CYCLING FOR SUCCESS: IMPROVING THE EFFECTIVENESS OF LOAD CONTROL PROGRAMS

Rachel Reiss Buckley

The Problem with Direct Load Control

Rather than replacing direct load control air-conditioning cycling programs with other load control or demand response options, many utilities are looking for ways to improve their existing programs for residential and small business customers. One way to do that is to increase the cost-effectiveness of the programs. We recently learned that many utility load control programs are leaving money on the table because they don't necessarily obtain the maximum amount of load reduction per customer.

Two common methodologies for reducing load are duty cycling and temperature offset. Duty cycling limits the runtime of the air conditioner for a fixed percentage of time. For example, if a utility uses a 50 percent duty cycle, the compressor in the air conditioner will only be allowed to run for 15 minutes in each half-hour period (**Table 1**). With the temperature offset approach, the utility sends out a signal that changes the current setpoints on participants' thermostats by a specific amount.

Table 1: Duty cycling levels

Duty cycling limits the runtime of the air conditioner to a fixed percentage of time. Many utilities base duty cycles on 30-minute increments. For example, if a utility uses a 50 percent duty cycle, the compressor in the air conditioner will only be allowed to run for 15 minutes in each half-hour period. There is no universally accepted cycling strategy for this type of load control, but according to our research the most common strategy is a 50 percent duty cycle. The data presented here show how long an air conditioner would be off during a 30-minute period at different levels of cycling.

Level of cycling	Time equipment is off in a 30-minute period (minutes)
25 percent	7.5
33 percent	10.0
40 percent	12.0
50 percent	15.0
67 percent	20.0
80 percent	24.0
100 percent	30.0

Source: Platts

Some utilities use single-level cycling—that is, one level of cycling all the time—to keep programs simple, but that approach might not change air-conditioner operating patterns enough to result in significant load reductions, and individual customers' comfort conditions are variable. Likewise, some utilities that are using temperature offset only get short-term load reductions. To top it all off, free-riders and low-riders—customers who contribute no or little load reduction, respectively—bring down the average reduction per customer and waste precious utility dollars spent on incentives and curtailment equipment.

For little additional effort or investment, utilities can garner more load reduction per customer and make their programs more cost-effective. A utility could increase the level of cycling for existing customers, vary the cycling for different types of customers, or even drop customers from the program if it identified them as free-riders.

If customers have controllable thermostats, a utility can take the temperature offset approach instead of duty cycling, or if the utility is already using the temperature offset method, it can implement additional measures to obtain more-sustained load reductions than temperature offset alone typically produces. If a utility is recruiting new customers for its load management program and wants to ensure the maximum reduction per customer, it can use switches with adaptive algorithms or do more-targeted marketing to ensure that it gets the right customers on the program.

Utility load control programs aren't likely to disappear anytime soon, despite an industry-wide push toward giving customers ultimate control over their equipment. At least one cooperative utility has found a way to combine its pricing program with direct load control, and many utilities will likely continue their load control programs while running pricing or other demand response pilots or programs. Regardless of what the future might bring, improving the cost-effectiveness of existing programs is a worthwhile endeavor.

Traditional Cycling Strategies

If a utility only has load switches in the field, its sole option for a load control program is to cycle customers' air conditioners. If the utility chooses to deploy thermostats, it can decide which way it prefers to control customers' loads—through duty cycling or temperature offset. Many utilities that use duty cycling have implemented single-level cycling, meaning that they use one level of cycling all the time. Although there is no universally accepted cycling level (**Table 2**) for load control of air conditioners, we found that 50 percent duty cycling is the most commonly used level. Even though it is simple and straightforward, single-level cycling may not be the most-effective means of obtaining load reduction. Some utilities with thermostat-based programs have chosen to use temperature offset strategies instead of duty cycling. That's because the temperature offset approach is fairer to customers, it's easy to understand, and its impact on customer comfort is predictable. The two main problems with temperature offset are that it produces shorter-term load reductions than duty cycling, and some customers think it's intrusive.

Table 2: Utility duty cycling levels

We've listed a number of cycling levels used by selected utilities in the U.S. along with the load reduction per customer those strategies have achieved. The data mostly reflect the impact of 50 percent cycling, but there are many other options available to utilities.

Utility	Program	Cycling level (%)	Hours	Load reduction per unit (kW)
Louisville Gas & Electric	Demand Conservation	45	4 (2:00 to 6:00 p.m.)	0.72
Long Island Power Authority	LIPAedge	50	4 (2:00 to 6:00 p.m.)	1.04 residential; 1.2 to 1.3 small businesses
Con Edison	Central Air Conditioning (pilot)	50	4 (2:00 to 6:00 p.m.)	1.16
Florida Power & Light	Residential On-Call	50	3	1.44
Savannah Electric	Power Credit	67	2 or 4	NA
Idaho Power	Residential Air Conditioning Pilot Program (2003)	50	4 (3:00 to 7:00 p.m. or 2:00 to 6:00 p.m.)	0.78
Xcel Energy	Saver's Switch	50 in Minnesota; 55 in Colorado	4 (3:00 to 7:00 p.m.)	0.8 to 1.2
Jersey Central Power & Light	Appliance Cycling/ Direct Load Control	50	4 (noon to 8:00 p.m.)	0.72

Note: kW = kilowatts; NA = not available.

Source: Platts; data from utilities

Single-Level Cycling

The goal in utility load control programs is to strike a balance between customer comfort and load reduction, while keeping the program fair for all participants. When utilities first started these programs more than 20 years ago, they were only able to choose one level of cycling because control software sophisticated enough to vary cycling wasn't yet available. Many utilities have stuck with single-level cycling because they feel it's sufficient for their needs, and it makes for a simple program.

Some utilities go to great lengths to determine what level of cycling to use. One method is to sponsor focus groups to gather customer input. For example, when Florida Power & Light (FPL) was developing its Residential On-Call program in the early 1980s, program managers conducted extensive research to find out what customers understood about such programs and how much discomfort they would accept in their homes. The results allowed FPL to identify the point at which customers would start to notice that the utility was controlling their equipment; the point at which they would get annoyed; and the point at which they would get very, very annoyed. The program managers decided that a 50 percent cycling strategy struck a good balance between customer comfort and peak load relief. As Ed Malemezian, one of the project team members when the On- Call program started, told us, "I attribute the resounding success of the program to these upfront efforts."[1]

Other utilities simply try a cycling level and wait to see whether customers complain. If the customers don't protest, the utility sticks with that amount of cycling. Joe Lopes, senior vice president of the Applied Energy Group (AEG), the firm that operates the call center for the LIPAedge program and the Con Edison Central Air-Conditioning Pilot Program, says that customers at Long Island Power Authority (LIPA) and Con Edison seem to be pleased with the 50 percent cycling strategy the two utilities use.[2] Customers rarely call to protest, so the utilities haven't changed their strategy. However, the low complaint rate could be attributed to the fact that these two New York utilities can only invoke the programs in the event of an emergency, and they haven't had to call many curtailment events in the past two summers.

