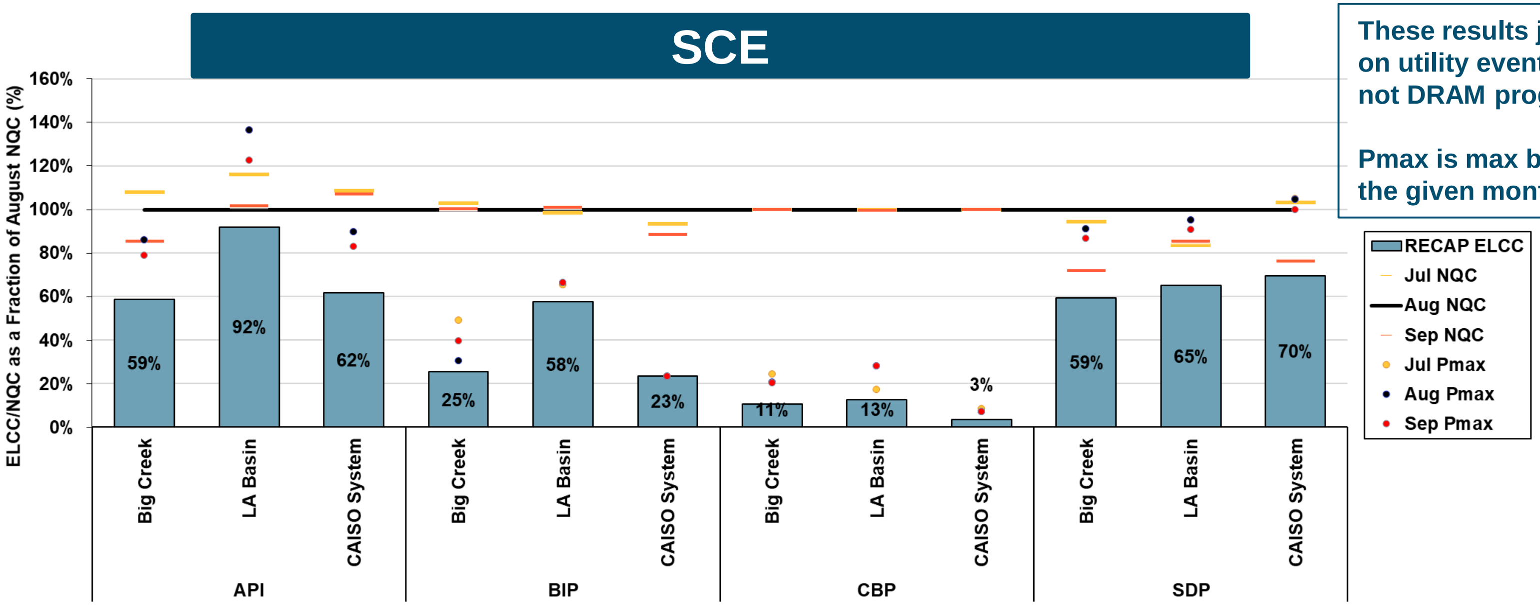
First-in ELCC of PG&E and SCE Programs

PG&E



0% ELCC for BIP and CBP Humboldt is a result of the program size being too small

SCE



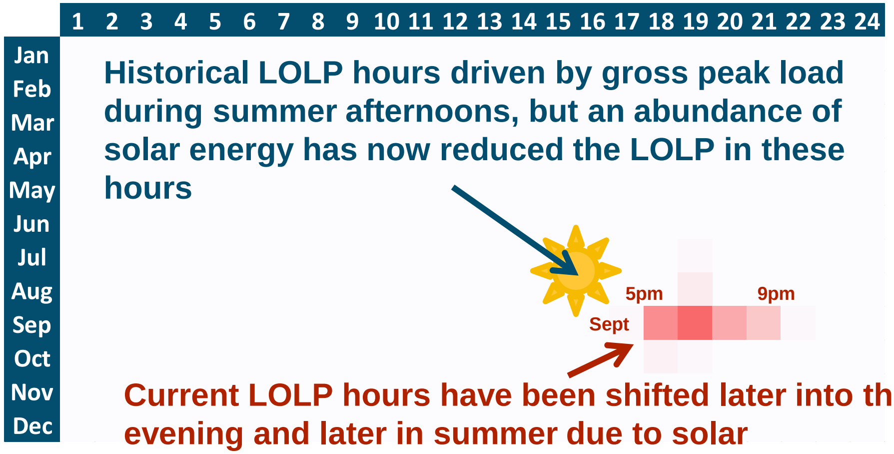
These results just focus on utility event-based DR, not DRAM programs

Pmax is max bid placed in the given month

Time Window Availability Needs for DR in 2019 & 2030

- Month/hour (12x24) loss of load probability heat maps provide a quick overview of "high risk" hours
- Key findings from this project are showing that strong interactions between storage and DR may elongate the peak period by 2030

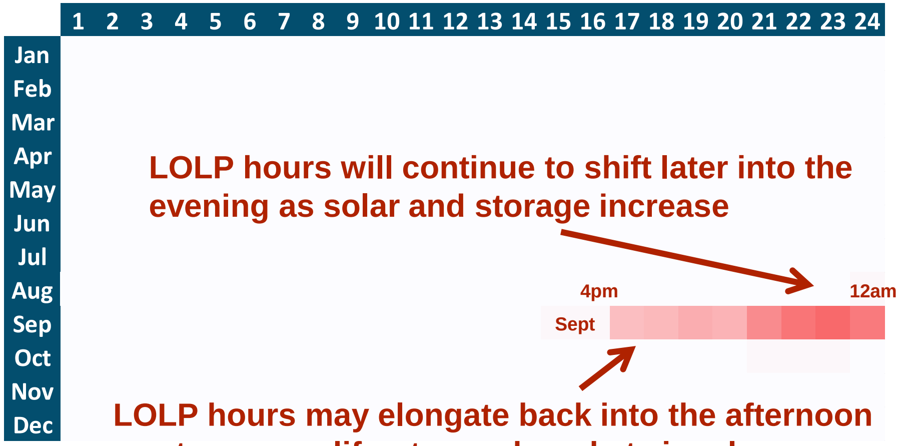
LOLP in 2019



Historical LOLP hours driven by gross peak load during summer afternoons, but an abundance of solar energy has now reduced the LOLP in these hours

Current LOLP hours have been shifted later into the evening and later in summer due to solar

LOLP in 2030



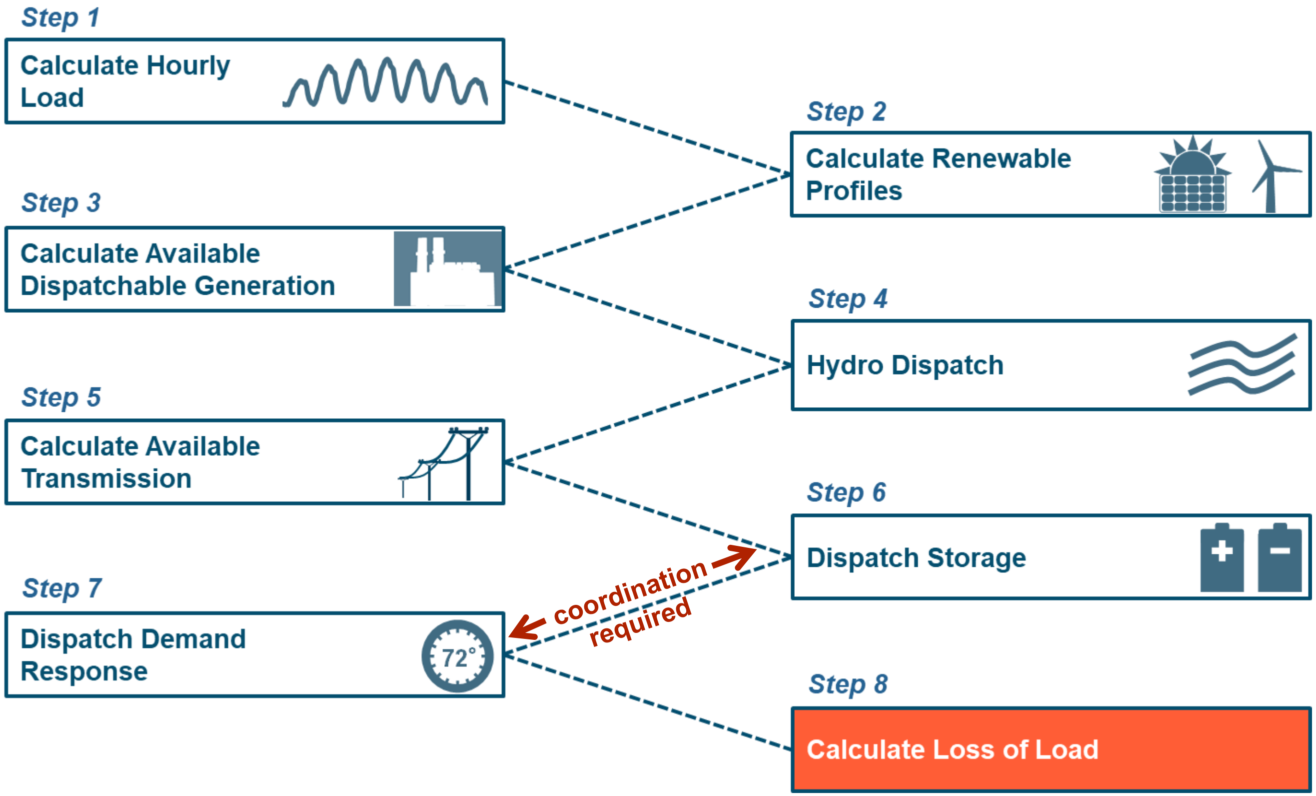
LOLP hours will continue to shift later into the evening as solar and storage increase

LOLP hours may elongate back into the afternoon as storage proliferates and market signals encourage it to wait to discharge during later hours

DR Interaction with Storage

- Historically, DR is dispatched as a resource of “last resort” which is how RECAP dispatched DR
- A system with high penetrations of storage require much more coordination in the dispatch of DR and storage in order to achieve maximum reliability

