C&I Unitary HVAC Load Shape Project
Final Report

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a project facilitated by Northeast Energy Efficiency Partnerships (NEEP)

Submitted to NEEP

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0 Executive Summary

This C&I Unitary HVAC Load Shape Project developed weather normalized 8,760 (representing every hour of the year) cooling end-use load shapes representative of hourly savings for the target population of efficient unitary HVAC equipment promoted by efficiency programs in the New England, New York and mid-Atlantic regions. Given the trade-offs between up-front capital costs and continuing operating costs, unitary HVAC is generally chosen for situations with minimal internal cooling loads, and where operating hours are not large and are concentrated in the summer. Unitary HVAC is one type of cooling equipment, with relatively low capital costs but high operating costs. Where cooling loads are more evenly distributed throughout the year and cover substantial internal heat gains, other types of cooling equipment - with higher capital costs, but lower operating costs, are typically chosen. These other types include (by ascending efficiency) air-to-air air conditioners and heat pumps, water-to-air heat pumps, and chillers. The unitary HVAC load shapes developed in this project further support program administrator calculations of savings in the forward capacity markets. These load shapes were based on results of primary data collection, including metering, completed as part of this study, as well as data available from existing sources. Not all Forum sponsors were able to provide sites for metering. However, by design and intent, the study goal was to serve all Forum members with results that are transferable within the Forum overall including those not able to provide sites for metering.

0.1 *Methodology and Sample Design*

The sampling and analysis results were developed relative to the key dimensions of unit size and unit location. The sampling framework was devised to meet the needs of sponsors and allow for determination of average coincident peak demand impacts according to independent system operator definitions and confidence/precision criteria. Data to establish the sample frame was received from 13 sponsors and 11 of those sponsors had data meeting the minimum study requirements. HVAC metered data was available from three sponsors, but only the BG&E Commercial AC Profiler project had data for units meeting the study criteria. All other C&I HVAC data identified in the NEEP Phase I Load Shape Project[1] was identified as representing larger or custom systems not characterized as “Unitary C&I HVAC from 1 to 100 ton”. The study population excluded units with rebated economizers, devices which optimize the amount

[1] The End Use Load Data Update Project – Final Report Phase 1, 2009, by KEMA for NEEP and Regional EM&V Forum sponsors, is available at www.neep.org/emv-forum/forum-products-and-guidelines.

of fresh outside air drawn into cooled spaces. For multiple sponsors this only included dual-enthalpy economizers which have temperature and humidity sensors both outdoors at the unit and indoors in the cooled space. For a few sponsors this included rebated economizers of unknown type. The economizers were excluded because the savings claim for those measures are based on reducing the normal operating hours of the high efficiency equipment and inclusion required oversampling that was outside the scope of the study.

The unit installed cooling capacity, its “size”, was used to develop a small and large sampling dimension based on prior studies and experience that larger units have different annual full load hours and peak coincidence timing. The units also are bi-furcated into small and large based on the fact that large units (between 11.5 and 100 nominal tons cooling) have multiple compressors and fans that operate in stages while a majority of small units (between 1 and 11.25 tons) are single stage units. The size cut point conforms to the ASHRAE 90.1 (2007) size class designations which set the minimum efficiency for new equipment based on nominal installed capacity range.

A set of six weather region categories met the need to minimize the number of weather regions while maintaining meaningful weather categorizations and staying within the task budget. A representative city with typical meteorological year (TMY3) weather data available would then be chosen for each weather region to provide normalized weather. The unit level regression models used the TMY3 weather data as inputs to weather normalize predicted loads which were based on actual metered year weather and also extrapolate data outside the metering period. The TMY3 weather files are developed to represent typical hourly conditions based on 15 years of data for a particular station. They represent conditions for annual energy computer simulations and do not represent extreme design conditions nor are they simply the average with no extreme hours or days.

The sample was designed to achieve minimum peak demand estimate precisions of 10% at the 90% confidence interval for the aggregate Loadshape which would require 133 to 530 sampled units depending on error ratio. An error ratio of 1.0 was chosen for small units and 0.6 for large units to achieve the desired precisions for peak demand estimates as well as annual load shapes based on review of all the available information from past studies. The error ratio measures the population variability of unit level demand relative to the connected load of the HVAC unit. The connected load is defined as the unit’s rated load used in the calculation of energy efficiency rating (EER) defined by American Heating and Refrigeration Institute (AHRI) standards 210/240. The connected load of the HVAC unit was obtained from tracking data directly or accurately through unit make and model number for the majority of A/C units in the study population. All connected loads in the analysis were estimated based on tonnage and unit EER.

The unit-level sample was designed such that total sample would be evenly allocated by weather region and within regions proportional to the population count for allocation by size for small and large units. This design was chosen given the limitation of having incomplete data on existing stratum-specific estimates of error ratios that could inform this study's design. Through multiple meetings the Forum came to agreement on a sample design of 45 small units and 30 large units for each of 6 weather regions for a total sample size of 450 units which would be supplemented by some available data for small units from the BG&E AC Profiler study. The following table describes the total achieved sample including the data leveraged from previous studies. As previously mentioned, only data from the BG&E Commercial AC Profiler study was applicable and most of the data fell under the small unit category. This study actually metered 22 units in the Mid-Atlantic small-stratum and leveraged existing metering data on 101 units from BG&E as shown in the table.

Table 0-1: Sample of Units and Connected Load by Region and Size Strata

Includes Leveraged Data

	Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
Region	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Mid-Atlantic - BGE	95	6	101	516.4	91.8	608.3
Mid-Atlantic - Metered	22	15	37	257.2	361.5	165.3

	Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
Region	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Mid-Atlantic	117	21	138	773.6	453.3	1,226.9
NE-East Mass	45	30	75	260.1	567.1	827.2
NE-North	45	30	75	251.8	664.2	916.0
NE-South Coastal	47	31	78	291.3	739.2	1,030.6
NY- Inland	44	33	77	252.7	438.3	691.0
NY- Urban/Coastal	44	24	68	383.1	383.8	766.9
Total	**348**	**163**	**511**	**2,212.7**	**3,245.8**	**5,458.5**

0.2 *Data Collection and Unit Analysis*

Following sample design, primary and backup samples were chosen for the purpose of scheduling metering installation and data collection site visits. The installation of meters began in May and ended in early June. All meters were removed in October. Data was collected for all HVAC units specified in the final sample design and selection in adherence to the on-site measurement protocols. The project recognized the critical importance of full compliance with all state and regional measurement requirements. The power measurement equipment complied with ISO New England and PJM Interconnection M&V protocols[2]. The data collection also included unit nameplate information, outside air control type, control settings, site building type, and data logger configuration.

Beginning with the removal of the first meters in October, regression modeling began. Each unit was modeled individually, taking into account factors such as day type, sequential hot days, and unique temperatures and humidity. All system fan usage during compressor and condenser "cooling" operation was included in the analysis. Peak coincidence factors and annual full load hours were defined to only include the cooling operation of unitary HVAC equipment and thus fan-only usage of systems was excluded from analyses.

The regression models were then used with a TMY3 full year normal weather series to generate normalized 8,760 hourly results. The load predicted by the model was set to zero if the THI was less than 50°F. This decision was made based on review of the BGE AC profiler data which included year round data collection for multiple years and usage during off-peak metered periods. This restriction had no effect on summer peaks, only on off-peak and annual usage. Any information collected about when the units are activated or shut down for winter was applied when extrapolating the results. If a unit was designated as being turned on in March and off in December then no modeled usage was calculated for January and February. At this stage there is a unit level 8760 weather-normalized profile for each sample point.

0.3 *Load Shape Analysis*

After all the unit level modeling was done and regional weather normalization completed, each load shape profile was pooled into 12 strata determined by 6 regions and 2 unit sizes (small <11.25 tons or large ≥11.25 tons). For each hour, the load for each stratum was calculated as the sum of the sample loads multiplied by their case weights. For each stratum, the case-weighted sample connected load was also calculated. The ratio of the total hourly load to the total connected load derived from the sample data in each stratum was multiplied by the total population connected load to estimate the total stratum hourly load. By performing this calculation for every hour, an annual load profile was estimated. The variation in the sample customer ratios in each hour, as well as the sample size was used to calculate the relative

[2] New England Independent System Operator (ISO-NE) M&V Manual for Wholesale Forward Capcity Market (FCM). www.iso-ne.com/rules_proced/isone_mnls/index.html
PJM Manual 18B:Energy Efficiency Measurement & Verification, Revision: 01
Effective Date: March 1, 2010 http://pjm.com/~/media/documents/manuals/m18b.ashx

precision at the 90% confidence interval of each hourly estimate. The analysis results were used to develop a savings workbook (the Loadshape Tool), which will allow sponsors to generate demand and energy savings over desired time intervals based on a connected load reduction input.

0.4 *Results*

The following tables present the annual usage and coincident peak estimates and relative precisions based on the developed load shapes. The data are normalized by connected load (based on EER and tonnage rating) such that the results are unit-less, coincidence and annual load factors, except for effective full load cooling hours. All tables include estimated factors or full load hours. Each estimated factor is presented with the relative precision of each estimate at the 80% and 90% two-tail confidence intervals, abbreviated respectively as "RP @ 80%CI" and "RP @ 90%CI. As a reminder, relative precision at the 80% two-tail interval is equivalent to that of the 90% one-tail.

The following table presents the annual load factor and effective full load hours for the regional totals and the relative precisions of the estimates. The annual load factor represents the fraction of hourly regional loadshape divided by connected load for all 8,760 hours or more simply, the fraction of effective full load cooling hours[3] (EFLH) over 8,760.

$$EFLH = \sum_{h=1}^{8760} \left(\frac{Estimated\ \ Hourly\ \ Load(kW)}{Connected\ \ Load(kW)} \right)$$

$$AnnualLoadFactor = \left(\frac{EFLH}{8,760} \right)$$

The relative precisions of the two estimates are identical given there is only division by a constant. The precisions were much lower than the planned precisions from the sample design for peak demand factors. As shown below, precisions for all of the load-weighted regional totals are less than 18%. The precision calculations are based on aggregation of the hourly estimates and hourly error terms and can be replicated in detail in the Load Shape Tool.

[3] Effective full load cooling hours (EFLH) represents the annual number of hours (8,760 hours = 1 year) that a cooling system would operate for, at full load. It can be used to estimate annual energy consumption of a system when the capacity and efficiency are known.

Table 0-2: Annual Load Factor and EFLH Estimate by Region Totals[4]

Total	Annual Load Factor (EFLH/8760)			EFLH = Effective Full Load Cooling Hours		
Region	Estimated Ratio	RP @ 80%CI	RP @ 90%CI	Annual Estimate	RP @ 80%CI	RP @ 90%CI
Mid-Atlantic	0.1707	±9.78%	±12.55%	1,495	±9.78%	±12.55%
NE-East Mass	0.1339	±10.12%	±12.99%	1,173	±10.12%	±12.99%
NE-North	0.0862	±13.14%	±16.87%	755	±13.14%	±16.87%
NE-South Coastal	0.0976	±11.44%	±14.69%	855	±11.44%	±14.69%
NY- Inland	0.1087	±13.58%	±17.43%	952	±13.58%	±17.43%
NY- Urban/Coastal	0.1704	±10.69%	±13.72%	1,492	±10.69%	±13.72%

Table 0-3: Load Ratio Estimate by Region Small Units[4]

SMALL units (<11.25 TONS)

Small Units	Annual Load Factor (EFLH/8760)			EFLH		
Region	Estimated Ratio	RP @ 80%CI	RP @ 90%CI	Annual Estimate	RP @ 80%CI	RP @ 90%CI
Mid-Atlantic	0.1157	±6.79%	±8.72%	1,014	±6.79%	±8.72%
NE-East Mass	0.1261	±14.78%	±18.97%	1,104	±14.78%	±18.97%
NE-North	0.0946	±19.18%	±24.62%	829	±19.18%	±24.62%
NE-South Coastal	0.1064	±14.98%	±19.22%	932	±14.98%	±19.22%
NY- Inland	0.0752	±25.39%	±32.59%	659	±25.39%	±32.59%
NY- Urban/Coastal	0.1375	±8.27%	±10.62%	1,204	±8.27%	±10.62%

Table 0-4: Load Ratio Estimate by Region Large Units[4]

LARGE units (≥ 11.25 TONS)

Large Units	Annual Load Factor (EFLH/8760)			EFLH		
Region	Estimated Ratio	RP @ 80%CI	RP @ 90%CI	Annual Estimate	RP @ 80%CI	RP @ 90%CI
Mid-Atlantic	0.2081	±13.24%	±16.99%	1,823	±13.24%	±16.99%
NE-East Mass	0.1396	±13.67%	±17.54%	1,223	±13.67%	±17.54%
NE-North	0.0775	±17.26%	±22.15%	679	±17.26%	±22.15%
NE-South Coastal	0.0905	±17.21%	±22.09%	793	±17.21%	±22.09%
NY- Inland	0.1215	±15.69%	±20.13%	1,065	±15.69%	±20.13%
NY- Urban/Coastal	0.1894	±14.78%	±18.97%	1,659	±14.78%	±18.97%

[4] Note that relative precision (RP) at the 80% two-tail interval is equivalent to that of the RP 90% one-tail.

The definition of the ISO-NE On-Peak, PJM On-Peak, and ISO-NE FCM seasonal coincident peak factor are described below:

- ISO-NE On-Peak Period: The ISO-NE summer “Demand Resource On-Peak Hours,” are defined as 1 PM to 5 PM on weekday non-holidays during June, July, and August.
- PJM On-Peak Period: The PJM On-Peak Period is structurally identical to the first, except that it will encompass the hours from 2 PM to 6 PM instead of 1 PM to 5 PM.
- ISO-NE FCM Seasonal Peak: The FCM Summer Seasonal Peak includes all non-holiday weekday hours in June, July and August during which the ISO New England Real-Time System Hourly Load is greater than 90% of the most recent “50/50” System Peak Load Forecast for the summer season.

A coincident peak factor of one would indicate all units ran at full load for the entire hour for all hours included in the peak definitions. The following table presents coincident factor estimates and precisions and the maximum hourly coincident load ratio and relative precisions for those hours. The precisions at the 90% confidence interval of the coincident peak estimates range roughly from 9% to 16%. They are low relative to the planned precisions across all peak definitions and regions. The precision of the maximum load ratio is for an individual hour by region and shows the greater variability at the hourly level with precisions from 6% to 17%. The coincidence factor estimates include the effects of oversizing and some peak defined hours where units operate at part loads. The results reflect diversity of usage within and between hours in the population.

Table 0-5: Coincidence Factor for Peak Demand Definitions by Region Totals[4]

	Total	Coincidence Factor			Maximum Load Ratio		
	Region	Hourly Average	RP @ 80%CI	RP @ 90%CI	Hourly Maximum	RP @ 80%CI	RP @ 90%CI
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	Mid-Atlantic	0.4892	±7.09%	±9.10%	0.718	±7.83%	±10.05%
	NE-East Mass	0.4488	±8.40%	±10.78%	0.699	±8.43%	±10.82%
	NE-North	0.3421	±11.98%	±15.38%	0.469	±12.23%	±15.69%
	NE-South Coastal	0.3397	±10.39%	±13.33%	0.526	±9.59%	±12.30%
	NY- Inland	0.3815	±12.59%	±16.15%	0.477	±13.01%	±16.69%
	NY- Urban/Coastal	0.5529	±8.24%	±10.58%	0.822	±5.80%	±7.44%
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	Mid-Atlantic	0.4833	±7.32%	±9.40%	0.718	±7.83%	±10.05%
	NE-East Mass	0.4443	±8.56%	±10.99%	0.699	±8.43%	±10.82%
	NE-North	0.3343	±12.16%	±15.61%	0.469	±12.23%	±15.69%
	NE-South Coastal	0.3341	±10.49%	±13.46%	0.526	±9.59%	±12.30%
	NY- Inland	0.3836	±12.62%	±16.20%	0.477	±13.01%	±16.69%
	NY- Urban/Coastal	0.5665	±7.83%	±10.05%	0.822	±5.80%	±7.44%
ISO-NE FCM Seasonal Peak	Mid-Atlantic						
	NE-East Mass	0.4863	±8.39%	±10.77%	0.699	±8.43%	±10.82%
	NE-North	0.4241	±12.23%	±15.70%	0.469	±12.23%	±15.69%
	NE-South Coastal	0.4369	±9.54%	±12.24%	0.526	±9.59%	±12.30%
	NY- Inland						
	NY- Urban/Coastal						

Table 0-6: Coincidence Factor for Peak Demand Definitions by Region Small Units[4]

	Small Units	Coincidence Factor			Maximum Load Ratio		
	Region	Hourly Average	RP @ 80%CI	RP @ 90%CI	Hourly Maximum	RP @ 80%CI	RP @ 90%CI
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	Mid-Atlantic	0.3578	±5.54%	±7.11%	0.588	±5.70%	±7.32%
	NE-East Mass	0.4345	±12.38%	±15.89%	0.722	±10.40%	±13.35%
	NE-North	0.3720	±16.23%	±20.84%	0.501	±15.91%	±20.42%
	NE-South Coastal	0.3498	±13.09%	±16.80%	0.536	±12.38%	±15.89%
	NY- Inland	0.2426	±22.73%	±29.18%	0.305	±22.31%	±28.63%
	NY- Urban/Coastal	0.4435	±7.50%	±9.63%	0.703	±7.69%	±9.87%
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	Mid-Atlantic	0.3596	±5.57%	±7.16%	0.588	±5.70%	±7.32%
	NE-East Mass	0.4305	±12.54%	±16.09%	0.722	±10.40%	±13.35%
	NE-North	0.3623	±16.24%	±20.85%	0.501	±15.91%	±20.42%
	NE-South Coastal	0.3357	±13.62%	±17.49%	0.536	±12.38%	±15.89%
	NY- Inland	0.2433	±22.70%	±29.14%	0.305	±22.31%	±28.63%
	NY- Urban/Coastal	0.4507	±7.38%	±9.47%	0.703	±7.69%	±9.87%
ISO-NE FCM Seasonal Peak	Mid-Atlantic						
	NE-East Mass	0.4758	±12.31%	±15.80%	0.722	±10.40%	±13.35%
	NE-North	0.4519	±16.20%	±20.79%	0.501	±15.91%	±20.42%
	NE-South Coastal	0.4311	±13.62%	±17.48%	0.536	±12.38%	±15.89%
	NY- Inland						
	NY- Urban/Coastal						

Table 0-7: Coincidence Factor for Peak Demand Definitions by Region Large Units[4]

	Large Units	Coincidence Factor			Maximum Load Ratio		
	Region	Hourly Average	RP @ 80%CI	RP @ 90%CI	Hourly Maximum	RP @ 80%CI	RP @ 90%CI
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	Mid-Atlantic	0.5787	±9.80%	±12.58%	0.874	±10.17%	±13.05%
	NE-East Mass	0.4591	±11.33%	±14.55%	0.683	±12.56%	±16.12%
	NE-North	0.3113	±17.75%	±22.78%	0.438	±18.65%	±23.93%
	NE-South Coastal	0.3314	±15.70%	±20.16%	0.543	±14.43%	±18.51%
	NY- Inland	0.4348	±14.49%	±18.59%	0.545	±15.04%	±19.30%
	NY- Urban/Coastal	0.6162	±11.25%	±14.44%	0.893	±8.58%	±11.01%
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	Mid-Atlantic	0.5674	±10.20%	±13.10%	0.874	±10.17%	±13.05%
	NE-East Mass	0.4543	±11.58%	±14.87%	0.683	±12.56%	±16.12%
	NE-North	0.3054	±18.35%	±23.55%	0.438	±18.65%	±23.93%
	NE-South Coastal	0.3328	±15.48%	±19.87%	0.543	±14.43%	±18.51%
	NY- Inland	0.4375	±14.53%	±18.64%	0.545	±15.04%	±19.30%
	NY- Urban/Coastal	0.6335	±10.62%	±13.64%	0.893	±8.58%	±11.01%
ISO-NE FCM Seasonal Peak	Mid-Atlantic						
	NE-East Mass	0.4940	±11.36%	±14.58%	0.683	±12.56%	±16.12%
	NE-North	0.3953	±18.60%	±23.87%	0.438	±18.65%	±23.93%
	NE-South Coastal	0.4416	±13.27%	±17.03%	0.543	±14.43%	±18.51%
	NY- Inland						
	NY- Urban/Coastal						

Preface

The Regional EM&V Forum

The Regional EM&V Forum (Forum) is a project managed and facilitated by Northeast Energy Efficiency Partnerships, Inc. The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track and report energy efficiency and other demand resource savings, costs and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast, New York, and Mid-Atlantic region. Jointly sponsored research is conducted as part of this effort. For more information, see http: www.neep.org/emv-forum.

