

Findings from 7 Years of Automated Demand Response in Commercial Buildings

Sila Kiliccote, Mary Ann Piette, Johanna Mathieu, and Kristen Parrish

Lawrence Berkeley National Laboratory

Demand Response Research Center

<http://drrc.lbl.gov/>

ACEEE 2010 Summer Study on Energy Efficiency in Buildings

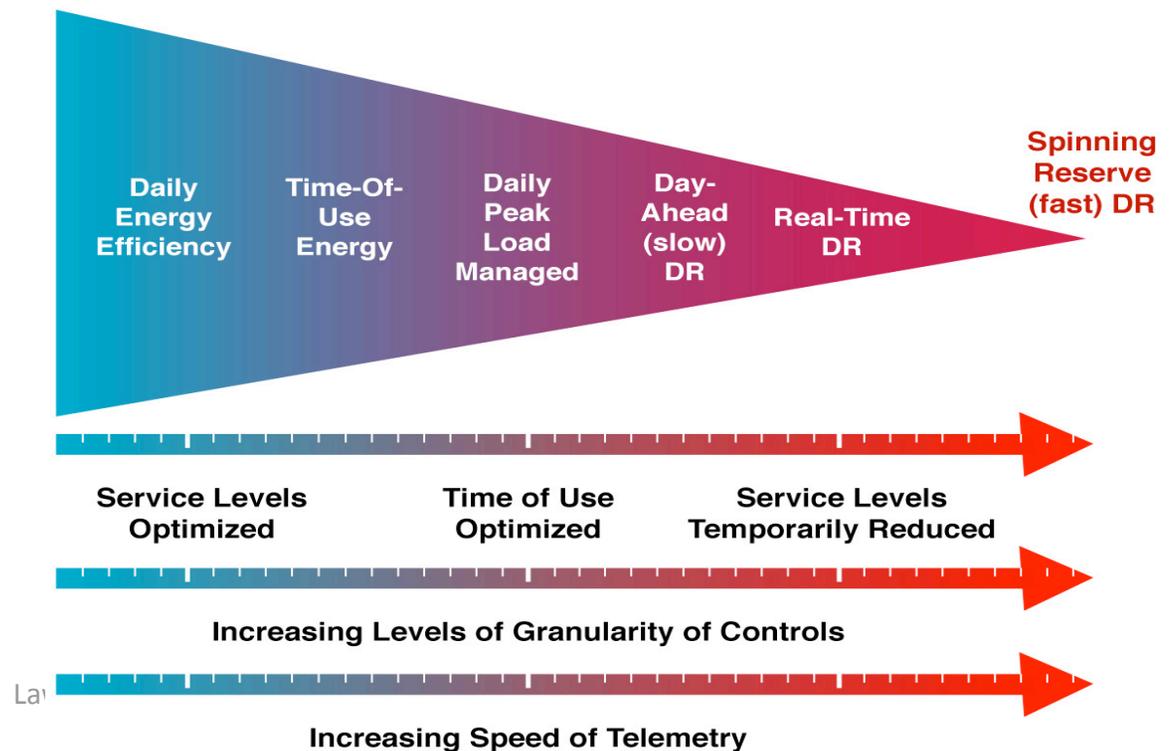
Panel 5: Utilities - Energizing Efficiency

Monday, August 16th

Sponsored by: PG&E, SDG&E, SCE, CEC PIER Program

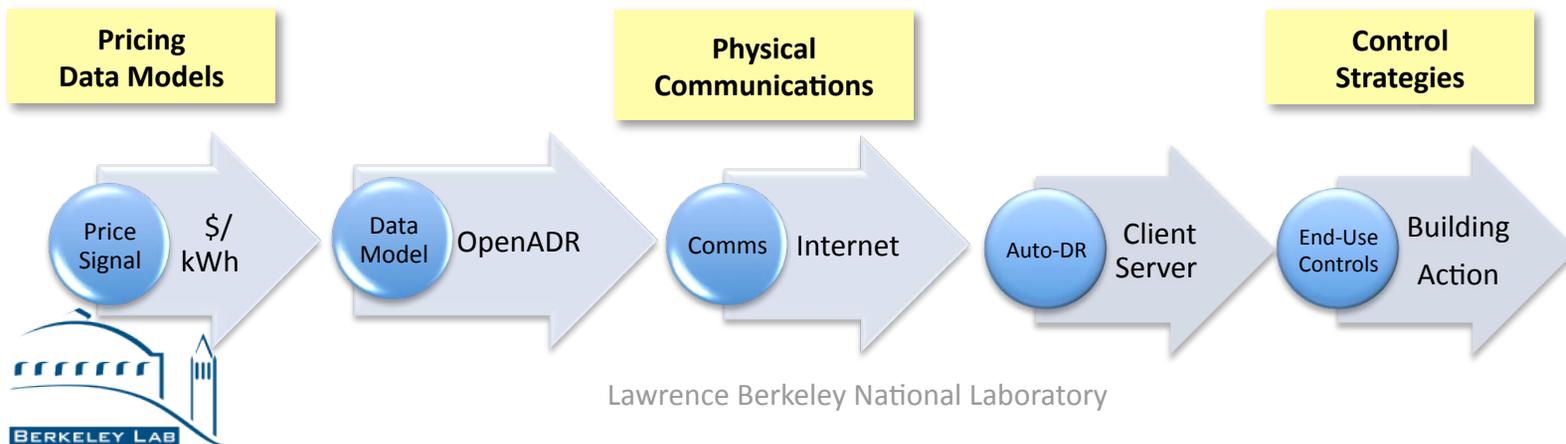
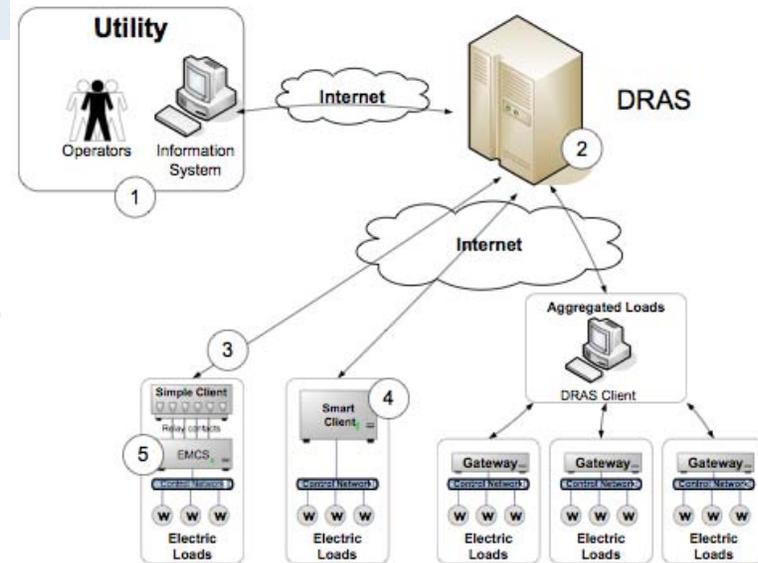
Overview

