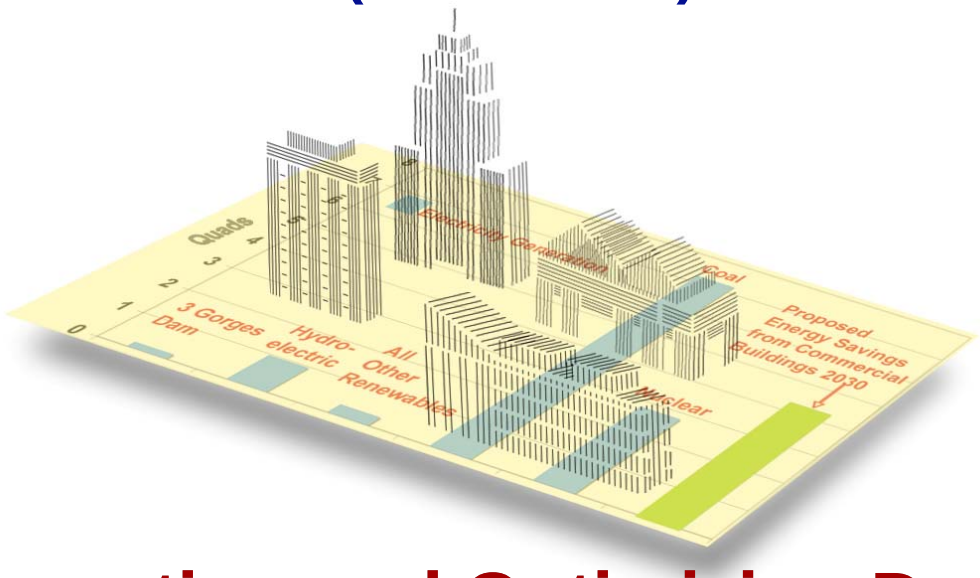
High Performance Buildings Research & Implementation Center (HiPer BRIC)



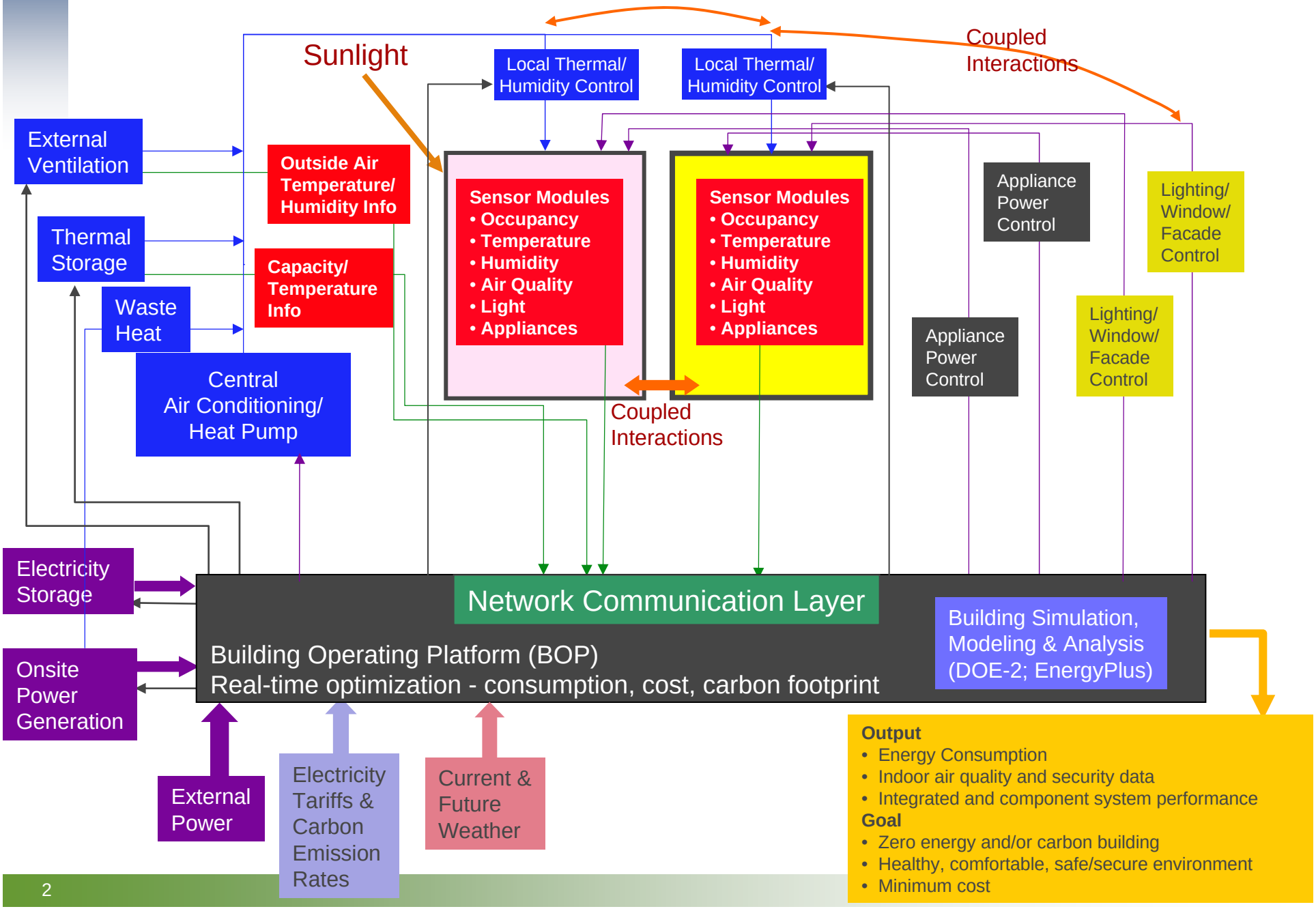
Automating and Optimizing Demand Responsive Commercial Buildings

Mary Ann Piette

Environmental Energy Technologies Division

December 21, 2007

Technical Scope of Buildings



Output
- Energy Consumption
- Indoor air quality and security data
- Integrated and component system performance

Goal
- Zero energy and/or carbon building
- Healthy, comfortable, safe/secure environment
- Minimum cost

