Final Draft

New Hampshire HVAC Load and Savings Research

March 29, 2013

Prepared for:
New Hampshire Public Utilities Commission and the New Hampshire Monitoring and Evaluation Team

NHPUC Liberty Utilities New Hampshire Electric Co-op Public Service of New Hampshire Unitil

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EXECUTIVE SUMMARY

In its *Order on Home Performance with ENERGY STAR® Program* (Order No. 25,402) issued on August 23, 2012, the New Hampshire Public Utilities Commission (NHPUC) approved the implementation of Home Performance with ENERGY STAR® (HPwES) as a fuel-neutral program in the New Hampshire utilities' 2013-2014 CORE program offerings, conditional on the execution and findings of additional program research. The order contained directives to the New Hampshire utilities—Public Service New Hampshire, the New Hampshire Electric Cooperative, Liberty Utilities, and Unitil Energy Systems—to conduct research related to electric cooling loads and cooling equipment, additional opportunities for energy-efficiency, and the comprehensive electric impacts of the HPwES program.

The New Hampshire monitoring and evaluation (M&E) team commissioned Cadmus to review available secondary data to respond to these three directives:

1. Study the drivers of the increasing air conditioning load in both the residential and commercial and industrial (C&I) customer sectors and to begin to develop cost-effective energy-efficiency programs to reduce this load;
2. Develop additional measures and programs to reduce air conditioning electric loads; and
3. Develop estimates of the ancillary electricity savings associated with various non-electric measures used in the HPwES Program.

Over a six-week period in February and March 2013, Cadmus collected and reviewed the New Hampshire energy-efficiency programs, historical electric load data, data from previous New Hampshire research studies and evaluations, data from surveys conducted for utility customers and New Hampshire residents, and additional data from Cadmus' work in other regions to respond to each of these three directives. We conducted the research in three tasks, each corresponding to one of the study directives. This report describes the objective, research methods and data employed, and key results for each task.

Task 1. Air Conditioning Load and Market

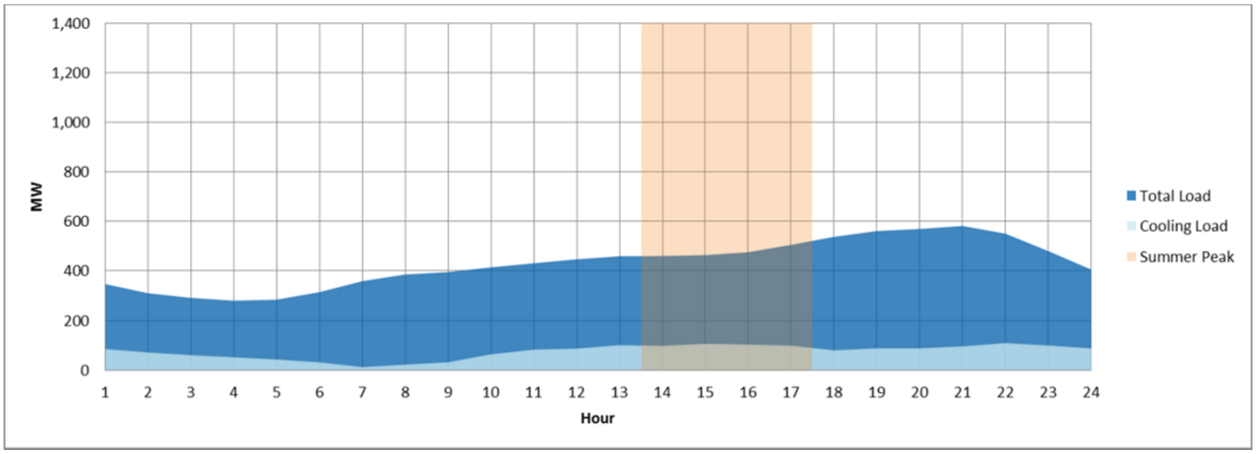
The first task involved analyzing the air conditioning load and market to identify the principle factors that account for the current market trend of increasing air conditioning load in the residential and C&I sectors.

Cadmus reviewed historical electric load data for the New Hampshire load zone and each utility customer class, customer survey data collected by the utilities and for a 2009 New Hampshire energy-efficiency potential study, and other secondary data to estimate typical cooling load profiles by sectors and assess the market saturation in each sector of cooling equipment.

Residential Sector

Figure E-1 shows the estimated cooling and total electric load profiles for the New Hampshire residential sector for an average summer weekday. The profile shows that the residential sector peak load occurs after the summer on-peak period and is driven by non-cooling loads, which remain relatively constant between noon and midnight.

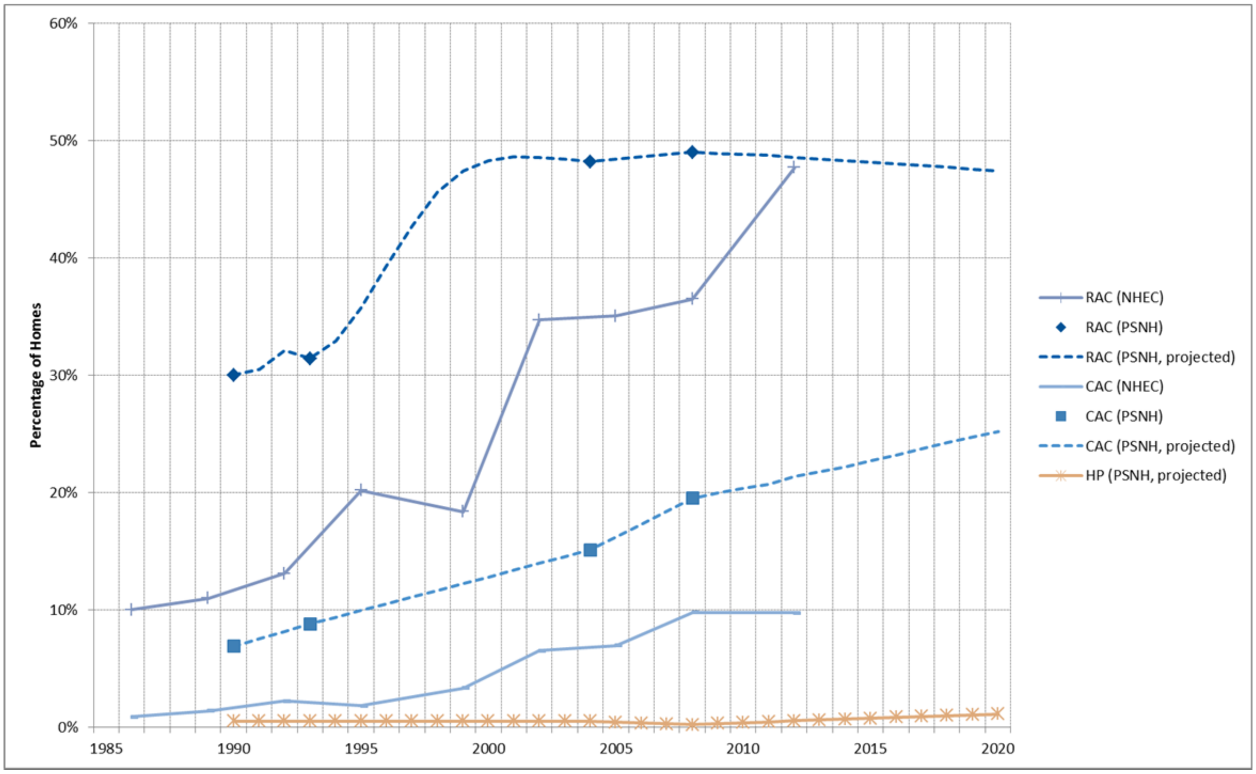
Figure E-1. Estimated Residential Total and Cooling Load Profile for Summer Weekday