- Background and Introduction
- Automated Demand Response Programs in California
- Case Study: IKEA East Palo Alto
- Understanding load and shed variability
- Future Directions

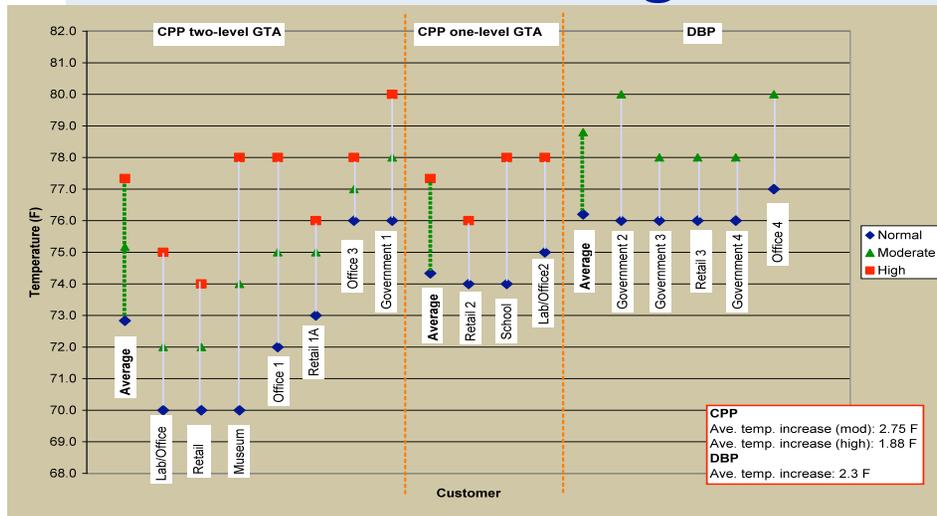


Background and Introduction

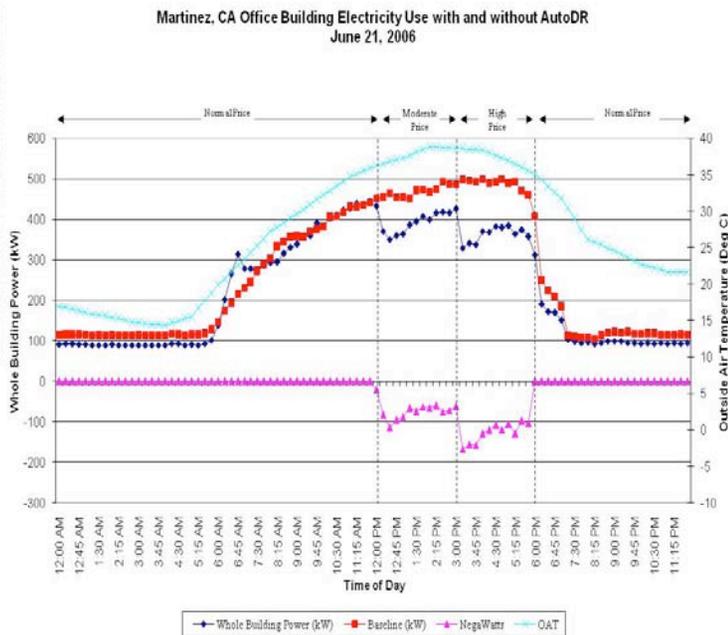
- **OpenADR: Open Automated DR Communication Specification Published April 2009**
- **Automated DR signaling system that uses utility-provided price, reliability, or event signals to automatically trigger customers' pre-programmed energy management strategies**
- **One of 1st 16 NIST Smart Grid Standards – used in > 250 facilities in California**



DR Control Strategies Evaluated in Previous Research



Building use	HVAC										Lighting			Other			
	Global temp. adjustment	Duct static pres. Increase	SAT Increase	Fan VFD limit	CHW temp. Increase	Fan qty. reduction	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
ACWD	Office, lab	X	X	X		X		X	X	X							
B of A	Office, data center		X	X	X	X		X									
Chabot	Museum	X					X										
2530 Arnold	Office	X								X							
50 Douglas	Office	X								X							
MDF	Detention facility	X															
Echelon	Hi-tech office	X	X	X		X					X	X	X	X			
Centerville	Junior Highschool	X					X										
Irvington	Highschool	X					X										
Gilead 300	Office			X													
Gilead 342	Office, Lab	X	X														
Gilead 357	Office, Lab	X	X														
IKEA EPaloAlto	Furniture retail	X															
IKEA Emeryville	Furniture retail	X															
IKEA WSacto	Furniture retail																
Oracle Rocklin	Office	X	X														
Safeway Stockton	Supermarket																X
Solectron	Office, Manufacture	X											X				
Svenhard's	Bakery																X
Sybase	Hi-tech office											X					
Target Antioch	Retail	X				X											
Target Bakersfield	Retail	X				X											
Target Hayward	Retail	X				X					X					X	
Walmart Fresno	Retail	X															X



