# Programmable Communicating Thermostats (PCT's)

**PIER Buildings Program**

**SCE Codes & Standards Program**

**CEC 2008 Title 24 Workshop**

**February 23, 2006**

# Key Concept

- During hottest times of year, air conditioning load high which drives peak demand
  - Higher electricity prices
  - Lower capacity margin - sometimes leading to black-outs
- Thermostats that can automatically increase setpoint 4°F temporarily
  - Reduce A/C load
  - Save customer costs under CPP (Critical Peak Pricing) rate
  - Increase system reliability - reduce black-outs
  - Small impact on comfort

# Programmable Communicating Thermostats (PCT's)

- Programmable
  - Existing programmable schedules
  - New feature – set-up based on outside signal, program price to set-up t-stat
- Communicating
  - One-way – receive load shed or price signal
  - Two-way – verify signal received, on/off status
- Thermostat – limit placed on discomfort
  - Control based on temperature (closed loop)
  - Not duty cycling (open loop)

# PCT's – Minimum Capabilities

- Thermostat receives load shed signal and increases setpoint 4°F
- Temporary reduction in AC consumption
  - Most reduction first hour, less following hours
- Can be controlled by location
  - Useful for local capacity shortage
- Indicates status – normal vs load shed
- Emergency response vs Price Response
  - Emergency – no override of set-up
  - Price Response – voluntary set-up to save $

# Communication infrastructure

- Dispatch
  - send emergency or real time price signal
- Communication mode
  - compatible with utility demand response communication infrastructure
- Metering
  - critical peak pricing, data processing, signal verification

# Methodology Overview

- Two components of value
  - Resource value estimated using TDV method
  - Emergency value of additional load reduction
- Analysis is careful not to double count

