Fast Demand Response with Residential and Light Commercial Loads

Duncan Callaway, Mark Dyson, Joe Eto,
Sila Kiliccote, Jason MacDonald

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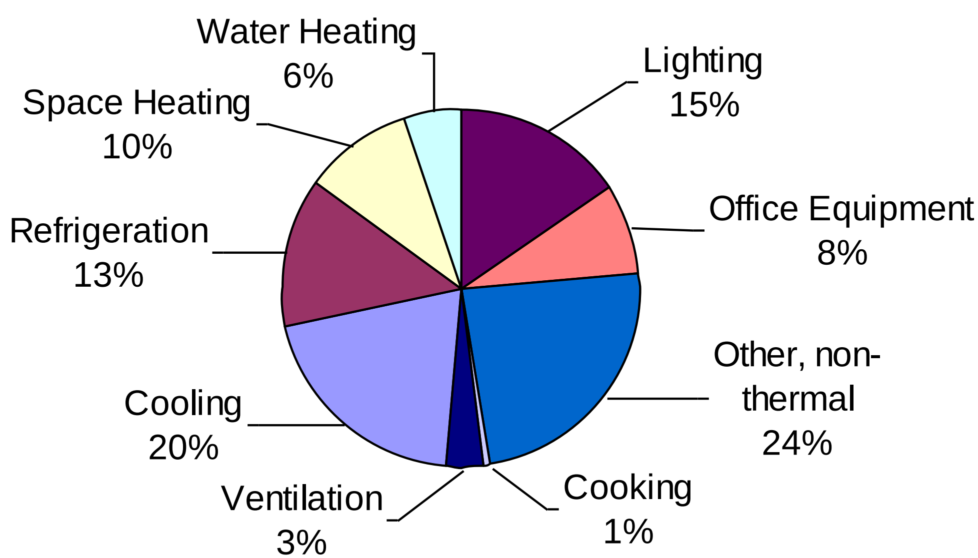
Basic question

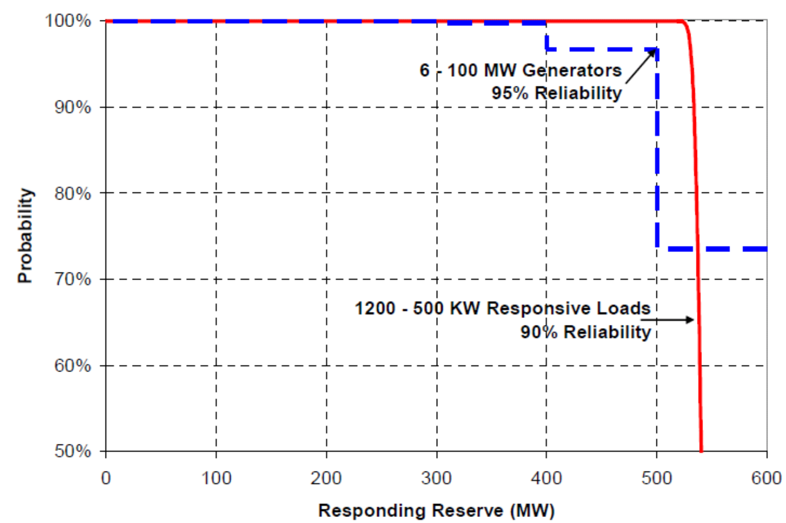
Can smaller loads (residential, light commercial) be profitably engaged in ancillary services?



Annual electric *energy* consumption for residential and light commercial loads in the US (Source: EIA)

Aggregating small loads: System operator perspective

- Benefit: continuous and fast response
  - Enables higher performance for regulation or load following services
- Benefit: Many small loads availability more certain than few larger loads
  - Improves reliability of service provision
- Benefit: Aggregated small loads are spatially distributed
  - Could enable location-aware provision of ancillary services



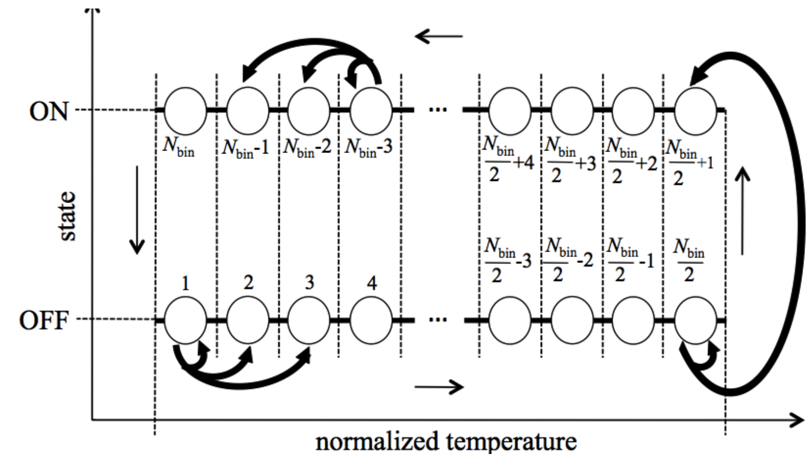
Source: Brendan Kirby

Likely challenges (incomplete list):

- What loads must be “visible” to ISO: none, some, all?
- Can these resources really prevent construction of generation assets?