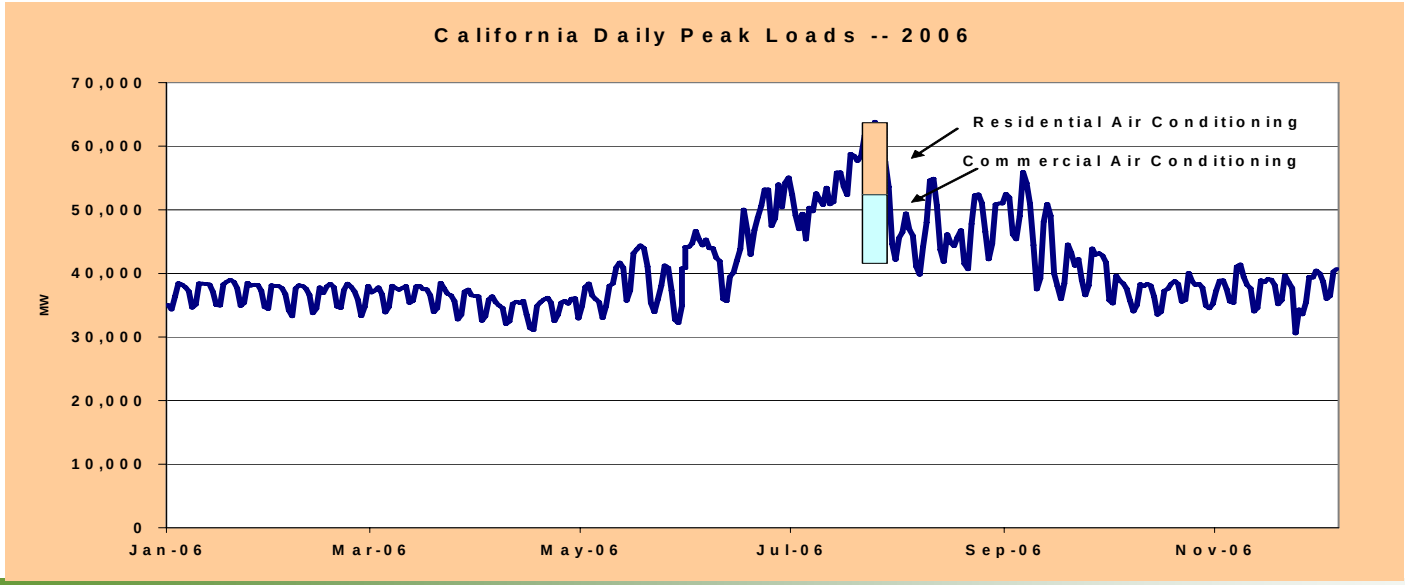
Demand Response Definitions and Technology Needs

DR Definition: Action to reduce load when

- Contingencies occur that threaten supply-demand balance
- Market conditions occur that raise supply costs
  - peak-load reductions different from efficiency, transient vs. permanent

DR Communications Infrastructure Needs

- Create real-time, automated DR infrastructure to respond to changing contingency and market conditions
- DR infrastructure should coexist with legacy systems, technology and tariff improvements, with near- and long-term benefits.



Automated DR Project Past and Present

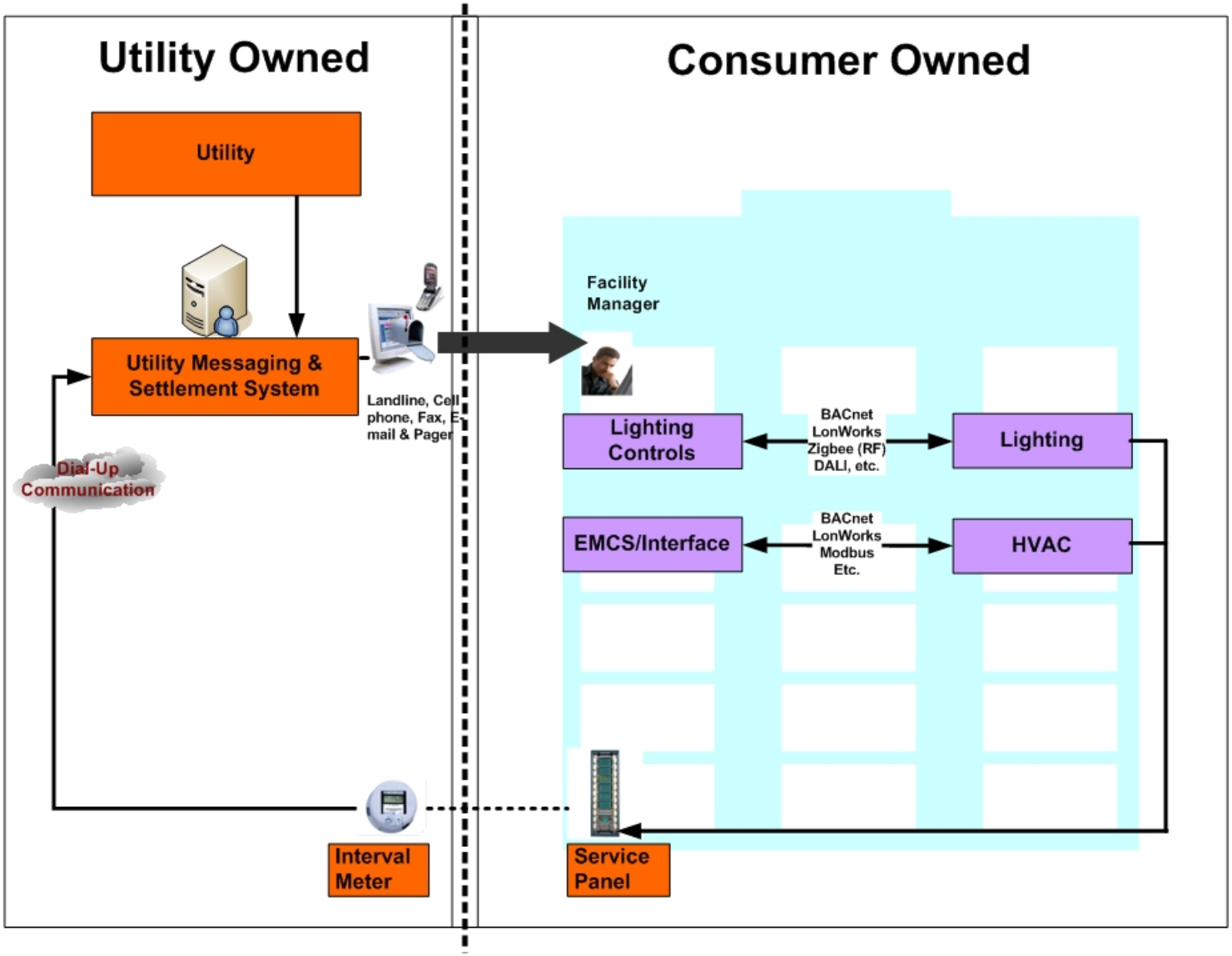
Recent Research Goals

- **Cost** - Develop low-cost, automation infrastructure to improve DR capability in California
- **Technology** - Evaluate "readiness" of buildings to receive signals
- **Capability** - Evaluate capability of control strategies for current and future buildings

