Programmable Communicating Thermostats (PCT's)

PIER Buildings Program
SCE Codes & Standards Program
CEC 2008 Title 24 Workshop
February 23, 2006

pier
"Research Powers the Future"

SOUTHERN CALIFORNIA EDISON
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Codes & Standards Enhancement Project

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

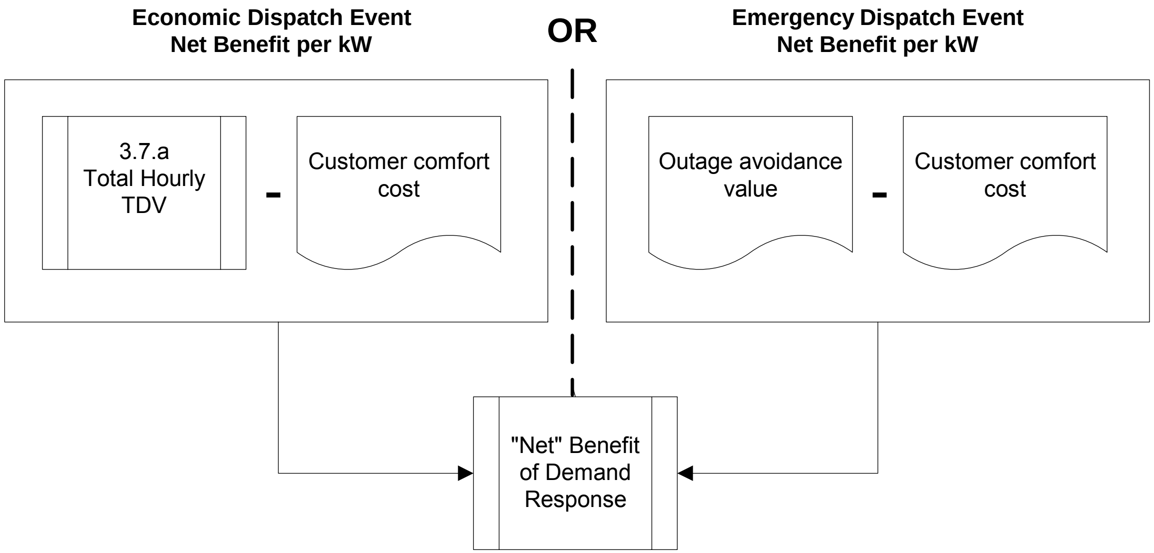
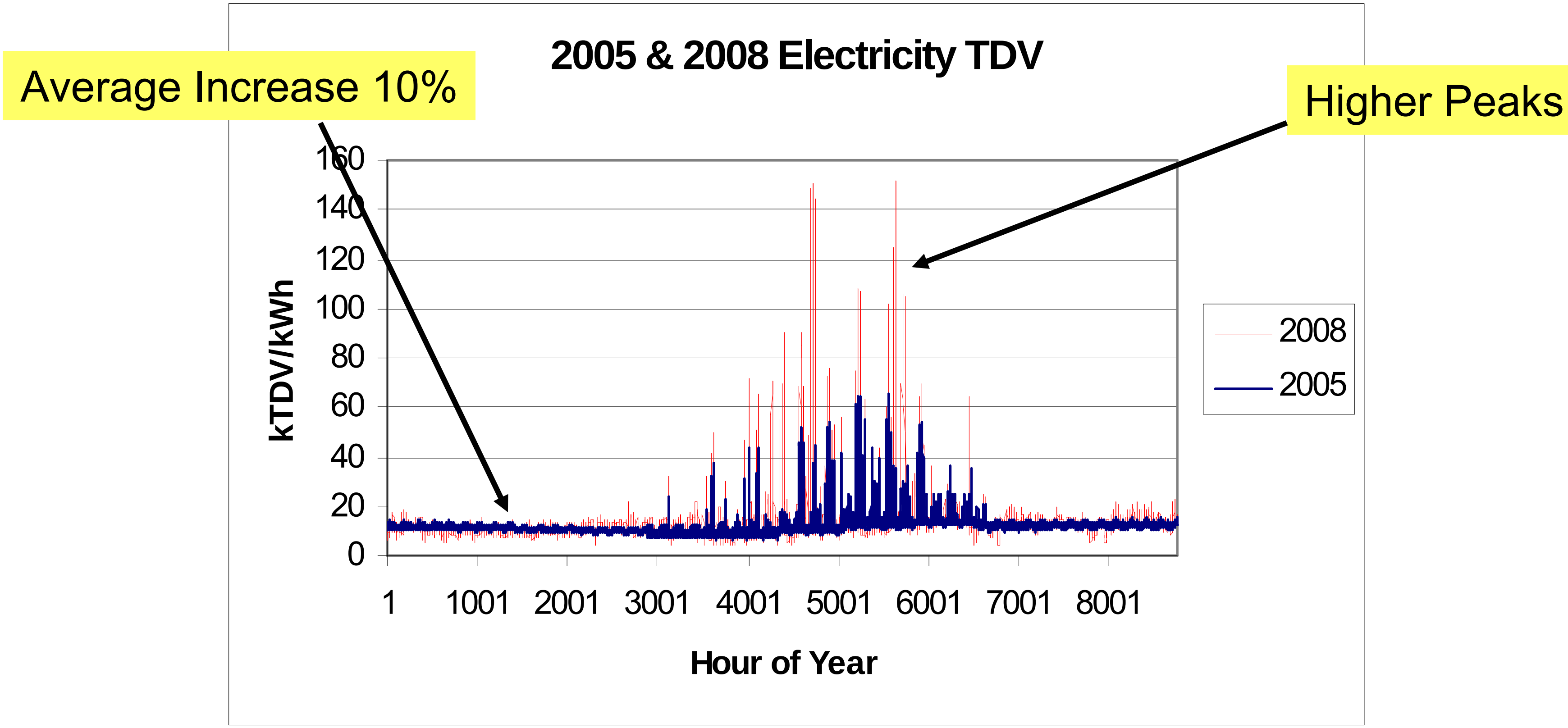