Aggregating small loads: Aggregator perspective

- Benefit: Small loads have simple local controls
  - Enables scalable program setup
- Benefit Aggregations can be modeled statistically
  - Could reduce metering and telemetry requirements
- Benefit: Diverse temporal patterns of availability
  - Improves availability during different hours and seasons



Likely challenges (incomplete list):

- Cost of communications and control infrastructure
- Cost to recruit and manage customer relationships
- Predicting seasonal / temporal availability
- Spatially distributed: distribution network effects?

Aggregating small loads: Customer perspective

- Benefit: enabling tech. may have other uses
  - Customer energy efficiency savings, other types of DR
- Benefit: Statistical control provides a layer between the ISO/ARC and individual customers
  - Security and privacy for customers

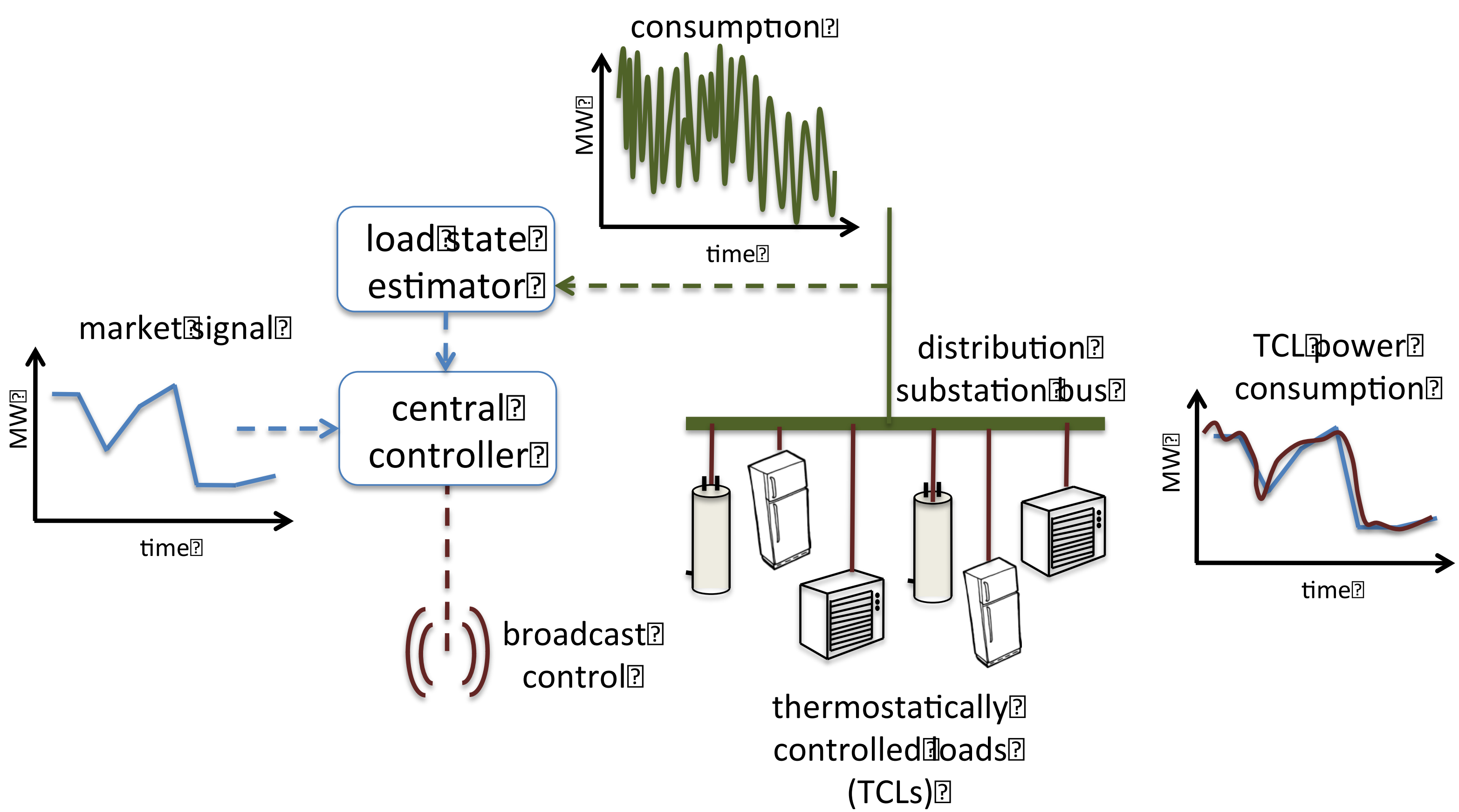
Likely challenge (incomplete list):

