Characterization and Demonstration of Demand Responsive Control Technologies and Strategies in Commercial Buildings

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Presentation Overview

- **Welcome and Introductions**
- **LBNL Presentation**
  1. Demand Response Basics and Demand Response in the U.S.
  2. DOE Research Project Objectives and Methods
  3. Demand Response Potential in Commercial Buildings
  4. Research in New York: *New York Times Office Building*
  5. Research in California: *Automation of Demand Response*
  6. Advanced Controls for Commercial Buildings
  7. National R&D Opportunities
  8. Summary and Resources
- **Question and Answer**

Welcome and Introductions

- **Meeting Objectives**
  - Update building controls companies on DR trends and Automated DR progress
  - Disseminate results of recent research
  - Seek feedback on the LBNL DR advanced building controls work to date
- **Review of Invitees**

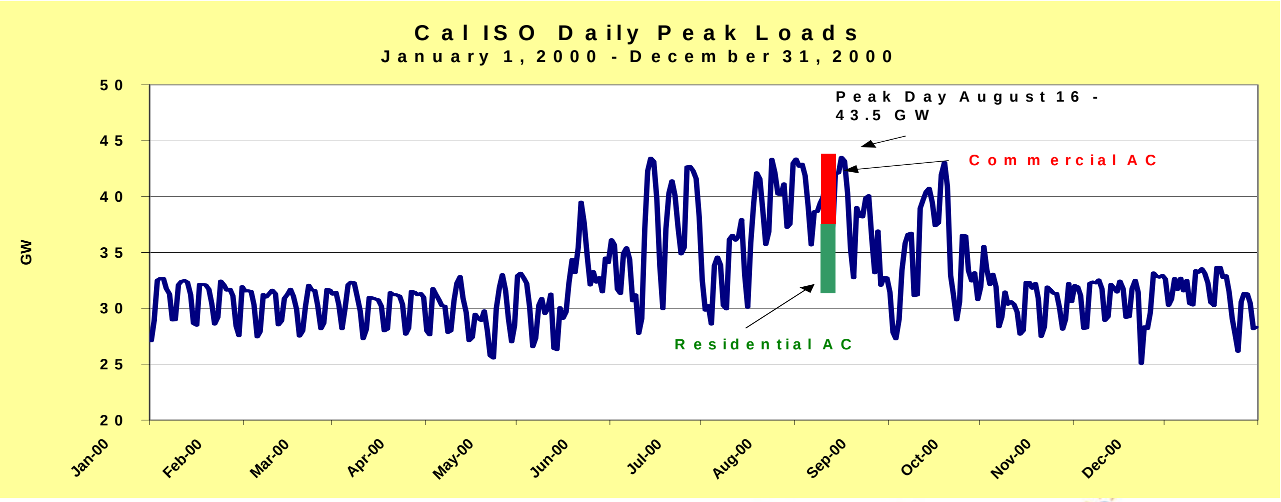
1. Demand Response Basics

Demand Response (DR) - action taken to reduce load when

- Contingencies (emergencies & congestion) occur that threaten supply-demand balance, and/or
- Market conditions occur that raise supply costs

Relevance

- Electric systems more vulnerable to outages with age, load factors decreasing, T&D and new capacity investments reduced, real time pricing promoted.



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2. DOE Project
Research Objectives for DR Controls

- Evaluate demand response capabilities, technologies and strategies, and link to energy efficiency
- Evaluate role of commercial buildings in US peak and value of DR
- Support DOE mission – increase reliability and efficiency of electricity generation, delivery, and use

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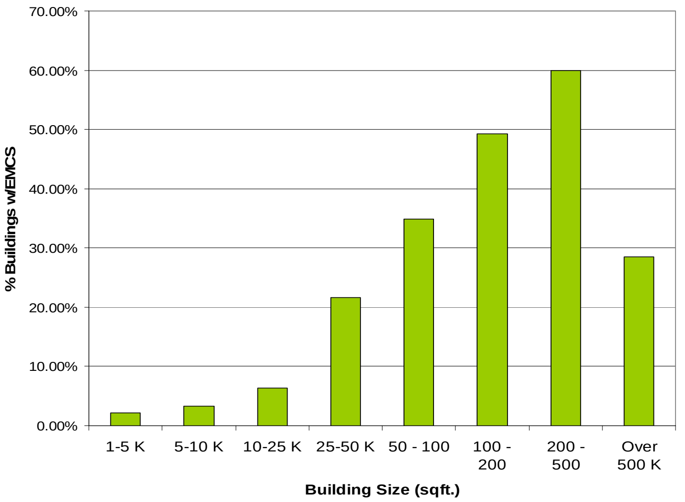
2. DOE Project Technical Approach

Methodology

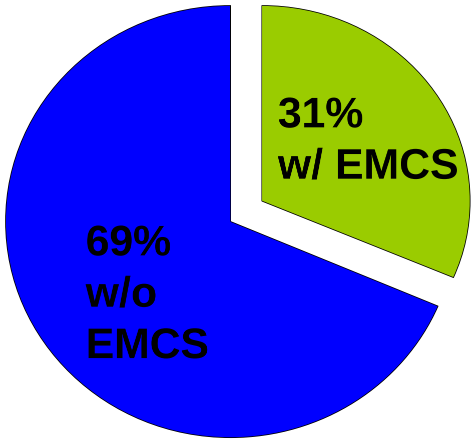
- Analyze role of commercial buildings in peak
- Review case study data, strategies and opportunities
- Develop conceptual framework
- Share results with Industry (e.g. controls co., owners, utilities), define research needs



Goals and Barriers

- Seek to enable widespread DR capability in commercial buildings, focus on large buildings
- Immature DR markets, prices not reflect true peak costs, limits economics to building owner
- Broad distribution of commercial control capabilities limits capabilities in stock (most capable are DDC EMCS)

Source: CBECS 2003



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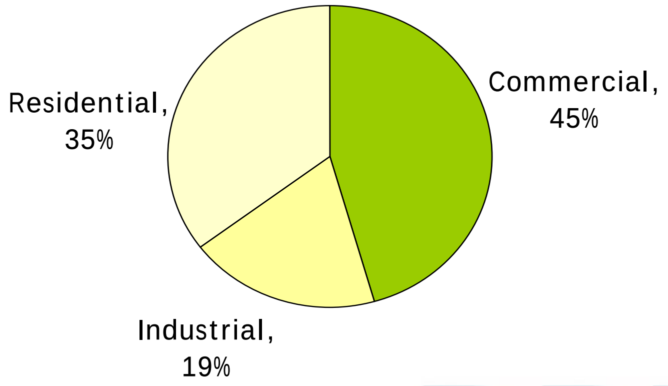
3. DR Potential
Commercial Buildings