Diagram is from methodology reports available on the CEC website, along with the development of the TDV values and associated spreadsheets. http://www.energy.ca.gov/title24/2008standards/documents/E3/index.html

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	10^{th} Hottest Day	10^{th} Hottest Day	10^{th} 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

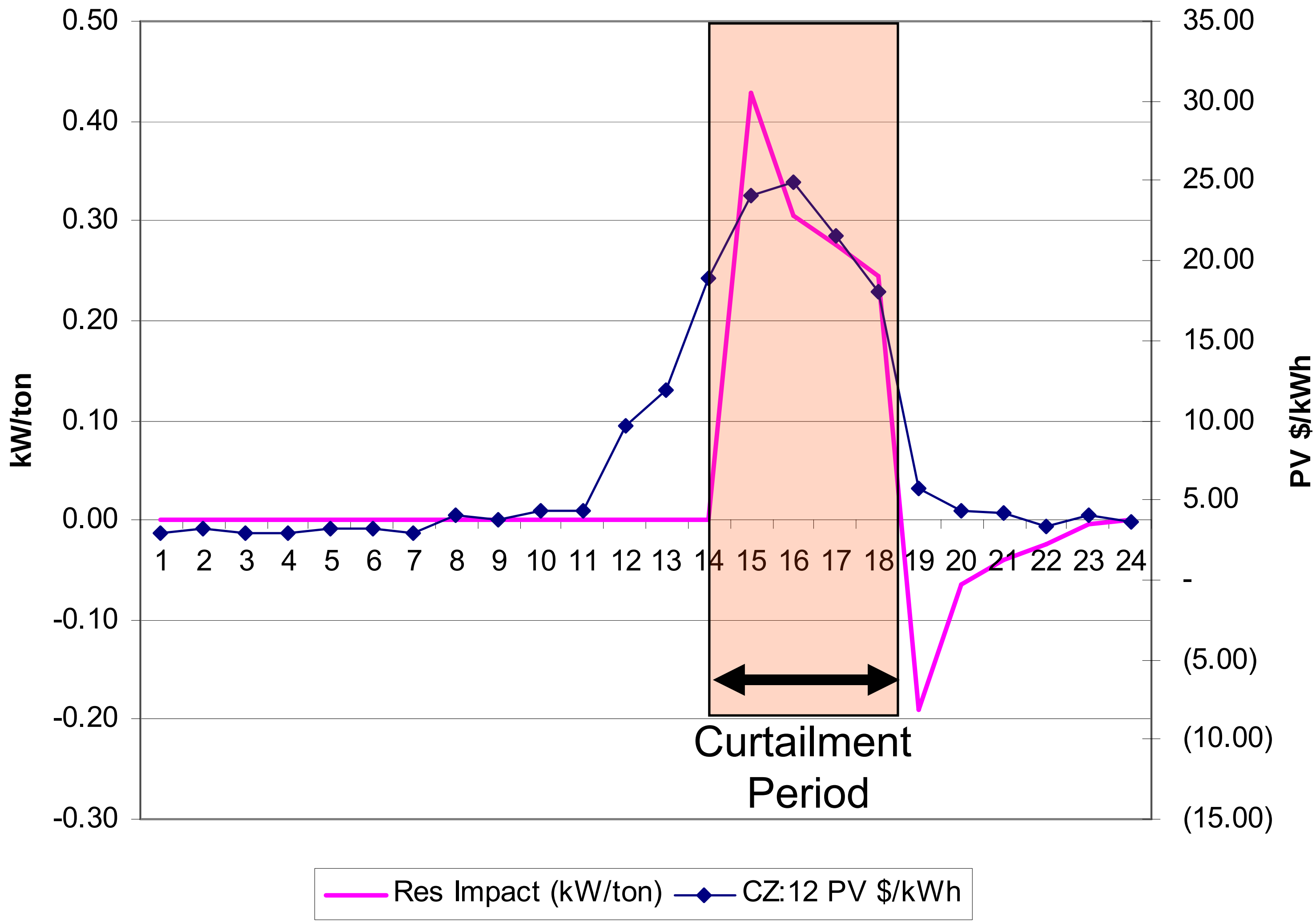
- Residential climate zone 12
- Base Case Assumptions
- Resource Value
  - Impact per installed thermostat
  - Lifecycle value per installed thermostat
- Emergency Value
  - Impact per installed thermostat
  - Lifecycle value per installed thermostat