- Defining acceptable comfort / changes in end-use function
- Resistant to *increases* in consumption to provide reg down

Project objectives

- Develop deeper understanding of state of practice
- Identify challenges to fast DR with small load aggregations:
  - Economic
  - Technical
- Identify areas where LBNL/UCB can advance the research agenda
  - Identifying pilot opportunities a priority
- Approach
  - ISO market assessment and data collection
  - Surveys with aggregators

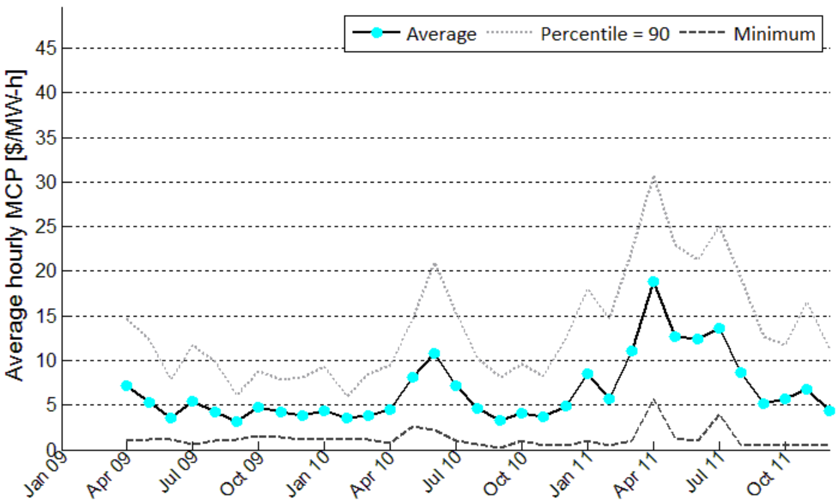
Possible control architecture



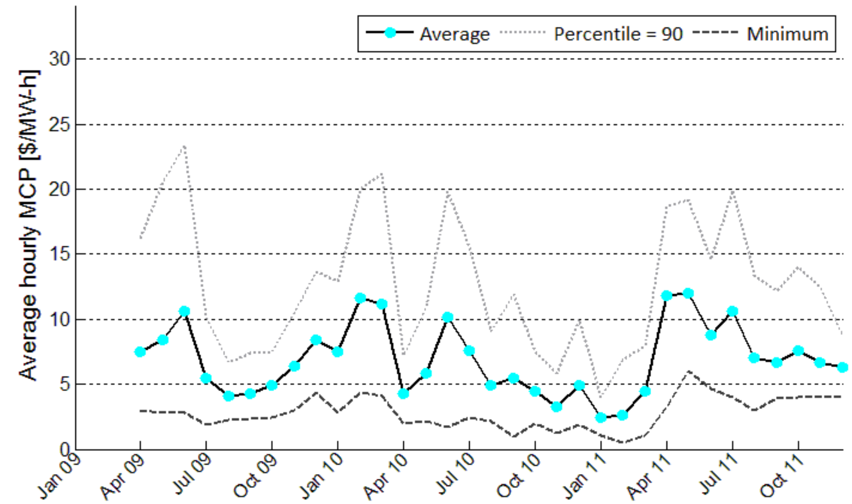
Mathieu, Koch and Callaway, IEEE TPWRS 2012