E3 RECAP Model Methodology



Step 1

Calculate Hourly Load

Step 2

Calculate Renewable Profiles

Step 3

Calculate Available Dispatchable Generation

Step 4

Hydro Dispatch

Step 5

Calculate Available Transmission

Step 6

Dispatch Storage

Step 7

Dispatch Demand Response

coordination required

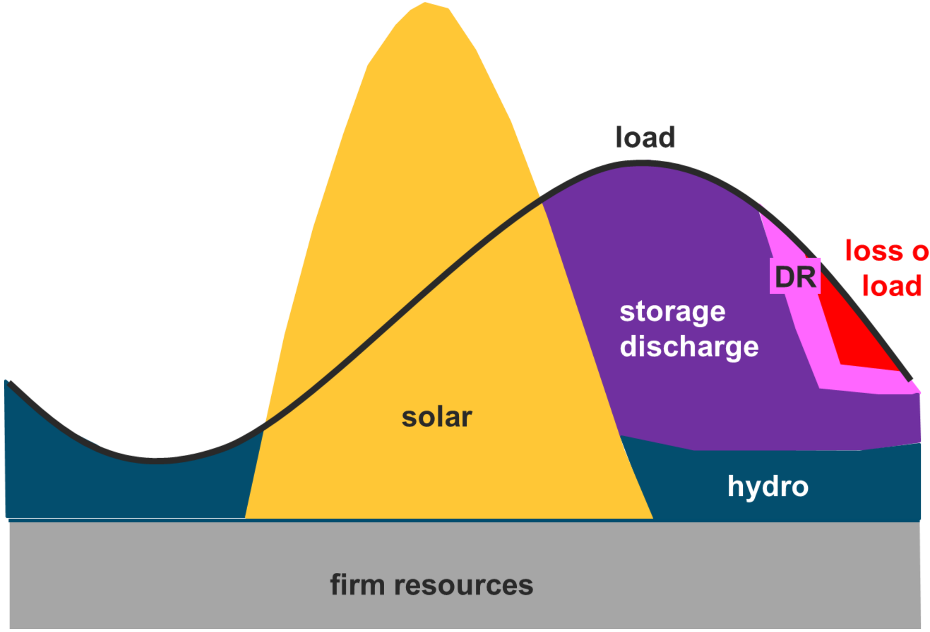
Step 8

Calculate Loss of Load

Last Resort vs. Optimal Dispatch

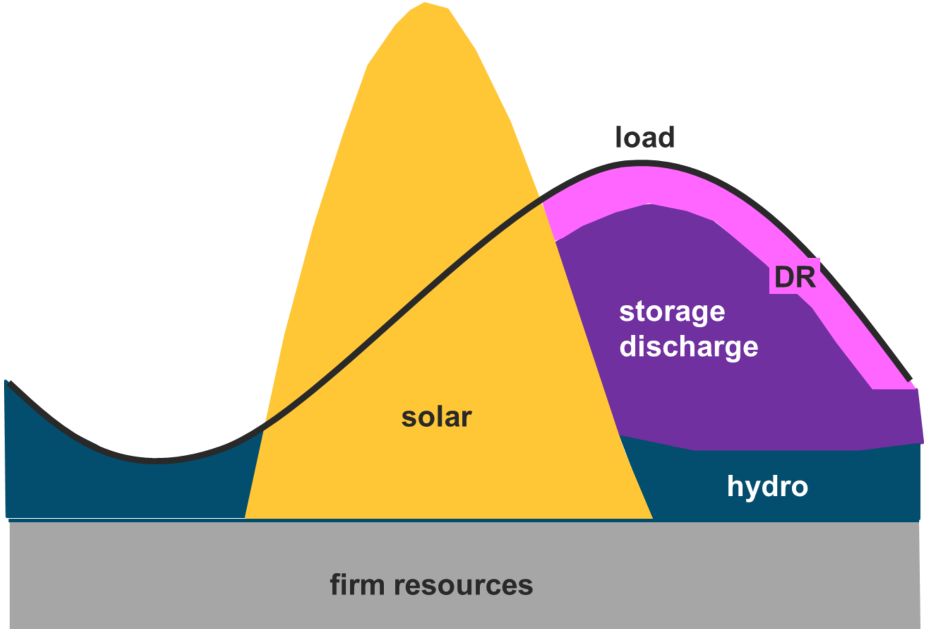
DR as Resource of Last Resort

When DR is dispatched as the resource of last resort, there is loss of load



DR Dispatch to Delay Storage Discharge

Preemptively dispatching DR to delay storage discharge eliminates loss of load event



Key takeaway: DR should be dispatched to delay storage discharge on days with potential loss of load

Call and Duration ELCC Results

First-in ELCC

2019

ELCC (% of nameplate)		Max annual calls						
		1	2	4	5	10	15	20
Max call duration (hrs)	1	46%	50%	51%	51%	51%	51%	51%
	2	63%	73%	78%	78%	78%	78%	78%
	4	70%	81%	94%	95%	95%	95%	95%
	6	70%	81%	94%	95%	95%	95%	95%
	8	70%	81%	94%	95%	95%	95%	95%

No interactions with storage – therefore no expected significant differences

2030

ELCC (% of nameplate)		Max annual calls						
		1	2	4	5	10	15	20
Max call duration (hrs)	1	41%	43%	43%	43%	43%	43%	43%
	2	60%	65%	65%	65%	65%	65%	65%
	4	72%	91%	95%	95%	95%	95%	95%
	6	73%	92%	98%	98%	98%	98%	98%
	8	73%	92%	98%	98%	98%	98%	98%

Last-in ELCC

2019

ELCC (% of nameplate)		Max annual calls						
		1	2	4	5	10	15	20
Max call duration (hrs)	1	59%	73%	73%	73%	73%	73%	73%
	2	74%	90%	94%	94%	94%	94%	94%
	4	77%	98%	100%	100%	100%	100%	100%
	6	77%	98%	100%	100%	100%	100%	100%
	8	77%	98%	100%	100%	100%	100%	100%

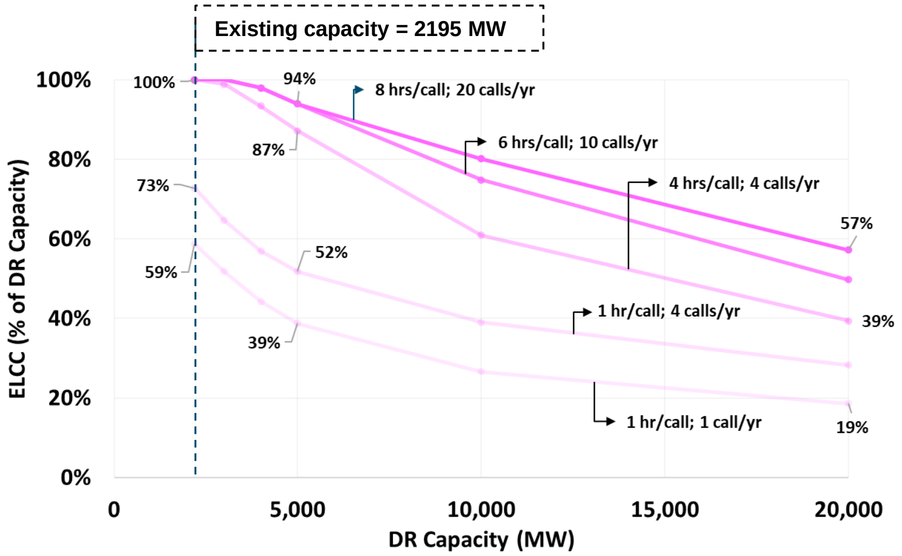
Significant degradation in last-in ELCC in 2030 is driven by saturation of energy-limited resources, primarily storage

2030

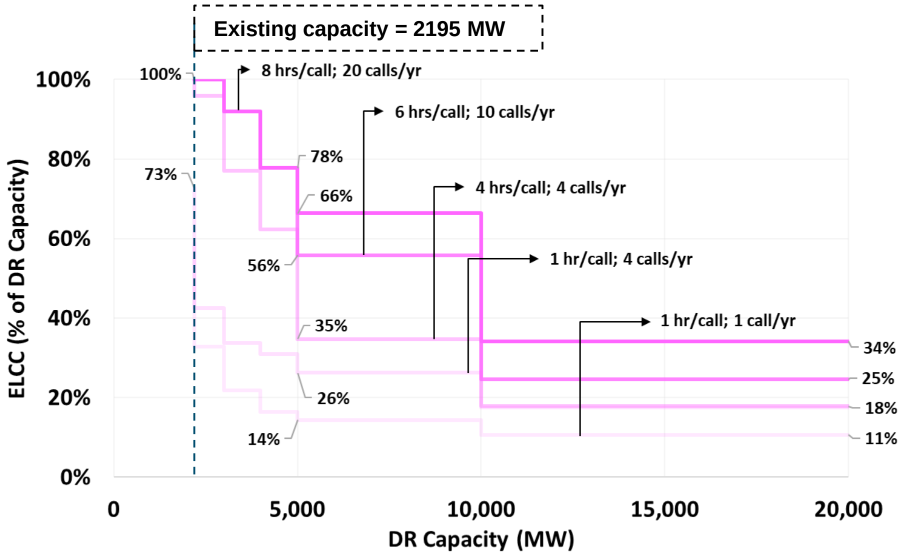
ELCC (% of nameplate)		Max annual calls						
		1	2	4	5	10	15	20
Max call duration (hrs)	1	35%	37%	37%	37%	37%	37%	37%
	2	44%	49%	49%	49%	49%	49%	49%
	4	52%	65%	69%	69%	69%	69%	69%
	6	56%	77%	77%	77%	77%	77%	77%
	8	75%	91%	93%	93%	93%	93%	93%

DR ELCC Performance at Increasing Penetrations (2019)

Average Last-in ELCC



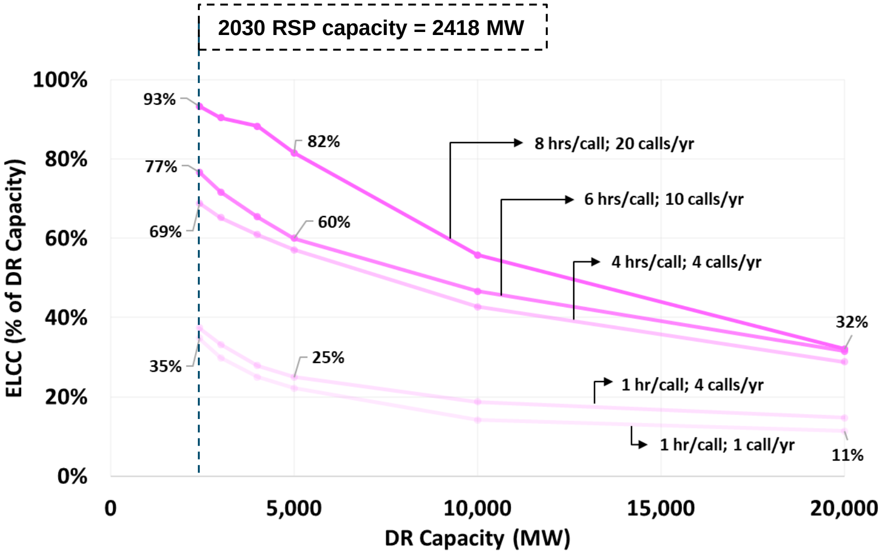
Incremental Last-in ELCC



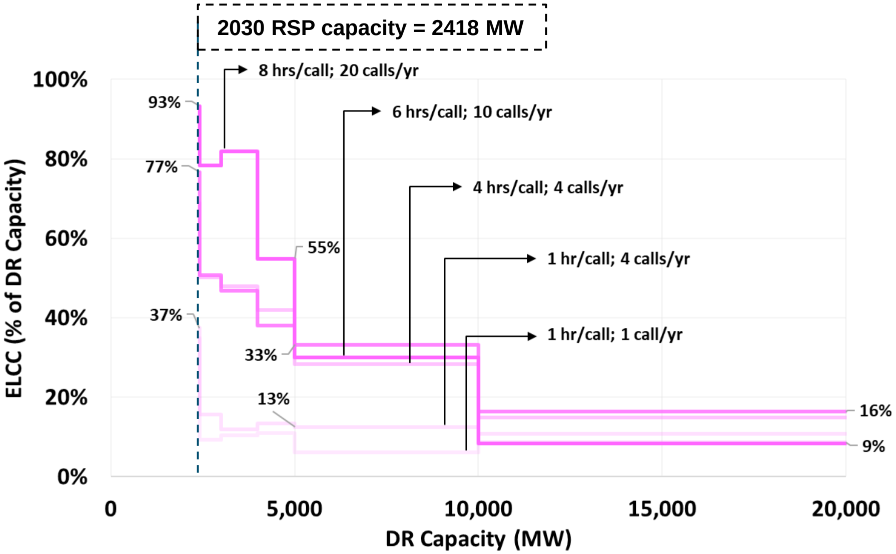
- **Average ELCC = Total Effective Capacity / Total Installed Capacity**
- **Incremental ELCC = ∆ Effective Capacity / ∆ Installed Capacity**
- **ELCC generally decreases as DR capacity on the system increases:**
  - Similarity in hours of operation and characteristics limits the incremental value that more of the exact same resource type can add to the system.
  - Degradation gets more severe as call constraints become more stringent.