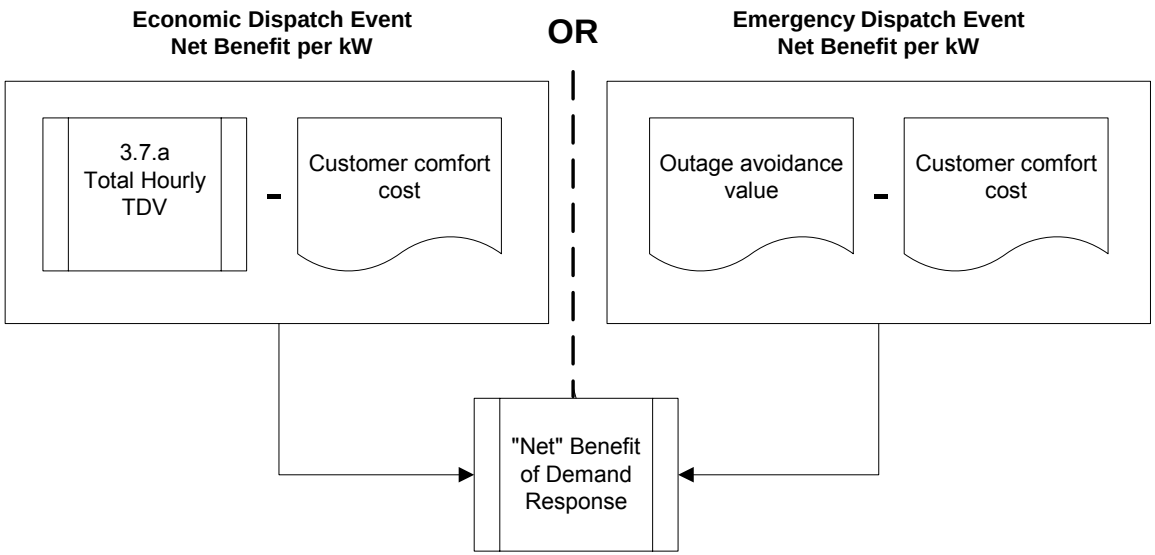
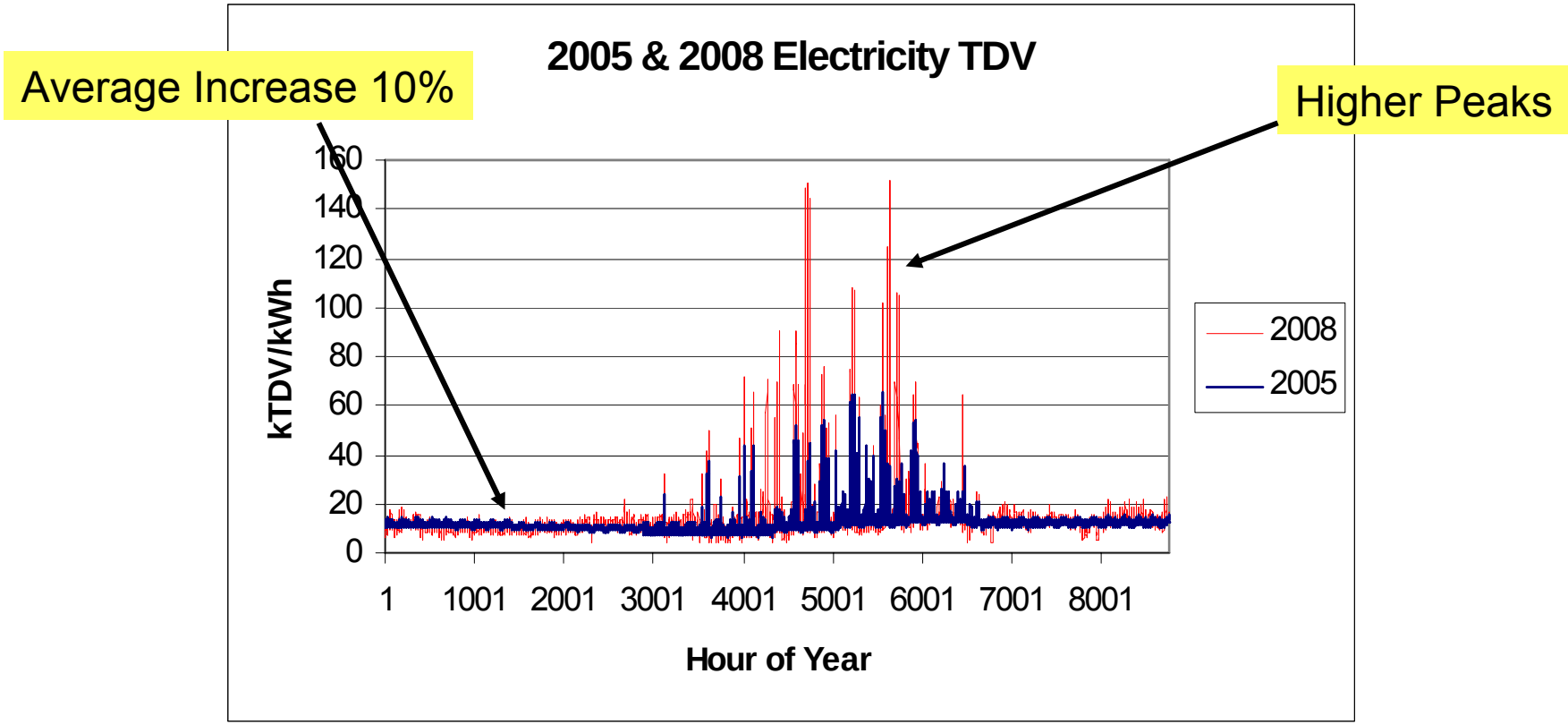



Diagram is from methodology reports available on the CEC website, along with the development of the TDV values and associated spreadsheets.
http://www.energy.ca.gov/title24/2008standards/documents/E3/index.html

# 2005 and 2008 Electricity TDV Value




Electricity TDV 'units' are the value of saving electricity relative to the cost of gas. The conversion of electric cost to TDV units is a constant multiplier established during the 2005 proceeding, and adjusted for inflation. A 10% higher average in 2008 implies a 10% increase in real escalation of electricity rates.