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Subcommittee for the Unitary HVAC Loadshape Project

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1 Introduction

This report serves the following functions:

- Document the intent and goals of this Unitary HVAC Load Shape Project
- Provide an overview of project activities and analysis methods
- Present selected results from the load shape analysis tool
- Present additional results based on analysis of the data set.

1.1 Project Intent and Goals

The primary goal of this project was to develop weather normalized 8,760 (representing every hour of the year) cooling end-use load shapes representative of hourly savings for the target population of efficient unitary HVAC equipment promoted by efficiency programs in the New England, New York and mid-Atlantic regions. Given the trade-offs between up-front capital costs and continuing operating costs, unitary HVAC is generally chosen for situations with minimal internal cooling loads, and where operating hours are not large and are concentrated in the summer. Unitary HVAC is one type of cooling equipment, with relatively low capital costs but high operating costs. Where cooling loads are more evenly distributed throughout the year and cover substantial internal heat gains, other types of cooling equipment - with higher capital costs, but lower operating costs, are typically chosen. These other types include (by ascending efficiency) air-to-air air conditioners and heat pumps, water-to-air heat pumps, and chillers. The unitary HVAC load shapes developed in this project further support program administrator calculations of savings in the forward capacity markets. These load shapes were based on results of primary data collection, including metering, completed as part of this study, as well as data available from existing sources.

The sampling and analysis results were developed relative to the key dimensions of unit size and unit location. The results of this project are delivered in multiple formats: this report, a savings workbook called the Loadshape Tool, and a data set of complete analysis results and collected data. This report contains a comprehensive description of the data collection process and the analytical methods used to develop the results. The savings Loadshape Tool provides savings load shapes across all key dimensions identified during project sampling. The Loadshape Tool outputs energy and demand savings estimates over any specified time frame based on the connected load reduction value entered into the Loadshape Tool. The data set includes 8760 analysis results for all units in the sample and other data collected for the metered units.

1.2 Overall Approach

This section provides a high level overview of the approach taken to complete this project.
To begin developing a sample frame for the project, a detailed data request was submitted to all sponsors. This data request asked for tracking information and secondary source data from any potentially relevant program or research efforts undertaken by sponsors. Using the data received from this request, a sampling framework was devised to meet the needs of sponsors and allow for determination of average coincident peak demand impacts according to ISO/PJM definitions and confidence/precision criteria.

Following sample design, primary and backup samples were chosen for the purpose of scheduling metering installation and data collection site visits. Scheduling was completed rapidly in order to capture as much of the cooling season as possible while still maintaining the integrity of the project sampling requirements. The installation of meters began in May and ended in early June. All meters were removed in October. Secondary facility data was collected concurrent with the May meter installations to inform the subsequent HVAC unit regression modeling.

Beginning with the removal of the first meters in October, regression modeling began. Each unit was modeled individually, taking into account factors such as day type, sequential hot days, and unique temperatures and humidity. The regression models were then used with a full year normal weather series to generate normalized 8,760 results. Unit level normalized results were aggregated based on the case weights determined during the sampling process. The analysis results were used to develop a savings workbook (the Loadshape Tool), which will allow sponsors to generate demand and energy savings over desired time intervals based on a connected load reduction input.

2 Methodology

2.1 Planning and Sampling

2.1.1 Procurement of Program Administrator and Secondary Data

Within one week of the kick off meeting, KEMA prepared and submitted a blanket data request to the Project Coordinator. This data request specified the required information to characterize C&I Unitary HVAC programs. The purpose of this data request was to obtain all available tracking data from unitary HVAC programs undertaken by Forum members within the past three years. The dimensionality of the sampling frame was dictated by the availability of common tracking variables across Forum member programs. The study's focus was on direct refrigerant expansion (DX) packaged unitary HVAC units installed at non-residential (C&I) facilities. Several types of efficiency programs were excluded from this data request, in particular:

- Custom programs that do not have parsed-out HVAC savings (whole building new construction programs, for instance).
- Programs with HVAC measures that make up less than 5% of a given sponsor's total number of unitary HVAC measures.
- Programs that include unitary HVAC equipment in excess of 100 tons are only required to provide savings data for equipment less than or equal to 100 tons. A cap of 100 tons has been designated for this project because differentiating between unitary and customized systems greater than 100 tons becomes an issue.

The following information was requested for each applicable Forum member program with additional details provided in the Appendix Section 5.1:

- Tracking savings estimates on a per unit/site basis
- Detailed equipment characteristics for each HVAC unit in the population
- Site Characteristics
- Load Zone / Climate
- Program Participant Contact Information
- Dated Records

The data were combined into common fields for development of the target population. Units were required to include installed capacity in tons (size) and efficiency for the purpose of estimating connected load where the connected load was not explicitly included. The target population included air-source split systems and packaged rooftop systems. Packaged terminal air conditioners (PTACS) were excluded along with all water-source and ground-source equipment. All equipment had to be installed between January 2007 and May 2010 so the population excluded older units or units not installed in time for metering in summer 2010.

In addition to tracking data, KEMA also requested that load data from recently completed applicable studies be provided. Due to the diverse nature of the load metering data and results generated through various programs, KEMA anticipated significant variability in the formatting and content of the provided metering data, results and documentation. Unit or site level documentation was to include equipment characteristics, site characteristics, and climate data according to the same guidelines provided for the tracking data request.

Data to establish the sample frame was received from 13 sponsors and 11 of those sponsors had data meeting the minimum study requirements. HVAC metered data was available from three sponsors, but only the BG&E Commercial AC Profiler project had data for units meeting the study criteria. All other C&I HVAC data identified in the NEEP Phase I Load Shape Project[5] was identified as representing larger or custom systems not characterized as “Unitary C&I HVAC from 1 to 100 ton”. Details of how the sample broke down by sponsor and the amount of leveraged data is included in the following section. Table 2-1 below details the sponsors who provided data, those with data qualified as meeting the unitary HVAC definition, and those with units which were excluded because they also included a rebated economizer. For multiple sponsors this only included dual-enthalpy economizers which have temperature and humidity sensors both outdoor at the unit and indoor in the cooled space. For a few sponsors this included rebated economizers of unknown type. The economizers were excluded because the savings claim for those measures are based on reducing the normal operating hours of the high efficiency equipment and inclusion required oversampling that was outside the scope of the study.

Table 2-1: Summary of Tracking Data Provided by Sponsors

Sponsor	Provided Data	Qualifying Data	Economizer Rebate Units Excluded
Baltimore Gas & Electric (BGE)	X	X	
Cape Light Compact (CLC)	X	X	X
Efficiency Maine (MAINE)	X		
National Grid (NGRID)	X	X	X
NSTAR	X	X	X

[5] The End Use Load Data Update Project – Final Report Phase 1, 2009, by KEMA for NEEP and Regional EM&V Forum sponsors, is available at www.neep.org/emv-forum/forum-products-and-guidelines.

Sponsor	Provided Data	Qualifying Data	Economizer Rebate Units Excluded
Northeast Utilities (NU)	X	X	X
New York Power Authority (NYPA)	X		
NYSERDA	X	X	X
PEPCO	X	X	
Public Service New Hampshire (PSNH)	X	X	X
United Illuminating (UILL)	X	X	
Unitil	X	X	
Efficiency Vermont (VEIC)	X	X	

2.1.2Sample Design

There were a number of dimensions under consideration as the sample design was developed through the kick off meeting discussions and additional meetings with the Forum. These dimensions include:

- Sampling unit: project, facility, or A/C unit;
- Climate: as per temperature data or weather region;
- Unit size: tracking savings, connected kW, or tonnage;
- Facility or business type;
- Unit outside air intake type: Economizers (dual or single enthalpy), fixed, or none
- Independent system operator (ISO) Load zone (ISO-NE, NY ISO, and PJM);
- Geography: State or Sponsor service territory;

Covering even several of these dimensions created some formidable challenges to the project. As an example, if we elected to design for four (4) weather/load zones, six (6) facility types, and stratify by three (3) size (e.g. savings) tiers, we end up with seventy-two (72) domains to cover with the available sample. KEMA had to work closely with the sponsors to prioritize these potential stratification dimensions and formulate an appropriately representative sample design that was affordable within the project budget. The final sample design was reviewed and approved by consensus from the project subcommittee.

Stratification was ultimately dictated by two factors: (1) the availability of common tracking variables across sponsor programs from which to devise the sample frame, and (2) the relative importance of the various possible sample dimensions to the sponsors.

We envisioned a multi-dimensional sample design using some of the dimensions discussed above. The challenge was to attain adequate coverage of all of the “important” characteristics (i.e. region, unit size, building type, etc.) that can be isolated for the population of program participants. This required consistency across the data elements secured for each of the sponsors.

After discussion with the project subcommittee, designing the samples and selecting the participants based on overall targets across all of the sponsors’ service territories and ISO load zones was chosen as the sample design strategy. The following section discusses each of the key parameters used and considered in the study.

2.1.2.1 Size Dimensions

Typically, these types of studies use a size dimension to help differentiate the contributors. Tonnage and tracking savings per unit were available for the population of units. The unit size was used to develop a small and large dimension based on prior studies and experience that larger units have different annual full load hours and peak coincidence timing. The units also are bi-furcated into small and large based on the fact that large units (between 11.5 and 100 nominal tons cooling) have multiple compressors and fans that operate in stages while a majority of small units (between 1 and 11.25 tons) are single stage units. The size cut point conforms to the ASHRAE 90.1 (2007) size class designations which set the minimum efficiency for new equipment based on nominal installed capacity range. The tracking system estimate of savings was used as a secondary variable to stratify within the large unit strata given the large range of estimated savings within the stratum whereas many small units had deemed savings which were uniform for units by sponsor and secondary stratification by savings would not differentiate unit usage.

2.1.2.2 Regions and Choice of Weather Data

There was consensus that peak demand and load shape results would likely vary by regional climate and weather. The sample was divided into weather regions to account for climatic differences within the entire region made up by all sponsor service territories combined. Each weather region may span one or multiple states and state lines were used as boundaries where appropriate. The lines used to divide weather regions within states were those of the independent system operator (ISO), i.e. ISO-NE load zones and NY ISO weather cities.

To begin the weather region development process, a consistent means of categorizing weather based on geographic location was searched for across the tracking data sets. In most of the tracking data sets, ISO-NE forward capacity market (FCM) load zone categorization was either provided or readily determined using other parameters provided in the tracking data. For New

York service territories, weather was categorized by the program sponsor based on a set of 6 statewide weather stations designated by NY ISO as representing New York State's climate hereafter called NY zones. A total of 16 ISO-NE load zones and NY zones were identified using this process. The International Energy Conservation Code weather regions were not applicable to this study because they are defined by heating degree days.

To reduce the number of weather regions to a more manageable list, one or more representative cities were chosen based on proximity and data availability from each ISO load zone/NY zone and the number of cooling degree days (CDD) was identified using readily available long term average data from the National Climatic Data Center with base temperature of 65°F. The CDD identified for each load zone/NY zone was then compared to the CDD identified in adjacent load zones/NY zone. Load zones and NY zones were grouped into weather regions based on two considerations: similarity of CDD values and geographic proximity to other load zones. Geographic proximity was considered to avoid creating discontinuous weather regions and to compensate for humidity variation and heat island effects[6] not captured in CDD. Table 2-2 shows the CDD data and provides an indicator of humidity in terms of Temperature-Humidity Index Degree Days (THIDD). For the purposes of this analysis, THI was defined according to the New England ISO (NE-ISO) definition:

Equation 1

$$THI = 0.5 \times OSA_{db} + 0.3 \times DPT + 15,$$

Where THI is the temperature-humidity index in °F,
OSA_{db} is the outside dry bulb temperature in °F, and
DPT is the outside air dew point temperature in °F.

THIDD was then calculated using a base THI of 70 °F chosen according to the American Meteorological Society claim that few people will feel uncomfortable at a THI below 70.[7] 8,760

[6] US EPA. The term "heat island" describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). http://www.epa.gov/heatisld/

[7] American Meteorological Society Definition of THI - Studies have shown that relatively few people in the summer will be uncomfortable from heat and humidity while THI is 70 or below; about half will be uncomfortable when THI reaches 75; and almost everyone will be uncomfortable when THI reaches 79.

hourly THI values were calculated using typical meteorological year (TMY3)[8] data sets. The TMY3 weather files are developed to represent typical hourly conditions based on 15 years of data for a particular station. They represent conditions for annual energy computer simulations and do not represent extreme design conditions nor are they simply the average with no extreme hours or days. The TMY3 weather was also used in the weather normalization of analysis results as described later in this Section.

Table 2-2: CDD and THIDD Data by City and Zone

City/Location	Load Zone or NY Zone	CDD for City/Location	THIDD, Base 70
New York			
Syracuse	Syracuse	437	130
New York (Central Park)	New York City	1094	300
Albany	Albany	506	128
Binghamton	Binghamton	337	84
Buffalo	Buffalo	477	83
Massena	Massena	310	46
NE			
Portland, ME	Maine	266	87
Concord Muni AP	New Hampshire	328	117
Burlington International AP	Vermont	387	93
9 station Average	WCMA	375 (187 to 751)	69 (Worchester)
Boston	NEMA	677	148
7 station average	SEMA	446 (313 to 729)	90 (Plymouth)
Providence	Rhode Island	605	176
Bridgeport	Connecticut	724	147
PJM			
Baltimore	BGE	1607	355
Washington, DC	PEPCO	1548	335 (Dulles AP)

A set of six weather region categories met the need to minimize the number of weather region while maintaining meaningful weather categorizations and staying within the task budget. A representative city with TMY3 weather data available would then be chosen for each weather region to provide normalized weather. The unit level regression models used the TMY3 weather data as inputs to weather normalize predicted loads which were based on actual year weather and extrapolate data outside the metering period.

[8] National Solar Radiation Data Base. *1991- 2005 Update: Typical Meteorological Year 3.* The TMY3 data set contains data for 1020 locations, compared with 239 for the TMY2 data set. The TMY3s are data sets of hourly values of solar radiation and meteorological elements for a 1-year period. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

New York State was broken into two weather region based on the commonality of CDD and THIDD values in the inland portion of the state regardless of latitude and the unique weather characteristics of the urban/coastal portion of the state near New York City. New England was broken into three weather regions. Maine, New Hampshire, and Vermont exhibited similar CDD/THIDD values and constitute the northern reaches of the region. The WCMA (Western Massachusetts) load zone shared similar degree day values with the aforementioned New England states and was also grouped in this mostly inland region. NEMA (Boston and other urban areas) and SEMA (Southeastern Massachusetts) represent the most populous regions of Massachusetts and the northern New England coast. Finally, Rhode Island and Connecticut represent the urban and coastal portions of southern New England and share comparable CDD/THIDD characteristics. The BGE and PEPCO load zones exhibited considerably higher degree day values than any of the other load zones and have been categorized together based on their geographic proximity. Table 2-3 below lists the load zones/NY zones together with the weather regions to which they have been matched.

Table 2-3: Weather Region Categorizations

Load Zone or NY Zone	Weather Region	Load Zone or NY Zone	Weather Region
NYC	NY-Urban/Coastal	SEMA	NE-East Mass
Syracuse	NY-Inland	NEMA	NE-East Mass
Albany	NY-Inland	Rhode Island	NE-South Coastal
Binghamton	NY-Inland	Connecticut	NE-South Coastal
Buffalo	NY-Inland	Maine	NE-North
Massena	NY-Inland	New Hampshire	NE-North
BGE	Mid Atlantic	Vermont	NE-North
PEPCO	Mid Atlantic	WCMA	NE-North

Local Weather Matching

All sites associated with the sampled units were geocoded (assigned latitude and longitude) with ArcGIS software and matched to the five closest National Oceanic and Atmospheric Administration (NOAA) weather stations. If the closest station's data quality was poor, the next closest station was used. Maps were developed to show the final assignment of sites to weather stations by weather region (Figures 2-1 through 2-6). The analysis methodology describes the use of the nearest station actual weather data during the metered time frame to develop unit level regression models in Section 2.3.2.

