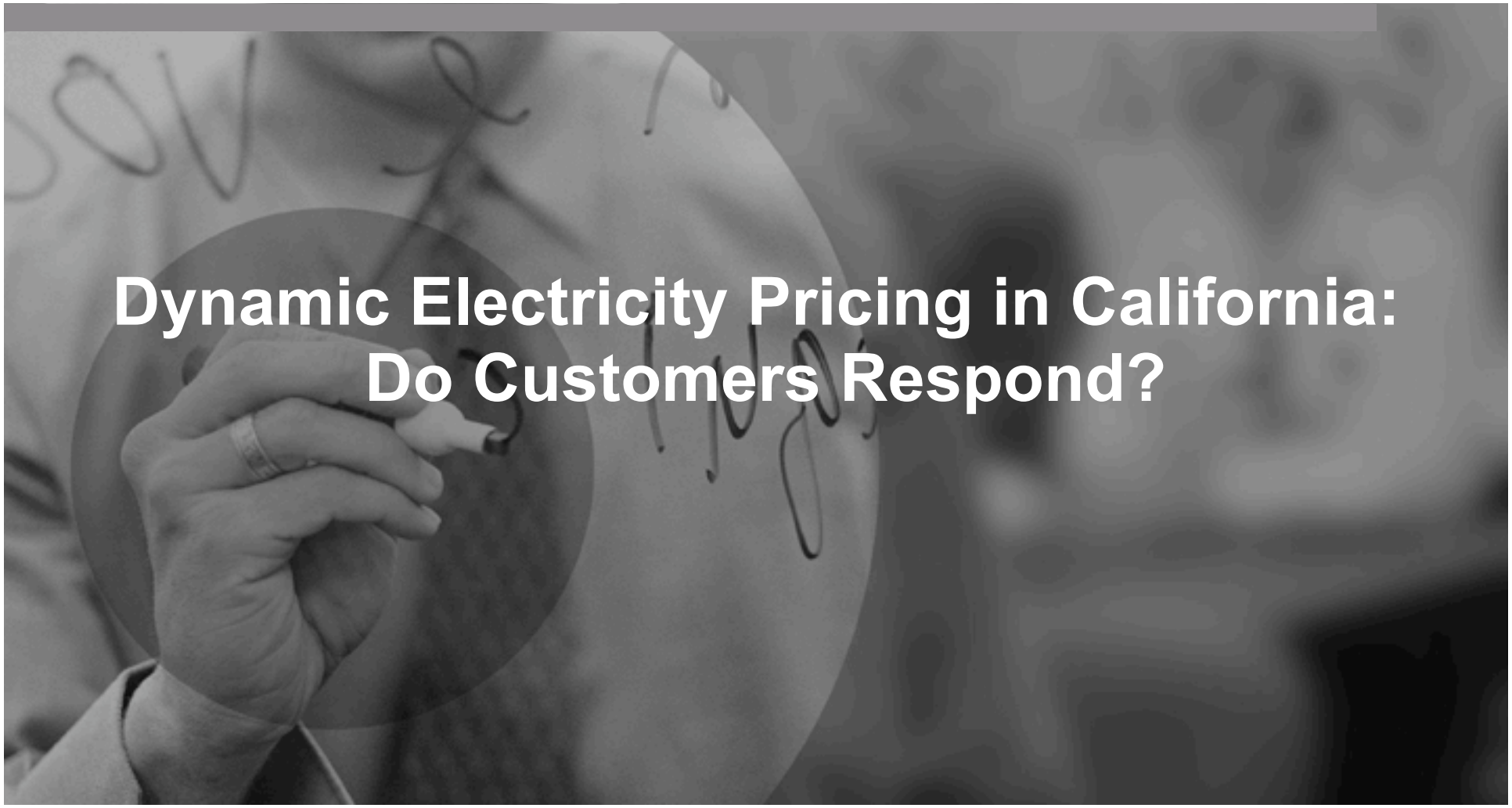


Dynamic Electricity Pricing in California: Do Customers Respond?

CRA INTERNATIONAL

May 16, 2006

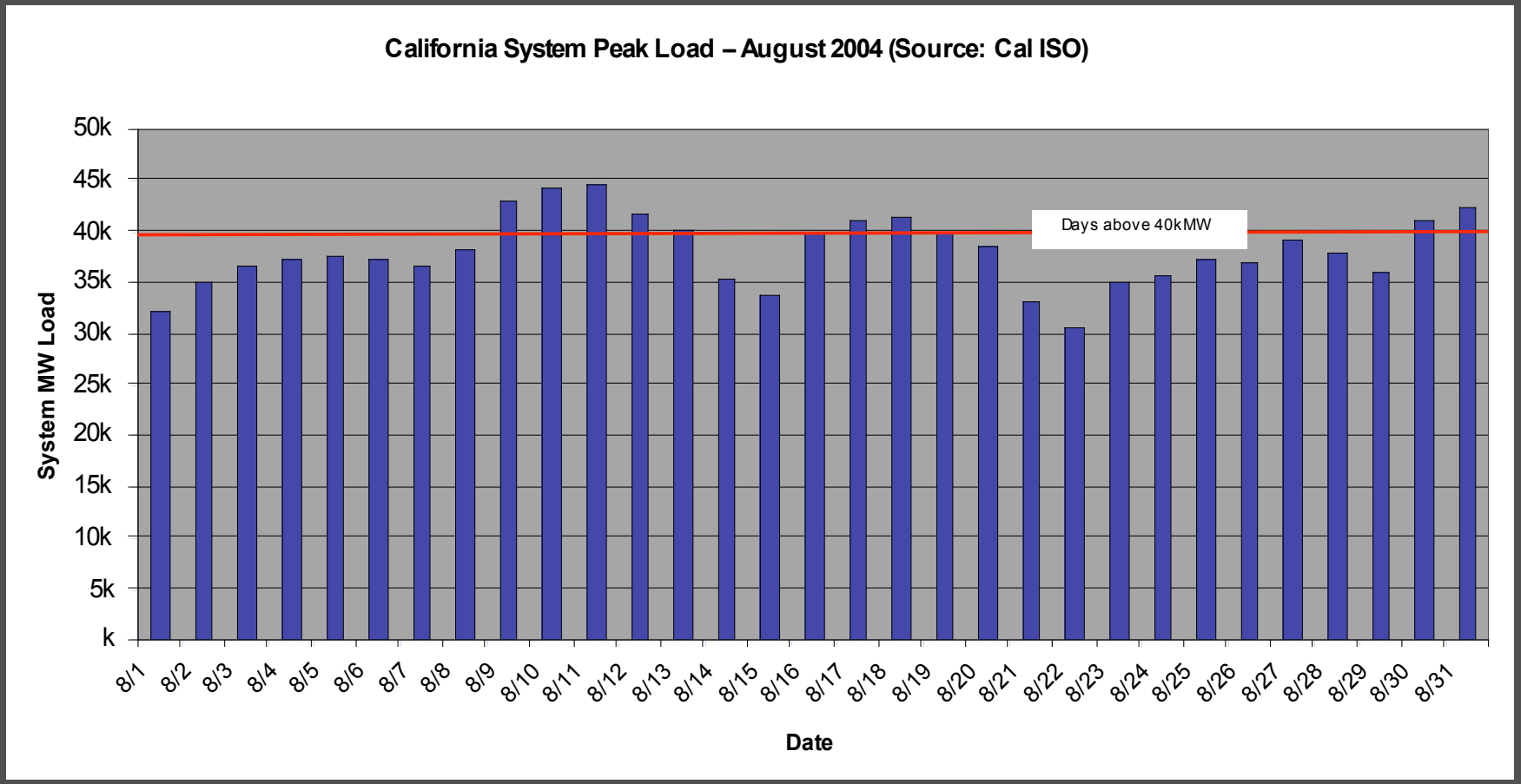
Matt Burgess

The next 40 minutes…

1. **The Problem**
   - 25% generating capacity used less than 100 hours/year
2. **The Proposed Solution**
   - Dynamic peak pricing
3. **The Rollout**
   - Business case for advanced metering