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

Figure E-2 shows the trends in cooling equipment type for NHEC and PSNH customers based on survey data and projections from 1986 and through 2020. The data show increasing saturations of room air conditioner (RAC) and central air conditioner (CAC) systems for both companies and a very modest projection for heat pump cooling equipment saturation.

Figure E-2. Cooling Equipment in Residential Sector (PSNH and NHEC)



Source: NHEC and PSNH residential customer survey data

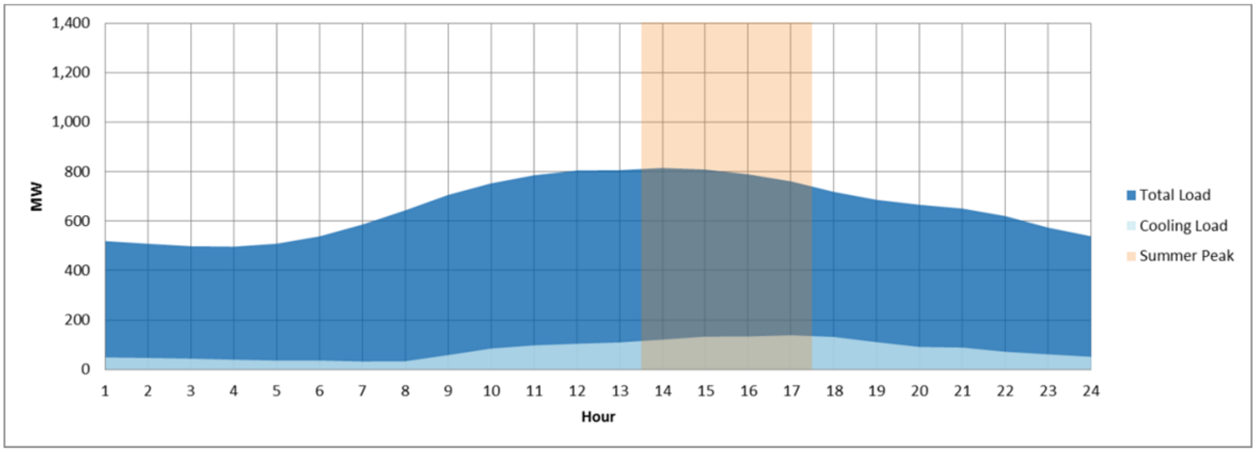
Cadmus' analysis of the system and sector electrical load and customer survey data revealed the following for the residential sector:

- Residential sector electric demand during summer weekdays peaks after the ISO-NE forward capacity market (FCM) on-peak period. The highest loads in the residential sector occur between 6:00 p.m. and 10:00 p.m. This peak late in the day is driven by non-weather related loads, including lighting and appliances.
- During the ISO-NE summer on-peak hours, the weather related (cooling) component of the summer residential load is 21% of the total summer residential load.
- The percentage of homes with either RAC or CAC cooling systems is increasing. In 2000, only 30% of NHEC homes and less than 60% of PSNH homes used RAC or CAC cooling. Only eight years later, in 2008, more than 45% of NHEC homes and 70% of PSNH homes had either RAC or CAC systems.
- Within New Hampshire homes that use RAC units for cooling, the number of RAC units is increasing. Survey data from NHEC showed increasing quantities of RAC units in homes cooled by RACs.

C&I Sector

Figure E-3 shows the estimated cooling and total electric load profiles for the New Hampshire C&I sector for an average summer weekday. The profile shows that the C&I sector peak coincides with the summer on-peak period and is influenced by cooling loads, which are highest during the summer on-peak hours.

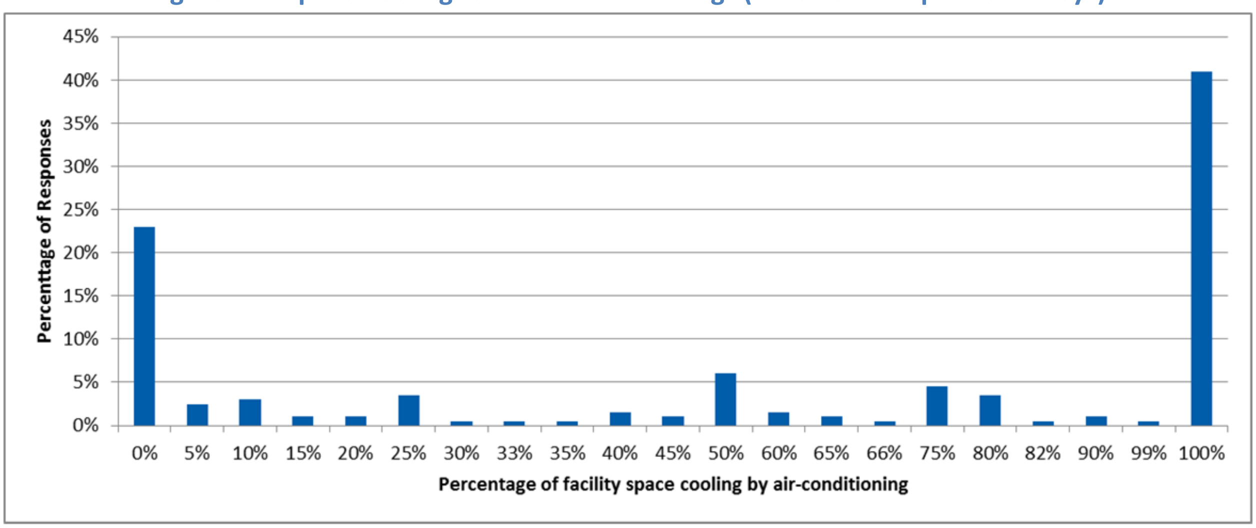
Figure E-3. Estimated C&I Total and Cooling Load Profile for Summer Weekday



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

Figure E-4 shows unweighted percentages of space cooling for commercial buildings indicated by 196 small commercial customers surveyed in the 2009 New Hampshire energy-efficiency potential study. The data show that over 20% of commercial facilities do not use any air-conditioning equipment and less than half cool the entire building.