Figure 2-1: Northern New England (NE-North) Sites and Assigned Weather Stations

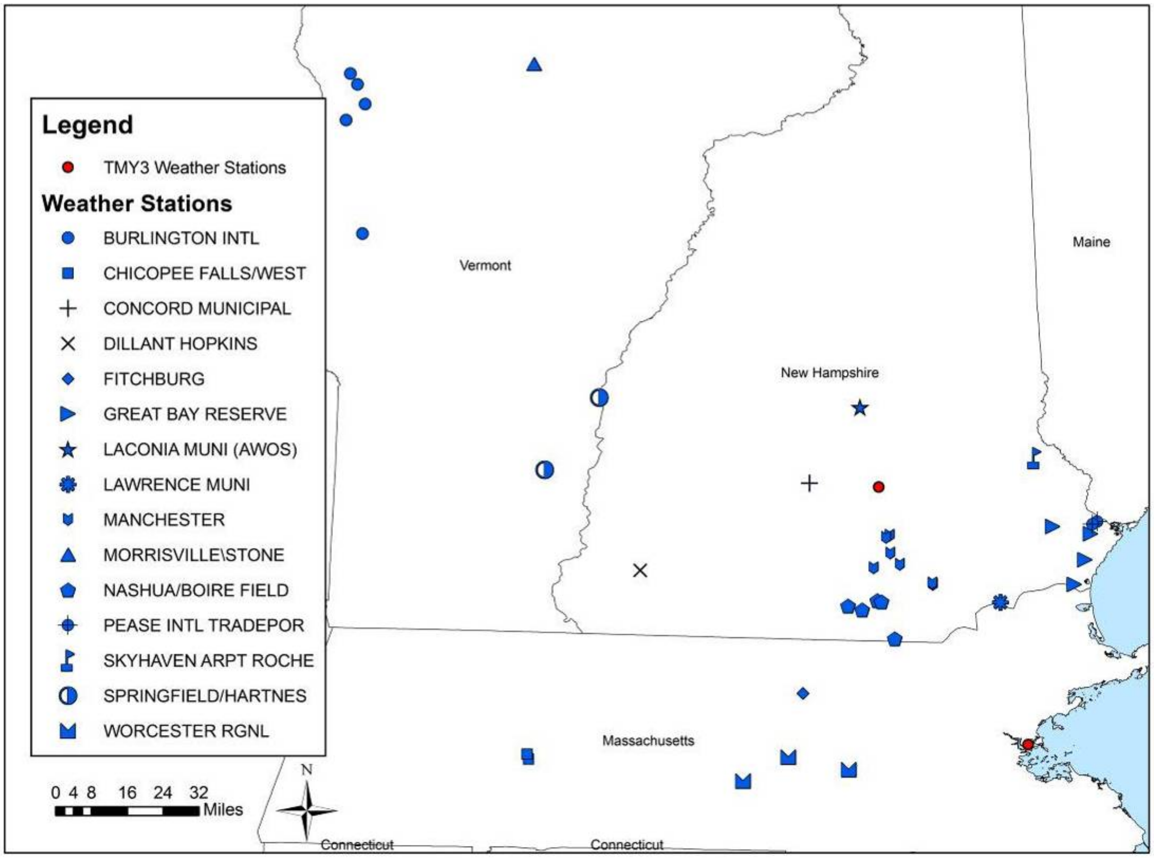


Figure 2-2: Southern New England (NE-South) Sites and Assigned Weather Stations

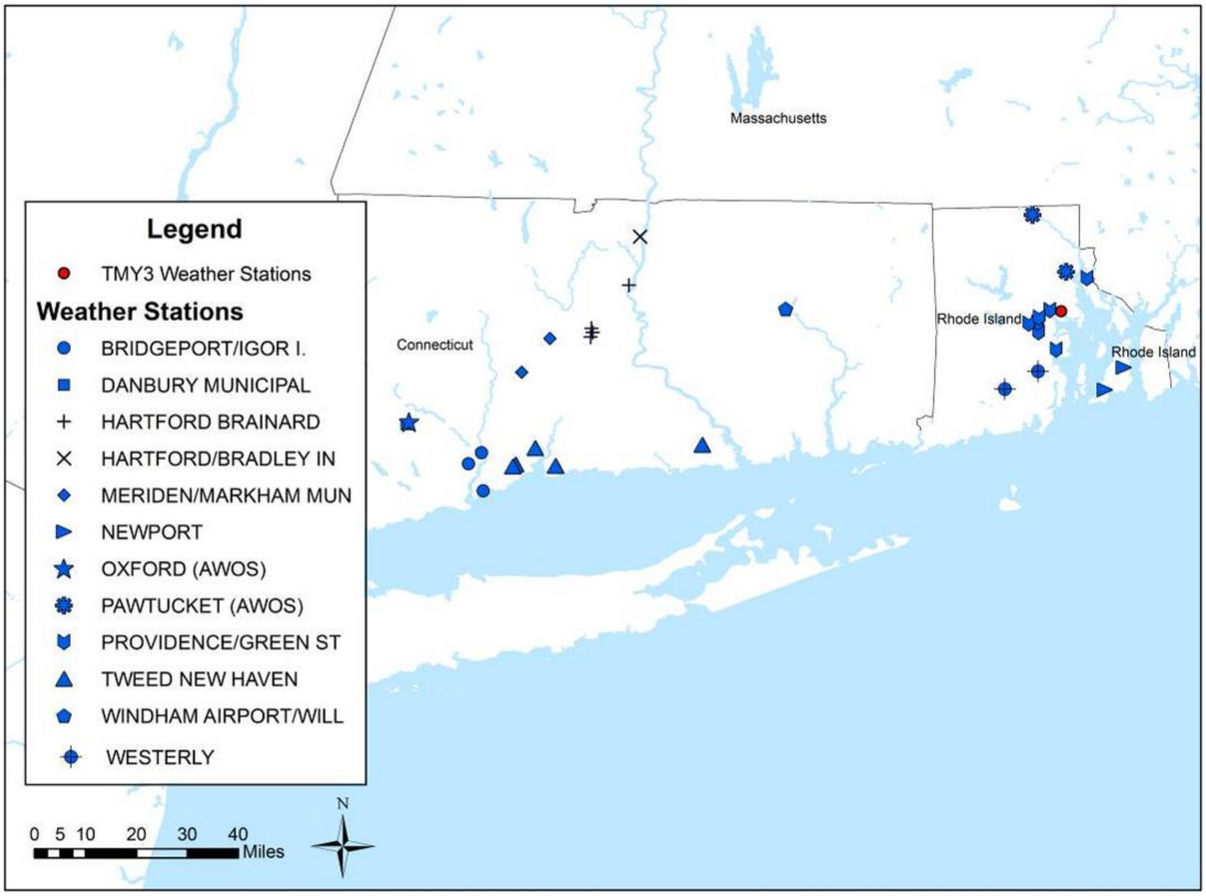


Figure 2-3: New England – Eastern Massachusetts (NE-East Mass) Sites and Assigned Weather Stations

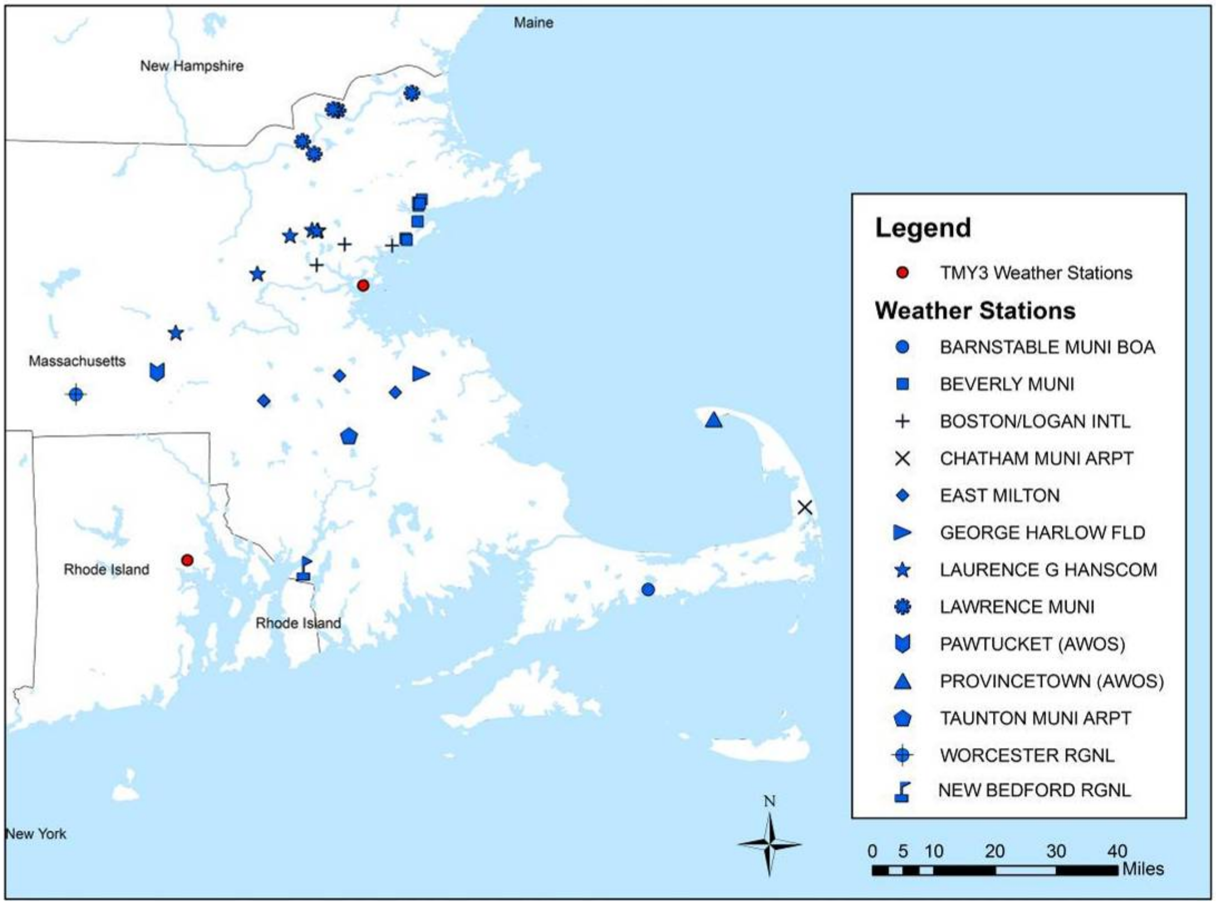


Figure 2-4: Mid-Atlantic Sites and Assigned Weather Stations

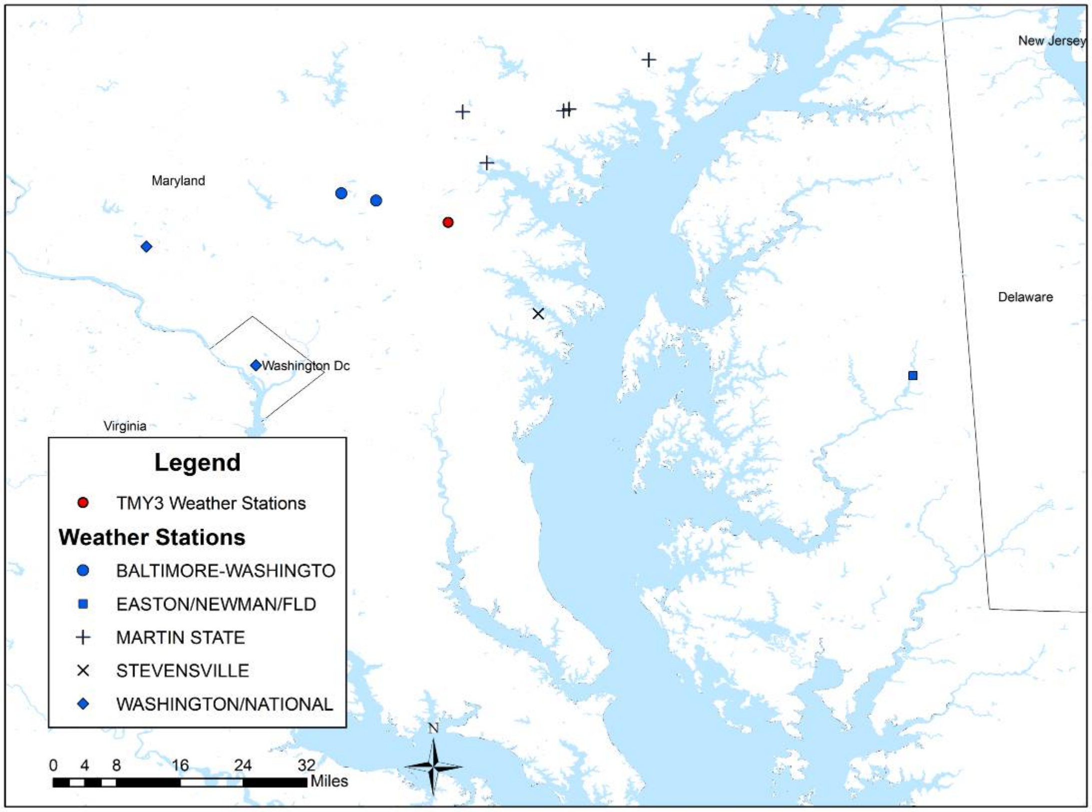


Figure 2-5: New York Urban Coastal (NY-Urban/Coastal) Sites and Assigned Weather Stations

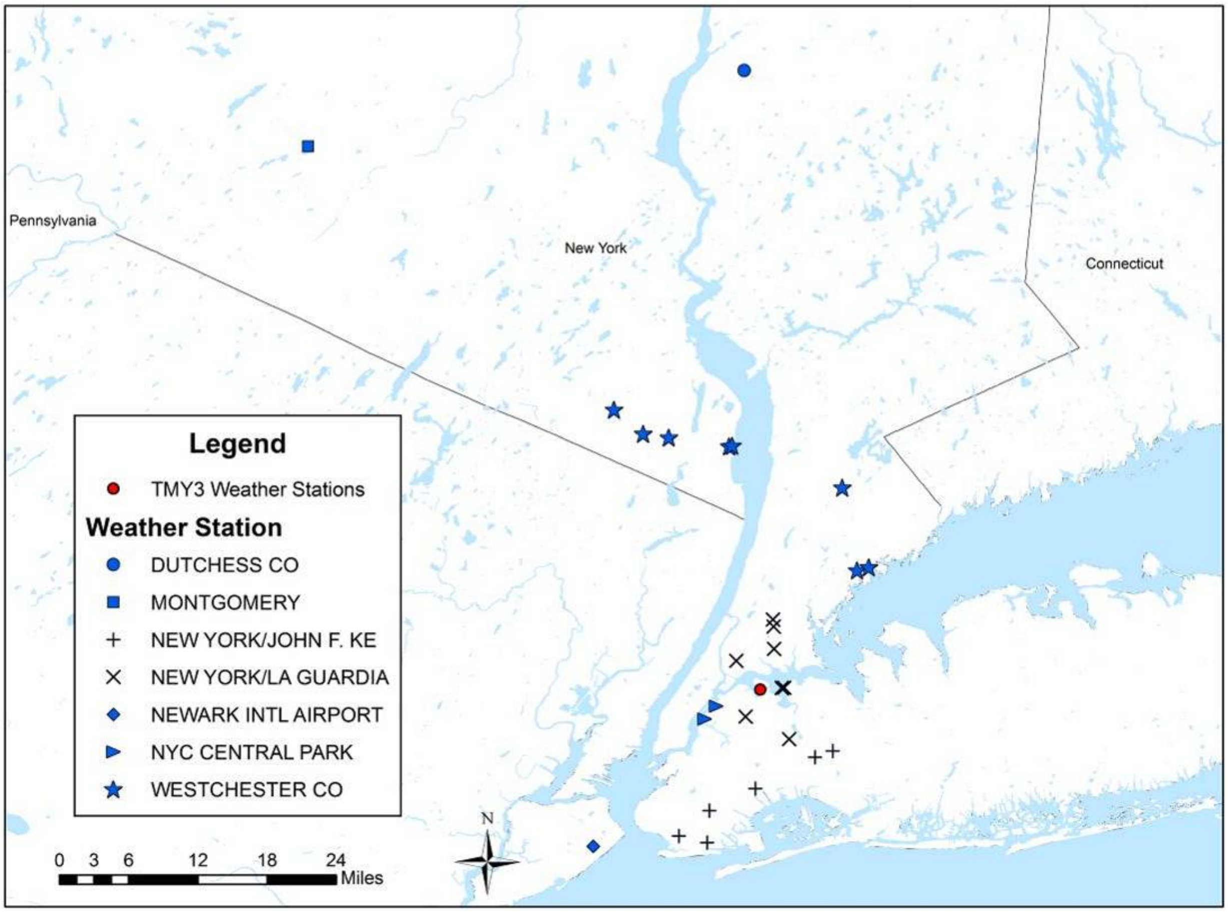
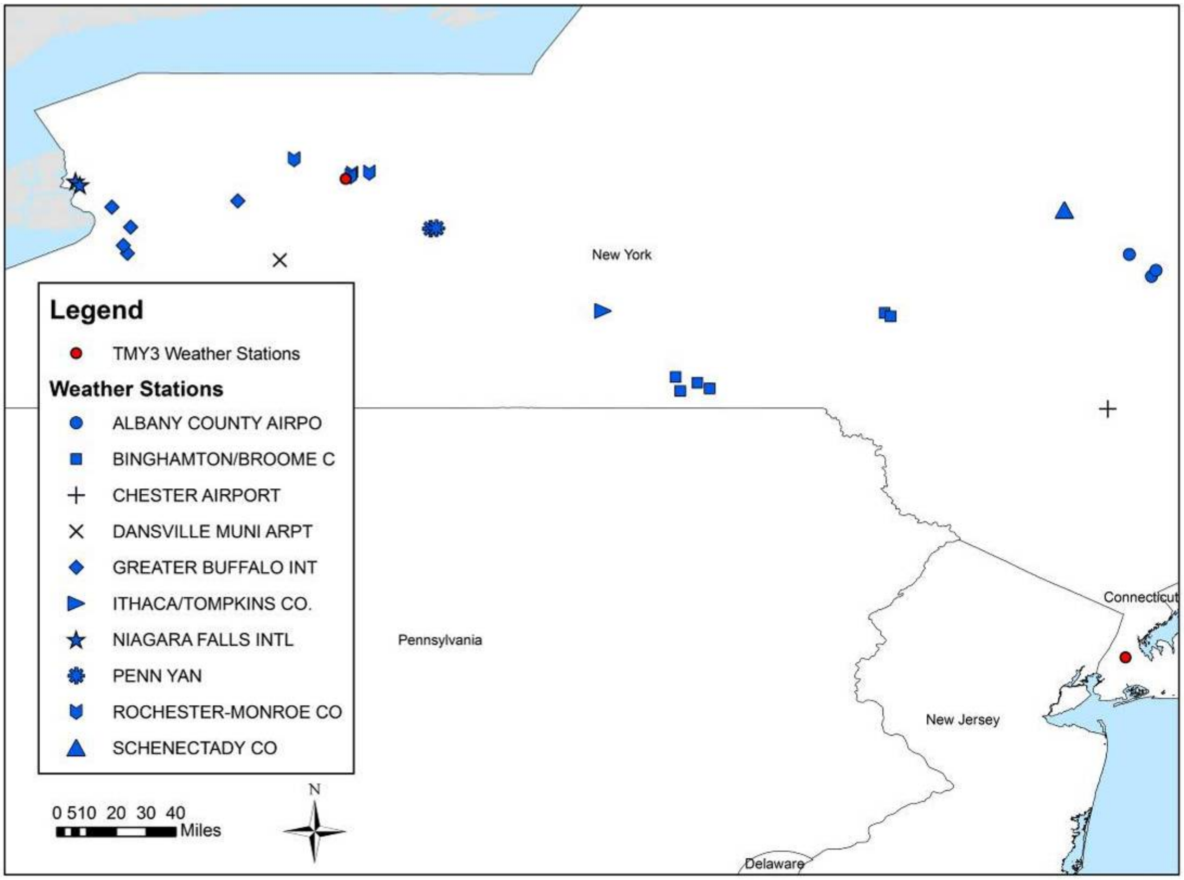


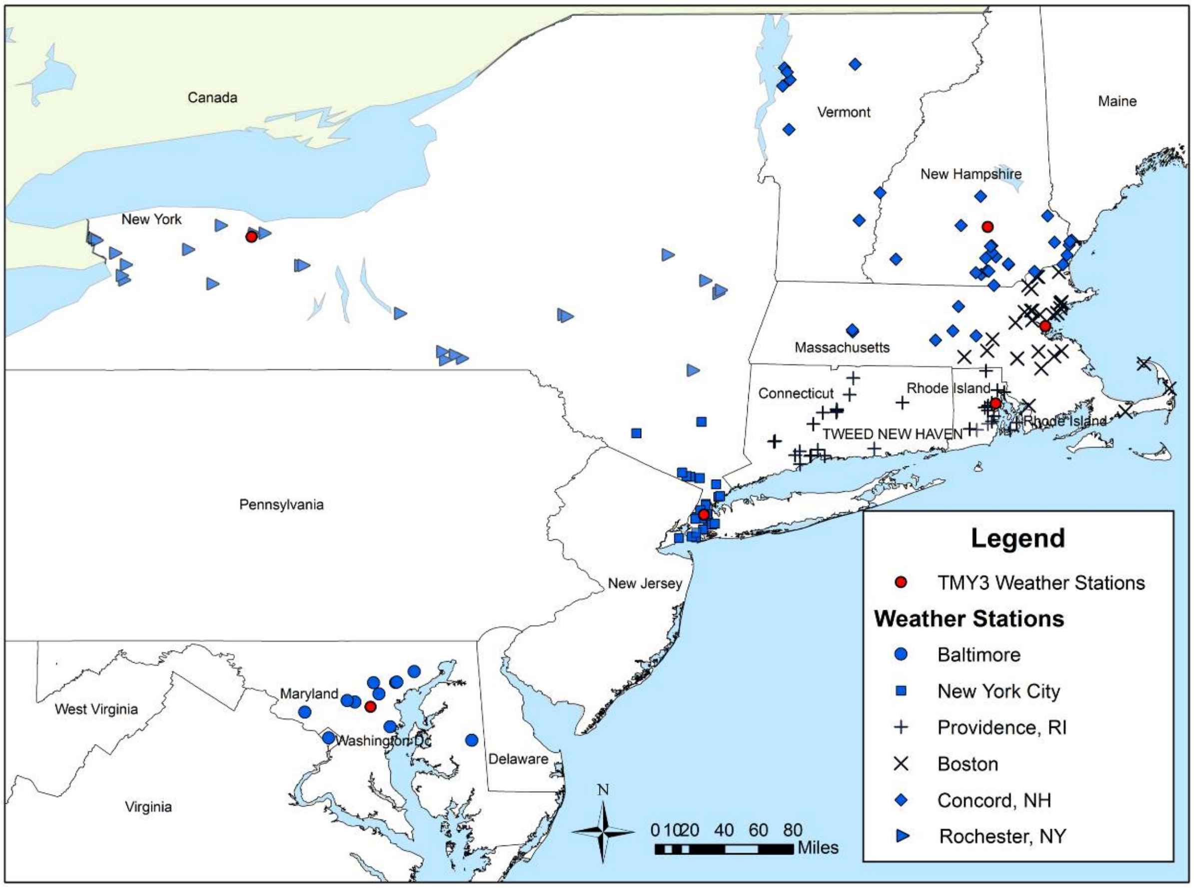
Figure 2-6: New York Inland (NY-Inland) Sites and Assigned Weather Stations



TMY3 Weather Stations

Regional lines were determined and agreed upon to be based on state and ISO load zone/NY Zone lines as described above. Within each weather region there are multiple sources of long term average data for a typical meteorological year, given the large number of TMY3 stations. The selections were made based on sample site proximity to the TMY3 station within a weather region. It was also agreed that data from one station would be used for each weather region rather than using any type of blended approach. A map was developed to show the units associated with each TMY3 station.