Over 50 Control Vendors Have Implemented the Client

Akuacom OpenADR Client Development Program

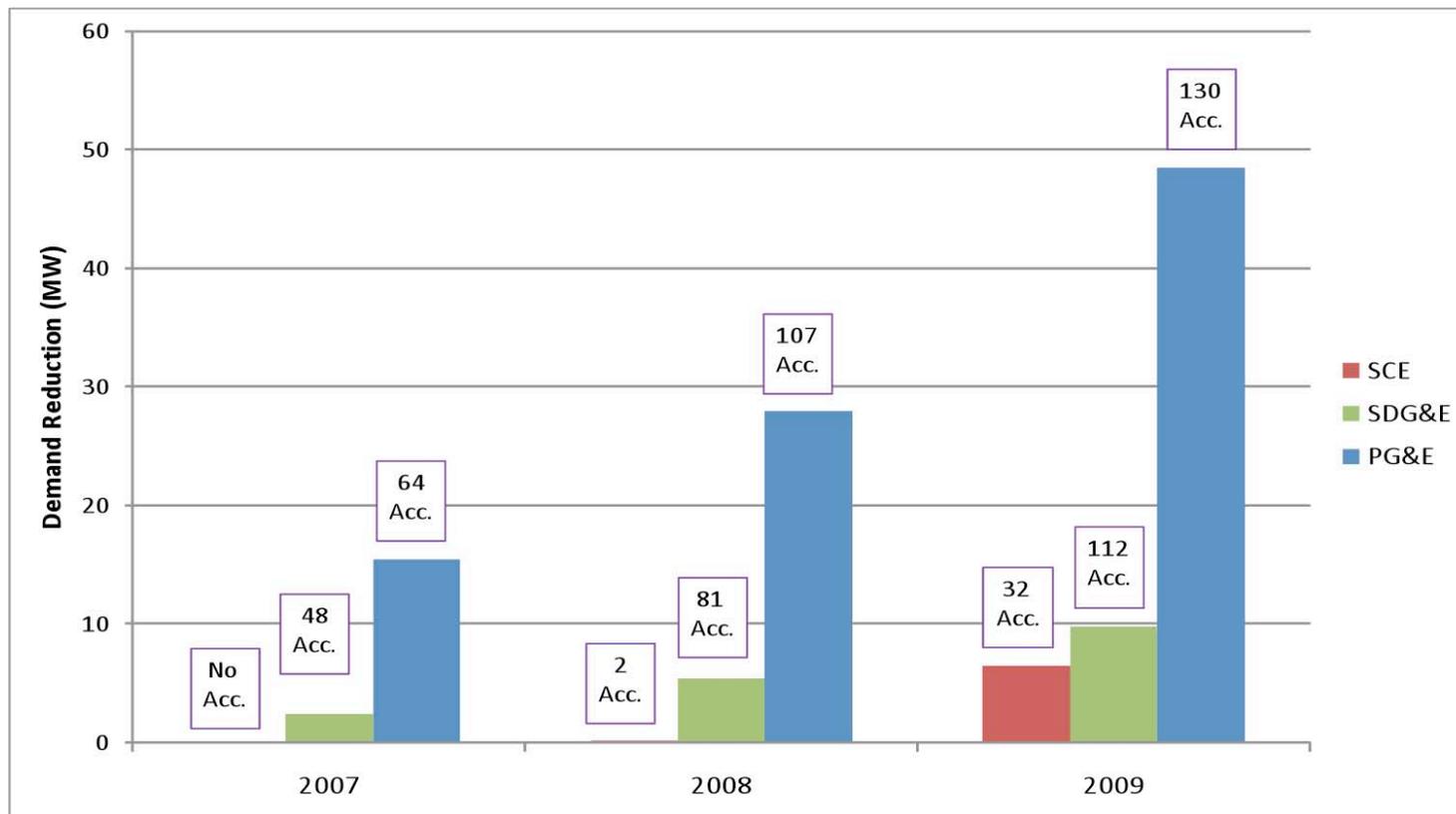


OpenADR Used in California DR Programs

Investor-Owned Utility	Year	Program	Automated Signal Description	# of DR events
Pacific Gas & Electric (Managed by 3 rd party)	2007-present	Critical Peak Pricing (CPP)	Mod. Price: 12-3pm High Price: 3-6pm Normal Price: Other	Max 12
	2007-present	Demand Bidding Program (DBP)	Standing bid with normal, mod., or high levels for each hour before noon and 8pm	Varies by year (no min/max)
	2008	Business Energy Coalition (BEC)	High prices to indicate event	Varies by year (no min/max)
	2009-present	Peak Choice (PC)	Similar to DBP; more choices	Varies by year
	2009	Participating Load (PLP) (wholesale)	Normal, mod., high; load level	Varies by year
	2010	Peak Day Pricing (PDP)	High price between 2- 6pm	Max 15
San Diego Gas & Electric (Managed In-house)	2007-present	Capacity Bidding Program (CBP)	High prices indicate an event to aggregators	Varies by year
Southern California Edison (Managed In-house)	2007-present	Critical Peak Pricing (CPP)	Similar to PG&E's CPP	Max 15
	2007-present	Demand Bidding Program (DBP)	Standing bid with normal, mod, or high levels for each hour between 12-8pm	