Market Variability: Trends

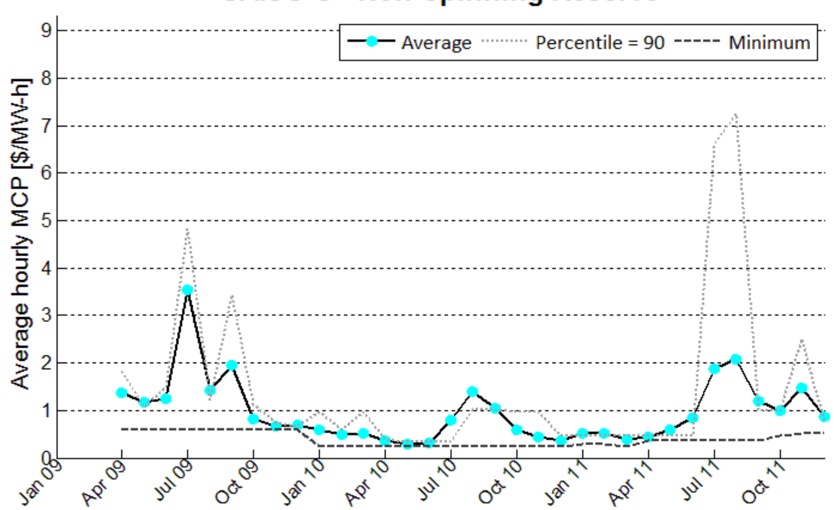
CAISO-S - 10 Minute Spinning Reserve



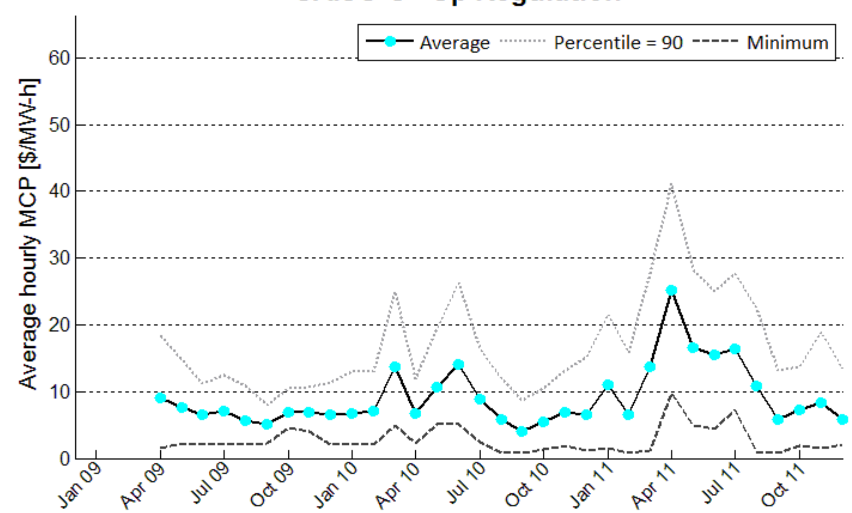
CAISO-S - Down Regulation



CAISO-S - Non-Spinning Reserve



CAISO-S - Up Regulation

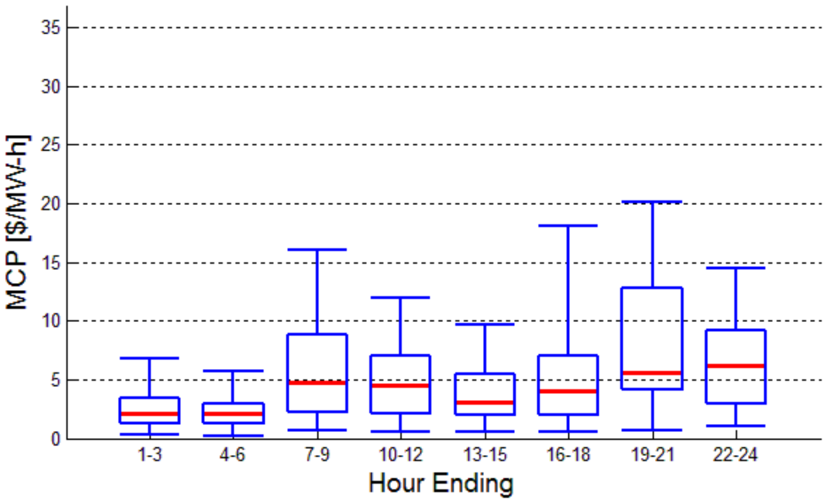


Prices vary widely over time. Sometimes the average is greater than 90% of the hours in a month.