- **Commercial buildings play major role in peak demand and may dominate coincident peak, but data lacking**
- **Analysis Results – National Total, All Sectors ~730 GW**
  - Commercial Buildings Energy Consumption Survey (CBECS) non-coincident peak ~ 270-320 GW in 1995 scales to 330 to 390 in 2003
  - National Energy Modeling System shows similar results of coincident peak of 330 MW (NEMS is an EIA simulation of all major energy supplies and demand, of the U.S. economy)



	1995 (GW)	2003 (GW)
CBECS (1) (non-coin.)	273	333
CBECS (2) (non-coin.)	317	387
NEMS Non-coincident	317	363
NEMS Coincident	291	328

3. DR Potential and Value
Commercial Buildings

Utility Systems and Societal Value

- Improve Reliability of the System
- Reduce Electricity Costs and Market Efficiency
- Risk Management, Insurance and Option Value
- Environmental Impact

Commercial Sector Value – Peaking Turbine

- 10% of 330 GW x $75/kW > $24 Billion

Buildings Industry Opportunity

- Controls - Leverage efficiency & DR capabilities, Zero Energy Buildings, dynamic response to DR prices and on-site renewables
- Energy Information - Leverage knowledge of electric load shape and energy use patterns, Link to commissioning

Over 20 States pursuing DR

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3. Advanced Controls for Commercial Buildings

	Efficiency and Conservation (Daily)	*Peak Load Management (Daily)*	*Demand Response (Dynamic Event Driven)*
Motivation	- Environmental Protection - Utility Bill Savings	- TOU Savings - Peak Demand Charge savings - Grid Protection	**- Economic** **- Reliability** **- Emergency** **- Grid Protection**
Design	- Efficient Shell, Equipment & Systems	Low Power Design	**Dynamic Control Capability***
Operations	- Integrated System Operations	Demand - Limiting Shifting Shedding	**Demand - Limiting Shifting Shedding**
Initiation	Local	Local	**Remote**

***Prefer closed loop strategies, granular control**

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4. Research in New York
New York Times Building

- **Technology designed for efficiency simulated to develop DR strategies**
  - Efficient features: Integrated movable, shading & dimming, Under floor air systems
  - Commissioning in mockup

- **Demand Response Strategies**
  - Dimming lights beyond daylighting, reset zone temperatures (gradient), reduce perimeter fan speed, raise supply air temperature
  - Direct implementation of DR control strategies in new building controls and commissioning plans

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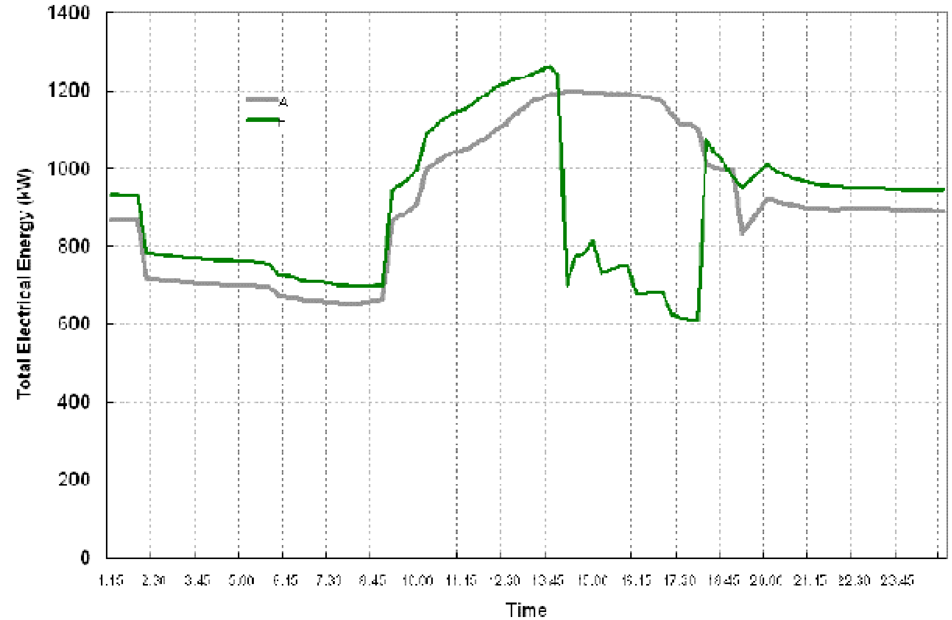
4. Research in New York
New York Times Building

- **Preliminary Results from whole building simulations of DR Strategies**
- **Preliminary analysis of DR control strategies in NY DR programs**



Predicted Annual Savings from 400 kW Shed

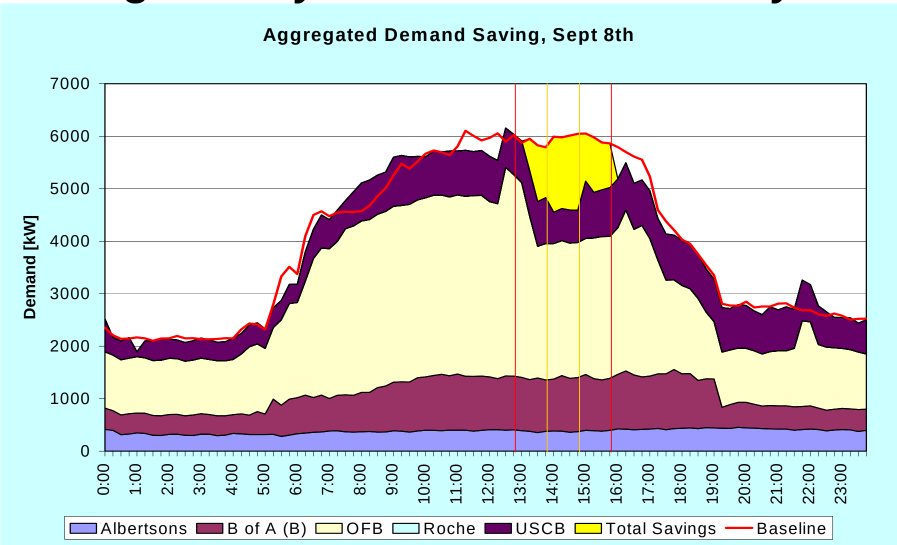
Program	Predicted Annual Savings*
Independent Capacity Program	$17,632.00
Emergency DR Program	$1,440.00
Distribution Load Relief Program	$1,600.00