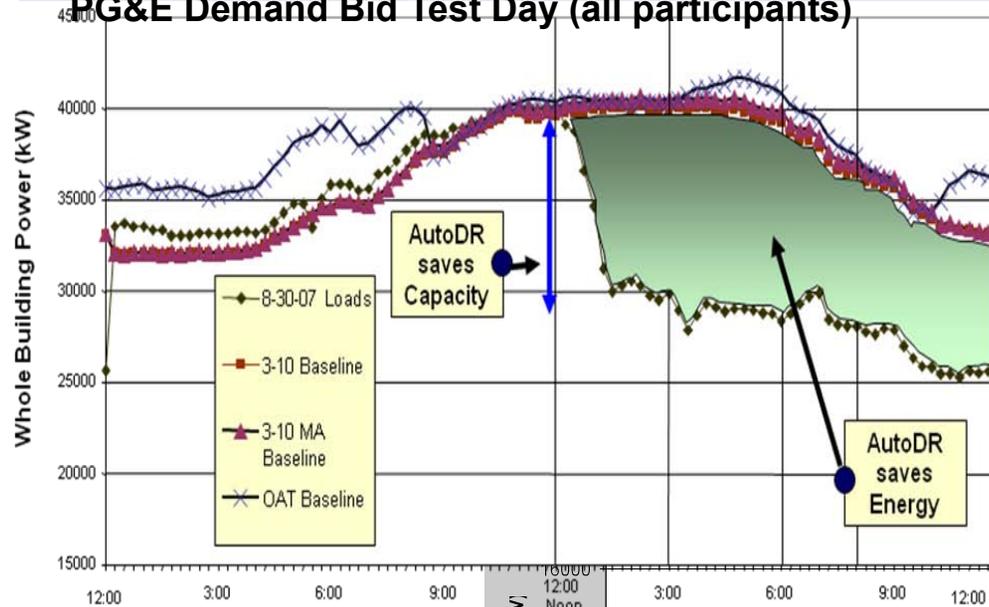
OpenADR Used in California in 274 Sites



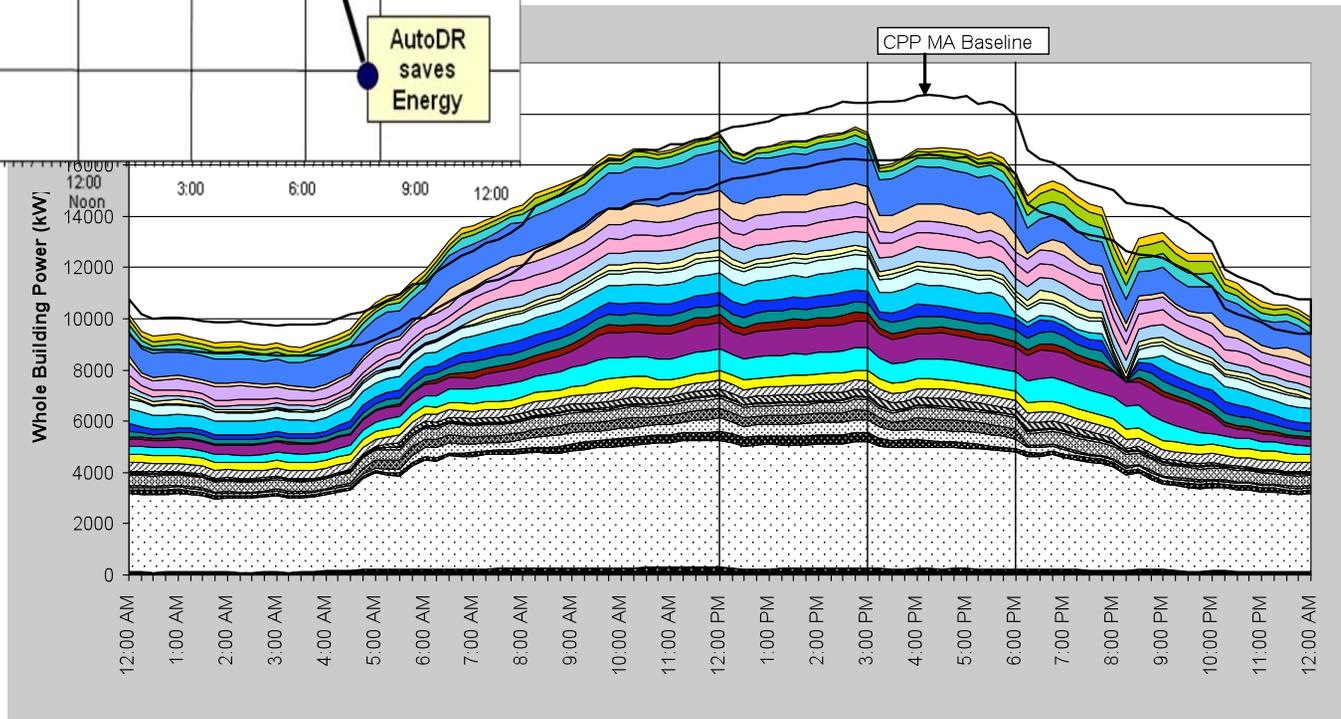
Large Aggregated Automated Demand Response

