Final Report
Coincidence Factor Study
Residential Room Air Conditioners

Prepared for;
Northeast Energy Efficiency Partnerships' New England Evaluation and State Program Working Group

Sponsored by:
Cape Light Compact
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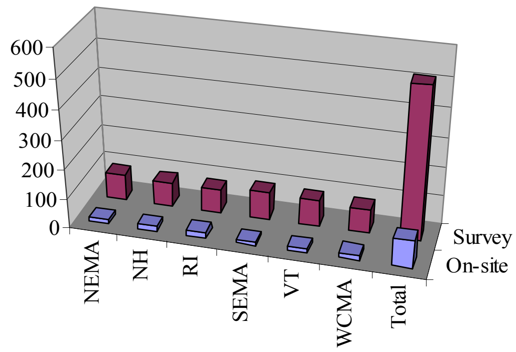
Executive Summary

The New England State Program Working Group (SPWG)[1] contracted with RLW to calculate on-peak and seasonal peak coincidence factors for residential room Air Conditioner (RAC) measures that could be consistently applied to energy efficiency programs that may bid into the ISO-NE Forward Capacity Market (FCM) in any of the New England states. The study covered four of the six New England states including Massachusetts, New Hampshire, Rhode Island and Vermont. Maine also sponsored the study although there were no participating units in the state and no on-site metering or survey activity was conducted in the state. Connecticut did not participate in the study because they no longer offer incentives for room AC units.[2]

The study utilized interval metered power data from 93 on-site visits that were nested within a sample of approximately 610 phone surveys. The sample was designed to allocate on-site visits and phone surveys equally by the six ISO-NE load zones with participating room AC units from program years 2005 and 2006. Figure i- 1 shows the actual distribution of data collection activities by load zones, the on-site numbers reflect sites with both a phone survey and site visit.

[1] Represented by the state regulatory agencies (CT DPUC, Maine PUC, MA DOER, NH PUC, RI PUC, and VT PSB) and associated energy efficiency program administrators (Cape Light Compact, Maine PUC, Efficiency Vermont, National Grid (MA, NH & RI), Northeast Utilities (CT&MA), NSTAR, PSNH, United Illuminating, and Unitil (MA&NH)).
[2] There are no participant sites in Maine, however results will be provided by adjusting the study results to Maine weather.

Distribution of On-sites and Phone Surveys Completed



	NEMA	NH	RI	SEMA	VT	WCMA	Total
On-site	15	16	19	10	15	18	93
Survey	89	83	81	93	89	82	517

Figure i- 1: Distribution of On-site and Phone Surveys

The analysis of the primary data utilized a two step approach the first step was to create a regression model of the operation of the Room AC units using the real year weather data and actual metered data. The second step was to use the resulting model to predict the operation of the room AC units across the ISO-NE FCM performance hours for 2007 and typical year after adjusting for any bias in the on-site sample. The nested on-site sample technique was used to control for potential bias in the on-site sample, specifically selection bias due to the increased probability that people who are generally home during the day would be over represented in the on-site sample.[3] A multi-variant regression model was constructed using the metered interval power data (for 114 room AC units) and the survey response data along with hourly weather data from the appropriate weather station.

There were six survey variables that were found to have statistically significant impact on the regression model as follows:

- Type of Area Served (i.e. Bedroom vs. Non-bedroom),
- Home During Day,
- Cooling Capacity per Area Served (BTU/ft^2),
- Outside Temperature when Cooling Begins,
- Schedule or Continuous Operation, and
- Cooling Setting.

[3] Phone survey results from surveys conducted during evening and weekend hours were used to establish occupancy rates for the population.

Each of these variables were tested to determine if there was a statistically different distribution of the variables within a load zone when compared with the mean values for the whole dataset using a T-test methodology. The largest single change from on-site data occurred in the occupancy variable, which had on-site customers reporting that 73% were generally home during the day as opposed to 53% in the larger survey sample. Both the space type and occupancy variables did not show significant variation between the overall survey results and the load zone level survey results. Table i - 1 provides a summary of the changes to the four remaining variables, which show that unique results were calculated for the NEMA, RI, SEMA and VT load zones. The results for the NH and WCMA load zones were identical to those provided by the model inputs using the average survey response data for all zones.

Load Zone	BTU/sqft	Outside Temp	Cont_Sched	Cooling Setpoint
All Zones	32.9	82.4	0.28	70.5
NEMA	**35.2**	**83.8**	0.28	70.5
NH	32.9	82.4	0.28	70.5
RI	32.9	**83.9**	**0.35**	**71.5**
SEMA	32.9	**81.0**	0.28	70.5
VT	**29.7**	82.4	0.28	70.5
WCMA	32.9	82.4	0.28	70.5

Table i - 1: Summary of Zonal Changes to Survey Variables[4]

The Coincidence Factors (CFs) and Full Load Equivalent Hours (FLEHs) were developed for the 2007 summer season using the operating profiles that had been adjusted for all applicable bias using the phone survey response data as described above. The calculation of the On-Peak CF was relatively straightforward since the performance hours are time dependent and can be calculated without having extreme ambient weather conditions. The calculation of the FLEHs was also straightforward and was calculated from the bias adjusted operating profiles directly. The weather normalized CFs and FLEHs were computed by using the bias adjusted regression model and using Typical Meteorological Year (TMY 2) weather data to calculate the results. Since the results are driven by differences in load zone variables and weather file data the results are reported out at the weather file level using survey inputs for the applicable load zones. The results were calculated by holding the survey variables static and then running the nine different weather files so that the hourly weather variables could be used to provide hourly results. Table i - 2 provides a summary of the results for all weather files using the average

[4] The zone specific responses that are different from the average for all zones are shown in bold font.

survey inputs for all Load zones for the On-Peak performance hours 1:00 PM to 5:00 PM June through August using 2007 and TMY2 weather data.

	2007 Weather		TMY2 Weather			
	Average for All Load Zones		Average for All Load Zones		Average for All Load Zones	
Weather Files	**On-Peak CF**	**Seasonal CF**	**On-Peak CF**	**Seasonal CF**	**2007 FLEH**	**TMY2 FLEH**
Albany, NY	0.154	0.276	0.142	NA	224	184
Boston, MA	0.134	0.304	0.125	NA	228	175
Burlington, VT	0.139	0.276	0.119	NA	166	141
Caribou, ME	0.080	0.131	0.080	NA	60	42
Concord NH	0.143	0.290	0.134	NA	171	149
Hartford, CT	0.170	0.303	0.171	NA	272	253
Portland, ME	0.111	0.270	0.111	NA	119	102
Providence , RI	0.159	0.296	0.144	NA	245	204
Worcester, MA	0.131	0.261	0.113	NA	172	134

Table i - 2: Summary of CF and FLEH by Weather File using Average Load Zone Data

Although there were slight differences in CF and FLEHs due to zonal differences in the model inputs the difference in the final results were not much more than ± 0.001 for CF and ± 3 hours for FLEH. Therefore although the zonal differences in survey responses for some of the model variables were statistically significant when these different model input were run the results did not provide numerically significant differences in the results.[5] As a result we recommend that the calculation of DRV for each load zone use the CFs provided in Table i - 2.

The project results are reported out by weather file because the CF and FLEHs were calculated using the regression model and hourly weather data. The optimum method for determining RAC savings for a sponsor that operates in multiple load zones and/or has customers that should be modeled using multiple weather files would be to assign load zones and weather file designations to each rebate based upon the location of the customer by town and or zip code. Once this has been accomplished then capacity or demand reduction weighted allocations can be developed for each load zone where multiple weather files are applicable. If all of the demand reduction within a load zone is associated with one weather file then the sponsor can simply select the appropriate CF for the weather file as given in Table i - 2.

The Seasonal Peak performance hours were calculated by determining the hours when the real-time system load meets or exceeds 90% of the 50/50 CELT forecast for the summer 2007 period of 27,360 MW.[6] There were a total of 24 hours during the summer of 2007 when the real–time system load was 24,624 MW or greater, eight hours during June and 16 hours during August, and the 2007 Seasonal Peak

[5] This was due to a combination of factors primarily the relatively small differences in the variables, and changes in multiple variables canceling each other out.
[6] Data taken from ISO-NE 2007 Capacity, Energy, Load and Transmission (CELT) report dated April 20, 2007.

CFs were calculated during those hours. It was not possible to calculate the TMY 2 Seasonal peak CF values because of the method used to create TMY 2 weather data, which uses "typical" months to create an annual file.[7] The ISO-NE report entitled "Summer 2007 Weather Normal Peak Load" noted that the weather normalized peak load for 2007 was 27,460 MW, 0.4% (100 MW) higher than the April 2007 forecast of 27,360 MW for the summer of 2007. According to the report "The summer of 2007 can be characterized as normal with respect to overall temperature and humidity." Therefore we would defer to ISO-NE characterization of the summer of 2007 as normal with respect to temperature and humidity and recommend that both the 2007 On-Peak CFs and 2007 Seasonal Peak CFs be used for future year DRV calculation by the project sponsors.

> Based on ISO-NE characterization of the summer of 2007 as normal with respect to temperature and humidity, we recommend that both the 2007 On-Peak CFs and 2007 Seasonal Peak CFs be used for future year estimates of Demand Reduction Values.

The relative precision of the estimated impacts provided from the bias adjusted model could not be calculated directly because the model used the average inputs from the survey data and thus provided only one set of numbers depending upon the load zone and weather file selected. A first order approximation of the relative precision is provided by the following equations;

$$Y = f(x) + E \Rightarrow E = Y - f(x)$$

$$Y_{adj} = f(x_o) + E$$

$$Y_{adj} = Y + [f(x_o) - f(x)]$$ Where,

Y = the actual CF for the hour from the metered

$f(x)$ = the predicted value from unadjusted model

$f(x_o)$ = the predicted value after adjusting the model for bias

E = expected error in the adjusted model

Y_{adj} = the predicted output from the adjusted model

[7] For example the June data for Albany could be from 1976, while the Boston data could be from 1980 and Hartford from 1978. In order to develop an accurate typical regional weather model it will be necessary to select typical months from the same year for all of the regional files.

Table i - 3 provides the estimated relative precision of the monthly and summer On-Peak CF values using the methodology explained above. The relative precision ranged from ±14.4% for June to ±10.4% for the summer season. Note that the mean value for June was 0.218, which was higher than expected because most of the June metered data was collected during a heat wave at the end of the month.[8]

Month	sample (n)	Mean	Standard Deviation	Cv	Relative Precision
June	82	0.218	0.222	1.02	±14.4%
July	108	0.156	0.155	0.99	±12.2%
August	108	0.174	0.164	0.94	±11.7%
Summer	114	0.175	0.152	0.87	±10.4%

Table i - 3: Estimated Relative Precision of On-Peak CF

[8] The adjusted model results reflect the mean coincident value during the entire month of June and are therefore significantly lower.

1 Introduction

The New England State Program Working Group (SPWG)[9] contracted with RLW to calculate coincidence factors for residential room Air Conditioner (AC) measures that could be consistently applied to energy efficiency programs that may bid into the ISO-NE Forward Capacity Market (FCM) in any of the New England states. State Program Working Group (SPWG) to determine the demand impacts of these units. The study will cover five of the six New England states, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. Connecticut will not be included in the study because they no longer offer incentives for room AC units.[10] The focus of the study will be to develop demand impacts during the performance hours defined by ISO-NE for the Forward Capacity Market (FCM). There are three different options that can be used to register an "Other Demand Resource" (ODR) that will results in slightly different performance hours across which the demand impacts will be measured.

Resulting coincidence factors presented in this report were developed to work as common values accepted by all New England states for the FCM that can be applied or used as appropriate; they are based on measures installed by energy efficiency programs in the New England states that have supported this research effort.

1.1 Background

For many years the state-funded efficiency programs in New England were separately operated. Each program had its own set of measurement and verification (M&V) protocols that were used to estimate the energy and demand savings that were generated by these programs. Recently, the New England Conference of Public Utility Commissioners (NECPUC) committed their states to work together to develop common M&V protocols so that these resources can participate in the Independent System Operator – New England (ISO-NE) Forward Capacity Market (FCM). One type of measure that has not been evaluated recently is residential room AC units. To our knowledge there has been only one recent study that collected primary metered data that captures the operating schedules of these units in the New England region.[11]

[9] Represented by the state regulatory agencies (CT DPUC, Maine PUC, MA DOER, NH PUC, RI PUC, and VT PSB) and associated energy efficiency program administrators (Cape Light Compact, Efficiency Maine, Efficiency Vermont, National Grid (MA, NH & RI), Northeast Utilities (CT&MA), NSTAR, PSNH, United Illuminating, and Unitil (MA&NH)).

[10] There are no participant sites in Maine, however results will be provided by adjusting the study results to Maine weather.

[11] National Grid contracted with Quantec to meter and evaluate room AC units during the 2004 summer season and these data may be available for the analysis as well

1.2 Primary Goals and Objectives

The primary goal of this evaluation was to collect enough interval metered power data of room air conditioners to develop summer peak coincidence factor with a statistical precision of at least ±10% at a confidence level of 80% using a two-tail confidence interval. Additionally Full Load Equivalent Hours (FLEHs) were determined from the metering data so that sponsors can determine annual energy savings estimates for room air conditioners.

The defining objective of this study was to develop new and/or revised coincidence factors that can be used to evaluate the demand impacts of room AC units that are suitable for submission into the ISO-NE Forward Capacity Market (FCM).

The summer peak hours are defined as follows:

- **Summer On-Peak Hours** occur weekdays from 1-5 PM throughout June, July and August.
- **Seasonal Peak Hours** occur when Real Time load is equal to or greater than 90% of the 50/50 seasonal peak load forecast during Summer (June – August).
- **Critical Peak Performance Hours** occur when the Day Ahead Load forecast is equal to or greater than 95% of the 50/50 seasonal peak load forecast during Summer (June – August).
    - **Shortage hours** occur during Operating Procedure[12] 4 (OP4) level 6 or higher events, at level 6 the 30-minute operating reserve begins to be depleted.

Coincidence Factors (CFs) are defined in this study as the fractions of the connected (or rated) load AC rated capacity and efficiency reductions that actually occur during each of the seasonal demand windows. They are the ratio of the demand reductions during the coincident windows to the maximum connected load reductions. Under this definition other issues such as diversity and load factor are automatically accounted for, and only the coincidence factor is necessary to determine coincident demand reductions from readily observable equipment nameplate (rated) information. In other words, coincident demand reduction will simply be the product of the coincidence factor and the connected equipment load kW reduction.[13] In the case of residential room AC units the connected kW reduction will be equal to the capacity of the unit (MBTUh) times the difference of the inverse of the baseline efficiency ($1/EER_{Baseline}$) and the inverse of installed efficiency ($1/EER_{Installed}$). There should be no net adjustments made to these

[12] Operating Procedures are from the ISO-NE to address potential capacity shortages.
[13] This is true when the baseline AC unit is assumed to be the same capacity as the installed AC unit. In the case of a retrofit program differences in capacity between pre and post units would have to be accounted for as well.

numbers that adjust for operating hours however if there are net impacts that adjust for installation rates these numbers should be used to calculate impacts.