Figure E-4. Space Cooling for Small C&I Buildings (based on 200 phone surveys)



Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

Cadmus' analysis of the system and sector electrical load and customer survey data revealed the following for the C&I sector:

- C&I sector electric demand during summer weekdays is coincident with the ISO-FCM on-peak period. The highest loads in the C&I sector occur between 11:00 a.m. and 3:00 p.m. This early peak in the summer is driven by building cooling loads.
- During the ISO-NE summer on-peak hours, the weather related (cooling) component of the summer C&I sector load is 17% of the total summer C&I sector load.
- The percentage of facilities with mechanical cooling systems is stable at 75% (based on PSNH survey data and EIA projections) and not expected to increase in the near future. It is expected that the C&I cooling market is saturated (i.e., those facilities without cooling equipment do not require cooling).
- A sizeable percentage of both small and large commercial facilities lack programmable controls system for their HVAC equipment. Based on surveys conducted for the 2009 NH potential study, less than 11% of small commercial buildings have programmable thermostats and less than 40% of large commercial buildings use a central HVAC control system.

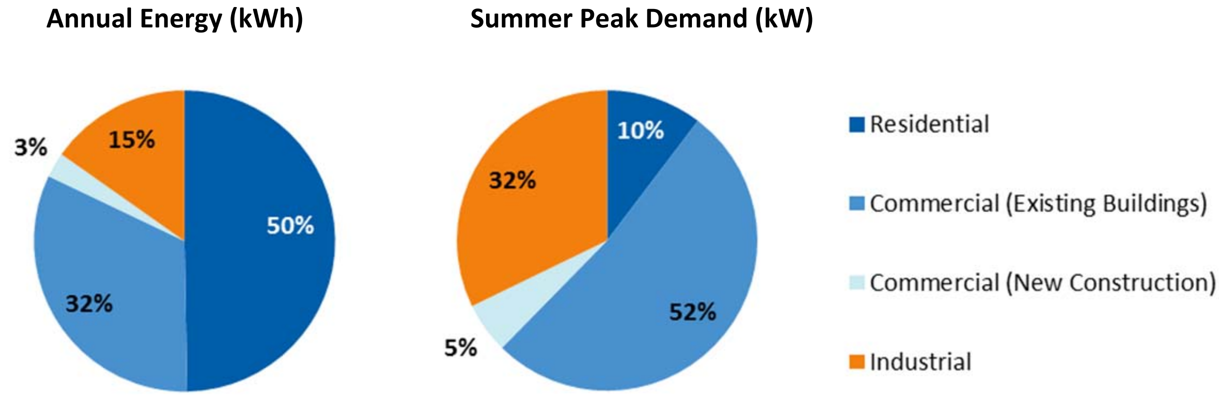
Task 2. Program Enhancements

The second task involved the development of recommendations to modify or expand the portfolio of existing core programs for the residential and C&I customer sectors to promote the installation of cost-effective measures to reduce air conditioning peak demand and energy consumption.

Cadmus reviewed the current portfolio of core energy-efficiency programs offered by the New Hampshire utilities, customer survey data collected by the utilities and for a 2009 New Hampshire energy-efficiency potential study, and other secondary data including program offerings in other regions. Using these secondary sources along with Cadmus' experience through data collection and evaluations, we developed recommendations to enhance the New Hampshire programs' effectiveness in reducing overall energy consumption and summer peak demand.

Figure 5 shows the summary of annual energy and summer peak demand reduction potential by sector as determined in the 2009 potential study.

Figure E-5. Electric Energy and Summer Peak Demand Reduction Potential by Sector



Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

The data show:

- The residential sector represents 50% of the potential electric energy savings but only 10% of the summer peak demand savings.
- The industrial market has only 15% of the energy reduction potential, but almost one third of the summer peak demand potential.
- There is large opportunity for both energy and demand reductions among existing commercial buildings.
- Commercial new construction has the lowest opportunity for both energy and demand reduction compared to the other markets.

Residential Sector

The highest opportunity to reduce electric energy consumption in the residential sector is for lighting, appliances, and standby power; however residential lighting and appliances typically have low summer peak coincidence factors and do not contribute to summer peak demand reduction.[1] Still, there is opportunity to reduce both residential cooling loads and summer peak demand reduction. Cadmus recommends the NH programs consider the following actions to enhance annual energy and peak demand reduction in the residential sector:

- Cooling Measures
  - Encourage the installation of ductless heat pump air-conditioners in place of central or window air-conditioners, ideally also replacing electric heating.

[1] The NH potential study did not take into account changes in lighting baseline standard due to the Energy Information and Security Act of 2007 (EISA 2007), so the potential for lighting energy savings are overstated and the percentages of total potential for non-lighting end-uses are understated.

- Ensure the programs capture opportunities to install the highest efficiency equipment for residential new construction and planned equipment replacement opportunities.
    - Encourage the early replacement of existing inefficient air-conditioners.
    - Encourage the installation of web-enabled programmable thermostat with central controls for demand response actions during summer peak periods.
- Non-Cooling Measures
    - Encourage the implementation of advanced power strips and computer management measures to reduce standby loads.
    - Provide incentives for heat pump water heaters to replace existing or new electric water heaters.
    - Provide additional education on the use of clothes washers to reduce energy costs.
    - Encourage the installation of low-flow showerheads and aerators for homes with electric hot water heating.

C&I Sector

Within the C&I sector, the highest opportunity to reduce energy consumption is in existing commercial and industrial facilities. The highest opportunity to reduce electric energy consumption is through upgrades to the equipment and controls in these end-uses: lighting, refrigeration, HVAC, and industrial machine drives. Since equipment in the C&I sector typically operates through the summer peak hours, the peak demand potential is comparable to the energy reduction potential.