5. Research in California
Levels of Automation in DR

- **Manual DR -** potentially labor-intensive human turning off or changing set points at each switch or controller
- **Semi-Automated DR -** pre-programmed demand response strategy initiated by a person via centralized control system
- **Fully-Automated DR -** initiated through receipt of an external communications signal to execute pre-programmed strategies

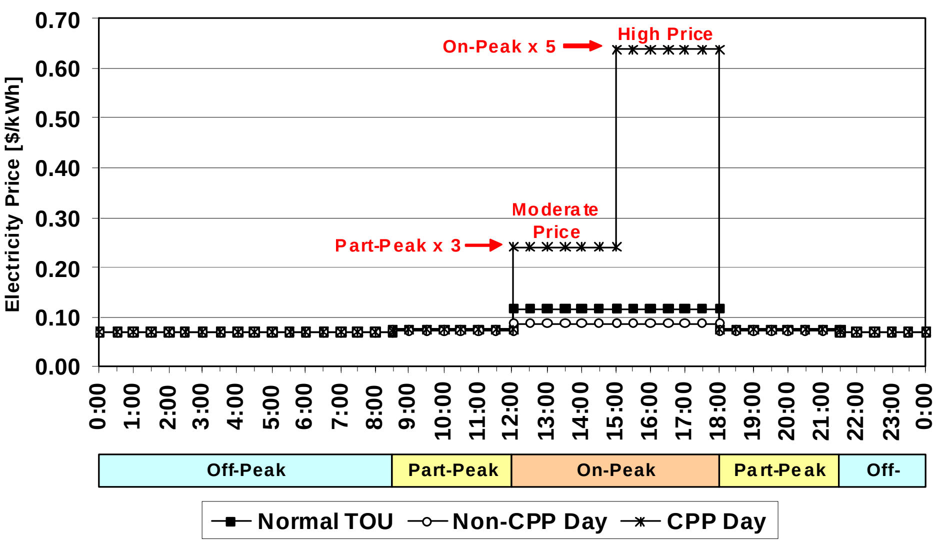
5. Research in California Automated DR Research

- **Goals**
  - Automate DR for large buildings linking EMCS to Price/Signal Server
  - Evaluate feasibility of automated DR and DR strategies
- **2003 Study** – 5 sites had Energy Information Systems
  - Fictitious prices, all XML gateways
- **2004 Study** - 18 (10 Million ft^2) sites linked to EIS & EMCS
  - Fictitious prices, XML gateways and Internet Relays



6. Research in California
Fully Automated Critical Peak Pricing

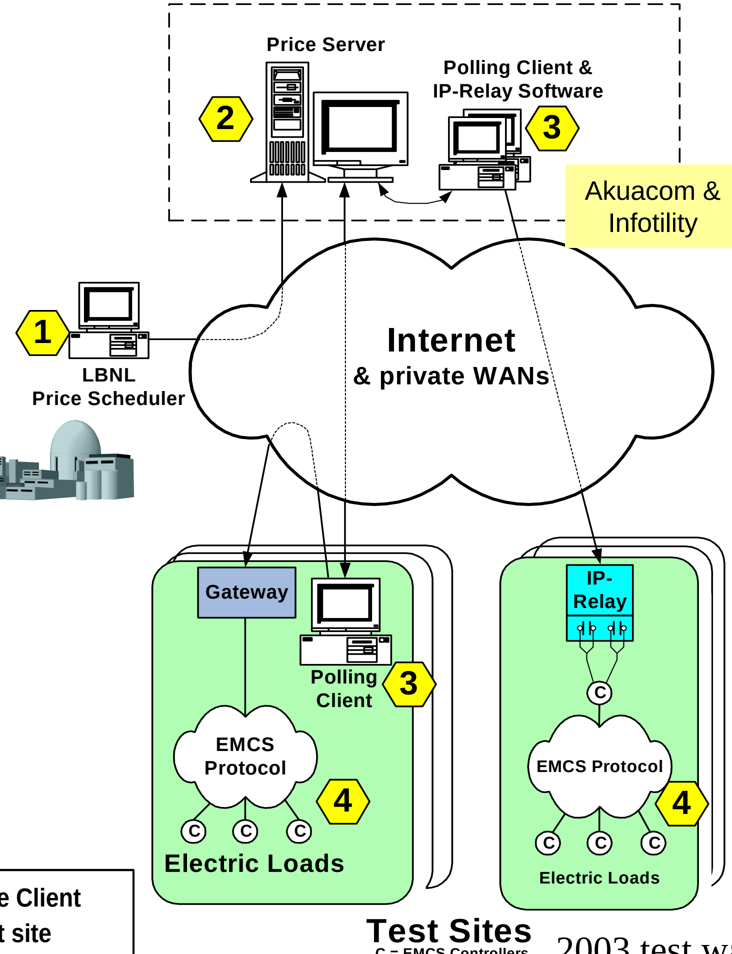
- **Objectives of 2005 Automated CPP Study**
  - Evaluate effectiveness of automated notification system for CPP
  - New Price Server for 2005 Study
  - Evaluate which shifting and shedding strategies can be automated
- **Determine occupant and tenant response**
  - Three pre-cooling sites
  - Three occupant comfort sites
  - One Indoor Air Quality (IAQ) site

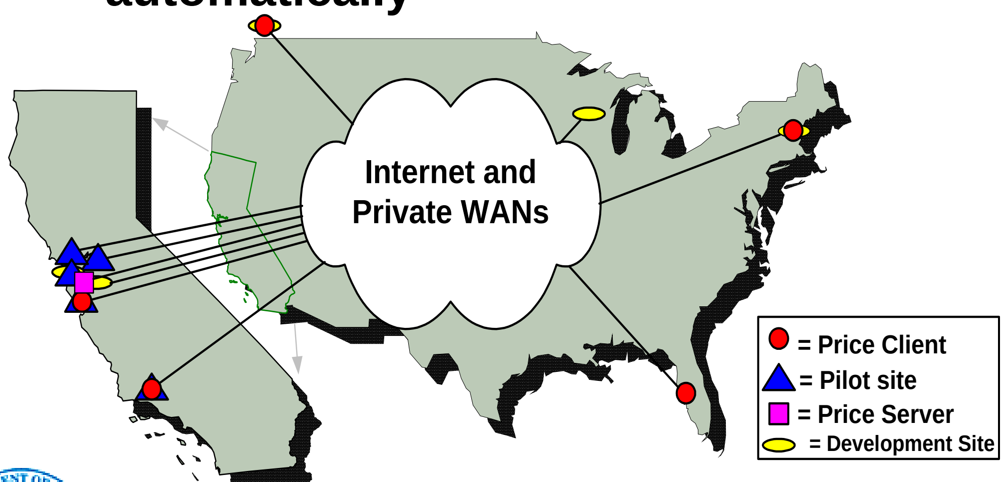


6. Research in California

2003, 2004 and 2005 Automation Systems

1. **PG&E or LBNL defines price schedule**
2. **Price published on LBNL XML (eXtensible Markup Language) server**
3. **Clients request price from server every minute & send shed commands**
4. **EMCS carries out shed automatically**