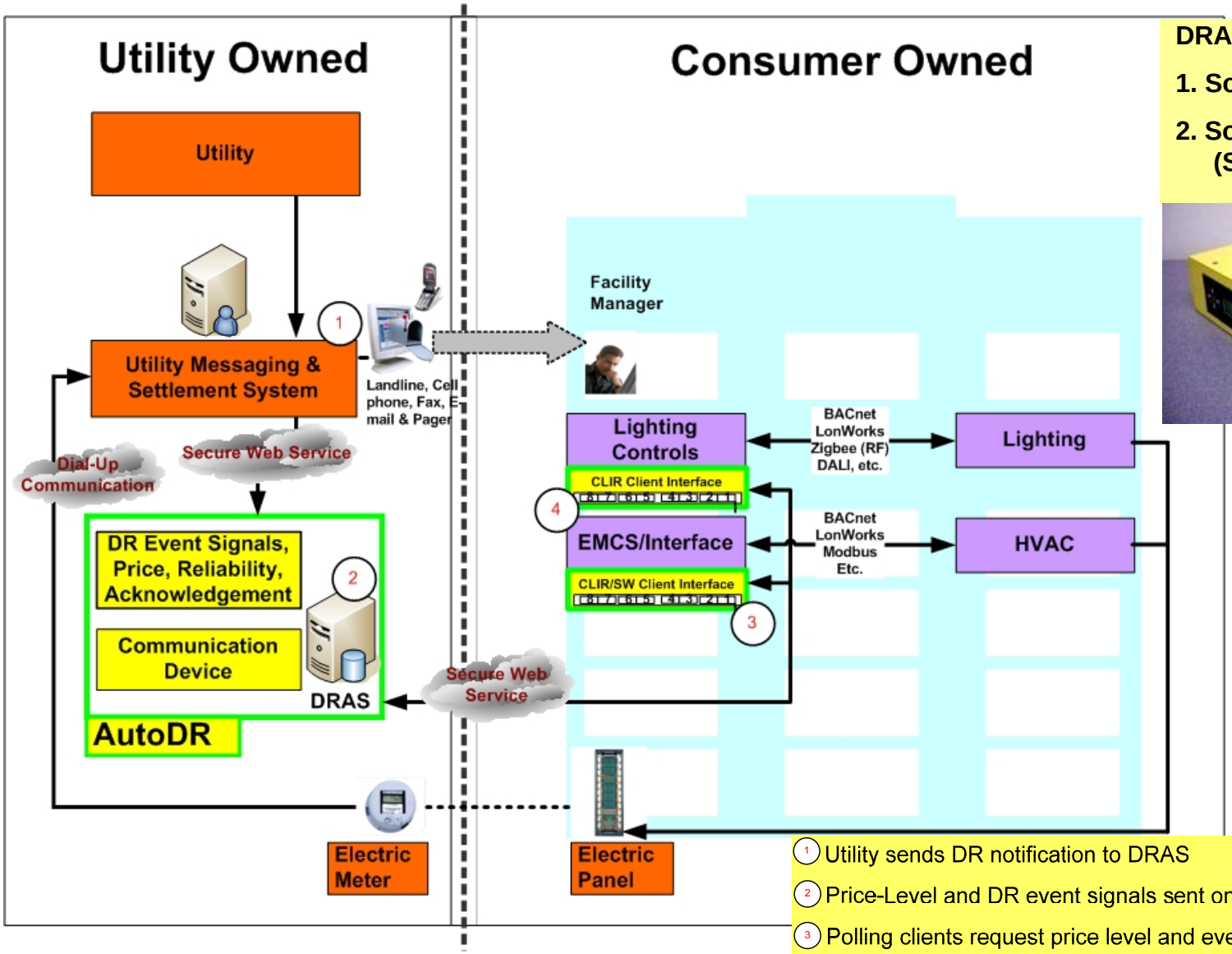
AutoDR Definition - Fully automated signal for end-use control

- **Signaling** – Continuous, secure, reliable, 2-way communication with listen and acknowledge signals
- **Industry Standards** - Open, interoperable standard control and communications to integrate with both common EMCS and other end-use devices that can receive a relay or similar signals (such XML)
- **Timing of Notification** - Day ahead and day of signals are provided to facilitate a diverse set of end-use strategies