The Coincidence Factors during Critical Peak Performance hours were not evaluated as a part of this study because none of the project sponsors have defined their energy efficiency resources as a critical peak resource for the ISO-NE Forward Capacity Market (FCM), and because a different analytical approach would be required to model critical peak coincidence. Defining the actual critical peak performance hours is problematic due to the Day Ahead Forecast of system load which is consistently lower than the real-time load during peak hours. This causes the number of Critical Peak performance hours to be quite low. Another complication is the somewhat random nature of OP-4 events, which can typically track with temperature, but can also be caused by some other type of system failure that is not related to temperature.

2 Analysis Approach

This evaluation project used four primary data sources to evaluate the residential room AC Coincidence Factor and savings impacts:

- Regional Room AC Rebate program Tracking Database,
- 15-minute interval power data for the Room AC units,
- Operating schedule data provided from phone surveys, and
- Hourly weather data from primary weather sites with TMY 2 weather files available

Figure 1 provides a graphical overview of the evaluation which shows the location of the various components. The nine weather sites are indicated by the airplanes, the 93 on-site locations are shown by the stars and the 517 phone survey only locations are shown by the circles.

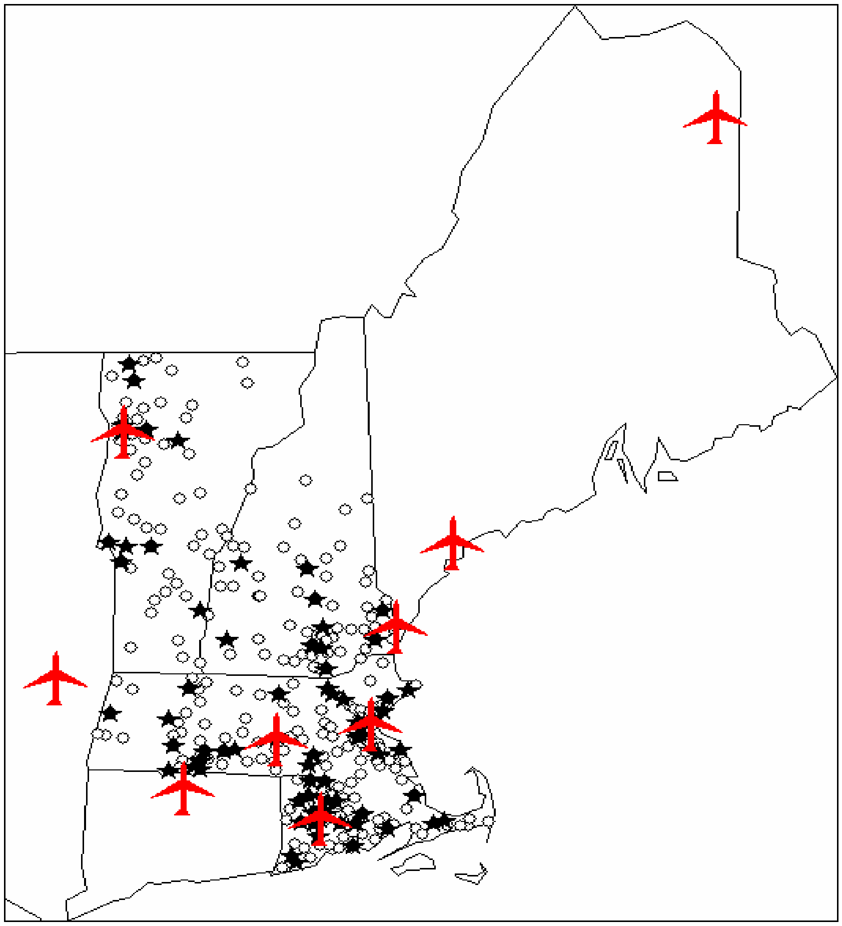


Figure 1: Distribution of On-site and Survey Sample Points

Figure 2 provides an overview of the data analysis process, which shows how the four primary data inputs were utilized to develop weather normalized aggregate operating profiles for the room AC units as a function of dry bulb temperature and enthalpy.[14] These aggregate operating profiles were adjusted to account for any on-site sample selection bias by comparing the results of on-site survey responses (93 surveys) to the larger group of phone survey responses (610 surveys). The bias adjusted Aggregate Weather normalized operating profiles were developed and used to calculate the Coincidence Factors for the Room AC units during the appropriate performance hours for each of the weather files. These data were also used to calculate the annual Full Load Equivalent Hours (FLEH) for the room AC units for each of the TMY2 weather files included in the analysis. The FLEH and CF were established so that the project sponsors will be able to directly calculate energy and demand impacts by applying these factors to their total connected kW reduction values. Since these values are free of baseline assumptions and other

[14] Enthalpy is a measure of the heat content of air and is in units of BTU/ft^3. This should have a better correlation than just dry bulb temperature or wet bulb temperature.

utility specific assumptions like persistence or in-service rates they can be used by all of the project sponsors.

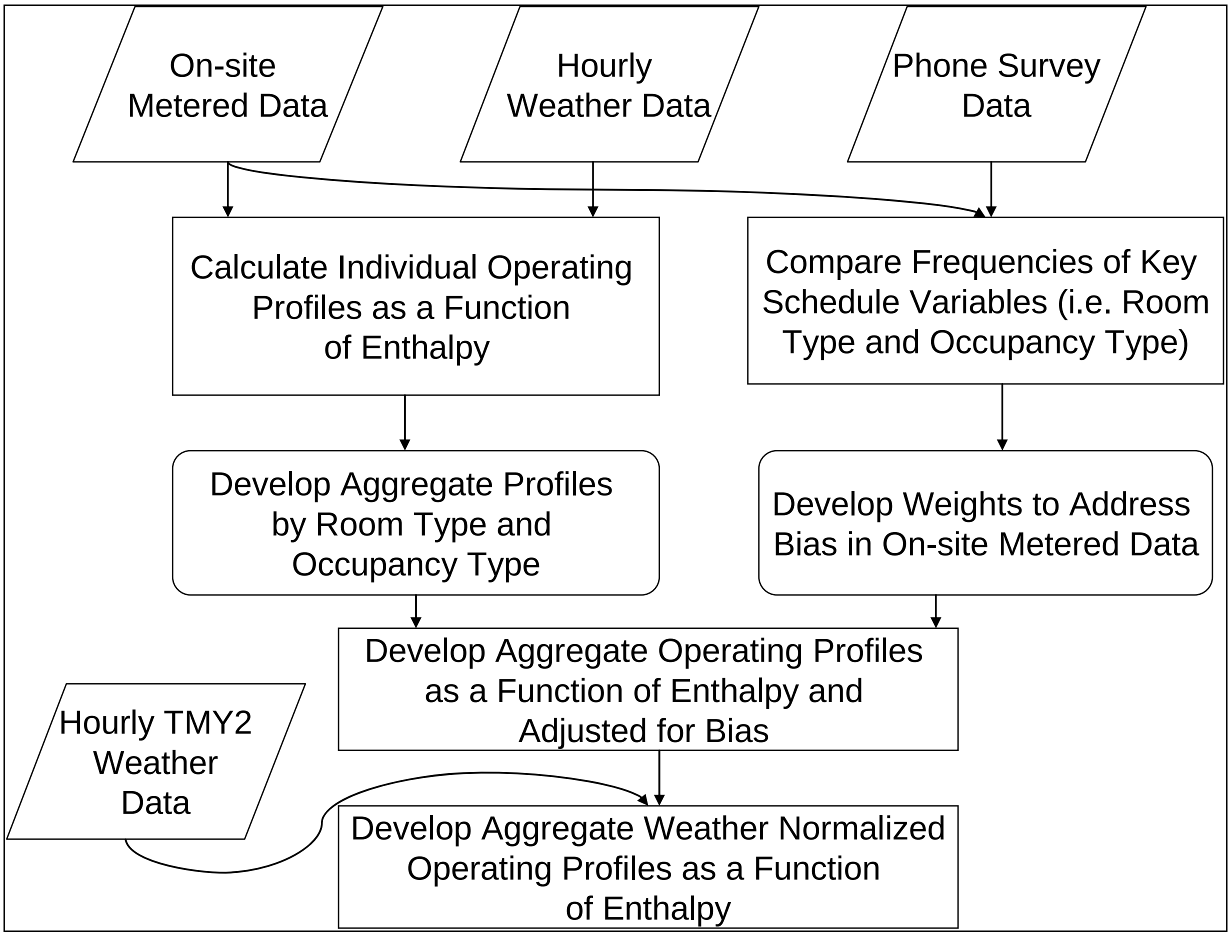


Figure 2: Data Analysis Flowchart

This evaluation report includes the following:

- Coincidence Factors derived from the aggregate room AC profiles
  - For Summer On-Peak Hours, and
  - For Summer Seasonal Peak Hours.
- Equivalent Full Load Hours derived from the aggregate room AC profiles.
- A regression model that can be used calculate new CF values as key input variables change

The following sections discuss the process that was used to collect the primary data inputs as well as analysis techniques that were used to develop the results and adjust for selection bias.

2.1 Sample Design

The ISO-NE M&V manual for Demand Resources indicates that for non-homogeneous measures a Cv of 1.0 should be used and for homogeneous measures a Cv of 0.5 is acceptable for the first evaluation. However, subsequent evaluations should use the calculated Cv from previous evaluations when determining new sample size requirements[15]. Table 1 shows the number of sample sites required to achieve the overall sampling precision of ±10% at a confidence interval of 80%, at various Coefficient of Variation (Cv) levels. It was decided that a Cv of 0.75 would be a reasonable compromise for planning purposes given that this is homogeneous measure that is anticipated to have a large amount of variation. These inputs provide a target sample of 92 sites for the overall evaluation.

rp	Confidence	Z	Cv	n
10%	80%	1.282	1.00	164
10%	**80%**	**1.282**	**0. 75**	**92**
10%	80%	1.282	0. 5	41

Table 1: Sample sites at Various Coefficients of Variation

The sample design was drawn from a regional tracking dataset of customers that participated in the room AC mail in rebate program. The data were tracked at the rebate level and each row in the dataset corresponded to one distinct room AC unit. The population data were drawn from program years 2005 and 2006 and the primary classification variable for the customers were those that received single rebates versus those that received multiple rebates. There were a total of almost 28,000 customers in the population and almost 35,000 rebated AC units, with 23% of the customers having received multiple rebates as shown in Table 2.

Load Zone	Customers	Rebates	Customers With Multiple Rebates	Customers With One Rebate	% Multiple Customers	% Single Customers
NEMA	3,608	4,444	835	2,773	23%	77%
NH	5,351	6,701	1,309	4,042	24%	76%
RI	3,644	4,512	846	2,798	23%	77%
SEMA	4,342	5,363	1,019	3,323	23%	77%
VT	5,387	6,863	1,134	4,253	21%	79%
WCMA	5,607	6,888	1,281	4,326	23%	77%
Totals	**27,939**	**34,771**	**6,424**	**21,515**	**23%**	**77%**

Table 2: Room AC Customers by Load Zone

15 ISO-NE Manual M-MVDR section 7.2.2 Required Sample Size page 7-4 bullet #7.

The sample was selected at the rebate level and then all of the rebated units at a customer home were included in the on-site metering. By using this technique more multiple unit homes were included in the on-site sample and more metered profiles were available for analysis. The initial allocation of the sample was to distribute the sample about equally across all load zones, with 15 sample sites in four load zones and 16 sample sites in two of the load zones. However, the SEMA load zone proved to be extremely difficult to schedule on-site visits and only ten on-sites were conducted there. Table 3 provides the distribution of the sample on-sites by load zone and shows that 93 on-sites were completed.

Load Zone	Proposed On-sites	Actual Scheduled	On-site Difference
NH	15	15	0
VT	15	16	1
NEMA	16	15	-1
WCMA	15	18	3
RI	15	19	4
SEMA	16	10	-6
Total	**92**	**93**	**1**

Table 3: Comparison of On-site Sample Allocation by Load Zone

The on-site sample was analyzed to compare the distribution of the size of the Room AC units in the on-site sample versus the population to make sure that the on-site sample was representative of the population. Figure 3 provides a graphical comparison of the sample and population distribution of room AC units by capacity, which shows a fairly strong correlation.

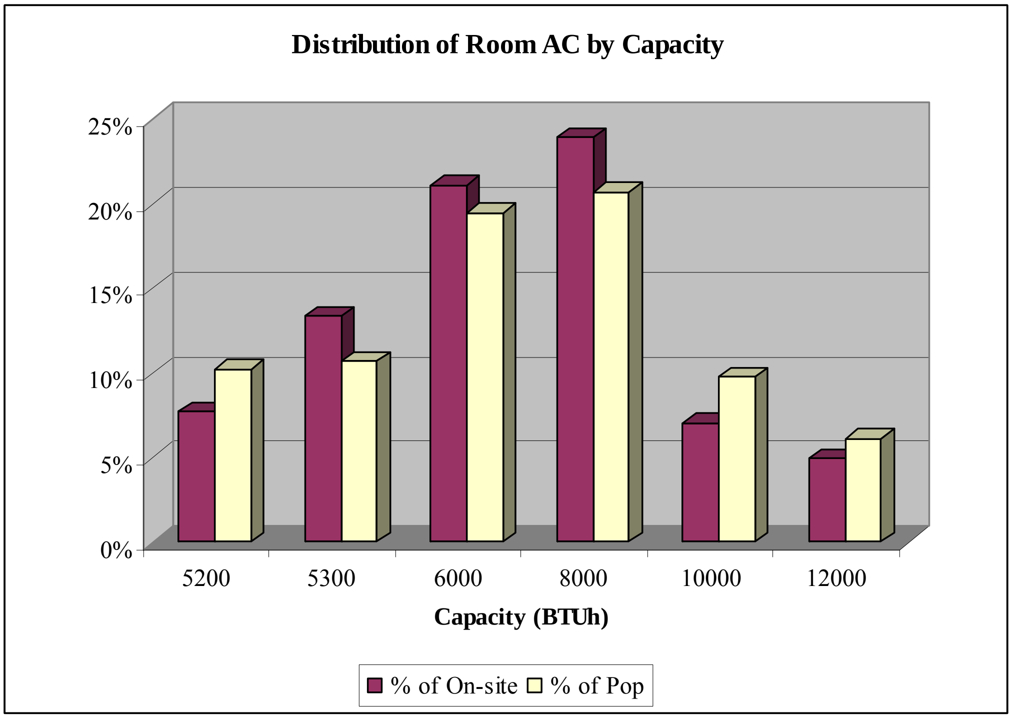


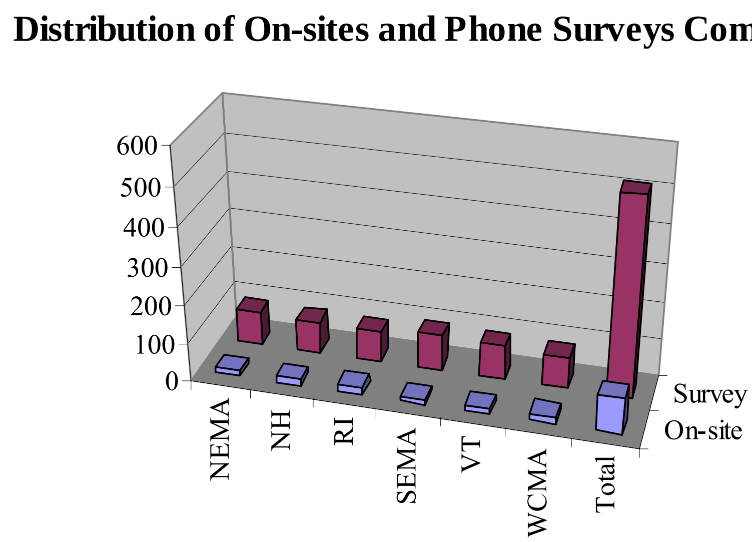
Figure 3: Comparison of On-site Sample and Population by Capacity

2.2 Participant Phone Survey

In order to address any sample selection bias and to provide a broader framework for evaluating and weighting metered results by various variables a participant phone survey was also conducted. The plan was to conduct 100 surveys per load zone for a total of 600 surveys. The survey was designed to determine several key variables that were believed to be drivers for the operating schedule of the room AC units and the on-site sample was nested within the survey sample. This allowed the survey to be both a recruitment call and customer information survey until the on-site quotas were filled in each of the zones. The following key driver variables for room AC operating schedules were identified:

- The room type or area served by the AC unit,
- The minimum outside air temperature at which the AC unit is turned on,
- General daily operating schedule,
- The daily operating schedule of the unit during a heat wave,
- General Seasonal operating schedule, and
- Fan and temperature setting under the units typical operating conditions in the home.

