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2025 California Demand Response Potential Study

Integrated Energy Policy Report Presentation

August 8, 2017

Lawrence Berkeley National Laboratory

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PresentationOverview

- Introduction
- Executive Summary
- Methods
- Results
- Recommendations
- Next Steps and Q&A

DR Potential Study Objectives

- **CPUC bifurcated IOU DR programs into 2 categories**
  - Load modifying resources reshape net load
  - Supply resources integrate into CAISO energy markets

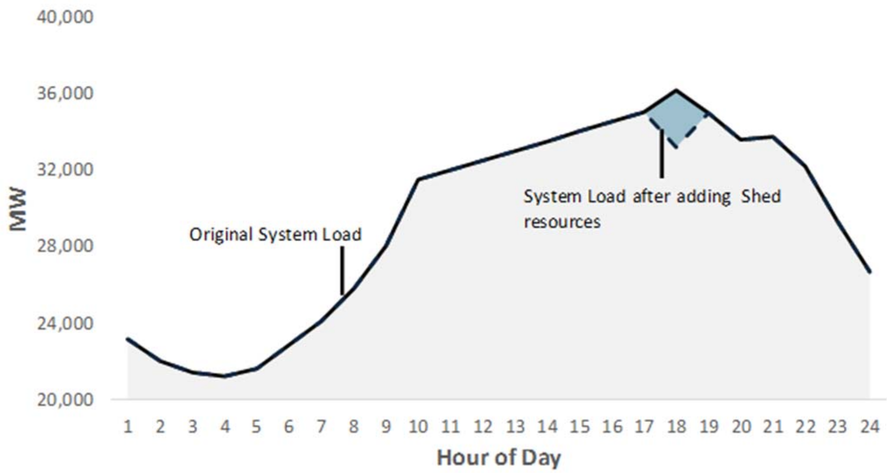
- **DR Potential Study** - part of CPUC's Order Instituting Rulemaking to Enhance Role of DR in Meeting State's Resource Planning Needs & Operational Requirements (13-09-011).

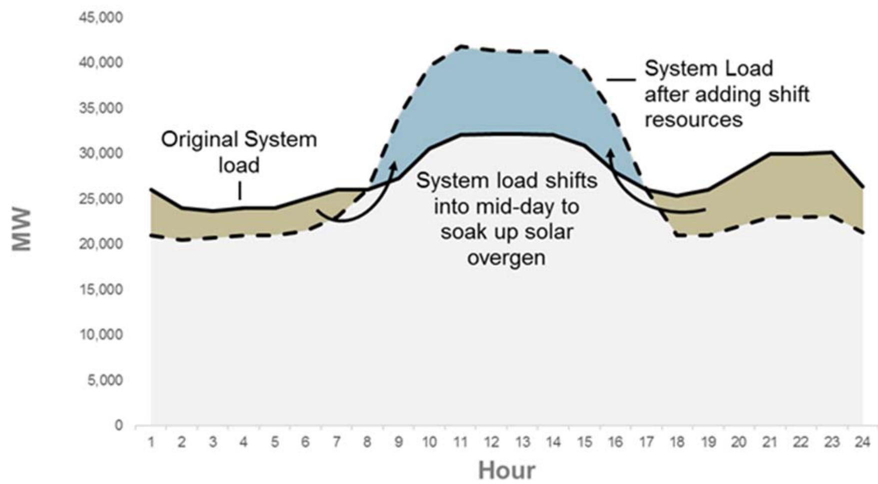
- **Objectives -** Assess CA DR Potential & valuation for bifurcated IOU DR programs & identify opportunities for DR to help meet long-term goals.

DR Service Types Address Grid Needs
Shed & Shift

Shed Service Type: Peak Shed DR

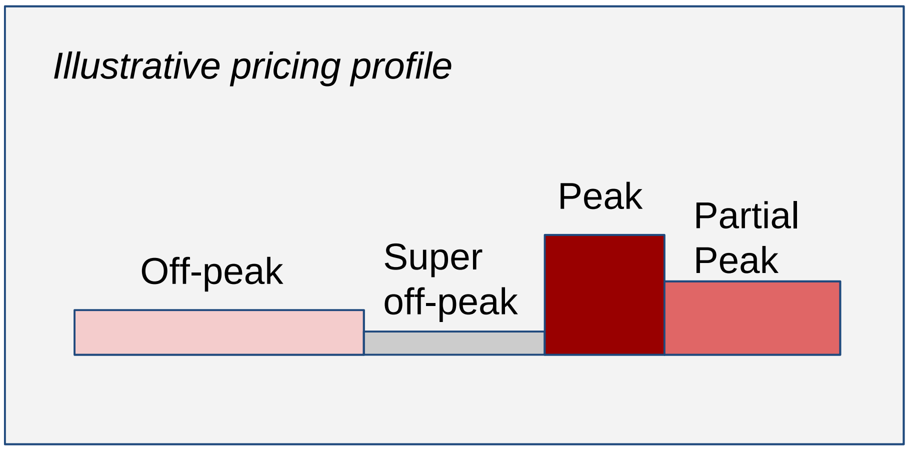
Shift Service Type: Shifting load from hour to hour to alleviate curtailment/ overgeneration



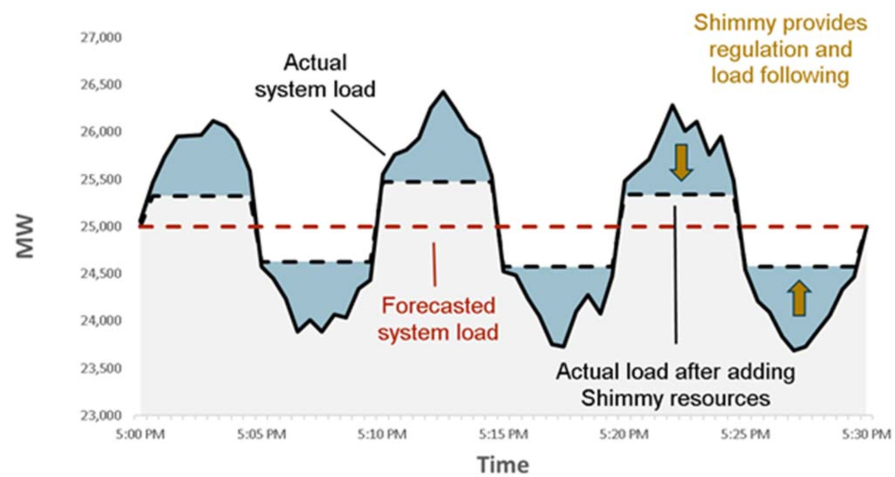


DR Service Types Address Grid Needs
Shape & Shimmy

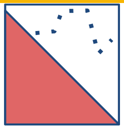
Shape Service Type as modeled: Accomplishes Shed & Shift with prices & behavioral DR.



