Consolidated Edison of New York
Room Air Conditioning Pilot

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Abstract

Within the urban NYC marketplace, one category of plug loads stands out. The demand resulting from room air-conditioners (2500 MW) outnumbers that from HVAC systems (600 MW), and accounts for almost 20% of the summertime load. Through a partnership with Con Edison, ThinkEco developed a new technology that enables the thermostatic, remote control and monitoring of room air conditioners (RACs). Because this technology allows for the remote cycling of RACs around a higher temperature during a demand response (or load curtailment) event, our hypothesis was that it would lead to a meaningful reduction of system load without significantly compromising occupant comfort. During the summer of 2011, this technology was deployed in a large residential mixed-income complex as a study involving 231 RACs. The study showed a KEMA-validated average load reduction of 26% across the three hottest days where demand response events were called. To test the veracity of savings, a comprehensive set of 24 matched day baselines were developed. These baselines were defined by qualifying days based on load and temperatures, true up periods and mechanisms. In addition, the NYISO baseline was also tested. The savings estimated by the alternative baselines were generally consistent and supported the conclusion that the technology reduced demand during event periods. To enable better planning of a more expansive program, estimates of variability were also developed using the study results. In summary, the study demonstrated that significant load curtailment is possible in a plug-load category that has previously been challenging to enroll in demand-response programs.

Project Description

Location

The experiment was designed using a single large, mixed income residential apartment complex in Manhattan, New York (Figure 1). This complex consisted of 4 identical buildings with 400+ apartments each. Residents had anywhere from one to five RACs in their apartments, with 2 being the average. Self reported age and income levels spanned a very wide spectrum, as did familiarity with computers and ownership of smartphones.

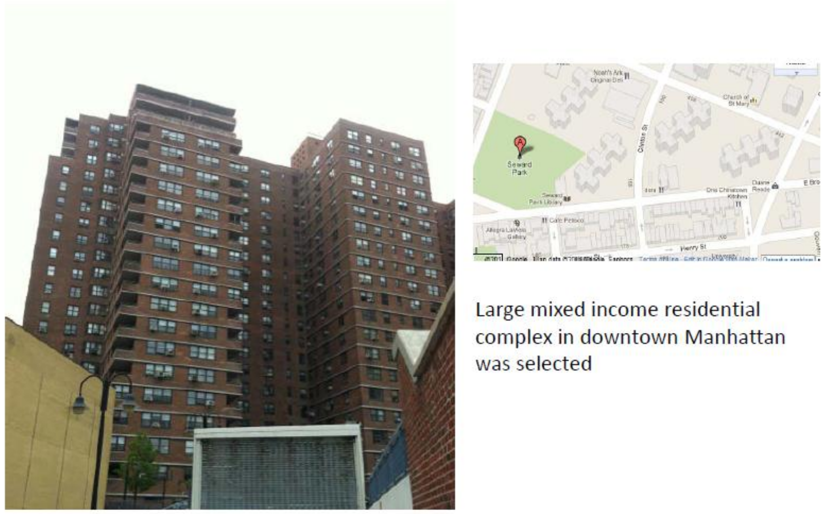

Figure 1. Large Mixed Income Residential Complex in Manhattan

Equipment

Figure 2 presents the ThinkEco technology solution. The ThinkEco technology uses a modlet attached to the RAC with a wireless remote control unit and includes the ability to display information through a web portal, smart phone or on the temperature indicator screen on the remote control unit. This allows consumers to "see" and control their RAC unit from inside or outside the home. In addition, the utility is given a view into the RAC performance allowing participation in a demand response program event. The ThinkEco technology was installed on the air conditioners in June, 2011. There were no events called in June, instead the project team monitored the baseline energy use of the units. During June, participants were asked to install the demand response equipment on their primary AC. In July, participants were given additional demand response equipment for the other air conditioners in their apartments.