Cadmus recommends the NH programs consider the following actions to enhance annual energy and peak demand reduction in the C&I sector:

- Cooling Measures
    - Promote building retro-commissioning to assess and upgrade HVAC control systems.
    - Promote installation of variable speed drives for data center CRAC and air handler fans.
    - Consider utilizing a remote interval data analysis tool to identify customers with the highest cooling loads and assess energy-efficiency opportunities.
- Non-Cooling Measures
    - Develop a targeted prescriptive refrigeration program for small and large C&I facilities.
    - Continue to support lighting system and control upgrades.
    - Encourage the implementation of advanced power strips and computer management measures to reduce standby loads.
    - Consider a targeted program for emergency generator block heaters.

Task 3. Ancillary Electric Savings

The third task involved the development of quantitative estimates of the electric energy and peak demand impacts associated with weatherizing homes in the HPwES program and resulting from the replacement of HVAC and DHW systems promoted by the ENERGY STAR Appliance Program.

Cadmus used secondary data to develop estimates of the electric energy and demand impacts of HPwES weatherization measures as well as the following residential HVAC measures: high-efficiency furnace with ECM, heat pump water heater, and early-replacement CAC.

Table E-1 shows the estimated energy and demand impacts of weatherization measures on auxiliary electric heating system equipment and for typical cooling system equipment.

Table E-1. Electric Impacts from Weatherization

Equipment Impact	Description of Impact	Annual kWh	Summer On-Peak kW	Winter On-Peak kW
Furnace fan	Reduced fan operation based on heating load reduction from weatherization measures	86	0	TBD
HW boiler circulation pump(s)	Reduced boiler pump operation based on heating load reduction from weatherization measures	9	0	TBD
Steam boiler	n/a	0	0	0
Average Heating System	*Average heating season electric impact of weatherization measures for non-electric heating system*	*55*	*0*	TBD
CAC	Reduced CAC cooling energy based on cooling load reduction from weatherization measures	77	TBD	0
RAC (per unit)	Reduced per unit RAC cooling energy based on cooling load reduction from weatherization measures	23	TBD	0
RAC (per home)	Reduced household RAC cooling energy based on cooling load reduction from weatherization measures and average units per RAC-cooled home	50	TBD	0
Average Cooling System	*Electric impact of weatherization measures for average residential cooling energy*	*34*	TBD	*0*

Table E-2 shows the estimated energy and demand impacts of other HVAC and DHW equipment offered through the NH Appliances program.

Table E-2. Electric Impacts from HVAC and DHW Equipment

Measure	Description of Impact	Annual kWh	Summer On-Peak kW	Winter On-Peak kW
Furnace with ECM	Reduced electricity requirements for fan ECM compared to existing fan motor	733[2]	0	TBD
HPWH	Reduced electricity requirement for hot water consumption compared to standard electric heater	961[3]	0.184	0.268
Early Replacement of CAC	Reduced electricity requirement for CAC cooling compared to existing inefficient CAC system	457	TBD	0

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2 PA Consulting Group. "*ECM Furnace Impact Assessment Report*." January 2009.

3 Cadmus. "*United Illuminating Heat Pump Water Heater Pilot: Impact and Customer Acceptance Study*." June 2010.

INTRODUCTION AND BACKGROUND

The New Hampshire Public Utilities Commission (NHPUC) and the New Hampshire utilities—Public Service New Hampshire, the New Hampshire Electric Cooperative, Liberty Utilities, and Unitil Energy Systems—offer to their customers a suite of energy-efficiency programs to encourage energy-efficiency best practices in the new construction, major renovation, equipment replacement, and retrofit markets to reduce overall energy consumption and electric demand during peak periods. Among these programs is the Home Performance with ENERGY STAR® (HPwES) program, which aims to improve efficiency in the residential sector through comprehensive home energy audits and implementation of efficiency measures that include weatherization and upgrades to heating, cooling, and hot water systems.

In its *Order on Home Performance with ENERGY STAR® Program* (Order No. 25,402) issued on August 23, 2012, the New Hampshire Public Utilities Commission (NHPUC) approved the implementation of HPwES as a fuel-neutral program in the New Hampshire utilities' 2013-2014 CORE program offerings, while also seeking additional program research.

In the Order, the NHPUC directed its staff and the utilities to conduct research to identify the drivers of air conditioning load, identify additional opportunities to enhance the energy-efficiency programs to target summer peak demand reductions, and quantify the electric energy and demand impacts of non-electric measures implemented through the HPwES Program.

The directives stated in the Order include:

1. Study the drivers of the increasing air conditioning load in both the residential and commercial and industrial (C&I) customer sectors and to begin to develop cost-effective energy-efficiency programs to reduce this load. Included window unit air conditioners and their installation in this analysis, as well as central air conditioning systems;
2. Develop additional measures and programs to reduce air conditioning electric loads; and
3. Develop estimates of the ancillary electricity savings associated with various non-electric measures used in the HPwES Program.

Cadmus conducted this study via three tasks, each of which corresponds to the NHPUC directives stated above.

Task 1. Characterize Air Conditioning Load and Market

The first task involved analyzing the air conditioning load and market to identify the principle factors that account for the current market trend of increasing air conditioning load in the residential and C&I sectors.

The key results of this task are:

- An assessment of the current market saturation and penetration of air conditioning equipment, disaggregated by equipment type (central air conditioning, room air conditioning, heat pumps), and
- An analysis of the relative contribution of each equipment category to summer peak energy and demand, as defined by ISO New England (ISO-NE) for the purpose of qualifying passive demand resources.[4]

Task 2. Develop Program Enhancements

The second task involved reviewing the current portfolio of CORE New Hampshire energy-efficiency programs for the residential and C&I customer sectors, and developing recommendations to enhance the programs' electric energy and peak demand impacts through the inclusion of new measures or new program elements that will cost-effectively reduce electric air conditioning load.

The key result of this task is:

- Detailed recommendations to modify or expand the portfolio of existing NH CORE programs for the residential and C&I customer sectors to promote the installation of cost-effective measures to reduce air conditioning peak demand and energy consumption.

Task 3. Develop Ancillary Electric Savings

The third task involved developing estimates of electric energy and peak demand savings resulting from weatherization measures and efficient HVAC and domestic hot water (DHW) system replacements being implemented in the HPwES Program.

The key results of this task are:

- Quantitative estimates of the electric energy and peak demand impacts associated with weatherizing homes in the HPwES Programs, and
- Quantitative estimates of the electric energy and peak demand impacts resulting from the replacement of HVAC and DHW systems promoted by the ENERGY STAR Appliance Program.