Figure 2-7: TMY3 Weather Stations Assigned to Sites


Canada
New York
Vermont
Maine
New Hampshire
Massachusetts
Connecticut
Rhode Island
TWEED NEW HAVEN
Rhode Island
Pennsylvania
New Jersey
West Virginia
Maryland
Washington Dc
Delaware
Virginia
N
0 10 20 40 60 80
Miles
Legend
TMY3 Weather Stations
Weather Stations
Baltimore
New York City
Providence, RI
Boston
Concord, NH
Rochester, NY

2.1.2.3 Facility Type Dimension

In the facility type dimension, the project team responded to sponsor interest in facility-level information from the study as follows: It confirmed inconsistencies exist in facility classifications across sponsors, and it confirmed that using something as detailed as the CBECS/MECS[9] classifications would create a plethora of strata that were not feasible to fill. However, the study could record consistent designation in CBECS and another highly detailed list of types to provide descriptive data for predominant facility types. Estimation of load shapes by facility was outside the scope of the study.

2.1.2.4 Outside Air Intake Dimension

Sponsor programs provide specific rebates for dual enthalpy economizers and it was decided by the sponsors to exclude units with rebated dual enthalpy economizers due to the fact that the units would affect runtime and would not offer enough results in a random sample to produce precise results by type. The type of economizer installed on each unit in the study population was still unknown and was not considered in the sample. The installed economizer type was determined during the site visit providing known information on the sample that the sponsors can use to inform their understanding of this population.

[9] The U.S. Department of Energy, Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS) and Manufacturing Energy Consumption Survey (MECS).

2.1.2.5 Planned Sample Design

KEMA employed model-based statistical sampling ("MBSS") to construct the sample design and provide the framework for the subsequent analysis. MBSS techniques have been used to create a very efficient and flexible structure for collecting data on countless energy efficiency evaluations, demand response evaluations, and interval load data analyses, e.g., load research and end-use metering, projects. MBSS methods provide the framework, through the use of case weights, to allow the sponsors to analyze the resulting data based on their varying portfolios of projects. The following sections fully describe the sample design and analysis approach that was used in this project.

Conventional methods are documented in standard texts such as Cochran's *Sampling Techniques*.[10] MBSS is grounded in theory of model-assisted survey sampling developed by C.E. Sarndal and others.[11] [12] MBSS methodology has been applied in load research for more than thirty years and in energy efficiency evaluation for more than twenty years. This fusion of theory and practice has led to important advances in both model-based theory and interval load data collection practice, including the use of the error ratio for preliminary sample design, the model-based methodology for efficient stratified ratio estimation, and effective methods for domains estimation.

As an initial assessment, we examined the error ratios associated with "large" C&I HVAC savings for one of the regional studies that KEMA recently conducted. The error ratio associated with the demand reduction for the forward capacity market[13] ("FCM") peak hours was estimated to be 0.78. Other studies reviewed showed the following:

- One study showed the error ratios are between .6 (single phase) and .8 (3 phase) for 60 to 80% of hours based on one set of data.

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[10] *Sampling Techniques*, by W. G. Cochran, 3rd. Ed. Wiley, 1977.

[11] *Model Assisted Survey Sampling*, by Carl Erik Sarndal, Bengt Swensson and Jan Wretman, Springer-Verlag, 1992.

[12] Wright, R. L. (1983), "Finite population sampling with multivariate auxiliary information," *Journal of the American Statistical Association*, **78**, 879-884.

[13] FCM peak demand impacts are coincident with "Demand Resource On-Peak Hours" as defined by ISO New England:

Summer:	June, July, and August, 1pm to 5pm, weekday non-holidays
Winter:	December and January, 5pm to 7pm, weekday non-holiday

- The error ratios for New York small C&I demand and non-demand data sets – .6 and .91 respectively.
- The error ratio from a 1998 RLW study was .35 for coincident peak demand savings
- Error ratios from a study where HVAC composed 50% of the projects (.92)

We recognize that there may be more variation for small C&I than for this recently observed group. We therefore calculated the required sample given a range of error ratios near this level.

Table 2-4 presents the required unit-level (not site level) sample sizes for error ratios that range from 0.7 to 1.4 at the 80% and 90% level of confidence and at ±10% and ±15% level of precision. For 80/10 confidence/precision, the sample sizes range from 81 to 322 depending on error ratio. The sample was designed to achieve minimum peak demand estimate precisions of 10% at the 90% confidence interval for the aggregate Loadshape which would require 133 to 530 sampled units depending on error ratio. The sample was designed such that total sample would be evenly allocated by weather region and within regions proportional to the population count for allocation by size for small and large units. This design was chosen given the limitation of having incomplete data on existing stratum-specific estimates of error ratios that could inform this study's design. Through multiple meetings the Forum came to agreement on a sample design of 45 small units and 30 large units for each of 6 weather regions for a total sample size of 450 units which would be supplemented by some available data from the BGE AC Profiler study.

Table 2-4: Required Sample Sizes for Considered Error Ratios and Precisions

Error Ratio	Required Sample Size			
	80% Confidence		90% Confidence	
	±10%	±15%	±10%	±15%
0.7	81	36	133	59
0.8	105	47	173	77
0.9	133	59	219	97
1	164	73	271	120
1.1	199	88	327	146
1.2	237	105	390	173
1.3	278	123	457	203
1.4	322	143	530	236

The primary data collection sample design is shown below along with planned precision estimates by stratum. The regions and size ranges were defined in the previous section. The tracking system estimate of savings was used as a secondary variable to stratify within the large unit strata given the large range of estimated savings within the stratum whereas many small units had deemed savings which were uniform for units by sponsor and secondary stratification by savings would not differentiate unit usage. There were three savings substrata in weather regions with one very large saving unit that was placed in a certainty stratum to ensure its inclusion in the sample.

The population used in the planned sample design in the three following tables included units that were eliminated after further review that did not meet planning criteria. The next tables show the precision estimates of the planned sample design and distributions including secondary savings stratification within the large stratum. An error ratio of 1.0 was chosen for small units and 0.6 for large units to achieve the desired precisions for peak demand estimates as well as annual load shapes based on review of all the available information.

Table 2-5: Planned Sample Sizes and Precisions at the 90% Confidence Interval for Primary Data Collection

		Population		Sample Size		Expected
Class	Sector	Units	Percent	Units	Percent	Precision
Climate	Unit Size					
Mid Atlantic	Small	158	2%	45	10%	±29.7%
Mid Atlantic	Large	82	1%	30	7%	±15.5%
NE-East Mass	Small	294	4%	45	10%	±26.1%
NE-East Mass	Large	128	2%	30	7%	±15.8%
NE-North	Small	1,225	17%	45	10%	±30.1%
NE-North	Large	355	5%	30	7%	±18.0%
NE-South Coastal	Small	470	6%	45	10%	±28.4%
NE-South Coastal	Large	151	2%	30	7%	±16.0%
NY-Inland	Small	2,537	35%	45	10%	±25.5%
NY-Inland	Large	672	9%	30	7%	±19.3%
NY-Urban/Coastal	Small	917	13%	45	10%	±28.6%
NY-Urban/Coastal	Large	256	4%	30	7%	±17.3%
Totals		7,245	100%	450	100%	±8.7%

The samples sizes including secondary stratification within the large stratum by savings are shown below. The maximum unit savings within each stratum shown serves as the cut point between strata.

Table 2-6: Planned Sample Sizes for Primary Data Collection

Climate Code	Climate	Unit Size Code	Unit Size	Stratum	Maximum Savings	Units	Savings	Sample Size	Inclusion Probability
1	Mid Atlantic	1	Small	1	1,519	158	60,415	45	0.28481
1	Mid Atlantic	2	Large	1	3,252	62	118,020	15	0.24194
1	Mid Atlantic	2	Large	2	9,734	20	98,764	15	0.75000
Subtotals						240	277,199	75	
2	NE-East Mass	1	Small	1	9,663	294	347,577	45	0.15306
2	NE-East Mass	2	Large	1	4,303	77	254,020	15	0.19481
2	NE-East Mass	2	Large	2	12,013	50	290,074	14	0.28000
2	NE-East Mass	2	Large	3	21,045	1	21,045	1	1.00000
Subtotals						422	912,716	75	
3	NE-North	1	Small	1	20,903	1,225	1,563,606	45	0.03673
3	NE-North	2	Large	1	3,968	261	628,572	14	0.05364
3	NE-North	2	Large	2	47,673	92	732,871	14	0.15217
3	NE-North	2	Large	3	61,030	2	122,060	2	1.00000
Subtotals						1,580	3,047,108	75	
4	NE-South Coastal	1	Small	1	9,250	470	487,413	45	0.09574
4	NE-South Coastal	2	Large	1	5,372	106	339,904	15	0.14151
4	NE-South Coastal	2	Large	2	16,676	45	432,187	15	0.33333
Subtotals						621	1,259,505	75	
5	NY-Inland	1	Small	1	11,077	2,537	1,847,963	45	0.01774
5	NY-Inland	2	Large	1	984	418	356,131	15	0.03589
5	NY-Inland	2	Large	2	15,124	254	355,368	15	0.05906
Subtotals						3,209	2,559,462	75	
6	NY-Urban/Coastal	1	Small	1	16,472	917	704,535	45	0.04907
6	NY-Urban/Coastal	2	Large	1	973	182	136,982	14	0.07692
6	NY-Urban/Coastal	2	Large	2	7,751	72	151,838	14	0.19444
6	NY-Urban/Coastal	2	Large	3	12,806	2	25,613	2	1.00000
Subtotals						1,173	1,018,968	75	
Subtotals			Small			5,601	5,011,508	270	
Subtotals			Large			1,644	4,063,448	180	
Totals						7,245	9,074,957	450	

The ultimate design used ratio estimation based on the ratio of the measured load over connected load. The connected load is defined as the unit's rated load used in the calculation of energy efficiency rating (EER) defined by American Heating and Refrigeration Institute (AHRI) standards 210/240. The connected load of the HVAC unit was obtained from tracking data directly or accurately through unit make and model number for the majority of A/C units in the study population. All connected loads in the analysis were estimated based on tonnage and unit EER. Field-observed nameplate ratings for sampled units confirmed this methodology reasonably estimated the connected load for units even without direct tracking data or specific model number information.

2.1.1Achieved Population and Sample

The population of study air conditioner units is presented below. It was different from the sampling population in the previous tables due to the late exclusion of some units discovered as older than 2007 or part of incomplete projects. The following tables describe the achieved total population and sample including the data leveraged from previous studies. As previously mentioned, only data from the BG&E Commercial AC Profiler study was applicable and those data all fell under the small unit category. The BG&E study includes the power measurement of 101 units over multiple years along with the relevant weather data. Given this primary data the study could model the units similarly to measured units and include them in the population and sample.

Table 2-7: Population of Units and Connected Load by Region and Size Strata

Includes Leveraged Data

	Population Size "N" (Count)			Population Connected Load (kW)		
Region	Small	Large	Total	Small	Large	Total
Mid-Atlantic	185	71	256	1,093	1,606	2,699
NE-East Mass	293	128	421	1,710	2,374	4,084
NE-North	1218	352	1570	6,948	6,717	13,665
NE-South Coastal	470	151	621	2,869	3,524	6,393
NY- Inland	470	582	1052	2,898	7,543	10,441
NY- Urban/Coastal	227	218	445	1,969	3,403	5,372
Total	**2,863**	**1,502**	**4,365**	**17,487**	**25,167**	**42,654**

The final achieved sample sizes and total stratum connected loads by region and size are shown in a series of tables. The building type and economizer distributions are presented in a data summary following the study results. The following table describes the total sample including the data leveraged from previous studies. As previously mentioned, only data from the BG&E Commercial AC Profiler study was applicable and most of the data fell under the small unit category. This study actually metered 22 units in the Mid-Atlantic small-stratum and leveraged existing metering data on 101 units from BG&E as shown in the table. The Mid-Atlantic-small stratum primary metering sample size was restricted to sites already recruited after reviewing the BG&E data in more detail which determined all secondary data could be used to fill the specific stratum. Of note, the relatively low population size of Mid-Atlantic-large units, 71 total units, meant that the sample of 30 units would require a nearly 50% recruitment rate which was not typical for this study. Only half the planned sample was achieved for the Mid-Atlantic large stratum due to the low population total of available units.

Table 2-8: Sample of Units and Connected Load by Region and Size Strata
Includes Leveraged Data

	Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
Region	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Mid-Atlantic - BGE	95	6	101	516.4	91.8	608.3
Mid-Atlantic - Metered	22	15	37	257.2	361.5	165.3

	Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
Region	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Mid-Atlantic	117	21	138	773.6	453.3	1,226.9
NE-East Mass	45	30	75	260.1	567.1	827.2
NE-North	45	30	75	251.8	664.2	916.0
NE-South Coastal	47	31	78	291.3	739.2	1,030.6
NY- Inland	44	33	77	252.7	438.3	691.0
NY- Urban/Coastal	44	24	68	383.1	383.8	766.9
Total	**348**	**163**	**511**	**2,212.7**	**3,245.8**	**5,458.5**

The following table shows the sample of metered units and disposition of units by those that were modeled and included in the final analysis and units "not modeled" due to metering issues experienced in the field. The table includes notation of the general disposition of metered units that were not included in the analysis due to issues with the data logger itself or its installation (4% of the 410 metered units) and issues due to unit usage (5% of the 410 metered units) such as atypical occupancy during large portions of the metering period and rare cases of unit service issues. Dispositions were identified by engineering and analytical review of the data from loggers with no installation issues.

Examples of issues due to installation were loggers installed that had some failure due to batteries or bad sensor connections; these failures result in no data. Examples of a-typical occupancy include a business owner who typically was open year round closing down unexpectedly for several of the hottest weeks in the middle of the metered period. Generally if most of the summer had typical occupancy, metered data was available for the regression, but several weeks closed followed by sporadic and a-typical occupancy compared with the initial data produced unreliable models with large errors relative to the actual usage pattern. An example of unit service issues would be water getting in electrical compartments that should be sealed which failed the logger in one case and logger and unit in another. Another case was where the unit was serviced and operation completely changed. If an economizer was repaired from stuck closed or a thermostat changed from constant setpoint to variable the data produced unreliable models with large errors relative to the actual usage pattern.

The methodology for data quality control and model review are described in the following section. The methodology for data quality control and model review are described in the following section.

Table 2-9: Sample of Units and Connected Load Included in Analysis

Includes Leveraged Data

		Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
	Region	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
Modeled	Mid-Atlantic	115	19	134	753.7	392.5	1,146.2
	NE-East Mass	43	29	72	251.0	545.2	796.2
	NE-North	41	28	69	236.5	638.6	875.2
	NE-South Coastal	42	29	71	268.0	699.3	967.3
	NY- Inland	32	32	64	179.7	419.2	599.0
	NY- Urban/Coastal	41	22	63	355.6	346.3	701.9
	Total	**320**	**153**	**473**	2,044.5	3,041.2	5,085.7
Not Modeled *	**Region**	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
	Mid-Atlantic	2	2	4	19.8	60.8	80.7
	NE-East Mass	2	1	3	9.1	21.8	31.0
	NE-North	4	2	6	15.2	25.6	40.8
	NE-South Coastal	5	2	7	23.3	39.9	63.3
	NY- Inland	10	1	11	56.9	19.0	75.9
	NY- Urban/Coastal	5	2	7	43.7	37.5	81.2
	Total	**28**	**10**	**38**	168.1	204.7	372.8

* - 9% Total, Failure rate (failed loggers and installations) - 4%, and
Other issues (HVAC unit issues and business vacancy) - 5% , Small Units Majority

The following table does not include leveraged data, in order to show the sample distribution of units metered by this study and ultimately included in the final analysis by Forum sponsor. Not all Forum sponsors were able to provide sites for metering. By design and intent, the study goal was to serve all Forum members with results that are transferable within the Forum overall including those not able to provide sites for metering. The sample size and connected load by sponsor are shown in Table 2-10.

Table 2-10: Metered Sample of Units and Connected Load By Sponsor
Does Not Include Leveraged Data

Table Does Not Include Leverage Data			
	Sponsor	**Sample Size "n" (Count)**	**Connected Load (kW)**
Modeled	Baltimore Gas & Electric (BGE)	25	402.2
	Cape Light Compact (CLC)	3	8.1
	National Grid (NGRID)	105	1470.9
	NSTAR	9	85.5
	Northeast Utilities (NU)	27	287.6
	NYSERDA	127	1300.8
	PEPCO	8	135.7
	Public Service New Hampshire (PSNH)	41	496.5
	United Illuminating (UILL)	11	141.6
	Unitil	2	27.6
	Efficiency Vermont (VEIC)	14	120.8
	Total	**372**	**4477.5**
Not Modeled *	Baltimore Gas & Electric (BGE)	3	58.9
	Cape Light Compact (CLC)		
	National Grid (NGRID)	1	3.9
	NSTAR	5	61.4
	Northeast Utilities (NU)	2	5.7
	NYSERDA	18	157.1
	PEPCO	1	21.8
	Public Service New Hampshire (PSNH)	5	39.4
	United Illuminating (UILL)	2	23.3
	Unitil		
	Efficiency Vermont (VEIC)	1	1.5
	Total	**38**	**372.8**

2.2 Data Collection

2.2.1Sample Selection and Customer Recruitment

Once the final sample design was approved by the NEEP project committee, KEMA drew a random sample of C&I Unitary HVAC program units and associated sites in accordance with the approved design and standard sampling techniques. Initial response rates by strata were used to determine if and how many priority backup units to meter at sites with many units in the population strata.

Recruiting methods are a vital component of studies such as this C&I Unitary HVAC Load Shape Project. KEMA had to overcome some recruiting challenges. First, the scope of work to be performed at a customer site was moderately intrusive; technicians required access to electrical closets, mechanical rooms, and for the most part rooftops, all of which tend to be access-controlled areas. Another issue of vital importance to the recruiting effort was KEMA's ability to prove our legitimacy to customers. Customers tend to be skeptical when a consulting firm they are unfamiliar with contacts them "on behalf" of their utility. As such, KEMA worked with program administrators to ensure that each sponsor had at least one point person for customer contact. In this way, KEMA was able to provide direct references to utility contacts during scheduling, if necessary, to alleviate customer concerns.

In addition to the aforementioned issues, recruiting and scheduling generally required detailed planning and organization to ensure sampling quotas are achieved, optimize the data collection process (e.g. coordinate technicians by date, time, and location), and minimize impact on the customers.

2.2.2Site Data Collection

Inextricably linked to the success of the preceding tasks, this Site Data Collection task represents the heart of this C&I Unitary HVAC Load Shape Project. In recognition of the inherent challenges, KEMA assembled a senior project management team with direct experience managing large-scale and geographically-diverse data collection efforts. Data loggers were installed in May and early June and meters were downloaded in late September and October of 2010.

KEMA collected data for all HVAC units specified in the final sample design and selection in adherence to the on-site measurement protocols described in this section and used the data collection form shown in the Appendix 6.3. KEMA recognizes the critical importance of full compliance with all state and regional measurement requirements. The power measurement equipment complied with ISO New England and PJM Interconnection M&V protocols[14]. The data collection also included unit nameplate information, outside air control type, control settings, site building type, and data logger configuration.

