New Approaches to Residential Direct Load Control in California

Michael Alexander, Pacific Gas and Electric
Ken Agnew and Miriam L. Goldberg, KEMA Inc.

ABSTRACT

New direct load control programs are being rolled out by utilities across the country. Traditional one-way, single-mode switch technologies are being replaced by remotely adjustable thermostats and adaptive switch technologies that learn how customers' air conditioners actually operate over time and then optimize load impacts during events.

Adaptive switches are designed to reduce air conditioner duty cycle by a percent of what the duty cycle would have been in the absence of the control event. Ramping strategies for thermostats increase temperature set point in several increments over the control period. These control approaches are designed to improve a program's demand reduction profile, while making control periods more comfortable for customers. To date, formal evaluation of these expected benefits has been minimal.

The PG&E SmartAC™ program offers a unique opportunity to explore these strategies within a single program in a single location. The SmartAC program began in spring 2007. It has a goal of obtaining 305 MW of load relief from about 400 thousand devices by 2011. Participation is expected to be 95% from residential customers and 5% from small commercial customers.

Customers were given a choice of two control technologies:

1. Adaptive switches
2. Programmable Communicating Thermostats (PCTs) with ramping capability

The impact evaluation of the Program's first year takes advantage of a sample of 300 residences evenly split between the two control technologies. New analysis methods were developed to address the new twists on standard switch and thermostat technologies. Savings were evaluated for fifteen control events during the summer of 2007.

Introduction

New Direct Load Control (DLC) programs are being rolled out by utilities across the country. Traditional one-way, single-mode switch technologies are being replaced by remotely adjustable thermostats and adaptive switch technologies that learn how customers' air conditioners actually operate over time and then optimize load impacts during events. The goal remains the same as for the traditional DLC program – provide large-scale, dispatchable peak load relief. Pacific Gas and Electric's (PG&E's) SmartAC™ program offers a unique opportunity to explore these new strategies within a single program in a single location.

PG&E is a summer-peaking (~ 23,000 MW), investor-owned utility serving 5.1 million electric accounts in northern and central California. PG&E estimates a population of about 1.6 million residential central air conditioners located primarily in the hot inland valley areas of its

70,000 square mile service territory. PG&E introduced a new DLC program starting in 2007 targeting central air conditioning.

The SmartAC program has a goal of obtaining 305 MW of load relief from about 400 thousand devices by 2011. While current participants are mostly residential, participation is eventually expected to be 95% from residential customers and 5% from small commercial customers.

During the first months of the Program's operation, customers were given a choice of two control technologies[1]:

1. Adaptive switches
2. Programmable Communicating Thermostats (PCTs) with ramping capability

For the purpose of evaluating the Program, PG&E committed to test events for a sample of participants representing both technologies. Fifteen test events were called for the evaluation sample over the course of the cooling season. The results from these test events provide valuable insight into the effectiveness of these new technologies in meeting the challenges of the new DLC program.

This paper is an exploration of the impact evaluation results for the PG&E SmartAC program. First we provide some general background on the Program. Then we provide further explanation of the two technologies that were deployed and the implications for load impact assessment. We provide a brief overview of the methodologies used to derive the impact estimates. Finally, we explore the impact evaluation results and discuss their implications for DLC programs in general.

Background

PG&E's SmartAC program is an air conditioner DLC program. The Program uses paging signals from commercial providers and control technologies to limit air conditioner usage during Program events. Full Program population events will be triggered by insufficient system operating reserve or localized transmission or distribution constraints. The events used for this evaluation were called for a sample of 300 metered homes only, for the purposes of the evaluation itself.

The SmartAC program first began enlisting customers in Spring 2007. As of the end of August 2007, the Program had approximately 8,800 participants. By January, 2008 there were 26,000 participants with installed devices and another 22,000 participants who were enrolled and awaiting device installations. The vast majority of these participants are residential customers. The Program began by recruiting customers in San Joaquin County (the city of Stockton and its surrounding areas) but has since expanded to other areas of the PG&E service territory.

PG&E manages the marketing efforts, initiates the control events, and manages the overall Program. An implementation vendor handles the dedicated Program hotline, enrolls customers, schedules installation appointments, and installs the control devices. A technology vendor manufactures the control devices and manages the system that makes the control events possible. The SmartAC program pays all participants a one-time $25 "thank you" payment.

[1] In the fourth quarter of 2007, PG&E changed the Program's marketing strategy to offer only one of the devices at a time. The SmartAC EM&V sample is composed only of customers that responded to the first marketing campaigns, where both devices were offered simultaneously to all potential participants.

The SmartAC tariff, approved by the California Public Utilities Commission, states that:

- Residential participants on switches will be controlled up to 50%, commercial up to 33%.
- Participants on thermostats will experience indoor temperature setbacks of up to 4 degrees.
- SmartAC events will not exceed six hours per event.
- SmartAC events will not exceed 100 hours per year.
- Participating premises with multiple AC units are to have all units enrolled in the Program.