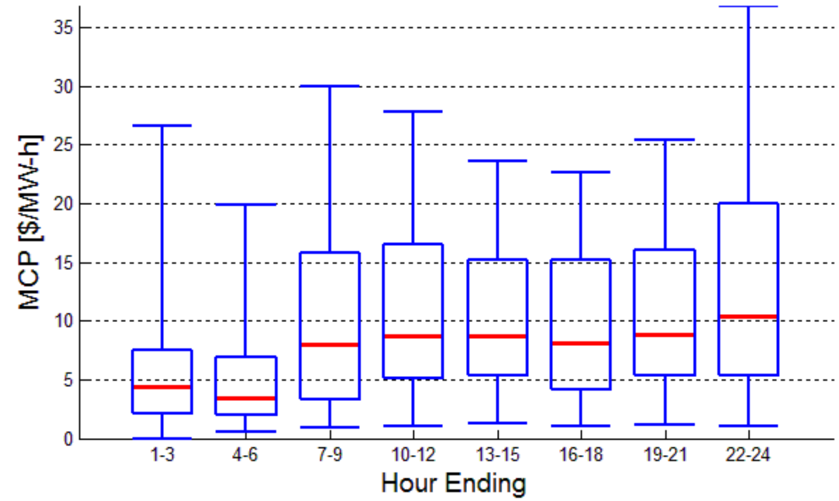
*Data represents MCP in CAISO, South of Path 26, in the Day Ahead Market

Market Variability: Capturing Value

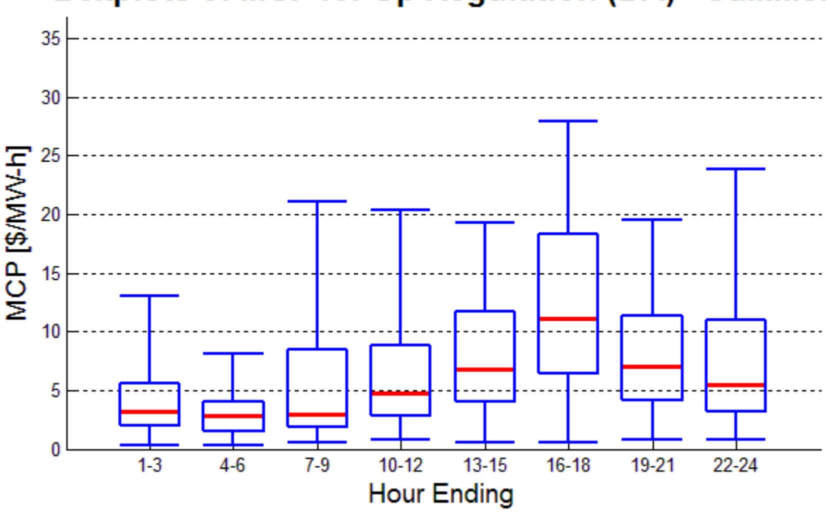
Boxplots of MCP for Up Regulation (DA) - Winter



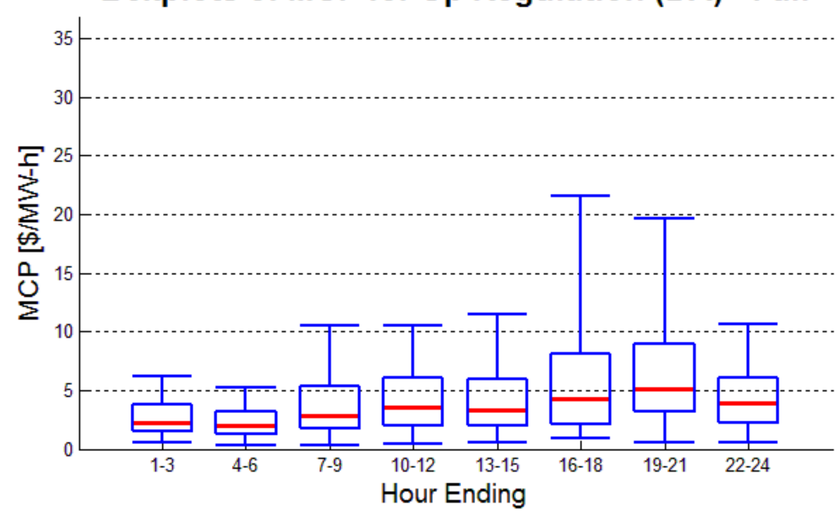
Boxplots of MCP for Up Regulation (DA) - Spring