While the measurement plans defined all monitoring equipment and methods, the monitoring strategy could be summarized as rigorous, compliant, and cost-effective. This system provided data at short intervals across a long duration on a single install: one-minute kW readings for the entire summer. While this may seem excessive, the notable analytical advantage to such high resolution was that it characterizes the peak observed kW of the system, avoiding any reliance on nameplate or assumptions on equipment over-sizing**.** Table 2-11 below provides equipment specifications for each of the key components of the metering suite. The metering suite includes sensors to measure true RMS current and voltage and a recording data logger. The current transducers and direct voltage connections of all three-phase legs are used by the Wattnode to calculate true RMS power and transmit pulse data to the Microstation data logger. Quantities in the table are indicated relative to the requirements of metering one sampled AC unit.

Table 2-11: Metering Equipment Suite for one AC Unit

Function /Data Point to Measure	Equipment Brand/Model	Qty Req'd	Rated Full Scale Accuracy	Accuracy of Expected Measurement	Planned Metering Duration	Planned Metering Interval
Power	Wattnode/WNB-3D-480-P	1	± 0.05%	± 0.45%	4+ Months	1 min
Power	Onset Hobo Micro Station	1		±0.4	4+ Months	1 min
Power	Magnelab Split-Core AC Current Transducer	3	± 1%	± 1%	4+ Months	1 min

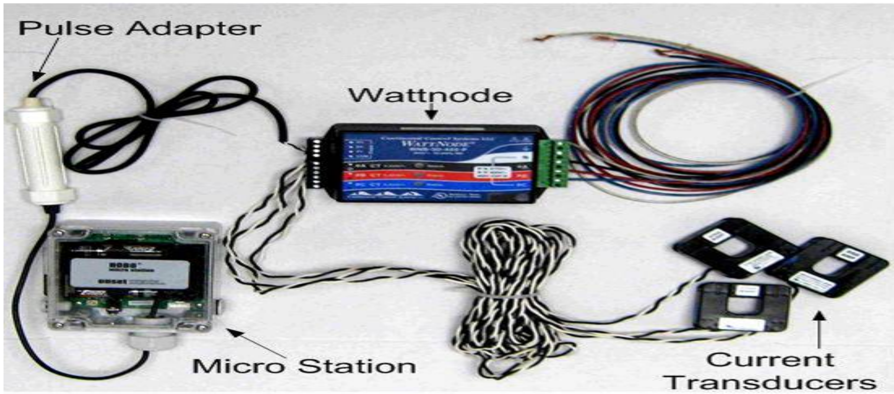
Temperature monitoring was not included in the KEMA work plan for reasons of cost-control and also because hourly ambient temperature is available at low cost from proximal weather stations.

[14] New England Independent System Operator (ISO-NE) M&V Manual for Wholesale Forward Capcity Market (FCM). www.iso-ne.com/rules_proced/isone_mnls/index.html
PJM Manual 18B:Energy Efficiency Measurement & Verification, Revision: 01
Effective Date: March 1, 2010 http://pjm.com/~/media/documents/manuals/m18b.ashx

Field staff began all site work by interviewing the site contact and performing a brief survey of the space served by the incented equipment. The survey portion of the site visit followed the progression provided below:

1. The field engineer presented the site contact with a document containing letterhead from *their local sponsor* that indicates the intent of the project, stated the scope of the work to be performed on site, and verifies the legitimacy of KEMA and L&S Energy Services. This document contained appropriate KEMA contact information should any issues arise with the metered equipment during the monitoring period. Contact information for the point person at the local utility was also provided should the contact still have any concerns about the legitimacy of the research effort.
2. Engineers explained what their on-site activities will entail and answered any customer questions. Field engineers reiterated the details provided to the site contact during the scheduling phone call and contained in the aforementioned document.
3. The site contact was interviewed to determine the operating schedules and set points of the incented unitary HVAC equipment. The contact was asked if the company uses a programmed set back schedule, or manually adjust the temperature set points to meet their needs. If set points were manually controlled, the site contact was asked to provide approximate on/off and hourly temperature set point schedules for the sampled AC units. The contact was also asked to provide specific schedules for weekends, holidays, and any other special events which may alter the normal operation of the unit. Should the contact indicate that the HVAC equipment follows a programmed schedule, field engineers asked if set points are ever changed, and if so, when and for what reasons. For sites with programmed schedules, the contact was asked to show the engineer the thermostat/ EMS interface for recording.
4. Field engineers requested that the site contact next provide access to the roof so that the metering tasks can be completed.
    a. Metering Equipment - The metering procedure uses the metering suite depicted below.

Figure 2-8: Metering Equipment Picture

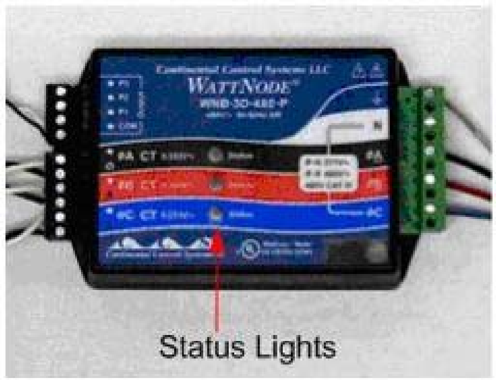


All on site metering activities will comply with NFPA 70E safety protocols. Furthermore, all KEMA field staff members were required to undergo additional electrical and ladder safety training courses annually.

b. **Meter Installation -** After being provided roof access by the site contact, the following protocols will be followed to install the metering suite and verify its correct operation.

1. Before touching any energized equipment, remove all metallic jewelry and put on all safety gear required by the NFPA 70E standards.
2. Turn off the power by flipping the manual disconnect switch.
3. Open the unit and verify that it is completely off. This can be done by measuring the phase voltage with a multi-meter at the unit's primary terminal block. Install the logger by hard wiring the voltage leads into each phase at the terminal block with an insulated screw driver. Attach current transducers (CTs) to the corresponding supply circuits on the *line* side of the terminal block.
4. Launch the Micro Station logger for 1 minute interval metering. Turn the unit on and verify that the logger is recording data and operating properly. Compare the logger readings to spot measured values collected using the procedure in section C. In the event that the logger is not recording data or the numbers do not compare within reason to the spot measured values, check the Wattnode status lights and consult the field troubleshooting guide (provided with all site kits).

Figure 2-9: Wattnode Status Indicator Lights



    5. After correct operation has been verified, turn the unit off again and close all HVAC unit panels. Turn the unit on and verify that it runs before leaving the roof. This can be done by decreasing the thermostat set point sufficiently to induce compressor operation.

  c. **Spot Power Measurement Check -** The accuracy of all meter installations must be verified using spot measurement checks. Spot measurements consist of voltage, amperage, power factor, and true power readings. A minimum of three sets of spot measurements taken 1 minute apart is required.

5. After meter equipment installation is complete, the site contact will next be asked to provide field engineers with access to areas of the facility served by the sampled HVAC units. Engineers will then record information regarding the space type and function (i.e. kitchen, general office, retail, etc.) and whether any significant internal loads (server farms, kitchen equipment, process equipment etc.) exist. For spaces with substantial internal loads, the equipment operating schedules, energy rating and efficiency of the equipment will be collected to inform the modeling effort. The site contact will also be asked how many people typically occupy the space and how the occupancy schedule fluctuates throughout the day. Engineers will also ask about and record shell characteristics data including wall construction and roof type.

6. Before leaving the facility, field engineers will notify the site contact that a KEMA employee will be contacting them in August to schedule a September meter retrieval date.

7. Meter removal followed all the steps of meter installation. After removing all logging equipment from the unit, securely reinstall the panels. Turn the unit back on and make sure it runs. If necessary, adjust the thermostat to force the unit to turn on.

Data collection concluded with a visit to pick up data loggers and ask site contacts to confirm unit operation and control strategy outside of the monitored period, especially winter months. The responses were included in the analysis at the unit level to inform extrapolation of results to hours outside the monitored period.

2.2.3Secondary Data Collection

Weather data for 2010 for the specified weather stations were obtained directly from the NOAA database. TMY3 regional weather is available for free from the location referenced above. The data collected from past studies and leveraged for load shape development was limited to that of the BG&E Commercial AC Profiler[15] project. Those load and weather data were provided by BG&E in a format such that the data could be re-analyzed according to the specifications in the following section. The study resulted from long term metering of units which were also subject to demand-response load control, but having the hourly power measurements and weather data for all hours outside the load control events was invaluable. There were four to five years of power and weather data to model for each unit, offering good tests of modeled usage versus actual usage across all relevant conditions. Each leveraged unit was modeled in the same fashion as units metered according to the above data collection protocols.

BG&E's load data were obtained from end-use meters that were installed on 101 air conditioning units. These meters provided integrated kW demand data on a fifteen-minute interval basis. During the summers of 2001 through 2007, BGE operated its load curtailment program on 106 summer days. Since the focus of their research was to develop profiles of uninterrupted air conditioner use, these days were excluded from the analysis and data set provided. In addition, BGE identified heating usage of heat pumps which was also excluded from the modeling in this NEEP study. The size distribution of units is shown in the table below which also shows that 95 units went to the small stratum and 6 units went to the large stratum within the MidAtlantic weather region.

[15] Baltimore Gas and Electric Company (BGE) - Development of Commercial Load Profiler for Central Air Conditioners and Heat Pumps. Contact Mary Straub at BGE.

Table 2-12: Distribution of Leveraged Data

Stratum	Tonnage	Number of Units
Mid-Atlantic Small	1	2
Mid-Atlantic Small	1.5	6
Mid-Atlantic Small	2	6
Mid-Atlantic Small	2.5	7
Mid-Atlantic Small	3	10
Mid-Atlantic Small	3.5	2
Mid-Atlantic Small	4	8
Mid-Atlantic Small	5	41
Mid-Atlantic Small	5.5	2
Mid-Atlantic Small	6	5
Mid-Atlantic Small	7.5	4
Mid-Atlantic Small	10	2
Mid-Atlantic Large	11	2
Mid-Atlantic Large	12	1
Mid-Atlantic Large	15	3
Total		101

2.3 *Data Analysis*

The highlights of the data analysis are as follows:

- Quality control performed on the hourly power measurements for all units for the cooling season provided by the logging effort.
- Modeling of each unit kW individually as a function of weather variables and other available data.
- Fitting models to normal weather series for both the normalization of the individual unit data and the extrapolation to 8,760 load shapes; that is average kW for each hour of the year.

The individual unit 8,760 load shapes were aggregated, hour by hour, with a ratio estimation approach using the case weight developed in the sample design.

2.3.1Quality Control

Logging of end-use data in the field is a complicated and challenging process. The first step of all data analysis using logged data is confirming that the data on the logger correctly reflects the usage of that end-use. In addition to all of the checks integrated into the logging process itself, we check each set of logger data before doing any analysis. Air conditioning data, in particular, has a clear visual signature that allows for confirmation of the data. Unexpectedly low usage may indicate a failed logger. Data analysts ran a series of tests on the data and worked with the engineers who performed the data logging to confirm that all data were correct. Quality control included checking for missing data, atypical peaking patterns, and low/high values that were inconsistent with the unit's size, etc. Table 2.3 in the Sample Design section describes the number of units excluded based on the QC criteria. The following section also describes how error analysis of the modeling results was also used to inform the engineering QC process.

As part of the quality control, the data was preprocessed to exclude times when the unit is in fan-only mode. Fan-only mode appears as a fraction of typical unit usage but a relatively flat line in a plot of a unit's power draw versus time. The fan's rated power was also factored in to determine the correct point at which to exclude fan-only data points in the final unit level analysis. This method excludes economizer-only and ventilation-only usage, however it does not account for changes in outside air intake fraction during cooling operation. All fan usage during compressor and condenser "cooling" operation was included in the analysis. Peak coincidence factors and annual full load hours were defined to only include the cooling operation of unitary HVAC equipment.

In addition, a time series of the power draw was inspected to capture any apparent operating schedule. The data were imported into a SAS program that extracts in different columns, the date, hour, Weekend/Weekday, hourly average power (kW), OSA dry bulb temperature, cooling degree hour (defined as OSA minus 65), outside air relative humidity, outside air dew point temperature, and the temperature-humidity index (THI).

2.3.2Unit Level Regression Modeling Approach

The analysis is based on the following equation to determine unit level hourly load estimates:

Equation 2

$$L_{dh} = \alpha + \beta_{Ch} THI_{dh} + \beta_{w(d)} w(d) + \beta_{g(h)} g(h) + \beta_{2h} H_{2d} + \beta_{3h} H_{3d} + \varepsilon_{dh}$$

where for a particular HVAC unit;

L_{dh} = load on day d hour h, day= 1 to 365, hour = 1 to 8760 in kW
THI_{dh} = Temperature-humidity index on day d hour h
w(d) = 0/1 dummy indicating day type of day d , Monday = 1, Sunday =7, Holiday = 8
g(h) = 0/1 dummy indicating hour group for hour h, hour group = 1 to 24
H_{2d} = 0/1 dummy indicating that hours in day d are the second hot day in a row
H_{3d} = 0/1 dummy indicating that hours in day d are the third or more hot day in a row
α β_{Ch} β_{Hh} $\beta_{w(d)}$ $\beta_{g(h)}$ = coefficients determined by the regression
β_{2h}, β_{3h} = hot day adjustments, a matrix of coefficients assigned to binary variables (0/1) for hours defined for 2nd and 3rd consecutive hot days, the matrix variables are unique to each hour in each hot day
ε_{dh} = residual error

Models using alternative weather variables were developed, but THI was used;

$C_{dh}(\tau)$ = cooling degree-hours for day d hour h, base $\tau - 65$°F
H_{dh} = relative humidity on day d hour h

The data were filtered for the hours when the unit is on, defined as when kW > “fan only” and other parameters (i.e. – specific hours per operating schedule) as determined necessary by the engineer. The inputs were run in SAS multi-variable regression for kW, THI (and alternatively CDH, RH), day-type, hour-type, and consecutive hot day adjustments. The regression used local weather data available closest to the unit’s location with the intent that modeling the unit this way will yield a much more accurate model that is highly sensitive to changes in temperature and humidity inputs to THI. The estimated values from the regression represent the α, β_{Ch}, β_{Hh}, $\beta_{w(d)}$, and $\beta_{g(h)}$ coefficient values in the original modeling equation as shown in Equation 1. These values were used to model the energy consumption of the unit based on THI, day type, and hour type. The 2nd and 3rd hot days, flags will be placed in the weather file to denote whether this is the 2nd or 3rd consecutive hot day. A hot day was defined as a day when the average dry bulb temperature for all 24 hours is greater than 80 °F. An adjustment is made for both 2nd and 3rd hot days in the following manner: These hot day variables represent the β_{2h} (d,h) and β_{3h} (d,h) terms in the original equation. Note that these terms depend on the day of the week and hour of the day for the hour in question. For each unit level model there are 340 regression coefficients, one for each of the variables CDH, RH, day-type, and hour-type and each consecutive hot day adjustment is 168 coefficients on the 0/1 dummy variables.

Finally, the model values are compared to the original metered data and a statistical analysis is done to determine the mean bias error (MBE). The MBE results for the metered time frame were used to prioritize review of the unit models by senior engineers and site staff to supplement the QC described above under data collection. Ultimately an engineering decision was made for each unit the model did not match to determine if poorly modeled data was a result of the actual unit usage or if there was a measurement or other issue requiring exclusion of the unit entirely from the aggregate load shape analysis. This error analysis can be computed mathematically using the residual error term in the regression and the graphing procedure for quality control also automatically calculated the mean bias error for the entire profile and for selected time periods. Investigating the error over the various peak hours was easier in the graphical interface. The comparative statistics are calculated for coincident data values, i.e. data values for time periods which contain data values for both the measured (base) and modeled (comparison) profiles. All time periods where data is missing for either the base or comparison profile are ignored. The mean bias error, MBE, is the mean of the error or difference between the base and comparison profiles for all pairs of coincident data points over the mean of the coincident data points of the base profile, as shown in the equation below.

$$\left. \frac{\sum_{i=1}^{n}(b_i - c_i)}{n} \middle/ \frac{\sum_{i=1}^{n} b_i}{n} \right.$$

where;

bi = data value of the base profile at time period i

ci = data value of the comparison profile at time period i

n = number of coincident data points

The unit level model was applied to one of six regional (TMY3) weather files to provide a weather-normalized 8760 load shape profile for the unit. The load predicted by the model was set to zero if the THI was less than 50°F. This decision was made based on review of the BGE AC profiler data which included year round data collection for multiple years and usage during off-peak metered periods. This restriction had no effect on summer peaks, only on off-peak and annual usage. Any information collected about when the units are activated or shut down for winter was applied when extrapolating the results. If a unit was designated as being turned on in March and off in December then no modeled usage was calculated for January and February. At this stage there is a unit level 8760 weather-normalized profile for each sample point.

2.3.1 Definition of Analysis Time Variables

This section describes the definition of peak periods and holidays included in the analysis.

2.3.2Peak Period Definitions

Peak period definitions vary by ISO territory. Accordingly, the Load Shape Tool and this report include the three peak period definition options originally specified in the RFP.

- ISO-NE On-Peak Period: The ISO-NE summer "Demand Resource On-Peak Hours," are defined as 1 PM to 5 PM on weekday non-holidays during June, July, and August. This peak period is defined inclusive of the start instant and exclusive of the end instant, meaning that the summer peak period therefore includes the four hours from 1:00:00 PM to 4:59:59 PM. In practice, this means that data time stamped from 1:00 PM to 4:59 PM will be included in the ISO-NE peak time frame for analysis purposes.
- PJM On-Peak Period: The PJM On-Peak Period is structurally identical to the first, except that it will encompass the hours from 2 PM to 6 PM instead of 1 PM to 5 PM.
- ISO-NE FCM Seasonal Peak: The FCM Summer Seasonal Peak includes all non-holiday weekday hours in June, July and August during which the ISO New England Real-Time System Hourly Load is greater than 90% of the most recent "50/50" System Peak Load Forecast for the summer season.

ISO-NE FCM Seasonal Peak Details

Calculation of summer seasonal peak demand reduction and related results, such as coincidence factors is based on performance hours. Seasonal demand performance hours for ISO-NE FCM are defined as hours when the real time ISO-NE system load meets or exceeds 90% of the predicted seasonal peak from the most recent Capacity, Electricity, Load and Transmission Report (CELT report).

For this project KEMA needed to translate the definition of summer seasonal demand performance hours in order to apply them to weather-normalized unit usage estimates. This process involved several steps summarized in this section and detailed in the Appendix. The method uses actual identified hours for 2010 and applies the actual year weather to the ISO system loads for those hours. KEMA developed a simple regression of hourly system load for peak hours as a function of outside temperature and THI at the various weather regions.

As expected, the summer of 2010 contained several hours to develop a regression of system load to weather. 2010 ISO-NE reports[16] posted for the period identified the following number of peak hours: 20 peak hours in June, 88 peak hours in July, and 53 peak hours in August. The following equation describes the model used for each weather region.

$$S_{dh} = \alpha + \beta_{Th} T_{dh} + \beta_{THIh} THI_{dh} + \varepsilon_{dh}$$

Where,

S_{dh} = ISO-NE System load for day d and hour h in megawatts (MW)

T_{dh} = Outdoor Dry-bulb temperature for day d and hour h in degrees ^{o}F

THI_{dh} = ISO-NE temperature-humidity index for day d and hour h in degrees ^{o}F

α, β_{Th} , β_{THIh} = coefficients determined by the regression

ε_{dh} = residual error

The system load to weather regression differed for each weather region. The resulting equation coefficients for each weather region are shown below along with predicted loads for an example input. The table below has shaded headings for the regression definitions and white headings to show an example of inputting the same weather condition in each equation.