PG&E's SmartAC program is a complex, large-scale endeavor. The process side of the SmartAC program was evaluated by KEMA in parallel with the impact evaluation (KEMA 2008a). This paper is focused on the Program performance in terms of load reduction impacts.

Technology Options

This section discusses the specifics of the control technology options offered by the SmartAC program as they relate to potential impacts. The available choice of control technology has a direct bearing on the potential impacts of the Program.

The thermostats and switches used by the PG&E SmartAC program, although produced by the same manufacturer, share only basic similarities. Each technology receives a signal via a paging device to control AC units during Program events. Neither the switches nor the thermostats have two-way communication capabilities. Participants with either device can access a website or call a toll-free number to opt out of an event.

The thermostat option offered by the Program replaces a participant's existing thermostat(s) with a programmable communicating thermostat (PCT) advertised as a $200 value. The participant gains the functionality of a programmable thermostat, including web-based access to remotely change the home AC settings. Installation of the thermostat requires an indoor visit by a technician.

The switch technology offered by the SmartAC program is installed at the AC unit. The installation of the switch generally does not require an indoor visit. The switch provides the participants no additional functionality. The switch may be effectively invisible to the participant.

The different features of these two control technologies give PG&E flexibility in their marketing efforts. Participants may be motivated by the monetary value and functionality of the device itself (thermostat) or may prefer privacy and invisibility (switch). Multiple control technology options allow PG&E to cater to a wider range of potential participants.

Offering both options to all potential participants also means that the technology-related sub-populations are self-selected, both in the Program as a whole and in our study samples. This proved to be an important consideration when working with the impact results.

Switches

Switches and thermostats differ in how they lower AC load. Switches generate load reduction by directly controlling the operation of the AC compressor. The specifics of how the switch controls the AC compressor determine the effectiveness of switches with regards to both load reduction and customer comfort.

To review, an AC compressor has two modes: on or off. The amount of cooling provided is determined by how much the compressor runs. Duty cycle, expressed in percentage terms, indicates the run-time of an AC unit during a period of time. A 60 percent duty cycle would indicate the unit is running a total of 36 minutes in an hour.

The traditional non-adaptive switch essentially disconnects the AC unit during predetermined periods of a set length. One control regime, for example, restricts units from running for 12 out of every 30 minutes. Levels of control (or cycling) are described by the percent of time the unit is disconnected and restricted from running: 12 minutes every half hour amounts to 40 percent control.

Importantly, an AC unit's duty cycle will adjust to periods of control. That is, if the AC unit is needed for cooling, it will run whenever the switch allows. Thus, a unit running at 70 percent duty cycle that receives a 40 percent control regime will drop to a 60 percent duty cycle. The reduction in duty cycle only amounts to 10 percent. Because an AC unit will adjust to switch control periods, load reduction only occurs when expected duty cycle is greater than that allowed by the control level.

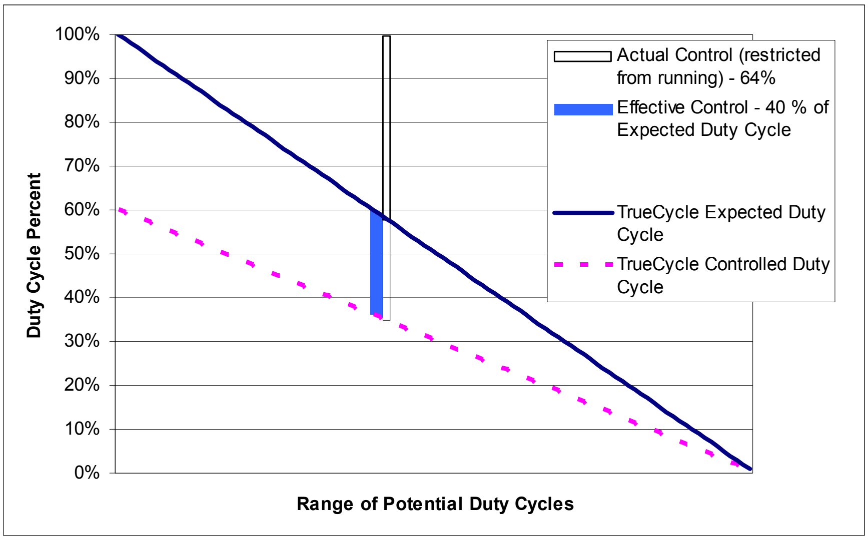
For this reason, program-level effectiveness of traditional switches is limited by AC units that are not running at higher duty cycles that generate greater duty cycle reduction. Oversized units and mild weather both cause "natural", un-controlled duty cycles to be less than 100%, thus lowering the duty cycle reduction. Oversizing, in particular, undermines load reduction even under the extreme conditions that typically motivate a DLC program event. This limitation to the effectiveness of traditional switches has led to a new generation of adaptive switches designed to anticipate the natural duty cycle of the AC unit[2].

