Demand Response in California- From Hot Summer to Any Time DR

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Lawrence Berkeley National Laboratory
Presentation Outline

• **The Past** – Demand Response for Extreme Events
• **The Present** – Any Time Dispatchable Resource
• **Automate Once** – Use Many Times
• **Future** – Quantifying Resource Availability on Multiple Time Scales
• **Summary and Next Steps**
The Past – DR for Extreme Events

Development of automated DR started in 2002

- **Cost** - Develop low-cost, automation infrastructure
- **Technology** – Evaluate reliability & readiness
- **Capability** – Evaluate strategies to modify loads

**OpenADR** - open standard for price & reliability signals

**OpenADR** - used for utility and ISO Automated DR programs
Linking Energy Efficiency and DR

Daily Energy Efficiency
Time-Of-Use Energy
Daily Peak Load Managed
Day-Ahead (slow) DR
Real-Time DR

Spinning Reserve (fast) DR

Service Levels Optimized
Time of Use Optimized
Service Levels Temporarily Reduced

Increasing Levels of Granularity of Controls

Increasing Speed of Telemetry
Demand Response Simplified

Objectives
- Reliability
- Economics
- Congestion
- Intermittent Resources

Data Model
- Schedule
- Price
- Signaling

Automation
- Manual
- Automated

Control Strategies
- Centralized
- Gateway
- Embedded

Standards
- ZigBee™
- openADR Alliance
Monthly reports on DR programs are available by each utility

<table>
<thead>
<tr>
<th>Programs</th>
<th>Service Accounts</th>
<th>Ex Ante Estimated MW¹</th>
<th>Ex Post Estimated MW²</th>
<th>Service Accounts</th>
<th>Ex Ante Estimated MW¹</th>
<th>Ex Post Estimated MW²</th>
<th>Service Accounts</th>
<th>Ex Ante Estimated MW¹</th>
<th>Ex Post Estimated MW²</th>
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<td><strong>Sub-Total Interruptible</strong></td>
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<td>209</td>
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<td><strong>Price Response</strong></td>
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<td>AMP - Day Ahead</td>
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<td>PDP (200 kW or above)</td>
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<td><strong>Sub-Total Price Response</strong></td>
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<td>130,003</td>
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<td><strong>Total All Programs</strong></td>
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<td>661</td>
<td>288,874</td>
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<td>284,089</td>
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</table>

**Note:** Ex Ante Estimated MW = in compliance with Decision 08-04-030, the values presented herein are based on the April 1, 2014 load impact report for Demand Response. The values reported are calculated by using the monthly ex ante average load impact per customer multiplied by the number of customers.
OpenADR Fundamentals

- Provides non-proprietary, open standardized DR interface
- Allows electricity providers to communicate DR signals directly to existing customers
- Uses common XML language and existing communications such as the Internet
Historic focus on Seasonal Grid Stress

OpenADR PG&E Demand Bid Test Day

OpenADR Northwest Test on Cold Morning

OpenADR Cumulative Shed in July 2008
### Control Strategies Evaluated in Previous Demos

#### Building Use

<table>
<thead>
<tr>
<th>Building</th>
<th>HVAC</th>
<th>Lighting</th>
<th>Other</th>
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</thead>
<tbody>
<tr>
<td>ACWD</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>B of A</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Chabot</td>
<td>X</td>
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<td>2530 Arnold</td>
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<td>50 Douglas</td>
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<td>MDF</td>
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<td>Echelon</td>
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<td>Centerville</td>
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<td>Irvington</td>
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<td>Gilead 342</td>
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<td>Gilead 357</td>
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<td>IKEA EPaloAlto</td>
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<td>IKEA Emeryville</td>
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<td>IKEA WSacto</td>
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</tr>
<tr>
<td>Oracle Rocklin</td>
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<tr>
<td>Safeway Stockton</td>
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<td>Solectron</td>
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<td>Sybase</td>
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</tr>
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<td>Target Bakersfield</td>
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</tr>
<tr>
<td>Walmart Fresno</td>
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</table>