1. THE PROBLEM

The Problem: California's Electric System Hits New Peaks Annually



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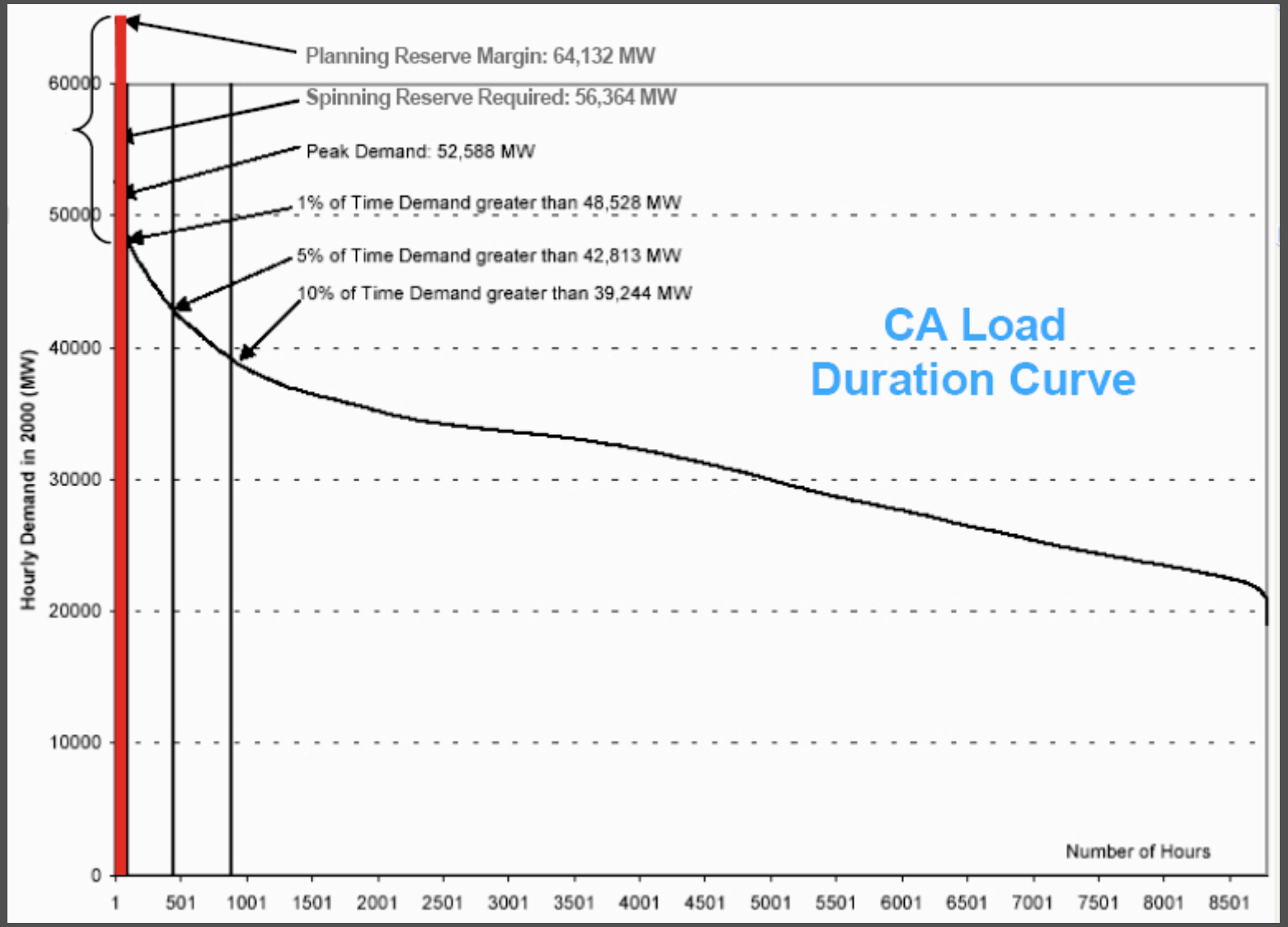
One quarter of capacity used less than 100 hours/year



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Related Problem

- Retail/wholesale price disconnect

→ Allocative efficiency losses

2. THE PROPOSED SOLUTION

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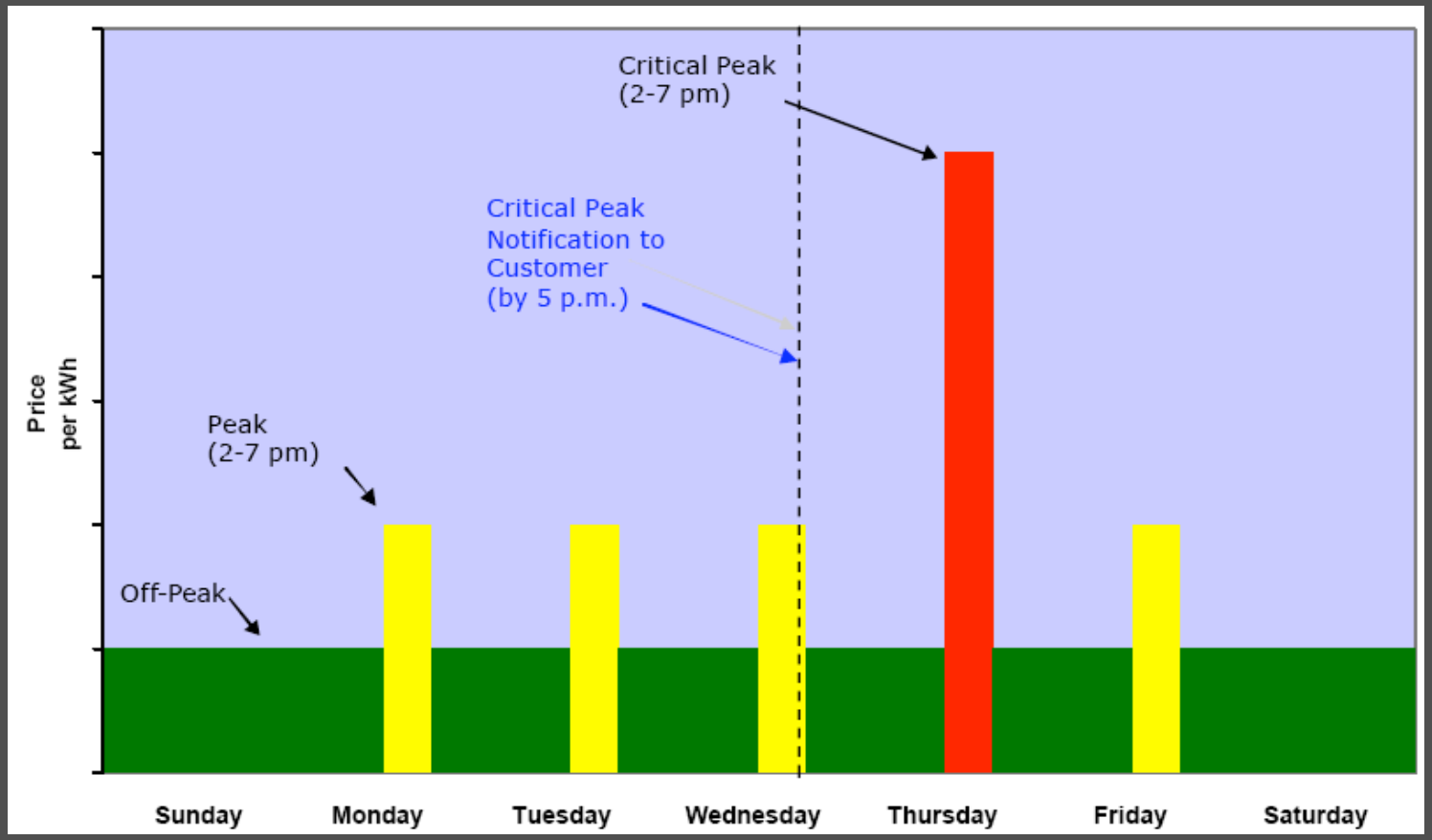
One Proposed Solution: "Manage the Peak" with Dynamic Pricing

- Critical peak pricing (CPP)



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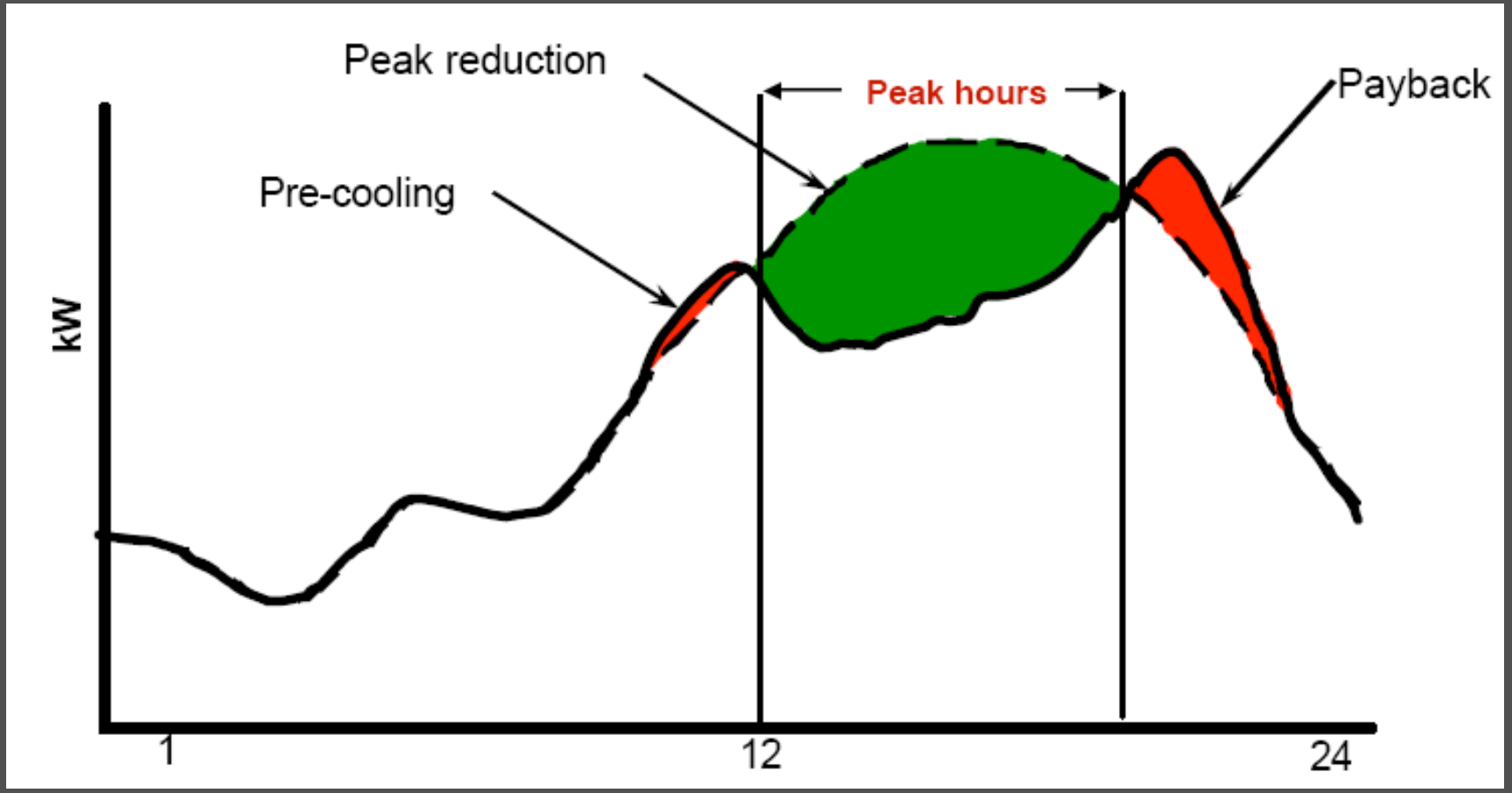
CPP Pricing



Source: Larsh Johnson, “California’s Statewide Pricing Pilot” (presentation), 25 March 2004

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Constraints on CPP

- Peak is random
- Technical constraints: new meters are needed
- Uncertainty: will consumers respond?