2003 test was Gateway only
2004 was Gateway or Relay
2005 both

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6. Research in California
Results on Automated-DR

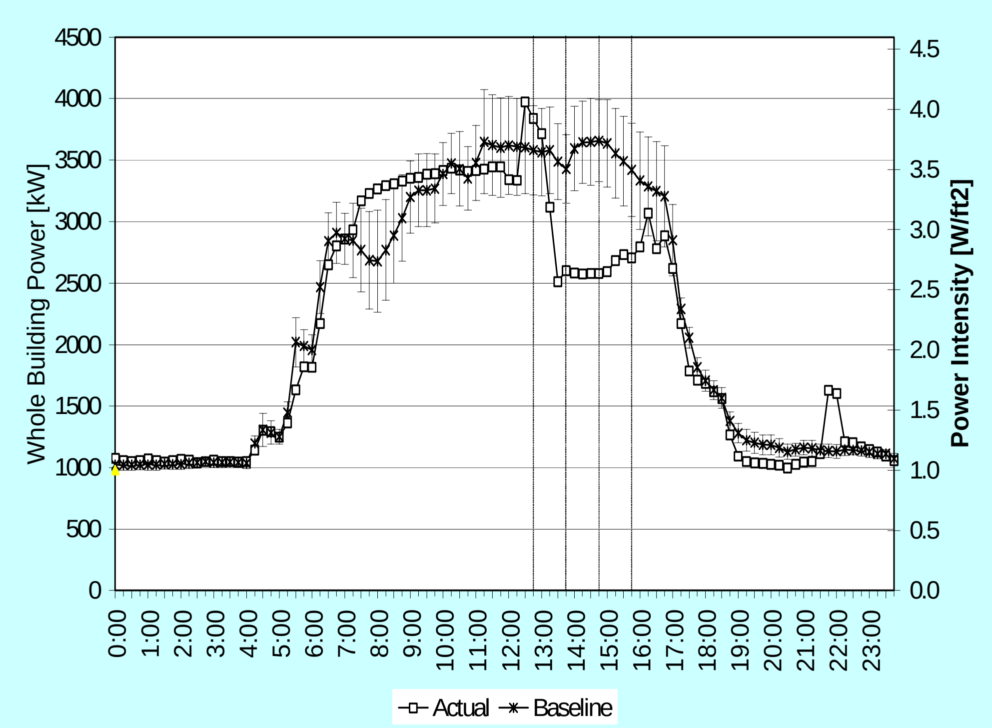
- Established capabilities of current controls and communications with EMCS and XML
- Demonstrated initial design of signaling infrastructure and system capability
- Demonstrated large sheds can take place without complaints
- Demonstrated range of strategies to produce sheds and capabilities needed
- Average reduction 8% among 28 buildings, up to 50%

	Number of sites	Avg. Savings (%)	Max. Savings (%)
2003	5	8	28
2004	18	7	56
2005	12	9	38

6. Research in California
Global Temperature Adjustment

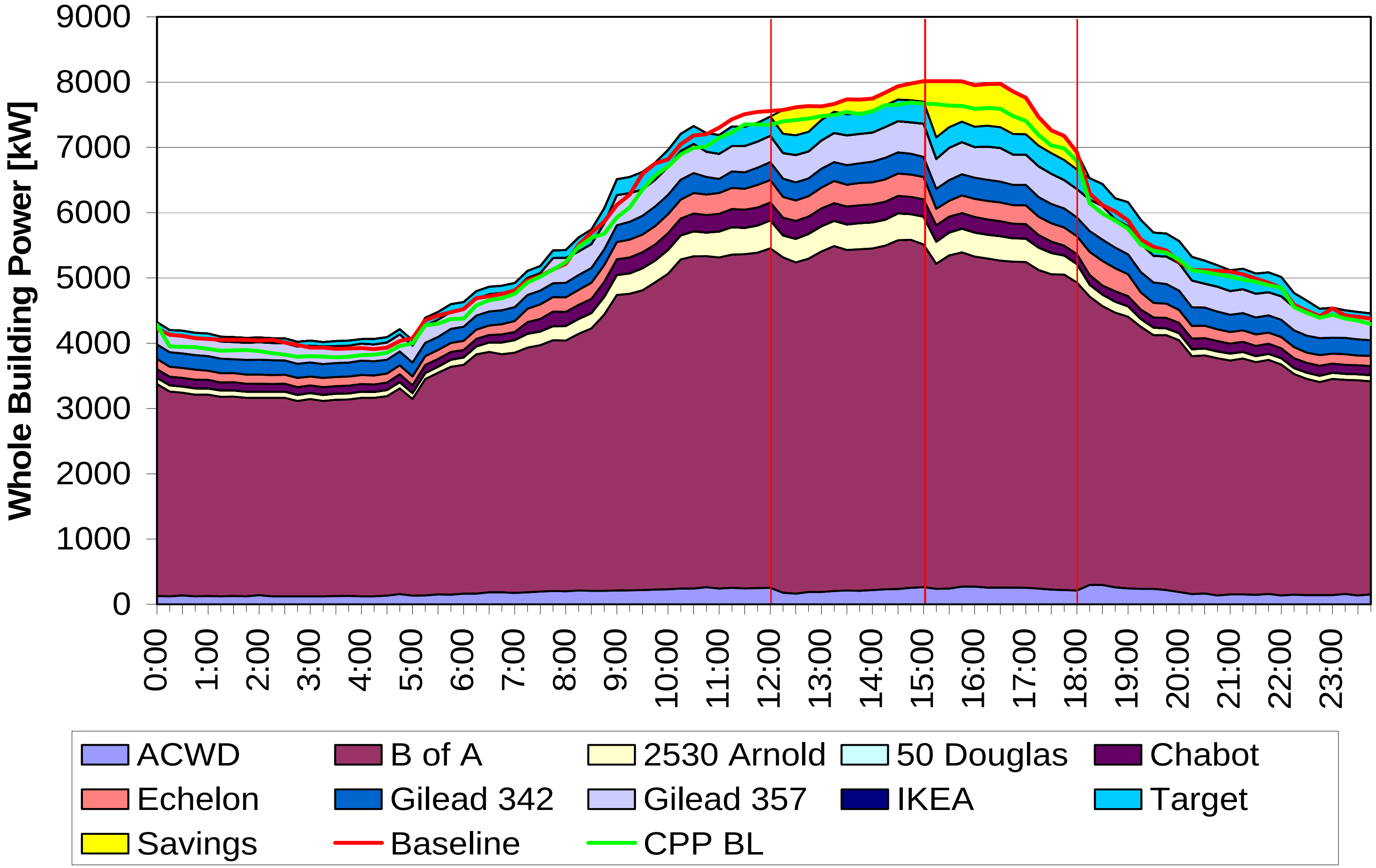
- **Demonstrated large sheds in existing DDC EMCS with minimal to no occupant issues**
- **Comply with comfort standards**
- **Oakland Federal Building, Sept. 8 2004**
  - **Average of ~800 kW, 0.8 W/ft^2 > 20% shed for 3 hrs. with two-step set point increase 72°F to 78°F**