Figure 4 provides a distribution of the completed phone surveys and on-sites by load zone, which shows that a total of 517 phone surveys were completed. Each of the load zones had at least 80 surveys completed.



	NEMA	NH	RI	SEMA	VT	WCMA	Total
On-site	15	16	19	10	15	18	93
Survey	89	83	81	93	89	82	517

Figure 4: Distribution of Surveys by Load Zone

The phone survey document and response rate frequencies for all of the survey questions are presented in Appendix A. The discussion in this section will be limited to the survey variables that were determined to have an impact on the operating schedule of the room AC units.

2.3 On-site Data Collection

The on-site audit consisted of four activities;

- Inspection and verification of the make and model number for the rebated unit,
- The installation of an interval plug meter to monitor unit operation,
- An on-site survey to collect building and major electrical appliance information, and
- Spot power measurements of the AC unit at different cooling and fan speeds.

The on-site auditors confirmed the installation of each rebated room AC unit and verify the room type or area served as well. The size of the space being cooled by the unit was measured and a ratio of cooling capacity per unit area (BTUh/FT^2) was developed. Similar data were also collected in the phone survey.

This will be an important variable because it defines the degree of over sizing or under sizing for the AC units. This will directly impact the unit loading because two units of similar size could have widely varying cooling loads based upon the amount of space that the unit is cooling. If a unit is extremely undersized for a space it may run continuously even during relatively mild ambient temperatures, while an oversized or properly sized unit may barely cycle at all. If all other variables are equal than a RAC unit that is undersized for the space being cooled would have a higher CF than an oversized or properly sized RAC.

The on-site auditors installed Electronic Educational Devices (EED) Watts Up Pro Extended Memory plug meters to monitor the power consumption of the room AC units for 15-minute intervals. The metering period for the project was selected to correspond with the summer On-Peak period which runs from June through August as defined by ISO-NE. The process of starting the project up and getting the meters in the field was compressed into a very tight timeframe and the project sponsors worked extremely hard to expedite and streamline the process. The on-site visits started on June 4, 2007 and 93 sample site visits were completed by July 3, 2007. Figure 5 provides a graphical presentation of the metering installation timeline for the sample on-site visits, which shows that by mid-June 25% of the on-site visits have been completed and by the end of June 95% of the on-site metering was installed.

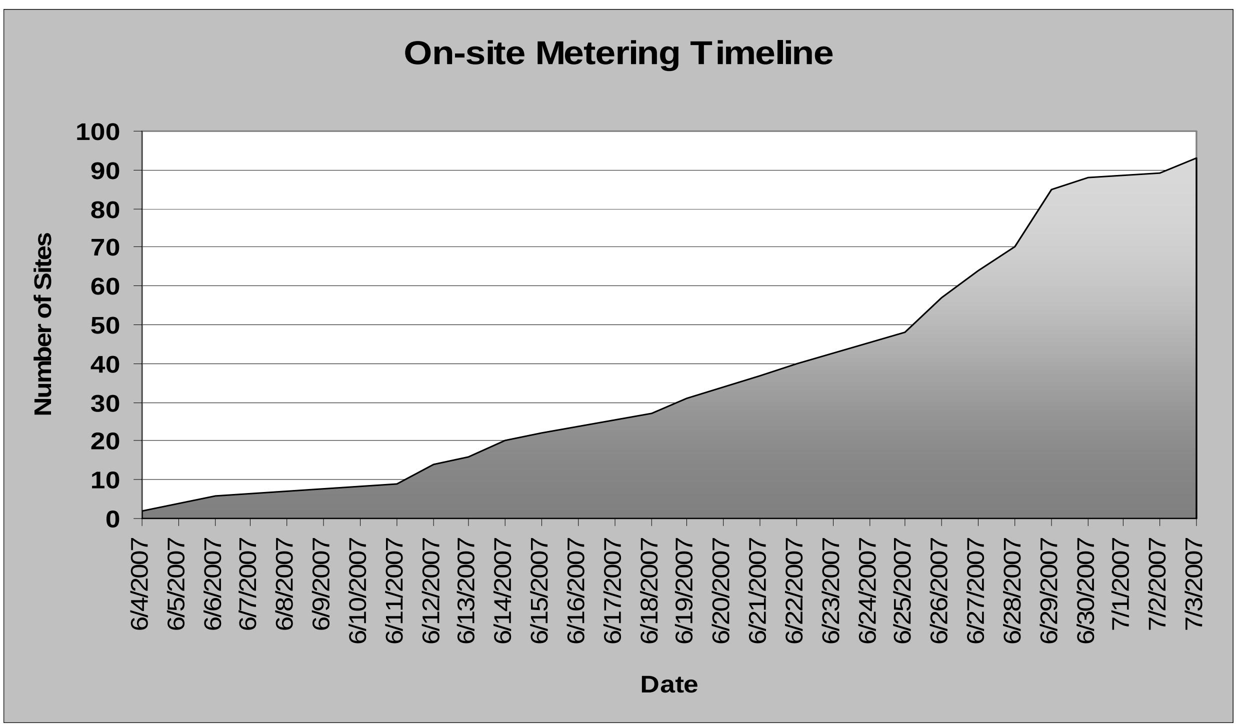


Figure 5: On-site Sample Metering Installation Timeline

In addition to collecting and verifying information about the rebated room AC units, the on-site auditors also collected data about any other cooling equipment as well as all of the major electrical appliances and the home configuration and shell features so that in the future optional DOE 2 models of the home could be created.

3 Data Analysis

As detailed previously in the data analysis flowchart, the data analysis consisted of processing four primary data inputs, the 15-minute interval metered data for the room AC units, the hourly 2007 weather files for the New England primary weather sites, the Hourly TMY 2 weather files for the primary weather sites and the phone survey data. The first three data sets were used to determine the operating profiles for the room AC units as well as the CFs and FLEHs and the fourth data set was used to insure that the metered data set was representative of the population and to adjust for sample selection bias in the on-site sample and load zones. The data analysis process consisted of the following steps:

- Preparation of Weather Files,
- Metered Data Preparation,
- Regression Analysis and Development of Operating Profiles,
- Phone Survey Data Analysis and Bias Adjustments, and
- Calculation of Coincidence Factors (CFs) and Full Load Equivalent Hours (FLEH).

The following sections will discuss each of these procedures in more detail.

3.1 Preparation of Weather Files

The first step in the analysis process was to obtain 2007 hourly weather file data from regional New England weather stations that were used to develop operating profiles for the individual room AC units as a function of real year ambient weather.[16] Table 4 provides a listing of the primary weather sites in the New England region as well as how we envision allocating the weather to the load zones. An exact mapping of the on-site sample was done using mapping software.

[16] The analysis included variables like enthalpy, which is the measure of heat content of the air and is in units of BTU/ft^3, because the units are volumetric it requires data for both dry bulb and wet bulb temperature as well as the air pressure to calculate using a fairly complex algorithm. This measurement was used to provide better regression analysis results than simply using dry bulb or wet bulb temperature.

Weather Files	Load Zones
Albany, NY	WCMA (Berkshires)
Boston, MA	NEMA, SEMA
Burlington, VT	VT (North), NH (North)
Caribou, ME	ME (North)
Concord, NH	NH (South), VT (South)
Hartford, CT	WCMA
Portland, ME	ME (South)
Providence, RI	RI
Worcester, MA	WCMA

Table 4: Primary Weather Sites

A comparison of the 2007 and TMY2 hourly dry bulb, wet bulb and enthalpy values was performed for the three summer months (June, July and August) during the four summer On-Peak Hours (1:00 PM – 5:00 PM) to determine what type of weather year 2007 was in terms of peak heat and overall seasonal temperatures. Table 5 provides the results of a comparison of the mean temperature data during on-peak hours for the 2007 and TMY2 weather data for Dry Bulb Temperature (ºF), Wet Bulb Temperature (ºF),[17] and Enthalpy (BTU/lbm).[18] The data indicates that for every weather file, but Hartford and Portland the mean DB Temperature was higher during 2007 than for the TMY2 weather file with an average increase of about 1.2 ºF. However, the mean WB temperature actually decreased on average by about 0.1 ºF and the mean Enthalpy only increased slightly by about 0.1 BTU/lbm.

	2007 On-Peak Means			TMY2 On-Peak Means			Difference (2007 - TMY2)		
Weather Files	**DB Temp**	**WB Temp**	**Enthalpy**	**DB Temp**	**WB Temp**	**Enthalpy**	**DB Temp**	**WB Temp**	**Enthalpy**
Albany, NY	77.8	65.9	31.0	76.7	65.6	30.7	1.2	0.3	0.3
Boston, MA	75.5	64.7	30.0	74.4	64.6	29.7	1.1	0.1	0.3
Burlington, VT	76.4	64.2	29.8	74.4	63.7	29.3	2.1	0.5	0.5
Caribou, ME	70.9	60.3	27.0	69.8	61.0	27.6	1.1	-0.8	-0.6
Concord NH	76.8	64.4	30.0	75.9	65.0	30.1	0.9	-0.6	-0.2
Hartford, CT	78.9	66.6	31.6	78.9	67.5	32.1	0.0	-0.9	-0.5
Portland, ME	72.3	63.5	29.1	72.4	63.6	29.0	-0.2	-0.1	0.1
Providence , RI	78.1	66.4	31.3	75.9	66.0	30.7	2.2	0.4	0.6
Worcester, MA	74.0	63.5	29.7	72.0	63.2	29.2	2.0	0.4	0.5
					Totals		**10.4**	**-0.8**	**1.0**
					Average Difference		**1.2**	**-0.1**	**0.1**

Table 5: Comparison of 2007 and TMY2 Mean On-Peak Weather Data

[17] Wet Bulb temperature is an indirect measure of the humidity of air and is defined as the temperature an air parcel would have if cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the air parcel. It is the temperature read by a wet bulb thermometer. The closer the wet bulb temperature is to the dry bulb temperature the higher the humidity content of the air

[18] Enthalpy is defined as the thermodynamic function of a system, equivalent to the sum of the internal energy of the system plus the product of its volume multiplied by the pressure exerted on it by its surroundings. It is a measure of the heat content of the air per unit of mass.

	2007 On-Peak Max			TMY2 On-Peak Max			Difference (2007 - TMY2)		
Weather Files	**DB Temp**	**WB Temp**	**Enthalpy**	**DB Temp**	**WB Temp**	**Enthalpy**	**DB Temp**	**WB Temp**	**Enthalpy**
Albany, NY	93	79	42.8	91	77	41	2.0	2.0	1.8
Boston, MA	96	79	42.5	92	74	37	4.0	5.0	5.2
Burlington, VT	96	76	39.8	99	78	41	-3.0	-2.0	-1.6
Caribou, ME	90	74	38.0	91	73	37	-1.0	1.0	1.0
Concord NH	97	77	40.7	93	78	42	4.0	-1.0	-0.8
Hartford, CT	95	79	42.9	100	81	44	-5.0	-2.0	-1.6
Portland, ME	93	77	40.6	90	76	39	3.0	1.0	1.2
Providence , RI	95	79	42.7	93	77	40	2.0	2.0	2.7
Worcester, MA	90	77	41.3	94	78	42	-4.0	-1.0	-0.7
					Totals		**2.0**	**5.0**	**7.2**
					Average Difference		**0.2**	**0.6**	**0.8**

Table 6: Comparison of 2007 and TMY2 Maximum on-Peak Weather Data

Table 6 provides a comparison of the 2007 and TMY2 maximum weather variables values during the on-peak hours. In this case almost half of the maximum DB temperatures were lower in 2007 than in the TMY2 weather files and the same was true for the maximum WB temperature and maximum enthalpy. In all three cases the average maximum values increased by 0.2 ºF, 0.6 ºF and 0.8 BTU/lbm, for the DB Temperature, WB Temperature and Enthalpy, respectively.

The data indicates that the 2007 weather data was generally slightly hotter in the region than the TMY2 data, but not significantly hotter with an average overall increase of about 1.5% for DB Mean Temperature, a 0.1% decrease in WB Mean Temperature and about a 0.4% increase in Enthalpy. This indicates that 2007 weather data could be used as a reasonable proxy for predicting future year results.

3.2 Determination of Seasonal Peak Hours

The Seasonal Peak performance hours occur when the ISO-NE real-time system load meets or exceeds 90% of the 50/50 CELT Peak forecast for the summer 2007 period of 27,360 MW[19]. There were a total of 24 hours during the summer of 2007 when the real–time system load was 24,624 MW or greater, eight hours during June and 16 hours during August, and the 2007 Seasonal Peak CFs were calculated during those hours. Table 7 provides the mean and maximum weather variables for each of the weather stations during the 24 Seasonal Peak Performance Hours, which shows that the Boston weather file has the highest mean and maximum DB Temperature of 92.1 ºF and 96 ºF, respectively.

[19] Data taken from ISO-NE 2007 Capacity, Energy, Load and Transmission (CELT) report dated April 20, 2007.

	2007 Seasonal Peak Means			2007 Seasonal Peak Max		
Weather Files	**DB Temp**	**WB Temp**	**Enthalpy**	**DB Temp**	**WB Temp**	**Enthalpy**
Albany, NY	86.7	73.9	37.6	93	77	40.6
Boston, MA	92.1	74.9	38.3	96	77	40.3
Burlington, VT	88.8	73.4	37.2	95	76	39.7
Caribou, ME	73.3	63.9	29.8	90	74	38.0
Concord NH	89.7	74.1	37.8	94	76	39.6
Hartford, CT	89.4	75.1	38.7	95	77	40.5
Portland, ME	84.5	74.1	37.7	93	78	41.4
Providence , RI	88.9	75.0	38.4	94	78	41.7
Worcester, MA	85.2	72.9	37.2	91	76	40.1

Table 7: Mean and Maximum Weather Variables during 2007 Seasonal Peak

3.3 Metered Data Preparation

All of the individual 15-minute interval metered data was processed into hourly data so that it could be analyzed with the hourly weather data. The metered data included maximum, minimum and average volts, amps and wattage data. The meters also had a duty cycle feature that could be set to monitor the percent of time during an interval when the average demand exceeded threshold wattage. This value was determined by setting a threshold of 120 Watts, which represents the maximum estimated power draw of a large room AC fan operating at the high speed setting. Unfortunately the duty cycle data was not reliable and we were unable to use the data to determine the percent of time during the interval when the air conditioner compressor was operating.