Statewide Pricing Pilot (SPP)

- Controlled experiment
- 2,500 customers
- Residential and small business only

SPP Objectives

- **Will customers shift or reduce load in response to time-varying price signals?**
- **Are these changes sustained over successive days and successive summers?**
- **Key policy issues:**

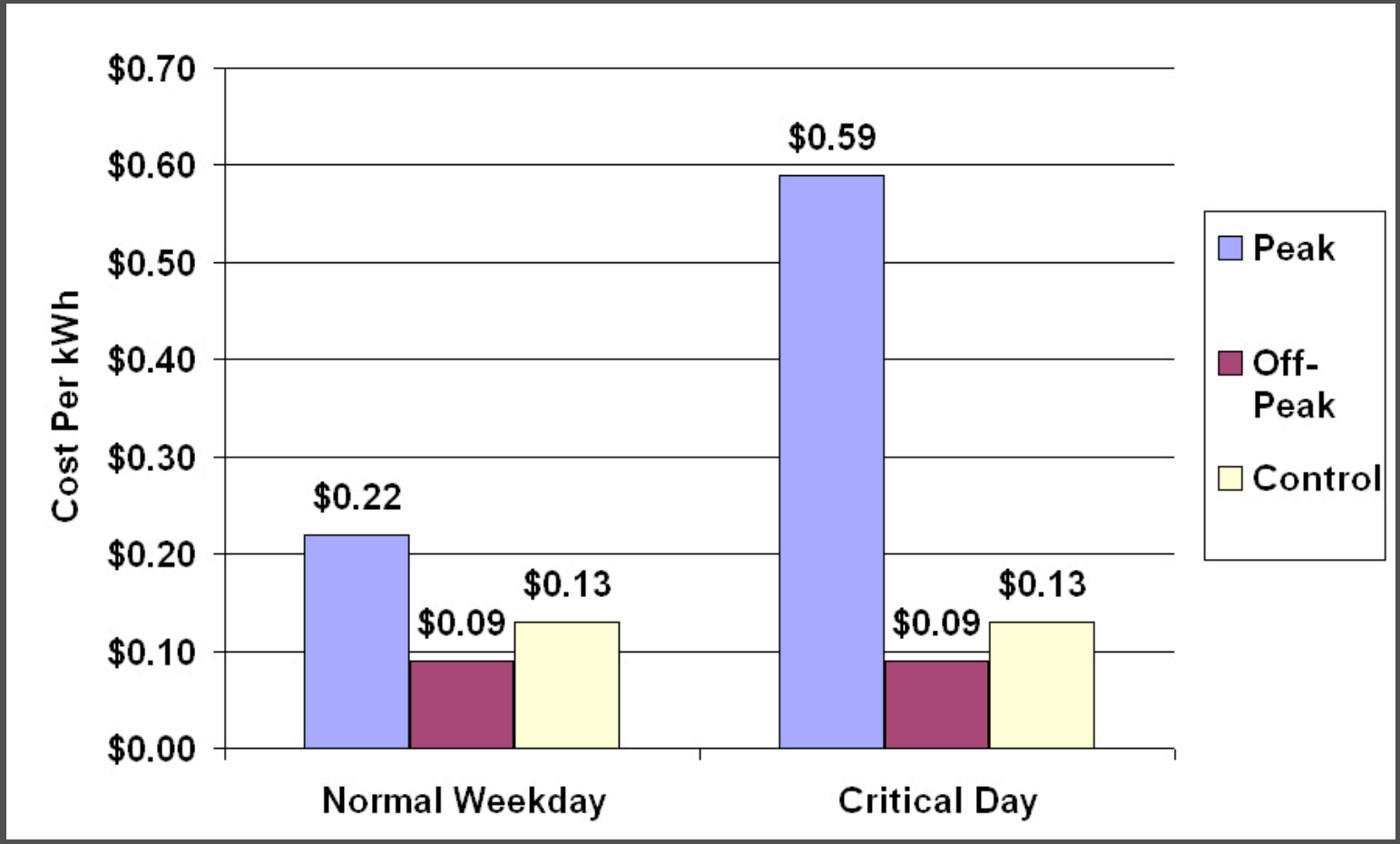
  Will demand reductions from dynamic pricing offset the cost of new meters?

  Can the price mechanism be used to manage demand-supply imbalances?

Experiment Design 1/3

- **Four rate structures:**
  - CPP-F
  - CPP-V
  - TOU
  - \+ Information Only
- **Control groups for each sample**
- **Sample sizes determined using pre-experimental data**

CPP-F Price Settings



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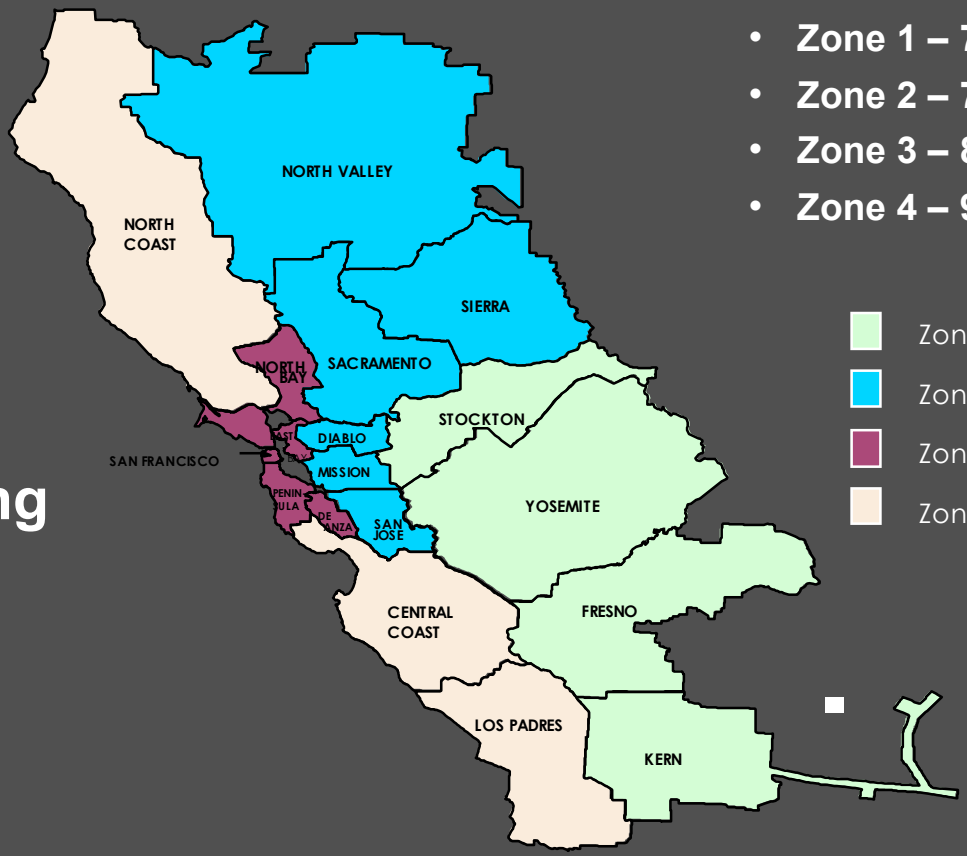
Experiment Design 2/3

- **July 2003-December 2004**
- **Total of 27 critical days declared in this period**
- **Three groups of customers**
  - Track A: representative
  - Track B: low-income customers
  - Track C: customers from a smart thermostat pilot

SPP sample segmented across four climate zones

CPP Weather

- Zone 1 – 73 °
- Zone 2 – 79 °
- Zone 3 – 88 °
- Zone 4 – 99 °



Air Conditioning

- Zone 1 – 6%
- Zone 2 – 29%
- Zone 3 – 69%
- Zone 4 – 73%

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Experiment Design 3/3

Experiment Constraints

- 15 critical days/year
- Revenue neutral for the average customer
- Maximum +/- 5% change in costs for unchanged behaviour
- Customers have opportunity to reduce bills by 10% if reduced peak usage by 30%

Sample Sizes

	Control	CPP-F	Info Only	CPP-V	TOU	Total
Track A - Representative Population Sample						
Residential	470	542	126	125	200	1463
Commercial <20kW	88	0	0	58	50	196
Commercial 20-200kW	88	0	0	80	50	218
Track B - San Francisco Co-Operative						
Residential	0	64	189	0	0	253
Track C - Smart Thermostat (AB970) Pilot						
Residential	20	0	0	125	0	145
Commercial <20kW	42	0	0	56	0	98
Commercial 20-200kW	42	0	0	76	0	118
Total Participants	750	606	315	520	300	2491

Estimation Methodology 1/2

Temperature

Daily: $$\ln(Q_d) = \alpha + \eta_d \ln(P_d) + \delta(CDH_d) + \sum_{i=1}^{N} \theta_i D_i + \varepsilon$$

Substitution: $$\ln\left(\frac{Q_p}{Q_{op}}\right) = \alpha + \sigma \ln\left(\frac{P_p}{P_{op}}\right) + \delta(CDH_p - CDH_{op}) + \sum_{i=1}^{N} \theta_i D_i + \varepsilon$$