# Emergency Value

## Summary of Average Summer Afternoon Outage Cost

| Class | | Average $/kWh | Statewide Sales (%) |
|---|---|---|---|
| Residential | $ | 5.07 | 39% |
| Commercial | $ | 109.04 | 30% |
| Industrial | $ | 24.77 | 28% |
| Agriculture | $ | 11.50 | 3% |
| Weighted Average | $ | 42.02 | |

*Data sources:*

PG&E. 2003. *Supplemental Testimony Pursuant to Appendix A of Assigned Commissioner's Ruling Dated February 13, 2003. Reliability Performance Issues.* Application No. 02-11-017. San Francisco, California.

PG&E. 2000. *Value of Service (VOS) Studies: Presentation to ISO Grid Planning Standards Subcommittee*. San Francisco, California.

SCE. 1999. *Customer Value of Service Reliability Study*. Rosemead, California.

Woo, C. K., and R. L. Pupp. 1992. "Costs of service disruptions to electricity consumers." *Energy* 17(2): 109–126.

# Analysis Assumptions (1)

| | (--) Very Pessimistic | (-) Pessimistic | (=) Base Case | (+) Optimistic | (++) Very Optimistic |
|---|---|---|---|---|---|
| Annual Days of Operation | 5 | 10 | 15 | 15 | 20 |
| Time Period of Dispatch | 2pm to 4pm | 2pm to 4pm | 2pm to 6pm | 2pm to 6pm | 2pm to 6pm |
| Temperature Set-up | 4 deg | 4 deg | 4 deg | 4 deg | 4 deg |
| Override Possible during non-emergency event | Yes | Yes | Yes | Yes | Yes |
| 'Emergency' Operations Rule | No Emergency | Only Participants | All PCT Owners | All PCT Owners | All PCT Owners |
| Dispatch of PCT | Alternate TDV cost days | Alternate TDV cost days | Highest cost TDV days | Highest cost TDV days | Highest cost TDV days |
| Dispatch Weather Assumption | 10th Hottest Day | 10th Hottest Day | 10th Hottest Day | Hottest Day | Hottest Day |
| Fraction of Population participating | DR or CPP 'opt-in' 20% | DR or CPP 'opt-in' 20% | CPP 'opt-out' 70% | CPP Mandatory 100% | CPP Mandatory 100% |
| Economic signal for participants | Reset with option to override | Reset with option to override | Reset with option to override | Reset with option to override | Reset with option to override |

# Analysis Assumptions (2)

| | (--) Very Pessimistic | (-) Pessimistic | (=) Base Case | (+) Optimistic | (++) Very Optimistic |
|---|---|---|---|---|---|
| Economic signal for participants | Reset with option to override | Reset with option to override | Reset with option to override | Reset with option to override | Reset with option to override |
| Residential: Fraction with T-stat ON | From RAS study by climate zone | | | | |
| Nonresidential: Fraction with T-stat ON | 100% | 100% | 100% | 100% | 100% |
| Fraction overriding voluntary signal residential | 30% | 20% | 10% | 10% | 5% |
| Fraction overriding voluntary signal nonresidential | 20% | 20% | 10% | 10% | 10% |
| Useful life of PCT | 15 yrs | 15 yrs | 15 yrs | 15 yrs | 15 yrs |
| Thermostat schedules res | T-24 | 76°F | 76°F | 74°F | 74°F |
| Thermostat schedules nonres | 74°F | 74°F | 74°F | 72°F | 72°F |
| Productivity loss | 50% | 35% | 20% | 20% | 10% |
| Value of loss of service ($/kWh) | N/A | $30 | $42 | $100 | $200 |