DR ELCC Performance at Increasing Penetrations (2030)

Average Last-in ELCC



Incremental Last-in ELCC



+ **ELCC generally decreases as DR capacity on the system increases:**
  - Similarity in hours of operation and characteristics limits the incremental value that more of the exact same resource type can add to the system.
  - For a given DR capacity on the system, ELCC in 2030 is lower than that in 2019 owing to saturation of energy-limited resources on the system in 2030, particularly storage.

CPUC Role in RA & ELCC Implementation

- **The CPUC has been a leader in North America through the incorporation of intermittent and energy-limited resources into RA frameworks**
  - One of the first to adopt and implement **ELCC** framework to value wind and solar
  - Currently the only jurisdiction that recognizes and accounts for **interactive effects** of resources through allocation of a “diversity benefit” to wind and solar
- **The CPUC has recognized that the concept of “interactive effects” applies not only to renewables but to storage and other resources, but has not yet established an approach for allocation that incorporates them all**

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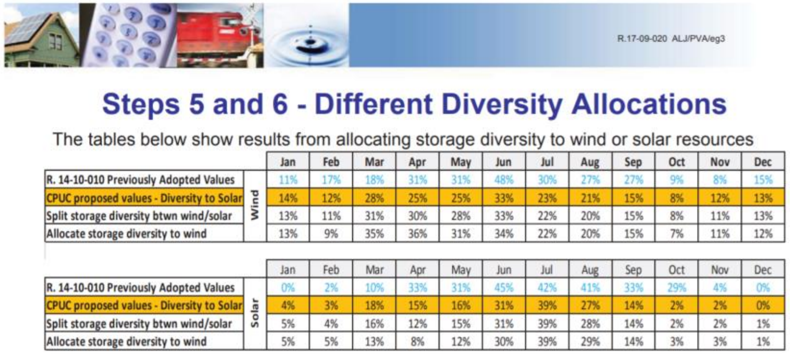

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Steps 5 and 6 - Different Diversity Allocations

The tables below show results from allocating storage diversity to wind or solar resources

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R. 14-10-010 Previously Adopted Values	Wind	11%	17%	18%	31%	31%	48%	30%	27%	27%	9%	8%	15%
CPUC proposed values - Diversity to Solar		14%	12%	28%	25%	25%	33%	23%	21%	15%	8%	12%	13%
Split storage diversity btwn wind/solar		13%	11%	31%	30%	28%	33%	22%	20%	15%	8%	11%	13%
Allocate storage diversity to wind		13%	9%	35%	36%	31%	34%	22%	20%	15%	7%	11%	12%

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R. 14-10-010 Previously Adopted Values	Solar	0%	2%	10%	33%	31%	45%	42%	41%	33%	29%	4%	0%
CPUC proposed values - Diversity to Solar		4%	3%	18%	15%	16%	31%	39%	27%	14%	2%	2%	0%
Split storage diversity btwn wind/solar		5%	4%	16%	12%	15%	31%	39%	28%	14%	2%	2%	1%
Allocate storage diversity to wind		5%	5%	13%	8%	12%	30%	39%	29%	14%	3%	3%	1%

- **Establishing a more generalized, durable framework for ELCC (capable of accounting for renewables, storage, and DR) will require a reexamination of the methods used to allocate ELCC and the “diversity benefit”**
- **This section examines alternative options for allocating ELCC among resources that could improve upon existing methods currently in use**

Allocating ELCC

- **Allocating Portfolio ELCC is necessary with a centralized or bilateral capacity market framework where individual resources must be assigned a capacity contribution for compensation purposes**
  - Directly impacts billions of dollars of market clearing transactions within California and other organized capacity markets
- **Allocating Portfolio ELCC can impact planning and procurement in California to the extent that entities procure based on the economic signal they receive in the RA program**
  - An allocation exercise is not necessary in vertically integrated jurisdictions or in systems with a centralized procurement process
- **There are an infinite number of methods to allocate Portfolio ELCC to individual resources and no single correct or scientific method, similar to rate design**

Sample ELCC Allocation Method Options

1. **Allocate proportionally to First-In ELCC**
2. **Allocate proportionally to Last-In ELCC**
3. **Allocate adjustment to First-In ELCC proportionally to differences between First-in and Last-In ELCC**
4. **Vintaging approach where each resource permanently receives Last-In ELCC at the time it was constructed**
5. **More**

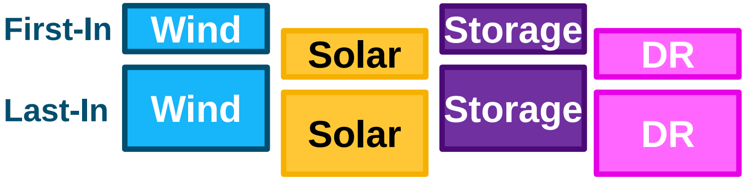
Framework to Incorporate DR ELCC Into CPUC RA Framework

- This section presents a framework as one option for attributing capacity value to DR ***within the current resource adequacy framework*** administered by the CPUC
- **This framework relies on several key principles:**
  1) **Reliability:** The ELCC allocated to each project/program should sum to the portfolio ELCC for all resources
  2) **Fairness:** ELCC calculations should be technology neutral, properly reward resources for the capacity characteristics they provide, and not unduly differentiate among similar resources
  3) **Efficiency:** ELCC values should send accurate signals to encourage an economically efficient outcome to maximize societal resources
  4) **Customer Acceptability:** ELCC calculations should be transparent, tractable understandable, and implementable

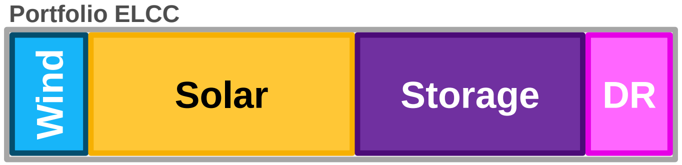
Overview of Framework

1 **Calculate portfolio ELCC**

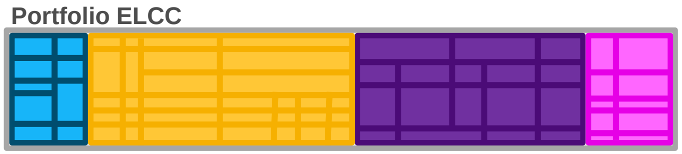
2 **Calculate "first-in" and "last-in" ELCC for each resource category**



3 **Allocate portfolio ELCC to each resource category**

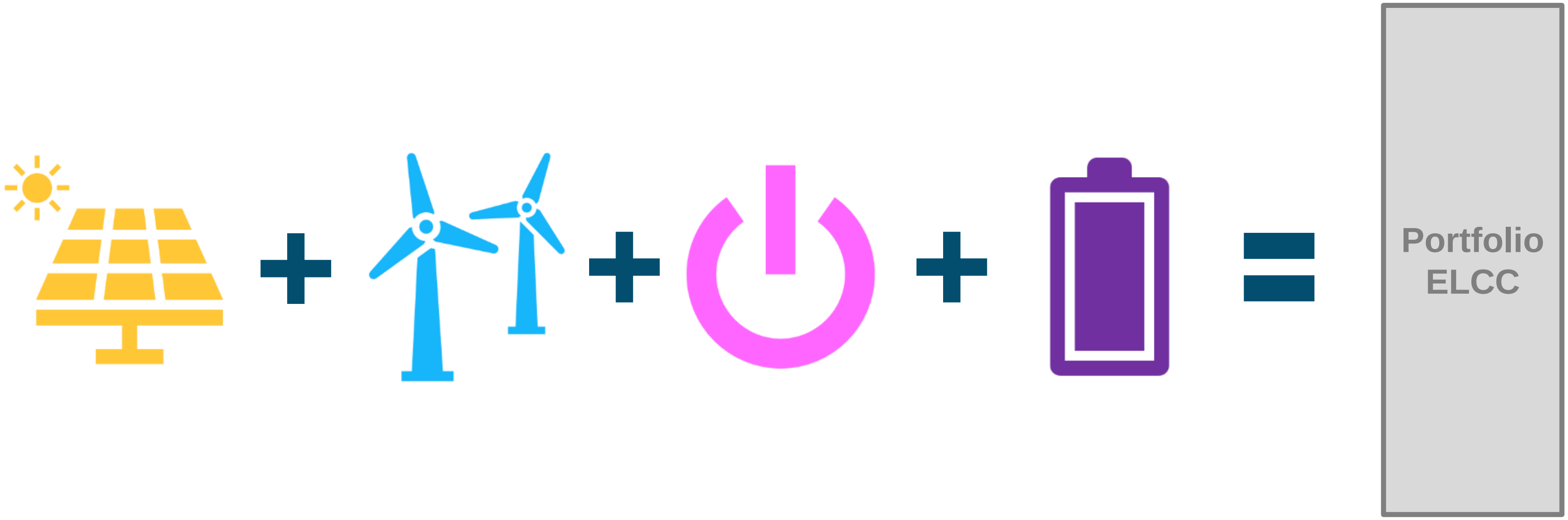


4 **Allocate resource category ELCC to each project/program using tractable heuristic**



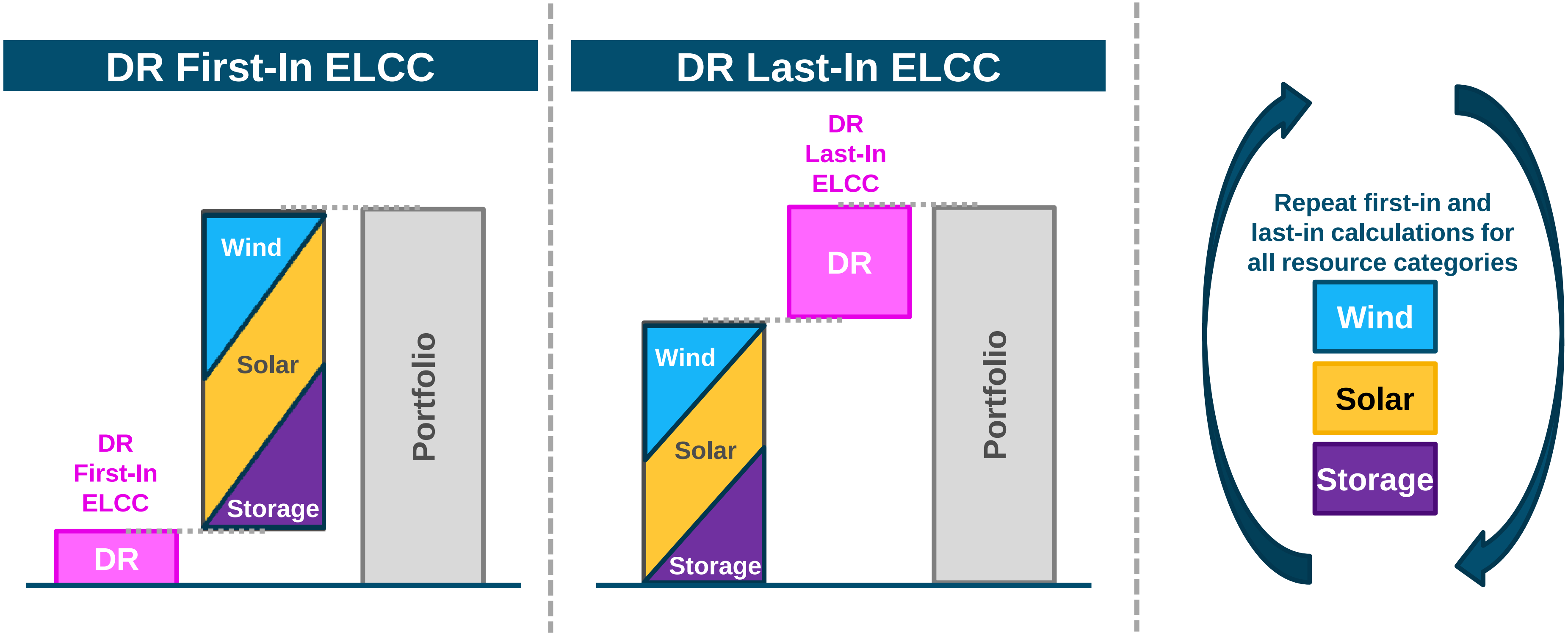
1) Calculate Portfolio ELCC

- **The first step should calculate the portfolio ELCC of all variable and energy-limited resources**
  - Wind
  - Solar
  - Storage
  - Demand Response