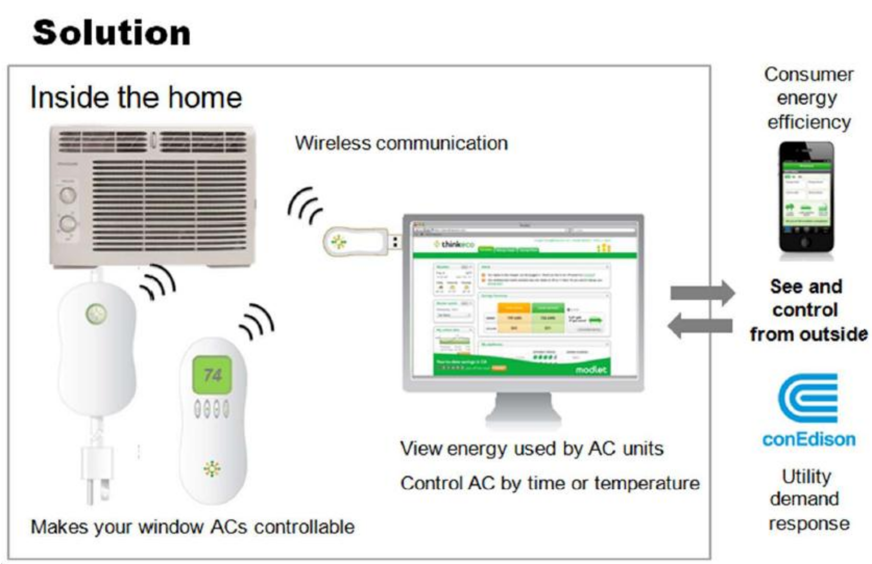

Figure 2. ThinkEco RAC's DR Solution

Customer Recruiting

Participants for the coolNYC™ study were recruited using a variety of strategies including: posting flyers in common areas, sending emails from the building property managers, and hosting a few tabling events in the building lobbies. The tabling events, in addition to allowing participants to sign up, also served as a means to educate potential participants about the study, show them the product, and answer questions about the study.

Potential participants were required to fill out an intake survey – either online or in person. The information gathered included:

- Basic contact information including
  - Name
  - Address
  - Phone number and
  - Email
- Information about their typical air conditioner usage,
- Number and type of air conditioners owned, and
- Type of computer owned
- Type of Internet connection

The basic criterion for inclusion in the study was: owning at least 1 window air-conditioner and having an Internet-enabled computer. Once potential participants were deemed eligible, they received a welcome letter to the study.

To distribute the coolNYC kits to participants, two on-site tabling events were hosted by the project team. The tabling events were beneficial as they provided a forum for the coolNYC team to:

- Confirm participants' information (contact info, number of RACs and type of computer),
- Review the installation procedure, and
- Distribute the materials.

Equipment Installation

The project team encouraged the participants to try to self-install after walking them through all the steps and providing a clear instructions sheet. However, the team was also available to assist those participants who were uncomfortable installing computer software or who had difficulty after trying to self-install. The result was that <u>80% of participants</u> were able to self-install.

Experimental and Sample Design

For this demonstration project, there was no control group requiring comparison days to be derived from participant "non-event" days. In addition, there was no formal "sample design" so the sample participants were treated as a simple random sample for analysis purposes. Finally, the participants "self-selected" themselves into the program which gives us some pause in extrapolating the findings to a broader based implementation of the program. Any extrapolation should be done with appropriate caveats.

2011 Events

A total of five load control events were conducted in July and August. The date and timing of these events are shown in Table 1. The July events coincided with demand response days in NYC. The temperatures on these days were very warm with a maximum of 104^{o}F reached on July 22, 2011.