The adaptive switches address the traditional switch limitation by "learning" the run-time behavior of the unit. The program administrator or system operator chooses learning days that have the characteristics of potential event days. The observed duty cycle on these learning days provides an estimate of expected duty cycle on an event day. The chosen level of control is then applied to the expected duty cycle, rather than selecting a level of control as a percent of a 100 percent duty cycle that occurs rarely, as with the non-adaptive switch.

Figure 1 provides a visual representation for a 40 percent adaptive control. The switch maintains an estimate of the expected duty cycle which may be less than 100 percent (solid line). Adaptive control disconnects the unit for 40 percent of the expected duty cycle (dashed line). If the expected duty cycle is at 60 percent, the effective control or duty cycle reduction will be 24 percent (40% x 60%, solid bar). To maintain that duty cycle reduction, the adaptive control will actually disconnect the unit for 64 percent of the time—that is, the time it would have been left off under natural conditions, plus 24 percent.

[2] The PG&E SmartAC program chose to use Cannon's TrueCycle technology adaptive switch.

Figure 1. Actual vs. Effective Control for Expected Duty Cycle of 60 Percent



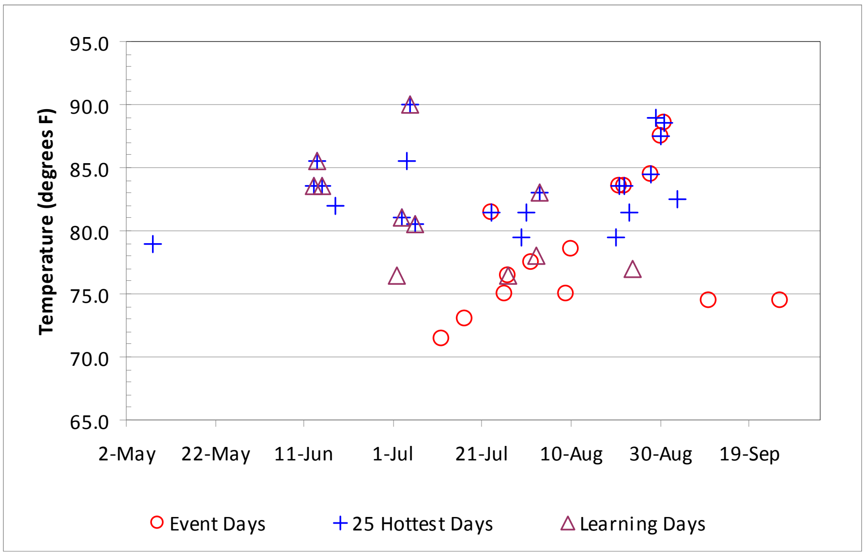
The success of the adaptive switch in overcoming the limitations of the traditional switch relies on the estimate of expected duty cycle. At the beginning of the cooling season, or any time the learning process fails, the default natural duty cycle for any hour is 100 percent. Under these default conditions, the adaptive switch control is identical with the traditional switch. As learning days are added, the estimated natural duty cycle is re-calculated, incorporating the observed duty cycle from the learning days. The manufacturer of the switch used for the SmartAC program indicates that they generally use a weight of one eighth for a single learning day. Under this scenario, if fewer than eight learning days have been identified, the remaining days included in the mean calculation are assumed to be at the default of 100 percent duty cycle. Using this approach, a rolling estimate of expected duty cycle for each hour is maintained for each AC unit. The switch also adjusts the hourly expected duty cycles to the duty cycle in the hour prior to the event to better match the actual magnitude of AC load on the event day.

The adaptive technology has a number of implications for the estimation of load impacts. Most importantly, traditional switch performance is the lower bound for the adaptive switches: adaptive load reduction can only increase duty cycle reduction compared to the traditional switches. In this respect, the technology has the potential to address the limitations of traditional switches with essentially no risk of decreasing load reduction.

The actual effectiveness of the adaptive technology in estimating expected duty cycle is difficult to determine. The number and choice of learning days drives the estimate along with the same day adjustment. Extreme conditions are experienced only infrequently, so the data on AC unit usage under extreme conditions is sparse. To the extent less extreme days are included in the calculation, the adaptive algorithm reflects the “shape” of hourly duty cycles on those less extreme days. The same-day adjustment may or may not correct for the difference in duty cycle magnitude between mild and extreme days. Any difference in the “shape” of mild and extreme day duty cycles through the afternoon will not be adjusted. In the interest of maintaining participant satisfaction, the adaptive switches are configured to revert to the default non-adaptive switch mode if the algorithm gives unexpected results.

Figure 2 plots the learning days used for the SmartAC adaptive switches along with the hottest 25 days and the event days.