2) Calculation First-In and Last-In Resource Category ELCCs

- The second step calculates the “first-in” and “last-in” ELCC for each resource category as a necessary input for allocation of the portfolio ELCC

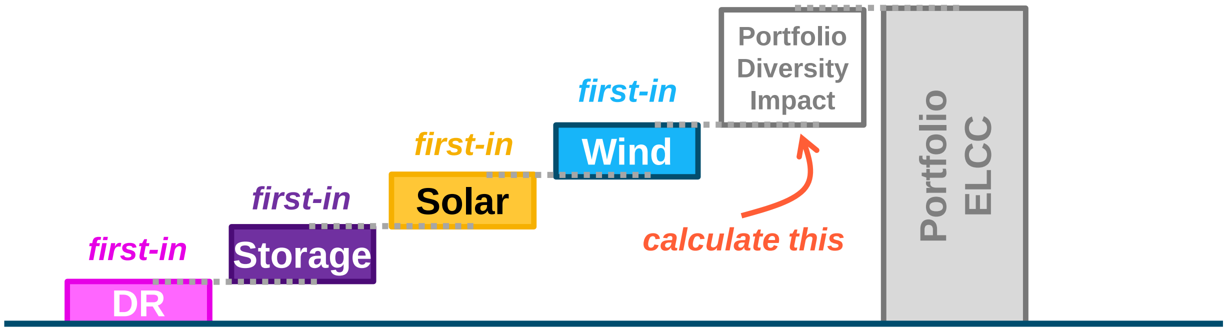


Repeat first-in and last-in calculations for all resource categories

3) Allocate Portfolio ELCC to Each Resource Category

1

Calculate diversity impact as the difference between portfolio ELCC and sum of first-in ELCCs



first-in
DR

first-in
Storage

first-in
Solar

first-in
Wind

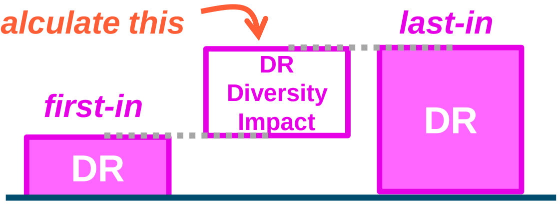
Portfolio Diversity Impact

calculate this

Portfolio ELCC

2

Calculate diversity impact for each resource category

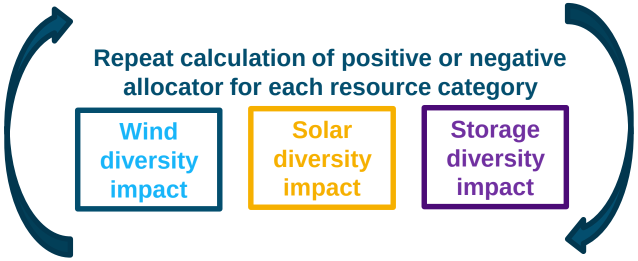


calculate this

first-in
DR

DR Diversity Impact

last-in
DR



Repeat calculation of positive or negative allocator for each resource category

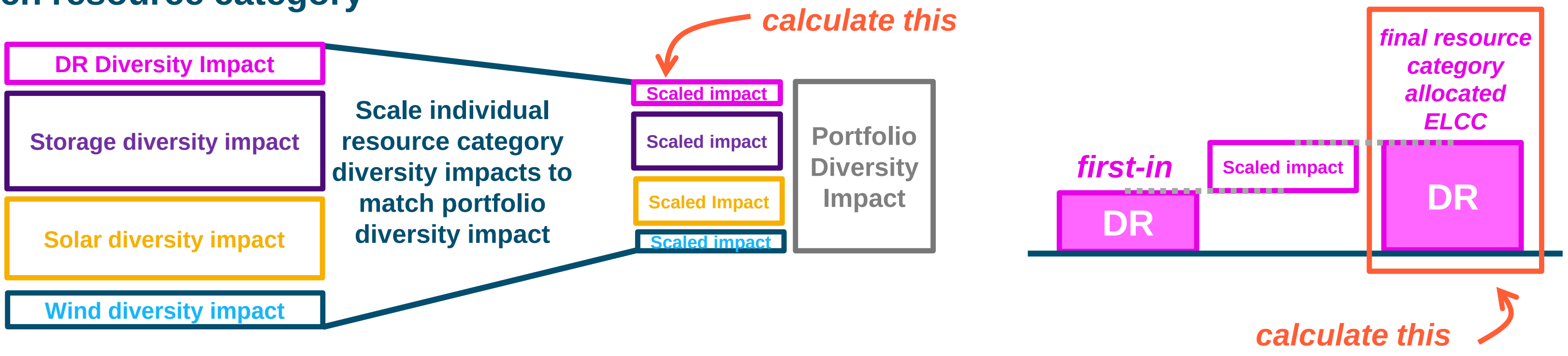
Wind diversity impact

Solar diversity impact

Storage diversity impact

3

Allocate diversity impact in proportion to the difference between first-in and last-in ELCC for each resource category



DR Diversity Impact

Storage diversity impact

Solar diversity impact

Wind diversity impact

Scale individual resource category diversity impacts to match portfolio diversity impact

calculate this

Scaled impact

Scaled impact

Scaled Impact

Scaled impact

Portfolio Diversity Impact

final resource category allocated ELCC

first-in
DR

Scaled impact

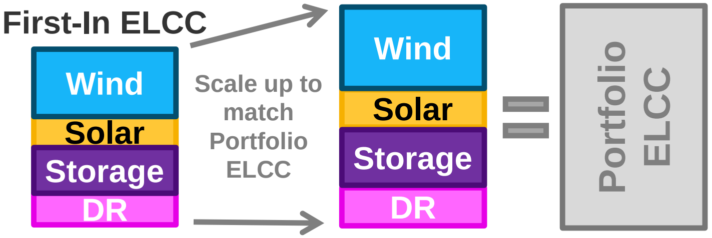
DR

calculate this

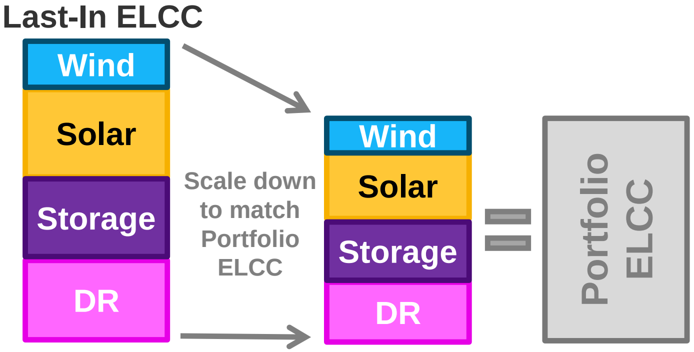
Benefits of this Approach

- There are several options to allocate Portfolio ELCC to each technology category, two examples of which are shown below

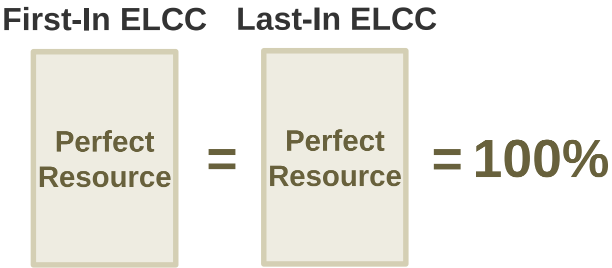
First-In ELCC Allocation Option



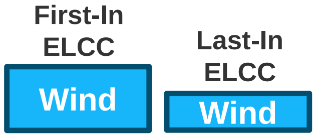
Last-In ELCC Allocation Option



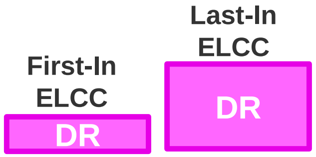
- Both of these options can lead to final ELCC allocations that fall outside the bounds of the first-in or last-in ELCC
  - For example, in the case of a "perfect" resource (e.g. ultra-long duration storage, always available DR, baseload renewables, etc.), this should be counted at 100% ELCC and should not be unduly scaled up or down based on the synergistic or antagonistic impacts of other resource interactions
  - Scaling the first-in or last-in ELCC in any way would result in an ELCC of either >100% or <100% for this perfect resource



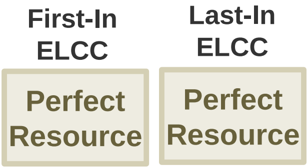
- The method presented in this deck scales resources based on the difference of their first-in and last-in ELCC in order to reflect their synergistic or antagonistic contributions to Portfolio ELCC



Negative diversity impact leads to first-in ELCC being scaled up to match Portfolio ELCC



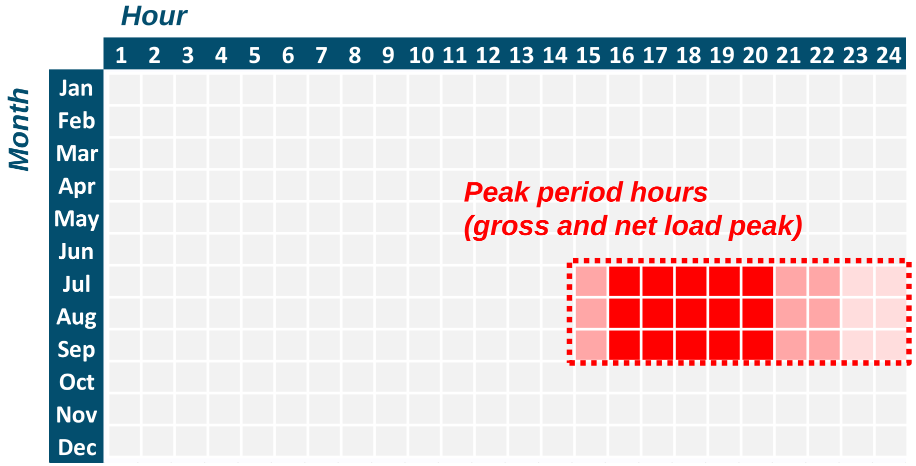
Positive diversity impact leads to first-in ELCC being scaled down to match Portfolio ELCC



No diversity impact leads to no scaling of first-in ELCC to match Portfolio ELCC

4) Allocate Resource Category ELCC to Individual Resource/Programs Using Heuristics

- **Each DR program submits the following information**
  - Expected output during peak period hours
  - Maximum number of calls per year
  - Maximum duration of call
- **Step 1) Calculate average MW availability during peak period hours (gross and net load)**
- **Step 2) Multiple MW availability from step (1) by lookup table de-rating factor to account for call and duration limitations**
  - DR category ELCC to individual program ELCC using first-in and last-in ELCC would work similarly to the allocation process of portfolio ELCC to resource category ELCC



Peak period hours (gross and net load peak)

First-In ELCC

ELCC (% of nameplate)		Max annual calls						
		1	2	4	5	10	15	20
Max call duration (hrs)	1	41%	43%	43%	43%	43%	43%	43%
	2	60%	65%	65%	65%	65%	65%	65%
	4	72%	91%	95%	95%	95%	95%	95%
	6	73%	92%	98%	98%	98%	98%	98%
	8	73%	92%	98%	98%	98%	98%	98%

Last-In ELCC

ELCC (% of nameplate)		Max annual calls						
		1	2	4	5	10	15	20
Max call duration (hrs)	1	35%	37%	37%	37%	37%	37%	37%
	2	44%	49%	49%	49%	49%	49%	49%
	4	52%	65%	69%	69%	69%	69%	69%
	6	56%	77%	77%	77%	77%	77%	77%
	8	75%	91%	93%	93%	93%	93%	93%

Questions?