Boxplots of MCP for Up Regulation (DA) - Summer



Boxplots of MCP for Up Regulation (DA) - Fall



Daily and seasonal variation can contribute to the potential value

*Data represents MCP in CAISO, South of Path 26, in the Day Ahead Market

Market Variability: ISO/RTO

Avg (std)	Regulation			Operating Reserves		
[$/MW-h]	Down	Up	Combined	10-Min Spinning	10-Min Non-Spinning	30-min Supplemental
CAISO	8.06 (9.28)	6.75 (5.54)		5.24 (5.87)	0.60 (2.55)	
ERCOT	9.76 (3.79)	8.58 (8.68)		9.03 (2.95)	4.31 (6.12)	
MISO			12.17 (6.41)	4.02 (4.59)	1.46 (1.37)	
PJM			17.95 (14.04)	0.12 (1.01)		
NYISO-E			28.80 (13.61)	6.23 (5.36)	2.29 (2.24)	0.13 (0.23)
NYISO-W			28.80 (13.61)	4.41 (3.63)	0.87 (1.52)	0.13 (0.23)
ISO-NE			7.07 (3.37)	1.76 (13.74)	1.16 (13.02)	0.43 (4.96)

*Represents MCP in 2010

Economics: results for specific load types

- Basic simulation setup:
  - 2010 market price data from PJM, ISONE, NYISO, CAISO, MISO, ERCOT
  - Simple first order models for A/C, heat pump, water heaters and refrigerators
  - Weather data, taken from NOAA US Climate Reference Network, apply to A/C and heat pump only
  - No heating when mean daily temp > 15°C
  - Assume *nondisruptive* control: Measure energy required to move all loads to one side of their deadband

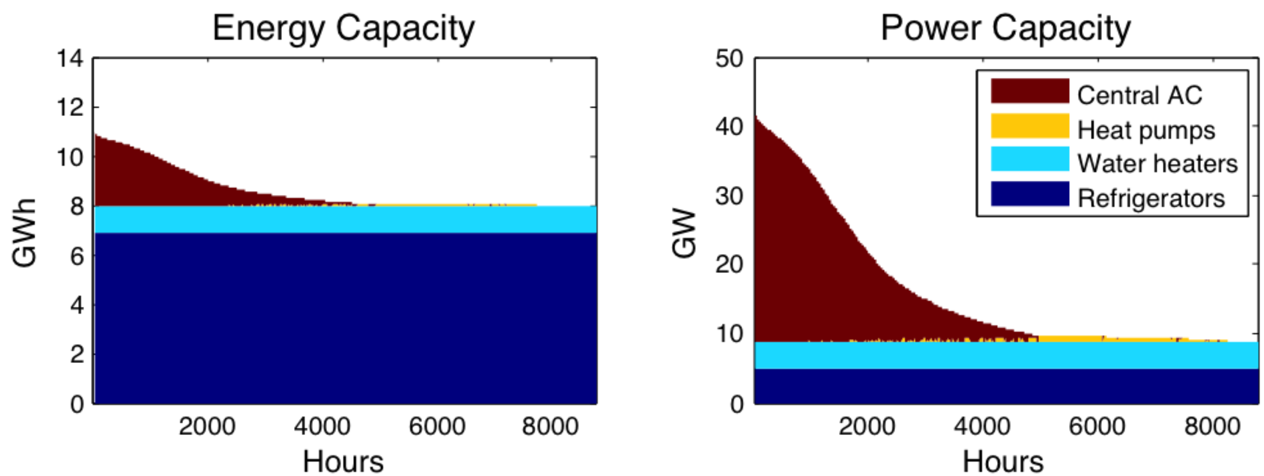
Regulation revenues by load and location

		0.25 to 1°C deadband Revenue per TCL per year				0.5 to 2°C deadband Revenue per TCL per year	
ISO	Product	A/C	HP	Refrig	DHW	A/C	HP
PJM	Reg	$32.88	$106.35	$15.25	$37.74	$33.14	$150.59
NYISO-E	DA Reg	$41.97	$185.40	$24.47	$60.55	$42.06	$267.38
NYISO-E	RT Reg	$35.49	$190.76	$22.65	$56.04	$36.01	$274.36
NYISO-W	DA Reg	$26.85	$204.05	$24.47	$60.55	$26.46	$289.48
NYISO-W	RT Reg	$23.14	$205.70	$22.65	$56.04	$22.84	$291.77
ISONE	RT Reg	$6.15	$52.53	$6.01	$14.86	$6.08	$75.06
ERCOT	DA Reg down	$22.55	$38.90	$7.03	$17.39	$23.47	$50.72
ERCOT	DA Reg up	$40.82	$38.55	$8.34	$20.62	$43.37	$51.18
CAISO	DA Reg up	$17.11	$27.37	$4.79	$11.86	$18.77	$31.71
CAISO	DA Reg down	$9.04	$24.21	$4.23	$10.47	$9.55	$28.80
MISO	DA Reg	21.59	73.83	10.34	25.59	21.39	101.04