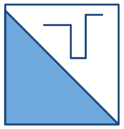
Shimmy Service Type: Load Following & Regulation DR



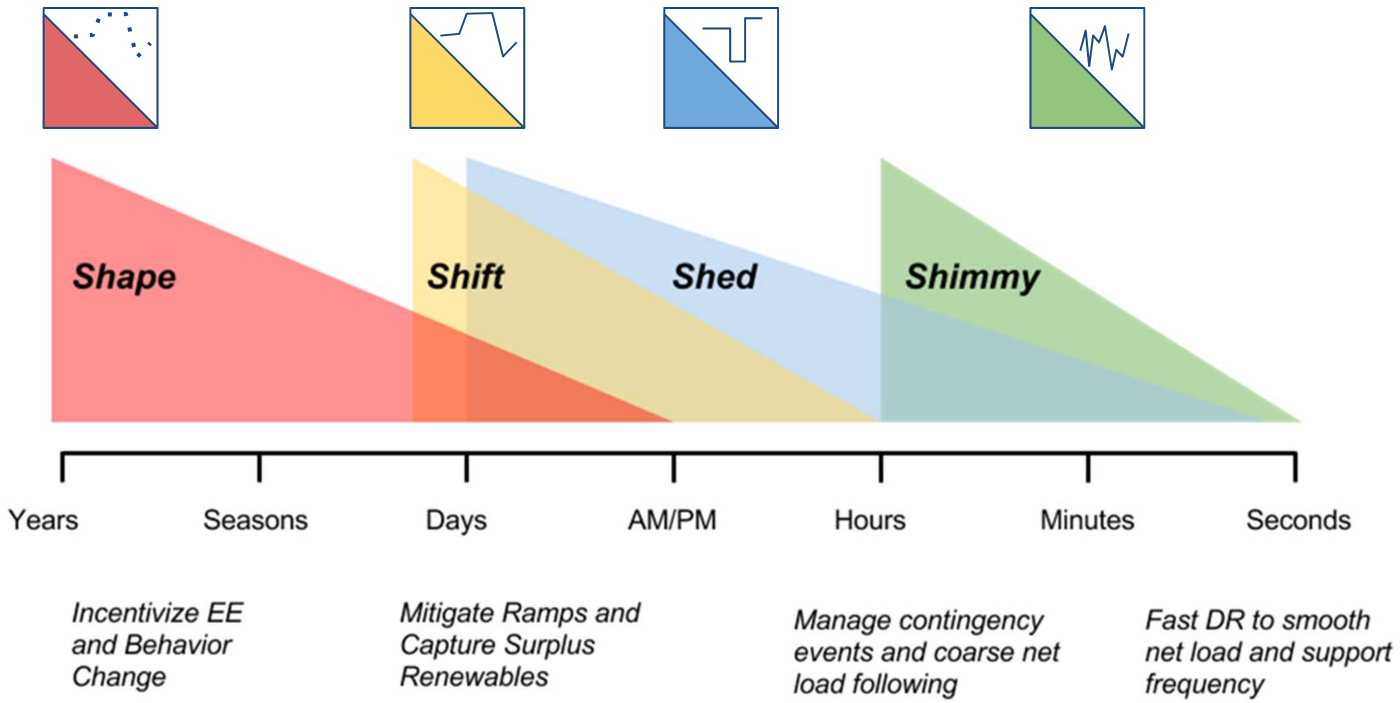
DR Service Type Table



Service Type	Description	Grid Service Products/Related Terms	Analysis Unit	**Shape** (TOU/CPP) Included in service type analysis?
Shift	Demand timing shift (day-to-day)	Flexible ramping DR (avoid/reduce ramps), Energy market price smoothing	kWh-year	Yes
Shed	Peak load curtailment (occasional)	CAISO Proxy Demand Resources/Reliability DR Resources; Conventional DR, Local Capacity DR, Distribution System DR, RA Capacity, Operating Reserves	kW-year	Yes
Shimmy	Fast demand response	Regulation, load following, ancillary services	kW-year	No



DR Service Spans Time Scales



Methodology

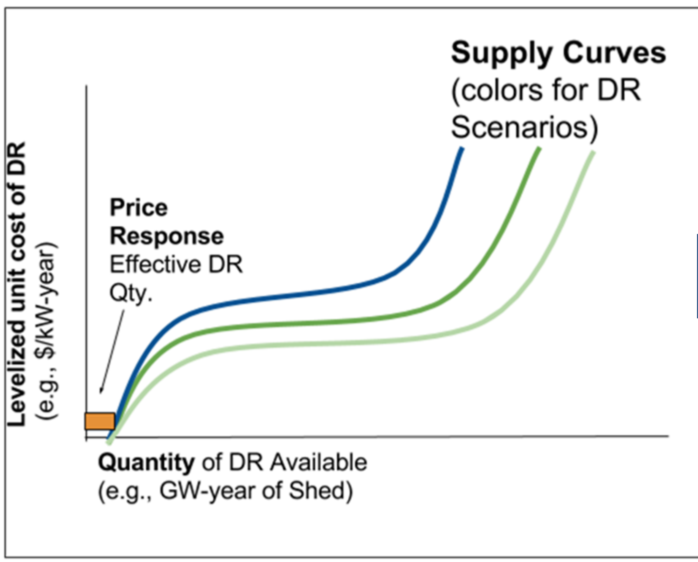
LBNL-Load analysis - IOU-provided customer load (~220,000 customers) & demographic data (~11 million customers) “clusters,” based on observable similarities. Developed characteristic load profiles for total & end use-specific load clusters. **LBNL-Load** forecasts loads for 2020 & 2025 according to 2015 IEPR.

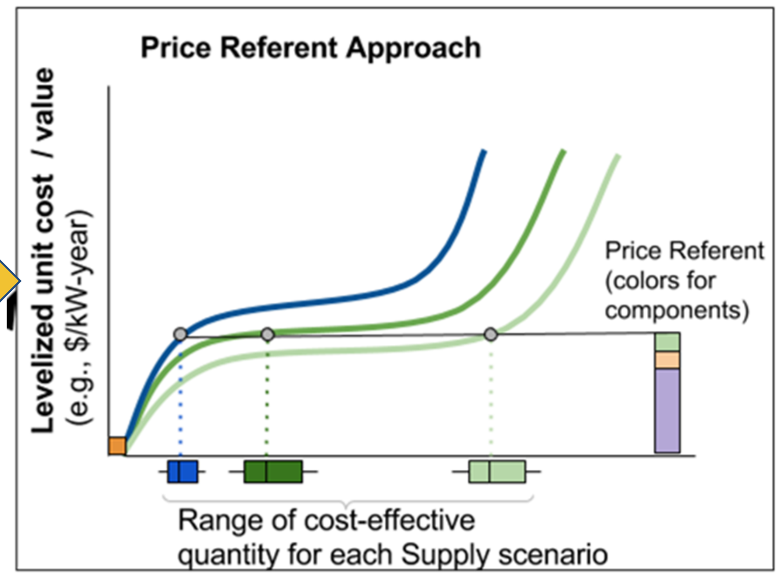
DR-Path generates range of DR pathways based on load forecasts from LBNL-Load. These pathways represent likely futures, given technology adoption, DR participation & cost projections for existing & emerging technologies.

Renewable Energy Solutions (RESOLVE) model estimates value benchmarks for each DR type based on avoided investment & operation costs when DR available for use. Availability ranges run to establish DR’s value **low & high** renewable curtailment.