Manual DR - Common Practice



DR Automation Server w/ DRAS Client

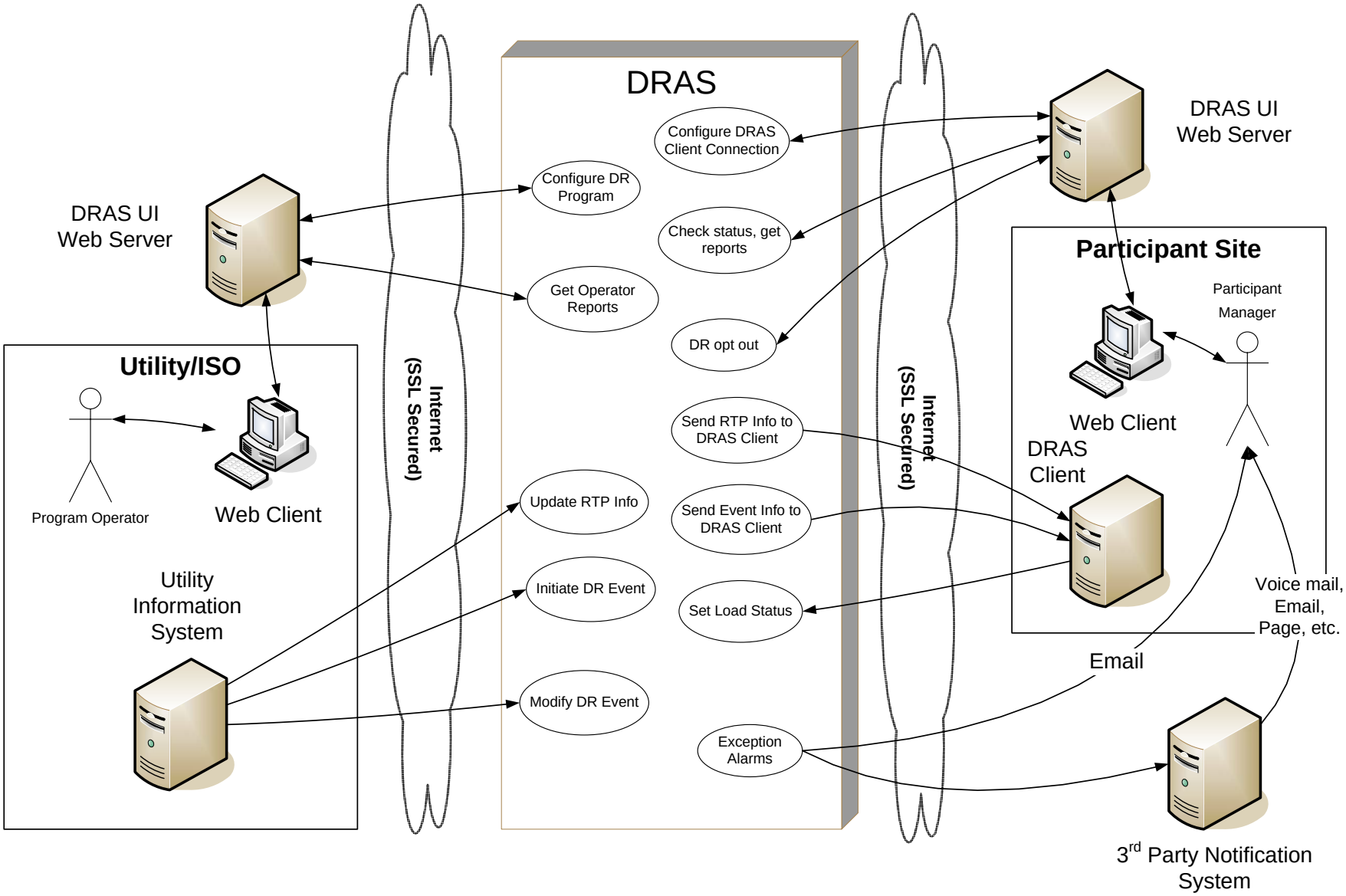


DRAS Clients –

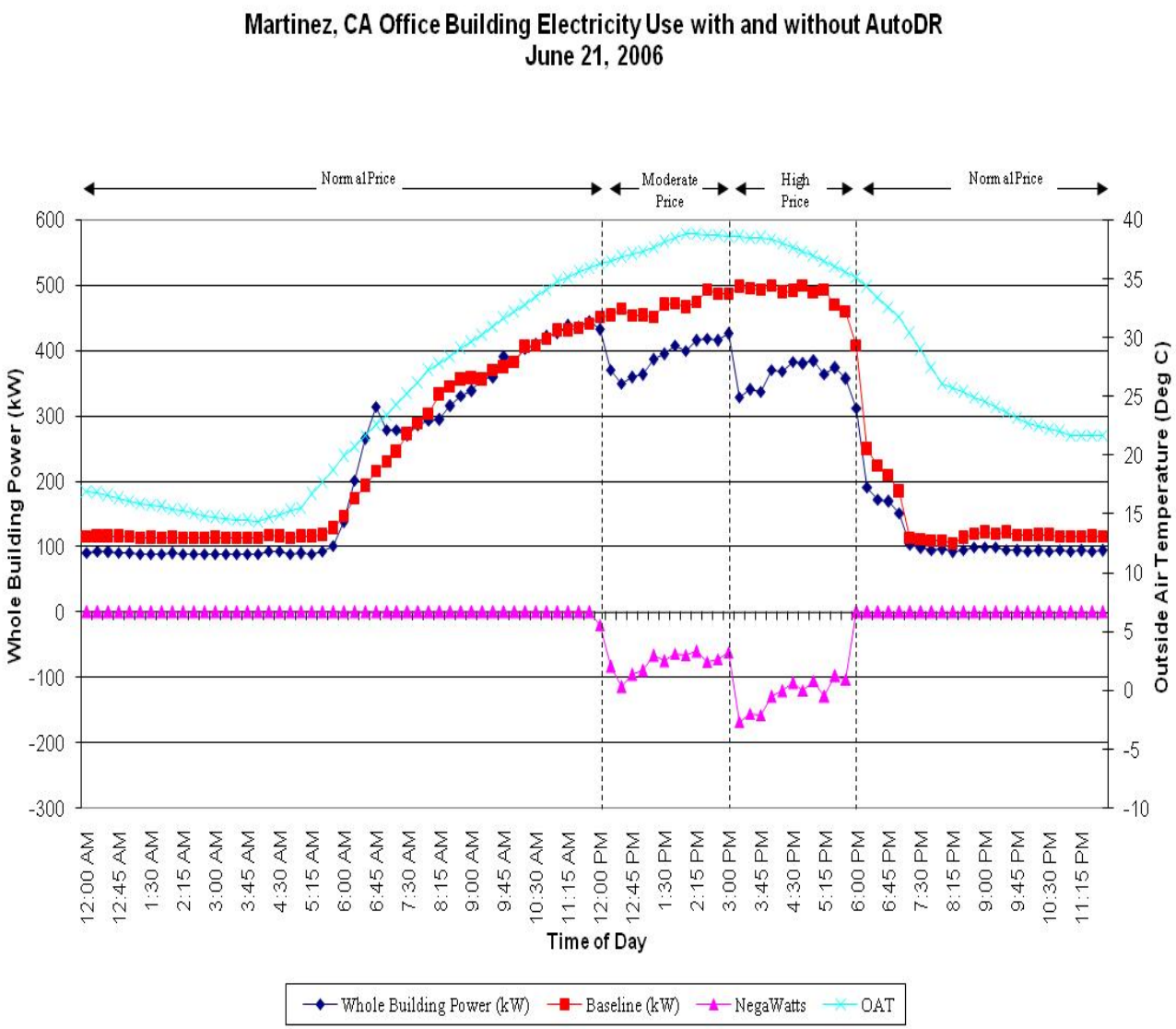
1. **Software only (Smart)**
2. **Software & Hardware (Simple)**

1. Utility sends DR notification to DRAS
2. Price-Level and DR event signals sent on DRAS
3. Polling clients request price level and event data every minute
4. Energy Management Control System (EMCS) and other systems carry out shed based on pre-programmed strategies.