In implementing the events, participants were notified via email 24 hours prior to an event, followed by a reminder 2 hours prior to the event. Participants were automatically opted in unless they actively opted out through the software or using the technology[1]. During the event, the temperature setting on the thermostat was raised by several degrees so that the AC units would cycle off more often. This raised temperature setting was reinforced halfway through each demand response event, so that even if participants opted out of the first half of the event, they would be opted back in for the second half. This 'refresh' ensured consistency in methodology between this study and Con Edison's other direct load control programs.

Table 1. CoolNYC Events

		Temperature (F)	
Date	Event Time	Average	Maximum
7/21/2011	12 pm - 5 pm	82	96
7/22/2011	2 pm -5 pm	93	104
8/2/2011	5 pm - 10 pm	80	92
8/17/2011	5 pm - 10 pm	77	85
8/25/2011	5 pm - 10 pm	75	81

Data Availability and Review

For the analysis, there were a total of 231 air conditioners in the study with very detailed 1-minute interval load data available for the event windows. The load data were available from June 10 through August 31st; however, due to insufficient data June 10th and July 15th were excluded from the analysis. To reduce the overall size of the dataset, the data were aggregated to 15-minute intervals for data transfer and analysis. Figure 3 and Figure 4 presents examples of the data available for analysis and present the customer-to-customer variability in room unit air conditioning use. Both figures present Thursday, June 16, 2011, a non-event day. Figure 3 displays the usage of the AC unit in the black line, the outdoor temperature in the red line and the indoor temperature in the green line. On this day, this unit was active in the late morning/afternoon from 11am until 3pm and in the evening from 5pm until after 10pm.

[1] Users were able to opt out prior to the event by logging into their online account, and clicking "disable" for each RAC they wanted to opt out on. During the event, users were able to opt out by manually changing the temperature on their thermostat remote.

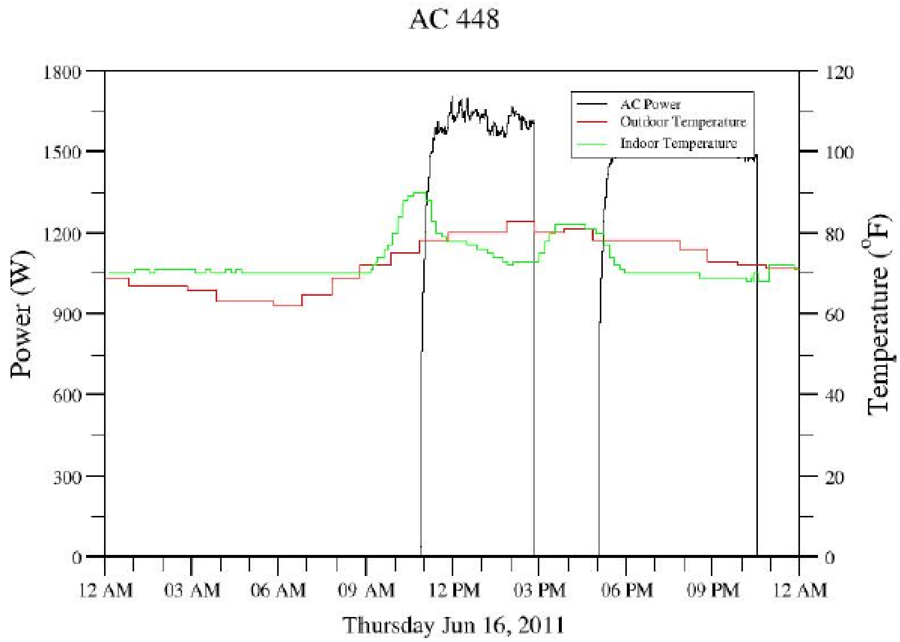

Figure 3. RAC Unit with Daytime and Evening Usage

Figure 4 shows a different customer for the exact same day, Thursday, June 16, 2011 with very different performance characteristics. For this participant the RAC comes on late in the evening and cycles throughout the night time hours but is off during the daylight hours.