# Example of Analysis Approach

- Residential climate zone 12
- Base Case Assumptions

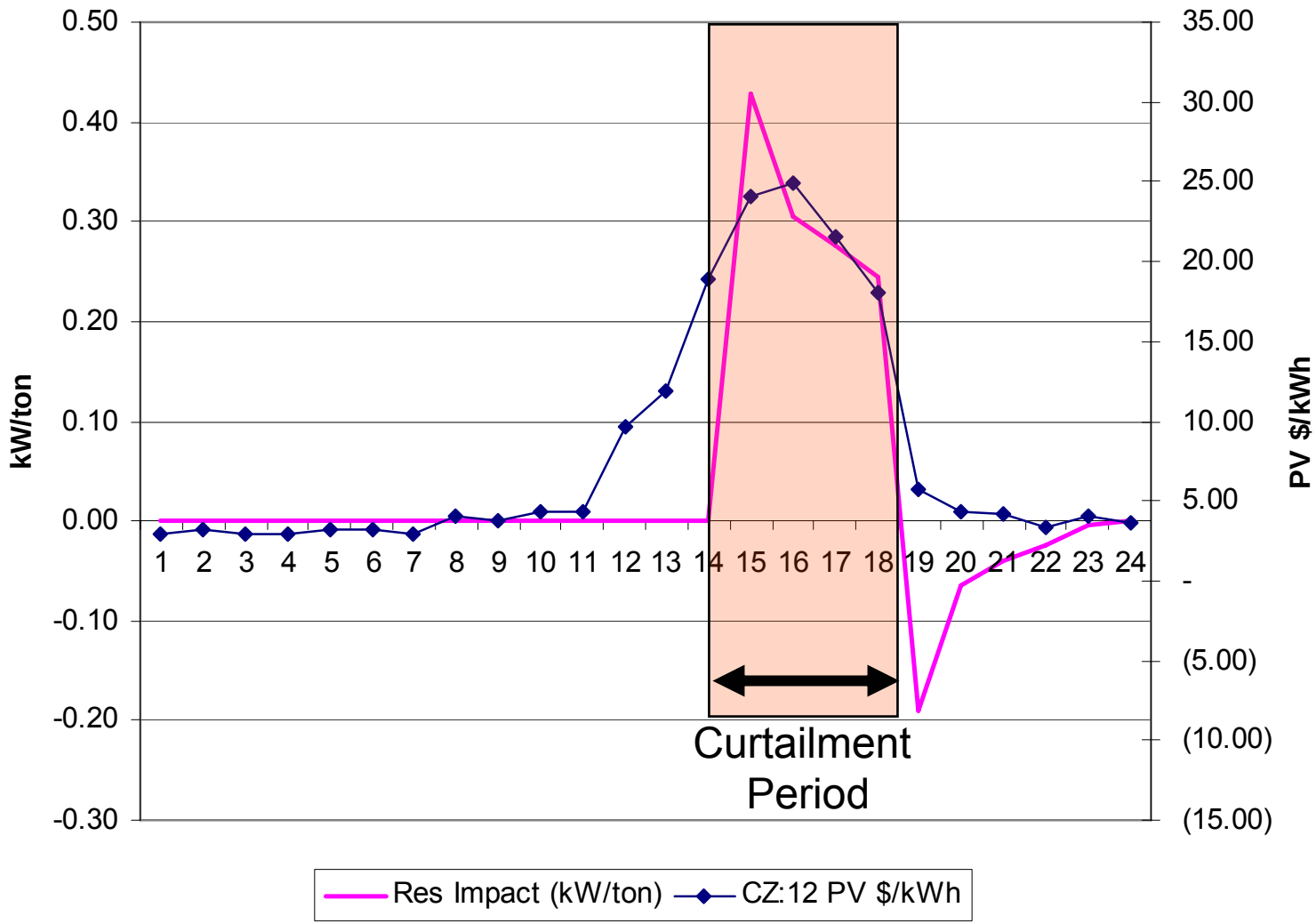
- Resource Value
  - Impact per installed thermostat
  - Lifecycle value per installed thermostat
- Emergency Value
  - Impact per installed thermostat
  - Lifecycle value per installed thermostat