Some other utilities chose the cycling level based on the amount of load reduction they get per customer compared with the cost of running the program. They conduct scientific tests to determine the break-even point. Southern California Edison (SCE), for example, has been running its Residential Air-conditioning cycling program since 1983 and has tried control levels ranging from 33 to 57 percent. SCE decided that anything below 50 percent cycling was not cost-effective, based on the demand reduction achieved relative to program costs.[3]

Issues Associated with Single-Level Cycling

As noted earlier, single-level cycling may not result in as much benefit as possible, and the comfort conditions of individual customers can be hard to predict. These issues are not necessarily limiting factors in a load control program, but utilities considering such programs should be aware of what they are getting themselves into.

Single-level cycling may not produce enough load reduction. For duty cycling to be effective, air conditioners have to be running above the utility-imposed cycle level. That is, if a utility sends a 50 percent cycle signal, an air conditioner's compressor has to be running more than 15 out of 30 minutes to yield any load reduction. If a utility is not cycling at a high-enough level, the benefits reaped by the program will be greatly diminished.

---

[1] Ed Malemezian (December 16, 2004), President, Ed Malemezian Consulting, Stuart, FL, 772-286-9831, ed@emalemezian.com.

[2] Joe Lopes (January 3, 2005), Senior Vice President, Applied Energy Group, Hauppauge, NY, 631-434-1414 ext 13, jlopes@appliedenergygroup.com.

[3] Mark Martinez (December 14, 2004), Manager of Program Development, Southern California Edison (SCE), Walnut Grove, CA, 626-302-8643, mark.s.martinez@sce.com.

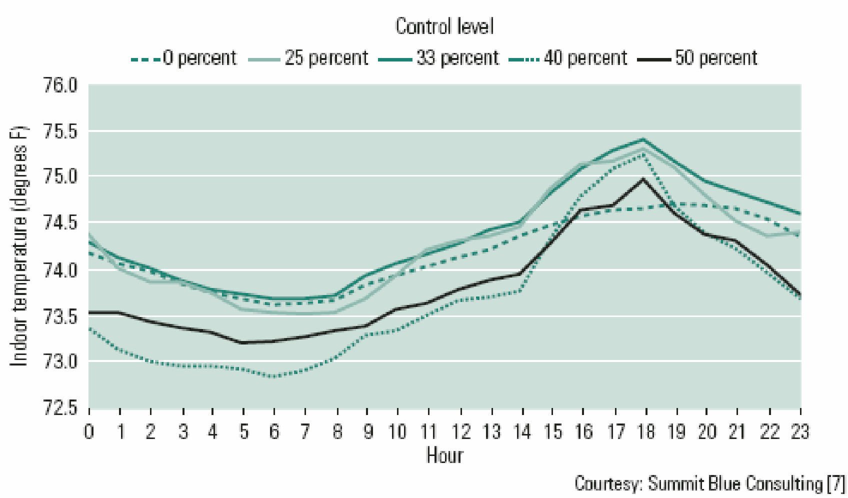
Dan Violette, principal at Summit Blue Consulting, told us that most utilities with direct load control programs could get more kilowatts of demand reduction for "free" if they cycled customer equipment at a higher level. The program costs are already paid for, including the equipment, incentives, and marketing.[4] All the utility would have to do is increase the cycling level or vary it by customer or by event.

Comfort conditions are variable. Every house will react differently to a given amount of cycling, which makes it difficult to predict exactly what will happen inside a customer's home during a curtailment. The amount by which internal temperatures increase will mostly depend on the following factors: Outdoor temperature, size of the air conditioner, tightness of the house, the house's susceptibly to solar gain (shading or lack thereof), and heat given off by the home's internal loads[5]. Utilities that have studied the effects of cycling agree that, on average, the impact on comfort is usually quite minimal. Past modeling performed by Summit Blue Consulting reveals an average increase of less than 2 degrees Fahrenheit (F) across control events in different geographic areas at all cycling levels.[6]

To evaluate its Demand Conservation Program, Louisville Gas & Electric (LG&E) installed a thermostat and a humidity sensor inside selected customers' homes, looking at the impact cycling had on internal temperature and relative humidity. The results showed that with 50 percent cycling there was an average increase of less than 1 degree inside the home over four hours (**Figure 1**), and about a 5 percent spike in indoor relative humidity (**Figure 2**).[7] LG&E generally controls customers' air conditioners on peak days from 2:00 to 6:00 p.m., because the utility usually hits its peak around 4:30 p.m.[8]

Figure 1: Average indoor air temperature at various control levels

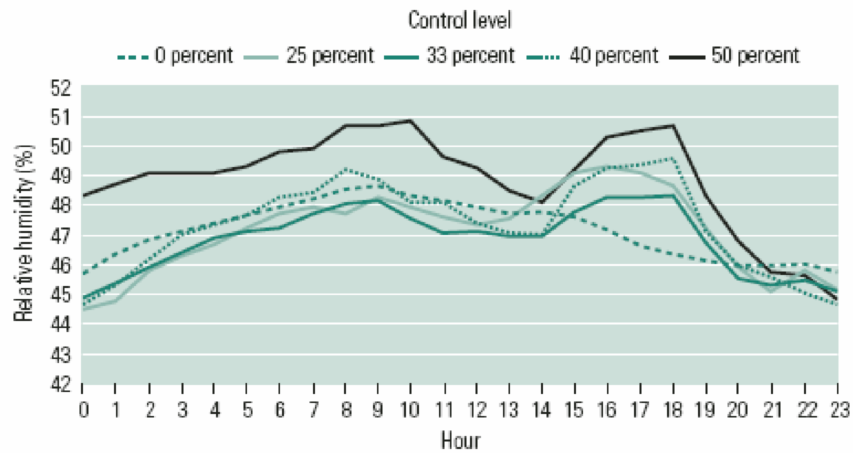
Louisville Gas & Electric found that the indoor temperature in monitored homes increased less than 1 degree Fahrenheit during several control events, even at the 50 percent cycling level.



[4] Dan Violette (December 28, 2004), Principal, Summit Blue Consulting, Boulder, CO, 720-564-1130, dviolette@summitblue.com.
[5] Joe Lopes [2]
[6] Dan Violette [4]
[7] Michael Ozog and Dan Violette, "Initial Evaluation Findings: Air-Conditioning Pilot Program," prepared for Idaho Power by Summit Blue Consulting (November 18, 2003), p. 26.
[8] Greg Fergason (January 4, 2005), Manager of Load Control, Louisville Gas & Electric, Louisville, KY, 502- 627-4883, greg.fergason@lgeenergy.com.