CES demand system used to predict the change in electricity use caused by dynamic pricing

Estimation Methodology 2/2

Temperature

Air conditioning

$$\ln\left(Q_d\right) = a + b_d \ln\left(P_d\right) + c(CDH_d) + d\left(P_d * CDH_d\right) + e(P_d * CAC) + \varepsilon$$

$$\ln\left(\frac{Q_p}{Q_{op}}\right) = a + b\ln\left(\frac{P_p}{P_{op}}\right) + c(CDH_{p-op}) + d(CAC) * \ln\left(\frac{P_p}{P_{op}}\right) + e(CDH_{p-op}) * \ln\left(\frac{P_p}{P_{op}}\right) + \varepsilon$$

- **The two-equation system estimated using daily observations**
- **Estimated in first differences to eliminate or reduce autocorrelation in error terms**

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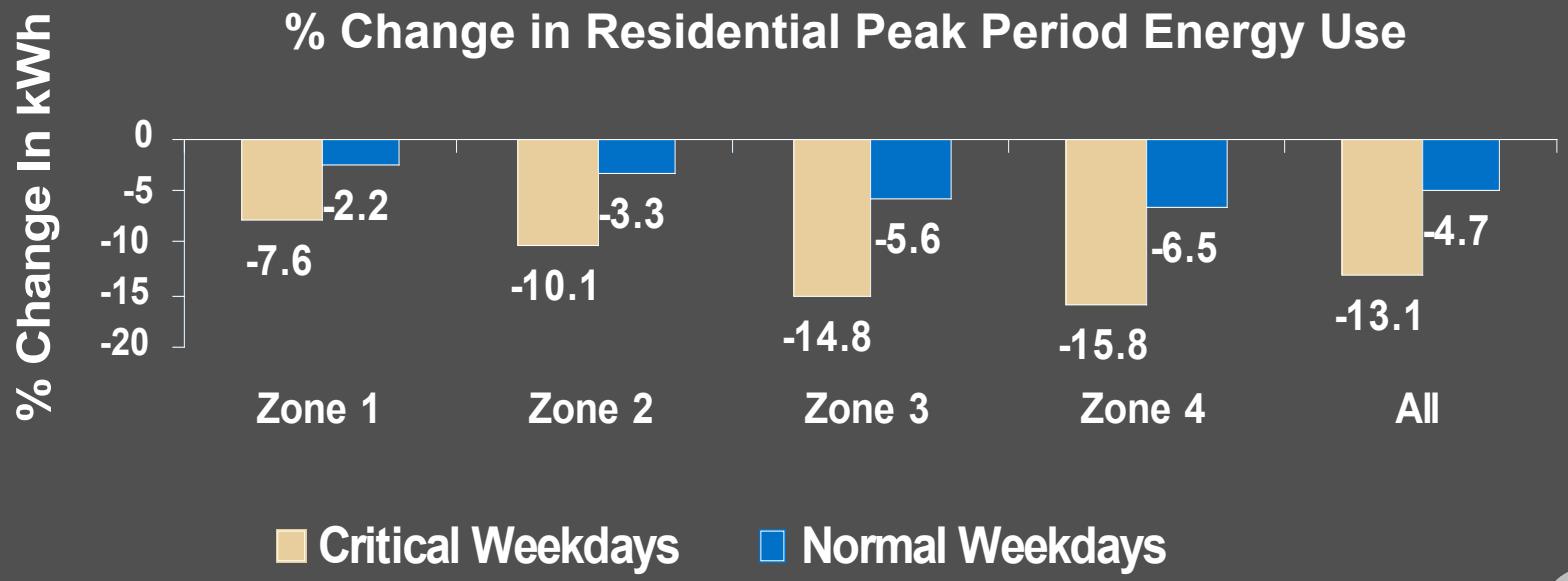
RESULTS

CPP Produces A Significant Residential Response

- The statewide summer impact on critical days was 13.1 percent
- Higher response in warmer climates



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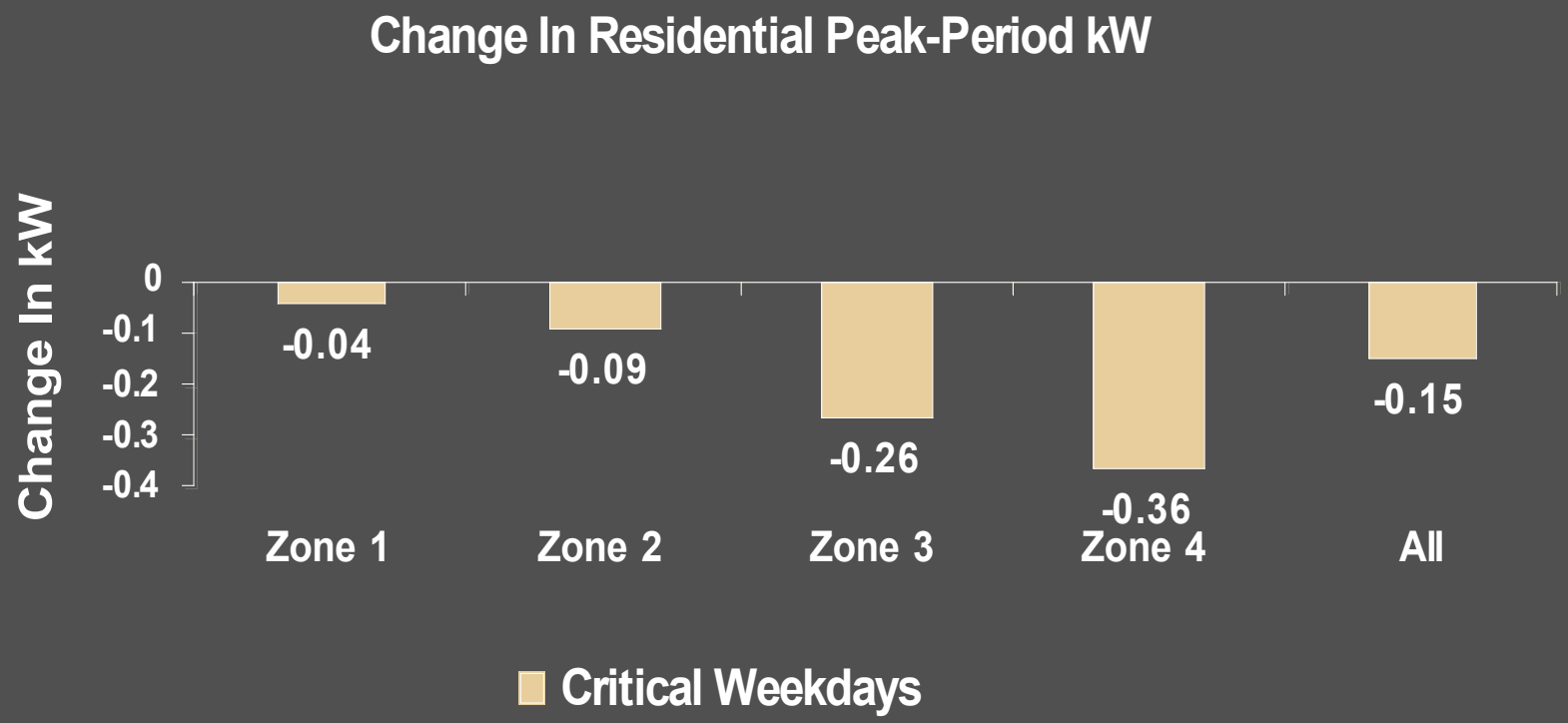
CPP Produces Consumer Response

- **Expressed in absolute terms, electricity reduction is more pronounced in hot climates**



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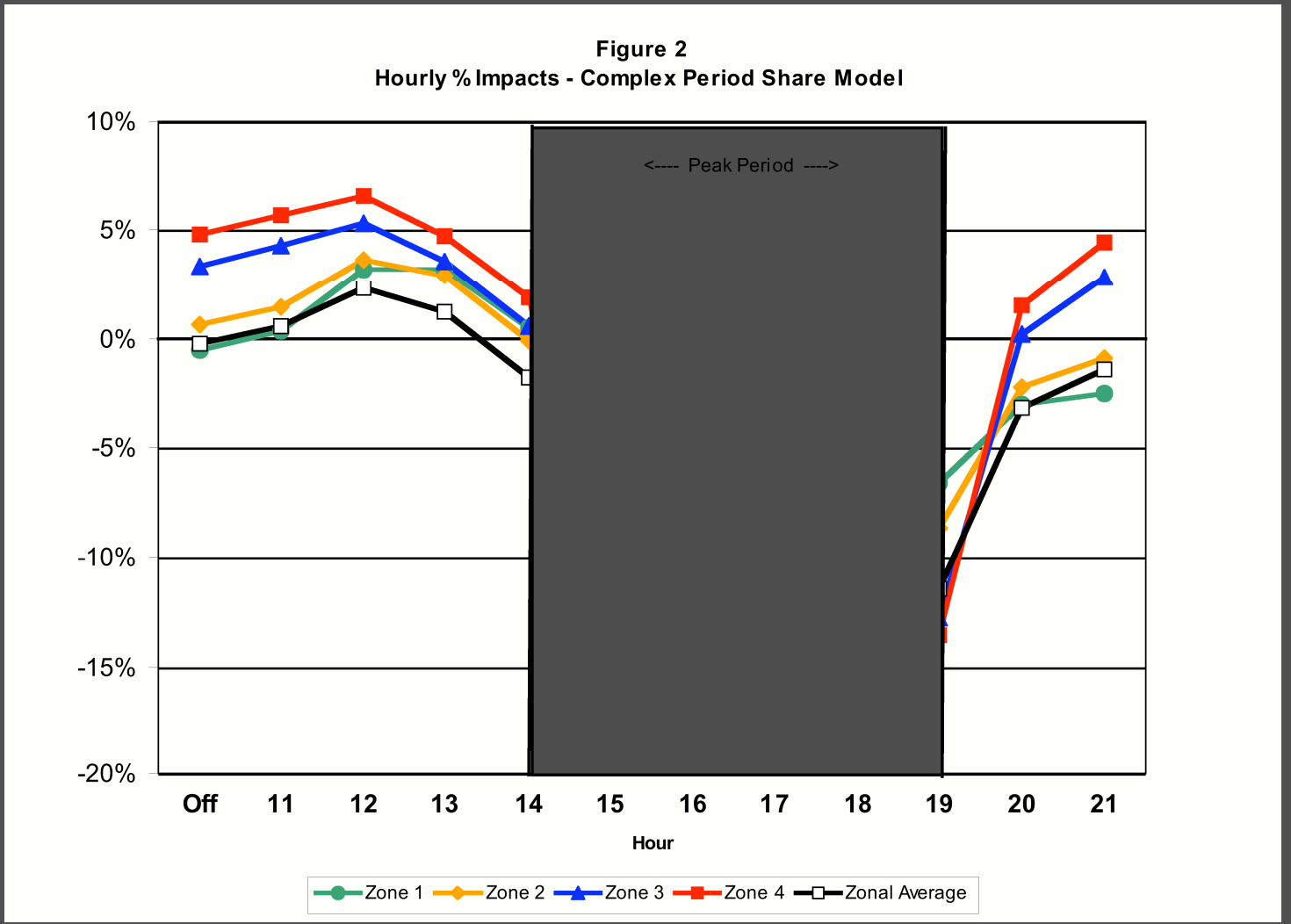
Critical Peak Period Response By Hour