The room AC manufacturers do not provide performance data for the room AC Units other than to report the Energy Efficiency Ratio (EER), which represent the cooling efficiency of the unit at the high cooling and high fan settings. The interval metered data was converted to average watts per hour and these values were compared to the maximum watts per unit to develop hourly coincidence factor data. The maximum demand was calculated using the following equation;

Max Demand = Cap x 1/EER where,

Max Demand = Maximum Demand (Watts)

Cap = Cooling Capacity (BTU)

EER = Energy Efficiency Ratio (BTU/Watt)

The maximum demand per unit was used with the average hourly wattage data to develop an hourly coincidence factor for each unit during the metering period. There were two types of Room AC Units in the study, ones that had phantom loads and ones that used no power when the units were off but still plugged in. The units with phantom loads had average loads of about 1.3 watts and 78% of the room AC units (89 of 114) had phantom loads that were set to zero percent on during the phantom load time period. Phantom loads do not contribute to the energy savings of the room ACs and were set to zero when the CFs were calculated.

3.4 Regression Analysis and Development of Operating Profiles

A data set was created containing the metered data and hourly 2007 weather data. A regression analysis was performed on each of the metered data files to develop operating profiles as a function of weather. The first regression model was constructed to examine the operation of the Room AC units as a function of temperature and the dependent variable (%peak) was the ratio of measured Watts to peak Watts[20]. The regression was limited to hours where the ratio was equal to or greater than 0.15, to ensure that compressors were actually running and not just the fans.[21] This technique was used because the general operation of the room AC units was highly variable and we wanted to capture the operation of the room AC units as a function of temperature without the added noise of occupancy schedules, which are difficult to model. This model was able to achieve a fairly high R-squared and adjusted R-squared of 0.4631 and 0.4623 respectively.

All of the survey variables were included in the initial regression model along with the three weather variables (DB Temp, WB Temp and Enthalpy) to determine if they had a statistically significant impact on the regression. The independent variables used in the regression were:

- **BTU/SQFT:** This is a numeric field representing the cooling capacity per ft^2 of area served.
- **Bed Nonbed:** (Area_served is NOT a numeric field, so a dummy variable for bedrooms(55.26% of data) was created (if area_served=bedroom then bdrm=1, otherwise 0). Other areas include – multi-zone, basement, beauty shop, dining room, kitchen, living room and office.
- **Home Not Home** (This dummy variable, is created from a non-numeric variable – home_during_day. If home_during_day="Yes" then home=1, otherwise home=0.
- **Schedule** (This is a dummy variable that has been derived from field sched_cont. If the unit operates continuously, then schd=1, otherwise schd=0.

[20] The measured watts were taken from the metered data and the peak watts were calculated using the AC unit capacity and the rated efficiency.
[21] The 15% cutoff was based upon measured fan power for room AC units relative to the full power when in cooling mode.

- **Outside Temp:** This is a numeric field that is the customer reported outside temperature at which they begin to operate their room AC.
- **DB Temp:** This is a numeric field that is the hourly Dry-bulb temperature.
- **Level of Cooling:** This is a numeric field that represents the cooling setpoint temperature that was provided by the customer.
- **Enthalpy:** This is a numeric field that represents the hourly Enthalpy a measure of the heat content of the air
- **hr_1,2,…,23**: Dummy variables created for every hour 1,2,…,23. That is, if data is for hour 1, then hr_1=1, else 0

Table 8 provides the regression model results for an overall model that looked at the performance of the units during a monitoring period from June 1, 2007 to August 31, 2007. In order to model the overall operating schedule there was no minimum %peak and all values were included in the regression.

Variable	Estimate	Standard Error	Prob> |T|
Intercept	0.45455	0.01618	28.1
BTU/SQFT	0.0004524	0.00004086	11.07
DB Temp	0.00499	0.00018408	27.13
Bed Nonbed	-0.00635	0.0015	-4.23
Home Not Home	-0.02292	0.00157	-14.56
Outside Temp	-0.00060134	0.00006802	-8.84
Schedule	0.03095	0.00165	18.75
Level of Cooling	-0.01252	0.00017996	-69.56
Enthalpy	0.01047	0.00029204	35.84
hr_1	-0.01871	0.00478	-3.92
hr_2	-0.02197	0.00478	-4.6
hr_3	-0.02577	0.00478	-5.39
hr_4	-0.02746	0.00478	-5.74
hr_5	-0.03376	0.00478	-7.06
hr_6	-0.05052	0.00478	-10.57
hr_7	-0.07838	0.00478	-16.4
hr_8	-0.10389	0.0048	-21.63
hr_9	-0.11783	0.00484	-24.33
hr_10	-0.12478	0.00489	-25.5
hr_11	-0.12709	0.00494	-25.7
hr_12	-0.1321	0.005	-26.41
hr_13	-0.12846	0.00503	-25.53
hr_14	-0.11751	0.00504	-23.32
hr_15	-0.105	0.00503	-20.89
hr_16	-0.09153	0.005	-18.31
hr_17	-0.07231	0.00495	-14.62
hr_18	-0.05727	0.00489	-11.7
hr_19	-0.03886	0.00483	-8.04
hr_20	-0.02475	0.0048	-5.16
hr_21	-0.01011	0.00478	-2.12
hr_22	0.00595	0.00477	1.25
hr_23	0.00861	0.00476	1.81

Table 8: Regression Model Results

The estimated coefficients of the independent variables from the regression are listed in the column titled "Estimate" in Table 8. The standard errors of the coefficients are listed in the "Standard Error" column. If a coefficient is large compared to its standard error, then it is likely to be different from 0. The t-statistics[22] and the P values[23] are listed in the last two columns.

[22] The t statistic tests the hypothesis that a population regression coefficient is 0 when the other predictors are present in the model. It is the ratio of the sample regression coefficient to its standard error. The statistic has the form (estimate - hypothesized value) / SE. Since the hypothesized value is 0, the statistic reduces to Estimate/SE.

[23] Prob > |T| labels the P values or the observed significance levels for the t statistics. A P value of 5% or less is the generally accepted point at which to reject the null hypothesis. With a P value of 5% (or .05) there is only a 5% chance that results you are seeing would have come up in a random distribution. In other words, one can say with a 95% probability of being correct that the variable is having some effect, assuming the model is specified correctly.

The regression equation for hour one is as follows:

%Peak = 0.45455 +0.0004524 x BTU/SQFT + 0.00499 x DB Temp -0.00635 x Bed Nonbed
-0.02292 x Home Not Home -0.00060134 x Outside Temp + 0.03095 x Schedule
– 0.01252 x Level of Cooling + 0.01047 x Enthalpy -0.01871 x hr_1 (hr_1 =1)

The equation shows that for each 1 ºF increase in DB Temperature there is a 0.005 increase in the %peak variable or roughly a 0.5% increase, assuming that the other variables do not change. The value of %Peak also increased with the BTU/SQFT variable, the Schedule and Enthalpy variable at the rate of about 0.04%, 3.1% and 1.0% respectively per unit increase in the variable. The value of %Peak was inversely related to the Bed Nonbed, Home Not Home, Outside Temp and Level of Cooling variables at the rate of -0.6%, -2.3%, -0.06% and -1.3 % respectively.

The hourly variables are dummy variables that take the value of 1 or 0 depending upon the hour of day and the base profile is for hour ending 24, which has no y-intercept adjustment factor. The model takes on a unique value for each hour as the y-intercept adjustment factor is multiplied by 1 for that hour and the remaining factors are multiplied by zero. The y-intercepts are negative for all but hour ending 10 PM and hour ending 11 PM, which means that with all other variables being equal the last three hours of the day have the highest %Peak. It is important to note that these adjustments do not account for temperature changes so the actual %Peak profile will still change as a function of DB temperature and enthalpy.

3.5 Phone Survey Data Analysis and Bias Adjustments

The results of the phone survey were compiled and frequency distributions of key variables were compared to the frequencies observed in the on-site sample. As previously mentioned there were six survey question variables that were found to have a statistically significant impact on the regression model as follows;

- Type of Area Served (i.e. Bedroom vs. Non-bedroom),
- Home During Day,
- Cooling Capacity per Area Served (BTU/ft^2),
- Outside Temperature when Cooling Begins,
- Schedule or Continuous Operation, and
- Cooling Setting.

Each of these variables were tested to determine if there was a statistically different distribution of the variables within a load zone when compared with the mean values for the whole dataset using a T-test methodology. The following sections will discuss the results for each of the variables and summarize the overall findings. A complete discussion of all of the survey results is provided in appendix A.

Type of Area Served

This survey variable captured the type of area served by the room AC unit, which were classified as one of eleven different types, as shown in Table 9. The table provides the distribution of the area served room type for both the phone survey only sample and on-site sample, which shows that the top seven categories were captured in the on-site sample. Bedrooms were the most prevalent area served making up approximately 55% of the survey sample space types, followed by Living rooms, which made up 22% of the survey sample. The data shows a good correlation between the on-site and phone survey sample distributions with respect to the area served and the on-site sample is representative of the larger phone survey population.

Space Type	Phone Survey	On-site	Survey %	On-site %
Bedroom	369	**76**	55%	58%
Living Room	150	**28**	22%	21%
Downstairs Multi-zone	47	**7**	7%	5%
Office	40	8	6%	6%
Dining Room	33	**4**	5%	3%
Kitchen	17	6	3%	5%
Basement	4	3	1%	2%
Upstairs Multi-zone	5		1%	
Attic	3		0.4%	
Appartment	2		0.3%	
Whole House	1		0.1%	
Total	671	132	100%	100%

Table 9: Distribution of Area Served

The average load profiles of the on-site metered data were visually examined using RLW's interval data analysis tool Visualize-IT ® to create normalized average weekday load profiles that were normalized to the maximum demand during the metered period. Figure 6 is a graph of the normalized profiles for the seven different room types captured in the on-site sample, which shows that the bedroom profile has an inverted "bell-shape", while the other profiles all have more of a "bell-shape". It should be noted that calculation of the normalized values to the maximum demand observed in the profile and not the rated maximum demand of the units cause the percentage values to be inflated.

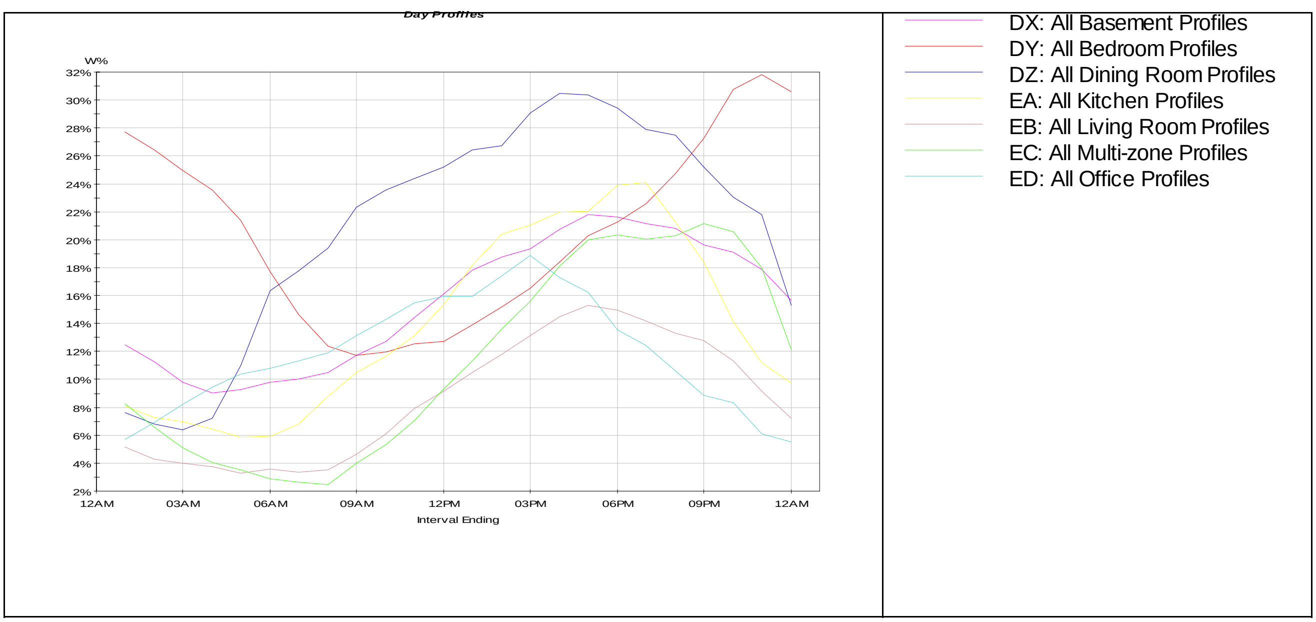


Figure 6: Normalized Profiles by Area Served

The previous figure shows that in general the bedroom profiles have a uniquely different shape from the other non-bedroom room types. The regression model was run using each of the room type as unique inputs and run with two space type variables, Bedroom and Non-Bedroom. The results indicated that two of the non-bedroom space types ("multi-zone" and "kitchen") were found to be significantly different from the non-bedroom results, however and the R-sq increased only marginally to .4646 from .4631. Given the small sample sizes associated with these space types and small improvement to the model it was decided that a two space type model would be used.

The distribution of the area served variable was also examined at the zonal level to see if there was statistically significant variation in the variable to warrant changing the mean value from the population to an individual zonal mean. T-Tests were run to test the null hypothesis that the population mean and the zonal mean were equal, a probability value (Pr> $|t|$) of 0.05 or less means that we must reject the null hypothesis that the means are equal and therefore the zonal mean is statistically different and should be used in the regression model. Table 10 provides the T-Test results for the Area served variable, which indicate that none of the zonal means were statistically significant and therefore the population mean of 55.2% Bedrooms and 44.8% Non-Bedrooms could be used for all zones

	Bed_Non-Bed		
Load Zone	**Mean**	**Pr > |t|**	**Change**
All Zones	0.5521	NA	NA
NEMA	0.5191	0.4818	No
NH	0.5496	0.9577	No
RI	0.5564	0.9268	No
SEMA	0.5649	0.7853	No
VT	0.5817	0.4999	No
WCMA	0.5354	0.7259	No

Table 10: T-Test Results for Area Served Variable

Home During The Day

This survey variable captured the type of occupancy at the home. Survey respondents were asked if they were generally home during the day or generally not home during the day. As previously discussed this variable was of some concern because of the issue of sample bias due to the relative ease of recruiting customers that are generally home during the versus those that are not generally home. The results at the premise level showed that the phone survey distribution is about 50% "Yes" and 50% "No" at the premise level. The results presented in this section were at the AC unit level and will be slightly different due to the distribution of multiple units.

Once again T-test were performed to test the null hypothesis that the population mean and the zonal mean were equal, a probability value (Pr>|t|) of 0.05 or less means that we must reject the null hypothesis that the means are equal and therefore the zonal mean is statistically different and should be used in the regression model.. Table 11 provides the results of the T-test for the Home vs. not home variable, which shows that the zonal mean was not statistically significant for any of the load zones and therefore the population mean of 53% "Yes home " and 47% generally not home would be used for all zones.