Figure 2. Summer 2007 Hottest Days, Event Days and Learning Days



While there were some extreme days identified as learning days, there were also learning days not in the top 25 hottest days of the year. A rolling eight day average from the 2007 learning days would reflect conditions substantially more mild than the conditions faced in late August. The same day adjustment was designed to address exactly this problem. There are, however, scenarios where the adjustment would not help and the participant would face an effective control of greater than 50 percent.

It should be noted that the late August event days are the important days to consider in this respect. The day of the system peak occurred in the midst of those late August event days; in combination, those days represent the most extreme and extended heat wave of the summer. For the purposes of the M&V process many events occurred on less extreme days but this should not obscure the fact that the key test of the adaptive switch is its effectiveness on extreme days.

Adaptive switches will affect home cooling levels under three scenarios. First, unlike a non-adaptive switch, a well trained adaptive switch should alter cooling levels at any level of natural duty cycle for all participants. That is, even during events on moderate days participants will receive less cooling than they would without the Program. Second, for participants with oversized units, a properly calibrated adaptive switch should reduce cooling at approximately the same rate as with right sized units. Finally, because the actual control is greater than the default control level, the adaptive algorithm opens up the possibility of control greater than the full default percentage for participants with certain kinds of duty cycle "shapes" and the right combination of learning days. As should be expected, the effects on the cooling delivered parallel the duty cycle reduction improvements.

Thermostats

Thermostat control technology directly controls household temperature. When activated to event mode, the controllable thermostats increase the cooling setpoint. The unit may turn off if already in cooling mode. If the unit is already off, it may remain off for a longer period so as to allow the home to reach the new, higher indoor temperature. Using the thermostat setpoint as the focus of control puts the premium on controlling the increase in participant indoor temperatures. No participant should experience an indoor temperature increase greater than the setpoint increase. In theory, increasing the thermostat setpoint equitably distributes temperature increase across the participating population regardless of house, occupant temperature preference, and AC unit characteristics.

As indicated, the direct control of thermostat setpoint has an indirect effect on AC energy usage. How an AC unit responds to the setpoint increase will be a function of the pre-event cooling regime, the cycling schedule of the AC unit, house specific characteristics affecting the rate of indoor heat gain and the amount of setpoint increase. The most common scenario involves the AC unit turning off (or staying off) until the indoor temperature reaches the level of the higher setpoint. For this period, while the house warms to the new setpoint, program-related savings are 100 percent of the pre-program usage. Once the new equilibrium is reached, the AC unit returns to cycling behavior necessary to maintain cooling at this higher setpoint. As AC usage is fundamentally a function of indoor temperature, usage at the new setpoint will be reduced relative to pre-event usage levels. Thus for any setpoint increase, after relatively higher levels of impact during the re-adjustment period, impacts will settle down to a constant, but lower, level of impact reflecting the new (higher) indoor temperature that the thermostat is seeking to maintain.

When thermostats were first deployed for DLC programs, the most common control strategy was a single setpoint increase of three, four, or five degrees Fahrenheit. A single, block setpoint increase exacerbates the front loading of impacts. The extended initial period during which all units are readjusting to their new setpoint generates greater impacts than will be generated once all units are at their new equilibrium. From a system load reduction perspective, this inability to maintain a constant level of load reduction is a limitation.

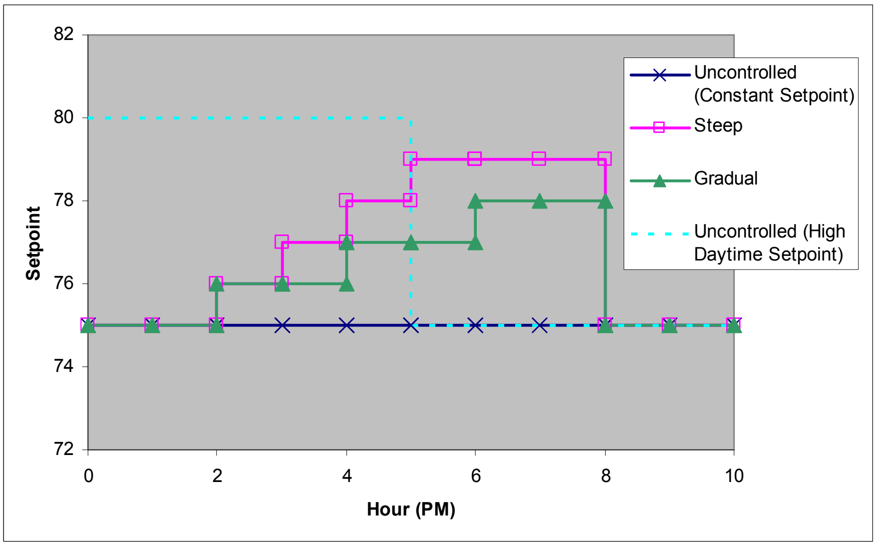
A single block setpoint increase has implications of a parallel nature for participants' perceptions of comfort. The period of readjustment to the new setpoint is experienced by the inhabitant as a period of no cooling. For what could be a substantial period of time, there is no blowing of the circulation system, no experience of cooling air. From a participant comfort perspective, the block set point increase also has limitations.