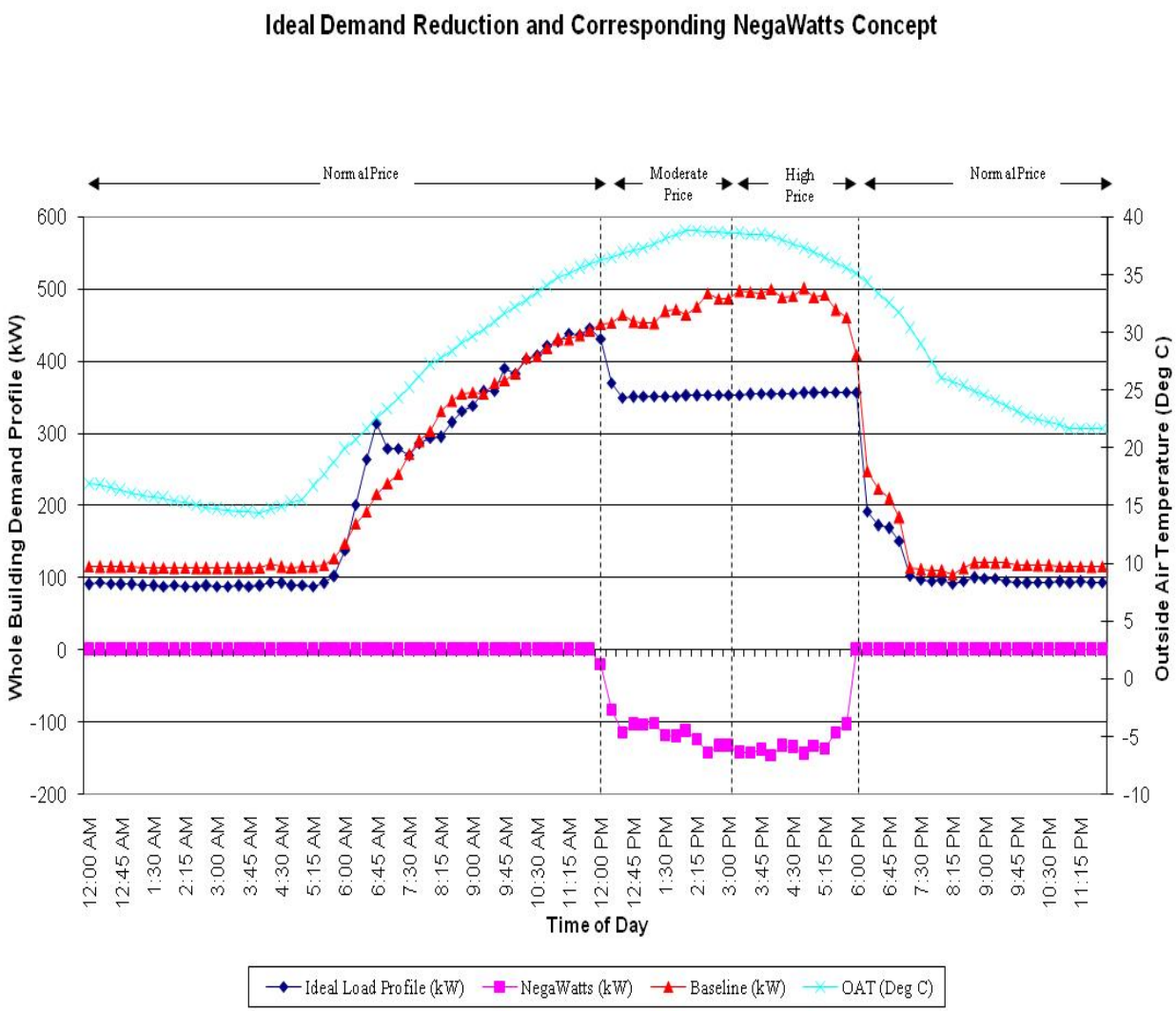
DR Automation Server Event Architecture



Auto-DR in 130,000 ft² County Office Current Practice



Auto-DR in 130,000 ft² County Office with Optimized Shed Shape



Improving DR capability in Buildings – from Present to Future

- Improved levels of granularity/modular control
- Improved intelligence of building modes – lighting, HVAC, other
- Improved end-use metering, service level performance metrics
- Multi-objective optimization

		HVAC											Lighting					Other
	Building use	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	

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DR AUTOMATION SERVER 3

Enhance Current AutoDR Web Portal: Retain Chain

logged in as: Target | logout | help

Summary | My Site | Options | About

Target

Control	Auto-CPP	Opt Out (NORMAL)	Forced Moderate	Forced High

Save

Upcoming Automated CPP Events for PGE_CPP_ZONE2

Received Event	Start	End
Fri Nov 10 09:22:20 PST 2006	Wed Nov 15 12:00:00 PST 2006	Wed Nov 15 18:00:00 PST 2006

Communication

Comm. Method	SOFTWARE
Event Level	normal
Last Contact	Fri Nov 10 09:24:55 PST 2006
Comm. Status	
Event Pending	NONE

Preparation Status

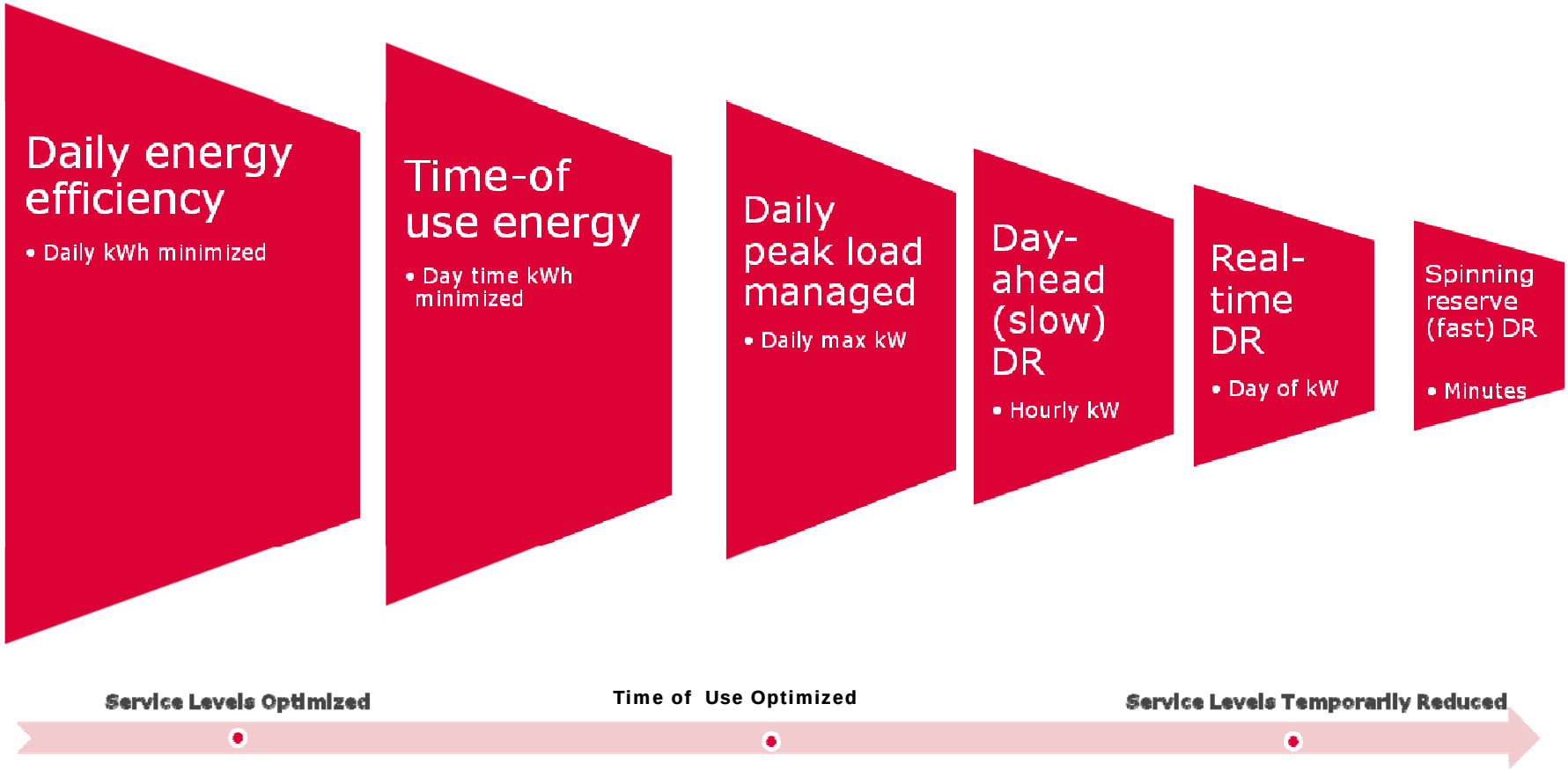
CPP Program	CPP sign-up	InterAct setup	Notify test	Activate
Target Antioch	Yes	No	Yes	05/01/2006
Target Bakersfield	Yes	Yes	Yes	05/01/2006
Target Hayward	Yes	Yes	Yes	05/01/2006