Load Zone	Home_Not Home		
	Mean	**Pr > |t|**	**Change**
All Zones	0.5307	NA	NA
NEMA	0.4651	0.1671	No
NH	0.5504	0.6773	No
RI	0.5725	0.3738	No
SEMA	0.5906	0.2089	No
VT	0.5063	0.5761	No
WCMA	0.504	0.5792	No

Table 11: T-Test Results for Home_Not_Home Variable

Cooling Capacity per Area Served

This survey variable captured the cooling capacity of room AC unit per area served and is measured in terms of BTU/ft^2. The capacity of the room AC unit was provided in the database and customers only had to confirm the capacity, while they had to provide an estimate of the size of the rooms being cooled by the AC unit. This variable had a considerable amount of variation, because the sizing of room AC units is done by the homeowner and often times is limited by the dimensions of the window that the AC unit is installed in.

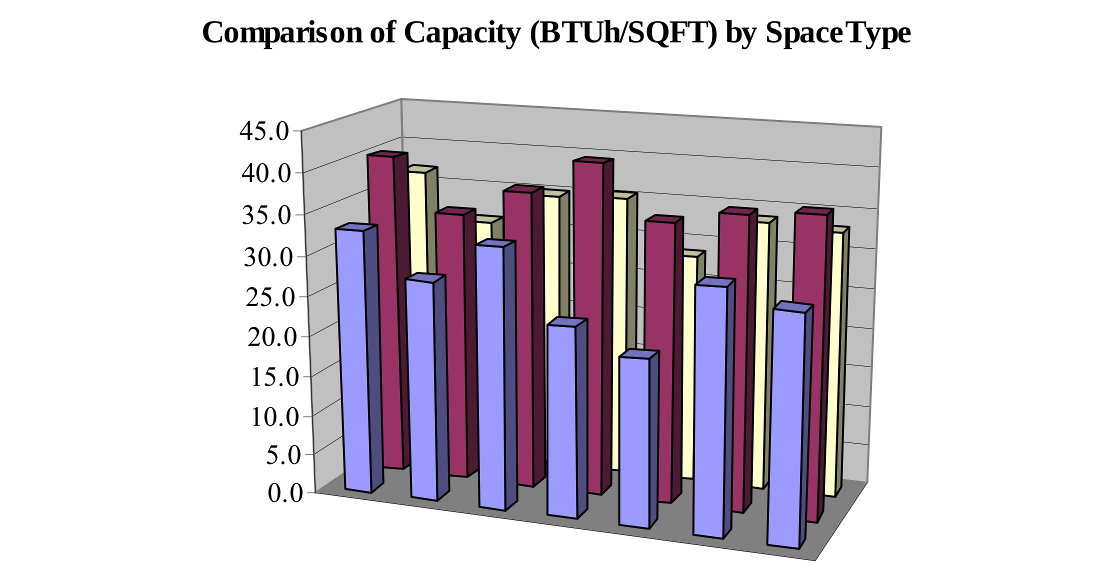
ENERGY STAR does offer guidance on the sizing of room AC units and this information is typically available on the boxes of the Room AC units, so homeowners do have access to the sizing information. Table 12 provides a summary table of the Energy Star sizing information available at http://www.energystar.gov/index.cfm?c=roomac.pr_properly_sized. Note that the as the size of the unit increases the ratio of BTUh/ft^2 decreases, which means that larger units are designed to cool more area per BTUh of capacity than smaller units. Analysis of the average capacity of the units showed that the average capacity ranged from a low of 7,392 BTUh in VT to a high of 8,501 BTUh in NH, with a population average of 7,829 BTUh. The average overall ratio of capacity per unit area (BTUH/ft^2) was 33.0 BTUH/ft^2, which is the expected range of results using the Energy Star sizing guidelines and the low Square footage recommendation.

Capacity (BTUh)	SQFT Low	SQFT High	BTUh/SQFT Low	BTUh/SQFT High
5,000	100	150	50.0	33.3
6,000	150	250	40.0	24.0
7,000	200	300	35.0	23.3
8,000	250	350	32.0	22.9
9,000	300	350	30.0	25.7
10,000	350	400	28.6	25.0
12,000	400	450	30.0	26.7
14,000	450	550	31.1	25.5
18,000	700	1,000	25.7	18.0
21,000	1,000	1,200	21.0	17.5
23,000	1,200	1,400	19.2	16.4
24,000	1,400	1,500	17.1	16.0
30,000	1,500	2,000	20.0	15.0
34,000	2,000	2,500	17.0	13.6

If the room is heavily shaded, reduce capacity by 10%
If room is very sunny, increase capaity by 10%
If more than two people regularly occupy the room add 600 BTUs for each additional
If unit is in a kitchen, increase capacity by 4,000 BTUs

Table 12: Energy Star Room AC Sizing Guidelines

The Ratio of cooling capacity per unit area (BTUH/ft^2) was highly variable in the survey data set and as expected it did vary significantly when examined by space type (Bedroom vs. Non-bedroom). Since the bedroom units tended to be smaller units the BTUh/ft^2 tended to be higher which is consistent with the EnergyStar sizing criteria. Likewise the Non-bedroom units tended to be larger and the ratio of BTUh/ft^2 tended to be smaller. Figure 7 provides a graphical comparison of the BTUh/ft^2 ratios by space type and load zone, which shows that the ratio of BTUh/ft^2 for bedrooms is consistently higher than for non-bedrooms for each load zone as well as the average for all load zones. The average capacity ratio for all load zones was 37.0 Btuh/ft^2 for bedrooms and 27.9 Btuh/ft^2 for Non Bedrooms, with an overall average ratio of 33.0 Btuh/ft^2.



	NEMA	NH	RI	SEMA	VT	WCMA	All Zones
Non-Bedroom	32.9	27.5	32.4	23.7	20.7	30.0	27.9
Bedroom	40.3	33.7	37.2	41.2	34.8	36.4	37.0
BTUh/SQFT	36.9	30.9	34.9	35.3	28.8	33.6	33.0

Figure 7: Average BTUh /ft^2 by Load Zone and Space Type

Based upon the data presented in Figure 7 it appeared obvious that there was a significant difference in the sizing ratio related to the area served variable. T-tests were performed to test the null hypothesis that the means were equal for the space type variable (bedroom, non-bedroom) and the occupancy variable (home, not-home). Table 13 provides the results of the T-Test, which clearly indicate that the space type variable has a statistically significant impact on the sizing ratio and the occupancy variable does not.

Survey Variables	Non Bedroom Mean	Bedroom Mean	Pr > |t|	Not Home Mean	Home Mean	Pr > |t|
Capacity BTUh/SQFT	**27.909**	**36.974**	**<.0001**	33.08	32.935	0.9128

Table 13: T-test Results for BTUh/ft^2 vs. Space type and Occupancy

The T-test was used to test the null hypothesis that the population mean and the zonal mean were equal. A probability value (Pr>|t|) of 0.05 or less means that we must reject the null hypothesis that the means are equal and therefore the zonal mean is statistically different and should be used in the regression model. Table 14 provides the results of the T-test, which shows that the zonal mean for both the NEMA and VT load zones for the non-bedroom space type were found to be statistically significant and those mean values were used to estimate demand and savings impacts in the model for those zones. The population mean was used for all other zones.

	Capacity BTUh/SQFT Non-Bedroom			Capacity BTUh/SQFT Bedroom		
Load Zone	**Mean**	**Pr > |t|**	**Change**	**Mean**	**Pr > |t|**	**Change**
All Zones	27.909	NA	NA	36.974	NA	NA
NEMA	**32.947**	**0.0497**	**Yes**	40.326	0.1016	No
NH	27.521	0.8791	No	33.709	0.1048	No
RI	32.371	0.0902	No	37.179	0.9249	No
SEMA	23.698	0.2283	No	41.247	0.0753	No
VT	**20.725**	**0.0016**	**Yes**	34.829	0.2454	No
WCMA	30.004	0.4623	No	36.412	0.7958	No

Table 14: T-Test Results for Capacity Ratio Variable by Space Type

Outside Temperature When Cooling Begins

This survey variable captured the customer reported temperature above which they started to operate their room AC. The results exhibited a fairly high degree of variation with the values ranging from a low of 60ºF to a high of 100 ºF. However the mean reported values were very tightly grouped. Table 15 provides a summary of the mean values reported for when room AC units are starting to operate, which shows little variation between bedroom and non-bedroom space types or by load zone. In general the room AC units are reported to start operating when the temperature is 82.4ºF, although there is some variation by load zone. There was little variation in the means with respect to space type or occupancy and t-test results confirmed that the variation was not statistically significant.

	Outside Temp. when Cooling Begins		
Load Zone	**Bedrooms**	**Non-Bedrooms**	**Average**
NEMA	84.2	83.3	83.8
NH	81.9	82.2	82.0
RI	83.9	83.9	83.9
SEMA	80.7	81.3	81.0
VT	81.6	81.3	81.5
WCMA	82.1	82.5	82.3
All Zones	**82.4**	**82.4**	**82.4**

Table 15: Outside Temperatures When Cooling Begins by Load Zone and Space Type

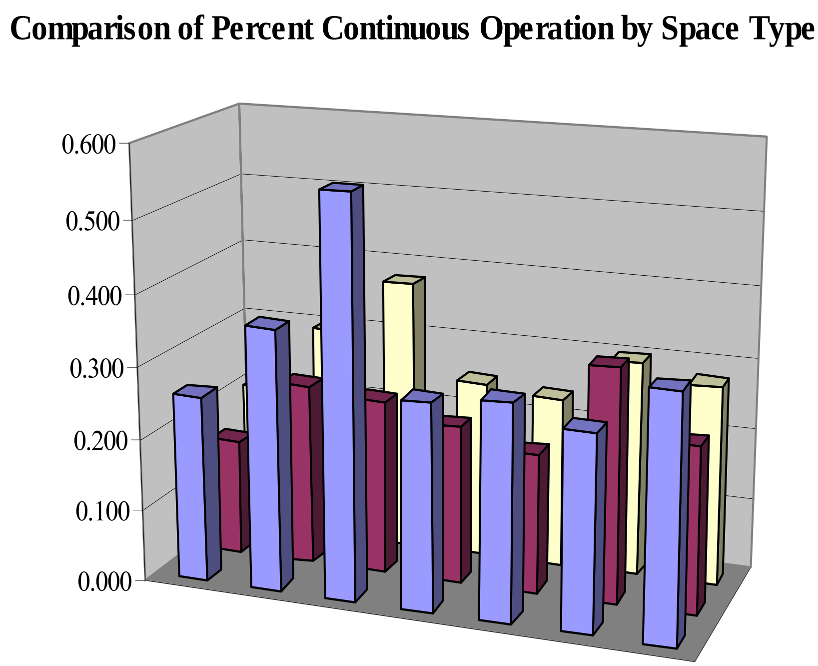
Once again T-tests were performed to test the null hypothesis that the population mean and the zonal mean were equal, a probability value ($Pr>|t|$) of 0.5 or less means that we must reject the null hypothesis that the means are equal and therefore the zonal mean is statistically different and should be used in the regression model. Table 16 provide the results of the T-tests, which show that zonal mean was statistically different from the population mean the NEMA, RI and SEMA zones and those mean values were used to estimate demand and savings impacts in the model for those zones. The population mean was used for all other zones.

Load Zone	Outside_Temp		
	Mean	**Pr > |t|**	**Change**
All Zones	82.424	NA	NA
NEMA	**83.8**	**0.0136**	**Yes**
NH	82.033	0.4976	No
RI	**83.894**	**0.0067**	**Yes**
SEMA	**80.991**	**0.0143**	**Yes**
VT	81.513	0.082	No
WCMA	82.282	0.804	No

Table 16: T-Test Results for Outside Temperature Variable

Schedule or Continuous Operation

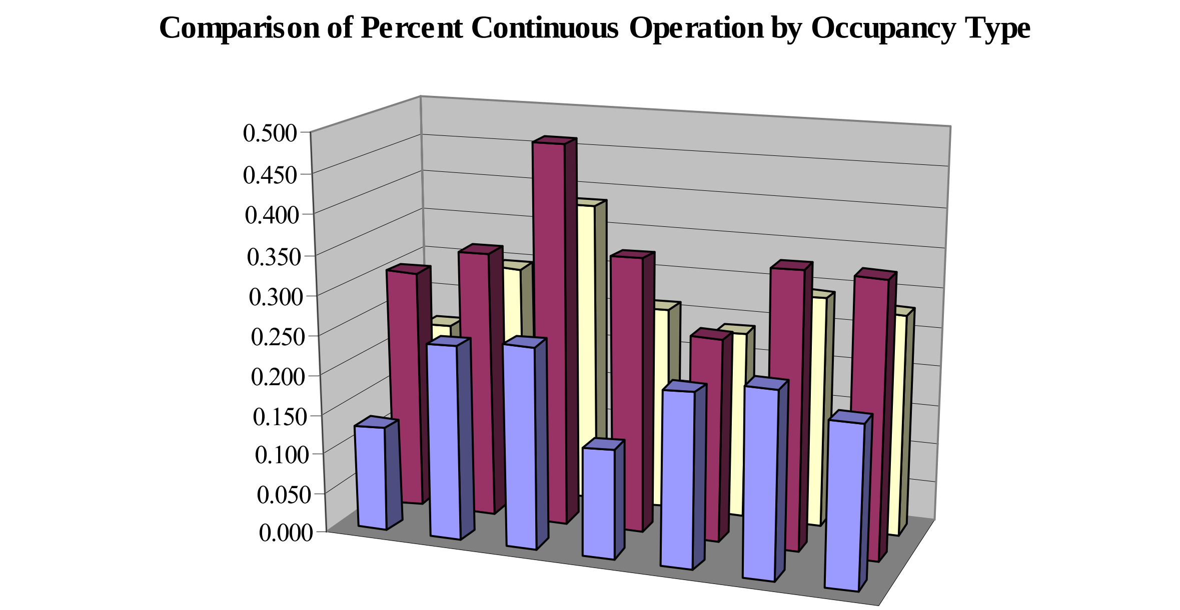
This survey variable captured the customer reported operating pattern for the room AC units, with the option being to report that room AC operating on a daily schedule or continuously. Units that operated continuously were typically controlled by a thermostat and were set to constant temperature, so that the room AC would only cycle into cooling mode when the temperature in the space would exceed the cooling temperature. One of the other response options was to report that the unit operated on some type of a daily schedule, where the possible operation would be limited to operating during a certain set of hours during the day. Figure 8 provides a comparison of the percent units that were reported to operate continuously segmented by Space Type variable. The data shows that on average across all load zones about 23% of the bedroom room AC units were reported to operate continuously, as opposed to about 34% of the non-bedroom AC units, which indicates a statistically significant difference between the two space types. The average for both in all load zones was about 28%.



	NEMA	NH	RI	SEMA	VT	WCMA	All Zones
Non-Bedroom	0.258	0.362	0.552	0.286	0.297	0.271	0.336
Bedroom	0.162	0.254	0.243	0.219	0.193	0.324	0.231
Avg Both	0.208	0.302	0.379	0.248	0.237	0.299	0.278

Figure 8: Average Percent Continuous Operation by Load Zone and Space Type

Additionally the continuous operation variable was examined by the occupancy variable (home, not-home) to see if this variable had an impact on the percentage of continuous operation for the room AC Units. Figure 9 provides a graphical comparison of the percentage of the room AC units that operate continuously by occupancy type (Home, Not home). The data indicates that for all load zones about 20% of the Room ACs operate continuously when the respondent is not generally home during the day as opposed to about 35% of the units when the respondent is generally home during the day. The average rate of continuous operation for all respondents was about 28%. As with the sector analysis of this variable by space type, the occupancy type of the respondent appeared to have a statistically significant impact on the percentage of room AC units that were reported to operate continuously.