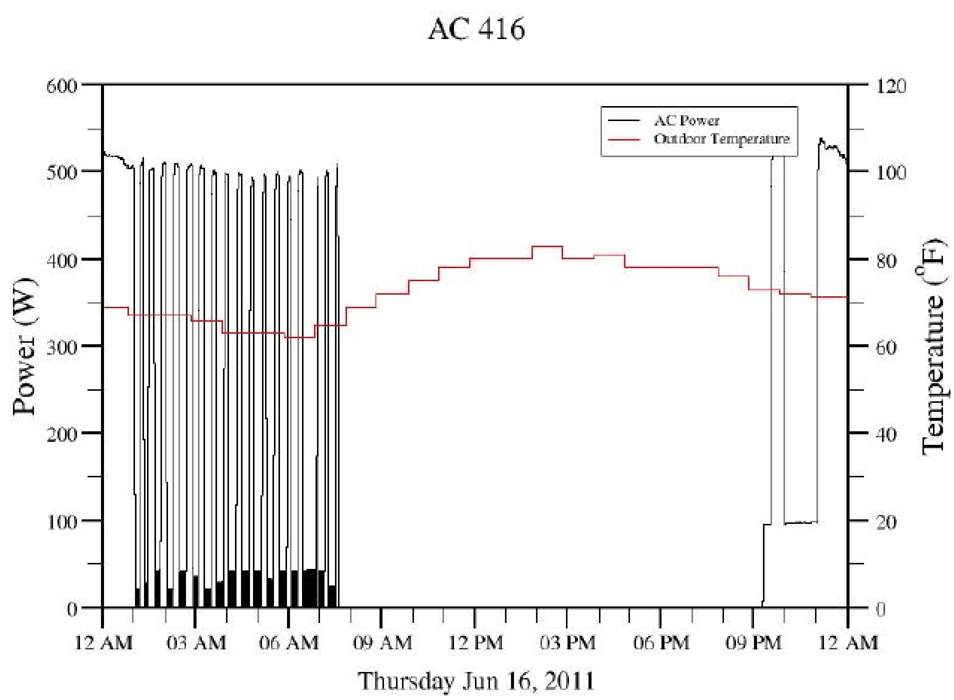

Figure 4. RAC Unit with Late Night and Early Morning Usage

Analysis Approach

The approach used in this study was based on three steps. The first step was to select the days to use in the calculation of the baseline. The second step was to select the method, if any, to use in calculating an adjustment factor for the baseline. The third step was to apply the adjustment factor appropriately to the baseline and calculate the reduction during the event time.

Selection Method for Baseline Days

Of all possible days, baseline days were selected based on the days with the smallest absolute difference with respect to the average usage during the observed time frame (except for the temperature method – see below). We examined three separate time frames:

1. Hours before one hour prior to the start of the event ("Before Only" Method);
2. Hours after one hour subsequent to the end of the event[2] ("After Only" Method); and
3. Hours before one hour prior to the start of the event and hours after one hour subsequent to the end of the event ("Before and After" Method).

The temperature method selected the three most appropriate days based on those days with the highest correlation to the event day's weather. The number of days selected was chosen to be three days, (the same number of days that were selected in the ThinkEco analysis). For consistency across all alternative methods observed, three days were the number of days selected to calculate the baseline. For the NYISO Baseline Method, the top five out of the last ten days with the highest average demand were selected to calculate the average baseline for event days that occurred on Monday – Thursday. For Fridays, the top two out of three days were selected. Once the days were selected, the baseline is calculated by averaging the demands for all fifteen minute intervals.

Selection Method for Adjustment Factor

Once the baseline day is calculated, the profile needs to be adjusted to accommodate for differing weather patterns. Similar to the selection method for the baseline days above, the same type of methods were employed to calculate an adjustment factor. The hours selected to calculate the adjustment compare the baseline against the event day in three different ways.