ASHRAE 55-2004
Time Period
2 ºF -15 min.
3 ºF - 30 min.
4 ºF - 1 hr
5 ºF - 2 hr
6 ºF - 4 hr



6. Research in California Automated Critical Peak Pricing

Sample Results from Sept 29: 8% shed, ~ 1 MW shed, 0.5 W/ft²



6. Research in California

Maximum DR from Auto-CPP Tests

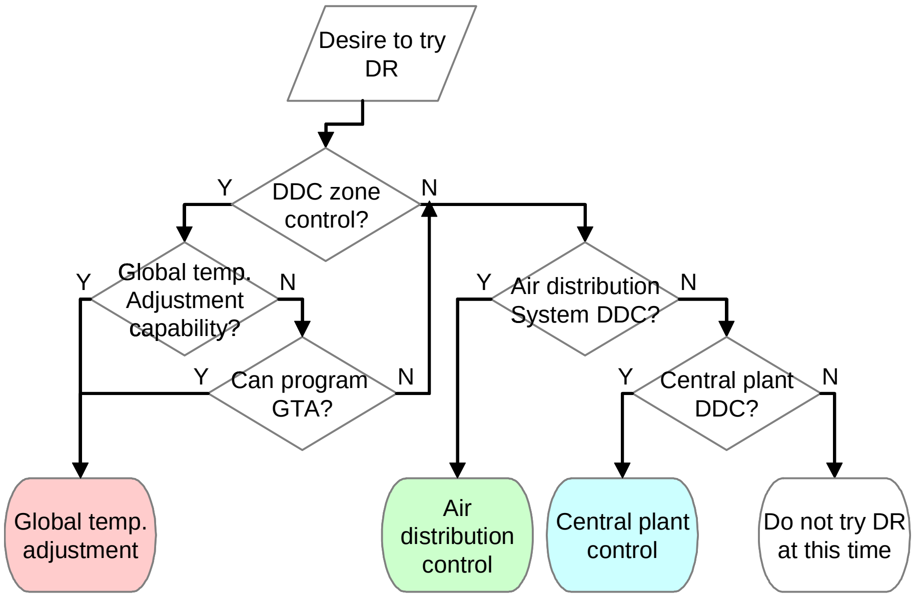
		Aug-08	Sep-22	Sep-29	Oct-06	Oct-13	Oct-25	Nov-10	2004	Max
ACWD	Baseline Peak kW			330	253	290	238			330
	Max Shed kW			101	74	83	77			101
B of A	Baseline Peak kW			5311		5163	5053			5053
	Max Shed kW			291		219	552			552
Chabot	Baseline Peak kW		225	308	244	270				308
	Max Shed kW		19	88	36	42				88
2530 Arnold	Baseline Peak kW	505	419	431	404	406	345			505
	Max Shed kW	176	119	90	63	89	40			176
50 Douglas	Baseline Peak kW	381					259			381
	Max Shed kW	95					78			95
Echelon	Baseline Peak kW		334	403	363	359	304			403
	Max Shed kW		115	143	132	117	84			143
Gilead 342	Baseline Peak kW		288	384	289	340	278			288
	Max Shed kW		94	75	45	55	80			94
Gilead 357	Baseline Peak kW			607		455	443			607
	Max Shed kW			150		119	145			150
IKEA	Baseline Peak kW					1982	1803			1982
	Max Shed kW					321	223			321
Oracle	Baseline Peak kW							507		507
	Max Shed kW							65		65
Target	Baseline Peak kW		314	364	328	341	296			341
	Max Shed kW		52	53	60	64	49			64
USPS*	Baseline Peak kW								1483	1483
	Max Shed kW								333	333
Total	Baseline Peak kW	886	1579	8138	1881	9608	9020	507	1483	12189
	Max Shed kW	272	399	992	410	1108	1329	65	333	2182

* 2004 data (Oct-13) is used for USPS because USPS failed to conduct demand shed in 2005.