For each task, we analyzed available secondary data—including historical electric load data available from ISO-NE, survey data for New Hampshire residents and utility customers, data collected for previous New Hampshire program evaluations, and data from Cadmus' studies—and discussed the results through multiple meetings with the New Hampshire monitoring and evaluation (M&E) team to develop the key results. This report describes the methods and findings for each task in this research.

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[4] Passive demand resources are non-dispatchable energy-efficiency measures that reduce load during summer on-peak or seasonal peak periods, as defined by ISO New England.

TASK 1. CHARACTERIZE ELECTRIC LOAD

This section describes the objective, methods, and key results from Task 1, including analysis of total electric and cooling load at the system and sector levels and assessment of the air conditioning market within each sector.

Objective

Order 25,402 states that: "*New Hampshire now reaches its peak electric usage in the summer; most of which is due to air conditioning load*" (page 24-25). The supposition is that the increasing electric load during the summer is driven by increasing air conditioning loads in the residential and C&I sectors. Under this task, the New Hampshire M&E team seeks to assess the components and key drivers of cooling load in each sector.

The key results of this task are:

- An assessment of the current market saturation and penetration of air conditioning equipment, disaggregated by equipment type (central air conditioning, room air conditioning, heat pumps), and
- An analysis of the relative contribution of each equipment category to summer peak energy and demand, as defined by ISO-NE for the purpose of qualifying passive demand resources.[5]

Method

To understand the components and key drivers of cooling load in each sector, Cadmus examined historical electric load profiles for the New Hampshire load zone and for each sector within New Hampshire. We also reviewed previous evaluation studies, market characterization studies, and surveys of New Hampshire customers to assess the air conditioning market in each sector.

System Load

Cadmus analyzed the electric load for the New Hampshire load zone, including the demand of all electric utilities, to examine load growth over time, understand the system load profile, and assess the cooling component of the total system load.

Historical System Peak Load

Figure 1 shows the historical summer and winter peak demand for the total ISO-NE system from 1980 through 2012, along with the historical summer and winter peak demand from the New Hampshire load zone from 2003 through 2012.[6]

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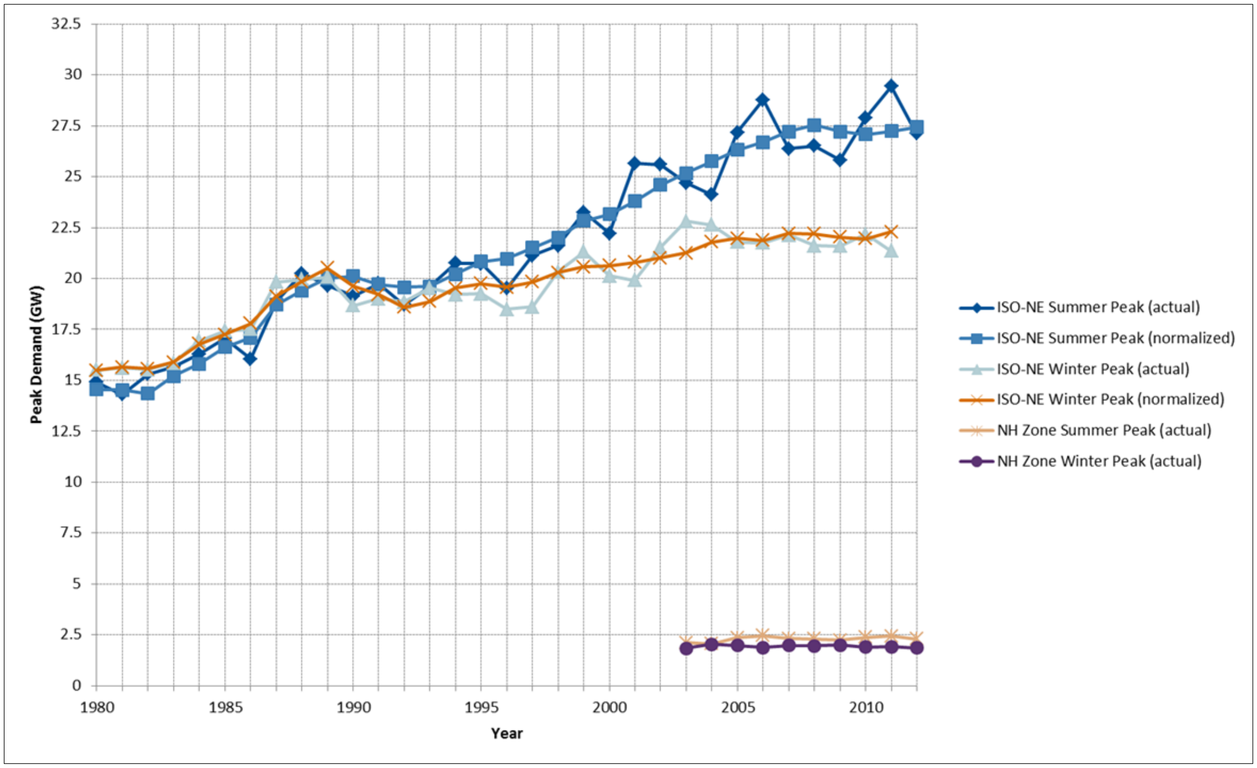
[5] Passive demand resources are non-dispatchable energy-efficiency measures that reduce load during summer on-peak or seasonal peak periods, as defined by ISO-NE.

[6] Data prior to 2003 were not available for the New Hampshire load zone.

Figure 1. Historical Seasonal Peaks for ISO New England and New Hampshire Load Zone



Source: ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

The data show growth in both the summer and winter peak demands in New England; however, the growth in peak demand for both seasons has slowed since 2008. The normalized summer peak load in 2005 was 14% higher than the peak five years prior in 2000; the normalized peak in 2008 was 9% higher than in 2003; and the peak in 2011 was only 2% higher than in 2006. The system winter peak shows a similar decline in load growth, with a relatively flat winter peak curve since 2007.

Data for the New Hampshire load zone show minimal growth in both the summer and winter peak demands since 2003. The growth in summer peak demand observed between 2000 and 2008 for the ISO-NE system is not evident in the New Hampshire load zone.

Historical System Peak Hour

Table 1 shows the peak hours for the ISO-NE total system and the New Hampshire load zone for 2004 through 2012.