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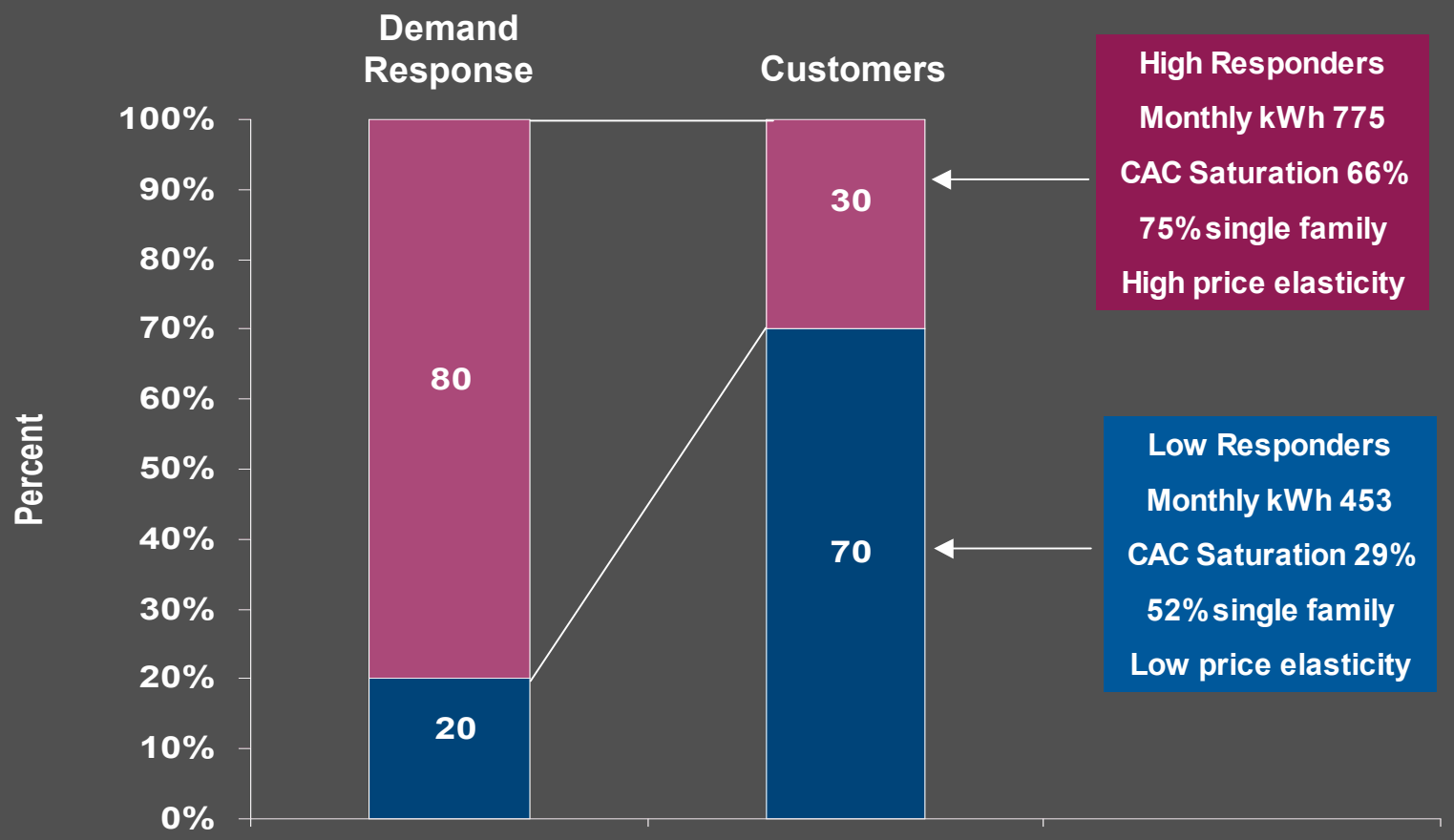
Distribution of Customer Responses

30% of residential customers provided 80% of demand response



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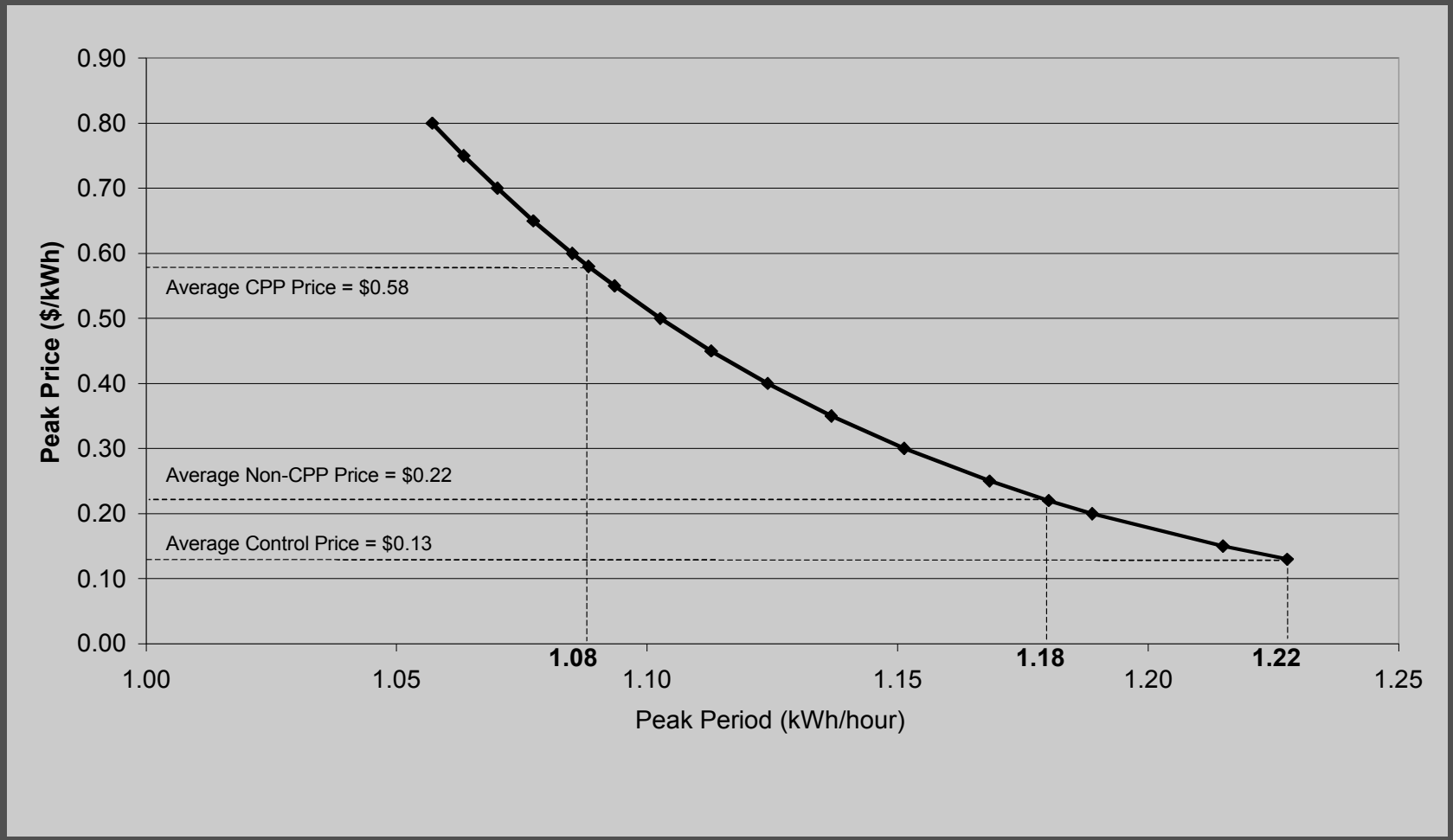
Econometric results can be used to produce demand curves

- CRA's pricing impact simulation (PRISM) model predicts the change in load shapes that are likely to be induced by time-varying rates
- PRISM results can be summarized as demand curves and impact curves