Utilities have experimented with ramped control strategies to combat the limitations of the block setpoint increase. Multiple increases of a degree or two should, in theory, mitigate both problematic aspects of the single block setpoint increase. Instead of inducing the load reduction and resulting lack of cooling in one long period at the beginning of the event, the periods of temperature equilibrium readjustment are shorter and spread out through the event.

The SmartAC program chose to use a ramping strategy for all Program thermostat participants if there were full-program events during summer 2007. Once the Program was deployed the ultimate strategy chosen imposed an increase of 1°F at the beginning of the first, third, and fifth hours of the event. We refer to this strategy as the "gradual" strategy. For the purpose of testing the ramping strategy concept, PG&E identified a second, more aggressive ramping strategy to be tested only on the M&E sample which we refer to as the "steep" strategy.

Figure 3 diagrams the two strategies applied in an alternating pattern to the two halves of the thermostat sample during the summer 2007. Consider first the constant uncontrolled setpoint. The gradual strategy is represented by three equal steps of one degree over two hours. The steep strategy increases the setpoint 1°F at the beginning of each of the first four hours. After the fourth increase, the steep strategy stays at a 4°F increase for the duration of the event. All else being equal, after the first hour the steep strategy ought to provide greater impacts than the gradual strategy.

Figure 3. Comparison of Ramping Strategies for 2 PM Start Time



The goal of both ramping strategies is to combat the twin limitations of a single block setpoint increase: front-weighted impacts and long periods with no cooling activity. This evaluation attempted to assess the effect of the ramping strategy on load reduction.

The thermostat re-set process has an additional complication. The thermostat calibrates all setpoint re-set levels, ramped or otherwise, using the lowest setpoint during the event period as its reference point. It does this to comply with the SmartAC tariff, which requires that PG&E setback the thermostat 4 degrees or less. Reconsider Figure 3 focusing on the uncontrolled setpoint set at 80° until 5pm. The controlled setpoint levels for the two ramping strategies are the same as for the constant setpoint at 75°. Thus, in the first hour, instead of a one degree increase in setpoint, the unit would experience a four degree lowering of the set-point. The next hour, the setpoint would increase a degree for the steep ramp, but this would still represent a setpoint three degrees lower than it would have been without the Program. This pattern continues until the time at which the thermostat would have been set down to the lower setpoint. On any day when the uncontrolled household temperature would have been above the ramped setpoint level, the thermostat re-set amounts to an increase in usage, or "anti-savings." The greater the difference between the uncontrolled internal household temperature and the daytime setpoint and the ramp setpoint levels, the greater the level of "anti-savings".

This additional complication is a direct outgrowth of participants using the programmable thermostat as it is best used – following the schedule of the dwelling's occupants. It is difficult to generate load reduction from resetting the setpoint of a unit that is initially off, and then turns on to cool an overheated house.[3] Once the new increased setpoint is reached (from above), the re-set delivers only the lower level load reduction associated with maintaining a higher indoor temperature.

Impact Analysis Methodology

Evaluation Meter Sample

For the impact evaluation, KEMA recruited a sample of 150 premises for each control technology, for a total of 300 premises. The samples were stratified by total tons (up to four tons or greater than or equal to four tons) and whether multiple units were present. The sample targets by size within each control technology were set proportionally to the number of cooling tons from the AC units enrolled in the Program. The initial Program rollout concentrated on marketing to residential rather than small commercial customers resulting in minimal participation of commercial customers. The sample reflects the population of Program participants.

KEMA installed loggers on all AC units at the selected sites. All sites using switch control were monitored using one-minute loggers. Sites with thermostat controls were logged with a mix of 15-minute and one-minute loggers. This was done to make use of available 15-minute loggers, while providing the high-frequency data needed for the planned duty cycle analysis. Loggers recorded instantaneous measures of amps every minute. The one-minute loggers permanently saved every reading, while the 15 minute loggers saved the mean value of these instantaneous readings every fifteen minutes. Amps were converted to kW using voltage measured at the unit.

Estimation of Impacts

We used two different modeling approaches to individually estimate unit-level load on event days in the absence of the Program.[4] One approach models unit kW as a function of degree days while the other approach models unit duty cycle as a function of degree days. The kW model is particularly useful for modeling thermostat based programs, while the duty cycle model allows for direct modeling of switch regimes.

The kW load model estimates load as a function of cooling degree days based on daily average temperature. Daily average temperature, calculated as the average of the maximum and minimum daily temperatures, captures the range of temperatures faced by the premise across the day. This model determines the optimal cooling degree base for each unit, effectively estimating the outdoor temperature at which cooling begins in the household. The model estimates hourly slope parameters using the single degree day level for each day. The hourly slopes on the degree day parameter represent the hourly AC usage per degree day.