# Estimating Impact per Thermostat

- Base case estimate of peak load reductions from the PCT, Residential CZ 12 example

| **Participation Estimate - Voluntary Program** | | | *Example Calculation* |
|---|---|---|---|
| *Row* | *Calculation* | *Description* | *Base Case: CZ 12* |
| A | Input | Percentage of AC that are on and below set point | 85% |
| B | Input | Percentage that receive and can act upon the signal | 97% |
| C | Input | Percentage that do not override | 90% |
| D | A*B*C | Technical potential | 74% |
| E | Input | Percentage w/ PCT participating in program | 70% |
| F | D*E | Overall fraction of potential including participation | **52%** |
| **Impact Estimates** | | | |
| G | Simulation | Average simulated kW reduction | 0.87 |
| H | F*G | Average kW reduction per Tstat installed | 0.45 |

# Resource Value Approach



# Calculation of Resource Value

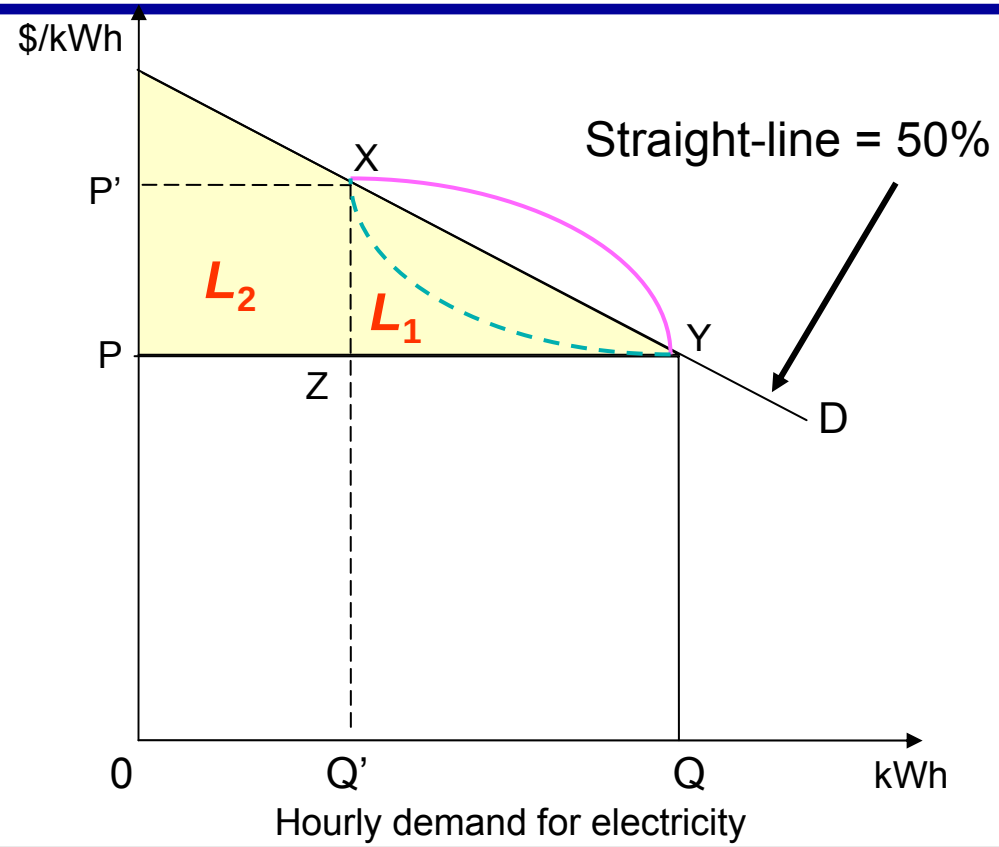
- Calculation of resource value, net of comfort and productivity losses for the PCT

| | | | |
|---|---|---|---|
| **Resource Value** | | Best Dispatch | |
| Avoided Cost Value | 1 | | |
| Avoided Cost Value (PV$/ton) | | $ | 271.30 |
| AC tons per thermostat | | | 2.79 |
| **Value per thermostat (PV$/tstat)** | | $ | 392.59 |
| Comfort and productivity loss | | | |
| Comfort loss as a percentage of avoided cost | | | 20% |
| **Comfort loss ($PV/tstat)** | | $ | (78.52) |
| Net Resource Value | | **$** | **314.07** |

# Partial Outage Cost for Voluntary Participation

**CP = X% (P' – P), requiring minimal amount of information to compute.**

- Consider a dispatchable price program that sends a price signal P' > P to the consumer. The consumer responds by reducing consumption to Q'.
- The loss in net consumption benefit is $L_1$ ≈ area of triangle XYZ = (P' – P) x (Q – Q') / 2, implying **$C_P$ = (P' – P) / 2.**
- If P' = \$0.9/kWh and P = \$0.2/kWh, $C_P$ = \$0.35/kWh [= (0.9 – 0.2) / 2].