The demand curve for peak period usage shows small but significant price responsiveness



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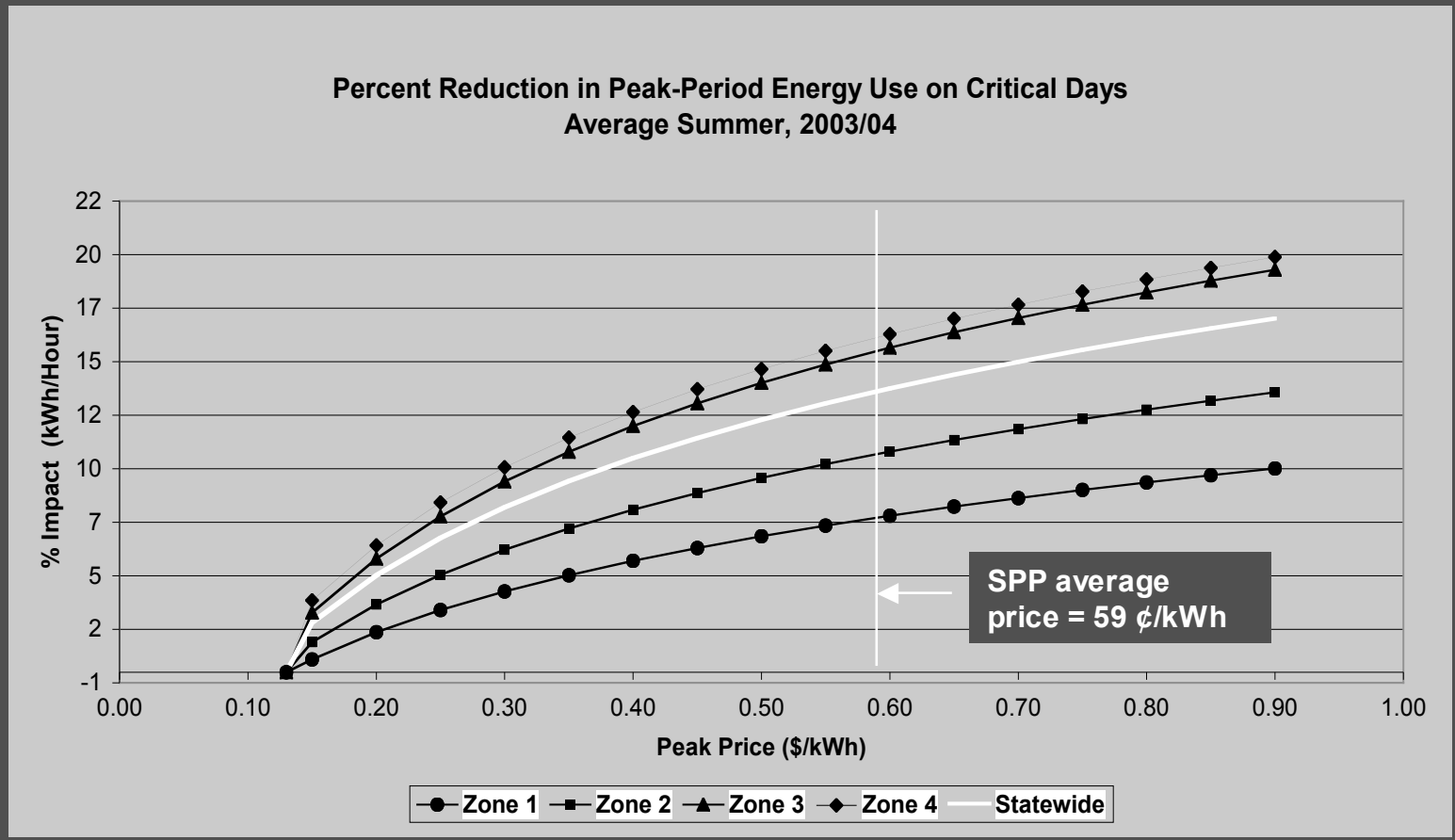
PRISM can be used to simulate the impact of a variety of prices



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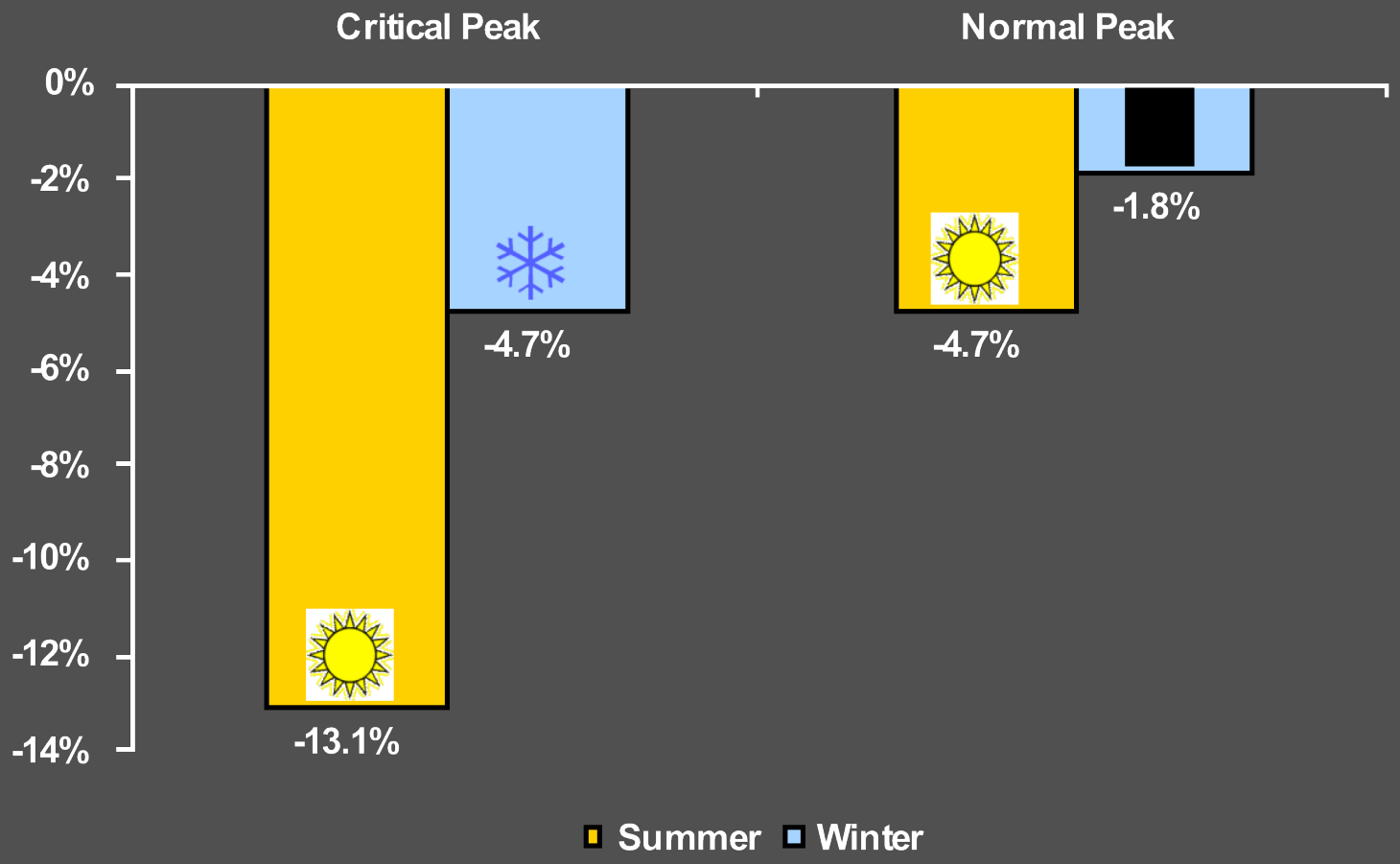
Drivers of % Impact on Critical Peak Energy Use

Variable	Customer Characteristic	Peak Period	Off-Peak Period	Daily Period
None	Average	-13.06	2.04	-2.37
Central A/C	Yes	-17.43	3.21	-2.82
	No	-8.05	0.68	-1.87
Average Daily Use	200% of Average	-14.70	1.77	-3.04
	50% of Average	-12.15	2.21	-1.99
Spa	Yes	-15.84	3.53	-2.13
	No	-12.94	1.93	-2.41
Electric Cooking	Yes	-11.53	0.32	-3.14
	No	-14.09	3.16	-1.87
Persons Per Household	Four	-12.13	1.51	-2.47
	Two	-13.99	2.46	-2.35
Annual Income	$100,000	-16.15	2.99	-2.60
	$40,000	-10.92	1.68	-2.00
Housing Type	Single Family	-13.98	2.72	-2.16
	Multi-Family	-11.78	0.43	-3.14
# Bedrooms	Four	-15.67	2.12	-3.07
	Two	-11.59	2.01	-1.96
College Education	Graduate	-18.52	3.69	-2.79
	Did Not Graduate	-8.56	0.93	-1.84
CARE Discount	Yes	-2.87	0.00	-0.84
	No	-15.56	4.04	-1.68

Source: CRA International, "Evaluation o/t California's Statewide Pricing Pilot" (presentation), 24 March 2005

Winter Results

- Winter defined as 1 November 2003 to 30 April 2004
- CPP-F: Winter demand response (DR) one third of summer