1. Hours before one hour prior to the start of the event ("Before Only" Method);
2. Hours after one hour subsequent to the end of the event[1] ("After Only" Method); and
3. Hours before one hour prior to the start of the event and hours after one hour subsequent to the end of the event ("Before and After" Method).
4. For the NYISO Baseline Method, two hours were selected. They were the two hours starting four hours before the start of the event (i.e. if the event started at noon then 8 am and 9 am were selected).

[2] Note that for the August dates, which had events ending at 10 PM, would have started at 11 PM for a comparison. Since this only allowed one hour to compare the possible days with the event days, two additional hours into the next morning were applied to the method to provide more data in the selection process.

Calculating and Applying the Adjustment Factor

Looking at the hours selected, we examined the use of an additive factor and a multiplicative factor applied to the baseline. To calculate the additive factor, we take the hours selected, subtract the baseline demand from the event demand for all fifteen-minute intervals, and calculate the average of those differences. Adding that adjustment factor back to all of the hours of the baseline profile adjusts the baseline profile appropriately.

To calculate the multiplicative factor, we take three hours for the selected (six hours if the selected method is both before and after) and divide the event power by the baseline power. Multiplying the factor to all intervals in the baseline profile adjusts the baseline appropriately. For the NYISO Baseline Method, the multiplicative method is used for the hours selected.

Baseline Summary

In this analysis, there were four possible methods to select the day to calculate the baseline, three possible methods to use to calculate the adjustment factor, and two possible methods to apply the adjustment factor to the baseline. Or, in total, twenty-four possible combinations to compare. Along with the NYISO Baseline Method, the analysis examined a total of twenty-five possible combinations.

During the analysis, we determined that the hours prior to the start of the event did not properly encompass the total load of the baseline days, so any method, with the exception of the NYISO method, that contained the "Before Only" selection method for either the baseline days or the adjustment factor were subsequently excluded. We also determined that there was no distinct difference in the "After Only" and "Before and After" selection methods for selecting baseline days. This resulted in examining nine combinations for inclusion in the final KEMA analysis based on Selection method for baseline days, true-up method for adjustment factor, and true-up basis. These are presented in the table below.

Table 2. Methods Used in Analysis

Selection Method	True-Up Method	True-Up Basis
1. Before and After	Before and After	Additive
2. Before and After	Before and After	Multiplicative
3. Before and After	After Only	Additive
4. Before and After	After Only	Multiplicative
5. Temperature	Before and After	Additive
6. Temperature	Before and After	Multiplicative
7. Temperature	After Only	Additive
8. Temperature	After Only	Multiplicative
9. NYISO	Before Only	Multiplicative

Analysis Findings

As discussed above, KEMA examined nine alternative analysis strategies. As an example of the analytical results, Figure 5 and Figure 6 present two graphical examples. The first shows the before/after, before/after with the additive adjustment. The second displays the NYISO approach. Both figures show significant reduction during the event period (highlighted in yellow). The NYISO method as compared to the matched day method produces lower savings estimates for warmer days, but higher savings for milder days.

