| **DOCKETED** |
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2025 California Demand Response Potential Study

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Nexant: Josh Bode, Adriana Ciccone, Ankit Jain
Presentation Overview

• 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** Service Type: Peak Shed DR

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

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*Graphs showing load profiles before and after Shed and Shift services.*
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

Illustrative pricing profile

- Off-peak
- Super off-peak
- Peak
- Partial Peak

Actual system load

Forecasted system load

Actual load after adding Shimmy resources
## DR Service Type Table

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

- **Shape**: Incentivize EE and Behavior Change
- **Shift**: Mitigate Ramps and Capture Surplus Renewables
- **Shed**: Manage contingency events and coarse net load following
- **Shimmy**: Fast DR to smooth net load and support frequency
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”.

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*Image diagrams showing supply curves and price referent approach.*
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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Clusters (Quantity)</th>
<th>Customer Count</th>
<th>Avg. Number of Time Series per Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(5th Percentile)</td>
<td>(Median)</td>
</tr>
<tr>
<td>Residential</td>
<td>493</td>
<td>1,450</td>
<td>11,148</td>
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<tr>
<td>Commercial</td>
<td>1,402</td>
<td>9</td>
<td>247</td>
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<tr>
<td>Industrial</td>
<td>1,614</td>
<td>4</td>
<td>43</td>
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<tr>
<td>Other</td>
<td>68</td>
<td>345</td>
<td>831</td>
</tr>
<tr>
<td>Total</td>
<td>3,577</td>
<td></td>
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</tbody>
</table>
# End Uses and Enabling Technologies

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

Components:

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

- **Annualized, including technology costs, financing, marketing & administration**

- **Average of Monte Carlo results for each scenario**

**SHED Example**

**Cumulative available DR (GW-year)**

**Levelized Cost ($/kW-year)**

- **DR market & technology trajectory scenarios**
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

Optimal investment point:
Marginal avoided cost of renewable overbuild = Marginal cost of solution
Enrollment Rates are Key Building Block

- Targeting
- Eligible customers (e.g., own AC)
- Enrollment policy (opt-in vs. opt-out)
- Incentive levels
- Extent of marketing
- Program design (e.g., dispatch frequency)
- Installation requirements
- Predisposition to participate
Process to Estimate Propensity Scores

Goal is to estimate customer predisposition to participate by cluster

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

Based on California empirical studies
Rate Scenarios for Shape Resource

Rate Mixes Analyzed in this Study

<table>
<thead>
<tr>
<th>Rate Mix 1</th>
<th>Residential</th>
<th>Non-Residential</th>
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</thead>
<tbody>
<tr>
<td>PG&amp;E Opt 2</td>
<td>Opt-in option</td>
<td>SCE Opt 3</td>
</tr>
<tr>
<td>Rate Mix 2</td>
<td>PG&amp;E Opt 2</td>
<td>+ CPP*</td>
</tr>
<tr>
<td>Rate Mix 3</td>
<td>PG&amp;E Opt 2</td>
<td>--</td>
</tr>
</tbody>
</table>

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

Pre-existing TOU and CPP impacts derived from Christenson, 2015.

Hourly Rate Structures

![Hourly Rate Structures Graph](graph.png)

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Shape as Shed: ~1 GW Total

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

Estimates based on model assumptions:

◆ 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
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

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**2025 Shed DR Potential Supply Curve vs. Price Referent**

![Graph showing supply curves compared to price referent](image)
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

Total MW:

<table>
<thead>
<tr>
<th>Sector</th>
<th>end_use</th>
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<tbody>
<tr>
<td>com</td>
<td>battery</td>
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<tr>
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</tbody>
</table>

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

Total Medium Scenario: 4.2 GW
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

![Illustrative Shimmy Resource](chart.png)
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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- Heather Sanders, SCE
- Nora Sheriff, CLECA
- Mike Ting, Itron
- Greg Wikler, Navigant
- Gil Wong, PG&E