Figure 2: Average indoor relative humidity at various control levels

In Louisville Gas & Electric's study, the indoor relative humidity in the monitored homes increased at most by 5 percent during several control days, even at the 50 percent cycling level.



Courtesy: Summit Blue Consulting [7]

In its pilot program, Idaho Power also evaluated changes in the average indoor temperature due to cycling. The utility compared hourly temperature readings on a cycling day with readings taken on a non-cycling day during the same hours. Because Idaho Power is using Cannon Technology's ExpressStats—which store runtime and temperature data in a chip inside the thermostat—a technician can go out to a customer's home and download temperature and runtime data via a handheld PDA rather than having to install a monitoring device solely for this purpose. (For more on these advanced thermostats and other mass-market demand response technologies, see "The Latest Mass- Market Demand-Response Technologies," E SOURCE Report, ER-04-13.) Evaluators observed that, on average, the internal temperature inside the buildings increased by just 0.5 degrees over four hours with 50 percent cycling. The average outdoor temperature on both days was 95°F.[9]

This data represents the average house, but some homes will suffer greater impacts. It's important for utilities to know what to expect at the extremes. According to LG&E's manager of load control, Greg Fergason, on the hottest day and during the longest curtailments, the most extreme temperature increase was 2.5 degrees.[10] At Idaho Power, the temperature inside 13 customers' homes—out of 167 total, or 7.8 percent—increased more than 4 degrees.[11]

Many utilities have not factored in how any given customer's home will react to cycling. Instead, some have opted to take the temperature offset approach. The comfort impacts are less variable with that method.

Temperature Offset

If a utility has installed controllable thermostats in customers' homes, it can use the temperature offset approach as a means of load control. In the summer, the utility might send a signal to raise setpoints by 4 degrees over a four-hour curtailment period. Only a few utilities that we know of use temperature offset in their load control activities; all the others that have installed thermostats for load control programs appear to operate the thermostats like switches by cycling them. SCE typically uses a 4-degree

---

[9] "Load Reduction Analysis of the Air-Conditioning Cycling Pilot Program," prepared for Idaho Power by Summit Blue Consulting (December 23, 2003), pp. 2-8 to 2-9.

[10] Greg Fergason [8].

[11] "Load Reduction Analysis of the Air-Conditioning Cycling Pilot Program" [9].

temperature increase during two-hour blocks. It has deployed more than 8,500 Carrier thermostats for small commercial customers enrolled in its Energy$mart thermostat pilot program. Ameren and Austin Energy also use temperature offset.

Temperature offset offers several benefits over duty cycling. They include the following.
Delivers at least minimal load reduction. With duty cycling, air conditioners have to be running above the utility-imposed cycle level for the utility to get any load relief. But with temperature offset, the duty cycle of the air conditioner isn't critical to achieving demand reduction. As long as the signal to raise the setpoint reaches the thermostat, that customer should yield at least some amount of load reduction because the air conditioner will automatically run less frequently, allowing the internal temperature to drift up to the new setpoint.

Is fairer to all customers. The effects of duty cycling can be potentially more severe for some customers than for others, including those with undersized air-conditioning systems or with homes that are prone to large solar gains. Some industry experts consider temperature offset to be fairer for customers because everyone's comfort is affected by the same amount, regardless of the size of their home's air conditioner or other physical attributes of their house.

Is easier to understand. Temperature offset may also be easier for customers to understand than duty cycling. Customers don't have to know anything about air conditioners or different cycling strategies to determine whether they should enroll in the program. And each customer knows exactly what will happen—the utility will raise the temperature inside their home or business by a specific amount.

Has a more predictable impact on customer comfort. With temperature offset, utilities don't have to worry about customers getting too uncomfortable. The temperature offset produces predictable changes in comfort because it raises temperatures in homes by the same amount for all customers, regardless of the many factors that can affect how frequently an air conditioner cycles.

These days, more utilities are offering thermostats to new program participants, so we're likely to see more utilities using temperature offset in their air-conditioner load control programs.

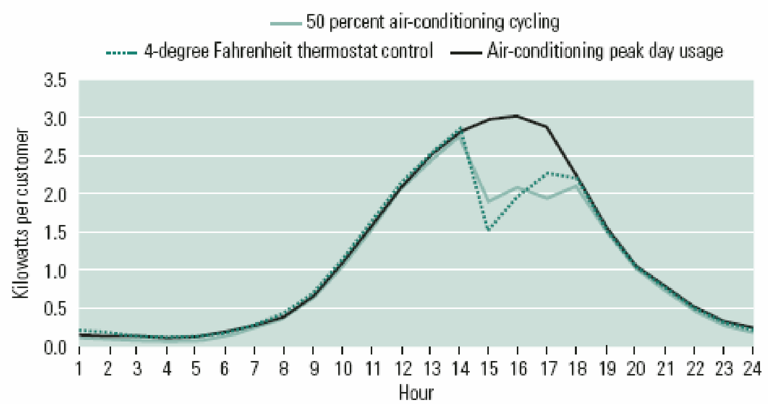
Issues Associated with Temperature Offset
There are two main drawbacks for temperature offset. First, the utility only gets short-term load reductions. Second, some customers find the temperature offset approach to be too intrusive.

Only delivers short-term load reduction. Duty cycling produces consistent load shed over the duration of the curtailment period because the air conditioners shut off for the same percentage of time during each hour. Temperature offset, on the other hand, does not produce an even load reduction over a curtailment period. The load reduction mainly occurs in the first hour, because it takes almost a full hour for the temperature inside individual houses to rise to the specified setpoint; during the next three hours the air conditioners run, but not as much as they otherwise would have.

The second and third hours do yield *some* reductions, because the air conditioners have to run to keep the temperature below the adjusted setpoint. Toward the end of the curtailment, the thermostats start to kick in more frequently to maintain the temperature and then to return the house to the lower programmed setpoint after the event is over. For example, through its Energy$mart Thermostat program, SCE offsets the temperature by 4 degrees and gets 1.5 kilowatts (kW) of load reduction in the first hour, 0.75 kW in the second, 0.25 kW in the third, and no reduction in the fourth. As **Figure 3** shows, the reduction isn't as consistent with temperature offset as it is with duty cycling.[12]

Figure 3: Load reduction with temperature offset and duty cycling

Most of the reduction from temperature offset occurs in the first hour, whereas with duty cycling the load reduction is consistent over the entire event. Mark Martinez, the manager of program development at Southern California Edison (SCE), constructed this graph using data from SCE's Energy$mart thermostat program and the Long Island Power Authority's LIPAedge program, because both of those utilities use Carrier ComfortChoice thermostats for their small business customers.