OpenADR Application Impacts

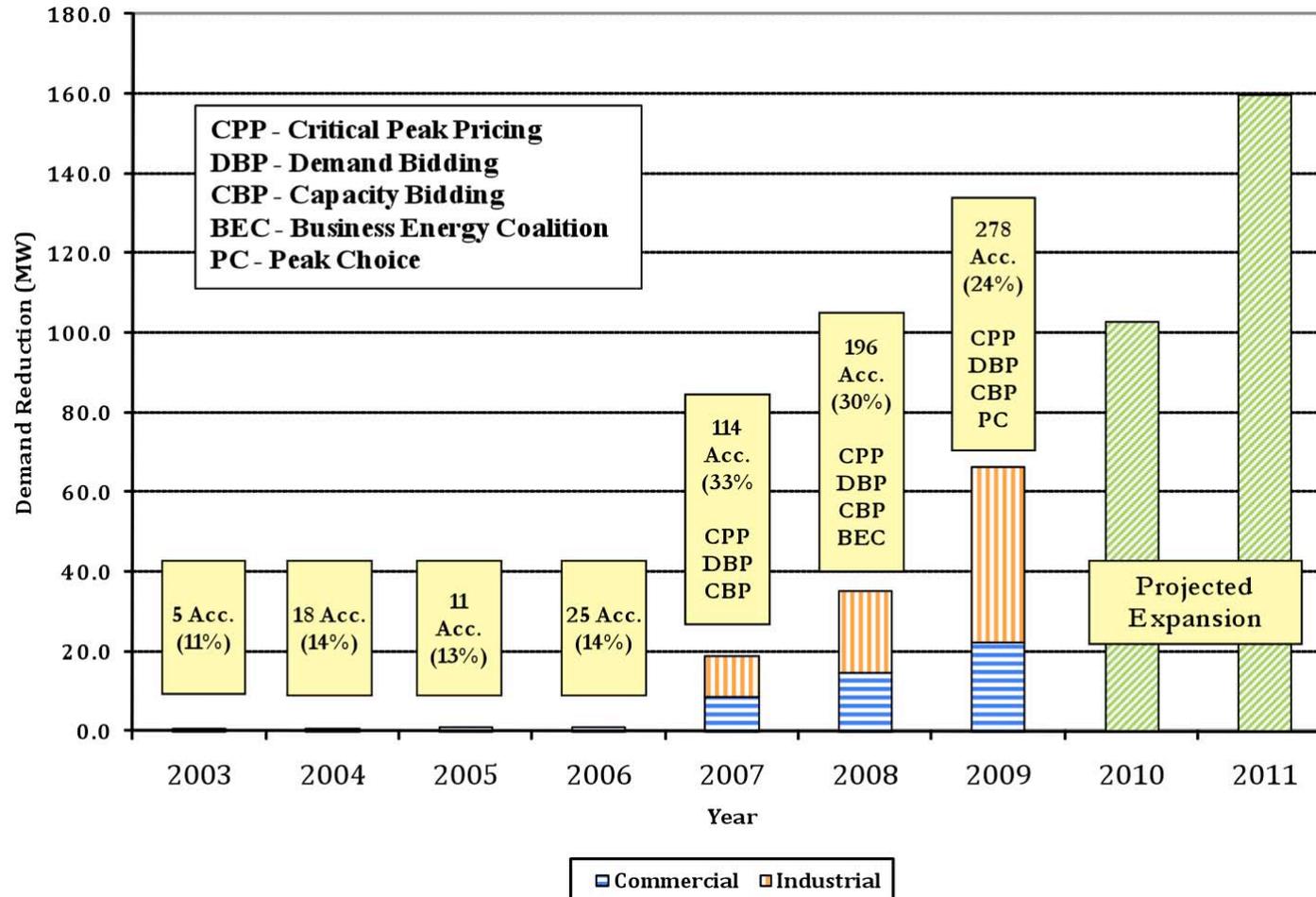
PG&E Demand Bid Test Day (all participants)