Total maxium demand and savings potential demonstrated

6. Advanced DR Controls Strategy Categorization and Analysis

- **Developed DR Control Categorization Framework**
- **Evaluated 32 Sites**
- **Most successful strategy -**
  - Direct digital control global temperature adjustment
  - In process for Title 24 2008
  - Closed loop
- **Forthcoming Guide to Strategies**
- **Need to link to Retro-Commissioning**



Zone control	Global Temperature Adjustment
	Thermal Mass Storage
	Reheat Loackout
Air distribution	Duct Static Pressure Reset
	Fan VFD Limit
	Supply Air Temp Reset
	Fan Quantity Reduction
	Cooling Valve Limit
Central plant	Chilled Water Temp Reset
	Chiller Demand Limit
	Chiller Quantity Reduction
Recovery	Slow Recovery Strategies

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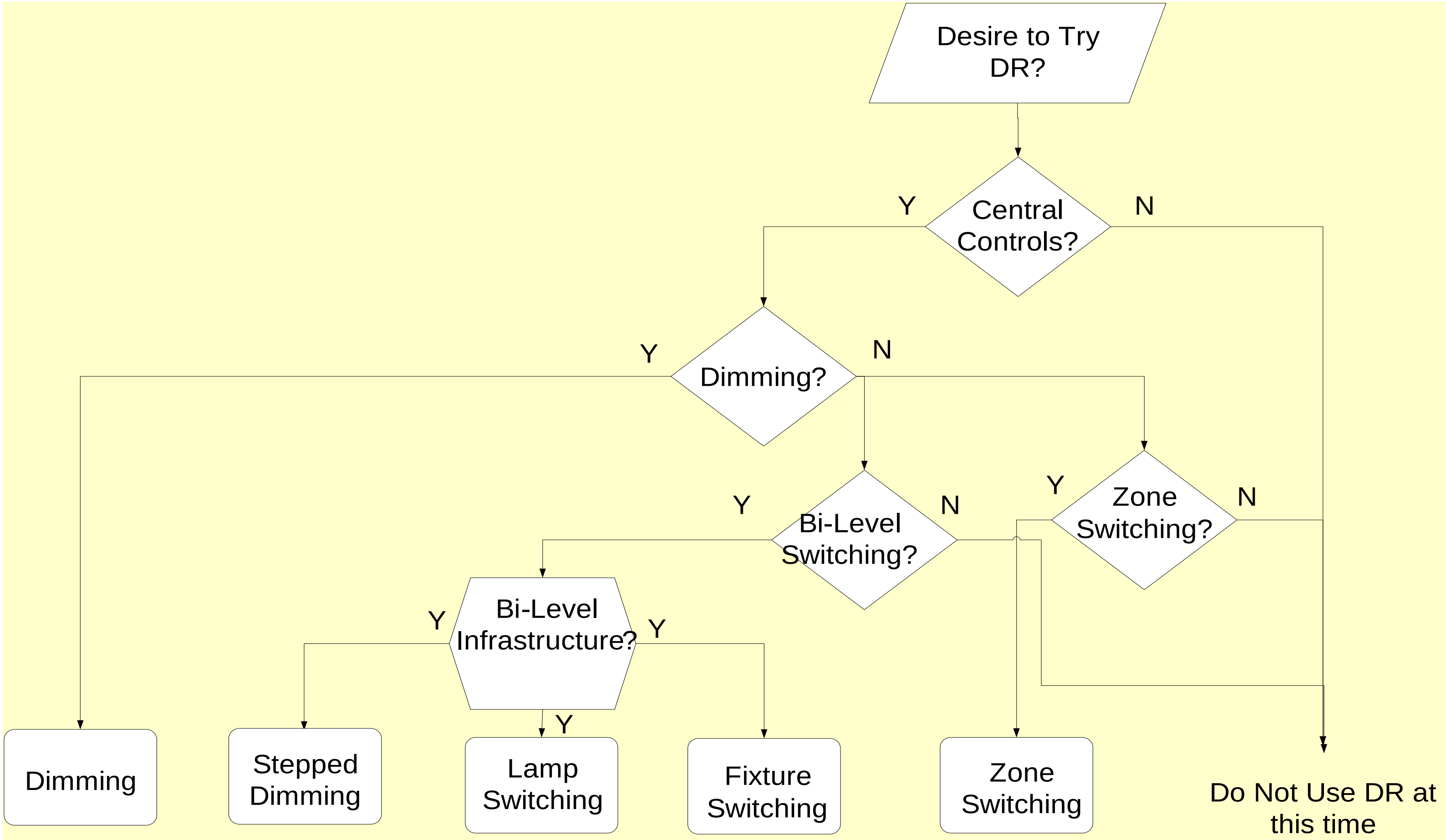
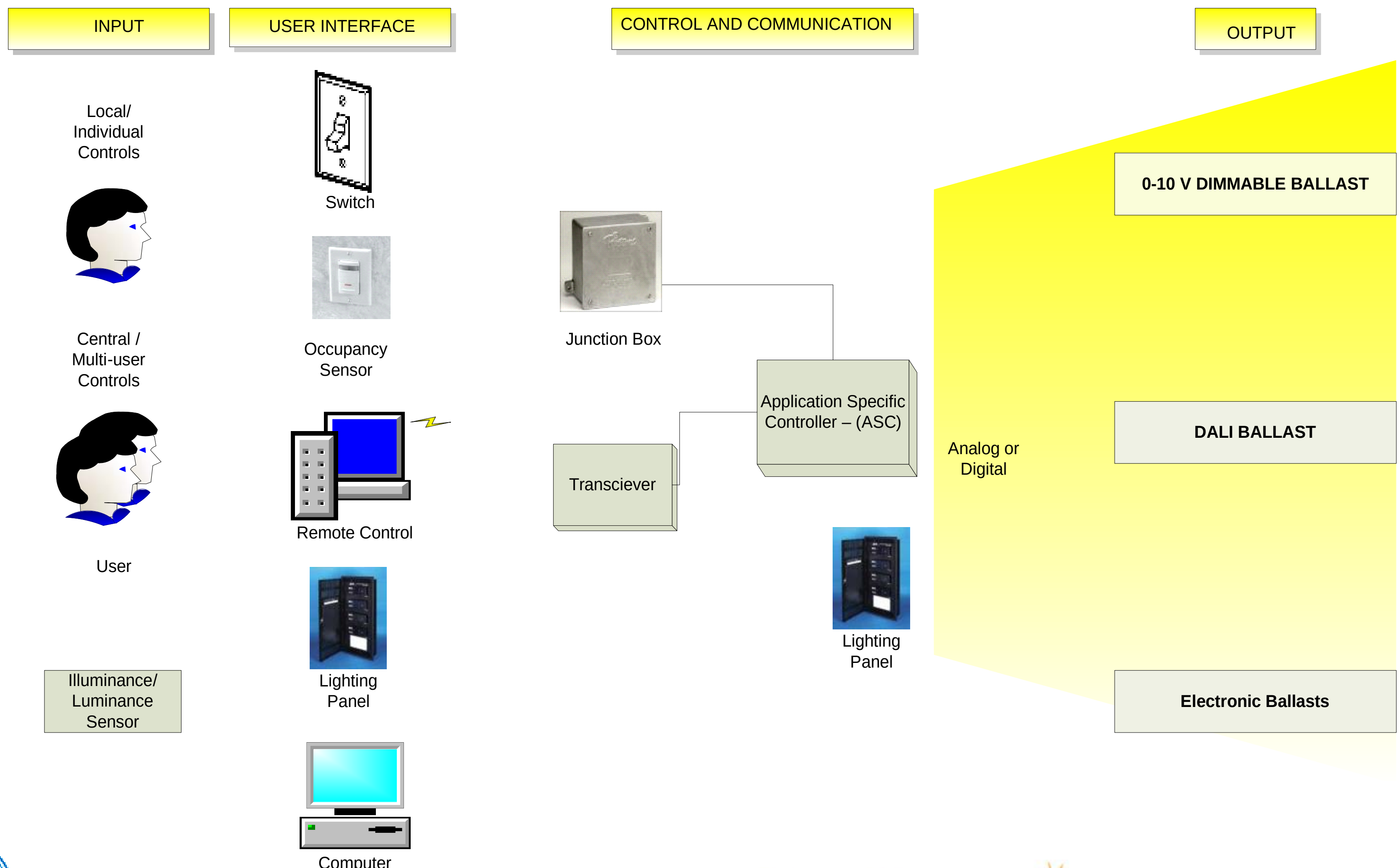
6. Advanced DR Controls Lighting Strategies