Courtesy: Southern California Edison [12]

Because temperature offset produces most of its load reduction during the first hour, it's a good strategy for short events such as brief transmission constraints or local distribution problems. If the utility is running short events, it can do temperature offsets much more frequently than duty cycling because, overall, the customers won't be affected for as long. That's an attractive attribute for utilities wanting to use load control to alleviate relatively short-lived problems.

Can seem intrusive to customers. Not everyone thinks temperature offset is a good idea. LG&E conducted a preference study among its load control customers and found that they overwhelmingly disliked the idea of having the utility change their setpoints. The surveyed customers thought temperature offset was more intrusive than duty cycling because they perceive it as taking place "inside the house," whereas cycling is perceived as occurring "outside the house" because that's where the switch is located. Around 75 percent of the respondents preferred cycling. It's possible, however that this survey drew on a biased sample, because the customers who were surveyed were already enrolled in the utility's cycling program.[13]

As you can see, both single-level cycling and temperature offset offer advantages and disadvantages (**Table 3**). By improving the application of either approach, utilities can increase the amount of load reduction per customer and improve the cost-effectiveness of their programs.

---

[12] Mark Martinez, Southern California Edison, "Demand Response as a Distributed Energy Resource," presentation to the PLMA Fall Conference, Orlando, FL (September 29, 2004), from www.peaklma.com/files/public/fall2004program.htm (December 2004).

[13] Greg Fergason [8].

Table 3: Comparison of duty cycling and temperature offset

Duty cycle control is more consistent, the reductions it produces are maintained over longer periods, it's better suited to residential customers, and it's better for emergency operation. Temperature offset is perhaps more fair to customers, as it has a more consistent impact across all program participants. However, the highest load reductions with temperature offset occur in the first hour of an event, and those reductions aren't sustained over the entire period.

	Duty cycling	Temperature offset
Consistent over curtailment	●	
Fair		●
Predictable comfort impacts		●
Better for frequent, short events		●
Suitable for long events	●	
Perceived by customers to be intrusive		●

Source: Platts

Challenges to Cost-Effective Load Control Programs

Free-riders and low-riders are the bane of utility direct load control programs because they waste the utility's time, money, and equipment while contributing little load reduction. But that's not the only challenge these programs must overcome. There's also the phenomenon of "snapback"—also known as the rebound effect—to contend with.

Low-Riders and Free-Riders

Low-riders are participants whose air conditioner isn't running enough during an event to contribute any load reduction. Free-riders are program participants who would already have their air conditioner turned off during a curtailment event, because they normally keep it turned off at that time every day. In milder climates, air conditioners don't run very often, even on peak days, so the utility garners little if any load reduction from its customers. As we noted earlier, duty cycling is only effective with customers whose base duty cycle, or runtime, exceeds the limit the utility imposes—most often 50 percent cycling.

Low-riders. Low-riders are a problem for many load control programs, but they are particularly hard on programs offered in milder climates where compressors don't cycle very often. Low-riders aren't as common in warmer climates. The load control tariff at Wisconsin Public Service (WPS), for example, states that the utility can cycle its customers' air conditioners off from 5 to 20 minutes out of every 30 minutes. Mary Klos, a member of the Customer Value & Support Services group at WPS, recently told us, "When we have tested cycling in the past, the impact has been minimal. Most of the air conditioners in our territory are very oversized due to the relatively low air-conditioning load in our climate. As a result, most of the units aren't running more than 50 percent of the time, even on hot days."[14]

WPS recently verified this assertion using hourly data from automated meter reads from a sample of 1,000 direct load control customers. The utility's load research analysts determined that WPS would get an average reduction of 1.3 kW per customer if it shed customers' entire air-conditioning load (that is, went to a 100 percent cycling level) during peak weather conditions. The connected air-conditioning load is about 2.5 to 3.0 kW, indicating that the air conditioners normally only run 50 percent of the time even during peak weather. Therefore, cycling them at 50 percent would do nothing to reduce peak load.

---

[14] Mary Klos (January 7, 2005), Customer Value and Support Services/Research Services, WPS Resources, Wisconsin Public Service (WPS), Green Bay, WI, 920-433-2554, mklos@wpsr.com.

Free-riders. There are two types of free-riders: those whose air conditioners are completely off, and those who are in houses or business facilities with multiple cooling zones. Although the average number of free-riders in load control programs across the U.S. runs around 30 percent of all participants, the actual numbers vary from one utility to another. At Idaho Power, roughly 35 percent of the participants in its Residential Air-Conditioning Pilot Program contribute zero or very minimal reductions on control days because their air conditioners are shut off or running below the utility-imposed cycling level on those days.[15]

At LG&E in Kentucky, program evaluators measured the percentage of air conditioners that were actually on during any given day at various outdoor temperatures (**Table 4**).[16] At 90°F, 36 percent of all program participants had their air conditioners turned off, meaning that if LG&E had run a curtailment event, at least 36 percent of the participants would not have contributed any load reduction. At LIPA in New York State, approximately 15 to 18 percent of residential air-conditioning units are off on hot days, mostly because people aren't home or because they prefer to not use their air conditioning. About 22 to 30 percent of the commercial units are off on hot days.

Table 4: Percentage of air conditioners operating under different climate conditions

In 2003, program evaluators for the Louisville Gas & Electric (LG&E) Demand Conservation program measured how many customers had their air conditioners turned on at various outdoor temperatures. At 90 degrees Fahrenheit, 36 percent of all program participants had their air conditioners turned off, meaning that if LG&E had run a curtailment event, at least 36 percent of the participants would not have contributed any load reduction.

Outdoor air temperature (°F)	Percentage of units turned on
80	35
85	54
90	64

Courtesy: Louisville Gas & Electric [16]

Homes or businesses with multiple HVAC zones also contribute to the free-rider count, because in a facility with two zones, only one of the air-conditioning units might be on at any given time, even though both units would be enrolled in the program. Nearly one-third (31 percent) of all residential customers enrolled in the LIPAedge program have multiple thermostats. Typically the upstairs thermostat in a two-zone house is the one that's off, because the residents aren't usually in their bedrooms during the day.[17] In SCE's Energy$mart Thermostat Pilot, 60 percent of the customers enrolled in the program had multiple air-conditioning units—some as many as 8 or 10—because all of the participants were business customers.[18]

Issues Associated with Low-Riders and Free-Riders

When low- and free-riders are enrolled in load control programs, the utility winds up spending money to install equipment for and providing incentives to customers who won't be delivering any load reduction.

---

[15] "Load Reduction Analysis of the Air-Conditioning Cycling Pilot Program" [9], p. 2-1.