Questions

Thank You

Arne Olson (arne@ethree.com)

Zach Ming, (zachary.ming@ethree.com)

Vignesh Venugopal (vignesh.venugopal@ethree.com)

Appendix

NQCs as a Basis for Comparison with ELCCs

- NQCs are calculated using load impacts (LI) , i.e. load reductions expected during peak conditions, calculated in line with the Load Impact Protocols.
- Load impacts are grossed up for transmission and distribution losses, as also the 15% PRM, owing to demand response being a demand reduction measure.

$$NQC \;=\; LI \;*\; 1.15\,(PRM) * \;T\&D\;loss\;factor$$[1]

- Load impacts for the year 2019 are referenced from the CPUC's RA Compliance documents[2]
- Load impacts are defined on an LCA level from 1 pm to 6 pm, Apr to Oct, and from 4 pm to 9 pm in the rest of the year, both with and without line losses.

[1] CPUC 2019 RA Guide

[2] CPUC 2019 IoU DR Program Totals

Key Question: What Call and Duration Characteristics are Needed to Maximize DR ELCC?

- **E3 tested how two primary constraints impact the ELCC of demand response resources**
  - Max # of calls per year
    - How many times can a system operator dispatch a demand response resource?
  - Max duration of each call
    - How long does the demand response resource respond when called by the system operator?
- **Key Assumptions:**
  - DR portfolio is divided into 100 MW units, each of which can be dispatched independently of the other
    - In other words, 2-hour-100 MW units can be dispatched in sequence to avoid an unserved energy event 100 MW deep and 4 hours long
  - Each 100 MW unit is available 24/7, at full capacity of 100 MW, subject to call constraints defined above to establish a clear baseline for ELCC %'s
  - Pure Shed DR; No shifting of load; No snap-backs

Average ELCC as a function of DR Capacity on the System

2019

First-in ELCC

Call constraints

ELCC (% of DR capacity) DR capacity (MW)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	46%	51%	70%	94%	95%	95%	94%	95%
3,000	40%	47%	61%	92%	94%	96%	93%	96%
4,000	36%	42%	52%	78%	80%	86%	80%	86%
5,000	32%	39%	46%	73%	75%	83%	74%	84%
10,000	21%	30%	31%	51%	60%	65%	53%	70%
20,000	14%	21%	20%	33%	46%	44%	35%	52%

Last-in ELCC

Call constraints

ELCC (% of DR capacity) DR capacity (MW)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	59%	73%	77%	100%	100%	100%	100%	100%
3,000	52%	65%	67%	99%	100%	100%	99%	100%
4,000	44%	57%	63%	93%	98%	98%	93%	98%
5,000	39%	52%	59%	87%	94%	94%	88%	94%
10,000	27%	39%	38%	61%	75%	75%	61%	80%
20,000	19%	28%	25%	39%	53%	50%	40%	57%

2030

First-in ELCC

Call constraints

ELCC (% of DR capacity) DR capacity (MW)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	41%	43%	72%	95%	95%	98%	98%	98%
3,000	38%	40%	66%	92%	93%	98%	97%	98%
4,000	35%	37%	56%	83%	88%	91%	85%	91%
5,000	32%	35%	50%	74%	80%	86%	77%	88%
10,000	23%	30%	33%	52%	62%	67%	55%	71%
20,000	15%	22%	22%	35%	47%	46%	37%	53%

Last-in ELCC

Call constraints

ELCC (% of DR capacity) DR capacity (MW)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	35%	37%	52%	69%	69%	77%	93%	93%
3,000	30%	33%	48%	65%	65%	72%	90%	90%
4,000	25%	28%	43%	61%	61%	65%	88%	88%
5,000	22%	25%	41%	57%	57%	60%	80%	82%
10,000	14%	19%	30%	43%	43%	47%	54%	56%
20,000	11%	15%	22%	29%	30%	31%	32%	32%

Incremental ELCC as a function of DR Capacity on the System

2019

First-in ELCC

Call constraints

DR capacity (MW)

ELCC (% of DR capacity)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	46%	51%	70%	94%	95%	95%	94%	95%
3,000	25%	36%	37%	86%	93%	99%	90%	99%
4,000	22%	29%	26%	34%	39%	57%	40%	58%
5,000	15%	23%	22%	52%	56%	69%	51%	73%
10,000	11%	22%	16%	30%	45%	47%	32%	57%
20,000	7%	11%	10%	16%	31%	23%	17%	33%

Last-in ELCC

Call constraints

DR capacity (MW)

ELCC (% of DR capacity)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	59%	73%	77%	100%	100%	100%	100%	100%
3,000	33%	42%	37%	96%	100%	100%	96%	100%
4,000	22%	34%	53%	77%	92%	92%	77%	92%
5,000	16%	31%	40%	62%	77%	78%	67%	78%
10,000	14%	26%	18%	35%	56%	56%	34%	66%
20,000	11%	18%	12%	18%	30%	25%	18%	34%

2030

First-in ELCC

Call constraints

DR capacity (MW)

ELCC (% of DR capacity)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	41%	43%	72%	95%	95%	98%	98%	98%
3,000	26%	28%	42%	81%	84%	96%	94%	96%
4,000	25%	28%	25%	53%	71%	72%	48%	72%
5,000	19%	25%	24%	39%	48%	65%	45%	76%
10,000	15%	26%	17%	31%	45%	49%	33%	53%
20,000	8%	13%	11%	17%	32%	25%	19%	36%

Last-in ELCC

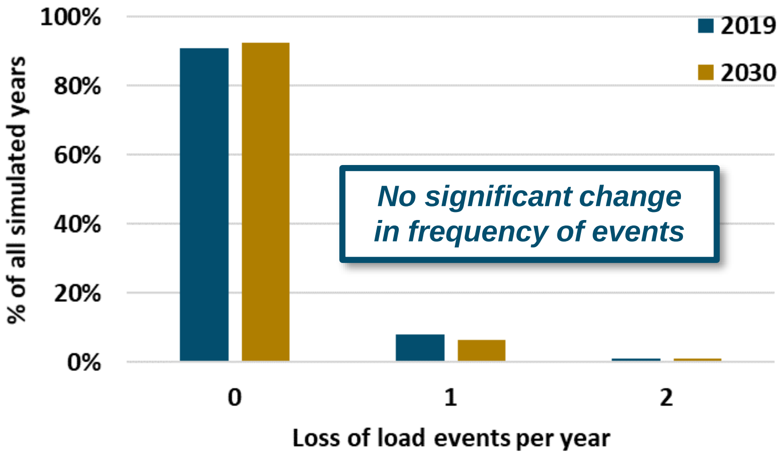
Call constraints

DR capacity (MW)

ELCC (% of DR capacity)	1 hour/call 1 call/year	1 hour/call 4 calls/year	4 hours/call 1 call/year	4 hours/call 4 calls/year	4 hours/call 20 calls/year	6 hours/call 10 calls/year	8 hours/call 4 calls/year	8 hours/call 20 calls/year
2,195	35%	37%	52%	69%	69%	77%	93%	93%
3,000	9%	16%	29%	50%	50%	51%	78%	78%
4,000	10%	12%	29%	48%	48%	47%	82%	82%
5,000	11%	13%	34%	42%	42%	38%	46%	55%
10,000	6%	13%	20%	28%	28%	33%	29%	30%
20,000	9%	11%	13%	15%	18%	16%	9%	8%

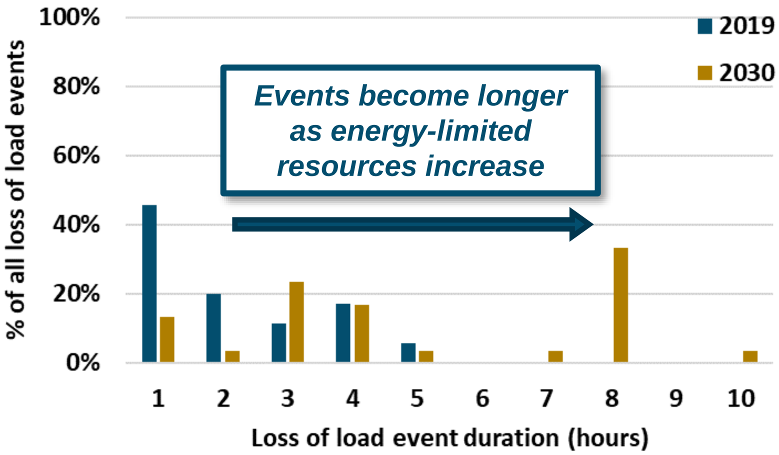
2019 vs 2030 Loss of Load Events

Frequency of Event Occurrence



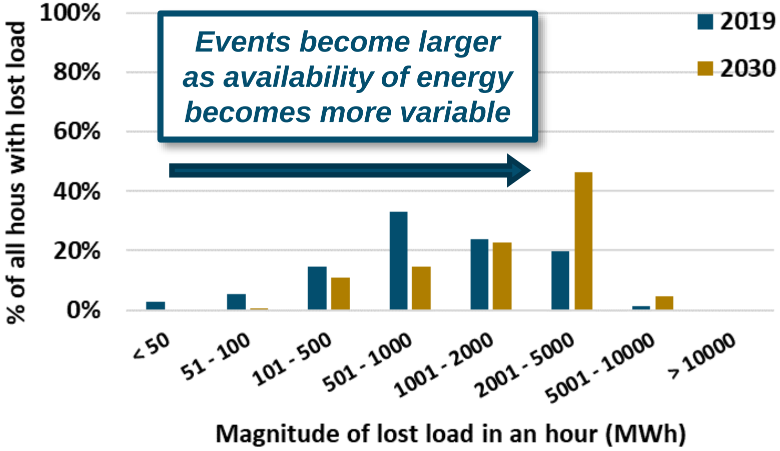
No significant change in frequency of events

Distribution of Event Duration



Events become longer as energy-limited resources increase

Distribution of Event Magnitude



Events become larger as availability of energy becomes more variable

Overview of Data

- **The 2019 PG&E and SCE DR ELCC results focus on "event-based" DR programs, as opposed to passive measures like dynamic pricing applicable throughout a season/year**
  - Does not consider SDG&E or Demand Response Auction Mechanism (DRAM) resources which are a significant portion of the data DR portfolio, due to data limitations
- **Data sources for RECAP ELCC calculations**
  1. Hourly PG&E DR bid data for 2019
     - BIP, CBP, and SAC
     - PSPS outage logs were provided by PG&E and used by E3 to identify and then fill gaps in DR bid data
  2. Hourly SCE DR bid data for 2019
     - API, BIP, CBP, and SDP

Data Benchmarking

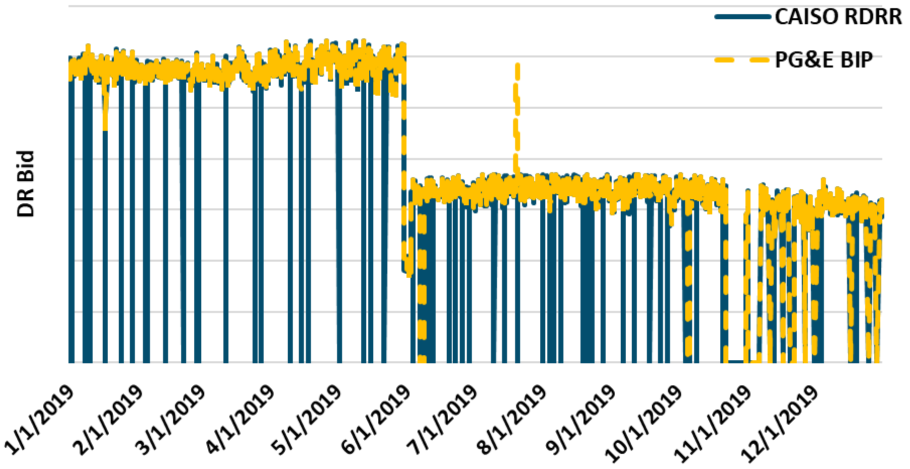
- **E3 used utility data directly from PG&E and SCE for two reasons**
  - CAISO does not have data by utility program
  - Wanted to ensure results were not predicated on CAISO data
- **E3 benchmarked utility data to CAISO data to ensure the veracity of the data**
  - Data generally benchmarked well
  - A few inconsistencies were spotted in the RDRR data:
    - In ~1.3% of hours in the year, DR bids present in PG&E's data are missing in CAISO's data. Technical glitches in transmitting/recording systems may explain this.
    - DR bids in SCE data were slightly lower than bids recorded in CAISO data across significant portions of the year.