1. Price Referent Approach

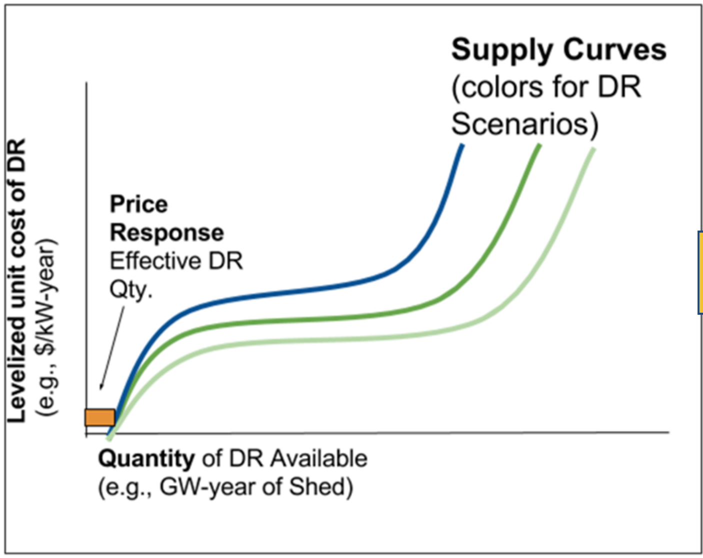
Price Referent Approach: Compares DR Supply to cost of procuring alternative resource (e.g., NG combustion turbine). A "horizontal" demand curve **for "Shed".**

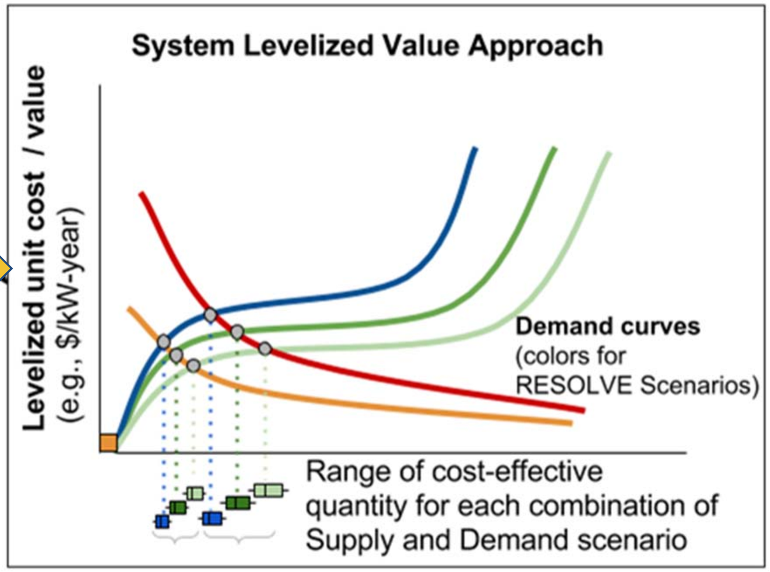




2. System Levelized Value Approach

System Levelized Value Approach: Compare DR supply with estimated "levelized value" to grid as effective annual demand curves.





Phase 2 DR Quantity Findings:

By 2025, Medium DR Scenario Suggests...

Shape: Conventional TOU / CPP rates provide 1 GW Shed & 2 GWh Shift at ~zero cost.

Shed: Generation overbuild means ~zero need for system-level shed, but 2-10 GW in cost-effective local Shed & distribution system service.

Shift: 10-20 GWh of cost-effective daily Shift (2-5% of daily load), with opportunity for system value at ~$200-500+M/year

Shimmy: 300 MW Load-following at 300 MW Regulation. Opportunity for system-level total value ~$25 M/year.

Keys to Achieving DR Potential

Opportunities for each resource could be:

Shape: Could there be *deeper potential* for shift with more aggressive rates & dynamic pricing, combined with automated DR?

Shed: *Targeted Shed* for local capacity & distribution system service, may require faster DR technology. ½ of Shed resources in local capacity area.

Shift: Explore conventional DR *transition* to Shift. ISO integration presents *baseline & settlement challenges*– pursue retail price pathways (“Shape”).

Shimmy: Ancillary services markets “thin” but high value for grid. *Explore portfolios* with Shimmy & other services with fast-responding automation.

DR Potential Value to Grid

RESOLVE: Advanced DR from‘Shift’ & ‘Shimmy’ have significant potential value

- Resources can help CA meet operational challenges associated with high renewable levels
- Shift: $700 million/year in 2025 @ 20% of load shiftable
- Shimmy: $21 million/yr for 600 MW of Load-Following & $22.5 million/yr for 600 MW of Regulation

Value grows over time

- Much higher value in 2030 than 2020 from higher renewables/curtailment

Value decays with increased DR penetration

- Shift market is saturated at 10% of load in 2025
- Regulation market is saturated by 600 MW in 2025
- Load Following market is not saturated by our current cases (up to 1,000 MW)
- Conventional DR measures are found to have low value
- Shed: $31 million/year in 2025 @ 10,000 MW

Cluster Summary

Sector	Clusters (Quantity)	Customer Count (5th Percentile)	(Median)	(95th Percentile)	Avg. Number of Time Series per Cluster
Residential	493	1,450	11,148	56,530	201
Commercial	1,402	9	247	2,639	55
Industrial	1,614	4	43	619	15
Other	68	345	831	2,308	23
Total	3,577				

End Uses and Enabling Technologies

Sector	End Use	Enabling Technology Summary
All	Battery-electric and plug-in hybrid vehicles	Level 1 and Level 2 charging interruption
	Behind-the-meter batteries	Automated DR (Auto-DR)
Residential	Air conditioning	Direct load control (DLC) and Smart communicating thermostats (Smart T-Stats)
	Pool pumps	DLC
Commercial	HVAC	Depending on site size, energy management system Auto-DR, DLC, and/or Smart T-Stats
	Lighting	A range of luminaire-level, zonal and standard control options
	Refrigerated warehouses	Auto-DR
Industrial	Processes and large facilities	Automated and manual load shedding and process interruption
	Agricultural pumping	Manual, DLC, and Auto-DR
	Data centers	Manual DR
	Wastewater treatment and pumping	Automated and manual DR

Enabling Technology Modeling Framework

<u>Components:</u>

Costs

- Initial
- Operating
- Etc.