#### HVAC Adjustments

- **Global temp. adjustment**
  - Average temp. increase (mod): 2.75°F
  - Average temp. increase (high): 1.88°F
- **Duct temp. increase**
- **SAT increase**
- **Fan VFD limit**
- **CHW temp. increase**
- **Pre-cooling**
- **Cooling valve limit**
- **Boiler lockout**
- **Slow recovery**
- **Extended shed period**
- **Common area light dim**
- **Office area light dim**
- **Turn off light**
- **Dimmable ballast**
- **Bi-level switching**
- **Non-critical process shed**

### Graphs

1. **Temperature (F)**
   - Normal
   - Moderate
   - High

2. **Average temp. increase**
   - 2.75°F (mod)
   - 1.88°F (high)

3. **Customer Temperature**
   - 68°F to 82°F

### Additional Graphs

- **Martinez, CA Office Building Electricity Use with and without AutoDR
  June 21, 2006**
- **Whole Building Power (kW)**
- **Outside Air Temperature (deg. C)**
- **Time of Day**

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*Source: Demand Response Research Center*
DR Data from 22 Commercial Buildings

![Bar chart showing demand reduction (kW) for different commercial buildings and CPP sites. The chart includes bars for average shed and estimated shed. Buildings such as School 1, School 2, Office/Data Center 1, Office/Lab 1, Retail 1, and others are listed on the x-axis. The y-axis represents the demand reduction in kW.](chart-image-url)
Demand Response Strategies Guide for Commercial Buildings

HVAC Systems
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3.1.3. Duct static pressure decrease ................................................................. 26
3.1.4. Fan variable frequency drive limit ......................................................... 27
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3.1.6. Fan quantity reduction ........................................................................ 29
3.1.7. Cooling valve limit ............................................................................. 30
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4. Implementation of DR Strategies
4.1. DR Strategy Development and Commissioning ..................................... 47
DR Quick Assessment Tool

Simple free EnergyPlus tool for retail and office buildings to provide DR estimates for common HVAC and lighting strategies.

Excellent performance predicting DR in southern Calif. Included modeling pre-cooling strategies.
OpenADR Interoperability Progress

Research initiated by LBNL/CEC

Official OpenADR specification (1.0) by LBNL/CEC*

1. Anytime DR Pilots
   - Wholesale markets
   - International demonstrations
   - Dynamic pricing, renewables

2. All end-use sectors

2002 to 2006

OpenADR 1.0 Commercialization
(PG&E, SCE, and SDG&E)

Development, tests (Utilities)

2007 to 2008

2009 to 2010

2011 to 2012

Communication Standards Development:
1. Research and development
2. Pilots and field trials
3. Standards development
4. Conformance and interoperability

Over 250 MW automated in California

National outreach with USGBC

1. OpenADR Standards Development
   - OASIS (EI TC), UCA, IEC
   2. NIST Smart Grid, PAP 09

EI 1.0 standards
- OpenADR profiles

OpenADR 2.0 specifications
- Products, commercialization
- International standards (IEC)

Certification/Testing (v2.0)
OpenADR 2.0 Application

*Figure Source: OASIS Energy Interop Draft Standards (http://www.oasis-open.org/committees/energyinterop/)
Current Status OpenADR in California

<table>
<thead>
<tr>
<th>Utility</th>
<th>Enabled Load Shed kilowatts (MW)</th>
<th>Cost of Enablement ($M)</th>
<th>Enrolled Service Accounts</th>
<th>Enrolled Load Shed (MW)</th>
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<tbody>
<tr>
<td>Pacific Gas and Electric</td>
<td>81</td>
<td>14</td>
<td>347</td>
<td>71</td>
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<tr>
<td>Southern California Edison</td>
<td>158</td>
<td>37</td>
<td>747</td>
<td>155</td>
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<tr>
<td>San Diego Gas &amp; Electric</td>
<td>11</td>
<td>3</td>
<td>126</td>
<td>8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>250</strong></td>
<td><strong>54</strong></td>
<td><strong>1,220</strong></td>
<td><strong>234</strong></td>
</tr>
</tbody>
</table>