[16] ISO NE Seasonal Peak Files: http://www.iso-ne.com/markets/othrmkts_data/fcm/reports/snlph/index.html

Table 2-13: ISO-NE System Peak to Weather Regression Results

Weather Region	Station	α Intercept	β_T Temp_degF	β_{THI} THI_degF	Example Temp/THI	Predicted System Load
NE_North	Boston, MA	**9,919**	**-77**	**287**	**85/80**	**26,335**
NE_South	Concord, NH	**8,845**	**-82**	**302**	**85/80**	**26,004**
NE_EastMass	Providence, RI	**15,829**	**-102**	**234**	**85/80**	**25,937**

The temperature and THI from the TMY3 weather files was substituted into the equation for each weather region to estimate system loads for weekday non-holidays in the summer months. The loads for each hour were reviewed to determine hours with load greater than 90% of the long term average 50/50 system peak. The derivation of the long term average is presented in the Appendix. The load representing 90% of the long term (2005 to 2010) average 50/50 system peak was 24,472 megawatts. The raw number of hours identified for each weather region is shown in the table below. The historic actual annual number of FCM summer seasonal peak hours was also reviewed to provide a foundation for reviewing the results of the regression and weather normalization process.

Table 2-14: Number of TMY3 Hours with Load Greater than 90% of Long term Average and Comparison to Number of FCM Seasonal Peak Hours (2008-10)

Weather Region	Station	RAW TMY3 FCM Peak Hours
NE_North	Boston, MA	**172**
NE_South	Concord, NH	**115**
NE_EastMass	Providence, RI	**49**

Year	Number of Summer Seasonal Peak Hours
2008	29
2009	1
2010	161

The 25 hours mutually identified across all ISO-NE weather regions are specified below along with TMY3 temperature and THI as well as predicted system load for each weather region.

Table 2-15: Final Set of FCM Season Peak Hours

				EastMass			NE-North			NE-South		
Month/ Day	Hour Ending	8760 hour	2010 Daytype	Temp. (°F)	THI (°F)	ISO-NE S_Load (MW)	Temp. (°F)	THI (°F)	ISO-NE S_Load (MW)	Temp. (°F)	THI (°F)	ISO-NE S_Load (MW)
7/19	13	4789	Tuesday	78.08	73.52	25,008	87.98	77.88	25,117	89.06	82.04	26,002
7/19	14	4790	Tuesday	75.02	72.32	24,898	91.04	78.54	25,066	93.02	83.10	25,848
7/19	15	4791	Tuesday	75.02	71.99	24,805	89.96	77.68	24,894	93.02	83.10	25,848
7/19	16	4792	Tuesday	75.02	71.99	24,805	89.06	77.55	24,930	91.04	82.70	25,956
7/19	17	4793	Tuesday	73.94	71.18	24,656	87.98	77.01	24,856	87.98	80.90	25,846
7/20	13	4813	Wednesday	75.92	74.55	25,469	91.04	80.33	25,604	89.06	77.82	25,014
7/20	14	4814	Wednesday	75.02	74.10	25,409	89.96	79.46	25,432	91.04	77.90	24,830
7/20	15	4815	Wednesday	75.02	73.23	25,161	89.96	79.19	25,351	89.96	77.68	24,889
7/22	13	4861	Friday	75.92	72.44	24,865	84.02	76.82	25,123	91.94	78.99	24,996
7/22	14	4862	Friday	73.94	70.86	24,562	84.92	76.94	25,086	91.94	80.18	25,274
7/22	15	4863	Friday	75.92	72.17	24,787	84.02	76.82	25,123	89.96	79.79	25,383
7/22	16	4864	Friday	75.02	71.72	24,727	82.94	76.55	25,130	89.06	79.93	25,508
7/22	17	4865	Friday	73.04	70.41	24,503	78.98	73.97	24,679	89.06	79.34	25,369
7/26	13	4957	Tuesday	78.98	72.78	24,727	86	77.21	25,079	95	79.28	24,752
7/26	14	4958	Tuesday	82.04	73.40	24,667	84.92	76.67	25,005	95	80.52	25,043
7/26	15	4959	Tuesday	82.94	73.85	24,727	84.02	75.90	24,845	95	79.88	24,891
7/26	16	4960	Tuesday	80.06	73.65	24,892	82.04	75.83	24,987	93.92	79.34	24,875
7/27	13	4981	Wednesday	84.92	74.24	24,688	86	77.21	25,079	93.92	83.87	25,938
7/27	14	4982	Wednesday	84.02	73.52	24,551	84.92	76.67	25,005	93.02	83.10	25,848
8/15	13	5437	Monday	80.06	76.35	25,667	91.04	80.92	25,784	91.94	83.15	25,970
8/15	14	5438	Monday	82.04	77.34	25,799	91.94	81.37	25,845	91.94	82.88	25,907
8/15	15	5439	Monday	78.98	75.81	25,595	91.94	81.96	26,025	91.04	82.70	25,956
8/15	16	5440	Monday	75.92	74.55	25,469	91.94	81.69	25,943	89.96	82.49	26,015
8/15	17	5441	Monday	75.92	74.28	25,392	91.04	81.51	25,963	87.08	81.05	25,971
8/15	18	5442	Monday	77	75.09	25,541	87.98	80.31	25,851	84.02	79.19	25,847

2.3.3Holidays

Holidays are part of the TMY3 weather data and 2010 day types (weekday versus weekend) and typical holidays were applied to the analysis results using a 2010 calendar. The Load Shape Tool allows for the user selection of time periods and allows for holiday exclusion. Only Independence Day, observed Monday July 5th in the 2010 calendar, falls within the period of the above peak definitions so this primarily affects annual estimates or custom time period analysis in the Load Shape Tool.

Holiday definitions vary across both ISOs and sponsor service territories. The full list of holidays included in annual (8760 hourly) estimates has used the ISO-NE holidays, ISO-NE Demand Response holidays, NERC holidays, and NSTAR holiday definitions to create the following list of potential holidays and highlighted summer season holidays relevant to the peak definitions:

- New Year's
- Martin Luther King Day
- President's Day
- Good Friday
- Patriot's Day
- Memorial Day
- Independence Day*
- Labor Day
- Columbus Day
- Veteran's Day
- Thanksgiving
- Day after Thanksgiving
- Christmas

KEMA chose to include holidays in the Load Shape Tool by providing sponsors with a list of holidays that can be individually selected. Each selected holiday can be selected in the "holiday" time frame category and thus excluded from relevant time periods

2.3.4 Extrapolation Out of Sample

Unit level normalized results were aggregated based on the case weights determined during the sampling process. The analysis results were used to develop hourly case-weighted normalized load shape data for each of the 12 strata (e.g. NY-Inland - Large). After all the unit level modeling was done and regional weather normalization completed, each load shape profile was pooled into 12 strata determined by 6 regions and 2 unit sizes (small <11.25 tons or large ≥11.25 tons). For each hour, the load for each stratum was calculated as the sum of the sample loads multiplied by their case weights. For each stratum, the case-weighted sample connected load was also calculated. The ratio of the total hourly load to the total connected load derived from the sample data in each stratum was multiplied by the total population connected load to estimate the total stratum hourly load. By performing this calculation for every hour, an annual load profile was estimated. The variation in the sample customer ratios in each hour, as well as the sample size was used to calculate the relative precision at the 90% confidence interval of each hourly estimate. The sampling and extrapolation were performed using Load Research Software which is specifically designed for developing estimates and precision from all 8760 hours. The software also aggregated loadshapes based on case weights to the total for region and size strata as well as across all units. These case-weighted aggregations of the 12 strata were not part of the tool or result tables because the Load Shape Tool was designed to use connected load to scale estimates and to aggregate small and large unit populations within a region. The precision of the estimate over the peak period as defined by ISO-NE and PJM as well as the precision of the annual estimate are calculations performed by the Load Shape Tool using the stratum level data. In all strata the load shapes were near precision targets for all peak definitions, therefore the use of cross regional load shapes was not deemed necessary for use in the reporting or tool and combinations could be based on weighting by connected load.

3 Results

This section focuses on the primary results which are the annual load shape for each size and region stratum and key parameters that can be calculated using the loadshape data. The annual results are presented in illustrative figures and tables below. The primary results of the study were unit-less load ratio estimates and precisions at the hourly level, which also serve as the basis of the Load Shape Tool. The load ratio is the hourly modeled load divided by the connected load. The average load ratio over the hours defined in a peak period is equal to the coincidence factor. The sum of load ratios over a year is equal to the equivalent full load cooling hours. Results (demand and annual energy) extrapolated to the population in physical units of kW and kWh are available through the Load Shape Tool by entering population connected loads.

The usage estimates generated from this study show some usage occurring outside the monitored period of May to September. Various steps were taken to explain the non-summer usage. Interviews with facility staff were conducted during the logger pickup visit to determine seasonal operation outside the metered period. While not all site contacts could provide detailed schedule information, many responses were that the units would operate if necessary in winter. Long term metered data that was leveraged for this study, provided by BG&E, showed actual metered non-summer usage consistent with the modeled usage of units (restricted to THI > 50) only monitored by this study in summer 2010 and extrapolated to the same weather data recorded in the long term metered data set. An extensive analysis was beyond the scope of this study, but a reasonable effort was made to validate the results. For large units, the internal building loads such as lighting and occupants are such that the cooling systems were used more consistently across temperature ranges than small units. Although not presented in the report, data in the Load Shape Tool show the relative precision and error ratios for winter hours were much higher than the hours included in peak definitions where there is more likely coincident usage across a region. The extreme error ratios were a result of many units having zero usage with one or a few units having some sporadic usage. The 8,760 profiles in section 3.2 show the limited usage in winter months, but rather extensive off-peak summer usage.

3.1 Normalized Study Results and Basis of Load Shape Tool

The following tables present the annual usage and coincident peak estimates and relative precisions based on the developed load shapes. The data are normalized by connected load such that the results are unit-less, coincidence and annual load factors, except for effective full load cooling hours. All tables include estimated factors or full load hours. Each estimated factor is presented with the relative precision of each estimate at the 80% and 90% two-tail confidence intervals, abbreviated respectively as “RP @ 80%CI” and “RP @ 90%CI. As a reminder, relative precision at the 80% two-tail interval is equivalent to that of the 90% one-tail.

The following table presents the annual load factor and effective full load hours for the regional totals and the relative precisions of the estimates. The annual load factor represents the fraction of hourly regional loadshape divided by connected load for all 8,760 hours or more simply, the fraction of effective full load cooling hours over 8,760.

$$EFLH = \sum_{h=1}^{8760}\left(\frac{Estimated\ \ Hourly\ \ Load(kW)}{Connected\ \ Load(kW)}\right)$$

$$AnnualLoadFactor = \left(\frac{EFLH}{8{,}760}\right)$$

The relative precisions of the two estimates are identical given there is only division by a constant. The precisions were much lower than the planned precisions from the sample design for peak demand factors. As shown below, precisions for all of the load-weighted regional totals are less than 23%. The precision calculations are based on aggregation of the hourly estimates and hourly error terms and can be replicated in detail in the Load Shape Tool.

Table 3-1: Annual Load Factor and EFLH Estimate by Region Totals

Total	Annual Load Factor (EFLH/8760)			EFLH = Effective Full Load Cooling Hours		
Region	Estimated Ratio	RP @ 80%CI	RP @ 90%CI	Annual Estimate	RP @ 80%CI	RP @ 90%CI
Mid-Atlantic	0.1707	±9.78%	±12.55%	1,495	±9.78%	±12.55%
NE-East Mass	0.1339	±10.12%	±12.99%	1,173	±10.12%	±12.99%
NE-North	0.0862	±13.14%	±16.87%	755	±13.14%	±16.87%
NE-South Coastal	0.0976	±11.44%	±14.69%	855	±11.44%	±14.69%
NY- Inland	0.1087	±13.58%	±17.43%	952	±13.58%	±17.43%
NY- Urban/Coastal	0.1704	±10.69%	±13.72%	1,492	±10.69%	±13.72%

The detailed definition of the ISO-NE On-Peak, PJM On-Peak, and ISO-NE FCM seasonal coincident peak factor are described in Section 2.3.1.1. A coincident factor of one would indicate all units ran at full load for the entire hour for all hours included in the peak definitions. The following table presents coincident factor estimates and precisions and the maximum hourly coincident load ratio and relative precisions for those hours. The precisions at the 90% confidence interval of the coincident peak estimates range roughly from 11% to 20%. They are low relative to the planned precisions across all peak definitions and regions. The precision of the maximum load ratio is for an individual hour by region and shows the greater variability at the hourly level with precisions from 6% to 17%. The coincidence factor estimates include the effects of oversizing and some peak defined hours where units operate at part loads. The results reflect diversity of usage within and between hours in the population.

Table 3-2: Coincidence Factor for Peak Demand Definitions by Region Totals

	Total	Coincidence Factor			Maximum Load Ratio		
	Region	Hourly Average	RP @ 80%CI	RP @ 90%CI	Hourly Maximum	RP @ 80%CI	RP @ 90%CI
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	Mid-Atlantic	0.4892	±7.09%	±9.10%	0.718	±7.83%	±10.05%
	NE-East Mass	0.4488	±8.40%	±10.78%	0.699	±8.43%	±10.82%
	NE-North	0.3421	±11.98%	±15.38%	0.469	±12.23%	±15.69%
	NE-South Coastal	0.3397	±10.39%	±13.33%	0.526	±9.59%	±12.30%
	NY- Inland	0.3815	±12.59%	±16.15%	0.477	±13.01%	±16.69%
	NY- Urban/Coastal	0.5529	±8.24%	±10.58%	0.822	±5.80%	±7.44%
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	Mid-Atlantic	0.4833	±7.32%	±9.40%	0.718	±7.83%	±10.05%
	NE-East Mass	0.4443	±8.56%	±10.99%	0.699	±8.43%	±10.82%
	NE-North	0.3343	±12.16%	±15.61%	0.469	±12.23%	±15.69%
	NE-South Coastal	0.3341	±10.49%	±13.46%	0.526	±9.59%	±12.30%
	NY- Inland	0.3836	±12.62%	±16.20%	0.477	±13.01%	±16.69%
	NY- Urban/Coastal	0.5665	±7.83%	±10.05%	0.822	±5.80%	±7.44%
ISO-NE FCM Seasonal Peak	Mid-Atlantic						
	NE-East Mass	0.4863	±8.39%	±10.77%	0.699	±8.43%	±10.82%
	NE-North	0.4241	±12.23%	±15.70%	0.469	±12.23%	±15.69%
	NE-South Coastal	0.4369	±9.54%	±12.24%	0.526	±9.59%	±12.30%
	NY- Inland						
	NY- Urban/Coastal						

The following table presents the annual load factor and effective full load hours for the small units for each region and the relative precisions of the estimates. The precisions were generally near the planned precisions for peak demand factors with the regional range at the 90% confidence interval of 11% to 33%. The precision calculations are based on aggregation of the hourly estimates and hourly error terms and can be replicated in detail in the Load Shape Tool.

Table 3-3: Load Ratio Estimate by Region Small Units

SMALL units (<11.25 TONS)						
Small Units	**Annual Load Factor (EFLH/8760)**			**EFLH**		
Region	**Estimated Ratio**	**RP @ 80%CI**	**RP @ 90%CI**	**Annual Estimate**	**RP @ 80%CI**	**RP @ 90%CI**
Mid-Atlantic	0.1157	±6.79%	±8.72%	1,014	±6.79%	±8.72%
NE-East Mass	0.1261	±14.78%	±18.97%	1,104	±14.78%	±18.97%
NE-North	0.0946	±19.18%	±24.62%	829	±19.18%	±24.62%
NE-South Coastal	0.1064	±14.98%	±19.22%	932	±14.98%	±19.22%
NY- Inland	0.0752	±25.39%	±32.59%	659	±25.39%	±32.59%
NY- Urban/Coastal	0.1375	±8.27%	±10.62%	1,204	±8.27%	±10.62%

The following table presents small unit coincidence factor estimates and precisions and maximum hourly coincident load ratios and associated relative precisions. The precisions of the coincident peak estimates were on the order of 10 to 29% across the range of definitions and regions. The precisions of the maximum load ratio at the hourly level were from 6 to 29%. The coincidence factor estimates include the effects of oversizing and some peak defined hours where units operate at part loads. The results reflect diversity of usage within and between hours in the population.

Table 3-4: Coincidence Factor for Peak Demand Definitions by Region Small Units

	Small Units	Coincidence Factor			Maximum Load Ratio		
	Region	Hourly Average	RP @ 80%CI	RP @ 90%CI	Hourly Maximum	RP @ 80%CI	RP @ 90%CI
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	Mid-Atlantic	0.3578	±5.54%	±7.11%	0.588	±5.70%	±7.32%
	NE-East Mass	0.4345	±12.38%	±15.89%	0.722	±10.40%	±13.35%
	NE-North	0.3720	±16.23%	±20.84%	0.501	±15.91%	±20.42%
	NE-South Coastal	0.3498	±13.09%	±16.80%	0.536	±12.38%	±15.89%
	NY- Inland	0.2426	±22.73%	±29.18%	0.305	±22.31%	±28.63%
	NY- Urban/Coastal	0.4435	±7.50%	±9.63%	0.703	±7.69%	±9.87%
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	Mid-Atlantic	0.3596	±5.57%	±7.16%	0.588	±5.70%	±7.32%
	NE-East Mass	0.4305	±12.54%	±16.09%	0.722	±10.40%	±13.35%
	NE-North	0.3623	±16.24%	±20.85%	0.501	±15.91%	±20.42%
	NE-South Coastal	0.3357	±13.62%	±17.49%	0.536	±12.38%	±15.89%
	NY- Inland	0.2433	±22.70%	±29.14%	0.305	±22.31%	±28.63%
	NY- Urban/Coastal	0.4507	±7.38%	±9.47%	0.703	±7.69%	±9.87%
ISO-NE FCM Seasonal Peak	Mid-Atlantic						
	NE-East Mass	0.4758	±12.31%	±15.80%	0.722	±10.40%	±13.35%
	NE-North	0.4519	±16.20%	±20.79%	0.501	±15.91%	±20.42%
	NE-South Coastal	0.4311	±13.62%	±17.48%	0.536	±12.38%	±15.89%
	NY- Inland						
	NY- Urban/Coastal						

The following table presents the annual load factor and effective full load hours for the large units for each region and the relative precisions of the estimates. They are low relative to the planned precisions across all peak definitions and regions. The precision calculations are based on aggregation of the hourly estimates and hourly error terms and can be replicated in detail in the Load Shape Tool.

Table 3-5: Load Ratio Estimate by Region Large Units

LARGE units (≥ 11.25 TONS)						
Large Units	Annual Load Factor (EFLH/8760)			EFLH		
Region	Estimated Ratio	RP @ 80%CI	RP @ 90%CI	Annual Estimate	RP @ 80%CI	RP @ 90%CI
Mid-Atlantic	0.2081	±13.24%	±16.99%	1,823	±13.24%	±16.99%
NE-East Mass	0.1396	±13.67%	±17.54%	1,223	±13.67%	±17.54%
NE-North	0.0775	±17.26%	±22.15%	679	±17.26%	±22.15%
NE-South Coastal	0.0905	±17.21%	±22.09%	793	±17.21%	±22.09%
NY- Inland	0.1215	±15.69%	±20.13%	1,065	±15.69%	±20.13%
NY- Urban/Coastal	0.1894	±14.78%	±18.97%	1,659	±14.78%	±18.97%

The following table presents large unit coincidence factor estimates and precisions and maximum hourly coincident load ratio and relative precisions for those hours. The precisions of the coincident peak estimates were on the order of 11 to 20% across the range of definitions and regions. The precisions of the maximum load ratio represent an individual hour by region and shows greater variability at the hourly level with precisions from 9 to 24%. The coincidence factor estimates include the effects of oversizing and some peak defined hours where units operate at part loads. The results reflect diversity of usage within and between hours in the population.