The duty cycle model directly models unit duty cycle as a function of daily average temperature. Duty cycle is easily derived from instantaneous one-minute kW data. These data are

[3] Interestingly, once the unit is in cooling mode, switches have no such trouble. In fact, the 100 percent duty cycle needed to cool the house from daytime temperatures should yield high impacts. However, such participants could face uncomfortably warm houses when they return home.

[4] The methods are described more fully in the presentation “Adapting to the Adaptations: Smart Methods for Smart controls”. See References.

either zero or connected load (the load level the unit draws when running). Duty cycle equals the fraction of minutes per hour the unit is at connected load. Connected load is itself a function of hourly temperature. Connected loads generally increase with temperature at rates as high as one percent per degree Fahrenheit.

The duty cycle model uses a Tobit approach to address the censoring of duty cycle data at zero and 100 percent. We estimate separate models for each hour of the afternoon. The result is an estimate of duty cycle for all hours across the range of possible temperatures. We convert the duty cycle model estimates back to kW using the unit-specific connected load estimate.

For both models, hourly, unit-level impact is the difference between the modeled load and the observed load for event hours. We aggregate these results to the event and event hour level using ratio estimation with respect to unit tons. Estimating impacts on a per-ton basis makes the impact estimates more flexible to the potential changing composition of the Program with respect to unit size.

Impact Evaluation Results

Event Level Results

Table 1 provides load impact estimates for the full SmartAC program, for the five hottest days in order of descending daily average temperature. The estimated demand reduction on the hottest event day generated an average of 1.21 kilowatts of load savings for each participating unit. The five hottest event days generated impacts with statistical precision of 11 to 17 percent at the 90 percent confidence level.

Table 1. Program Impact Results, Average Per-Unit kW per Event (*)

Event Date	Event Day Daily Average Temperature	Event Start	Event Duration	Per Unit Impact (kW)	Participating Units	Program Wide Impact (MW)	Confidence Interval Lower Bound (MW)	Precision at 90 Percent Confidence (90/xx)
8/31/2007	88	2 PM	5	1.21	8,843	10.7	9.5	11%
8/30/2007	87	3 PM	4	1.02	8,809	9.0	7.8	13%
8/28/2007	84	3 PM	4	0.85	8,690	7.4	6.6	12%
8/21/2007	84	2 PM	5	0.71	8,306	5.9	5.1	13%
8/22/2007	83	2 PM	5	0.56	8,391	4.7	3.9	17%

(*) Event Averages do not include the first half hour of the event period when all participants are not yet activated.

The design of the PG&E SmartAC program sets up an inevitable comparison between the two control technologies. While it is impossible to avoid this, there are two essential caveats to be considered. First, as already stated, these two groups are self-selected. The very fact that they chose one control technology over the other makes them different. The differences between the two groups could extend to other characteristic and could be correlated to potential impacts. For example, frugal participants might be both attracted to the added value of the thermostats and also less inclined to use their AC. This combination could lead to lower impacts for the thermostats, but not necessarily as a result of thermostat effectiveness compared to switch effectiveness.

If this were the only difference between the two groups then the control technology results would provide a useful comparison of technology-specific impacts that *include* self-selection effects. After all, the participants a control technology attracts are a characteristic of that technology. However, there is a second caveat. As discussed above, the two control technologies have quite different control regimes, and importantly, it is very difficult to compare the expected magnitude of savings. Thus, the differences expressed here between the two different control technology groups' impacts reflect some combination of self-selection effects and potentially different expected impact magnitudes if there were no self-selection.

Table 2 presents results by control device for the five hottest days of 2007. On the hottest event day of the summer, August 31, 2007, the average impact for the switch control is 50 percent higher than the average impact for the thermostats. Over the five hottest days, the average impact for the switch controls is almost twice the average impact for the thermostats. These hot day impact differences between thermostats and switches are all statistically significant.

Table 2. Thermostat and Switch Impact Results, Average Per-Unit kW per Event

Event Date	Event Day Daily Average Temperature	Thermostat Participants			Switch Participants			Per-Unit Impact Difference Statistically Significant
		Per- Unit Impact (kW)	Standard Error	Precision at 90 Percent Confidence (90/xx)	Per- Unit Impact (kW)	Standard Error	Precision at 90 Percent Confidence (90/xx)	
8/31/2007	88	0.89	0.11	21%	1.34	0.10	12%	X
8/30/2007	87	0.48	0.11	38%	1.24	0.11	14%	X
8/28/2007	84	0.45	0.09	33%	1.02	0.08	12%	X
8/21/2007	84	0.51	0.08	27%	0.79	0.07	15%	X
8/22/2007	83	0.27	0.09	52%	0.68	0.07	18%	X

(*) Thermostat control results are a combination of the two ramping strategies used by the Program.