[16] "LG&E/KU Demand Conservation Program Evaluation Report," prepared by Summit Blue Consulting for Louisville Gas & Electric (January 13, 2004), p. 6.

[17] Joe Lopes [2].

[18] Joe Lopes, "Case Studies in Advanced Thermostat Control for Demand Response," presentation to AEIC Load Research Conference, St. Louis, MO (July 2004).

And because these customers don't contribute load reductions, they dilute the load control resource for the utility.

While working for a utility a number of years ago, AEG's Joe Lopes tested a few different control strategies. He discovered that the highest amount of reduction the utility could ever obtain, no matter what cycle level it used, was 40 percent, because so many air conditioners were actually off during the peak period. So, for example, LIPA gets an average duty cycle reduction of 35 percent for residential customers when its dispatchers send out a 50 percent curtailment signal.

In addition to dealing with low- and free-riders, utilities must account for snapback when estimating the impacts of their load control programs.

Accounting for Snapback

Snapback is a secondary spike in demand. It typically occurs in a load control program when many air conditioners collectively run after the control period ends to provide cooling that the curtailment event deferred. Snapback, which is common in most climate zones, is found within both residential and small business programs and it occurs with both duty cycling and temperature offset. Increased kilowatt usage after a curtailment period shows that cooling demand has been time-shifted rather than truly shed.

The amount of snapback depends on four key factors. The first is rural versus urban settings. If the building the utility is controlling is located in a city, it will likely produce more snapback. That's because urban buildings stay hotter later in the day thanks to the heat retention of all the concrete and asphalt. When the curtailment ends, the air conditioner kicks in to cool down the space. As we might expect, AEG's experts say that Con Edison's more urban program suffers more from snapback than does LIPA's less urban program.

Another facet of the rural versus urban factor is that individual commuting patterns can also affect the size of snapback. In areas around cities, people tend to have longer commutes. As a result, those who live outside a city may not need their air conditioner to come back on toward the end of the curtailment period (they won't be home yet). Workers who have a shorter commute are more likely to turn their air conditioners on when they get home after a curtailment, thereby contributing to snapback as they cool down their homes in the early evening.

The second factor is the type of establishment, especially within the small business sector. As we saw in Figure 3, SCE does not encounter much snapback. This is probably due to the fact that the program participants are business customers, and by the time the curtailment is over, many of these businesses are closing down for the day and are shutting off their air conditioners anyway.[19] For restaurants, dinner patrons usually don't arrive until after a curtailment is over, so there isn't usually a lot of snapback from those customers either.[20] Retail stores, on the other hand, want to keep their customers comfortable until the stores close for the evening, so snapback from those businesses will probably be greater.

Climate is the third key factor that contributes to snapback. In a humid climate, people might run their air conditioners later into the evening to mitigate the humidity, whereas in a more arid climate like that of Boulder, Colorado, once the sun goes down the air quickly gets cooler and more pleasant.

Hot days separated by cool nights will also have a different impact on snapback than consistently hot days and nights. If it gets cool at night, people are likely to be more tolerant, knowing that they'll be able to get the heat out of their homes at night. If it stays hot longer into the evening, or if it is hot for

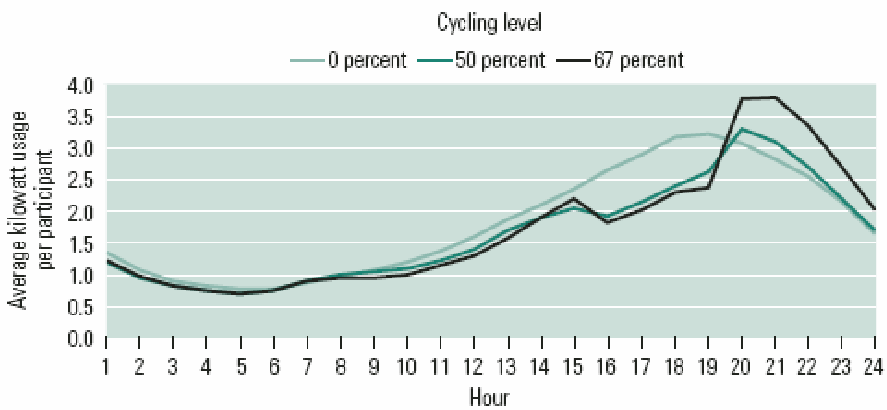
[19] Mark Martinez [3].
[20] Joe Lopes [2].

several days in a row, customers will likely want to cool off more after the curtailment period ends. When Idaho Power studied the impact of a range of nighttime temperatures, it found that a single hot day surrounded by cooler days would result in very different amounts of snapback as compared with a hot day in the middle of a heat wave.[21]

The fourth key factor is cycling levels. Deeper cycling levels typically result in a bigger snapback. The longer an air conditioner is off, the hotter it's likely to get inside, and the customer will want additional cooling when the curtailment is over. That's certainly what Idaho Power has seen with deeper cycling (**Figure 4**).[22]

Figure 4: Snapback from different cycling levels

In July 2004, Idaho Power tested both 50 and 67 percent duty cycling. The snapback from the 67 percent cycling was significantly higher than the snapback from the 50 percent cycling.



Courtesy: Summit Blue Consulting [22]

Getting More out of Existing Participants

The best way to make a program more cost-effective is to get a higher average load reduction per customer. There are a few mechanisms that can help you accomplish this, including increasing the cycling level, using multi-level cycling, switching to the temperature offset approach, and finding ways to sustain reductions.

Increase Cycling Levels

Increasing the single-level cycling utilities impose on customers will increase the average load reduction per customer. For example, in summer 2003 the Idaho Power Residential Air- Conditioning Pilot Program used 50 percent cycling, but in 2004 the program managers tested 67 percent cycling. They cycled 20 days at 50 percent and 10 days at 67 percent, starting in mid- July. When they increased the cycling from 50 to 67 percent, the load reduced per customer went from 0.8 to 1.2 kW (refer back to Figure 4).

Through its PowerStat pilot, SMUD also tested various control strategies at different temperatures to determine what the optimal cycling strategy was. As **Table 5** shows, the load reductions increased with higher cycling levels and on hotter days.[23]

---

[21] Michael Ozog and Dan Violette, "Air-Conditioning Pilot Program 2004 Evaluation," prepared for Idaho Power by Summit Blue Consulting (December 10, 2004), p. 18.

[22] Michael Ozog and Dan Violette [21], p. 4; and Michael Ozog (January 12, 2005), Senior Consultant, Summit Blue Consulting, Boulder, CO, 720-564-1130, mozog@summitblue.com.