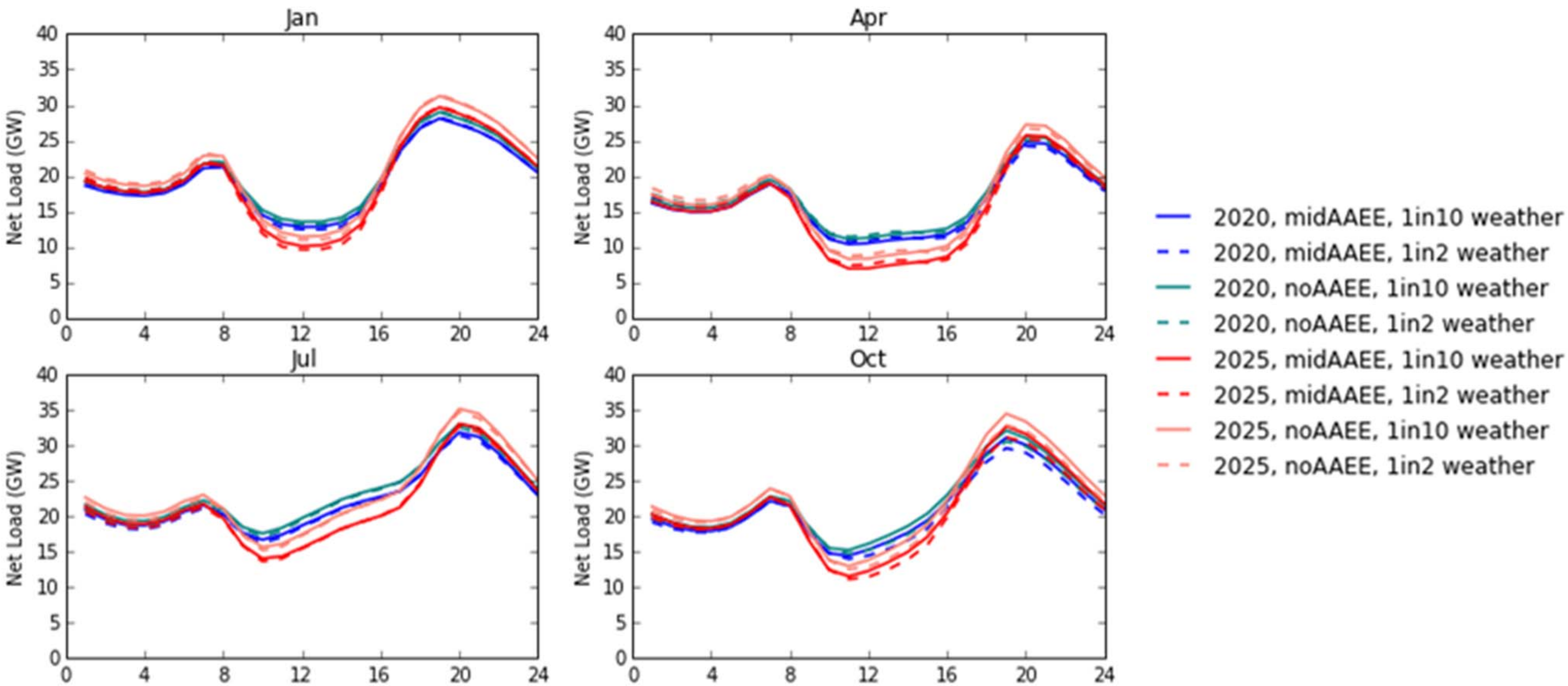
Performance

- Speed of response
- Magnitude
- Persistence

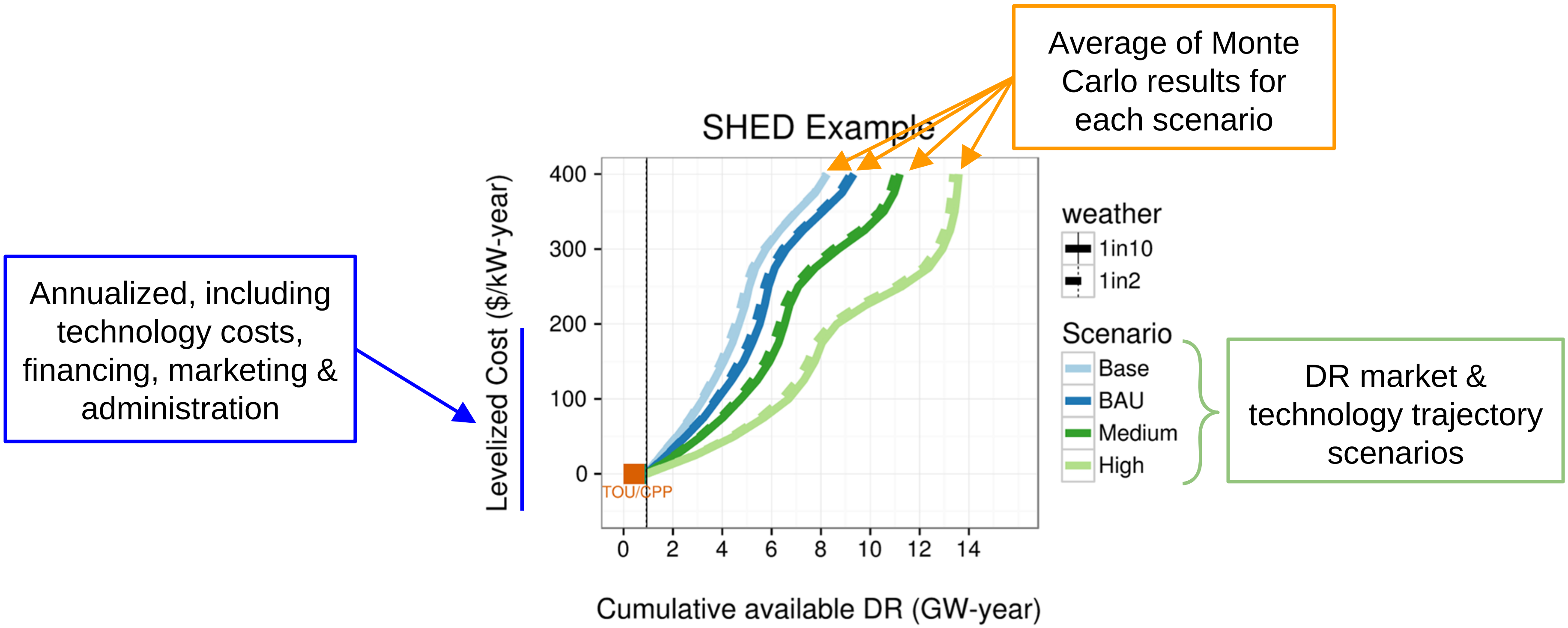
Propensity to Adopt

- Based on customer factors

Forecast Results - System Net Load for 8 Scenarios (Gross Demand - Solar & Wind Generation)



How to Read a DR Supply Curve



Supply Curve Cost Variations

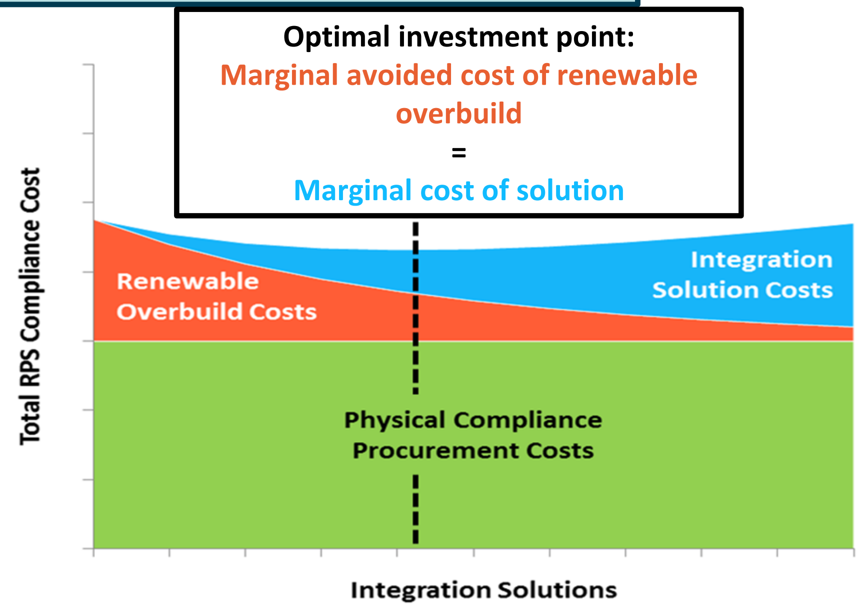
Each supply curve presented will use one of 4 costs as y-axis:

1. **Total cost (i.e., “gross” cost)**
   Levelized cost to a DR aggregator, including: up-front fixed & operational technology costs, marketing, customer incentive costs.
2. **Net Market Revenue**
   Includes annualized market revenues estimated to come from energy/capacity/RA markets
3. **Net Revenue & other Co-Benefits**
   Net costs plus cost reduction realized from non-DR benefits of installing DR enabling technologies at site (e.g., EE benefits)
4. **Net Revenue + Co-Benefits + Distribution System Service**
   Same as above, also with illustrative revenue from distribution system service.