This computation assumes:

1. A revenue-neutral rate design eliminates $L_2$ = (P'–P) x Q', the bill increase due to the high price P' for the remaining consumption Q'.
2. A straight line is reasonable approximation of the segment XY without any additional information. If the segment is the *blue dash* (*pink solid*) line with sharp curvature, the computation understates (overstates) $C_P$.

# Estimating Emergency Impact

- Emergency Impact is the <u>additional</u> load impact achieved by disabling the override feature of the PCT

| **Participation Estimate - Emergency Program** | | | *Example Calculation* |
|---|---|---|---|
| *Row* | *Calculation* | *Description* | *Base Case: CZ 12* |
| A | Input | Percentage of AC that are on and below set point | 85% |
| B | Input | Percentage that receive and can act upon the signal | 97% |
| C | Input | Percentage that do not override | 90% |
| D | A*B*C | Technical potential | 74% |
| E | Input | Percentage w/ PCT participating in program | 70% |
| F | A*B*(1-C)*E | Incremental Emergency kW/ Tstat (Participants Only) | **6%** |
| G | A*B*(1-C) | Incremental Emergency kW/ Tstat (All PCT Owners) | **8%** |
| **Impact Estimates** | | | |
| H | Simulation | Average simulated kW reduction | 0.87 |
| J | F*H | Incremental Emergency kW per Tstat (Participants Only) | 0.05 |
| K | G*H | Incremental Emergency kW per Tstat (All PCT Owners) | 0.07 |

# Emergency Value per Thermostat

- Emergency value per thermostat is the weighted average value of lost load, less comfort and productivity loss times the load reduction.

| **Emergency Value** | | | | | |
|---|---|---|---|---|---|
| Class Weighted Average VOS ($/kWh) | | $ | 42.00 | | |
| Comfort and Produtivity Loss ($/kWh) | | $ | 2.50 | | |
| Net Gain of reduced outages costs ($/kWh) | | $ | 39.50 | | |
| Reliability Target (1 Day in X Years) | | | 10 | | |
| Expected Outage Hours (hours per year) | | | 2.4 | | |
| Reduced Outage Cost $/kW-yr | | $ | 94.80 | | |
| Present Value Factor | | | 19.60 | | |
| Real Discount Rate | 3% | | | | |
| Number of Years | 30 | | | | |
| Reduced Outage Cost ($PV/kW) | | $ | 1,858.12 | | |
| Average reduction per t-stat (kW/t-stat) | | | 0.05 | | |
| Reduced Outage Cost ($/t-stat) | | | | **$** | **93.52** |

# Partial outage costs during emergency

Estimate of $2.50 per kWh unserved for non-voluntary AC curtailment

| | Original $/kWh | 2004$/kWh |
|---|---|---|
| PG&E 1993 VOS survey: summer partial outage cost of voluntary curtailment* | 3.87 | 5.06 |
| PG&E 1998 Residential AC load shedding program participation study | 1.63 | 2.61 |
| SCE Residential A/C Cycling Program late 1980's, study in 1999, 100% cycling | 1.23 to 3.05 | 1.47 to 3.64 |
| SCE Non-residential A/C Cycling Program late 1980's, study in 1999 50% cycling | 1.59 to 3.98 | 1.90 to 4.75 |

Note: We used CA Department of Finance CPI to converting Original$ to 2004$.