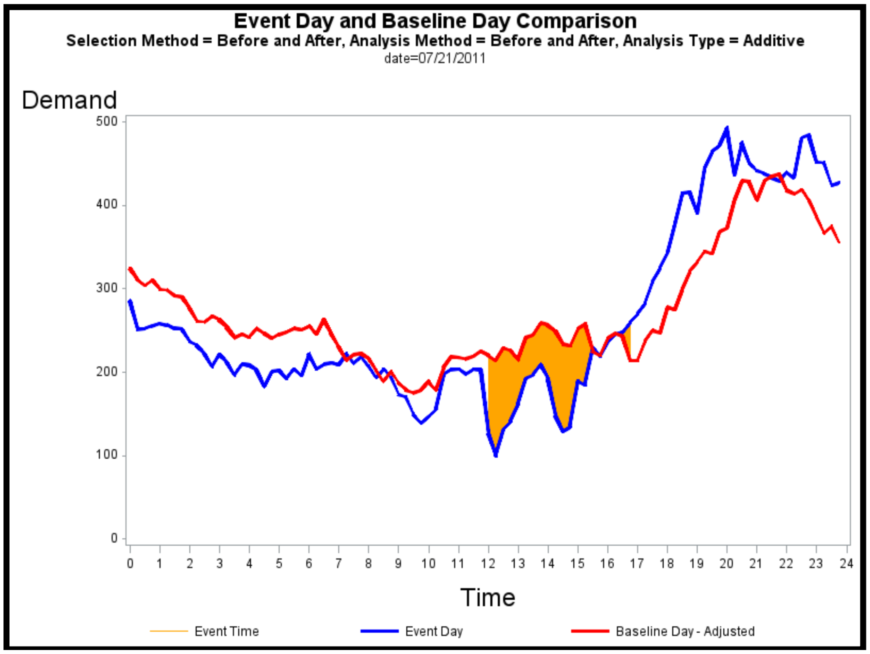

Figure 5 – July 21, 2011 (Before After, Before After, Additive)

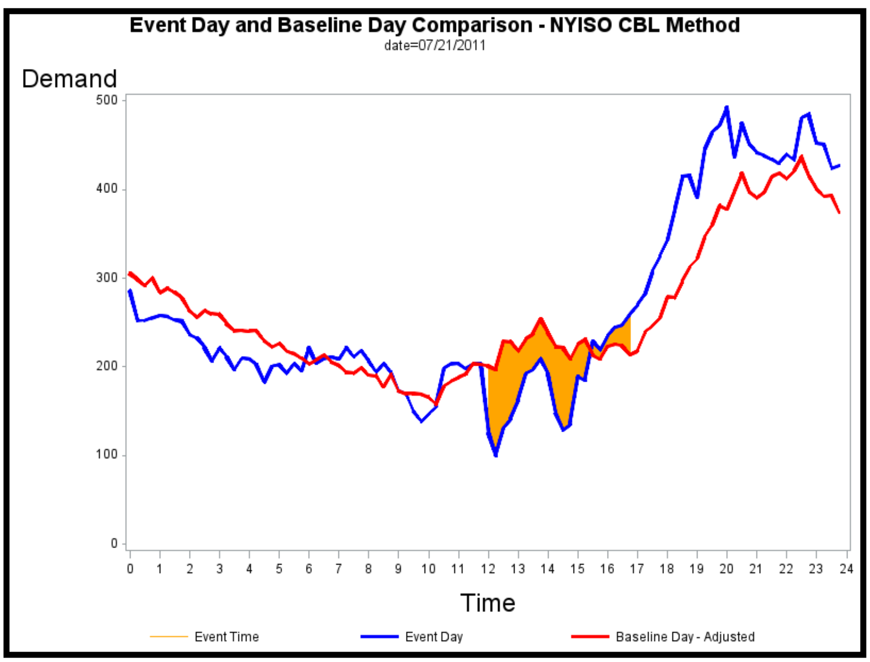

Figure 6 – July 21, 2011 (NYISO)

Given the event times, the difference between the adjusted baseline profile and the event day was calculated for each hour. The average reduction was calculated by taking the average value across all hours during the event. Finally, the average reduction percentage is calculated by dividing the calculated reduction by the total demand during the event time of the adjusted baseline profile. Table presents a comparison of results for these nine baselines. The table presents the average reduction across the entire event period.

Table 3 presents a recapitulation of the information in Table 2 by presenting the range of average demand savings estimates across all the methods. This table shows the median, mean, maximum and minimum savings across the event window. The best performance occurred on the first two events. Interestingly, the baseline methods that use “temperature” as a matching basis produces savings estimates that are more variable across the various approaches. This may be a result of factors other than dry bulb temperature (e.g., humidity, heat buildup, etc.) influencing the load shape. In aggregate, over the five days the savings were similar.