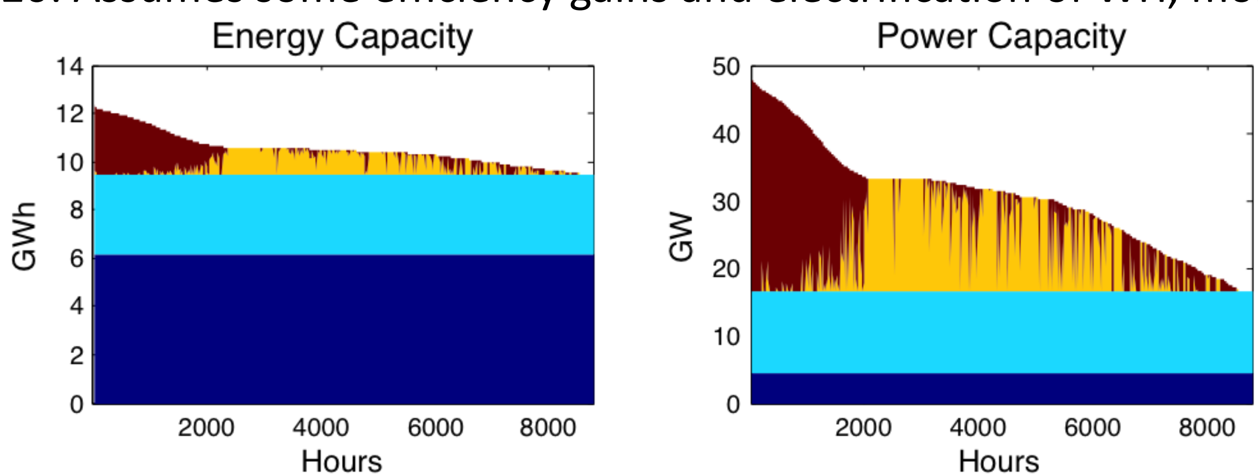
Spin amounts, not shown, are in the $1-5 / year range

Resource duration curves: California

2012: Current resource if all AC, HP, elec. WH and ref. in CA are used



2020: Assumes some efficiency gains and electrification of WH, more HP



Aggregator interviews

- Informal phone interviews with aggregators over the last two months:
  - Consert
  - EcoFactor
  - Energate
  - ThinkEco
  - EnerNOC
  - Comverge
  - Cooper
  - iES

Current state of the practice: Residential aggregation

Business model	Load management for LSEs paying spot energy prices / capacity charges. Primary client is utility but also aware of consumer value proposition.
Utility communications	Web portal showing availability of curtailable loads.
Aggregator-to-customer communications	Varies, but generally Web, 3G/4G, RF; less common is AMI. Both open- and closed-loop controls are common.
Gateway-to-load communications	Usually ZigBee, but everyone claims to be "agnostic" to in-home technology.
Customer value	Variously: increased energy efficiency, controllability/visibility from iPhone app, comfort by using control hardware. No companies actually *pay* the customer.
Potential for A/S provision	Several companies are working on A/S pilots. Most companies' technology could be adapted, if market rules allowed it and it were cost-effective.