Technical Prep	Site survey	EMCS program	Server comm. test	Control test
Target Antioch	No	No	No	No
Target Bakersfield	No	No	No	No
Target Hayward	Yes	Yes	Yes	Yes

LBNL Auto-CPP Newsletters

Done | Internet

Time Scales of Building/Grid Optimization – Automated DR Future



Multi-objective Optimization

Energy

-On/off mode/control
-Weather/solar/wind
-Occupancy/comfort/schedule
-Equipment loads
- Continuous diagnostics

Operating Costs

- Rate $/kWh, TOU, demand charges
- Dynamic – critical, variable peak, RTP
- DR program – shed frequency, duration
- Maintenance and operations

Emissions

-Real-time CO_2/kWh (time of day)
-Grid or on-site power
-Energy source

Demand Response / Grid

- Loads to limit, shift, shed
- Service level control capability
- Service level requirements
  Duration, frequency of DR participation
- Spinning reserve participation

	Energy (kWh)	Operating Costs ($)	Emissions (CO_2)	Demand Response ($/kW)
Conventional Variable Air Volume				
Ice/Chilled Water Storage				
VAV with Pre-Cooling				

Research Needs and Operations Vision

MODELING AND MONITORING

- Improved real-time models and model predictive control
- Improved sensing and forecasting of occupancy, lighting, HVAC, misc. loads
- Continuous diagnostics
- Dashboard objects and common performance metrics

DISSEMINATION

- Test bed demonstrations
- Engineering guides and training

EXTERNAL DATA NEEDS

- Economic feedback – standard representation of tariff structures
- Common communications infrastructure
- Real-time and forecasted emissions data
- Grid/on-site generation status

LOW POWER (DR) MODES

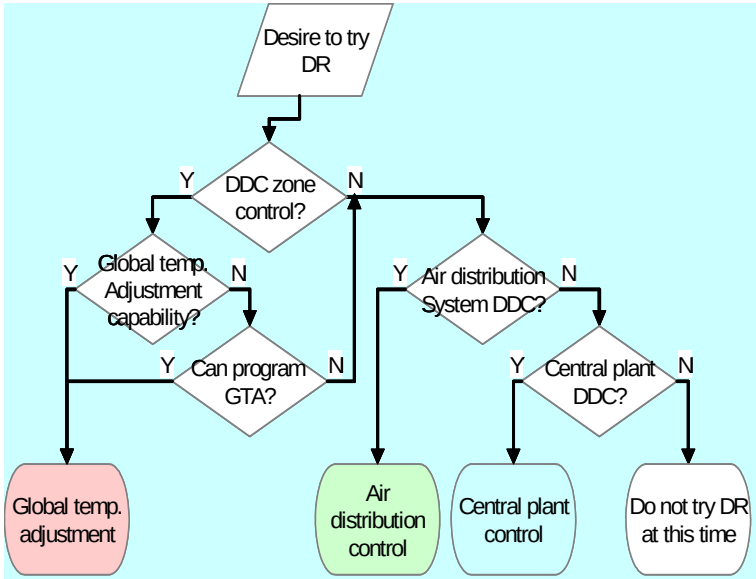
- Designed, commissioned and controlled as part of building lifecycle
- Continuous “mode” optimization