- As of summer, 2014, 234 MW, 1200 accounts currently enrolled
- ~$215/kW statewide average enablement cost
- Additional sites in SMUD, Palo Alto, coming to LADWP
- Additional sites with WIFI Communicating Thermostats
Demand Response and Baseline Models

Utilities use 10 previous days as baseline
May use a morning adjustment
Regression, built from baseline
  - Time-of-week indicator variables
  - Piecewise linear temperature dependence

Renewables and Managing the “Duck” Curve


Note, this curve is being updated, it is used here to represent how we should look at what we are trying to accomplish.
# New Markets for Responsive Loads

<table>
<thead>
<tr>
<th>Product Type</th>
<th>General Description</th>
<th>How fast to respond</th>
<th>Length of response</th>
<th>Time to respond</th>
<th>How often called</th>
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<tbody>
<tr>
<td>Regulation</td>
<td>Response to random unscheduled deviations in scheduled net load</td>
<td>30 sec</td>
<td>Energy neutral in 15 min</td>
<td>5 min</td>
<td>Continuous w/in specified bid period</td>
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<tr>
<td>Flexibility</td>
<td>Load following reserve for un-forecasted wind/solar ramps</td>
<td>5 min</td>
<td>1 hr</td>
<td>20 min</td>
<td>Continuous w/in specified bid period</td>
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<tr>
<td>Contingency</td>
<td>Rapid &amp; immediate response to supply loss</td>
<td>1 min</td>
<td>≤ 30 min</td>
<td>≤ 10 min</td>
<td>≤ Once/day</td>
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<tr>
<td>Energy</td>
<td>Shed or shift energy consumption over time</td>
<td>5 min</td>
<td>≥ 1 hr</td>
<td>10 min</td>
<td>1-2 x/day &amp; 4-8 hr notification</td>
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<tr>
<td>Capacity</td>
<td>Ability to serve as an alternative to generation</td>
<td>Top 20 hrs coincident w/balancing authority peak</td>
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</table>
Ancillary Services

Operating Reserves respond when a contingency event occurs to restore balance.
- respond within 10 minutes
- event duration typically 10-30 minutes
- Includes Synchronous and Non-Synchronous

Regulation rectifies small discrepancies between load and 5-minute real time dispatch
- Receives operating point instruction and responds within 4 sec
- Energy neutral, although not in practice

Operating Reserve
Regulation
Advanced Applications- Using Demand-side Resources for Grid Reliability with DR and Microgrids

Fast DR – Evaluating how loads can act like generators

- Development of communication, control and telemetry requirements
- Understanding markets and market participation rules
- Research concepts supported with field tests

Communication Latency

Architecture

Load

ICCP Source

OpenADR Server

OpenADR Client

DR Controller

Commercial Facility

Industrial Facility

Etc.
Evaluating Which Loads are Most Flexible

<table>
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<tr>
<th>LOADS</th>
<th>FLEXIBILITY FILTER</th>
<th>ANCILLARY SERVICES PRODUCTS</th>
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<td>Residential</td>
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<td>Commercial</td>
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<tr>
<td>Agricultural</td>
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</table>

### Response Parameters
- Flexibility range (reg up, reg down, both)
- Speed of Response
- Store, Shift or Shed

### Size of Response
- Controllable
- Sizing of Resource
- Min and max daily consumption requirements
- Cycling Rate Impacts (wear/tear)

### Impacts on Overall Response
- Rebound/Recovery Issues
- Charge/Discharge
- Independence

### How to Predict
- Predictable or Variable (daily, seasonal, geographic)
- Time or Operational dependence

### How it Participates
- Individual or Aggregated

*Builds on 10 years of field work by DRRC*
5 Field Studies Beyond Hot Summer Days

- Cold mornings for winter peak regions (Seattle)
- Non-spin reserve ancillary services (No. Cal)
- Regulation ancillary services (No. Cal)
- Economic dispatch - integrated price signals (NY NY)
- Fast telemetry for small commercial (No. Cal.)
Fast DR in Commercial Buildings

Buildings can provide ramping
- Costs will be lower if used in many DR programs
- How often can load be called?