Barriers to implementation

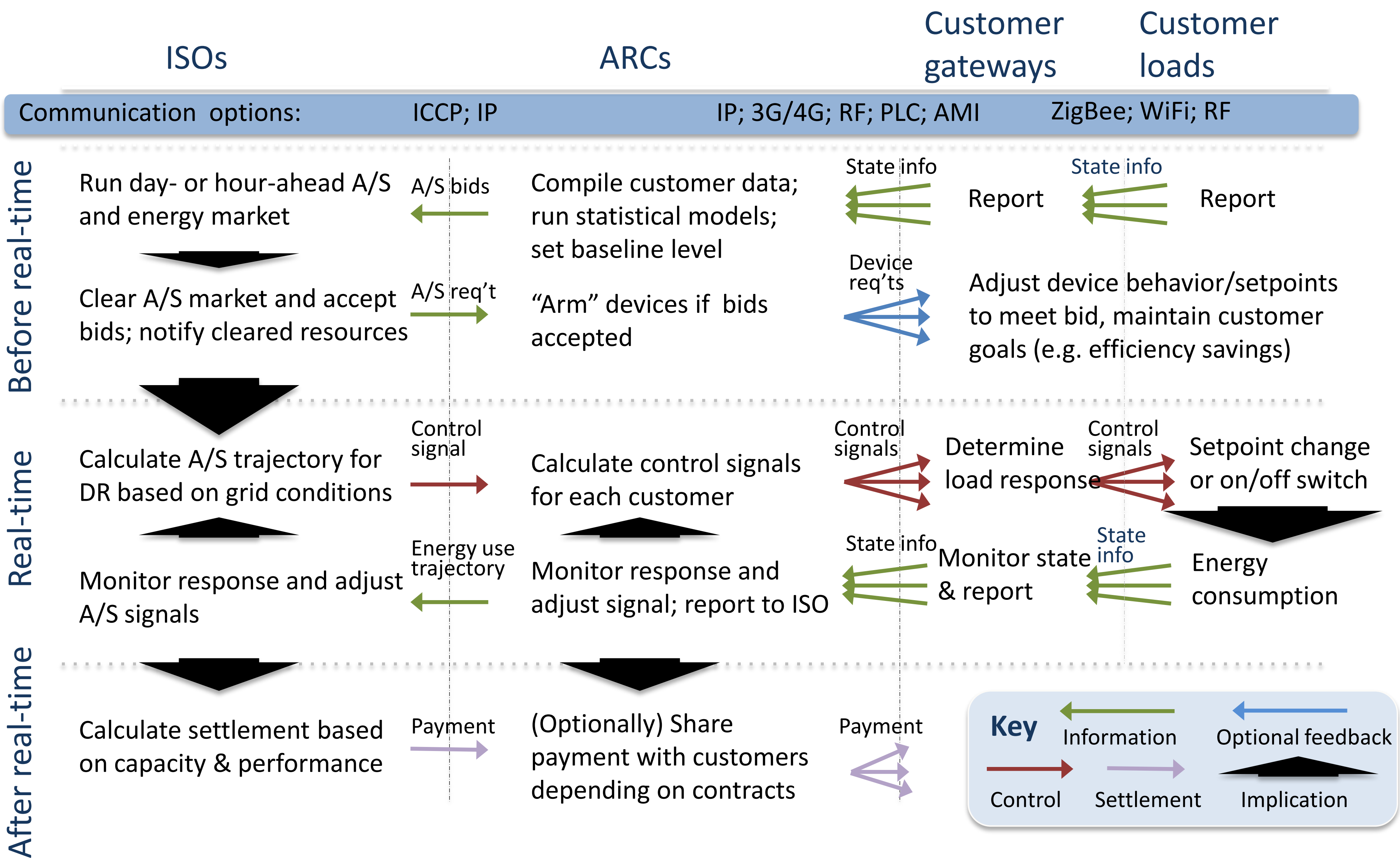
- Minimum size requirement (e.g. 100 kW) of individual resources
- Metering and telemetry requirements on each load
- Load not allowed to participate in spin/regulation in some regions
- Requirement to submit energy bid as well as A/S bid
- High cost of communications, monitoring and control hardware
- Cost to recruit and retain customers
- Risk of stranded assets

Future research agenda

- Identify low-cost means to achieve accurate operational telemetry & settlement metering; statistical aggregation
  – Need a pilot to establish a baseline
- Algorithms for control of heterogeneous loads
  – Co-optimization of load “plant” into various applications including energy markets, capacity markets, ancillary services.
- Quantify co-benefits of DR-enabling equipment
- Identify communication standards
- Determine the requirements for the long-term viability of A/S markets with significant load participation

Thank you

A taxonomy of aggregation for ancillary services: Operations and settlement



Current state of the practice: A/S pilots

PJM	Water heater regulation pilot	Steffes/EPRI specialized water heater with controllable heating behavior
PJM	V2G fleet & water pumping	U Delaware eV2G + NRG; Enbala's GridBalance both providing regulation
PJM	Residential A/C pilot	Confidential; Comverge (?)
CAISO	PG&E and SCE residential A/C	Tested for compliance with operating reserve requirements
AESO	UFRs for spinning reserve	AESO pilot (LSSi)
BPA	EnerNOC: load following pilot	Using cold storage as battery to track consumption trajectory signal
ERCOT	UFRs for spin: commercial	Longstanding program that hooks up large customers to UFRs

Current state of the practice: Wholesale aggregation

Business model	Standard ARC (e.g. EnerNOC): Bid curtailment of many, generally C&I, facilities into capacity markets.
Utility communications	Generally, ICCP and/or DNP3
ARC-to-customer communications	Varies, but generally Web-based (e.g. AutoDR) or manual (phone). Closed-loop controls are common.
Gateway-to-load communications	Varies; frequently involves a building- or facility-specific energy management system.
Customer value	ARCs pay the customer an incentive and/or share the capacity market proceeds with them.
Potential for A/S provision	Several companies are working on A/S pilots, and/or are already providing. Most companies' technology could be adapted, if market rules allowed it and it were cost-effective.