APPENDICES

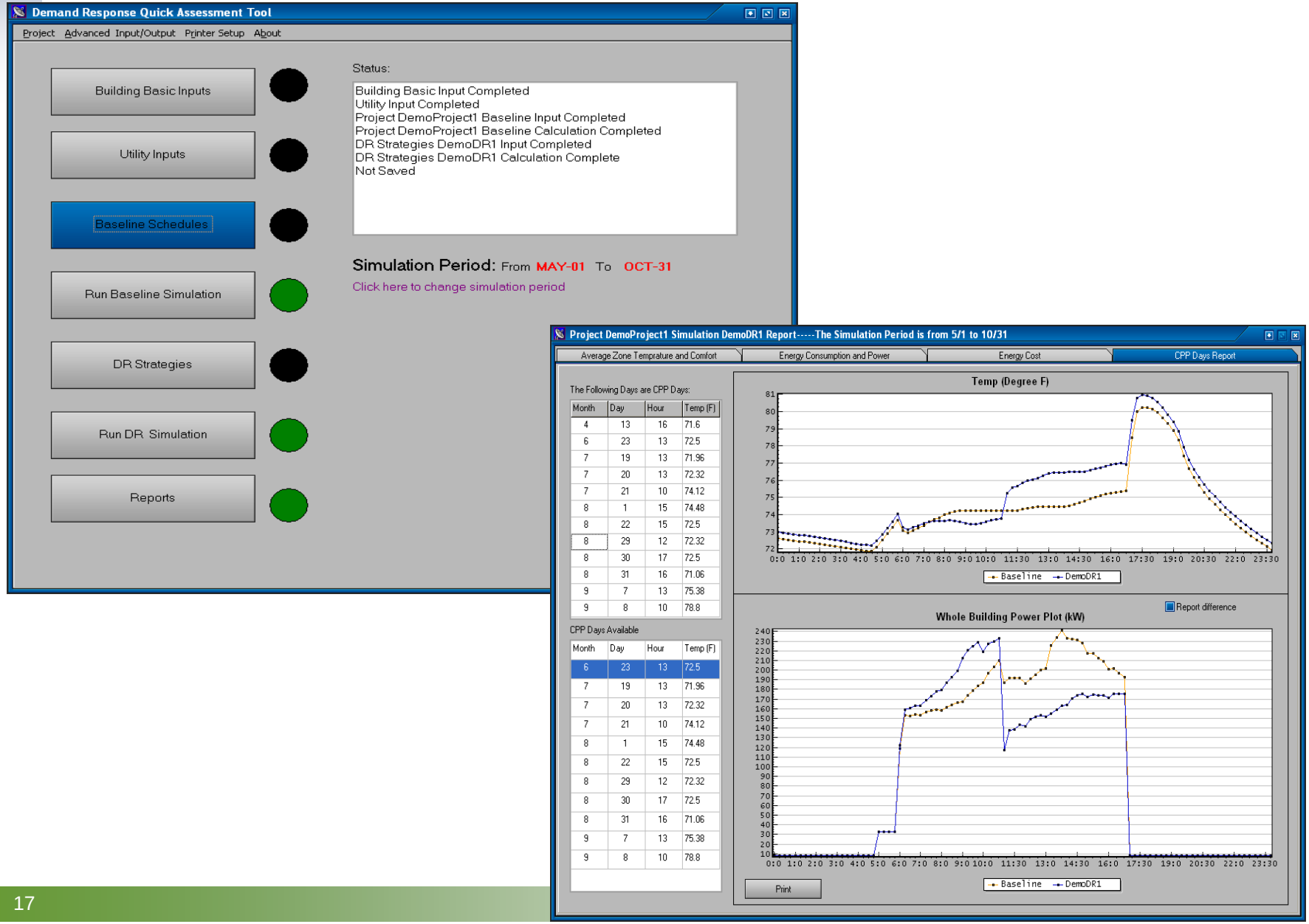
Linking DR and Energy Efficiency

Ideal start - good commissioning, retro-commissioning, advanced/new controls

- **HVAC -** Direct digital control (DDC) global temperature adjustment
  - In process for Title 24 2008
  - Closed loop
- **Lighting Continuum** - Zone Switching, Fixture Switching, Lamp Switching, Stepped Dimming, Continuous Dimming
- **Maybe you "can" use a strategy every day?**



EnergyPlus DR Assessment Tools



2006 Auto-CPP Participants (n=24)

Wide variety of building types

Short Name	Location	CPP Zone	Building Use	# of Bldg	Floor Space		Peak Load kW
					Total	Conditioned	
ACWD	Fremont	2	Office, lab	1	51,200	51,200	348
B of A	Concord	2	Office, data center	4	616,000	708,000	5712
Chabot	Oakland	2	Museum	2	86,000	86,000	336
2530 Arnold	Martinez	2	Office	1	131,000	131,000	536
50 Douglas	Martinez	2	Office	1	90,000	90,000	459
MDF	Martinez	2	Detention facility	1	172,300	172,300	561
Echelon	San Jose	2	Hi-tech office	1	75,000	75,000	523
Centerville	Fremont	2	Junior Highschool	1	N/A	N/A	332
Irvington	Fremont	2	Highschool	1	186,000	186,000	446
Gilead 300	Foster City	1	Office	1	83,000	83,000	288
Gilead 342	Foster City	1	Office, Lab	1	32,000	32,000	495
Gilead 357	Foster City	1	Office, Lab	1	33,000	33,000	662
IKEA EPaloAlto	East Palo Alto	1	Furniture retail	1	300,000	300,000	1466
IKEA Emeryville	Emeryville	2	Furniture retail	1	274,000	274,000	1191
IKEA WSacto	West Sacramento	2	Furniture retail	1	265,000	265,000	1055
Oracle Rocklin	Rocklin	2	Office	2	100,000	100,000	552
Safeway Stockton	Stockton	2	Supermarket	1	65,000	65,000	479
Solectron	Milpitas	2	Office, Manufacture	9	499,206	499,206	4655
Svenhard's	Oakland	2	Bakery	1	101,000	101,000	696
Sybase	Dublin	2	Hi-tech office	2	425,000	425,000	1995
Target Hayward	Hayward	2	Retail	1	130,000	130,000	449
Target Antioch	Antioch	2	Retail	1	140,686	140,686	572
Target Bakersfield	Bakersfield	2	Retail	1	143,941	143,941	645
Walmart Fresno	Fresno	2	Retail	1	125,503	125,503	571
				35	3,714,706	3,806,706	23,235

Communications Systems

Site	Communication Method	Device	Price Client Host	Price Client Host Location	Price Client Hosted at Co-Lo
ACWD	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
B of A	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
Chabot	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
2530 Arnold	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
50 Douglas	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
MDF	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
Echelon	Software client	i.LON	Kenmark	San Francisco, CA	No
Centerville	CLIR	CLIR	CLIR	Onsite	No
Irvington	CLIR	CLIR	CLIR	Onsite	No
Gilead 300	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
Gilead 342	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
Gilead 357	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
IKEA EPaloAlto	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
IKEA Emeryville	CLIR	CLIR	CLIR	Onsite	No
IKEA WSacto	CLIR	CLIR	CLIR	Onsite	No
Oracle Rocklin	CLIR	CLIR	CLIR	Onsite	No
Safeway Stockton	CLIR	CLIR	CLIR	Onsite	No
Solectron	CLIR	CLIR	CLIR	Onsite	No
Svenhard's	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
Sybase	CLIR	CLIR	CLIR	Onsite	No
Target Hayward	Software client	Canon Technologies	Target	Minesota	Yes
Target Antioch	Software client	Automated Logic	Target	Minesota	Yes
Target Bakersfield	Software client	Automated Logic	Target	Minesota	Yes
Walmart Fresno	Software client	EnergyICT	EnergyICT	Belgium	Yes