[23] Data from"PowerStat Pilot Program Evaluation Report," prepared by the Sacramento Municipal Utility District (SMUD) and Summit Blue Consulting (October 2003); Derric Rebello (January 26, 2005), Vice President, Quantum Consulting Inc.,

Table 5: Estimated load reduction at different levels of cycling

Sacramento Municipal Utility District's PowerStat pilot program tested various control strategies on days with different temperatures. Load reductions increased with the amount of cycling and with temperature.

	Cycling level							
	25 percent	33 percent	37 percent	50 percent	66 percent	75 percent	87 percent	100 percent
Outdoor temperature (°F)	Estimated load reduction (kW per air-conditioning unit)							
90 or less	0.46	0.60	0.68	0.91	1.21	1.37	1.59	1.83
91 to 95	0.49	0.64	0.72	0.98	1.29	1.46	1.70	1.95
96 to 100	0.54	0.71	0.80	1.08	1.43	1.62	1.88	2.17
101 to 105	0.60	0.80	0.89	1.21	1.59	1.81	2.10	2.42

Note: F = Fahrenheit; kW = kilowatts. Courtesy: Sacramento Municipal Utility District [23]

Such data clearly indicate that customers are willing to tolerate more cycling. A national market research study conducted by Quantum Consulting in 2002 shows that most customers are willing to accept a higher level of control than utilities think. In fact, a majority of customers are willing to accept at least 50 percent cycling, and more than half of the survey participants expressed a preference for cycling at 50 percent or higher. One-third of the survey participants said they considered levels of 67 percent or more to be okay.[24]

Some industry experts claim that if no one is uncomfortable or complaining, the utility probably isn't getting enough demand relief from program participants.[25] But utilities are often reluctant to increase the amount of cycling for fear that customer comfort will be sacrificed. They want to keep a healthy balance between customer satisfaction and load reduction. SMUD's PeakCorps program, however, routinely cycles up to 83 percent. The program has high customer penetration, too—one-half of all SMUD's residential customers with central air conditioning are participating. The only real program dropouts come from move-ins and move-outs. The program has been around for a long time, so it's possible that customers who are already on the program are used to it, whereas newcomers may have doubts about how much their comfort would be affected if they opted to participate.[26]

Not everyone agrees that increasing the cycling level is a good idea, because at some point you'll increase the number of free-riders. In the late 1980s, LIPA ran a program with three different incentive levels. The utility found that once cycling exceeds 50 percent, the program begins to draw too many free-riders. In fact, most of the people who signed up for the highest level of cycling (67 percent) turned out to be free-riders.[27]

Use Multi-Level Cycling

Rather than simply instituting higher single-level cycling, some utilities vary the amounts of cycling by customer or by day. Some give customers a choice, whereas others make a decision based on what their technicians observe when they install the necessary equipment in the field. Some implement different cycling levels based on how much load reduction they need on any given day, and others prefer to reduce a customer's amount of cycling rather than drop that customer off the program if he or she complains. Some traditional load switches can handle different levels of cycling, but it depends on the

---

510-540-7200, drebello@QCWorld.com; and Craig Sherman (January 11, 2005), Demand-Side Specialist, SMUD, 916-732-6943, csherman@smud.org.

[24] Derrick Rebello, PhD, "Survey of Residential Direct Load Control Customers: A National Benchmark," prepared by Quantum Consulting Inc. (February 4, 2002), p. 2-35.

[25] Charles Parsons, Load Control Product Manager, and Roger Rognli, Load Management Engineer (December 27, 2004), Cannon Technologies, Golden Valley, MN, 763-595-7777, rrognli@cannontech.com and cparsons@cannontech.com.

[26] Dan Violette (December 13, 2004) [4].

[27] Joe Lopes [2].

vendor—each load control manufacturer provides its own control software.[28] Cannon and Comverge each build flexibility for multiple levels of cycling into their systems, but other companies may not.

Customer's choice. Many utilities offer their customers different incentives based on the level of cycling the customer chooses or the level of inconvenience a customer is willing to tolerate. A utility might offer an incentive of $5 per month for 67 percent cycling or $3 per month for 50 percent cycling. (**Table 6** provides some examples of utilities that offer customers multi-level cycling.) A few utilities offer their customers even more choices, such as letting them select the upper limit of how many days they are willing to have their equipment cycled in one season. SCE's Residential Air-Conditioner Cycling Enhanced Program offers double the incentive provided to participants in its Residential Air-Conditioner Cycling Base Program because "Enhanced" program customers agree to an unlimited number of cycling periods during the summer. The "Base" program limits cycling to fewer than 15 periods during the summer[29]

Table 6: Utilities offering multi-level cycling strategies

Some utilities offer higher incentives to customers who agree to accept higher cycling levels. Southern California Edison's Base Program limits cycling to less than 15 control days per summer, whereas the utility's "Enhanced" program allows an unrestricted number of cycling days. Sacramento Municipal Utility District's PowerStat pilot program tested the use of thermostats, and its Peak Corps program is a traditional load control switch program.

Utility	Program name	Percentage of cycling	Incentives ($)
Southern California Edison	Residential Air-Conditioner Cycling Base	100	0.18 per ton of AC per day
		67	0.10 per ton of AC per day
		50	0.05 per ton of AC per day
	Residential Air-Conditioner Cycling Enhanced	100	0.36 per ton of AC per day
		67	0.20 per ton of AC per day
		50	0.10 per ton of AC per day
Sacramento Municipal Utility District	Peak Corps	100	5.00 per month, plus 3.00 for each cycling day
		65	3.75 per month, plus 2.00 for each cycling day
		45	2.50 per month, plus 1.00 for each cycling day
Pepco	Kilowatchers	100	4.00 credit per month plus 1.50 per cycling day
		43	1.00 credit per month plus 1.00 per cycling day
Sacramento Municipal Utility District	PowerStat (pilot)	100	5.00 per month
		66	3.75 per month
		50	2.50 per month
Wisconsin Public Service	HELP	100	8.00 per month (June–September)
		17 to 67	No bill credit
ComEd	Nature First	100	10.00 per month (June–September)
		50	5.00 per month

Note: AC = air conditioning.

Source: Platts; data from utilities

Dispatcher's decision. A utility can also choose to set cycling levels based on the amount of load reduction it needs on a particular day. This could be done per event or multi-level cycling could be used within an event. For example, a utility could implement 50 percent cycling for the first two hours and 67 percent for the second two hours, when overall energy use hits its peak. SMUD is one utility that varies

---

[28] Dan Violette (December 13, 2004) [4].