The results in Table 2 illustrate that variation across units with thermostat control is generally greater than the variation across units with switch control.

Figure 4 shows the two devices' different impact trends through the hours of the events. Both technologies show an increase in impact through the hours of the events. This is expected for switches. Houses absorb the day's heat through the afternoon approaching maximum internal temperatures well after the time of the maximum outdoor temperature. As natural duty cycles increase to address the warmer house, impacts based on a fraction of those duty cycles will also increase.

The increase in thermostat impacts over hours is consistently steeper than the switch impacts. The ramping strategies used for the thermostat are expected to counteract the common front-weighting of thermostat re-set impacts but they do not explain steeply increasing impacts like this. The only possible explanation for this impact trajectory is the disproportionately large effect of thermostats with high daytime setpoints. Due to the re-set algorithm these participants actually increase usage during the early hours of events, offsetting load reductions from other participants. This explains event impacts at 0.2 kW and lower in the early event hours on some of the hottest days of the summer.

Figure 4. Thermostat and Switch Impact Results, Average Per-Unit kW per Hour on Hottest Days

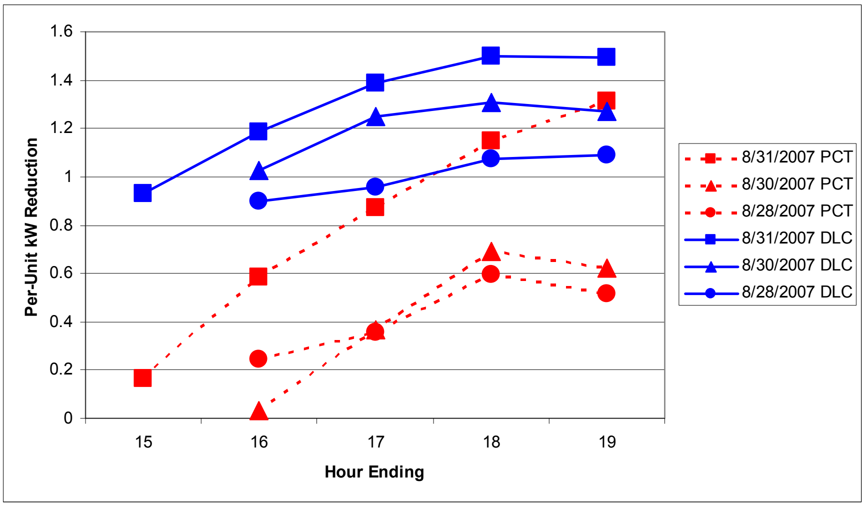


Figure 5 shows the hourly impacts for the two different ramping strategies. The ramp-specific results do not provide clear differentiation of ramp performance. The ramp strategies were alternated between two thermostat subgroups. The one day that shows statistically significant difference between the two ramp strategies (August 30th) is the only day of the three where that particular combination of group and ramp strategy occurred. To the extent that the difference reflects differences between the groups rather than between the ramp strategies, the ramp differentiation may be exaggerated on August 30th while underestimated on the other two days. This likely explains the unexpected greater impacts for the gradual ramp for the first three hours of the hottest day, August 31st.

Figure 5. Gradual and Steep Ramp Impact Results, Average Per-Unit kW per Hour on Hottest Days