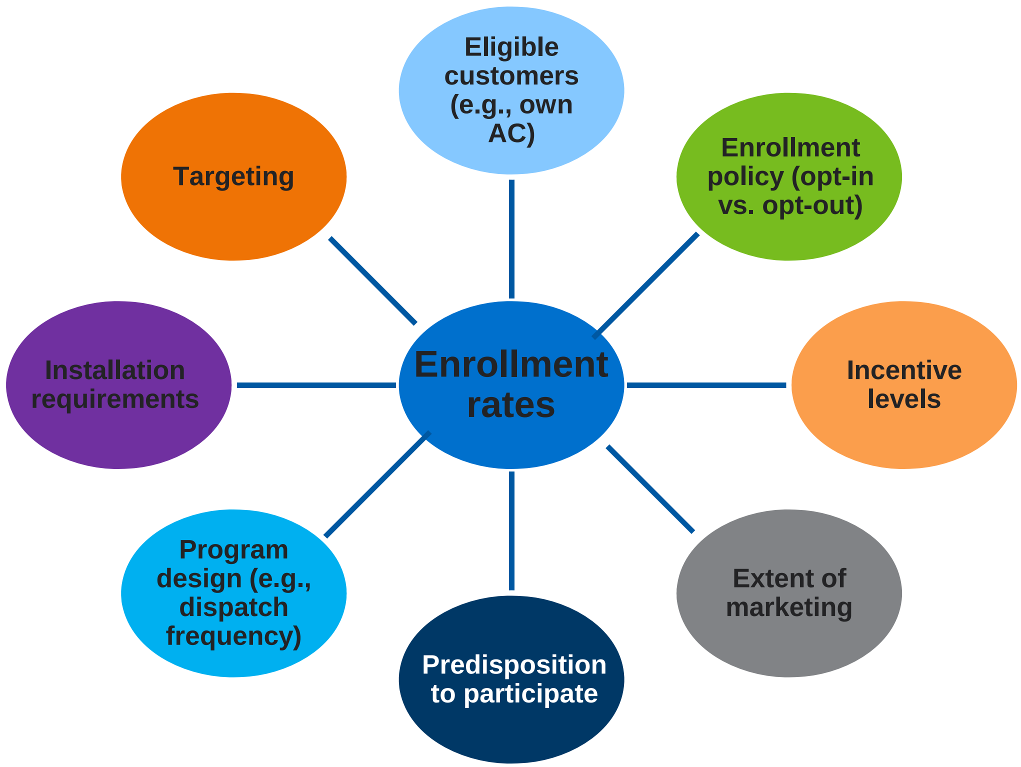
RESOLVE Provides a Framework for Valuation of Flexible Resources

Economic curtailment & renewable overbuild are default solution to flexibility challenges, & form "avoided cost" of power system inflexibility

- Sizing elect system to deliver every MWh of renewable generation is cost-prohibitive
- Reduction of renewable curtailment & overbuild provide value to ratepayers
- Flexible resources selected when benefits—primarily reduced renewable overbuild—are greater than costs



Enrollment Rates are Key Building Block



Process to Estimate Propensity Scores

Goal is to estimate customer predisposition to participate by cluster

Based on California empirical studies

1. Estimate an econometric model from customer choices → **2. Add effect marketing tactics** → **3. Add incentive levels & requirements for installation** → **4. Calibrate to reflect enrollment based on marketing** → **5. Predict participation using low, medium, & high marketing** →

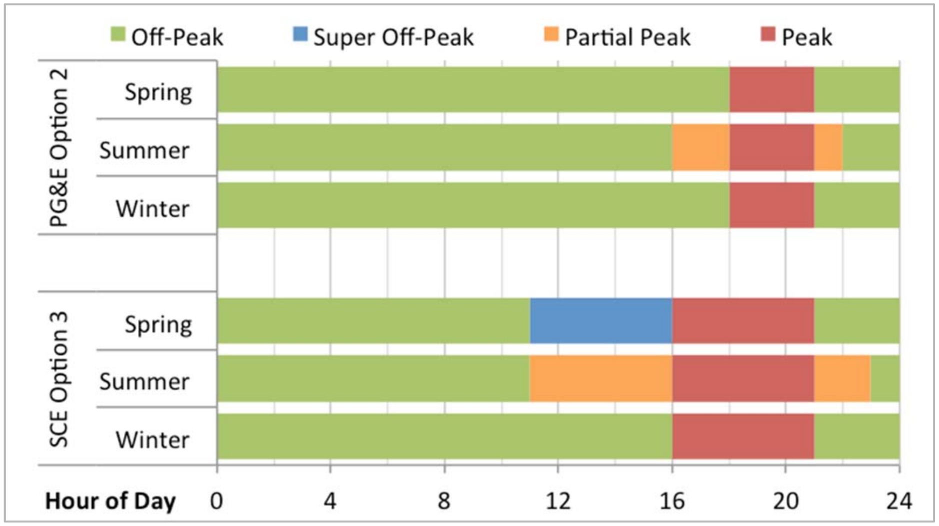
Participation by:
- Marketing level
- Incentive level
- Customer type
- Installation requirements

Rate Scenarios for Shape Resource

Rate Mixes Analyzed in this Study

	Residential			Non-Residential
	Default	Opt-in option	Opt-out option	
Rate Mix 1	PG&E Opt 2	SCE Opt 3	Flat	**Pre-existing** TOU and CPP impacts derived from Christenson, 2015.
Rate Mix 2	PG&E Opt 2	+ CPP*	Flat	
Rate Mix 3	PG&E Opt 2	--	Flat	