	NEMA	NH	RI	SEMA	VT	WCMA	All Zones
Not Home	0.132	0.246	0.255	0.137	0.219	0.233	0.203
Home	0.305	0.338	0.480	0.347	0.256	0.350	0.347
Avg Both	0.213	0.296	0.385	0.260	0.238	0.292	0.280

Figure 9: Average Percent Continuous Operation by Load Zone and Occupancy Type

T-tests were performed to test the null hypothesis that the means were equal for the space type variable (bedroom, non-bedroom) and the occupancy variable (home, not-home). Table 17 provides the results of the T-Test, which clearly indicate that both space type and the occupancy type have a statistically significant impact on the percent of continuous operation.

Survey Variables	Non Bedroom Mean	Bedroom Mean	Pr > |t|	Not Home Mean	Home Mean	Pr > |t|
Cont_Sched	**0.3361**	**0.2308**	**0.0009**	**0.2033**	**0.3549**	**<.0001**

Table 17: T-test Results for Percent Continuous vs. Space type and Occupancy

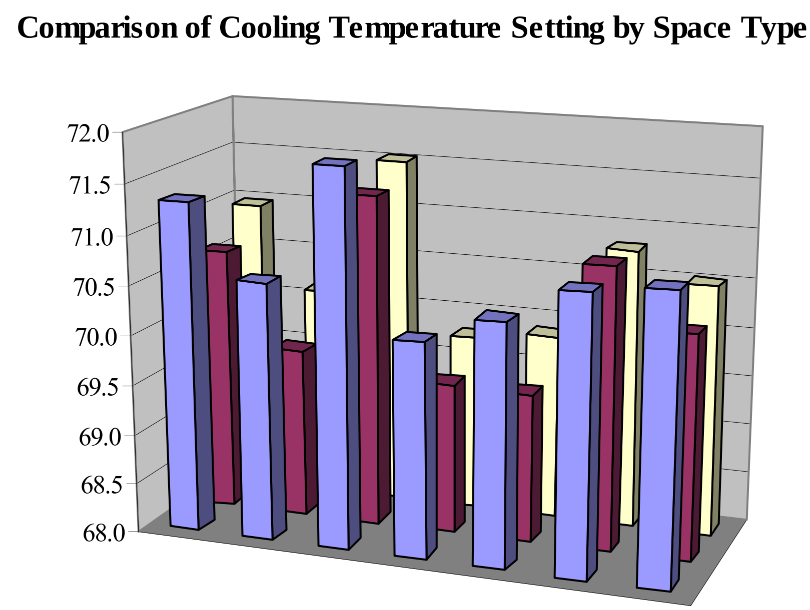
Additionally T-test were performed at the zonal level to see if there was any statistically significant variation in the Continuous operation variable by load zone after being segmented by Space type and Occupancy type. Table 18 provides a summary of the zonal level results of the T-test under the four different scenarios, which shows that the only significant difference occurred for non-bedroom, home during day AC units in the Rhode Island Zone. The rest of the T-test results indicated that the null hypothesis was valid and the average value for all zones was used.

	Cont._Sched			Cont._Sched			Cont._Sched			Cont._Sched		
	Non-Bedroom, Not Home			Non-Bedroom, Yes Home			Bedroom, Not Home			Bedroom, Yes Home		
Load Zone	**Mean**	**Pr > |t|**	**Change**	**Mean**	**Pr > |t|**	**Change**	**Mean**	**Pr > |t|**	**Change**	**Mean**	**Pr > |t|**	**Change**
All Zones	0.2345	NA	NA	0.4175	NA	NA	0.1826	NA	NA	0.2938	NA	NA
NEMA	0.1563	0.3366	No	0.3793	0.6974	No	0.1111	0.2943	No	0.2333	0.4948	No
NH	0.1538	0.5098	No	0.4419	0.7695	No	0.2727	0.1723	No	0.2222	0.4401	No
RI	0.3333	0.3021	No	**0.7059**	**0.0017**	**Yes**	0.1935	0.884	No	0.2927	0.9882	No
SEMA	0.15	0.3989	No	0.3824	0.7014	No	0.129	0.4651	No	0.3158	0.7862	No
VT	0.3333	0.2788	No	0.2703	0.0924	No	0.1522	0.6244	No	0.2439	0.5191	No
WCMA	0.2414	0.9368	No	0.3103	0.273	No	0.2258	0.5667	No	0.4412	0.0866	No

Table 18: T-test Results Percent Continuous by Load Zone, Space Type and Occupancy

Cooling Setting

This survey variable captured the customer reported level of cooling (High, Medium, or Low) or temperature setting at which they typically operated their room AC units. The response rate of numerical cooling temperature settings was quite high in the survey data, with about 85% of the 830 respondents (based on number of AC units) providing a numerical value, ranging from a low of 60ºF to a high of 80ºF. Figure 10 provides a graphical presentation of the cooling setting analyzed by space type and load zone. Note that for all load zones but WCMA the bedroom cooling setting was lower than for the non-bedroom space type and in WCMA the settings were the same. Across all load zones the average cooling setting was 70.2 ºF for bedrooms and 70.9 ºF for non-bedrooms.



	NEMA	NH	RI	SEMA	VT	WCMA	Grand Total
Non-Bedroom	71.3	70.6	71.8	70.2	70.4	70.8	70.9
Bedroom	70.7	69.7	71.3	69.5	69.5	70.8	70.2
Avg Both	71.0	70.1	71.5	69.8	69.9	70.8	70.5

Figure 10: Comparison of Cooling Temperature Setting by Load Zone and Space Type

The survey reported cooling temperature setting data were analyzed by space type and occupancy variables using T-Tests to see if there was any statistically significant variation due to either variable at the aggregate level. Table 19 provides the aggregate T-test results, which indicate that difference in mean values for bedroom and non-bedroom space types is statistically significant and the difference in mean values for the occupancy variable is not.

Survey Variables	Non Bedroom Mean	Bedroom Mean	Pr > |t|	Not Home Mean	Home Mean	Pr > |t|
Cooling_Setpoint	**70.86**	**70.248**	**0.0371**	70.653	70.418	0.428

Table 19: T-Test results for Cooling Setting by Space Type and Occupancy Type

Additionally T-tests were performed at the zonal level to see if the zonal mean values for cooling setting were significantly different than the average mean value for all zones after segmenting by the Space type variable. Table 20 provides the results of the T-test, which shows that the mean Cooling Setting of 72.1ºF for the Bedroom Space type in the Rhode Island Load Zone was statistically significant from the mean value of 70.2ºF and was used for the Bedroom component of the RI Load Zone. The mean value for All Zones by space type was used as the model input for the remaining load zones.

	Cooling_Setpoint			Cooling_Setpoint		
	Non-Bedroom			Bedroom		
Load Zone	**Mean**	**Pr > |t|**	**Change**	**Mean**	**Pr > |t|**	**Change**
All Zones	70.86	NA	NA	70.248	NA	NA
NEMA	71.31	0.385	No	70.651	0.4651	No
NH	70.585	0.6046	No	69.707	0.3336	No
RI	71.759	0.0948	No	**72.074**	**0.0359**	**Yes**
SEMA	70.152	0.2426	No	69.516	0.1886	No
VT	70.423	0.4171	No	69.5	0.1339	No
WCMA	70.769	0.8741	No	70.839	0.2847	No

Table 20: T-test Results Cooling Setting by Load Zone and Space Type

3.6 Summary of Bias Adjusted Variables

As detailed in the previous sections there were six survey variables that were used to construct the regression models and these variables were examined to adjust for any bias that may have occurred in the on-site sample do to selection bias. The largest single change from on-site data occurred in the occupancy variable, which had on-site customers reporting that 73% were generally home during the day as opposed to 53% in the larger survey sample. Both the space type and occupancy variables did not show significant variation between the overall survey results and the load zone level survey results. Table 21 provides a summary of the changes to the four remaining variables, which show that unique results will be predicted for the NEMA, RI, SEMA and VT load zones based on statistically significant survey responses. The results for the NH and WCMA load zones will be identical to those provided by the model inputs for all zones.

Load Zone	BTU/sqft	Outside Temp	Cont_Sched	Cooling Setpoint
All Zones	32.9	82.4	0.28	70.5
NEMA	**35.2**	**83.8**	0.28	70.5
NH	32.9	82.4	0.28	70.5
RI	32.9	**83.9**	**0.35**	**71.5**
SEMA	32.9	**81.0**	0.28	70.5
VT	**29.7**	82.4	0.28	70.5
WCMA	32.9	82.4	0.28	70.5

Table 21: Summary of Zonal Changes to Survey Variables

3.7 Calculation of Coincidence Factors and FLEH s

The Coincidence Factors (CFs) and Equivalent Full Load Hours (FLEH s) were developed for the 2007 summer season using the operating profiles that have been adjusted for all applicable bias using the phone survey response data as described above. The calculation of the On-Peak CF was straightforward since the performance hours are time dependent and can be calculated without having extreme ambient weather conditions. The calculation of the FLEHs was also calculated from the bias adjusted operating profiles directly. The calculation of weather normalized CFs and FLEHs were completed by adjusting the 2007 operating profiles and using Typical Meteorological Year (TMY 2) weather data to calculate the results.

The method for calculating the results involved holding the survey variables static and then running the nine different weather files so that the hourly weather variable could be used to provide hourly results. The load zone specific changes to the models were also run with each weather file as appropriate and results are provided on a weather file and load zone specific basis. Table 22 provides a summary of the On-Peak CF, Seasonal Peak CF and Full Load Equivalent Hours (FLEH) for each of the nine weather files used in the analysis using the mean value of the survey inputs for all zones. Although there were slight differences in CF and FLEHs due to zonal differences in the model inputs the difference in the final results were not much more than ± 0.001 for CF and ± 3 hours for FLEH. Therefore although the zonal differences in survey responses for some of the model variables were statistically significant when these different model input were run the results did not provide numerically significant differences in the results. This was due to a combination of factors primarily the relatively small differences in the variables, and changes in multiple variables canceling each other out. As a result we recommend that the calculation of DRV for each load zone use the CFs provided in Table 22.

	2007 Weather		TMY2 Weather			
	Average for All Load Zones		Average for All Load Zones		Average for All Load Zones	
Weather Files	**On-Peak CF**	**Seasonal CF**	**On-Peak CF**	**Seasonal CF**	**2007 FLEH**	**TMY2 FLEH**
Albany, NY	0.154	0.276	0.142	NA	224	184
Boston, MA	0.134	0.304	0.125	NA	228	175
Burlington, VT	0.139	0.276	0.119	NA	166	141
Caribou, ME	0.080	0.131	0.080	NA	60	42
Concord NH	0.143	0.290	0.134	NA	171	149
Hartford, CT	0.170	0.303	0.171	NA	272	253
Portland, ME	0.111	0.270	0.111	NA	119	102
Providence , RI	0.159	0.296	0.144	NA	245	204
Worcester, MA	0.131	0.261	0.113	NA	172	134

Table 22: Summary of CF and FLEH by Weather File using Average Load Zone Data

The Seasonal Peak performance hours were calculated by determining the hours when the real-time system load meets or exceeds 90% of the 50/50 CELT forecast for the summer 2007 period of 27,360

MW[24]. There were a total of 24 hours during the summer of 2007 when the real–time system load was 24,624 MW or greater, eight hours during June and 16 hours during August, and the 2007 Seasonal Peak CFs were calculated during those hours. It was not possible to calculate the TMY 2 Seasonal peak CF values because of the method used to create TMY 2 weather data, which uses "typical" months to create an annual file. Since the system load for New England relies on the interaction between all of the weather in the region and the TMY 2 methodology selects typical months for each weather site which results in adjacent sites having typical months from different years and it is impossible to use these data to construct an accurate model.[25] As previously discussed we recommend that the 2007 Seasonal CF values be used as an estimate of typical year values as the 2007 summer season was fairly representative of typical year weather.

ISO-NE uses a statistical regression model that utilizes economic variables as well as weather variables to forecast the summer and winter peak loads for the New England system. The process also includes historic weather data for the eight New England weather stations shown Table 23, which are weighted as indicated and used to predict the system peak loads. The ISO-NE methodology uses a variable called a WTHI – a three day Weighted Temperature Humidity Index – to predict the summer system peak however an exact definition of this variable is elusive. The variable appears to be a daily peak variable averaged over three days. The reference case value of the WTHI (80.1) is the 50th percentile of the portion of a WTHI distribution that encompasses the range of WTHI values at which the seasonal peak would occur. The extreme case value of the WTHI (82.0) is the 90th percentile of that distribution. Although difficult to characterize a "normal" dry bulb temperature and the dew point temperature, (because the three day weighting of the WTHI can be any number of combinations of temperature and humidity) a reasonable approximation would be 90 degree F with a dew point of 70.[26]

[24] Data taken from ISO-NE 2007 Capacity, Energy, Load and Transmission (CELT) report dated April 20, 2007.

[25] For example the June data for Albany could be from 1976, while the Boston data could be from 1980 and Hartford from 1978. In order to develop an accurate typical regional weather model it will be necessary to select typical months from the same year for all of the regional files.

[26]This definition was taken from Northeast Power Coordinating Council Multi-Area Reliability Probability Assessment Summer 2003 pages 7-8.

Weather Station	State	Station Code	Closest Load Zone	NE Summer Weight	NE Winter Weight
Boston	MA	BOS	NEMASSBost	0.201	0.214
Bridgeport	CT	BDR	--	0.070	0.075
Burlington	VT	BTV	VT	0.046	0.040
Concord	NH	CON	NH	0.058	0.055
Portland	ME	PWM	ME	0.085	0.082
Providence	RI	PVD	RI & SEMASS	0.049	0.048
WindsorLks	CT	BDL	CT	0.277	0.277
Worcester	MA	ORH	WCMASS	0.214	0.209

Table 23: ISO-NE Weather Stations used for Peak Forecasts

The ISO-NE report entitled "Summer 2007 Weather Normal Peak Load" noted that the weather normalized peak load for 2007 was 27,460 MW, 0.4% (100 MW) higher than the April 2007 forecast of 27,360 MW for the summer of 2007. According to the report "The summer of 2007 can be characterized as normal with respect to overall temperature and humidity. There were 3 week days near or above the expected WTHI of 80.1°, which corresponds to a New England dry bulb temperature of approximately 90° and dew point temperatures in the70s." The peak day methodology does not lend itself well hourly regression models because it lacks the proper level of detail. Therefore we would defer to ISO-NE characterization of the summer of 2007 as normal with respect to temperature and humidity and recommend that both the 2007 On-Peak CFs and 2007 Seasonal Peak CFs be used for future year estimates.

> Based on ISO-NE characterization of the summer of 2007 as normal with respect to temperature and humidity, we recommend that both the 2007 On-Peak CFs and 2007 Seasonal Peak CFs be used for future year estimates of Demand Reduction Values.