Table 1. Historical Peak Hours for ISO New England and New Hampshire Load Zone

Year	ISO New England			New Hampshire Load Zone		
	Peak Date	Hour Ending	Peak Hour	Peak Date	Peak Hour	Offset from ISO-NH Peak Hour
2004	August 30	15	2 - 3 p.m.	August 30	3 - 4 p.m.	+ 1 hour
2005	July 27	15	2 - 3 p.m.	July 27	2 - 3 p.m.	same
2006	August 02	15	2 - 3 p.m.	August 02	1 - 2 p.m.	- 1 hour
2007	August 03	15	2 - 3 p.m.	August 03	2 - 3 p.m.	same
2008	June 10	17	4 - 5 p.m.	June 10	3 - 4 p.m.	- 1 hour
2009	August 18	15	2 - 3 p.m.	August 18	1 - 2 p.m.	- 1 hour
2010	July 06	15	2 - 3 p.m.	July 06	2 - 3 p.m.	same
2011	July 22	15	2 - 3 p.m.	July 22	1 - 2 p.m.	- 1 hour
2012	July 17	17	4 - 5 p.m.	July 17	5 - 6 p.m.	+ 1 hour

Source: ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

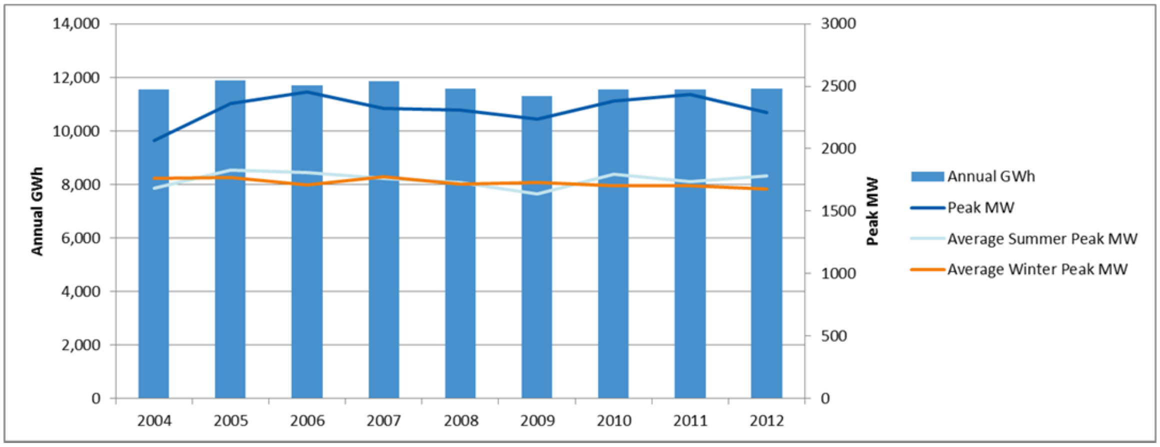
The ISO-NE system typically peaks in July or August between 2:00 p.m. and 5:00 p.m. These hours are within the ISO-NE summer on-peak window (1:00 – 5:00 p.m.) as defined for energy-efficiency resources in the Forward Capacity Market (FCM). The New Hampshire load zone follows a similar pattern and peaks on the same day as the total system, although not always during the same hour. Between 2004 and 2012, the New Hampshire load zone peaked during a summer weekday as early as 1:00 p.m. and at late as 6:00 p.m.

Historical Demand for New Hampshire Load Zone

A closer look at historical energy consumption and peak demand for the New Hampshire load zone shows relatively stable electric loads in the past decade. Figure 2 shows the historical electric consumption, peak demand, and the summer and winter on-peak demand for the New Hampshire load zone from 2004 through 2012.[7]

[7] The summer on-peak demand is calculated as the historical average demand during the period 1:00 – 5:00 p.m. on weekdays in June, July, and August. The winter on-peak demand is calculated as the historical average demand during the period 5:00 – 7:00 p.m. on weekdays in December, January, and February.

Figure 2. Historical Consumption and Peak Loads for New Hampshire Load Zone



Source: ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

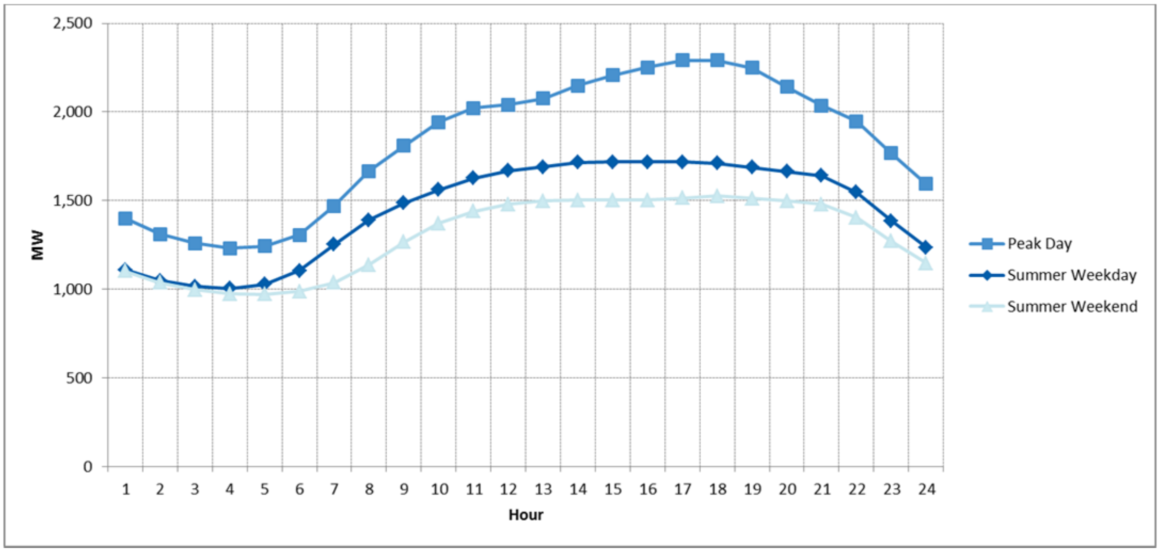
The New Hampshire annual energy consumption has remained under 12,000 GWh over the past decade, and the total energy consumption in 2012 is within 1% of the total consumption in 2004. Similarly, the peak demand does not show an increasing trend, and other than in 2004, the peak demand has remained within ±6% of the average peak demand from 2004 to 2012. The average demand during both the summer and winter peak hours shows no significant growth.

Summer and Winter Profiles for New Hampshire Load Zone

To investigate the hourly electrical load for the New Hampshire load zone, Cadmus analyzed the system load profiles for the average weekday, weekend, and peak day in the summer and winter seasons.