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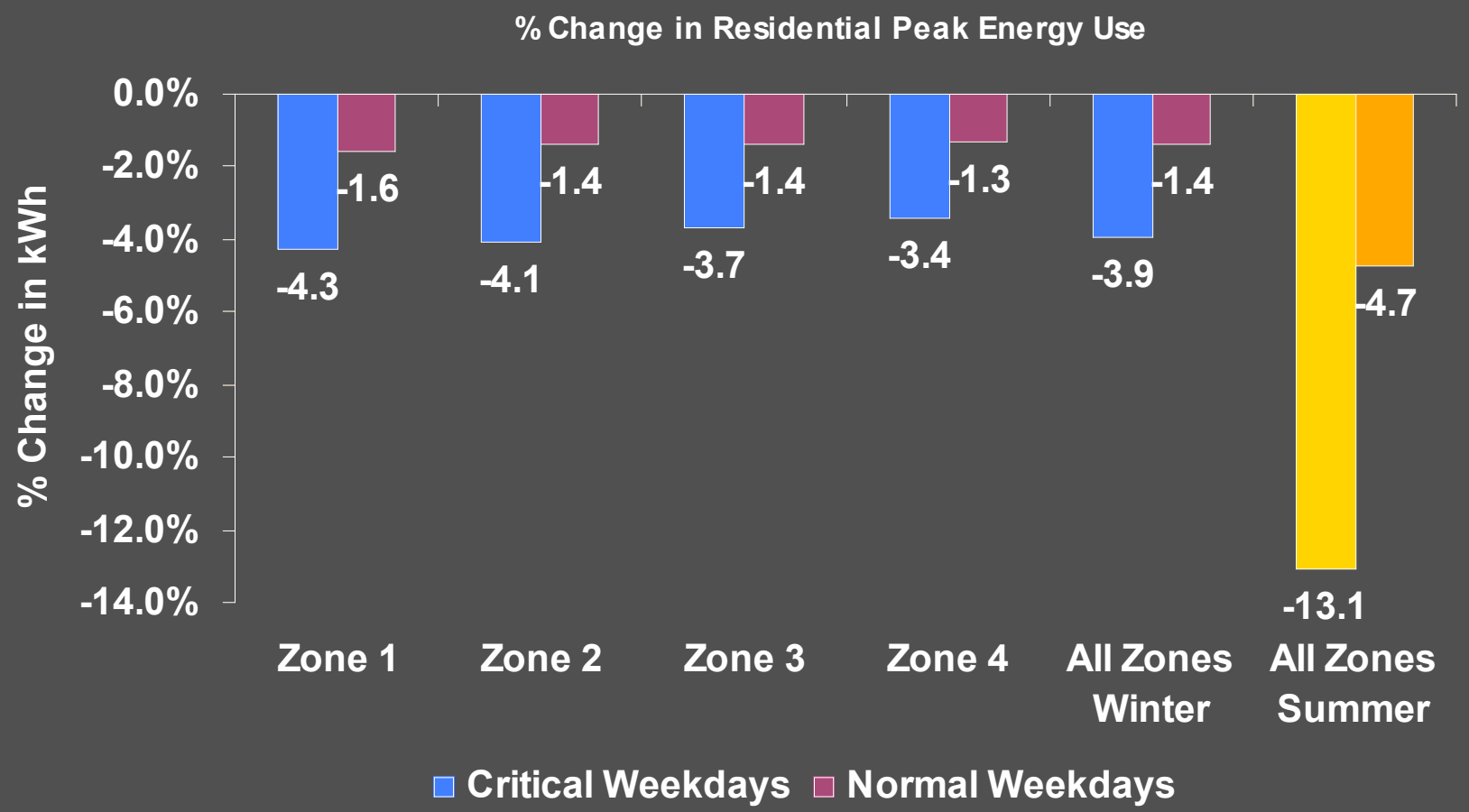
Winter CPP Impact By Zone



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Other key findings for the CPP-F rate

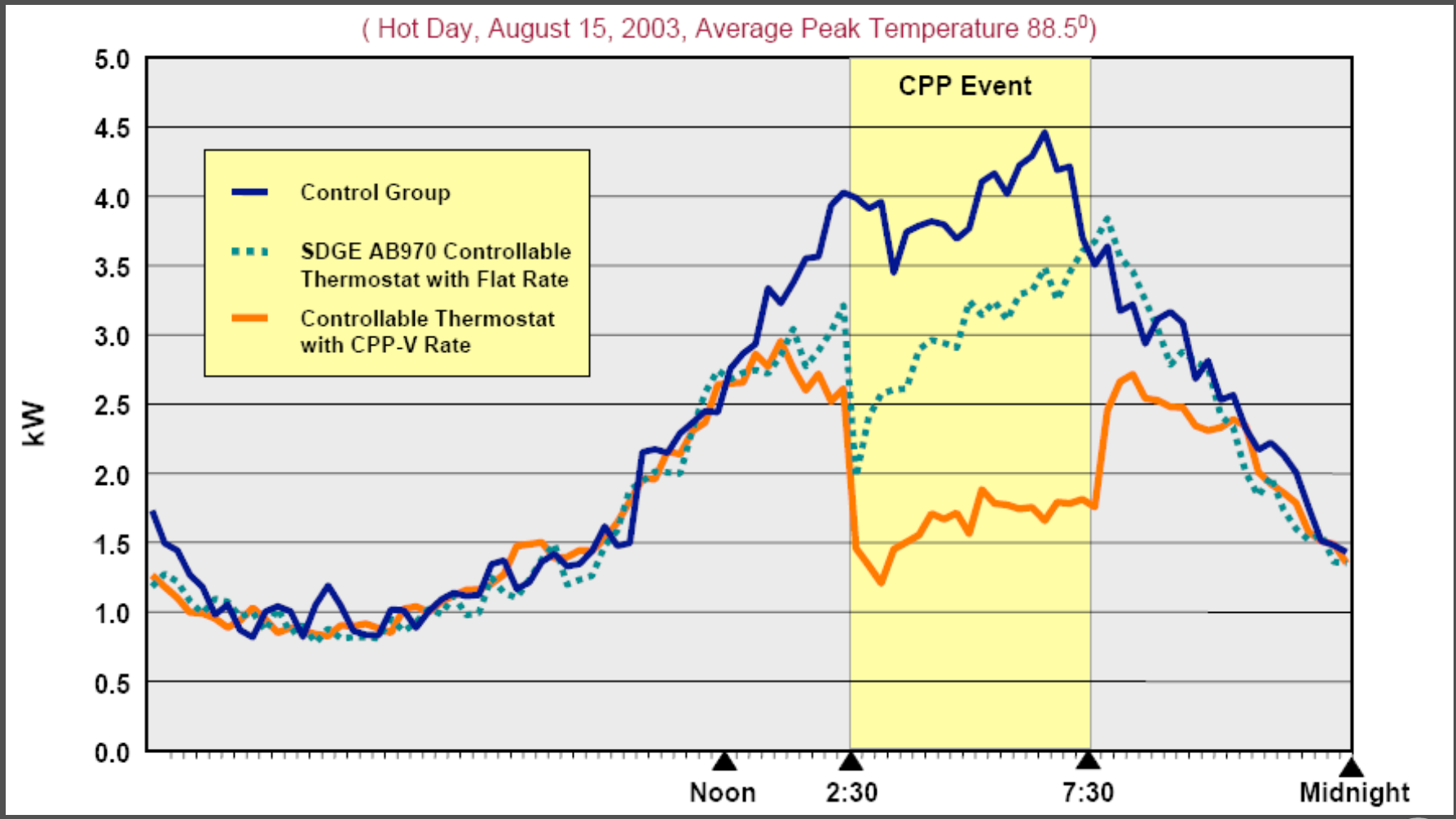
- Peak-period demand reduction persisted into second summer – TOU did not
- Peak-period demand reduction persisted on 2nd or 3rd days of multi-day critical events
- Critical-day impacts were greatest in mid summer (-14.4%) than cooler shoulder months (-8.1%)
- Overall annual energy use unchanged

CPP-V Results

- **50% of customers on CPP-V is business**
- **Stronger critical peak reduction due to a) higher use of CAC in this sample, b) greater use of enabling technology**
  - Track A: 16% reduction in critical peak period (vs. 13% for CPP-F)
  - Track C: 27% reduction
- **Allowed the effect of enabling technology to be isolated**

- **Conclusion: Enabling technology matters**

CPP-V Results: The Effect Of Enabling Technology



Source: Rates during the Summer of 2003, September 13, 2004, CEC Report.

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Information Only Results

- Some response in 2003 to Information Only, especially in one zone
- No response at all in 2004
- Customers were confused – most thought they were still on the high rates – they weren't! This confusion *increased* over time