Notes on applicability of partial outage cost studies

- PG&E's 1993 VOS survey result is 2004$5/kWh unserved for a summer 4-hour (noon - 4 pm) voluntary load curtailment. This estimate is too high because it is the same as the cost numbers for full summer 1-hour and 4-hour afternoon outages contained in the *same* survey.
- The 2004$2.6/kWh unserved estimate is based on a survey of program participants [Keane DM, McDonald D, Woo CK (1988) "Estimating residential partial outage cost with market research data," *Energy Journal–Reliability Special Issue*, 9: 151-172.] It applies to AC load shedding, not AC cycling under PCT implementation.
- SCE study is for AC cycling (on or off) NOT PCT implementation.

# Residential Base Case Results

Example from Previous Section

| Base Case Cost, Energy & Demand Savings per Tstat Estimates for Res New Construction | | | | | | |
|---|---|---|---|---|---|---|
| Title 24 California CTZ | Total Value per Tstat ($/Tstat) | Resource Value per Tstat ($/Tstat) | Emergency Value per Tstat ($/Tstat) | Non-Emergency Avg Demand Savings per Tstat (kW/Tstat) | Emergency Avg Demand Savings per Tstat (kW/Tstat) | Energy Savings per Tstat (kWh/Tstat) |
| 1 | $144 | $110 | $34 | 0.17 | 0.02 | 9.45 |
| 2 | $290 | $221 | $69 | 0.33 | 0.04 | 15.88 |
| 3 | $250 | $187 | $63 | 0.31 | 0.03 | 13.42 |
| 4 | $311 | $238 | $73 | 0.36 | 0.04 | 17.28 |
| 5 | $306 | $242 | $65 | 0.31 | 0.03 | 20.12 |
| 6 | $239 | $174 | $66 | 0.32 | 0.04 | 13.70 |
| 7 | $331 | $258 | $73 | 0.36 | 0.04 | 17.75 |
| 8 | $277 | $207 | $70 | 0.34 | 0.04 | 14.74 |
| 9 | $426 | $325 | $102 | 0.49 | 0.05 | 23.25 |
| 10 | $338 | $252 | $86 | 0.41 | 0.05 | 19.68 |
| 11 | $436 | $341 | $95 | 0.46 | 0.05 | 20.75 |
| 12 | $408 | $314 | $94 | 0.45 | 0.05 | 20.17 |
| 13 | $404 | $306 | $98 | 0.48 | 0.05 | 22.59 |
| 14 | $449 | $340 | $109 | 0.53 | 0.06 | 24.48 |
| 15 | $529 | $394 | $134 | 0.65 | 0.07 | 29.74 |
| 16 | $318 | $245 | $72 | 0.35 | 0.04 | 15.87 |