Table 3-6: Coincidence Factor for Peak Demand Definitions by Region Large Units

	Large Units	Coincidence Factor			Maximum Load Ratio		
	Region	Hourly Average	RP @ 80%CI	RP @ 90%CI	Hourly Maximum	RP @ 80%CI	RP @ 90%CI
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	Mid-Atlantic	0.5787	±9.80%	±12.58%	0.874	±10.17%	±13.05%
	NE-East Mass	0.4591	±11.33%	±14.55%	0.683	±12.56%	±16.12%
	NE-North	0.3113	±17.75%	±22.78%	0.438	±18.65%	±23.93%
	NE-South Coastal	0.3314	±15.70%	±20.16%	0.543	±14.43%	±18.51%
	NY- Inland	0.4348	±14.49%	±18.59%	0.545	±15.04%	±19.30%
	NY- Urban/Coastal	0.6162	±11.25%	±14.44%	0.893	±8.58%	±11.01%
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	Mid-Atlantic	0.5674	±10.20%	±13.10%	0.874	±10.17%	±13.05%
	NE-East Mass	0.4543	±11.58%	±14.87%	0.683	±12.56%	±16.12%
	NE-North	0.3054	±18.35%	±23.55%	0.438	±18.65%	±23.93%
	NE-South Coastal	0.3328	±15.48%	±19.87%	0.543	±14.43%	±18.51%
	NY- Inland	0.4375	±14.53%	±18.64%	0.545	±15.04%	±19.30%
	NY- Urban/Coastal	0.6335	±10.62%	±13.64%	0.893	±8.58%	±11.01%
ISO-NE FCM Seasonal Peak	Mid-Atlantic						
	NE-East Mass	0.4940	±11.36%	±14.58%	0.683	±12.56%	±16.12%
	NE-North	0.3953	±18.60%	±23.87%	0.438	±18.65%	±23.93%
	NE-South Coastal	0.4416	±13.27%	±17.03%	0.543	±14.43%	±18.51%
	NY- Inland						
	NY- Urban/Coastal						

3.2 Additional Results

The primary results presented in the previous section provide a summary of the load shape data. This section provides additional figures to illustrate other aspects of the load shapes developed.

The first set of figures provides a graphical representation of the annual load shapes. The format is an energy print which displays the hours of the day on the x-axis and the day of the year on the y-axis with color coding to show hourly load ratios with black representing zero and lighter colors representing increasing regional cooling demand. There are energy prints for each region representing the total load shape across small and large units as well as the separate regional profiles for small and large units. Note that the y-axis provides the first letter of the month and the x-axis provides the hours zero through 24. The plots are of load ratio so there are no physical units. The maximums correspond to the maximum hourly demands shown in the section 3.1 tables.

Figure 3-1: Annual Small Unit Load Shapes Shown as Energy Prints

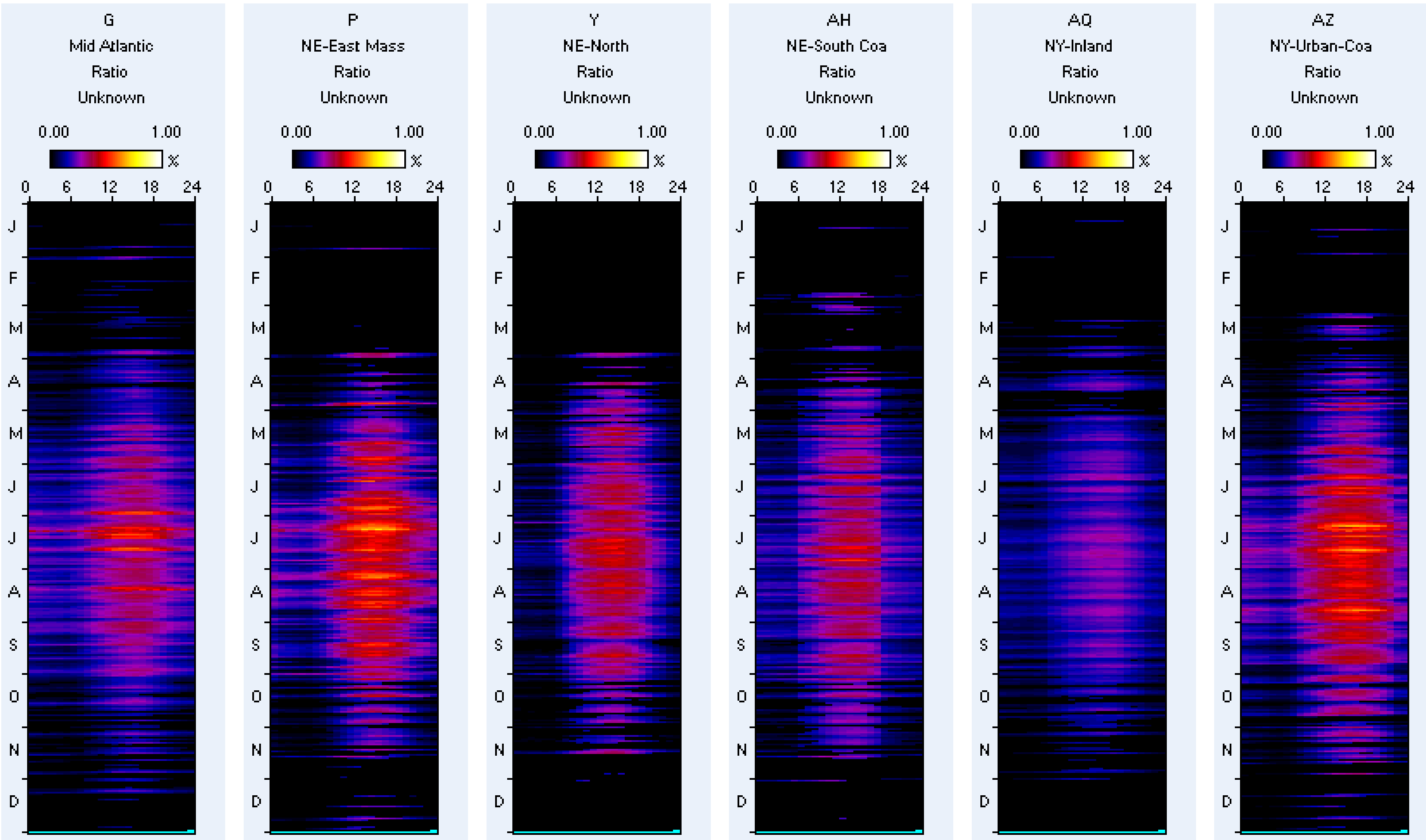
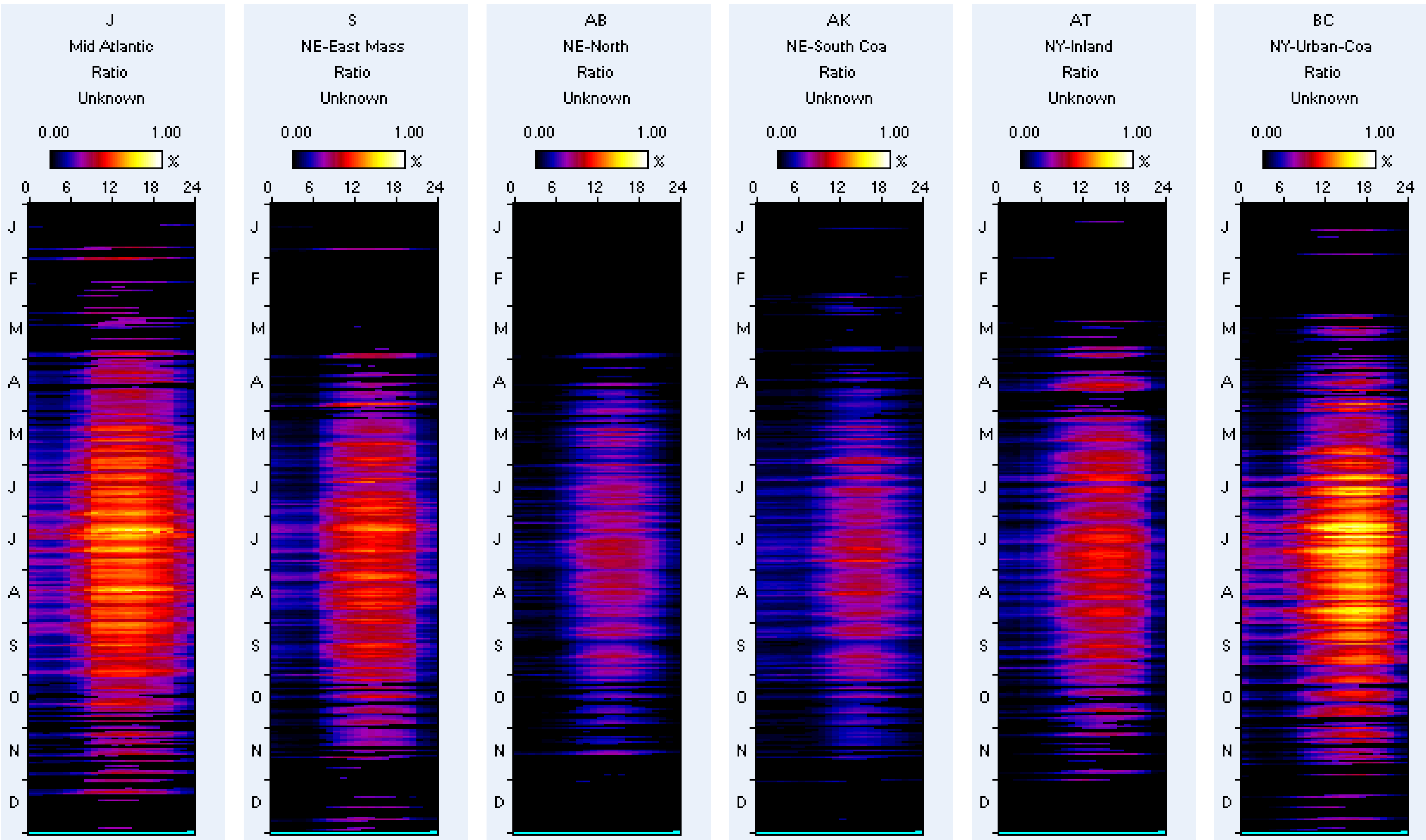


Figure 3-2: Annual Large Unit Load Shapes Shown as Energy Prints



3.3 Data Summary

This section of the report presents other results that may be gleaned from the data collected, but were not primary study objectives and are provided in response to sponsor interests. The data summary provides insight into the average performance of sample units based on several parameters which were inconsistent across sponsor data and thus cannot be extrapolated to the population. Precisions were thus not calculated as the values would not be consistent with the population weighted results developed and used in the Load Shape Tool. The sample size distributions are presented, followed by annual and peak averages for each cross tabulation of the sample. The data are presented in two sections; Building Type Summary and Economizer Summary. There is intentionally little discussion of the data summary tables as they are provided to share information on secondary study objectives.

The following table shows the sample size and total connected load in the metered sample by building type and size of HVAC unit. Recall that connected loads are based on EER and tonnage. The data are un-weighted by sample weights for the sample of units characterized by building type. The sample (including leveraged units) was dominated by retail and office types; smaller samples exist for other building types.

Table 3-7: Sample of Units and Metered Connected Load by Building Type and Size

CBECS Building Type	Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
	Small	Large	Total	Small	Large	Total
Education	11	6	17	78.2	150.7	228.9
Food Sales	14	3	17	111.6	94.6	206.2
Food Service	9	2	11	73.1	33.5	106.7
Health Care-inpatient	2	0	2	30.0	0.0	30.0
Health Care-outpatient	1	2	3	2.1	78.1	80.1
Lodging	6	1	7	20.6	8.6	29.3
Mercantile (Retail)	111	95	206	859.3	1,793.6	2,652.9
Mercantile (Mall)	3	21	24	37.0	371.1	408.1
Office	96	11	107	514.9	259.7	774.6
Other	49	14	63	224.0	278.1	502.1
Public Assembly	3	1	4	14.4	23.5	37.9
Public Order and Safety	3	1	4	14.8	21.2	36.0
Religious Worship	31	0	31	158.4	0.0	158.4
Service	1	5	6	3.6	104.5	108.1
Warehouse and Storage	8	1	9	70.6	28.6	99.2
Total	348	163	511	2,212.7	3,245.9	5,458.5

The following table shows the average load factor and effective full load cooling hour averages for the sample and indicates where sample sizes are less than 10. The table is followed by analysis results of the standard error for each estimate which further supports or advises caution of the use of these sample un-weighted averages. All results are inherently weighted by connected load of the units in the cross-tabulation.

Table 3-8: Annual Energy Estimate by Building Type

Sample n > 10
Sample n < 10

CBECS Building Type	Annual Load Factor (EFLH/8,760)			EFLH = Effective Full Load Cooling Hours		
	Small	Large	Total	Small	Large	Total
Education	**0.119**	**0.043**	0.060	**1,044**	**376**	524
Food Sales	**0.169**	**0.096**	0.127	**1,477**	**840**	1,116
Food Service	**0.175**	**0.198**	**0.192**	**1,536**	**1,733**	**1,678**
Health Care - Inpatient	**0.134**	**0.000**	**0.134**	**1,178**	**-**	**1,178**
Health Care - Outpatient	**0.097**	**0.030**	**0.032**	**848**	**261**	**276**
Lodging	**0.082**	**0.134**	**0.098**	**721**	**1,175**	**855**
Mercantile (Retail)	0.113	0.123	0.120	992	1,073	1,048
Mercantile (Mall)	**0.084**	0.110	0.108	**734**	967	945
Office	0.083	0.101	0.091	726	886	799
Other	0.089	0.131	0.115	780	1,147	1,006
Public Assembly	**0.032**	**0.104**	**0.076**	**281**	**908**	**670**
Public Order and Safety	**0.131**	**0.021**	**0.066**	**1,144**	**187**	**579**
Religious Worship	0.040	**0.000**	0.040	351	**-**	351
Service	**0.067**	**0.185**	**0.181**	**591**	**1,622**	**1,588**
Warehouse and Storage	**0.056**	**0.362**	**0.263**	**489**	**3,174**	**2,307**

Annual Load Percent Standard Error / Mean

CBECS Building Type	Small Standard Error [Standard Dev / n^.5]	Large Standard Error [Standard Dev / n^.5]
Education	26%	34%
Food Sales	19%	20%
Food Service	13%	13%
Health Care-inpatient	9%	
Health Care-outpatient		
Lodging	59%	
Mercantile (Retail)	6%	10%
Mercantile (Mall)	35%	30%
Office	11%	8%
Other	15%	16%
Public Assembly	67%	
Public Order and Safety	78%	
Religious Worship	27%	
Service		63%
Warehouse and Storage	40%	

The detailed definition of the ISO-NE On-Peak, PJM On-Peak, and ISO-NE FCM seasonal coincident peak factor are described in Section 2.3.1.1. A coincidence factor of one would indicate all units ran at full load for the entire hour for all hours included in the peak definitions. The following table presents coincidence factor estimates and indication of sample sizes less than 10 for all peak definitions and building types. The table is followed by analysis results of the standard error for each ISO-NE On-peak estimate which further supports or advises caution of the use of these un-weighted sample averages.

Table 3-9: Coincidence Factor Estimate by Building Type

Does Not Include Leverage Data

	CBECS Building Type	Coincidence Factor		
		Small	Large	Total
ISO-NE On-Peak (1-5PM, WDNH, Jun-Aug)	**Education**	**0.388**	**0.167**	0.238
	Food Sales	0.547	**0.413**	0.553
	Food Service	**0.682**	**0.650**	**0.812**
	Health Care-inpatient	**0.586**	**0.000**	**0.948**
	Health Care-outpatient	**0.463**	**0.122**	**0.142**
	Lodging	**0.246**	**0.297**	**0.343**
	Mercantile (Retail)	0.401	0.461	0.446
	Mercantile (Mall)	**0.409**	0.434	0.448

	CBECS Building Type	Coincidence Factor		
		Small	Large	Total
	Office	0.318	0.385	0.357
	Other	0.345	0.465	0.437
	Public Assembly	**0.135**	**0.386**	0.343
	Public Order and Safety	0.438	0.152	**0.396**
	Religious Worship	0.123	**0.000**	0.149
	Service	**0.290**	**0.568**	**0.568**
	Warehouse and Storage	**0.187**	**0.901**	**0.714**
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	**Education**	**0.373**	**0.151**	0.223
	Food Sales	0.550	**0.425**	0.519
	Food Service	**0.675**	**0.664**	**0.803**
	Health Care-inpatient	**0.535**	**0.000**	**0.843**
	Health Care-outpatient	**0.449**	**0.111**	**0.132**
	Lodging	**0.269**	**0.292**	**0.360**
	Mercantile (Retail)	0.405	0.466	0.451
	Mercantile (Mall)	**0.394**	0.435	0.447
	Office	0.308	0.370	0.344
	Other	0.341	0.454	0.429
	Public Assembly	**0.139**	**0.370**	0.338
	Public Order and Safety	0.440	0.129	**0.384**
	Religious Worship	0.126	**0.000**	0.153
	Service	**0.263**	**0.586**	**0.584**
	Warehouse and Storage	**0.180**	**0.908**	**0.714**
ISO-NE FCM Seasonal Peak	**Education**	**0.453**	**0.204**	0.285
	Food Sales	0.557	**0.479**	0.556
	Food Service	**0.708**	**0.654**	**0.811**
	Health Care-inpatient	**0.622**		**0.984**
	Health Care-outpatient	**0.494**	**0.000**	**0.025**
	Lodging	**0.041**	**0.000**	**0.044**
	Mercantile (Retail)	0.121	0.221	0.193
	Mercantile (Mall)	**0.461**	0.459	0.476
	Office	0.277	**0.158**	0.230
	Other	0.238	**0.131**	0.186
	Public Assembly	**0.019**	**0.352**	**0.233**
	Public Order and Safety	**0.524**	**0.232**	**0.489**
	Religious Worship	**0.000**		**0.002**
	Service	**0.419**	**0.407**	**0.422**
	Warehouse and Storage	**0.054**	**0.930**	**0.668**

ISO-NE On-Peak Percent Standard Error / Mean

CBECS Building Type	Small Standard Error [Standard Dev / n^.5]	Large Standard Error [Standard Dev / n^.5]
Education	29%	42%
Food Sales	77%	23%
Food Service	37%	11%
Health Care-inpatient	17%	
Health Care-outpatient		
Lodging	55%	
Mercantile (Retail)	5%	9%
Mercantile (Mall)	18%	28%
Office	14%	11%
Other	12%	19%
Public Assembly	61%	
Public Order and Safety	65%	
Religious Worship	40%	
Service		70%
Warehouse and Storage	67%	

Recall that units with rebated economizers were excluded from the study population such that all economizers present in the study represent the random occurrence of unit outside air economizer (dry bulb or enthalpy) use for cooling. The following table shows the sample size and total connected load for each of the simple averages presented by economizer type.

The data are sample-unweighted results for the sample of units characterized by outside air intake type. The sample (assuming no economizers on leveraged units) had a very low saturation of dual temperature and enthalpy economizers. The single temperature and enthalpy economizers tended to be on small units and a large number of units had unknown outside air controls. All "don't know" units had non-fixed outside air intake and many were believed to be single temperature/enthalpy but there was no definitive confirmation for some economizers from third party manufacturers (an economizer not specified by the AC manufacturer as associated with the unit). Note that the table groups dual temperature and dual enthalpy units under "differential temperature" as well as single temperature and single enthalpy under "single temperature" units given the sample sizes and limited information for some economizer brands.

Table 3-10: Sample of Units and Connected Load by Economizer Type and Size

	Metered Sample Size "n" (Count)			Metered Connected Load (kW)		
Economizer	Small	Large	Total	Small	Large	Total
Differential Temperature	17	18	35	112.3	429.4	541.7
Single Temperature	66	16	82	527.8	347.4	875.2
Fixed	12	1	13	46.8	12.5	59.3
None	186	69	255	1,032.4	1,120.1	2,152.4
Don't Know	61	65	126	493.4	1,336.5	1,829.9
Total	**348**	**163**	**511**	**2,212.7**	**3,245.9**	**5,458.5**

The following table shows the average load factor and effective full load cooling hour averages for the sample and indicates where sample sizes are less than 10. The table is followed by analysis results of the standard error for each estimate which further supports or advises caution of the use of these un-weighted sample averages. Large units show an expected trend while small units showed potential that single temperature economizers may be malfunctioning and increasing run hours over no economizer.