Hourly Rate Structures



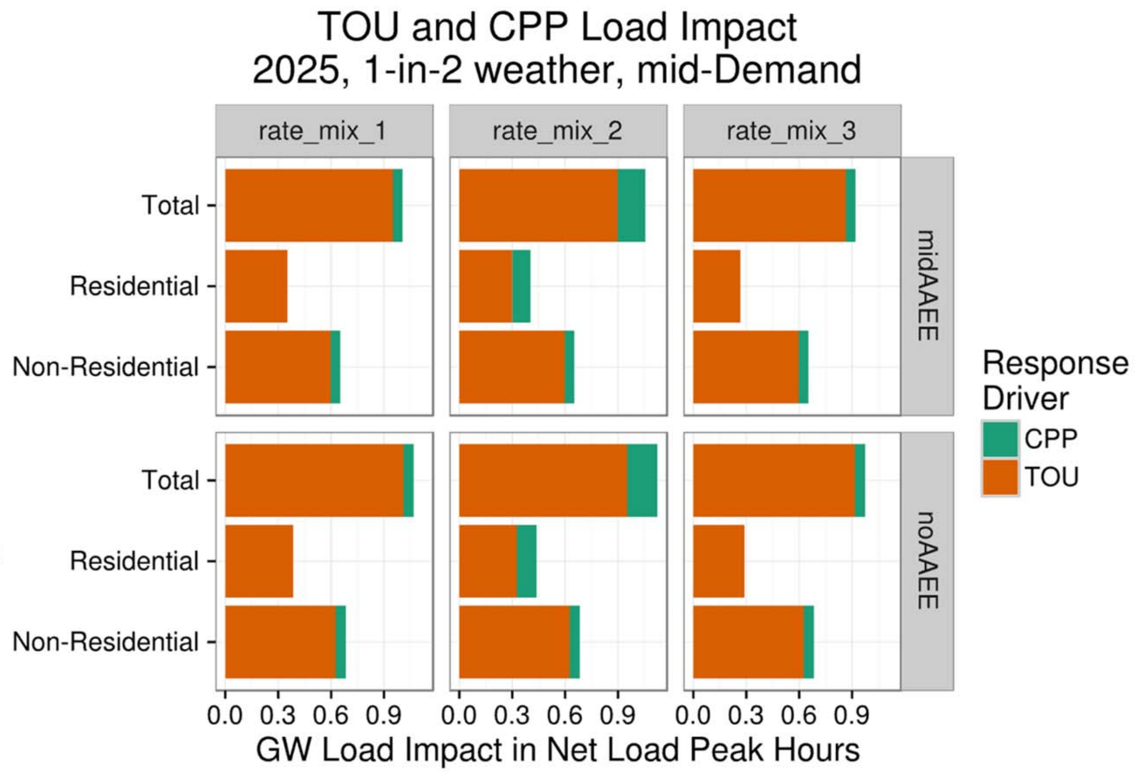
**Residential CPP dispatched 15 x for 4 hrs. Customers who opt-in to CPP remain on default TOU rate during non-CPP hours.*

Shape as Shed: ~1 GW Total

Quantity estimate is same as "dispatched Shed" -- top 250 annual hours.

<u>Estimates based on model assumptions:</u>

- **Rate Mix #1: 0.9 GW** total
  - Opt-in to "super-off-peak" with extra low mid-day prices
- **Rate Mix #2, 1 GW** total
  - Opt-in to a residential CPP option
- **Rate Mix #3: 0.8 GW** total
  - No special opt-in option
  - Same as "Phase 1" of our study



For CPP valuation: 15 events occur on the days with the highest daily peaks, each lasting 4 hours, dispatched during the summer months, for a total of 60 hours.

Shift Service Type

- Daily Load Management: Energy-neutral load management able to reduce system ramping needs, lower system peak & avoid renewable curtailment.

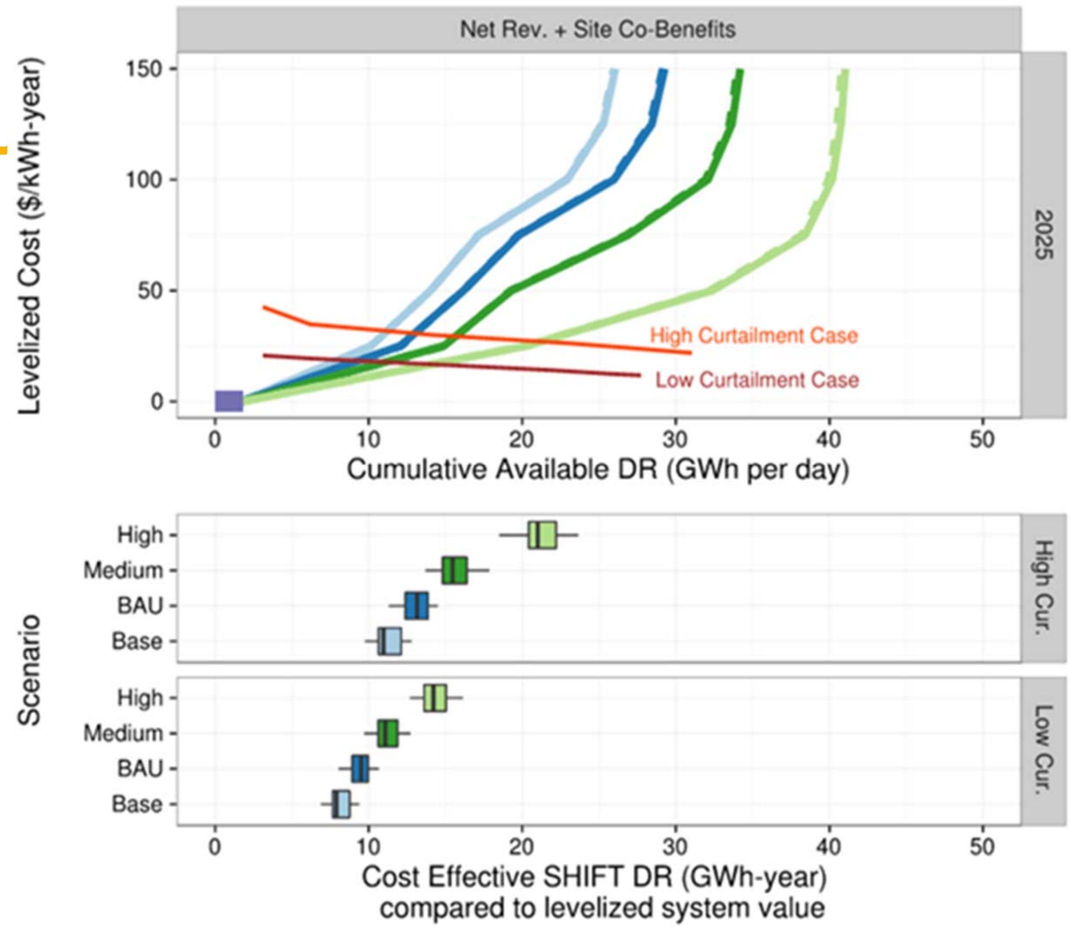
- Units of analysis:
  - Quantity: **GWh/day,** amount of energy shifted during day, averaged over year
  - Cost: **$/kWh-year**, levelized cost of providing shiftable kWh, available on every day of year