The relative precision of the estimated impacts provided from the bias adjusted model could not be calculated directly because the model used the average inputs from the survey data and thus provided only one set of numbers depending upon the load zone and weather file selected. A first order approximation of the relative precision is provided by the following equations;

$$Y = f(x) + E \Rightarrow E = Y - f(x)$$

$$Y_{adj} = f(x_o) + E$$

$$Y_{adj} = Y + [f(x_o) - f(x)]$$ Where,

Y = the actual CF for the hour from the metered

f(x) = the predicted value from unadjusted model

$f(x_o)$ = the predicted value after adjusting the model for bias

E = expected error in the adjusted model

Y_{adj} = the predicted output from the adjusted model

Table 24 provides the estimated relative precision of the monthly and summer On-Peak CF values using the methodology explained above. The relative precision ranged from ±14.4% for June to ±10.4% for the summer season. Note that the mean value for June was 0.218, which was higher than expected because most of the June metered data was collected during a heat wave at the end of the month.[27]

Month	sample (n)	Mean	Standard Deviation	Cv	Relative Precision
June	82	0.218	0.222	1.02	±14.4%
July	108	0.156	0.155	0.99	±12.2%
August	108	0.174	0.164	0.94	±11.7%
Summer	114	0.175	0.152	0.87	±10.4%

Table 24: Estimated Relative Precision of On-Peak CF

4 Using the Results

The results of this study are meant to be used by the sponsors to determine the Demand Reduction Value (DRV) for room AC measures in the ISO-NE FCM. The CFs were calculated during the performance hours defined as follows;

- **Summer On-Peak**: average non-holiday weekdays from 1-5 PM June, July and August.
  - ➢ There were a total of 260 Summer On-Peak performance hours in 2007
- **Summer Seasonal Peak** hours occur when Real Time load is equal to or greater than 90% of the 50/50 seasonal peak load forecast during Summer (June – August).
  - ➢ There were a total of 24 Summer Seasonal Peak performance hours in 2007

It is important to understand the time period used to calculate the CFs. Use of summer On-Peak CF in a model that is designed to accept demand impacts during a system peak hour would result in underestimating the peak impact of the measure during the system peak hour. This is because the summer On-Peak CF is calculated over a 260 hour period. The summer Seasonal Peak CF provides a significantly more accurate estimate of system peak because it was calculated during the 24 hottest hours of 2007.

[27] The adjusted model results reflect the mean coincident value during the entire month of June and are therefore significantly lower.

5 Summary of Findings

One of the more obvious findings of this study is the fact that the summer On-Peak performance period tends to greatly reduce the demand impacts of the room AC measure. Defining the coincidence period across every summer weekday hour from 1 PM to 5 PM regardless of weather conditions greatly reduces the value of this measure, which is highly temperature dependent. Comparing the Boston 2007 On-Peak CF of 0.134 to the Boston 2007 Seasonal Peak CF of 0.304 shows that all things being equal a sponsor that registers their room AC measure as a Seasonal Peak resource would have a 227% higher Demand Reduction Value (DRV) than the same resource registered as an On-Peak resource. Clearly the overall benefit to the system from room AC measures is greater than the DRV that is determined using On-Peak performance hours because the demand impact for this measure is maximized during system peak hours when it is most needed. The decision about how to enroll Room AC measures must be viewed in the larger context of the entire energy efficiency portfolio and the tradeoff between evaluation costs and the relative size and interaction between measures within a portfolio. It is important to keep in mind that the ISO-NE FCM market rules do not allow an ODR project to contain both On-Peak and Seasonal Peak resources and each project must achieve 10% relative precision at the 80% confidence interval.

Appendix A: Phone Survey and Results

NECPUC Residential Room Air Conditioner Participant Telephone Survey

Hello, my name is _______, and I am calling on behalf of <SPONSOR>. We are evaluating the ENERGY STAR Room Air Conditioner rebate program that you participated in over the past two years. We want to find out how much energy is typically saved by ENERGY STAR AC units so we would like to ask you a few questions about how you use the room air conditioners in your home. Would you be able to take 5-10 minutes to answer a few questions for us?

Type of Building (Circle One): Residential Commercial

According to our records you received rebates on the following room air conditioners through the program:

Unit #	Mfg	Model #	Size (Btuh)	Store	Store City	Rebate Date
1						
2						
3						
4						
5						

1. How many of these room AC units do you currently operate? _________

2. Do you have any additional room AC units that you currently operate? _________ how many? __________

I would like to ask you some questions about the areas that the rebated AC unit(s) is/are) installed in and the seasonal operation.

Unit #	3. What type of room is it installed in?	4. Do you use it to cool a single room, a zone, or the whole house?	5. What is the size of the room/area it serves (sq. ft.)	6. What month is the unit typically installed/used for the first time?	7. What month is the unit typically removed/shut down for the season?	8. At approximately what outside temperature do you start to use the unit?
1				Early, Mid, Late _______	Early, Mid, Late _______	
2				Early, Mid, Late _______	Early, Mid, Late _______	
3				Early, Mid, Late _______	Early, Mid, Late _______	
4				Early, Mid, Late _______	Early, Mid, Late _______	
5				Early, Mid, Late _______	Early, Mid, Late _______	

Now I would like to ask you some questions about the typical daily operating schedule of the unit(s).

Unit #	**9. Do you use it continuously when the outside temp is above** (Q8 Response) **or do you operate on a daily schedule?**		**10. During a heat wave (90 degrees and above) do you operate the unit all of the time?**	**11. Under normal conditions what hour of day is the unit typically turned on during the week?**	**12. Under normal conditions what hour of day is the unit typically turned off during the week?**	**13. Under normal conditions what hour of day is the unit typically turned on during weekends?**	**14. Under normal conditions what hour of day is the unit typically turned off during weekends?**
1		If continuous, Skip to Q15; otherwise Go on to Q10.					
2							
3							
4							
5							

Unit #	**15. What level of Cooling (High, Med, Low) or Temperature Setting do you typically use?**	**16. What fan speed do you typically use during this time (low, medium, or high)**
1		
2		
3		
4		
5		

This portion of the survey will only be read to customers selected in our on-site sample.

As part of our evaluation we are installing metering equipment to measure when the AC unit(s) operates. In order to compensate you for your inconvenience we are paying customers a $100 cash incentive in exchange for their participation in the on-site portion of our study.

We would like to record the actual energy use of some ENERGY STAR AC units over the summer. We would set up a time to visit your home and install monitoring devices on each of the room air conditioners that were rebated through the program. The devices would stay on for the entire summer and be removed in early September. We would then call you to set up a time to pick them up and provide you with your incentive.

Does this sound like something that you might be interested in?

The metering device is a small plug meter that is plugged into the power outlet and than the AC unit is plugged into the plug meter. The plug meter records the interval power consumption of the AC unit, but does not use any additional power to take these measurements. The dimensions of the meter are 7" long, 4"wide and 2" high.

The telephone survey assessed the operation of 815 room air conditioners that were rebated through the program. As Table A- 1 shows almost all (98.8%) of these units were installed and in-use at the time of the survey, according to the customer.

Is the unit installed? (n=815)	
Yes	98.8%
No	1.2%

Table A- 1: Installation Rate

Table A- 2 presents the areas where customers reported the rebated units were installed. More than three-quarters (77.4%) of the units were installed in a bedroom or the living room. Table A-3 shows that more than 60% of the rebated units are serving single rooms that are approximately 224 square feet in size. The remaining units are serving zones that average about 486 square feet in size.

Room	**% Installed (n=805)**
Bedroom	55.3%
Living Room	22.1%
Multi-downstairs	7.1%
Office	6.0%
Dining Room	4.6%
Kitchen	2.7%
Basement	0.9%
Upstairs Multi-zone	0.6%
Attic	0.4%
Apartment	0.2%
Whole House	0.1%

Table A- 2: Room Unit Is Installed In

Area Served	**% Installed (n=805)**	**Avg. Size of Area (sq. ft.)**
Single Room	61.5%	223.6
Zone	38.3%	485.8
Don't Know	0.2%	-
Total	**100.0%**	**321.1**

Table A- 3: Area served by Room Air Conditioner

Each surveyed customer was asked to provide the months (and time of month) that they installed and removed the room air conditioner that was rebated through the program. Figure A- 1 provides the in-service rates by month and time of month. Customers reported installing the units as early as late April/early May, with the last removal occurring in late December. Almost every unit (99.7%) is in-service between late July and mid-August. More than 90% of the units are used from late June through mid-August.

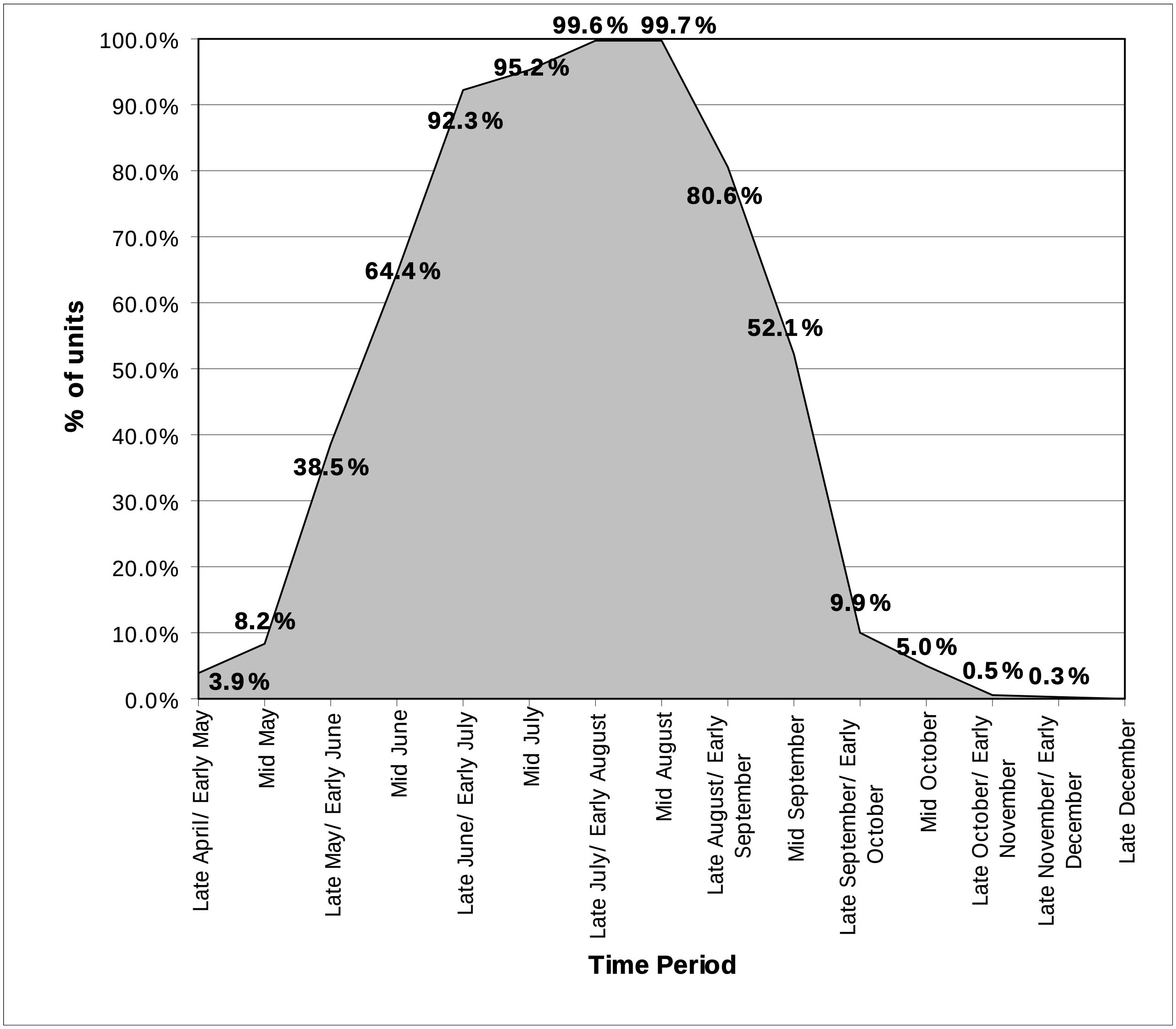


Figure A- 1: Room Air Conditioner In-Service Rates from April to December

Figure A- 2 shows that more than half (55.0%) of the respondents reported that they start to use their room air conditioner when the temperature is 80-85 °F. An additional 15.3% reported using it when the temperature is 90-95 °F, while 14.5% do so from 70-75 °F. The average temperature provided by all respondents was 82.4 °F.

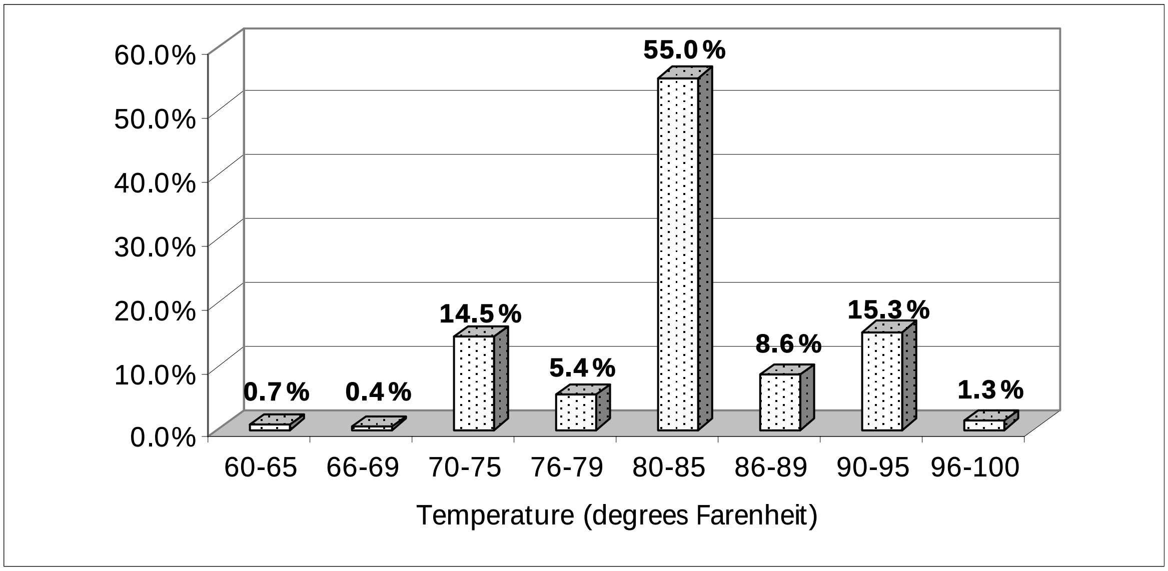


Figure A- 2: Temperature at which Room Air Conditioner is used

Almost three-quarters (72.4%) of the respondents reported that they run their room air conditioner on some type of schedule, with the remainder running it continuously. Of those running their units on a schedule, 68.5% reported that not even a heat wave (90 ^{o}F or higher) would cause them to run their unit continuously. Approximately 30% would run their unit continuously during a heat wave, with the remaining 1.4% reporting that it would depend on how hot it got and for how long.

When asked to provide weekday and weekend operating hours, only about 60% of the respondents were able to do so. The average operating hours reported by these customers was 9.3 hours per weekday and 10.2 hours per weekend day.

Figure A- 3 presents the distribution of responses relating to the customer reported temperature setting used on the rebated room air conditioners. Almost half (48.2%) of the respondents set their room air conditioner between 70-73 ^{o}F. More than three-quarters (77.9%) set them between 68-75 ^{o}F.