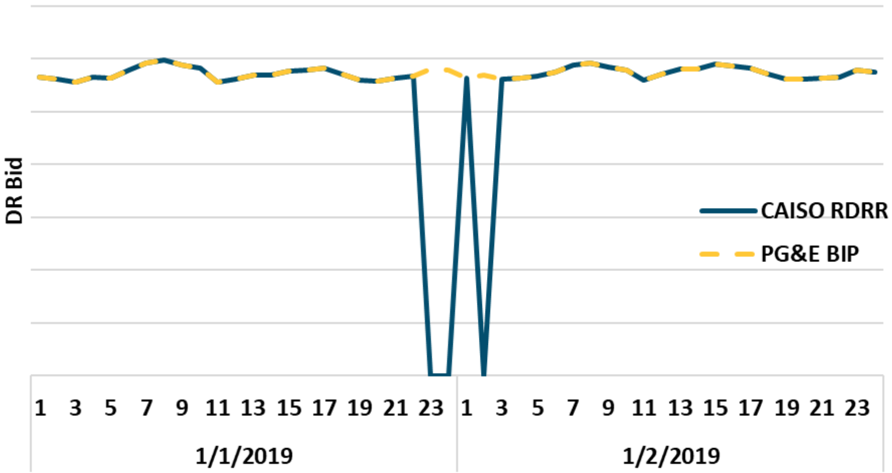
      Underlying reason is currently not known.

Benchmarking of 2019 Bid Data from PG&E and CAISO

- **PDR data from the two sources are identical**
- **There are a few hours (114 out of 8760) where RDRR data is inconsistent:**
  - Several instances across each of the 24 hours of the day
  - These are hours where data is missing in the CAISO dataset
  - Unclear if a bid was not placed, or if it was placed but not recorded due to technical glitches

Example comparison for one of the subLAPs over the entire year and a couple of days in specific

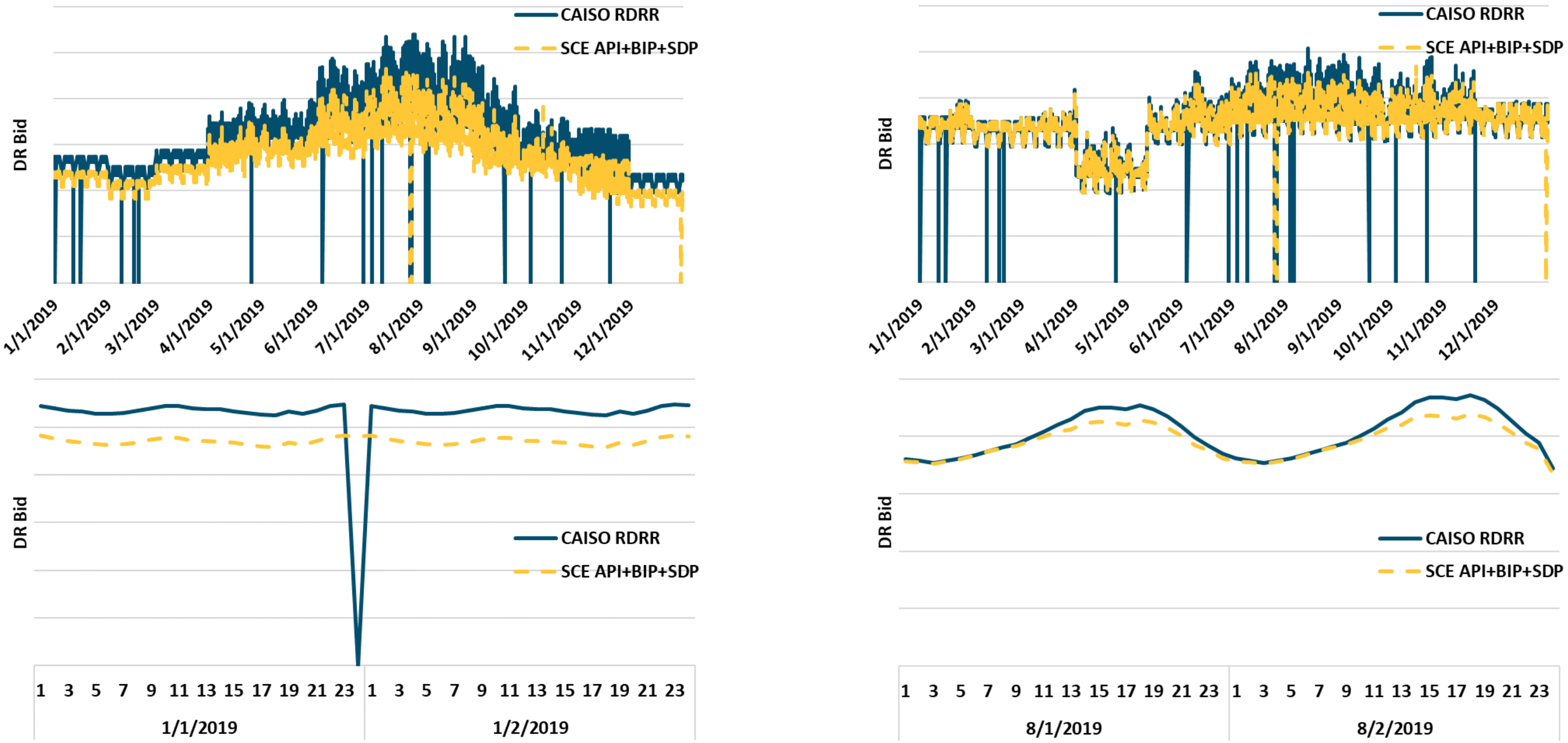




Benchmarking of 2019 Bid Data from SCE and CAISO data

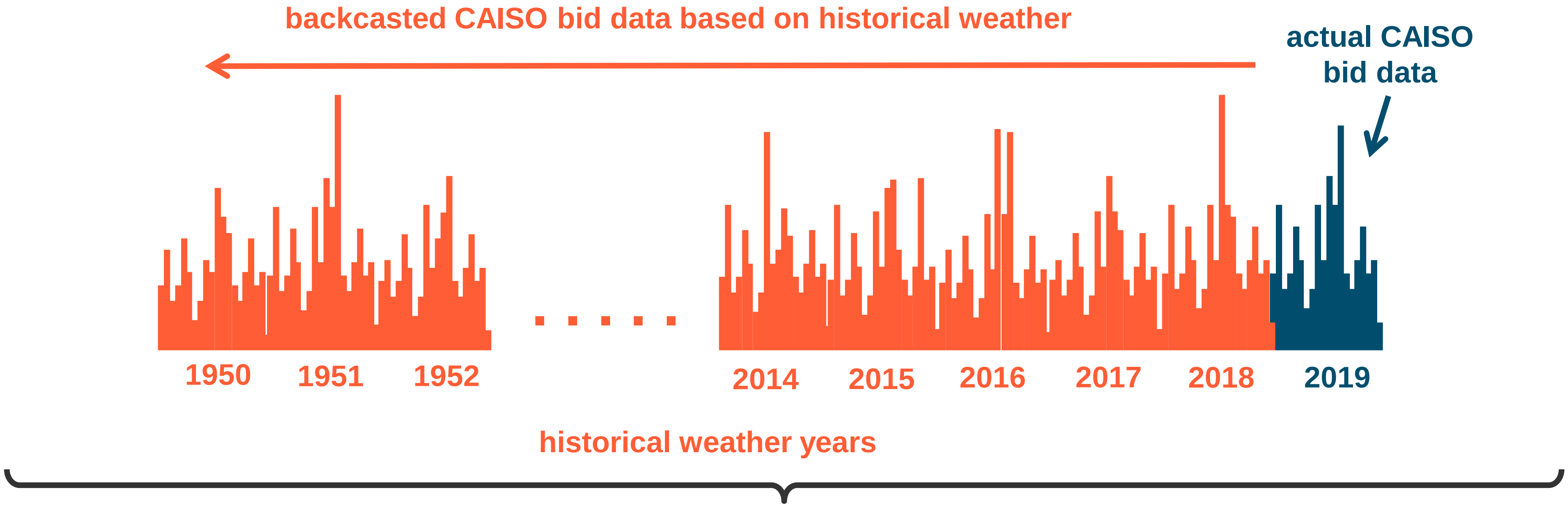
- PDR data from the two sources are identical
- Inconsistencies exist in RDRR data – unclear if the difference is systematic and attributable to a single factor, like treatment of line-losses

Example comparisons for 2 subLAPs- across the entire year and across a couple of days in specific



Extrapolation of DR Bid Data

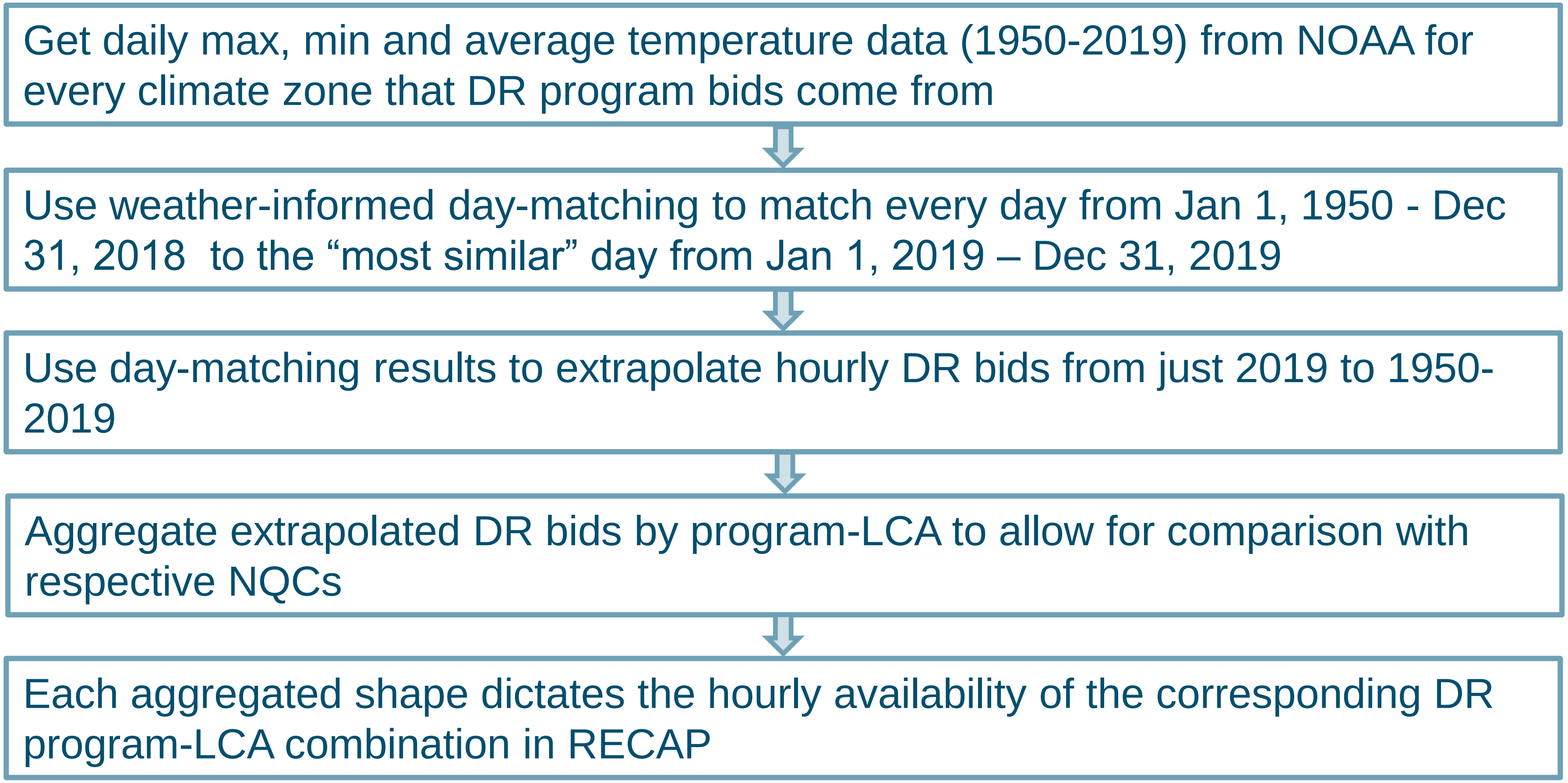
- In order to calculate the ELCC of a DR program or portfolio, RECAP must predict how these programs will perform over many different conditions and weather years
- Therefore, E3 must extend actual 2019 data over the entire historical temperature record as a data requirement for the E3 RECAP model