Shift Supply Curves

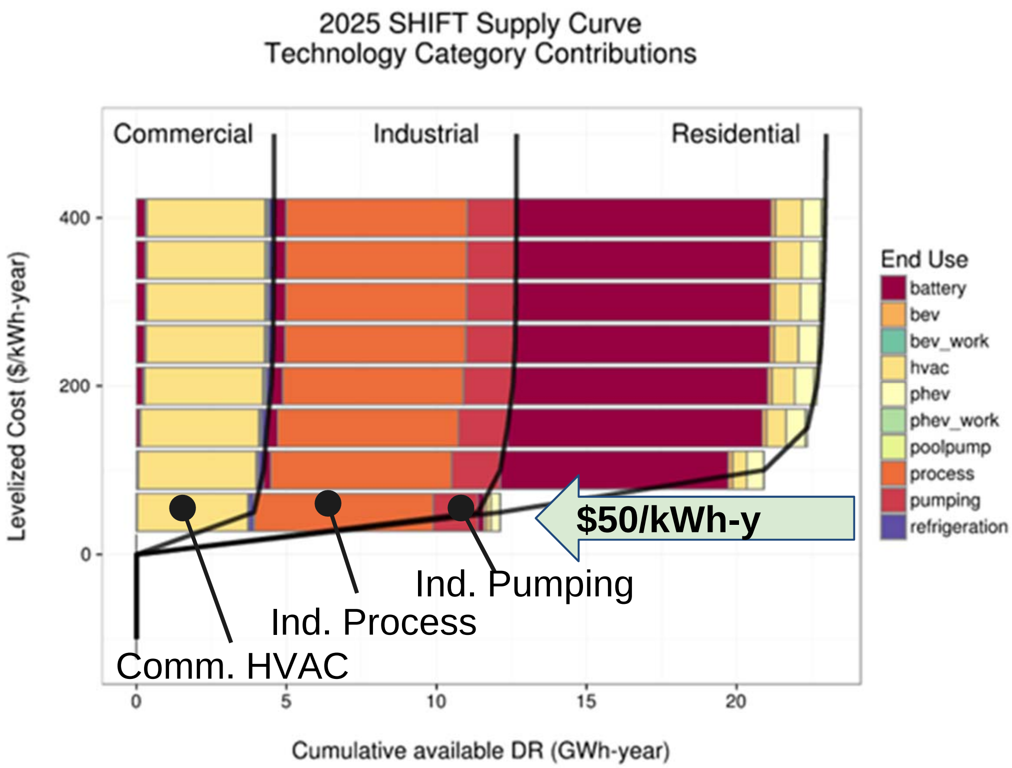
2025 Supply + Demand
(Net ISO Rev and Co-Benefits)

Shown with *~2 GWh Shape-Shift*

10-20 GWh cost-effective supply
(~ 2-5% of daily load shifted)



Shift Technologies



Key Technology Options at $50 /kWh-year cost:

- Industrial process & pumping
- Commercial HVAC Loads

Electric Vehicles & Batteries could be significant if prices fall.

Shed Service Type

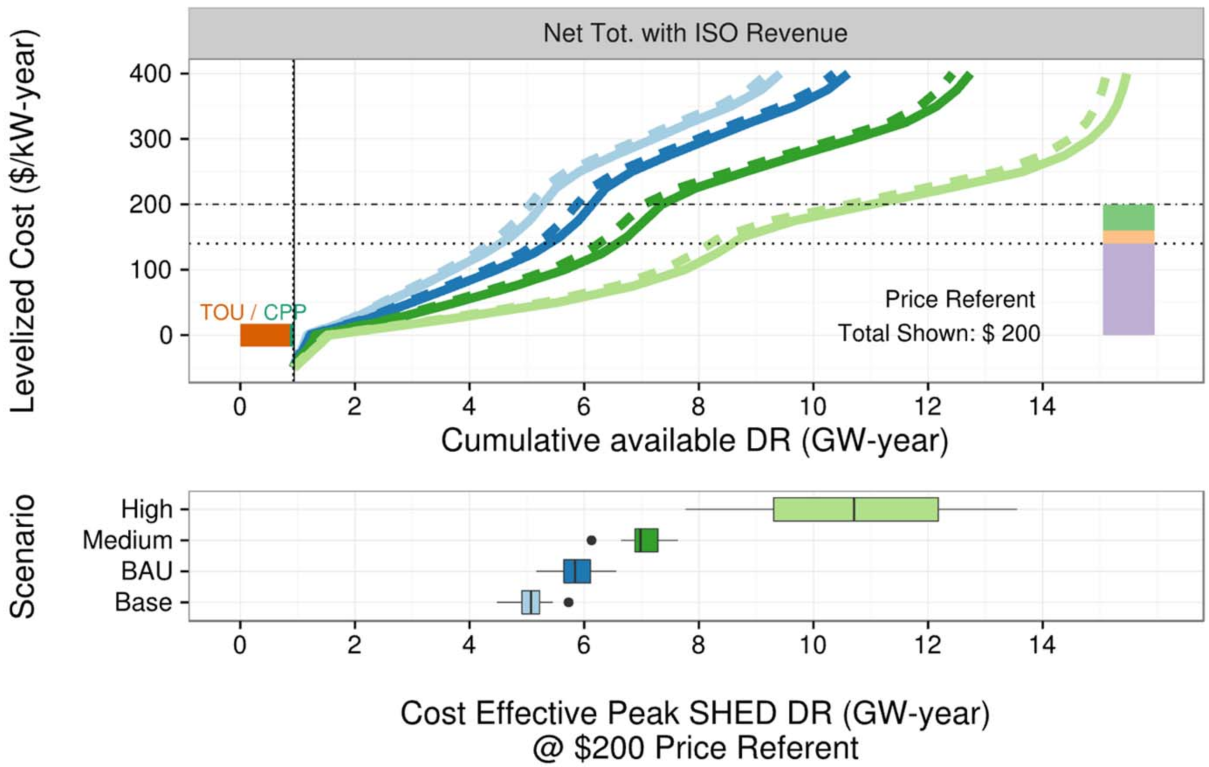
- Peak Load Curtailment - Conventional DR dispatched to decrease load during a peak day event, meant to offset the need for peaking power plants or respond to contingencies
- Units of analysis:
  - Quantity: **GW-year**, average amount of load shed during top 250 net load hours of the year
  - Cost: **$/kW-year**, levelized cost of providing 1 kW of peak load shed throughout year

2025 Shed DR Potential Supply Curve vs. Price Referent

Supply Curves compared to **conventional price referent** suggest 6-10 GW of cost-effective Shed.

- **Take Home:** Significant Shed potential with price referent approach that assumes capacity investments are offset.