<table>
<thead>
<tr>
<th>Site</th>
<th>Available Capacity (MW)</th>
<th>Min. Operating Limit (MW)</th>
<th>Max. Operating Limit (MW)</th>
<th>Ramp Rate (MW/min.)</th>
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</thead>
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<tr>
<td>UC Merced</td>
<td>0.16</td>
<td>0</td>
<td>0.17</td>
<td>Reg up: 0.022, Reg down: 0.022</td>
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<tr>
<td>West Hill Farms</td>
<td>0.03</td>
<td>0</td>
<td>0.16</td>
<td>Reg up/down: 0.03</td>
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<tr>
<td>SMCC</td>
<td>0.2</td>
<td>0</td>
<td>0.2</td>
<td>Reg up: 0.05, Reg down_1: 0.066, Reg down_2: 0.134</td>
</tr>
</tbody>
</table>
Integrated Sensing and Communication: Low-Cost Telemetry of Demand Side Ancillary Services

• Low-cost, Internet connected embedded systems enable telemetry and control
• $50/kW site enablement vs traditional at $300/kW
• Demonstrated across 12 sites and four load types
## Metrics for Response

<table>
<thead>
<tr>
<th>Site</th>
<th>Ave. Load Reduction (W, W/ft², %)</th>
<th>Latency (Control-to-response)</th>
<th>Latency (Transition)</th>
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<tr>
<td>Small Commercial 1</td>
<td>5 kW, 0.8 W/ft², 17%</td>
<td>&lt;30 sec.</td>
<td>&lt;1 min.</td>
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<td>Small Commercial 2</td>
<td>9 kW, 1.5 W/ft², 52%</td>
<td>&lt;30 sec.</td>
<td>&lt;1 min.</td>
</tr>
<tr>
<td>Small Commercial 3</td>
<td>15 kW, 1 W/ft², 37%</td>
<td>&lt;30 sec.</td>
<td>&lt;1 min.</td>
</tr>
<tr>
<td>Small Commercial 4</td>
<td>34 kW, 0.4 W/ft², 16%</td>
<td>&lt;30 sec.</td>
<td>&lt;1 min.</td>
</tr>
</tbody>
</table>
Title 24 - SECTION 120.2 – CONTROLS FOR SPACE-CONDITIONING SYSTEMS

(h) Automatic Demand Shed Controls.

**DDC to Zone level be programmed to allow centralized demand shed for non-critical zones:**

Controls have capability to
- remotely setup cooling temp by 4 F or more in non-critical zones with EMCS

Controls require following features:
- Manual control. Manual control by authorized facility operators to allow adjustment of heating and cooling set points globally from a single point in the EMCS; and
- Automatic Demand Shed Control. Upon receipt of a DR signal, space-conditioning systems conduct a centralized demand shed, as specified in Sections 120.2(h)1 and 120.2(h)2.
Occupant Controlled Smart Thermostat in Title 24

OCSTs are self-certified by manufacturer to Energy Commission to meet T24. Spec focuses on 3 interfaces:
Communications, User Display and HVAC System Interface

Appendix JA5.2.3.1 Price Signals
Price signals allow utility or entity to send a signal or message to occupant’s OCST to provide pricing info to occupant and initiate DR Control for DR Period utilizing a DR Signal.

JA5.2.3.2 Demand Response Periods
This event class allows utility to initiate DR Control for DR Period utilizing a DR Signal. Signal attributes shall be specified within messaging protocol.

Messaging Protocols in CEC List are Apples and Oranges
ZigBee Wireless Mesh
BACnet MSTP
ANSI 709.1
OpenADR 2.0
Enocean Wireless Protocol
Summary

Key Issues

• California has a vibrant set of DR programs
• Continued changes in goals and motivations
• Growing capabilities of buildings to provide services to the electric grid
• New telemetry and control systems provide low cost automation

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