Table 2. Comparison of KEMA Analysis Results

	Analysis Approach								
	Matched Day	Matched Day	Matched Day	Matched Day	Matched Day	Matched Day	Matched Day	Matched Day	NYISO
Selection Basis	Before and After	Before and After	Before and After	Before and After	Temperature	Temperature	Temperature	Temperature	Before
True Up Basis	Before and After	Before and After	After	After	Before and After	Before and After	After	After	Before
True Up Method	Additive	Multiplicative	Additive	Multiplicative	Additive	Multiplicative	Additive	Multiplicative	Multiplicative
Average Reduction During Event (W)									
7/21/2011	53	68	103	93	48	55	122	98	39
7/22/2011	113	86	102	53	113	92	114	83	110
8/2/2011	57	10	65	61	18	19	36	18	20
8/17/2011	24	41	4	8	-6	45	27	46	46
8/25/2011	21	75	9	11	26	93	22	23	74
Reduction Percentage									
7/21/2011	22%	27%	36%	34%	21%	23%	40%	35%	35%
7/22/2011	35%	29%	33%	20%	35%	30%	35%	28%	28%
8/2/2011	20%	4%	23%	22%	8%	8%	14%	8%	8%
8/17/2011	18%	26%	4%	6%	-6%	28%	19%	29%	29%
8/25/2011	15%	39%	7%	9%	18%	44%	16%	17%	17%

Table 3. Summary of Savings Across Methods

Date	Median	Average	Maximum	Minimum
7/21/2011	81	80	122	39
7/22/2011	97	95	114	53
8/2/2011	27	35	65	10
8/17/2011	25	24	46	-6
8/25/2011	23	35	93	9

Variability of the Estimates

For planning purposes, an estimate of variability of savings was developed. Table 4 presents the variability estimates[3] for each of the savings estimates for the ThinkEco baseline approach and the NYISO approach. The ThinkEco matched day method produces slightly less variable confidence intervals than the NYISO approach.

Table 4. Variability of Savings

ThinkEco Method							
					90% Confidence Interval		
Date	Event Time	Average Reduction During Event (W)	Reduction Percentage	Standard Error of the Reduction During Event (W)	Lower Limit	Upper Limit	RCI
7/21/2011	12 pm - 5 pm	53	22%	11.16	34.15	70.86	35%
7/22/2011	2 pm - 5 pm	113	35%	21.00	78.94	148.05	30%
8/2/2011	5 pm - 10 pm	57	20%	16.53	29.33	83.72	48%
8/17/2011	5 pm - 10 pm	24	18%	5.63	15.08	33.59	38%
8/25/2011	5 pm - 10 pm	21	15%	7.82	8.55	34.26	60%
NYISO Method							
					90% Confidence Interval		
Date	Event Time	Average Reduction During Event (W)	Reduction Percentage	Standard Error of the Reduction During Event (W)	Lower Limit	Upper Limit	RCI
7/21/2011	12 pm - 5 pm	39	18%	11.04	21.05	57.38	46%
7/22/2011	2 pm - 5 pm	110	34%	21.77	74.13	145.75	33%
8/2/2011	5 pm - 10 pm	20	8%	15.08	-5.16	44.46	126%
8/17/2011	5 pm - 10 pm	46	29%	8.02	33.04	59.43	29%
8/25/2011	5 pm - 10 pm	74	38%	10.33	56.91	90.90	23%

Conclusions

Several conclusions are derived from this analysis:

- The analysis supports the conclusion that the program reduces demand and energy during event periods;
- The average demand savings over the five events based on the nine baseline approaches is 268w;
- The percent savings was the highest on the hottest days;
- A variability estimate around the savings is approximately ±38%.
- Matched day based on load levels produces less variable results than Matched Day based on event period temperature; and
- Matched day based on load levels produces less variable results than the NYISO baseline method.

[3] Given the pilots experimental design, the estimates of variability should be considered indicative, but not conclusive.