complete time-series of DR bids is needed as an input into the E3 RECAP model

- In response to stakeholder feedback from the May 3 CAISO ESDER meeting, E3 modified the backcasting approach to include temperature for temperature-dependent air conditioner DR programs
  - More details on this process and methodology can be found in the appendix

Process of Extrapolating Actual DR Bid Data to Entire Weather Record



Get daily max, min and average temperature data (1950-2019) from NOAA for every climate zone that DR program bids come from

Use weather-informed day-matching to match every day from Jan 1, 1950 - Dec 31, 2018 to the “most similar” day from Jan 1, 2019 – Dec 31, 2019

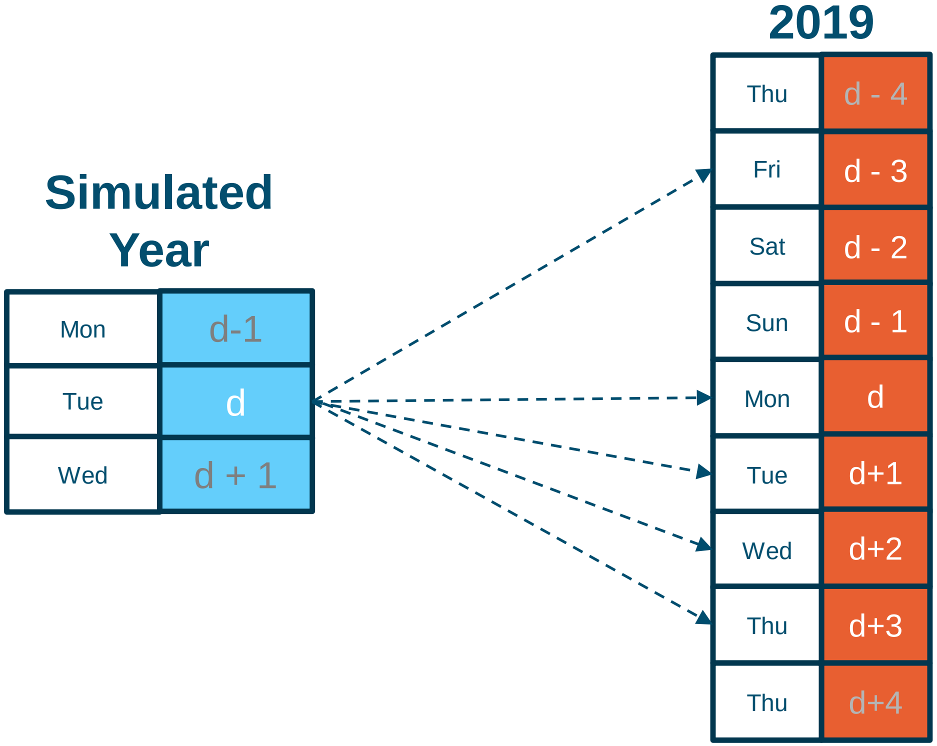
Use day-matching results to extrapolate hourly DR bids from just 2019 to 1950-2019

Aggregate extrapolated DR bids by program-LCA to allow for comparison with respective NQCs

Each aggregated shape dictates the hourly availability of the corresponding DR program-LCA combination in RECAP

Simple Day-Matching Algorithm for CBP, BIP and API DR Programs

- As in the previous phase of this project, E3 used a simple day-matching approach for CBP, BIP and API programs
- DR bid forecasts for these programs were not as strong a function of the temperature as Smart AC
- For an individual DR program and a particular day, ‘d’ in a simulated year, pick one day out of +/- 3 calendar days, ‘d+3’ to ‘d-3’ of the same type (workday/holiday) from the actual 2019 data at random



Simulated Year

Mon	d-1
Tue	d
Wed	d + 1

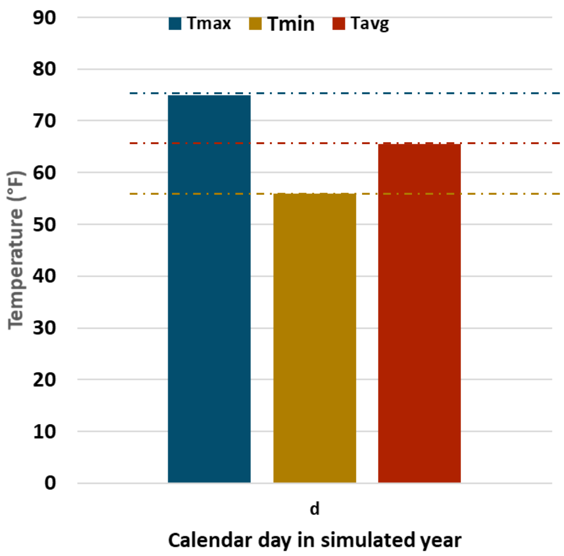
2019

Thu	d - 4
Fri	d - 3
Sat	d - 2
Sun	d - 1
Mon	d
Tue	d+1
Wed	d+2
Thu	d+3
Thu	d+4

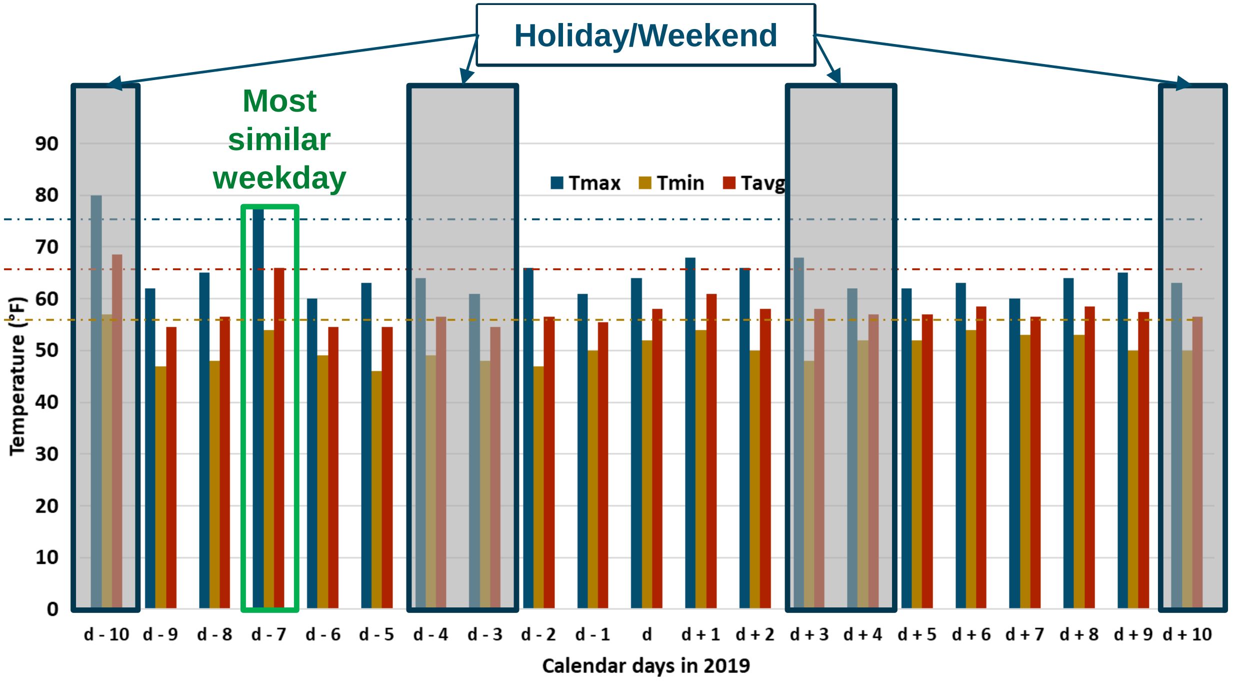
Weather-informed Day-Matching Algorithm for AC cycling DR Programs

- Inclusion of weather for air conditioner DR is in direct feedback to stakeholder comments from the May 3, 2020 CAISO ESDER meeting
- For an individual DR program and a particular day in a simulated year, pick one day out of +/- 10 calendar days of the same type (workday/holiday) from actual 2019 data with the closest T_{max}, T_{min} and T_{avg}
- Applied to PG&E's Smart AC program and SCE's Summer Discount Plan program data to account for influence of temperature on DR availability

Example weekday in simulated year



Candidate (2019) days for matching

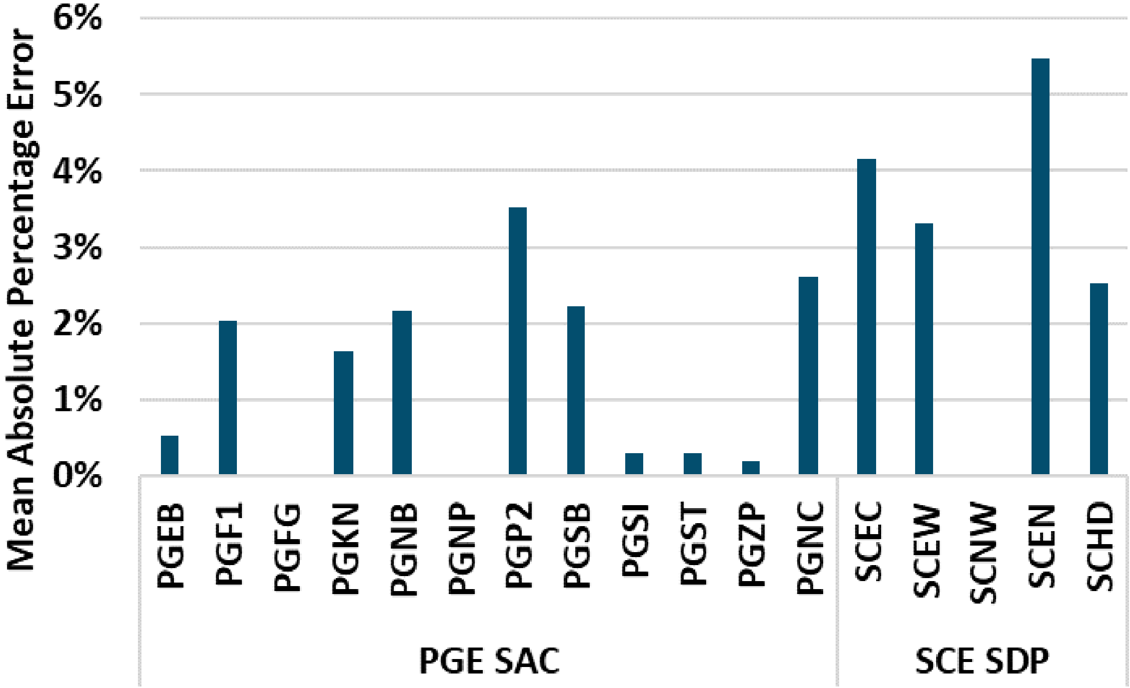


Comparison of day matched and real values

- The Mean Absolute Percentage Error (MAPE) is defined as:

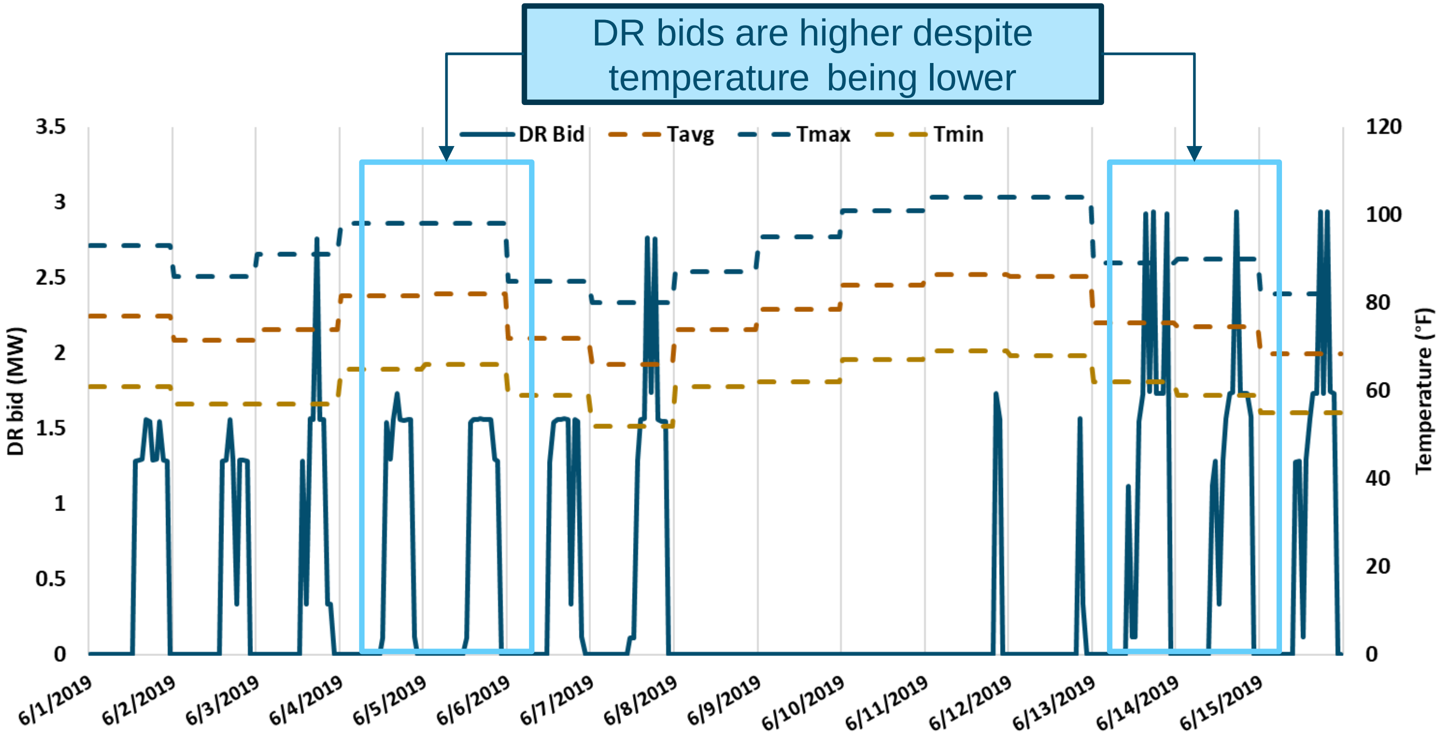
$$\frac{\text{Abs(Day–matched value – Actual Value) x 100}}{\text{Actual Value}}$$

- MAPE is calculated and shown below for July-September, 4 pm to 10 pm



Why Day Matching and not Regression?

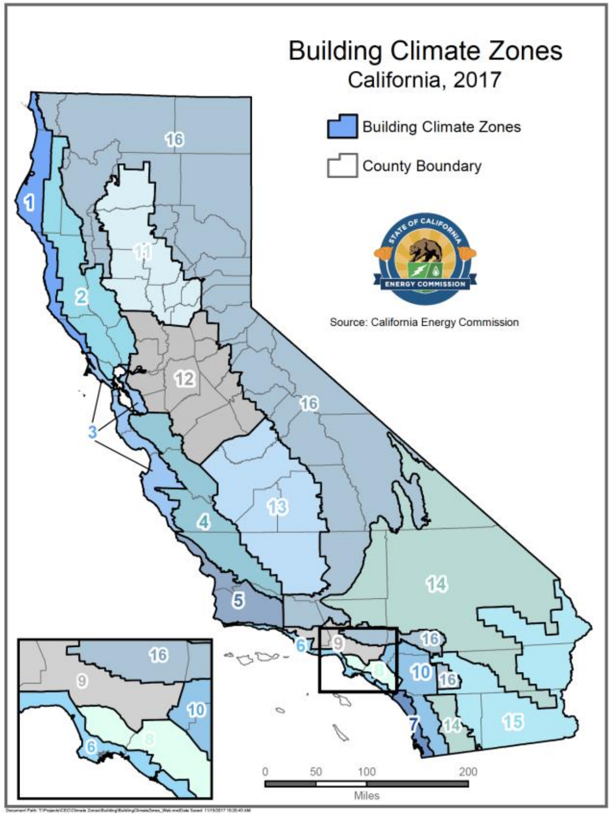
- **Regression based on temperature, month and day-type couldn't explain movement in DR bids. Potential reasons could be:**
  - Mismatch in temperature data used by E3 and IoUs.
  - Not accounting for other explanatory variables that IoUs use in their forecasts.
- **Absence of reliable hourly temperature records going back to 1950 meant only regression for daily DR bids was doable.**

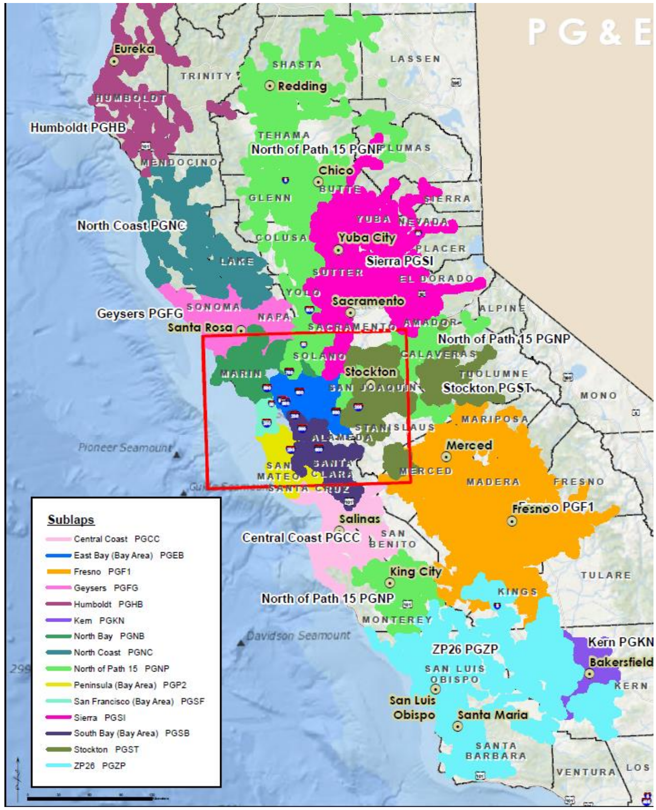

DR bids are higher despite temperature being lower

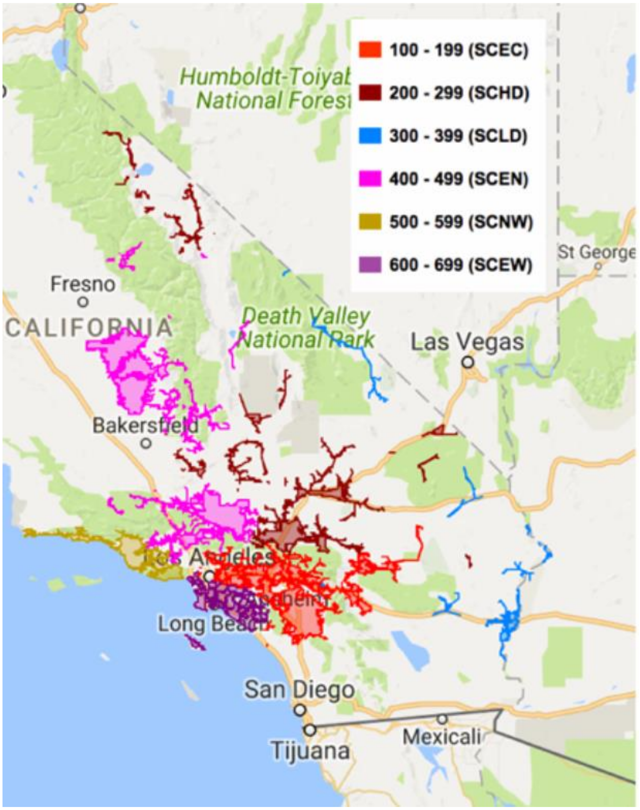
Assumptions on DR Program Characteristics

Utility	**DR Program**	**Event Duration** (hours/call)	**Max. Events per Month**	**Max. Events per Year**	**Comments on RECAP Implementation**
PG&E	**BIP**	6	10		
	CBP	6	5		30 hrs/month is interpreted as 5 events/month
	SAC	6		17	100 hrs/year is interpreted as 17 events/year
SCE	**API**	6	7		40 hours/month is interpreted as 7 events/month
	BIP	6	10		60 hours/month is interpreted as 10 calls/month
	CBP	6	5		30 hours/month is interpreted as 5 calls/month
	SDP	6		30	180 hours/year is interpreted as 30 events/year

Climate zones and sub-LAPs for reference







Sub-LAPs vs. Local Capacity Areas

Sub-LAP	Sub-LAP (long form)	Local Capacity Area
PGCC	PG&E Central Coast	Bay Area
PGEB	PG&E East Bay	Bay Area
PGF1	PG&E Fresno	Greater Fresno
PGFG	PG&E Fulton-Geysers	North Coast/North Bay
PGHB	PG&E Humboldt	Humboldt
PGKN	PG&E Kern	Kern
PGNB	PG&E North Bay	North Coast/North Bay
PGNC	PG&E North Coast	North Coast/North Bay
PGNP	PG&E North of Path 15 - non local	CAISO System
PGP2	PG&E Peninsula	Bay Area
PGSB	PG&E South Bay	Bay Area
PGSF	PG&E San Francisco	Bay Area
PGSI	PG&E Sierra	Sierra
PGST	PG&E Stockton	Stockton
PGZP	PG&E ZP26 (between Path 15 and 26) -non local	CAISO System
SCEC	SCE Central	LA Basin
SCEN	SCE North (Big Creek)	Big Creek/Ventura
SCEW	SCE West	LA Basin
SCHD	SCE High Desert	CAISO System
SCLD	SCE Low Desert	CAISO System
SCNW	SCE North-West (Ventura)	Big Creek/Ventura
SDG1	SDG&E	San Diego/Imperial Valley
VEA	VEA	CAISO System