[29] SCE, "2004 Load Management Annual Report" (May 2004), from www.sce.com (accessed December 2004); and SCE, "Summer Discount Plan," from www.sce.com/RebatesandSavings/Residential/SummerDiscountPlan (accessed January 6, 2005).

the amount of cycling on a per-event basis; its dispatcher decides how much load relief is needed that day and sends a signal for cycling that can range between 25 and 100 percent.[30]

Installer's selection. There are three things installers of load control devices can look for to decide how much cycling an individual customer can handle. First, if the installer sees that there are lots of trees surrounding the house that would prevent the home from getting too hot inside, it's likely that this customer could handle a higher amount of cycling. Second, if the installer discovers that a customer has an undersized air conditioner, which would result in the internal temperature increasing a lot if that unit were cycled more, that customer would be put on a lower cycling strategy. Third, when an installer goes out to install a switch, he or she can check the program on the customer's thermostat. If the thermostat is set to cool at the peak, the installer would put that customer on a lower cycling level.[31] This is one way to keep customers comfortable while still getting some load relief for the utility.

Complainer's cycle. Another strategy for balancing customer satisfaction against higher amounts of load relief is to reduce a customer's cycling level if the customer calls to complain. That allows the utility to continue getting some load reduction rather than letting the customer drop out of the program. Some utilities call this a secondary program.[32]

Some industry experts don't endorse the idea of offering different amounts of cycling, because they feel it's unfair to some customers. LG&E's Greg Fergason says that the impact on different homes is related to the size of each home's air conditioner, and the customer usually doesn't have any control over that. Most often it's the contractor who decides what size the air conditioner should be, and only 20 percent of the time do contractors properly size these units. Contractors commonly install a model with the same capacity as the existing unit or they might upsize it a bit. Therefore, it's unfair to pay some customers more than others for enduring the same inconvenience.[33]

AEG's Joe Lopes also warns against varying the amount of cycling within a program because of bad feelings that can arise among customers. He points out that LIPA got many of its sign-ups for LIPAedge from word-of-mouth recommendations exchanged among customers. If one person on the block is being cycled at 33 percent and another at 67 percent, but they are getting the same incentive, the utility and its program could suffer.[34]

Adopt the Temperature Offset Approach

We know of a few utilities that have installed controllable thermostats but operate them like switches. But if thermostats are available, one way to increase the average load reduction is to adopt the temperature offset approach. Because an air conditioner will hardly run as it allows the temperature to drift up to the utility-imposed setpoint, it's likely that the utility will obtain at least some reduction.

Fine-Tune Temperature Offset to Achieve Sustained Reductions

If a utility is already using temperature offset, there are three options for getting around the fact that temperature offset only produces significant load relief in the first hour.

Phase in areas. One way to extend the load reduction is to phase in different neighborhoods or parts of the service territory at different times. This will help produce an even curtailment over four hours, because each area will be contributing first-hour reductions at different times.

---

[30] Dan Violette [4].
[31] Charles Parsons and Roger Rognli [25].
[32] Charles Parsons and Roger Rognli [25].
[33] Greg Fergason [8].
[34] Joe Lopes [2].

Refresh the curtailment. Refreshing a curtailment after a few hours makes sense for several reasons. Where customers are able to override curtailments, refreshing the signal will cancel out any overrides. Also, radio signals—often delivered via paging technologies—sometimes don't get through to all of the thermostats on the first try, so sending the signal more than once may help it reach all possible targets. Furthermore, if a utility only planned to do a two-hour event, by the end of the second hour the air conditioners may be working to bring the temperature back down to the customer-programmed setpoint. Because there is usually some latency in paging, it might take around 10 minutes for a signal to reach a given thermostat. Let's say that the first event was supposed to end at 4:00 p.m., and the utility sends a new signal at 4:00 p.m. to extend the event. If the signal doesn't reach the thermostat until 4:10, in that 10 minutes the air conditioner will have been working at full strength to get back to the customer's setpoint. The second signal would give the utility a new round of first-hour load reduction.

SCE, for example, did a pair of two-hour events back-to-back on October 14, 2004. The average outdoor temperature was 87°F. The resulting energy reductions were as follows: 0.21 kilowatt-hours (kWh) per ton in the first hour, 0.17 kWh/ton in the second hour, 0.21 kWh/ton in the third hour, and 0.13 kWh/ton in the fourth hour. By issuing two signals, SCE was able to get two first-hour reductions during the same event while also sustaining the event for longer.[35]

Ramp up the temperature. Some industry experts assert that the threshold for people to notice a temperature change is about 4 degrees in total,[36] while others claim that people can tolerate a temperature increase of 1 degree per hour without really noticing it.[37] Therefore, if a utility sends a signal to ramp the temperature up by about 1 degree per hour, customers likely wouldn't even notice the warmer temperatures, and the utility would garner a consistent reduction over the course of the curtailment event. So, for a four-hour curtailment, the utility would raise the temperature setpoint 1 degree in the first hour, 2 in the second, 3 in the third, and 4 in the fourth hour. According to Cannon Technologies, two of its utility customers are currently testing similar strategies. Both utilities are ramping up the temperature 3 degrees over four hours. They also ramp back down (by 3 degrees) in the last hour of control to reduce snapback after the end of the event. Cannon representatives report that the initial statistics for this strategy look very promising.

Solutions for New Participants

If a utility's goal is signing up new program participants, then installing switches armed with adaptive algorithms and using targeted marketing can help ensure maximum load reduction per customer and enhance the program's cost-effectiveness.

Switches with Adaptive Algorithms

Some utilities are using switches with adaptive algorithms to get more load reduction per customer. Adaptive algorithms are instructions on a chip built into a load switch that will cycle the equipment based on an individual customer's actual usage. The switch stores information about the runtime of an air conditioner. When the utility sends a control signal, each customer's air conditioner is automatically cycled based on that unit's baseline data, producing equal demand savings from all customers. (For more on how the technology works, see the E SOURCE report ER-04-13 and E NEWS issue 67.)

Some load control vendors offer a replacement board with an adaptive algorithm to retrofit existing switches. This could also be beneficial for older programs with existing customers. As the utility is inspecting its switches, it could install the new circuit boards. As we noted on page 7, Mary Klos from

---

[35] Mark Martinez (December 14, 2004 and January 26, 2005) [3].
[36] Joe Lopes [2].
[37] Charles Parsons and Roger Rognli [25].

WPS told us that the utility receives very minimal load reduction from cycling because most of the air-conditioning units aren't running more than 50 percent to begin with. She says, "We are very excited about the TrueCycle adaptive algorithm option from Cannon. That technology may allow us to cycle at levels lower than 100 percent and get reductions in load."[38]

Adaptive algorithms have also been shown to minimize low-riders on a program. LG&E, for example, was not getting as much load reduction as program managers had expected when they started the program in 2002. That's because many of the utility's customers had oversized air conditioners and the compressors weren't cycling enough. LG&E's Greg Fergason told us that the utility put interval meters on 20 homes to monitor the performance of switches both with and without adaptive algorithms. Based on that investigation, he thinks it's "well worth the effort to put in the adaptive algorithms, because in homes where we weren't getting any load reduction at all, we're now getting a significant amount. We're seeing more than a 15 percent increase in the amount of peak demand reduction overall as a result of the adaptive algorithms."