Supply Curve Notes: Rate Mix 3, Mid AAEE, Net Revenue + Site Co-Benefits

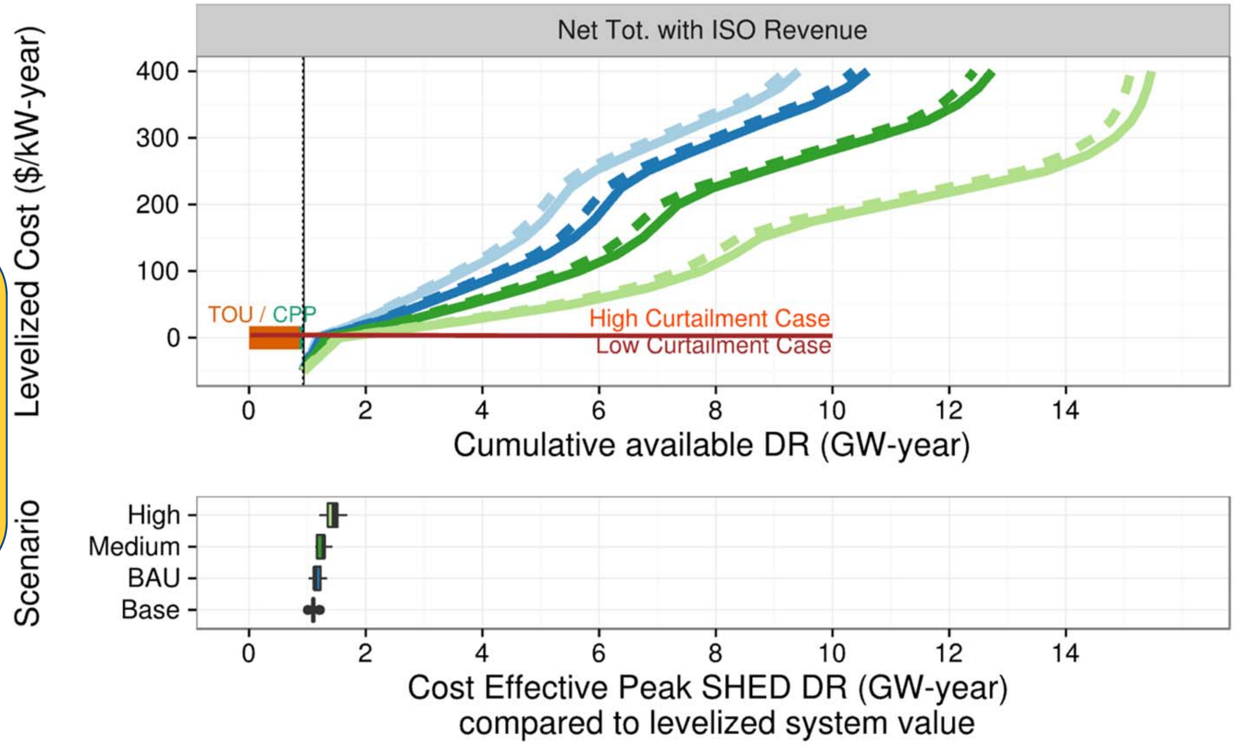


2025 Shed DR Potential Supply Curve Vs. Levelized System Value

Supply Curves compared to **levelized system value** suggest 0-1 GW of cost-effective Shed.

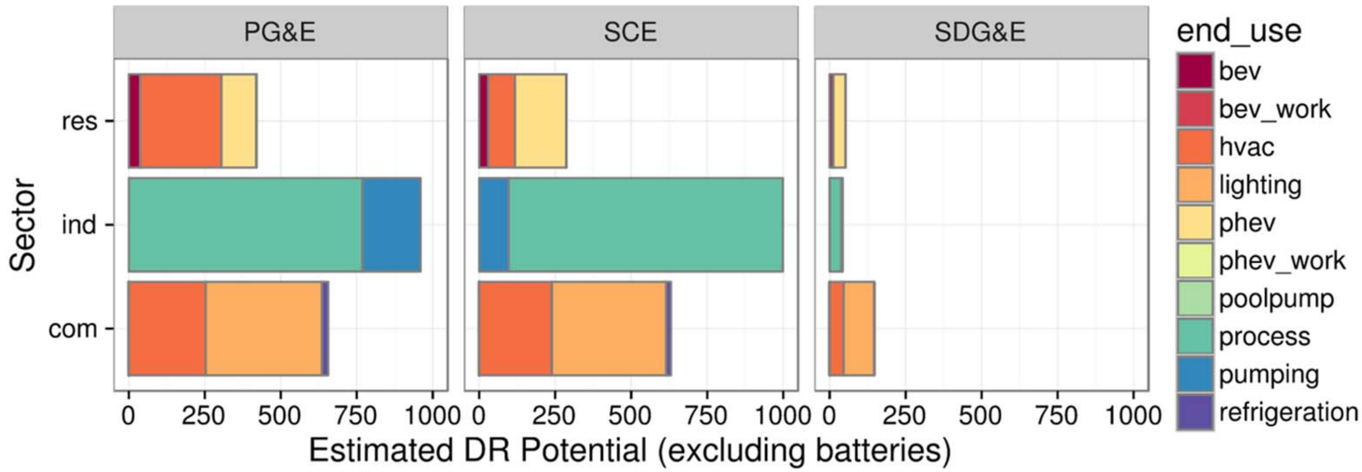
- **Take Home:** Essentially zero potential with RESOLVE model approach that incorporates expected capacity surplus

Supply Curve Notes: Rate Mix 3, Mid AAEE, Net Revenue + Site Co-Benefits



Shed Technology Mix at $200 Price Referent

2025, Rate Mix 3, Mid AAEE, 1-in-2 Weather, Net Total Cost, Medium Case



PG&E total: 2.0 GW   SCE total: 1.9 GW   SDG&E total: 0.24 GW

Total Medium Scenario: 4.2 GW

Total MW:

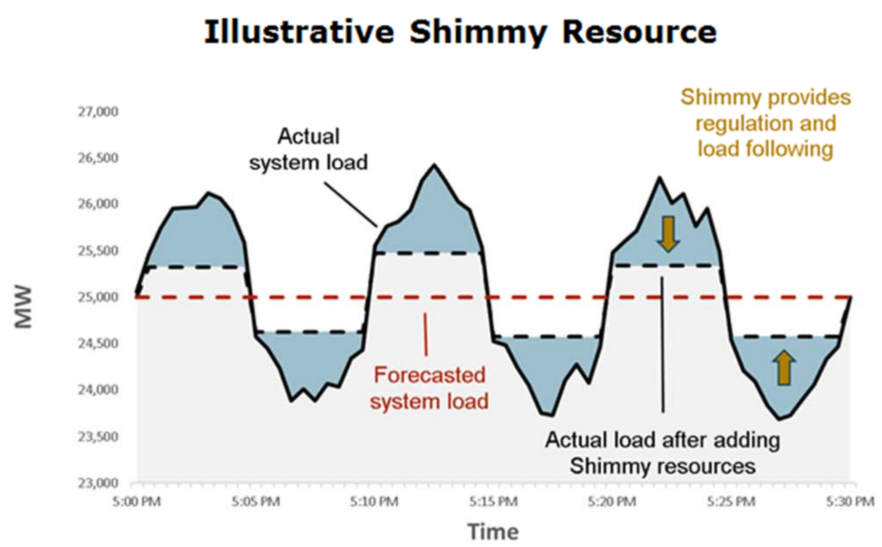
sector	end_use	tot
com	battery	0
com	bev	0
com	bev_work	0
com	hvac	538
com	lighting	860
com	phev	0
com	phev_work	0
com	refrigeration	36
ind	battery	0
ind	process	1710
ind	pumping	292
res	battery	0
res	bev	79
res	hvac	356
res	phev	324
res	poolpump	0

Shimmy Service Type

- **Fast response DR**: available daily in two types
  - **Load-following:** 5-minute dispatch signal
  - **Regulation:** 4-second dispatch signal
- Units of analysis:
  - Quantity: **GW**, market price-weighted average of hourly availability to provide regulation or load-following
  - Cost: **$/kW-year**, levelized cost of providing kW of service available during all hours

Modeling *Shimmy* in RESOLVE

- Shimmy = Loads providing Load Following and Regulation ancillary services (modeled separately)
  - Modeled using hourly resource availability in RESOLVE



Recommendations for Guiding California's DR Pathways

- Policy Direction
  - Data-driven Energy Markets & Policy
  - Catalyze Shift
  - Future Rate Design for Residential & Non-Residential Customers
  - Developing Market Mechanisms for Market Entrance
- Technology Advances
  - Shift as Energy DR
  - Explore linking EE and DR and Integrated DSM
  - Interoperability Standards for Plug & Play Grid
  - Distribution System Automation

Possible Next Steps

- **Research to be considered for future work:**
  - Analysis on EE & DR technologies' costs, integrated DSM.
  - Deep dive on DR's value to distribution system
  - Further analysis of shift technologies and values
  - Forecast error, extreme weather and emergencies
  - Partnership on integrated systems, internet communications, performance guarantees

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