Cumulative Shed on 7/9/08

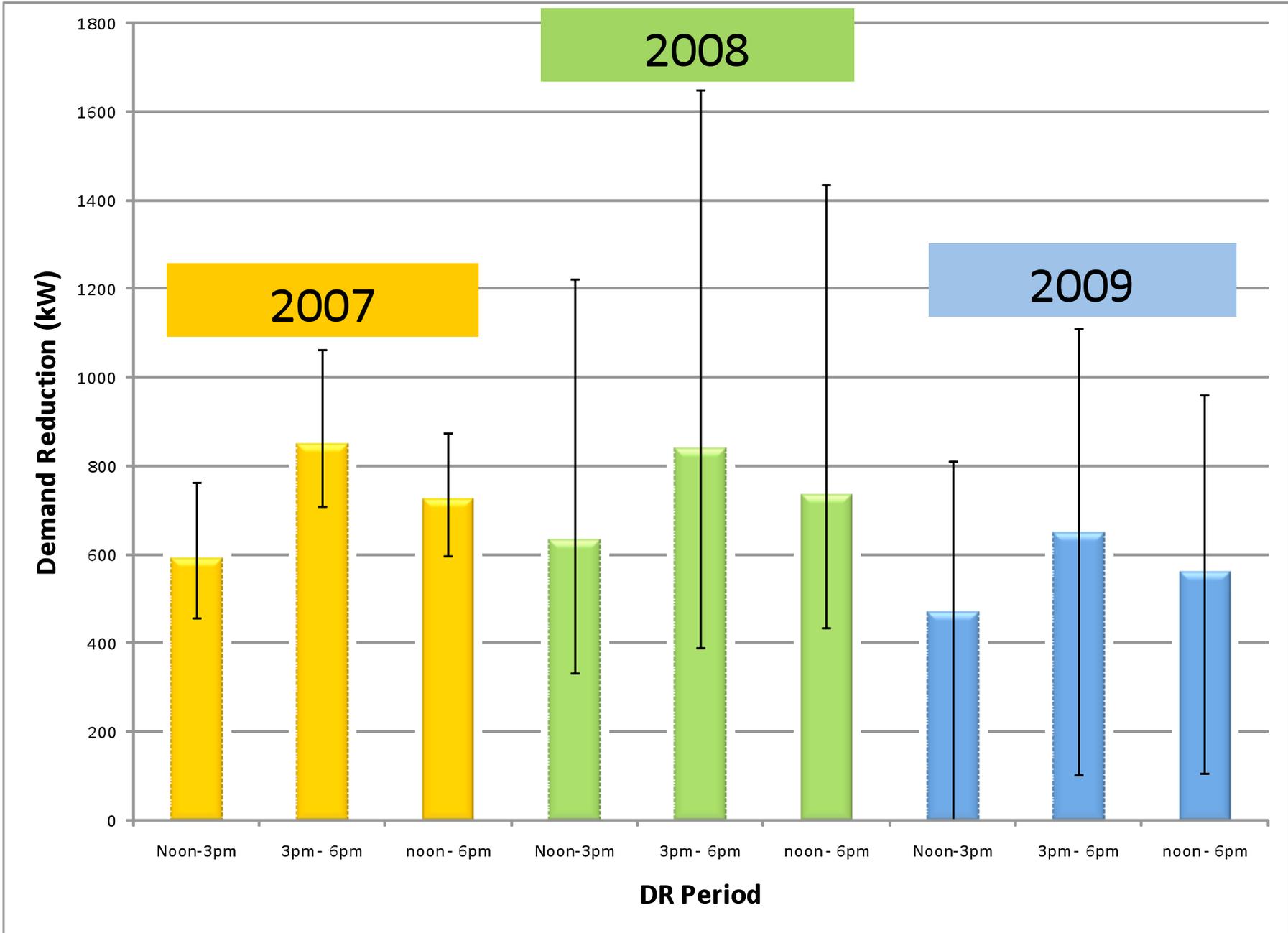


OpenADR Capability in California

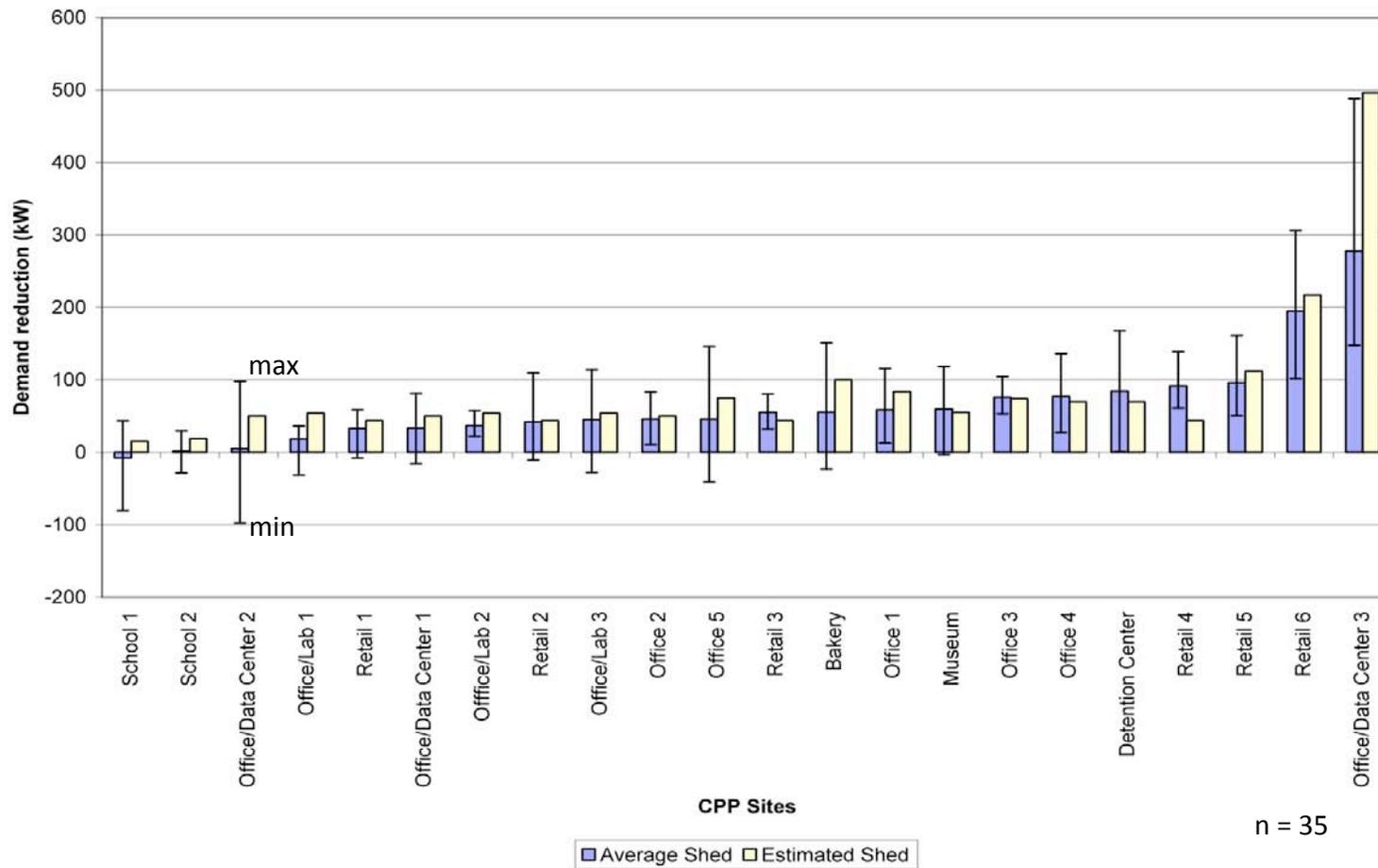


OpenADR projects have or soon will also be in Seattle, New York, Chicago, Florida, Canada, India, Korea, and Australia