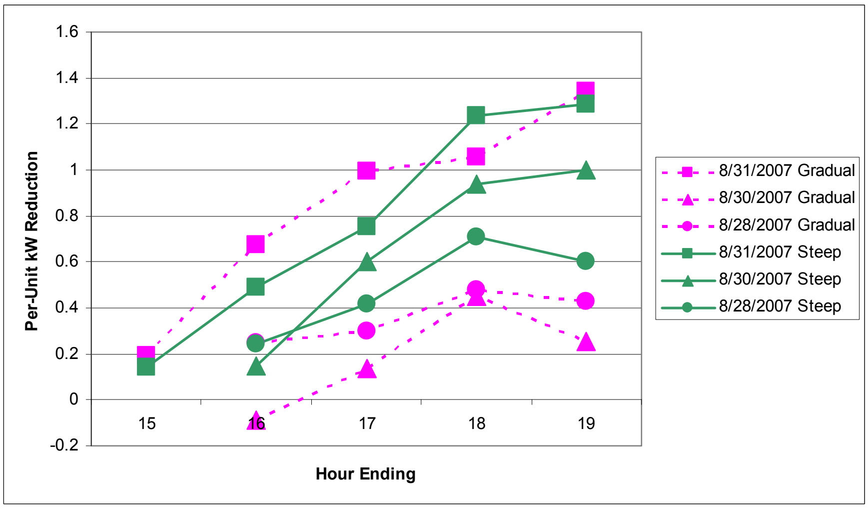
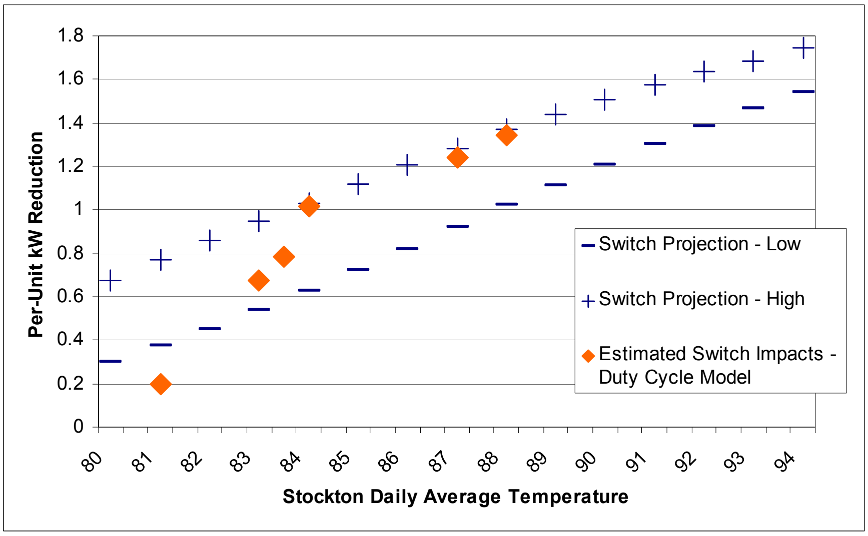


Figure 6 provides adaptive switch results compared to projected results using the underlying unit-specific models. The low projected results represent expected load reduction given a traditional straight 50 percent cycle regime. This plot indicates that the adaptive switches provide increased load reduction relative to that baseline standard.

Figure 6. Switch Impact Results vs. High and Low Projections



The high projection represents a simplified attempt to mimic the adaptive algorithm. This projection uses the model-based expected duty cycle and halves it to produce an estimate of adaptive switch impacts. The model-based estimate has the advantage over the actual adaptive algorithm of a full season of data and an explicitly temperature-based model. The plot illustrates that on the three hottest days the estimated switch impact results almost reach the idealized model projection levels.

Conclusions and Next Steps

In the SmartAC program, PG&E is successfully implementing an ambitious new DLC program. The number of participants already activated and/or signed up after only a year is impressive. The control technologies chosen for SmartAC program give PG&E flexibility in how the Program is marketed, and flexibility in the control strategies employed to generate load impacts.

This evaluation confirmed the effectiveness of the SmartAC program in generating impacts under peak load conditions. The adaptive switches delivered load impacts greater than one kW on the extreme days of summer 2007 (a relatively mild summer). The thermostats also delivered substantial load impacts on the most extreme days, despite the fact that one of the ramping strategies tested was relatively moderate. The load impact results from the two control technologies should not be directly compared given the self selection of technologies, and the differences in control levels employed for each technology.

For the adaptive switches, there is clear evidence they offer improved load impacts over traditional straight 50 percent switches. For the thermostats, the evidence on the ramping strategies is less clear. The comparison of ramping strategies did not show a consistent differential between the two strategies. More importantly, the thermostat impact results appear to highlight the difficulty of achieving load reduction from thermostats programmed with increased daytime temperature setpoints.

Next Steps

The evaluation of the SmartAC program continues in 2008. A substantially larger sample will be used reflecting the increased size and geographical spread of the Program. The evaluation will seek to quantify the impacts of the expanding program.

An additional goal of the 2008 evaluation is to further explore the issues surrounding thermostat impacts. The Program will test operating strategies including a ramping algorithm that starts with an initial two degree increase followed by two single degree increases over the next two hours. In addition, the Program will test the effectiveness of the thermostat when used to implement a straight 50% cycle.

Another goal of the 2008 evaluation is to assess program opt out rates. There were too few examples of opt out behavior in the evaluation sample for the summer of 2007 for the evaluation to directly assess opt outs as a function of various event characteristics. There may be many potential contributing factors which include; customers' lack of awareness of actual events in progress and awareness of their ability to opt out. The second summer of the Program may have different opt out rates and thus allow a more direct evaluation of this aspect of the Program.

References

Goldberg, M., M. Alexander, K. Agnew, P. Ham-Su. 2008. "Adapting to the Adaptations: Smart Methods for Smart controls". AEIC Load Research Workshop Presentation. February 23-25, 2008. http://www.aeic.org/load_research/docs/9_Smart_Methods_for_Smart_Control.pdf.

KEMA. 2008. *Final Report: Process Evaluation of 2007 PG&E Smart AC Program*. Study ID PGE0262.01. http://www.calmac.org.

KEMA. 2008. *Final Report Pacific Gas and Electric SmartAC Load Impact Evaluation*. Study ID PGE0262.02. http://www.calmac.org.