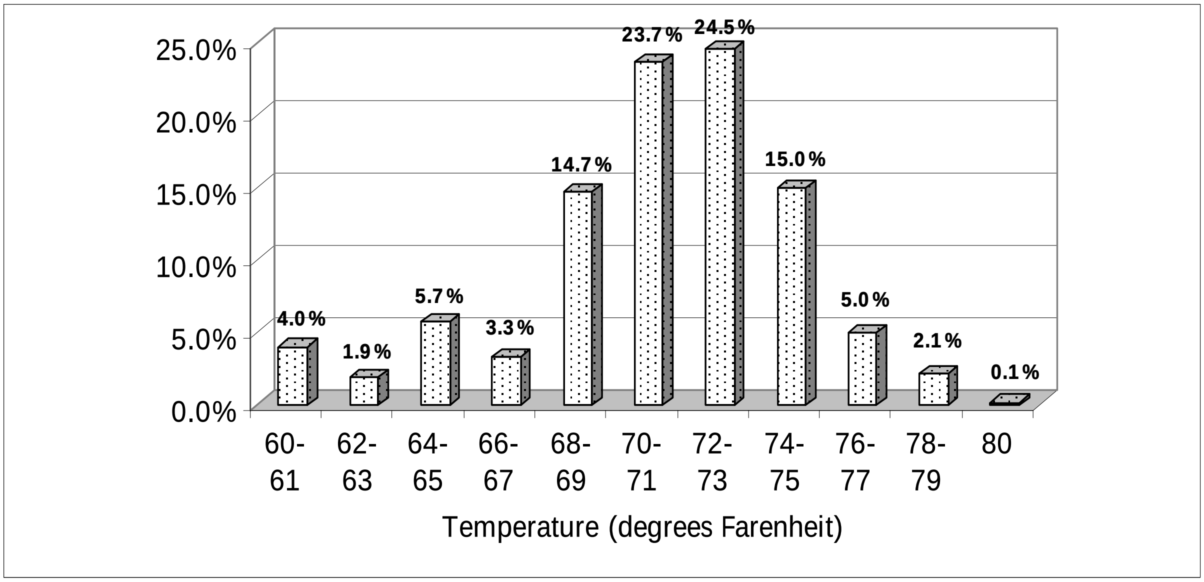


Figure A- 3: Room Air Conditioner Temperature Setting

Figure A- 4 shows that almost half (47.9%) of the respondents use the medium fan speed, while almost one-quarter (24.9%) use the high speed. The remainder use the low (21.4%) and 'Energy Saver' (5.8%) speeds.

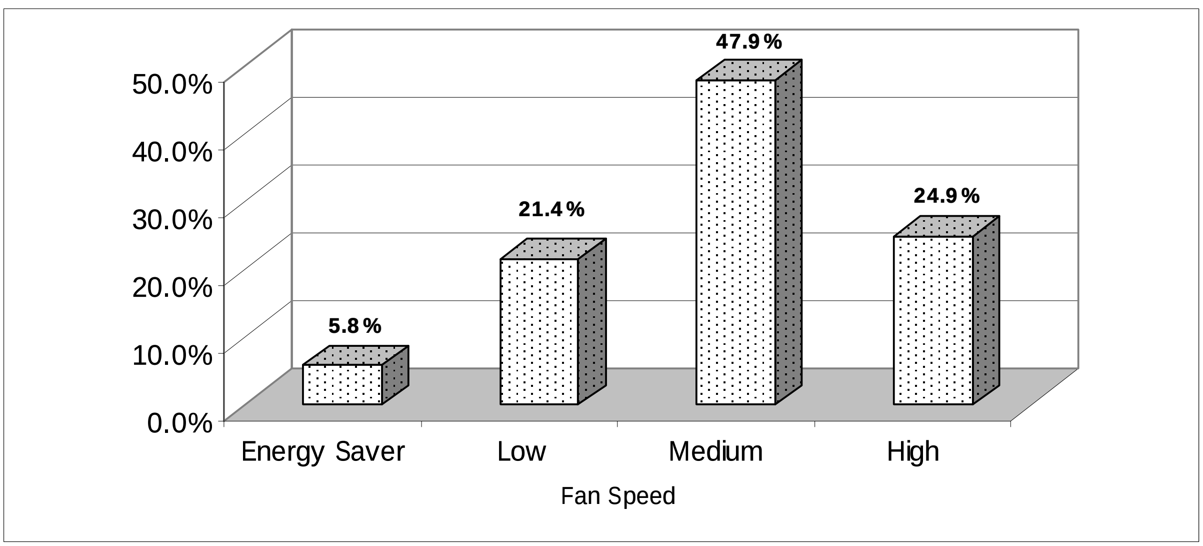


Figure A- 4: Room Air Conditioner Fan Speed

Appendix B Meter Compliance

Section 10.2 of the ISO-NE M&V manual contains a list of seventeen requirements for metering equipment that is used for measuring Demand Reduction Values (DRV) in the Forward Capacity Market (FCM). The requirements can be divided into four general categories, which are Standard Conformance, Technical Specifications, Usage & Method and Calibration & Maintenance, as presented in Table B - 1.

#	Application	Standard Conformance	Technical Specs	Usage/ Method	Calibration/ Maintenance
1	All solid-state measurement equipment	X			
2	Equipment directly measuring power or demand	X			
3	Instruments measuring volts, amps, and phase angle	X			
4	Data recorders that are recording pulses			X	
5	Equipment exposed to significant harmonics	X			
6	True RMS kW measurements and accuracy		X		
7	Measuring imbalanced three-phase loads			X	
8	Sampling rate on circuits with significant harmonics	X	X		
9	Accuracy of demand calculated with proxy variables		X	X	
10	Demand calculations to use power factor of the end-use			X	
11	Data recorders must be synchronized in time with NIST	X	X	X	
12	Equipment calibration to appropriate standards	X			X
13	Equipment maintenance to appropriate standards	X			X
14	Documentation of calibration and maintenance activities				X
15	Availability of calibration and maintenance records				X
16	Alternative accuracy, calibration, and maintenance standards				X
17	Interval data collection frequency		X	X	

Table B - 1 ISO-NE M&V Metering Requirements

Some of the requirements listed are clearly not applicable to the single phase meters used in this study, including # 4 for pulse meters, # 7 for three phase loads, and #9 for proxy variables. There are eight requirements (#1, #2, #3, #5, #8, #11, #12, and #13) that refer to some set of standards, be they ANSI, IEEE, relevant, equivalent, or industry/manufacturer in nature. Five of the requirements (#6, #8, #9, #11, and #17) indicate a technical specification that must be met. Six requirements (#4, #7, #9, #10, #11, and #17) involve the methods by which the equipment is installed or used. Finally, five requirements (#12, #13, #14, #15, and #16) specifically target calibration and maintenance of M&V equipment. Many of the ANSI and IEEE and other documents are lengthy and are primarily focused on revenue grade socket meters. The following sections will discuss the metering compliance with requirement numbers 1, 6, 8, 11, 13 and 17, which we have deemed to be relevant and reasonable to address.

The metered data used for this study was collected using Educational Electronic Devices (EED) WattsUP? Pro ES plug meters to measure the True RMS power of the room AC units. The manufacturer lists the meter accuracy at ± 1.5% for true RMS power measurement and all of the meters were calibrated to that standard prior to shipping. The meters were also checked for accuracy prior to installation as shown in Figure 11 below. Note that in this case the WattsUP? Plug meter and the Yokagawa hand held meter were within 3 watts of each other on a 360 Watt load, which is less than a 1% difference within the low end of the expected operating range for the room AC units. The WattsUP? meters are solid state electronic meters that require infrequent calibration and they should have remained within factory specifications for the duration of the data collection period for this project. (# 6 and #13).

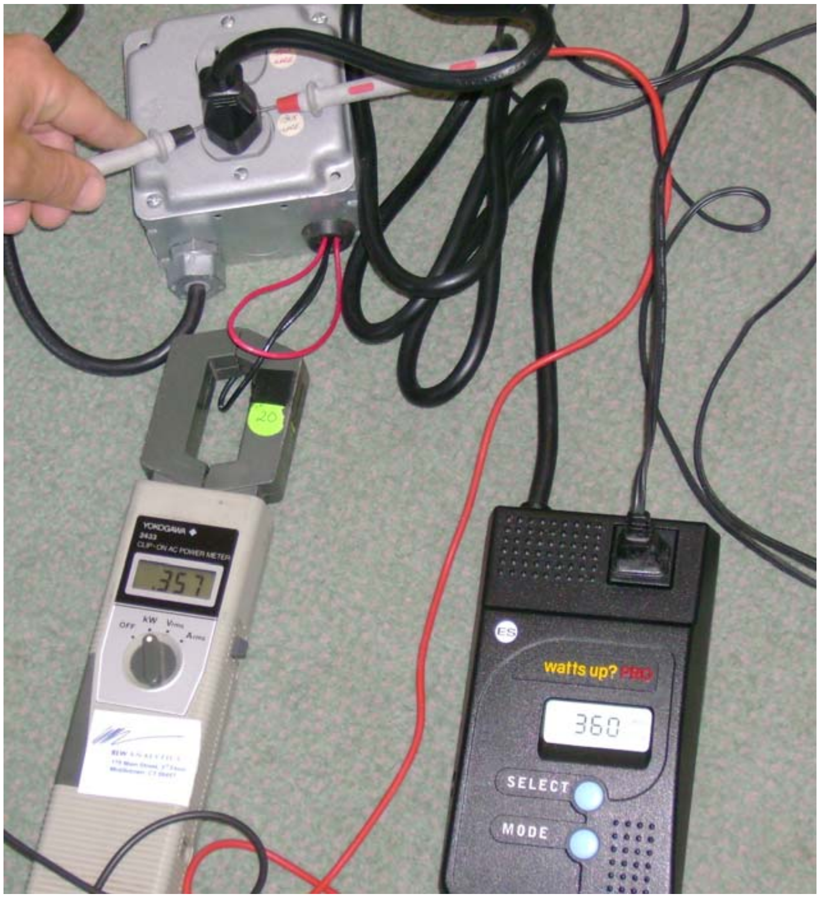


Figure 11: Checking the Calibration of WattsUp? Plug Meter

Section 10.2 of the ISO-NE M&V manual specifies that measurement tools must be synchronized in time within an accuracy of ±2 minutes per month with the National Institute of Standards and Technology ("NIST") clock. The EED WattsUP? ES meter contains a solid state circuit that exceeds the ±2 minutes per month standard for time drift. RLW standard operating procedure was to synchronize all of the WattsUP? Plug meters project to a desk top computer clock that is linked to our network server and maintained in synch with the NIST clock (#11).

The WattsUp? meters are UL rated for safety for indoor use at a temperature range between 43ºF and 117 ºF. The meters are also rated to operate up to an elevation of 6,562 feet and at a relative humidity of up to 80% at 98ºF declining linearly to an RH of 50% at 117 ºF and we can reasonably assume that all of the units we operated at these UL rated conditions. UL ratings are equivalent to the American National Standard Institute ("ANSI") standards (#1).

Requirement 17 of the ISO-NE M&V Manual states that "Interval metering devices shall collect electricity usage data at a frequency of 15 minutes or less." Although it is unclear if this requirement is ambiguous for failing to differentiate between sampled and integrated values. The likely intention was to double the Nyquist frequency thus mitigating data aliasing in equipment that duty cycles such as air conditioning and water heaters. Many interval metering devices (including the WattsUp? meter) sample data continuously, integrating and storing data at a programmable interval. For data of this nature, rigorous computation of coincident peak demand impacts requires no more resolution than hourly data. In any event, the WattsUp? meters were set up to record data at 15-minute intervals so even under the strictest interpretation of this requirement the metered data would be in compliance (#17).

Finally the WattsUp? meter's literature indicates that the meter measures voltage and current thousands of times per second and is capable of measuring non-sinusoidal wave form power accurately. The manufacturer has indicated that the sampling rate is in excess of the 2.6 kHz requirement for measuring harmonics listed in the ISO-NE M&V manual (#8). Based on the meter specification data provided by the manufacturer we conclude that the metered data used for this study is in compliance with the ISO-NE M&V requirements.

Appendix C Statistical Sampling Compliance

Section 7.2 of the ISO-NE M&V Manual provides requirements for statistical sampling used for calculating the Demand Reduction Value (DRV) for an Other Demand Resource (ODR) project in the Forward Capacity Market (FCM). The manual states that "If the Demand Reduction Value is estimated from one or more samples, the required sample size(s) must be based upon targeting 10% relative precision at an 80% confidence level. If a Demand Resource Project consists of multiple sites and/or measures, and the Project Sponsor uses multiple samples to estimate the aggregated Demand Reduction Value during the Performance Hours in each Load Zone as the sum of all individual measured Demand Reduction Values, the sampling requirements may be met (1) for each sample or combination of samples used, (2) for the combination of all samples, or (3) by using strata as described in Section 7.2.2(2)." We interpret statement #2 to mean that the Room AC sample as a segment of a larger project would not have to achieve the target relative precision, as long as the target precision was achieved for the combined sample for the overall project.

The M&V manual goes on to define Strata in Section 7.2.2(2) as "any subset of the Project's population that is based on known information. The concept of strata may include, but is not limited to: programs in a state sponsored demand side management portfolio or subsets of an entire population of affected equipment at a project site that have similar operating characteristics." In this case the M&V manual states that "If the Demand Reduction Value is estimated from a sample drawn from 2 or more strata the overall test sample size must be based upon targeting 10% relative precision with an 80% confidence interval." Our interpretation of this statement is that as long as the room AC measures are treated as a component or strata within an overall project, each individual stratum does not need to achieve the 10% relative precision at the 80% confidence interval, as long as the combined precision for the overall project achieves the target precision.

In the case of the present study the overall relative precision did not achieve the target precision primarily because the actual Coefficient of Variation (Cv) was higher than the value used in the sample design. However given that room AC measures are but a small portion of the sponsors overall ODR projects, the results should not exclude their overall projects from achieving the target relative precision of 10% at the 80% confidence interval.

Additionally section 7.4 addresses the issue of "sampling for a population of similar Demand Resources spanning multiple Load Zones", by stating that "project sponsor must demonstrate that the accuracy and precision requirements apply… to the overall population of Demand Resources being studied, rather than to the Project or Projects within each individual Load Zone" and demonstrate the method for controlling any bias attributed to sampling across Load Zones. We believe that design of this study using a large survey sample with a nested on-site metering sample and multiple weather files along with running T-test to look for differences across load zone has adequately addressed the requirements for sampling across load zones.

Appendix D Monitoring Frequency Compliance

Section 11.2 provides the requirements for the monitoring frequency and duration of ODRs for the purposes of calculating Demand Reduction Values (DRV) as can be summarized as follows: The duration and frequency of metering and monitoring must be sufficient to ensure an accurate representation of the amount of electrical demand consumed or generated both without and after Project installation and during Performance Hours, while accounting for independent parameters such temperature, humidity, etc. that impact the DRV. In the case of the present study we feel that the monitoring period collected data at a sufficient frequency (integrated energy recorded at 15-minute intervals) and that the duration of the monitoring period (Starting June 4th and running into September) was sufficient to meet the requirements of this section. Additionally the use of multiple real year weather files for modeling the results should address the need for accounting for independent parameters that impact the DRV during the performance hours.