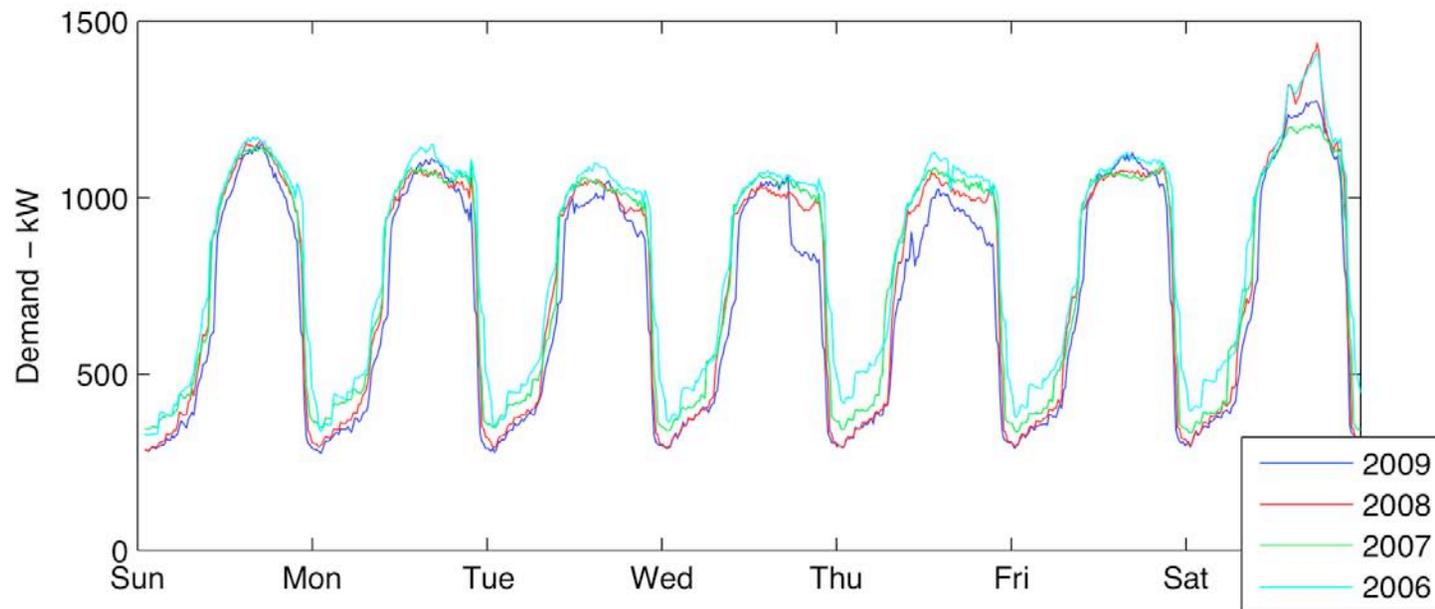


Variation of 22 Automated Critical Peak Pricing –Sites Between 2006-2008



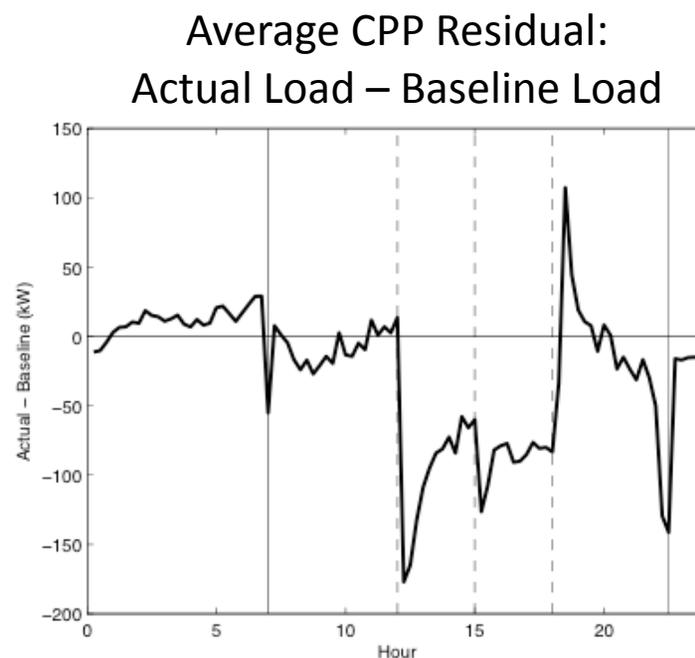
IKEA East Palo Alto

- 2-story, 300,000 ft² facility, 43 rooftop packaged units
- Maximum weekday demand is 1.2 MW
- Maximum weekend demand is 1.4 MW
- Participated in CPP from 2006-2009