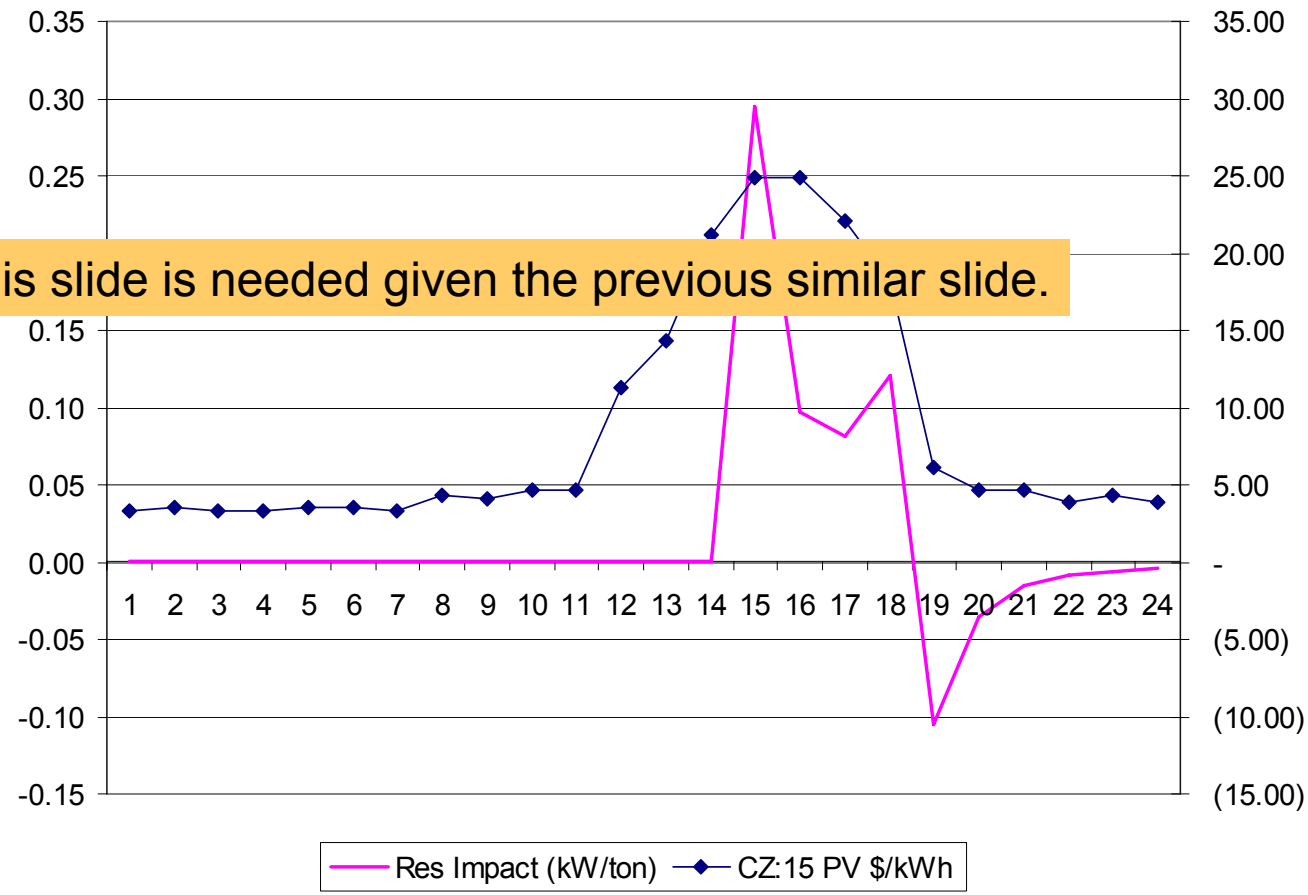
# Environmental impact

- Reduced energy consumption at peak
- Increased consumption immediately after peak
- Increased consumption before peak for pre-cooling if warning signal given
- Time Varying Emissions Factors used to calculate net emissions impacts
  - Related to resource mix at different times
- Small overall impact

# Example Dispatch on Top Day

- Load Impact and TDV on Top Day (Fri, Aug23)

Not sure this slide is needed given the previous similar slide.



# PCT estimated installed costs E-Source survey

| | 1 way PCT's | |
|---|---|---|
| Annual Volume | Retail | Wholesale |
| 50,000 | $195 to $300 | $175 to $260 |
| 100,000 | $180 to $270 | $160 to $235 |
| 250,000 | $160 to $225 | $145 to $200 |

Approximately $60 incremental cost

# Code Proposal

- Standards - Mandatory requirement
- Nonresidential - Section 122(c) Shut-off, Reset and Demand Responsive Controls for Space-conditioning Systems
- Residential - Section 150(i) Setback and Demand Responsive Thermostats

# Control Capabilities

- be capable and installed to set up the cooling setpoint by 4°F and …
- if controlling a heat pump be capable and installed to turn off supplementary resistance heating …
- during emergency or voluntary demand response period
- Not capable of being overridden during emergency demand response period
- Exceptions: zones that must have constant temperatures for patient health or to prevent degradation of materials, a process, or plants or animals

# Other considerations

- Who creates and maintains PCT specification?
  - Each utility
  - Statewide specification in Title 24
    - LBNL/PIER PCT project

# For more information

- http://www.title24dr.com/
  - Minutes and presentations of PCT stakeholder meetings
  - Reference documents
- PCT Draft CASE Report

  http://www.energy.ca.gov/title24/2008standards/documents/2006-02-22+23_workshop/2006-02-15_PROGRAMBLE_COMM.PDF

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