- **Lighting Strategies -** Zone Switching, Fixture Switching, Lamp Switching, Stepped Dimming, Continuous Dimming



6. Advanced DR Controls
Generic Lighting Control Pathways



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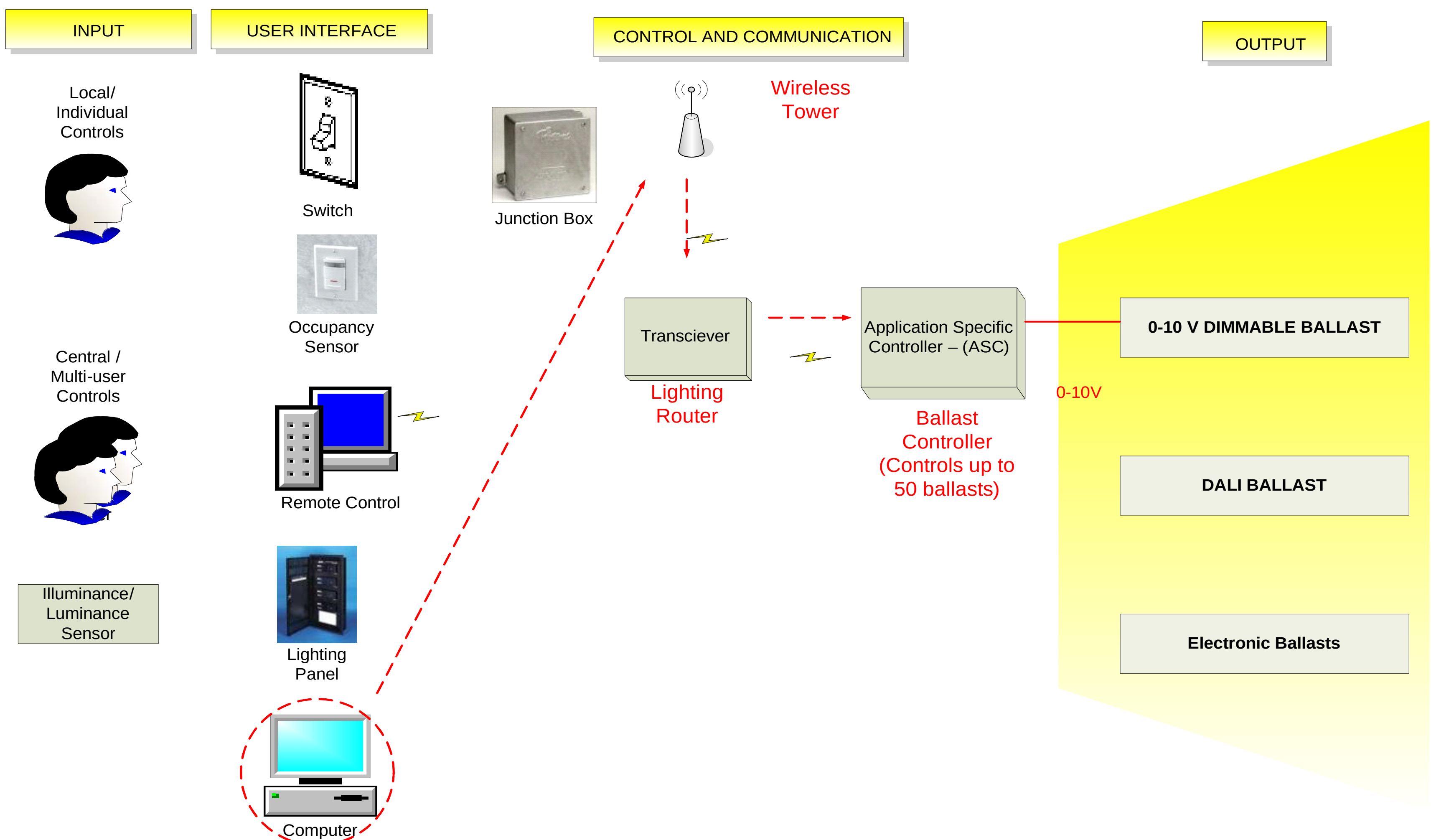
6. Advanced DR Controls

Prototype Wireless Lighting Control Pathway



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7. National R&D Opportunities: Analysis of Strategies (32 DR Sites)