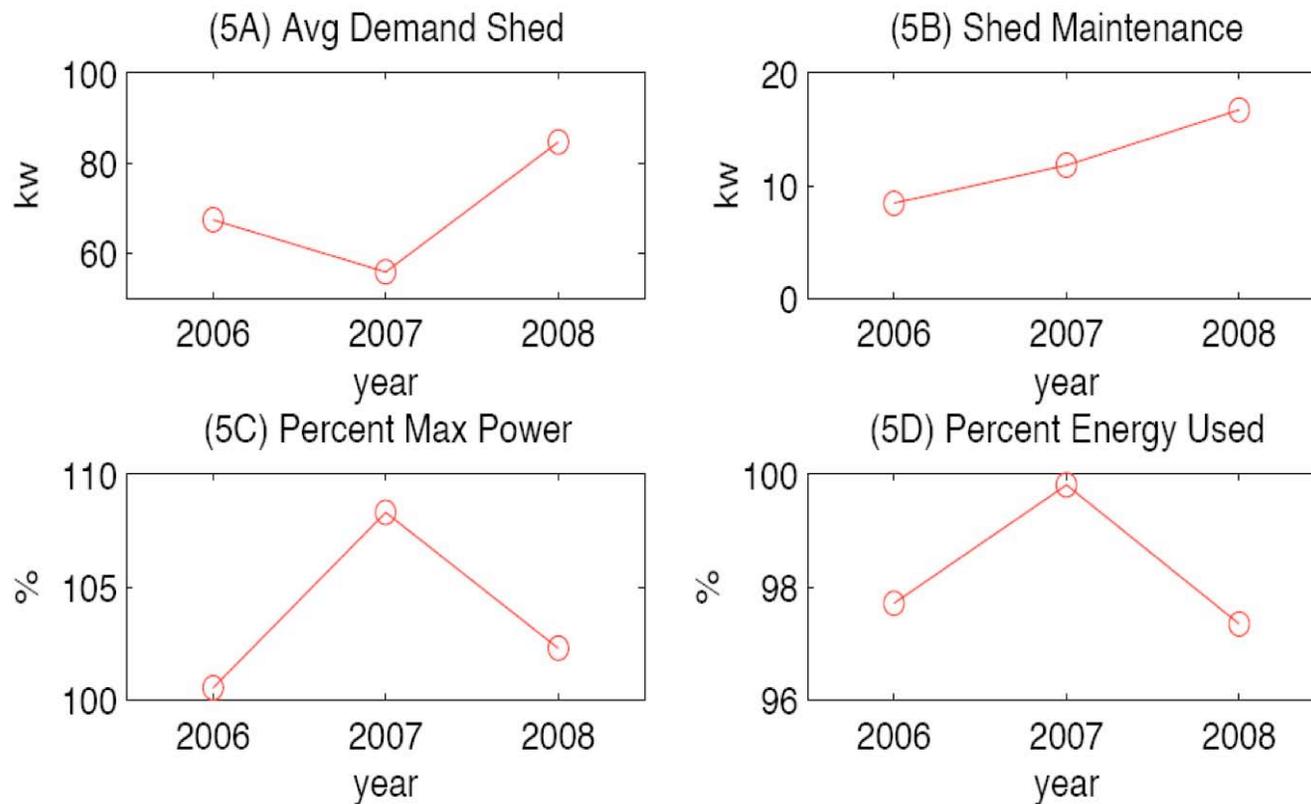


Definitions of DR Parameters Investigated

- **Average Demand Shed (kW):** average power shed during CPP event (3-6 pm)
- **Shed Maintenance (standard deviation of demand shed) (kW):** standard deviation of power shed during CPP event (3-6 pm)
- **Percent Maximum Power (%):** actual maximum daily demand divided by baseline-predicted maximum daily demand
- **Percent Energy Used (%):** actual daily energy use divided by baseline-predicted daily energy use

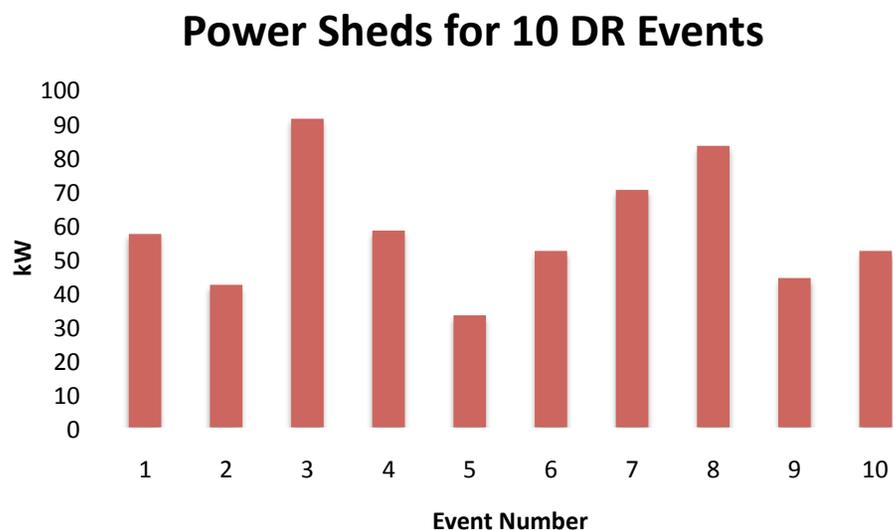


Change in DR Parameters for 2006 to 2008



Understanding Shed Variability (1)

We can plot demand reduction per event...



But shed are estimate using a baseline model...

- **Baseline models have error so all reduction estimates also have error.**
- **The more variable the building is, the larger the baseline model error, and the larger the error associated with the DR estimate.**



Understanding Shed Variability (2)

Shed variability

- building is not variable
- baseline model error is small
- shed error is small

What is causing variability?

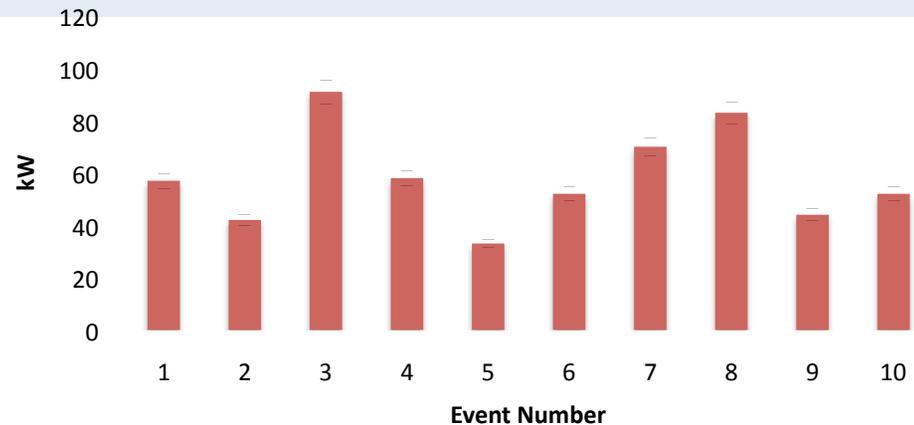
- buildings opting-out (unlikely)
- DR event-driven behavior change
- others reasons?

No significant shed variability:

- building is variable
- baseline model error is large
- power shed error is large

→ The variability you see in the plot could be from error associated with baseline model.

Power Sheds for 10 DR Events



Power Sheds for 10 DR Events



Future Directions with Automating DR

- **Linkage between energy efficiency, peak load management, and demand response**
- **Multi-time scale of DR to allow more grid scale renewables**
- **Dynamic rates**
- **Formation of OpenADR Alliance**
- **Building Codes and Title 24**