During the 2004 testing season, the hottest day LG&E experienced was only 93°F, and that was only for one day. If LG&E were to have a hotter summer, it would likely see load reduction improvement of up to 20 percent. He says, "I'm a big believer in switches with adaptive algorithms and won't be installing any switches without them going forward. Both the Cannon and Comverge algorithms—we're testing both—work equally well."[39]

Xcel Energy has also had success with an adaptive algorithm switch Cannon built especially for the utility's Saver's Switch program. When Xcel tested the new technology among residential customers in Colorado and Minnesota and business customers in Wisconsin, it gained about 30 percent additional load reduction as compared with the previous technology—totaling around 1.24 kW of load reduction per switch using a 50 percent cycling strategy. Peter Narog, manager of consumer DSM programs at Xcel, told us that the company is planning to add 40,000 more switches with its version of the TrueCycle algorithms by summer 2005.[40]

Some observers think the adaptive algorithm approach is fairer for customers, because it gives a break to those who have undersized air conditioners and takes something away from those with oversized units. We recommend at least giving switches with adaptive algorithms a try.

Targeted Marketing: Get the Right People on the Program

Another strategy for weeding out free-riders and increasing the average load reduction per customer is to target only those customers who can really contribute to the program. For residential customers, it makes sense to target potential participants based on electricity usage. The first assessment methodology is to look at total monthly energy usage. Customers with low energy usage (less than 500 kWh) each month are also likely to have low or no air-conditioning usage. Second, utilities could restrict thermostat enrollment to one thermostat per home, only allowing residential customers to enroll the thermostat on the main floor.

The third technique involves looking at the change in monthly energy usage between a low cooling period and a high cooling period, such as between May and August. Customers with lots of air-conditioning usage are likely to have a large differential in energy consumption from spring to summer. A model developed by Summit Blue Consulting for Idaho Power revealed that program participants with

---

[38] Mary Klos [14].
[39] Greg Fergason [8].
[40] Peter Narog (December 21, 2004), Manager, Consumer DSM Programs, Xcel Energy, Denver, CO, 303-294- 2138, peter.narog@xcelenergy.com.

minimal changes in monthly consumption between May and August do indeed produce less load reduction. The average reduction from these customers is 0.64 kW versus 0.77 kW for all program participants.[41]

Con Edison and LIPA agree that targeted marketing is a good idea, and they mostly use direct mail to market their programs. These utilities developed a ratio consisting of April/October usage divided by July/August usage to pinpoint the customers who had and who used central air conditioning. The average usage ratio ranged from 1.7 to 1.8. Customers with higher ratios typically used their air conditioning a lot, and anyone with a ratio higher than 2.0 received a direct mailing. The utilities verified the accuracy of this method by sending technicians into the field to confirm which customers had air conditioning. The ratios turned out to be very accurate in identifying customers who fit the optimal profile.[42]

However, as with multi-level cycling, some utilities may not want to pursue this approach—or their commissions won't allow them to—because it could be seen as discriminating against potential participants. Note that if the program isn't closed to other participants, some customers will get more mailings than others.

Epilogue: Out with the Old?

Direct load control is here to stay, so it's important to make the most of it. Although many utilities are seeking ways to improve their direct load control programs, others—or, in some cases, the same ones—are conducting time-variant pricing experiments for demand response. Price-triggered demand response is gaining favor, but how will it work with direct load control?

Some utilities are offering direct load control in conjunction with pricing programs. The Community Energy Cooperative in Chicago, Illinois, offers a residential real-time pricing program called the Energy-Smart Pricing Plan. The program, which is intended to enhance customer response to market signals, provides customers with fair options for managing their electricity use, because the retail prices reflect the cost of power in wholesale markets.

So far, program evaluators have noticed that customers with the least price elasticity (those least likely to respond to high prices) tend to have central air conditioning rather than no air conditioning or window air conditioning in both single- and multi-family residences (**Table 7**).[43] To increase the load reductions from the low-elasticity customers and to help the co-op avoid high real-time prices, Community Energy added switches to its pricing program in 2004. Program managers offered 50 customers (out of about 400) who had central air conditioning an opportunity to be automatically cycled at 50 percent during high price periods.

---

[41] "Load Reduction Analysis of the Air-Conditioning Cycling Pilot Program" [9], p. 2-6 to 2-7.
[42] Joe Lopes [2].
[43] "Evaluation of the Energy-Smart Pricing Plan," prepared by Summit Blue Consulting for Community Energy Cooperative (February 2004); and 2004 update from Dan Violette [4].

Table 7: Load reductions by house type and air-conditioning equipment

Customers in single-family homes with central air conditioning were the least responsive to high price signals, whereas multi-family customers without air conditioning of any kind showed the most elasticity.

House type	Air-conditioning equipment	Load reduction (%)
Single family	No AC	8.0
Single family	Window AC	8.0
Single family	Central AC	5.2
Multi-family	No AC	11.7
Multi-family	Window AC	10.5
Multi-family	Central AC	8.7

Note: AC = air conditioning.

Source: Platts; data from Summit Blue Consulting [43]

When Summit Blue Consulting, the program evaluator, looked at those 50 customers' load reductions, it found that although they did decrease their usage, the co-op only garnered about a 10 percent reduction rather than the expected 50 percent reduction. That was due to the weather being unusually mild in Chicago during the summer of 2004.[44] Only a few days were warmer than 90°F, so it wasn't hot enough to use air conditioning more than 50 percent of the time. Furthermore, temperatures both before and after the high-priced days were very low, so there weren't any hot days outside the high-price periods to compare results against. Community Energy is planning to try the cycling again during summer 2005 and may install more switches before then.[45]

Although we don't think utility load control programs are likely to disappear anytime soon, there is an industrywide push toward giving customers ultimate control over their own equipment. Whatever the future brings, improving the cost-effectiveness of existing programs is still a useful exercise. We recommend that utilities consider the following options:

- Varying the level of cycling or the temperature offset by hour or by customer
- Using aggressive cycling levels
- Conducting targeted marketing based on billing data
- Using switches with adaptive algorithms

A combination of several different strategies may double or triple a utility's return on investment.

[44] Dan Violette [4].

[45] Kathy Tholin (January 11, 2005), General Manager, Community Energy Cooperative, Chicago, IL, 773-486- 7600 ext 130, kathy@energycooperative.net.