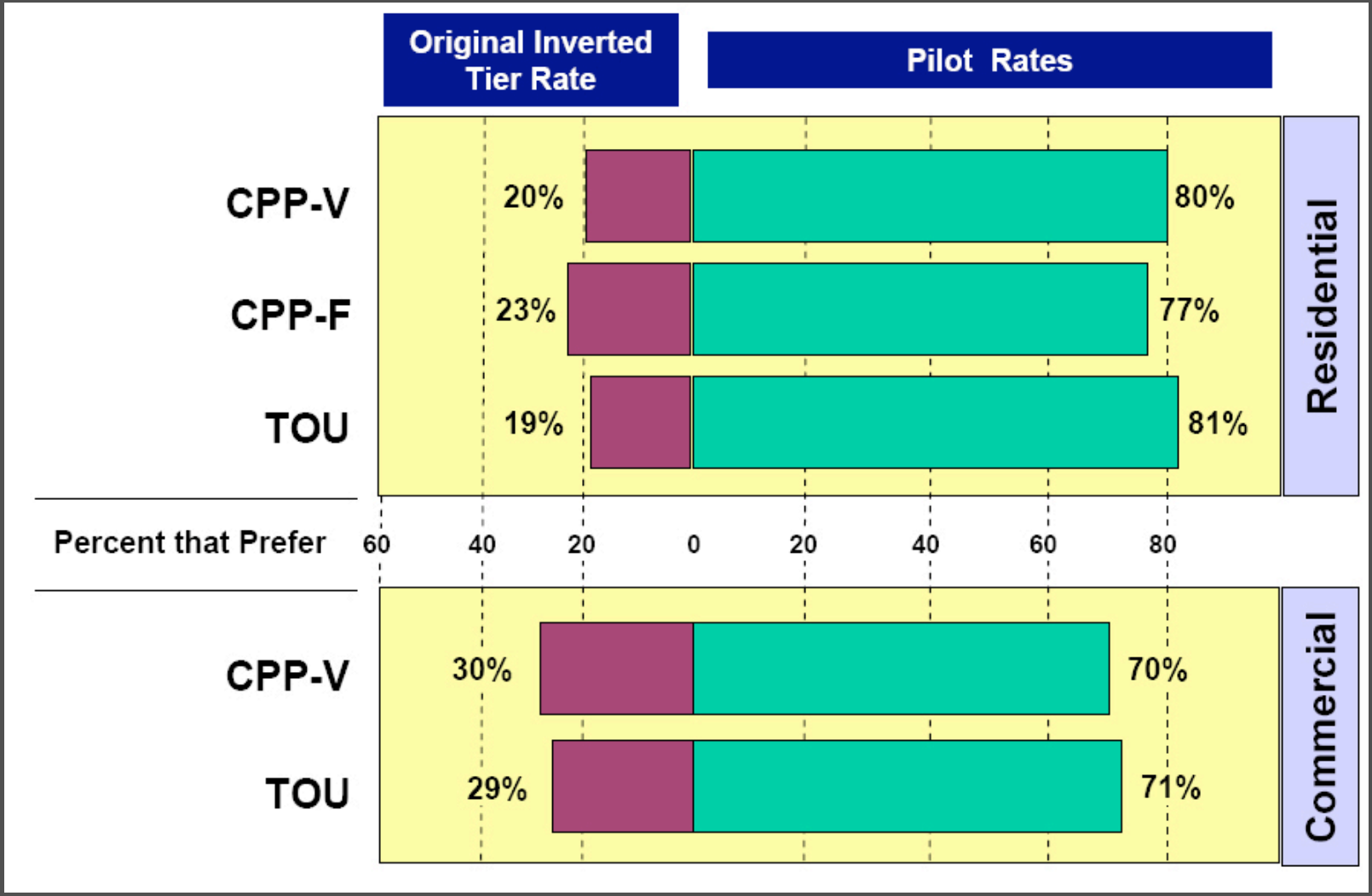
→ Financial incentives do matter

Most Customers Saw Bill Reductions

		Residential			Small Business	
		CPP-F	CPP-V	TOU	CPP-V	TOU
Customers With Bill Savings	Participants %	71.1%	73.7%	70.0%	80.3%	58.2%
	Average Monthly Savings	$6.81	$3.89	$3.25	$155.17	$90.65
Customers With Bill Increases	Participants %	28.9%	26.3%	30.0%	19.7%	41.8%
	Average Monthly Increase	$5.03	$4.93	$3.32	$22.89	$62.52

Source: Statewide Pricing Pilot, Shadow Bill Results, WG3 report, June 9, 2004.

Customer Response Is Positive



Source: SPP End-of-Summer Survey Report, Momentum Market Intelligence, WG3 Report, January 21, 2004.

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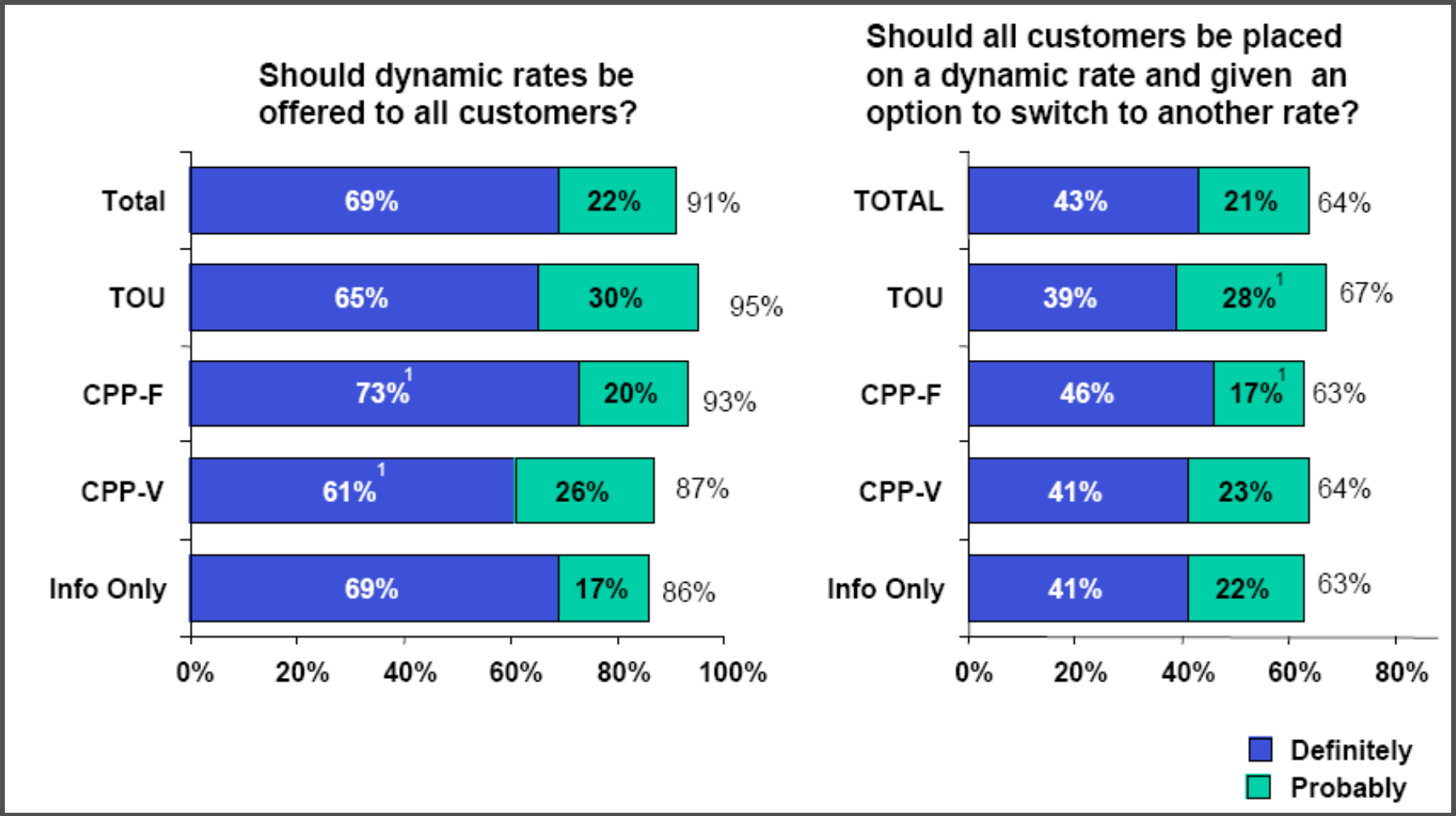
Customer Response Is Positive



Source: Mike Messenger (CEC),"Statewide Pricing Pilot Overview and Results 2003-2004," (presentation).

For in-depth analysis of perceptions, see Momentum Intelligence, "Statewide Pricing Pilot: End-of-Pilot Participant Assessment", December 2004, from CEC web site.

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Summing Up: Seven Surprises…

1. That customers responded at all
2. People understood the rates enough to respond
3. CPP response persisted across years and across multi-day critical events
4. TOU response not sustained
5. Not everyone will take a free enabling technology
6. Significant impacts are achievable without enabling technology
7. Customers liked the rates and most chose to stay on them

Not so surprising…

- **Price matters**
- **The magnitude of customer response varies with customer characteristics**
  - Central air conditioning the key driver
  - High users (that have more appliances) have more load to shift
- **The CPP-F tariff did not have a measurable effect on overall, annual energy use**
  - Encouraged by off-peak price reductions, customers' total energy consumption unchanged.

3. ROLLOUT

Demand Response and AMI – Advanced Metering Infrastructure

- In December 2002, California Public Utilities Commission asks Pacific Gas & Electric to investigate AMI

AMI Module

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Benefits of Demand Response

- Lowers peak capacity requirements, raises system reliability
- Reserve margin multiplies avoided capacity costs
- Connects retail prices to cost, increasing demand elasticity and producing allocative efficiency benefits
- DR is a check on market power of suppliers

The AMI Business Case (PG&E Only)

- PV Cost of rolling out AMI: $2.265 billion
- PV Operational benefits of AMI (excluding DR): $2.024 billion

  Gap: $241 million
- Can DR via dynamic pricing cover this cost? **Yes**
- Avoided peak capacity costs $270 million

  + avoided transmission and distribution capacity $68 million

  = total DR savings of $338 million
- Assumes one third of customers with CAC adopt, 5% of customers without CAC
- PG&E has requested that it begin deployment in 2006

Conclusion

- The SPP has shown conclusively that small customers respond to time-varying prices
- Residential responses significantly higher in warmer climate zones and for customers with central air conditioning
- Estimated peak load reduction of 1,500 to 3,000 MW over 5 years
- A voluntary, opt-in critical pricing rate offered to residential customers with central air conditioning has the potential to add value

Further Information

- **Full SPP data set available for research purposes from CEC. Contact Mike Messenger *mmesseng@energy.state.ca.us***

  Requires statement of purpose and signing non-disclosure

- **CRA contact: Ahmad Faruqui *afaruqui@crai.com***

- **Comprehensive documentation of SPP available from http://www.energy.ca.gov/demandresponse/documents/**

  Recommended reading: March 24, 2005 CRA report

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