Figure 3 shows the load profile for an average summer weekday, weekend, and peak summer day for the New Hampshire load zone in 2012. The profile shows the summer peak occurring between 4:00 p.m. and 6:00 p.m. (hours 17 and 18). This maximum summer peak only partially coincides with the ISO-NE summer on-peak period (1:00 – 5:00 p.m. or hours 14 – 17).

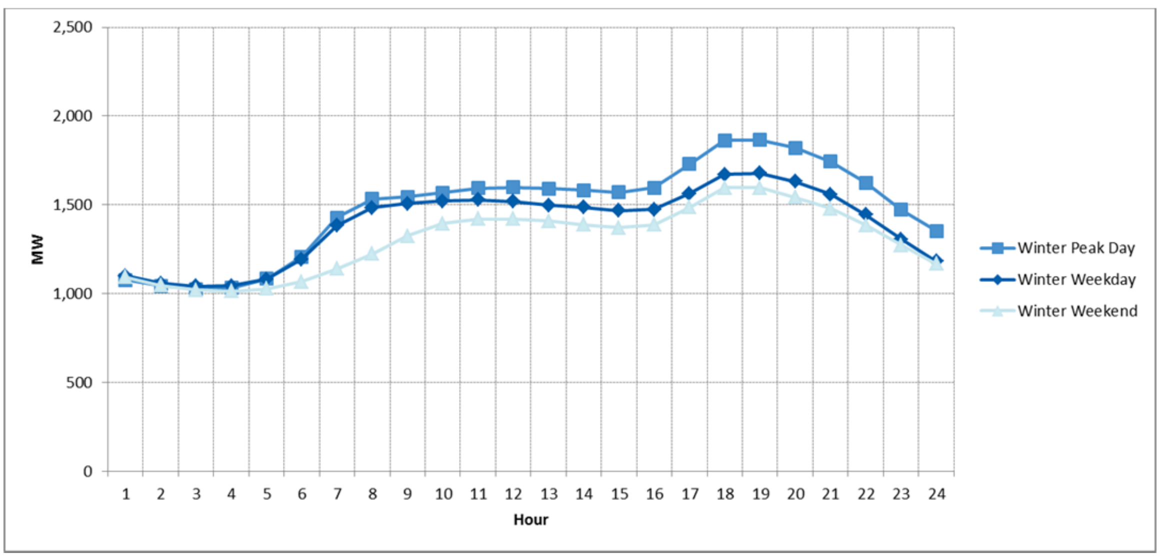
Figure 3. Summer Load Profile for New Hampshire Load Zone, 2012



Source: ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

Figure 4 shows the load profile for an average winter weekday, weekend, and peak winter day for the New Hampshire load zone in 2012. The profile shows the winter maximum peak occurring between 5:00 p.m. and 7:00 p.m. (hours 18 and 19). This maximum winter peak coincides with the ISO-NE winter on-peak period (5:00 – 7:00 p.m. or hours 18 and 19).

Figure 4. Winter Load Profile for New Hampshire Load Zone, 2012

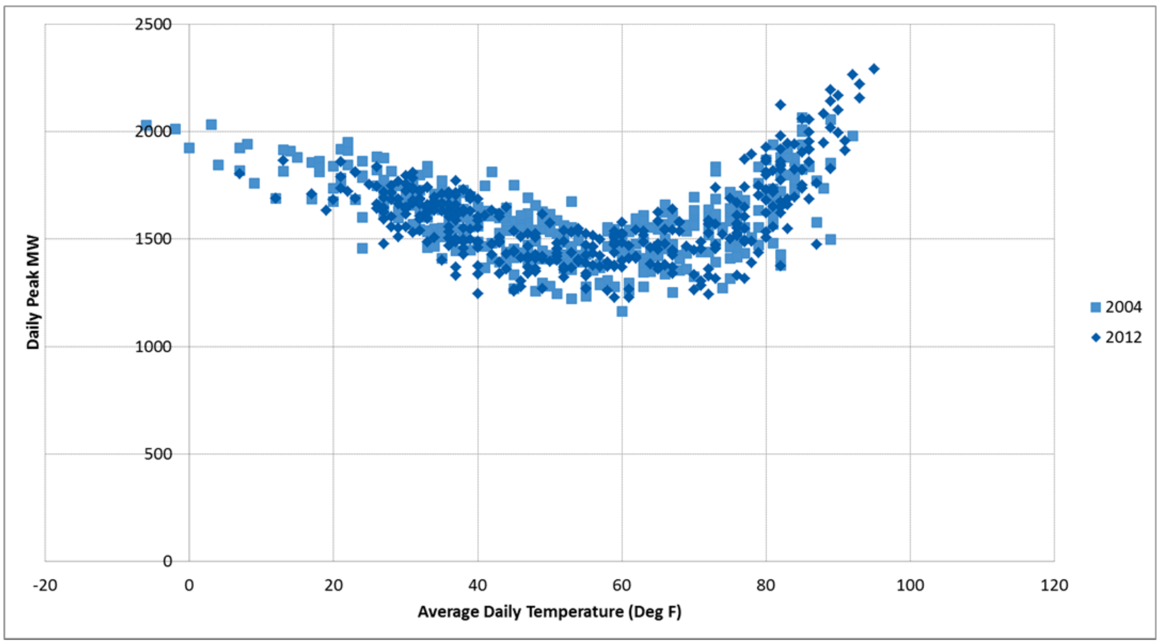


Source: ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

Load Versus Weather Analysis

To visualize the weather dependence of the New Hampshire load zone demand, Cadmus compared the daily peak and average daily temperatures.[8] Figure 5 shows the relationship between daily peak demand and daily average temperature for the New Hampshire load zone in 2004 and 2012. The figure shows the system load as highly dependent on both hot and cold weather data, indicating that electric energy consumption correlates with both cooling and heating.

Figure 5. Load Weather Response for New Hampshire Load Zone, 2012



Source: ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

To further analyze the weather response of the system load, Cadmus performed a regression analysis of hourly system demand and hourly temperature to separate the system demand into the following three components:

1. ***Base load:*** The system base load is the electric demand that does not respond to weather variations. In Figure 5, the base load is represented by the bottom of the curve, or the minimum observed system demand.
2. ***Weather-dependent cooling:*** The system weather-dependent cooling load is identified as the electric demand that responds to increasing warm temperatures. In Figure 5, the cooling load is represented by the increasing demand as the daily average temperature rises above 60 degrees Fahrenheit. Cooling energy that is not weather dependent (e.g., data center or other process cooling) is included in the base load.