Related Research - Pre-Cooling Studies

	# of Sites/ Location	Peak Shift (W/ft^2)	% (whole building)	Strategies	Comfort	Peak outside temp °F
2003	1 / Santa Rosa	**2.3**	~60%	**Pre cool – one step temp set up**	No complaints	90-95
2004	2 / Santa Rosa, Sacramento	**0.5~2.0**	10~66%	**Pre cool – one step temp set up**	Comfort survey	85-90
2005	2 / Oakland	**0.5~1.0**	10~25%	**Pre cool - various shed & recovery strategies**	Comfort survey, indoor monitors	80-85
2006	1 / Visalia	**0.5~1.0**	10~15%	**Pre cool - various shed & recovery strategies**	Comfort survey, indoor monitors	95-100

DR Automation Server: Summary - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.electricprice.net/pss2.website/secure/summary.jsp Go Links

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DR AUTOMATION SERVER 3

logged in as: operator | logout | help

Summary | SAID | Comm Dev | Logs | Channels | Users | Schedule | Options | About

Upcoming Automated CPP Events

DR Group	Received Event	Start	End
PGE_CPP_ZONE1	Fri Nov 10 09:22:08 PST 2006	Wed Nov 15 12:00:00 PST 2006	Wed Nov 15 18:00:00 PST 2006
PGE_CPP_ZONE2	Fri Nov 10 09:22:20 PST 2006	Wed Nov 15 12:00:00 PST 2006	Wed Nov 15 18:00:00 PST 2006

Summary

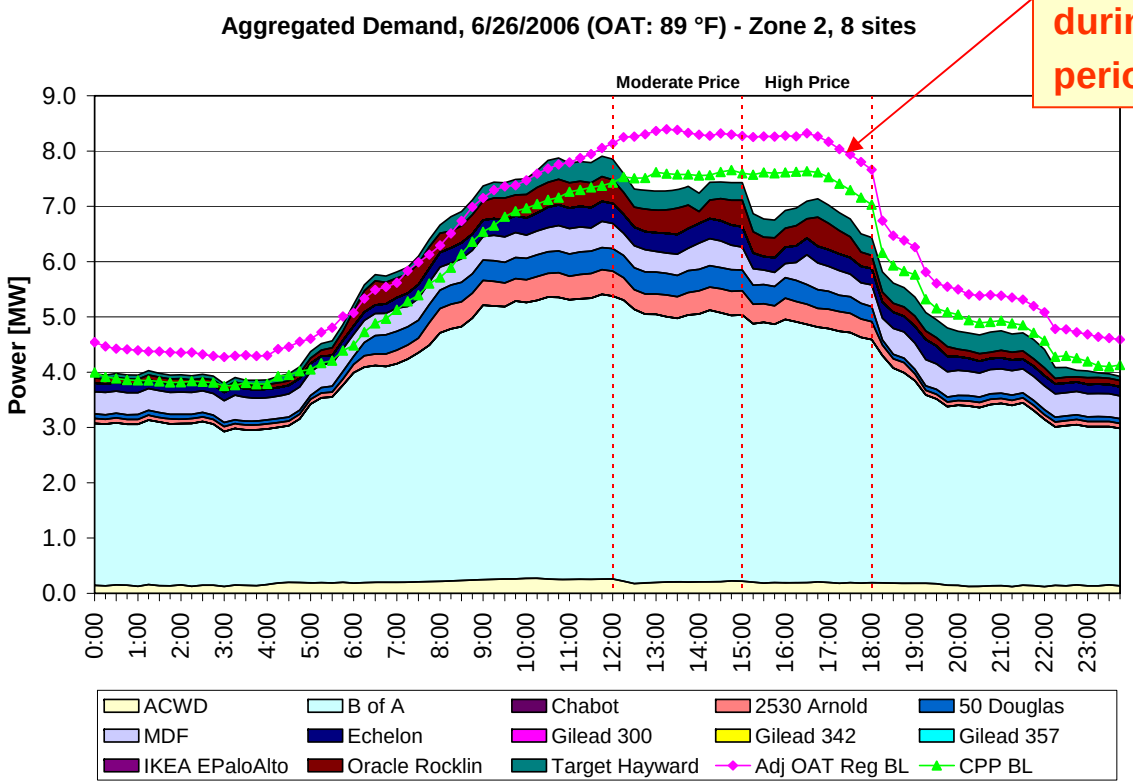
Show: ○ All Sites ◉ Ready Sites Only

Organization	Comm Dev Name	Service Agreement Name	DR Group	Event Level	Prep. Status	Comm. Status
ACWD	ACWD	ACWD	PGE_CPP_ZONE2	normal	Yes	No
B of A	B of A	B of A	PGE_CPP_ZONE2	normal	Yes	Yes
Chabot	Chabot	Chabot	PGE_CPP_ZONE2	normal	Yes	Yes
Contra Costa	Contra Costa	2530 Arnold	PGE_CPP_ZONE2	normal	Yes	Yes
Contra Costa	Contra Costa	Martinez Detention	PGE_CPP_ZONE2	normal	Yes	Yes
Contra Costa	Contra Costa	50 Douglas	PGE_CPP_ZONE2	normal	Yes	Yes
Echelon	echelon	Echelon	PGE_CPP_ZONE2	normal	Yes	Yes
FUSD	FUSD_Cent	Centreville JrHigh	PGE_CPP_ZONE2	normal	Yes	Yes
FUSD	webservice1	Irvington High	PGE_CPP_ZONE2	normal	Yes	No
Gilead	Gilead	Gilead 300	PGE_CPP_ZONE1	normal	Yes	Yes
Gilead	Gilead	Gilead 342	PGE_CPP_ZONE1	normal	Yes	Yes
Gilead	Gilead	Gilead 357	PGE_CPP_ZONE1	normal	Yes	Yes
IKEA	IKEA	IKEA Palo Alto	PGE_CPP_ZONE1	normal	Yes	Yes
Oracle	webservice2	Oracle Rocklin	PGE_CPP_ZONE2	normal	Yes	No
Svenhard's	Svenhard's	Svenhard's	PGE_CPP_ZONE2	normal	Yes	Yes
Target	target	Target Hayward	PGE_CPP_ZONE2	normal	Yes	Yes

Done Internet

Aggregated AutoDR Results – June 26, Zone 2
OAT and CPP Baselines show different results

1.3 MW reduction during high price period



	Average kW		Average %		Average W/ft²	
	Moderate	High	Moderate	High	Moderate	High
ACWD	78	91	28%	32%	1.53	1.78
B of A	478	604	9%	12%	0.67	0.85
2530 Arnold	102	140	20%	29%	0.78	1.07
50 Douglas	57	94	13%	22%	0.63	1.04
MDF	90	155	17%	30%	0.52	0.90
Echelon	-2	80	0%	22%	-0.02	1.07
Oracle Rocklin	85	60	17%	14%	0.85	0.60
Target Hayward	59	56	15%	15%	0.45	0.43
Aggregated	946	1281	11%	16%	0.65	0.88