Table 3-11: Annual Energy Estimate by Economizer Type with Standard Error

Sample n > 10 **Sample n < 10**	Annual Load Factor (EFLH/8,760)			EFLH = Effective Full Load Cooling Hours		
Economizer	Small	Large	Total	Small	Large	Total
Differential Temperature	0.093	0.087	0.089	816	765	775
Single Temperature	0.137	0.106	0.125	1,199	929	1,092
Fixed	0.041	**0.142**	0.062	358	**1,244**	545
None	0.089	0.136	0.116	782	1,191	1,013
Don't Know	0.097	0.115	0.110	851	1,006	964

Mean Annual Load Percent Standard Error / Mean

Economizer	Small Standard Error [Standard Dev / n^.5]	Large Standard Error [Standard Dev / n^.5]
Differential Temperature	19%	31%
Single Temperature	7%	18%
Fixed	22%	
None	8%	5%
Don't Know	7%	9%

KEMA

The detailed definition of the ISO-NE On-Peak, PJM On-Peak, and ISO-NE FCM seasonal coincident peak factor are described in Section 2.3.1.1. A coincidence factor of one would indicate all units ran at full load for the entire hour for all hours included in the peak definitions. The following table presents coincidence factor estimates and indication of sample sizes less than 10 for all peak definitions and economizer types. The table is followed by analysis results of the standard error for each estimate which further supports or advises caution of the use of these un-weighted sample averages.

Table 3-12: Coincidence Factor Estimate by Economizer Type with Standard Error

Sample n > 10 **Sample n < 10**

		Coincidence Factor		
	Economizer	**Small**	**Large**	**Total**
ISO-NE On-Peak (1-5PM WDNH, Jun-Aug)	**Differential Temperature**	0.357	0.310	0.320
	Single Temperature	0.429	0.409	0.421
	Fixed	0.151	**0.447**	0.214
	None	0.306	0.423	0.367
	Don't Know	0.322	0.398	0.377
	Total	0.338	0.396	0.373
PJM On-Peak (2-6PM, WDNH, Jun-Aug)	**Differential Temperature**	0.355	0.309	0.319
	Single Temperature	0.439	0.410	0.428
	Fixed	0.140	**0.445**	0.204
	None	0.307	0.434	0.373
	Don't Know	0.319	0.399	0.377
	Total	0.340	0.400	0.376
ISO-NE FCM Seasonal Peak	**Differential Temperature**	0.401	0.196	0.238
	Single Temperature	0.213	0.161	0.193
	Fixed	0.204	**0.661**	0.300
	None	0.062	0.264	0.167
	Don't Know	0.212	0.270	0.255
	Total	0.152	0.248	0.209

ISO-NE On-Peak Percent Standard Error / Mean

Economizer	**Small Standard Error [Standard Dev / n^.5]**	**Large Standard Error [Standard Dev / n^.5]**
Differential Temperature	19%	32%
Single Temperature	7%	18%
Fixed	22%	
None	15%	5%
Don't Know	1%	9%

4 Description of HVAC Load Shape Tool and Final Data Set

The following information is also described on the ReadMe worksheet of the C&I Unitary HVAC Load Shape Tool.

4.1 *Overview of HVAC Load Shape Tool*

The C&I Unitary HVAC Load Shape Tool (LST) was designed to calculate the peak and annual energy savings from the installation of typical high efficiency unitary direct expansion (DX) systems installed at commercial and industrial sites based on a specified load reduction. The tool also outputs the energy load shapes in EEI (Edison Electric Institute) format. The following documents the inputs, outputs, and instructions for how to use the tool. The LST is intended to represent single air conditioning units or multiple units so long as the units are greater than 1 ton and less than 100 ton and are unitary DX systems

The above report describes the methodology and results of the study which provide the underlying data of the LST. The tool includes a summary of the total number of units and total connected load that were sampled from in the metering study are listed in primary input and output page. Metered data and actual weather data were used to develop a linear regression in SAS and models were then run using TMY3 typical weather data for the region. The LST includes active calculations of precision based on the underlying study results. There is a specific worksheet in the tool with the extrapolated load ratios (ratio of modeled kW / connected load kW) and precision (90% two tail) for each hour for each strata. The coincidence factor in the LST is equal to the average of the hourly load ratios for the defined period in the peak definition. The Load Shape Tool also allows user specification of time periods and/or temperature thresholds for user defined analyses.

4.2 *Instructions for obtaining and using HVAC Load Shape Tool*

The C&I Unitary HVAC Load Shape Tool can be obtained from NEEP through their website www.neep.org. The tool instructions are provided in this section to illustrate inputs and outputs of the tool.

4.3 *Step-By-Step Instructions*

1. Select a peak definition and region
    a) Appropriate hours and day types will be automatically included
    b) The listed holidays will be automatically excluded from coincidence factor (but not annual) analysis unless the user specifies

2. Specify the connected load reduction (CLR) in kW for the population or by size classification.
   a) Defaults for each region are shown below the CLR inputs
   b) If 0% is entered for small and large then defaults will be used
   c) Enter percentage of total CLR for small and large or enter 100% in correct size range and 0 in the other to represent one unit.

3. Choose a custom time frame to include in the analysis
   a) Check the months you would like to include in your analysis
   b) Check the days you would like to include in your analysis
   c) Check the hours of the day you would like to include in your analysis. (i.e.- for hours 10 AM – 11 AM, check 11 AM)
   d) Check the Holidays to include in the analysis. If not checked, energy savings, if any for these holidays, will not show up in the results.
   e) Enter high and low outdoor temperatures and those not meeting the criteria will be excluded in the results.
   f) Enter high and low THI and those not meeting the criteria will be excluded in the results.

4. The results sections in orange color will provide you with the annual 8760 kWh savings, the selected period kWh savings, the selected period demand savings averaged over the specified hours, and the demand savings per the peak definition. It also has the selected period kWh savings as a percent of the 8760 savings, the number of hours included in the period of interest and the precision at 80% and 90% confidence. These values are also broken out into unit sizes.

5. Switch over to the labeled tab to view the load shape in EEI format.

4.4 *Overview of Data Set Available to Sponsors*

The load shape tool and report provide the study methodology and primary results. The study produced a large amount of data to arrive at the final results that were not presented in either format. The sponsors were provided a data set including all metered data, site observations, weather data, and unit level analysis result. The data were formatted and analyzed in SAS and thus the data set is best replicated in the available SAS format. The data was also provided in a comma-delimited format to allow for review in any analysis format.

5 Appendix

5.1 *C&I Unitary HVAC Data Request Submitted to Forum Members*

The following information was requested for each applicable Forum member program:

a) ***Tracking savings estimates on a per unit/site basis –***
   - *For any program, we request that gross tracking savings (kWh and coincident kW) be provided individually for each HVAC unit in the population. In the event that unit level tracking data was unavailable, project level savings information should be provided at a minimum. For programs with savings specified at the project level, the scope of project designation should be clearly indicated (i.e., whether an individual building, multiple buildings, or a specific customer constitutes one project).*
   - *Documentation indicating computational inputs and procedures used to calculate savings for each measure should be provided. If deemed savings were used to calculate savings, KEMA requires the appropriate work papers indicating the theoretical basis of the deemed values. This information was used to evaluate the consistency of measure savings calculations across different Forum members' programs. It will therefore indicate if sample stratification by claimed measure savings was a reasonable option.*

b) ***Detailed equipment characteristics for each HVAC unit in the population –***
   - *All tracked equipment characteristics should be provided. For the purposes of this study, equipment type (heat pump or AC, split or packaged), nameplate capacity, nameplate efficiency, and economizer type are of the greatest importance. All other available parameters should however be furnished when possible.*
   - *If the tracking data does not include specific equipment information and uses unit size ranges instead of exact unit sizes, those data should conform to the ASHRAE 90.1 (2007) size class designations.*
   -
   -
   - *Exhibit 5-1 below provides a list of the ASHRAE size bins for unitary and split air cooled HVAC systems.*

Exhibit 5-1: ASHRAE 90.1 Unitary HVAC Size Bins

Air Cooled Unitary AC and Split Systems	***Air Cooled Heat Pumps***
<65,000 Btu/h (5.4 tons)	*<65,000 Btu/h (5.4 tons)*
≥65,000 Btu/h (5.4 tons) and <135,000 Btu/h (11.25 tons)	*≥65,000 Btu/h (5.4 tons) and <135,000 Btu/h (11.25 tons)*
≥135,000 Btu/h (11.25 tons) and <240,000 Btu/h (20 tons)	*≥135,000 Btu/h (11.25 tons) and <240,000 Btu/h (20 tons)*
≥240,000 Btu/h (20 tons) and <760,000 Btu/h (63 tons)	*≥240,000 Btu/h (20 tons)*
≥760,000 Btu/h (63 tons)	

c) ***Site Characteristics –*** *Site specific data should include:*
   - *Business type (e.g. grocery, retail, small business, etc.)*
   - *Building type (e.g. high bay warehouse, hospital, small office building, etc.)*
   - *NAICS or SIC codes*
   - *Number of affected high efficiency HVAC units at the facility*
   - *Site address (City, State, ZIP Code for all sites)*

d) ***Load Zone / Climate –*** *Although provided site addresses will implicitly indicate the appropriate climate data, other information such as ISO specific load zones may provide an efficient means of stratification. Therefore, unit level ISO load zone data are requested, as well as any other data specifically demarcating climate based boundaries.*

e) ***Dated Records –*** *The date of measure installation and/or service should be provided for all affected units in all programs.*

f) ***Program Participant Contact Information –*** *Contact information should be provided for all program participants. Contact information should include appropriate contact names, phone numbers, and email addresses.*

5.2 *Statistical Model References*

MBSS and conventional methodologies are currently taught in the Association of Edison Illuminating Companies' *Advanced Methods in Load Research* seminar. MBSS methodology is also documented in *The California Evaluation Framework*.[17] MBSS has been used in countless load research and program evaluation studies. It has also been examined in public utility hearings and in at least two EPRI studies.

5.3 Analysis Definitions Supporting Tables

"Typical" System Loads

The study had to determine a typical value for system load and typical value for 90% of the 50/50 forecasted load to be used for identifying FCM peak hours in typical year weather data (TMY3). There was only one hour for the summer of 2009 and 161 hours in summer 2010 at which the ISO-NE system load met 90% of the CELT forecast peak, evaluators looked at the trend of forecast and actual system peak for past years to develop a standard load cutpoint that could be applied to specific TMY3 weather files. The effort to identify long term average FCM peak hours also had to be developed knowing they would be based on 2010 weather to load data relationships. The Table 5-1 below shows the actual load variation in the six period was roughly double that of the forecast. The actual system peak is more variable than the forecast and for given years the forecast has been exceeded such as 2005, 2006, and 2010, but on average the forecast was a statistically-insignificant 1.3% greater than actual. It was important to understand the variability in the number of FCM seasonal peak hours from year to year which are based on actual and forecast load in order to define weather conditions that represent seasonal peak hours.

Table 5-1: Mean /Standard Deviation of ISO-NE Actual Peak and 50/50 Forecast

2005-2010 Actual Peak	Std. Deviation	StDev/ Mean	Actual/ Forecast
26,841	1,348	0.050	0.987
2005-2010 Average 50/50 Forecast	**Std. Deviation**	**StDev/ Mean**	**Actual/ Forecast**
27,191	660	0.024	

[17] The report can be downloaded from the web at http://www.calmac.org/calmac-filings.asp

The figure below shows the actual load (diamond points, bold) and the 50/50 forecast (square points) as the top lines and 90% of each year for the past 6 years (circles, bold). The figure shows straight lines for 90% of the 6 year forecast average and 90% of the actual average which were the potential cutpoint and a reference point. The past two years (2009, 2010) well illustrate the challenge that in some years there will be few FCM peak hours where actual load is close to 90% of 50/50 forecast which will correspond to the maximum weather conditions of that particular year like 2009. However, in 2010 a range of weather conditions were covered due to the large difference between actual load and 90% of forecast.

Figure 5-1: Historical FCM Peak Data and Forecast

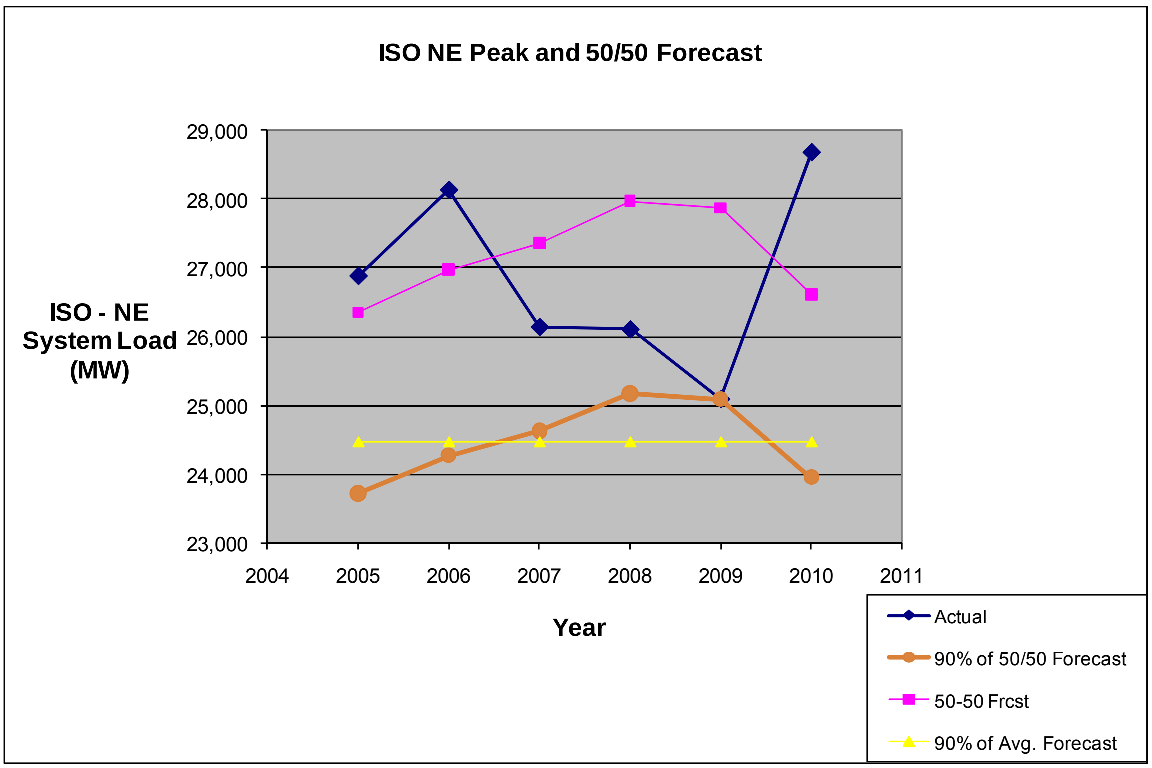


Table 5-2: ISO-NE FCM Seasonal Peak Data and Analysis Summary

FCM Seasonal Peak Data from ISO-NE Archive

System Load Summer Peak				
		Actual	50-50 Frcst	90% of
Year	Date	Peak (MW)	Peak (MW)	50-50 Frcst
2005	July 27, 2005	26,885	26,355	23,720
2006	August 2, 2006	28,130	26,970	24,273
2007	August 3, 2007	26,145	27,360	24,624
2008	June 10, 2008	26,111	27,970	25,173
2009	August 18, 2010	25,100	27,875	25,088
2010	July 6, 2010	28,676	26,618	23,956

FCM Seasonal Peak Data Analysis

Peak Analysis				
Actual/	50-50 Frcst	90% of	Actual/	90%(Avg.)/
Frcst	Average	50-50 Avg.	50-50 Avg.	90%Frct
1.020	26,841	24,472	1.099	1.032
1.043	26,841	24,472	1.149	1.008
0.956	26,841	24,472	1.068	0.994
0.934	26,841	24,472	1.067	0.972
0.900	26,841	24,472	1.026	0.975
1.077	26,841	24,472	1.172	1.022

5.4 *Data Collection Form*

ONSITE VERIFICATION FORM - C&I Upstream AC Temp/Power Metering

Site ID:		Unit ID:		Primary Contact:	
Address 1:				Phone 1:	
Address 2:				Phone 2:	
City:	State:	Zip:		Phone 3:	
Account Number:		Install Date:	/ /	Email:	
Application ID:		Quantity to Meter:		Total Quantity rebated:	
Annual Savings:				Secondary Contact:	

SITE NOTES:

Building Type:		Industry Type:			
Corrected Bld Type:		Corrected Ind. Type:			
Inspector Initials:	Site Visit Date:	/ /	Site Visit Time:		
	Inspection Date:	/ /	Inspection Time:	Start:	End:

Scheduling Notes:

Holidays Observed

Holiday	New Year's Day	MLK Day	President's Day	Easter	Memorial Day	July 4th	Labor Day	Columbus Day	Veteran's Day	Thanksgiving	Christmas
# Days											

Building Hours of Operation

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Open							
Close							

HVAC INFO							
UNIT #		**ZONE**					

HVAC UNIT							
REFRIGERANT	☐ TXV	☐ NON-TXV	☐ R-22	☐ R-410a			
DUCT LOCATION	Roof ☐	Plenum ☐	In Zone ☐	Other ☐			
HVAC DISPOSITION	EARLY REPLACEMENT ☐		REPLACED ON BURNOUT ☐		? choose one		
MANUFACTURER							
MODEL #				SERIAL #			
ELECTRIC INFO	**QTY**	**RLA-VOLTS**	**FLA-VOLTS**	**HP**	**CFM**	**NOTES:**	
COMPRESSOR 1							
COMPRESSOR 2							
COMPRESSOR 3							
CONDENSER FAN 1							
CONDENSER FAN 2							
SUPPLY FAN 1							
SUPPLY FAN 2							
RETURN FAN 1							
RETURN FAN 2							
EXHAUST FAN 1							
EXHAUST FAN 2							
SUPPLY VOLTAGE							
COOLING CAPACITY		FACTORY CHARGE		YR MANF	Rated Efficiency		SEER/EER (circle one)

ECONOMIZER DATA							
ECONOMIZER TYPE	SINGLE POINT TEMP ☐	SINGLE POINT ENTHALPY ☐	DIFFERENTIAL TEMP ☐	DIFFERENTIAL ENTHALPY ☐	FIXED ☐	OA FRACTION	
Appears Functional			Y N	Describe:			

Spot Power Measurements				
Unit in Cooling Mode (wet coils)				
	Comp1	**Comp2**	**Comp3**	**Comp4**
Volts1 Ph-Gnd **V1**				
Volts2 Ph-Gnd **V2**				
Volts3 Ph-Gnd **V3**				
Amps1 **A1**				
Amps2 **A2**				
Amps3 **A3**				
Power 1 **W1**				
Power 2 **W2**				
Power 3 **W3**				
Power Factor1 **PF1**				
Power Factor2 **PF2**				
Power Factor3 **PF3**				

logger number	
Wattnode serial	
CT size	

Installation Notes:

CONTROLS ON UNIT							
UNIT #		**ZONE**					
Check box if below schedule is controlled manually				☐			
Cooling							
CONTROL TYPE		SETPOINT TEMP 1		TEMP 2		TEMP 3	
COOLING SETTINGS	SUN	MON	TUE	WED	THU	FRI	SAT
TIME SET TO TEMP1							
TIME SET TO TEMP2							
TIME SET TO TEMP3							
TIME OFF							

CONTROLS ON UNIT							
UNIT #		**ZONE**					
Check box if below schedule is controlled manually				☐			
Cooling							
CONTROL TYPE		SETPOINT TEMP 1		TEMP 2		TEMP 3	
COOLING SETTINGS	SUN	MON	TUE	WED	THU	FRI	SAT
TIME SET TO TEMP1							
TIME SET TO TEMP2							
TIME SET TO TEMP3							
TIME OFF							

CONTROLS ON UNIT							
UNIT #		**ZONE**					
Check box if below schedule is controlled manually				☐			
Cooling							
CONTROL TYPE		SETPOINT TEMP 1		TEMP 2		TEMP 3	
COOLING SETTINGS	SUN	MON	TUE	WED	THU	FRI	SAT
TIME SET TO TEMP1							
TIME SET TO TEMP2							
TIME SET TO TEMP3							
TIME OFF							