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

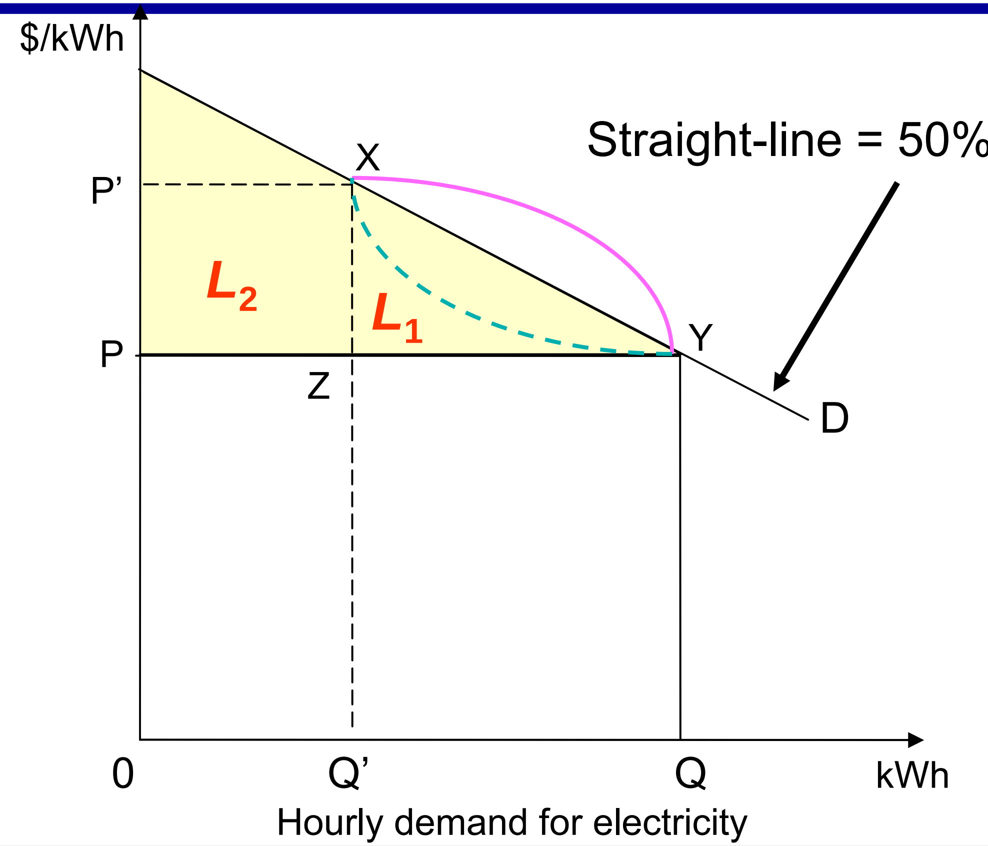
- Calculation of resource value, net of comfort and productivity losses for the PCT

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$.