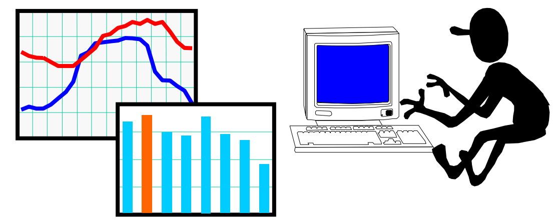
		Participation				HVAC														Light, Misc.						
		CA-2003	CA-2004	CA-2005	NY	Global temp. adjustment	Fan-coil unit off	SAT reset	Fan VFD limit	Duct static pres. reset	Fan quantity reduction	Electric humidifier off	CHW temp. reset	CHW current limit	Chiller demand limit	Boiler lockout	Pre-cooling	Extended shed period	Slow recovery	Common area light dim	Office area light dim	Elevator cycling	Anti-sweat heater shed	Fountain pump off	Transfer pump off	Rock crashers off
300 CapMall	**Office**		●			X			X		X		X											X		
ACWD	**Office**			●		X		X		X			X	X		X		X								
Albertsons	**Supermarket**	●																		X			X			
B of A	**Office**	●	●	●				X	X	X			X	X												
Chabot Museum	**Museum**			●		X											X									
Cal EPA	**Office**		●							X										X	X					
CETC	**Office**		●								X	X														
Cisco	**Office/Data**		●			X	X									X				X	X					
2530 Arnold	**Office**		●	●		X													X							
50 Douglas	**Office**		●	●		X													X							
Echelon	**Office**		●	●		X		X		X	X									X	X					
GSA 450 GG	**Office**		●			X																				
GSA NARA	**Archives**		●			X																				
GSA Oakland	**Office**	●	●			X																				
Gilead 300	**Office/Lab**			●				X																		
Gilead 342	**Office/Lab**			●		X		X																		
Gilead 357	**Office/Lab**			●		X		X																		
Home Depot	**Retail**				●															X						
Irvington	**High School**			●		X											X									
IKEA	**Retail**			●		X																				
Kadent	**Industry**		●																						X	
Lafarge	**Industry**				●																					X
LBNL OSF	**Office/Data**			●		X											X									
Monterey	**Office**		●																	X						
NY Times	**Office**				●	X	X	X									X			X	X					
Oracle	**Office**			●		X				X																
OSIsoft	**Office**		●			X																				
Roche	**Office/Cafeteria**	●	●								X															
Rockefeller Center	**Office**				●				X				X									X				
Target	**Retail**			●							X									X						
UCSB Library	**Library**	●	●						X	X				X												
USPS	**Postal**		●	●											X				X							

7. National R&D:
Current EMCS Characterization

Current Control Systems (California Enhanced Automation Guide)			
Controls	**Basic**	**Common**	**Advanced**
Type	Pneumatic / Analog	Pneumatic / Analog	DDC
Alarms	●	●	●
Remote Access		●	●
Oper. Info		●	●
Trend logs			●
Energy Use Info			●
Real-time Mon.			●
Internet Connection			●
Control Capability	**Preprogrammed, fixed parameters**	**Rudimentary capability (e.g., economizer, VFD)**	**Sophisticated algorithms**
Installation Costs Average($/ ft^2)	$ 1.75	$ 3.00	$ 4.00

7. National R&D: Future DR Modes in Master/Supervisory Control Architecture

- **Orchestrate modes using schedules, signals, optimization algorithms:**
  - Occupied/Unoccupied
  - Maintenance/Cleaning
  - Warm up/Cool down
  - Night purge/Precooling
  - Low power DR mode

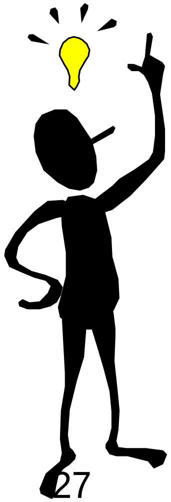


- **Intelligence needed for decision making**
- **Customized, simple and transparent interface**

- **Financial feedback systems need to present operational value**
- **Similar capability for Zero Energy Buildings**
- **Embed DR Communications from EIS to EMCS**

8. Summary (1 of 2)

1. **Demand Response opportunities have been identified as a new multi-billion dollar opportunity for commercial buildings**
2. **DR capabilities improve with advanced controls that simultaneously support energy efficiency**
3. **Field tests show DR potential 5-10% in many buildings with EMCS, yet limited knowledge on broad scale use of DR strategies**



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8. Summary (2 of 2)

4. **Automation appears feasible with many existing systems.**
5. **Research needed on DR control capabilities in stock, vintage, upgrade capabilities, market segments, and new construction**
6. **DR is not driver, high performing buildings are:**
   - Low energy costs, well-commissioned, low maintenance costs
   - Key is advanced controls, feedback systems, integrated performance
   - Research on controls for ZEB are similar to DR control research needs

8. Related Papers and Reports

- Kiliccote, S. and M.A. Piette. October 2005 "Control Technologies and Strategies Characterizing Demand Response and Energy Efficiency", *Proceedings of the Fifth Annual International Conference on Enhanced Building Operations*, Pittsburgh PA, October 11-12, 2005. LBNL # 58179.

- Kiliccote, S, M.A. Piette and David Hansen (DOE), "Advanced Control and Communication Technologies for Energy Efficiency and Demand Response", *Proceedings of Second Carnegie Mellon Conference in Electric Power Systems: Monitoring, Sensing, Software and Its Valuation for the Changing Electric Power Industry*, Pittsburgh PA, January 11-12 2006. LBNL # 59337.

- Piette, M.A. , D. Watson, N. Motegi, S. Kiliccote and Eric Linkugel (PG&E), "Automated Demand Response Strategies and Commissioning Commercial Building Controls", Forthcoming *Proceedings, National Conference on Building Commissioning*. April 19-21, 2006.

- Kiliccote, S, M.A. Piette, D. Watson, Glenn Hughes (New York Times), "Dynamic Controls for Demand Response in New and Existing Commercial Buildings in New York and California", Forthcoming, *Proceedings of the 2006 Summer Study on Energy Efficiency in Buildings*, August 13-18, 2006.

- Watson, D., S Kiliccote, N. Motegi, M.A. Piette, "Automated Demand Response Control Strategies in Commercial Buildings", Forthcoming, *Proceedings of the 2006 Summer Study on Energy Efficiency in Buildings*, August 13-18, 2006.

- Automated DR research referenced in Feb. 2006 DOE EPACT DR Benefits Study, including link to building codes

- Available at drrc.lbl.gov – Publications List - Advanced Controls for Demand Response

8. Additional Resources

- **Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them. US DOE. (February 2006).**
  - http://www.electricity.doe.gov/documents/congress_1252d.pdf
- **Web-based Energy Information Systems for Energy Management and Demand Response in Commercial Buildings. Motegi, N., M.A. Piette, S. Kinney, and K. Herter. (April 2003) LBNL Report 52510.**
  - http://buildings.lbl.gov/hpcbs/pubs.html
- **Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities, Piette, M.A., D.S. Watson, N. Motegi, and N. Bourassa (Sept. 05) LBNL-58178.**
  - http://drrc.lbl.gov/pubs/58178.pdf

- **Questions and Answers**

- **Post Webcast Survey**
  - http://drrc.lbl.gov/pubs/Post-webcast-survey.pdf
  - Survey collection to be completed March 31, 2006