<u>Notes on applicability of partial outage cost studies</u>

- 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

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

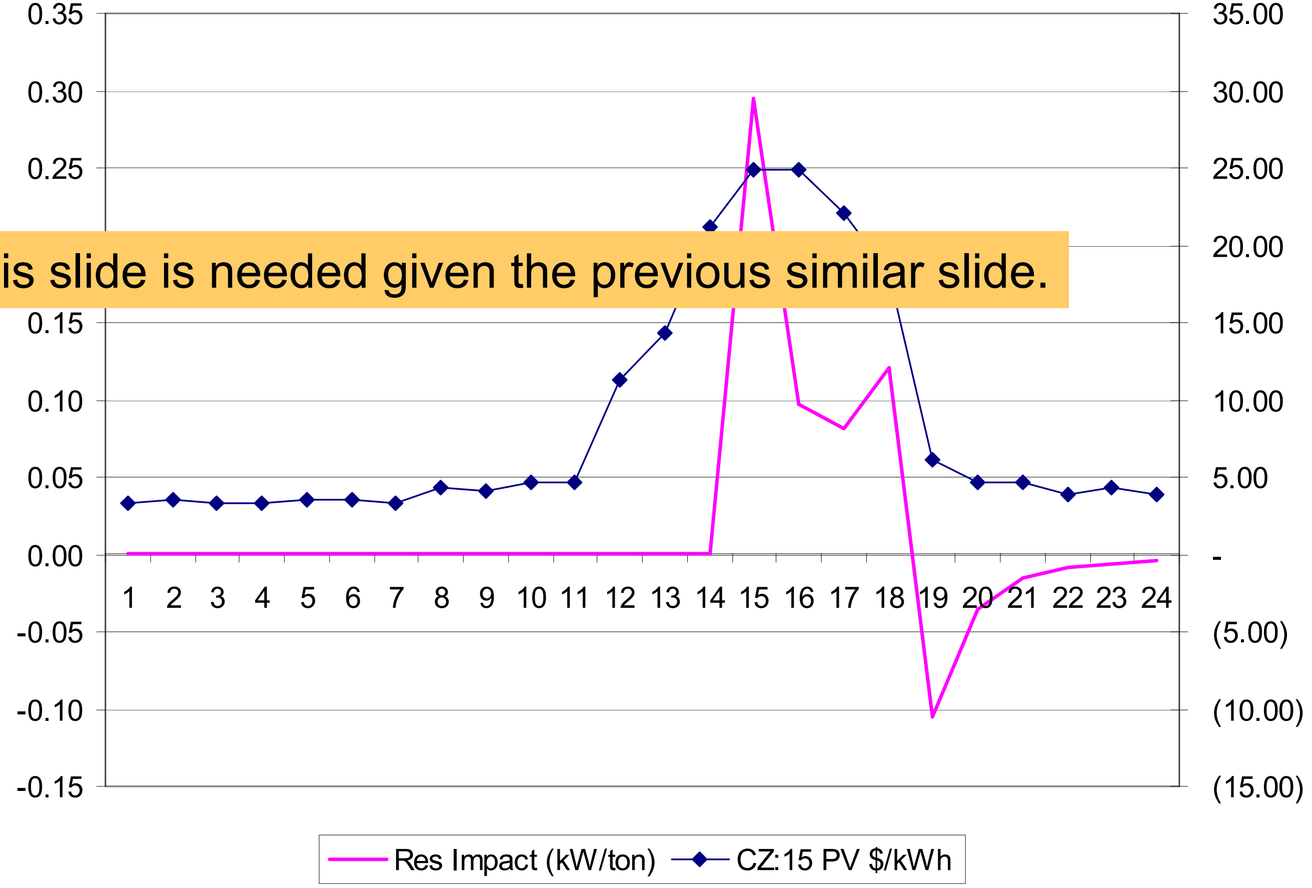
Example from Previous Section →

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

Acknowledgements

- CEC PIER Buildings Program
  - Nancy Jenkins
- SCE Codes & Standards Program
  - Carlos Haiad
- E3 Energy and Environmental Economics
  - Snuller Price & Brian Horii
- HMG Heschong Mahone Group
  - Douglas Mahone, Jon McHugh, Abhijeet Pande, Heather Larson, Matt Tyler
- E-Source/Platts
  - Rachael Reiss