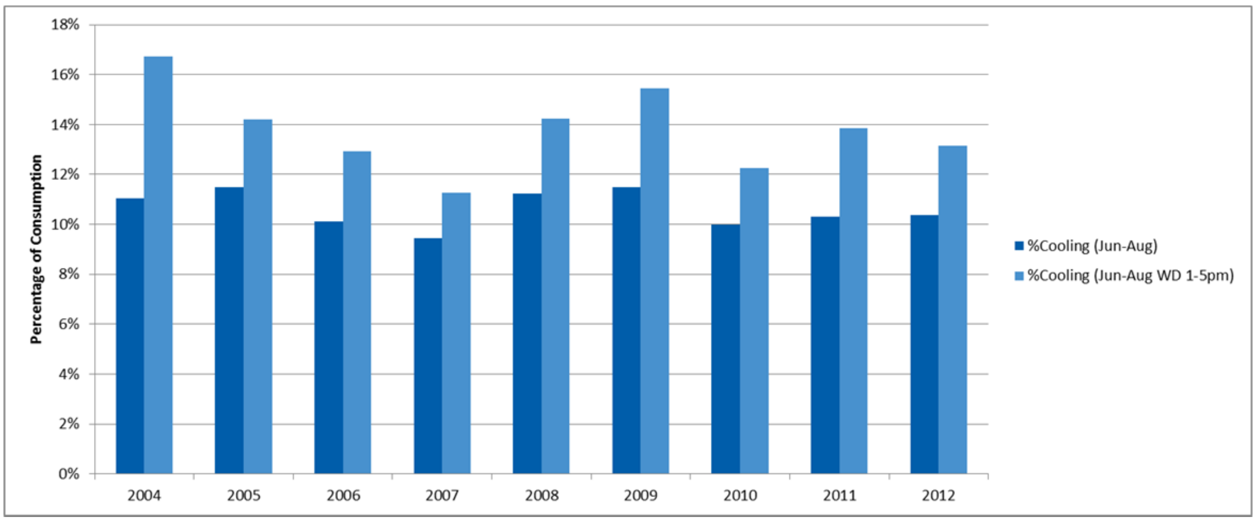
[8] We used weather data provided by ISO-NE with the historical hourly electric load data for the NH load zone. For New Hampshire, ISO-NE uses the weather station in Concord, NH (CON).

3. ***Weather-dependent heating:*** The system weather-dependent heating load is identified as the electric demand that responds to decreasing cold temperatures. In Figure 5, the heating load is represented by the increasing demand as daily average temperatures drop below 60 degrees Fahrenheit. Heating energy that is not weather dependent (e.g., process heating) is included in the base load.

The methods Cadmus used to develop this weather analysis are provided in Appendix B.

Cadmus applied the regression results to historical weather data to determine the contribution of each load component to system total consumption, average demand, and peak demand. Figure 6 shows the percentage of energy consumption attributable to normalized weather-dependent cooling during the summer months (June through August) and during the summer on-peak hours (summer weekdays between 1:00 p.m. and 5:00 p.m.) from 2004 to 2012.

Figure 6. Weather-Normalized Cooling Consumption for New Hampshire Load Zone



Source: Cadmus weather-based load analysis using hourly model regression and ISO-NE historical market data (http://www.iso-ne.com/markets/hstdata/index.html)

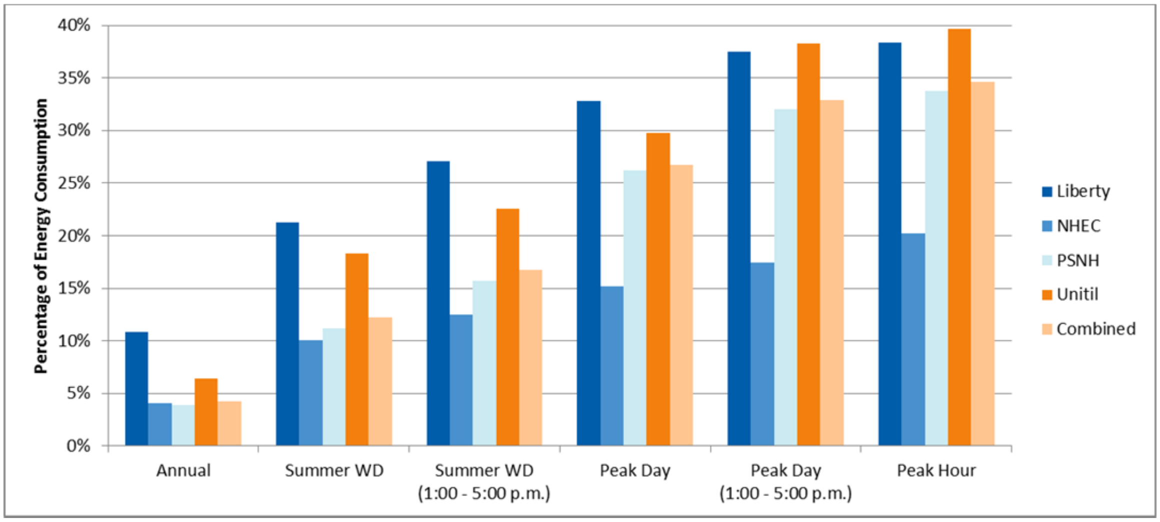
The data shows that the percentage of total summer energy consumption attributable to weather-dependent cooling varied from 9% and 11%, and the percentage of weather-dependent cooling consumption during the summer on-peak hours varied from 11% and 17%.

Figure 7 shows the estimated weather-dependent cooling energy consumption as a percentage of total energy consumption for each utility and for all utilities combined, for each of the following periods:

- ***Annual:*** The fraction of total annual energy consumption attributed to cooling loads.
- ***Summer WD:*** The fraction of energy consumed during summer weekdays attributed to cooling (all hours).
- ***Summer WD (1:00 – 5:00 p.m.)***: The fraction of energy consumed during the summer on-peak hours attributed to cooling.

- ***Peak Day:*** The fraction of energy consumed during the peak day attributed to cooling (all hours).
- ***Peak Day (1:00 – 5:00 p.m.):*** The fraction of energy consumed during the summer on-peak hours on the peak day attributed to cooling.
- ***Peak Hour:*** The fraction of energy consumed during the peak hour attributed to cooling.

Figure 7. Cooling Consumption by Utility for Summer Periods, 2012



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

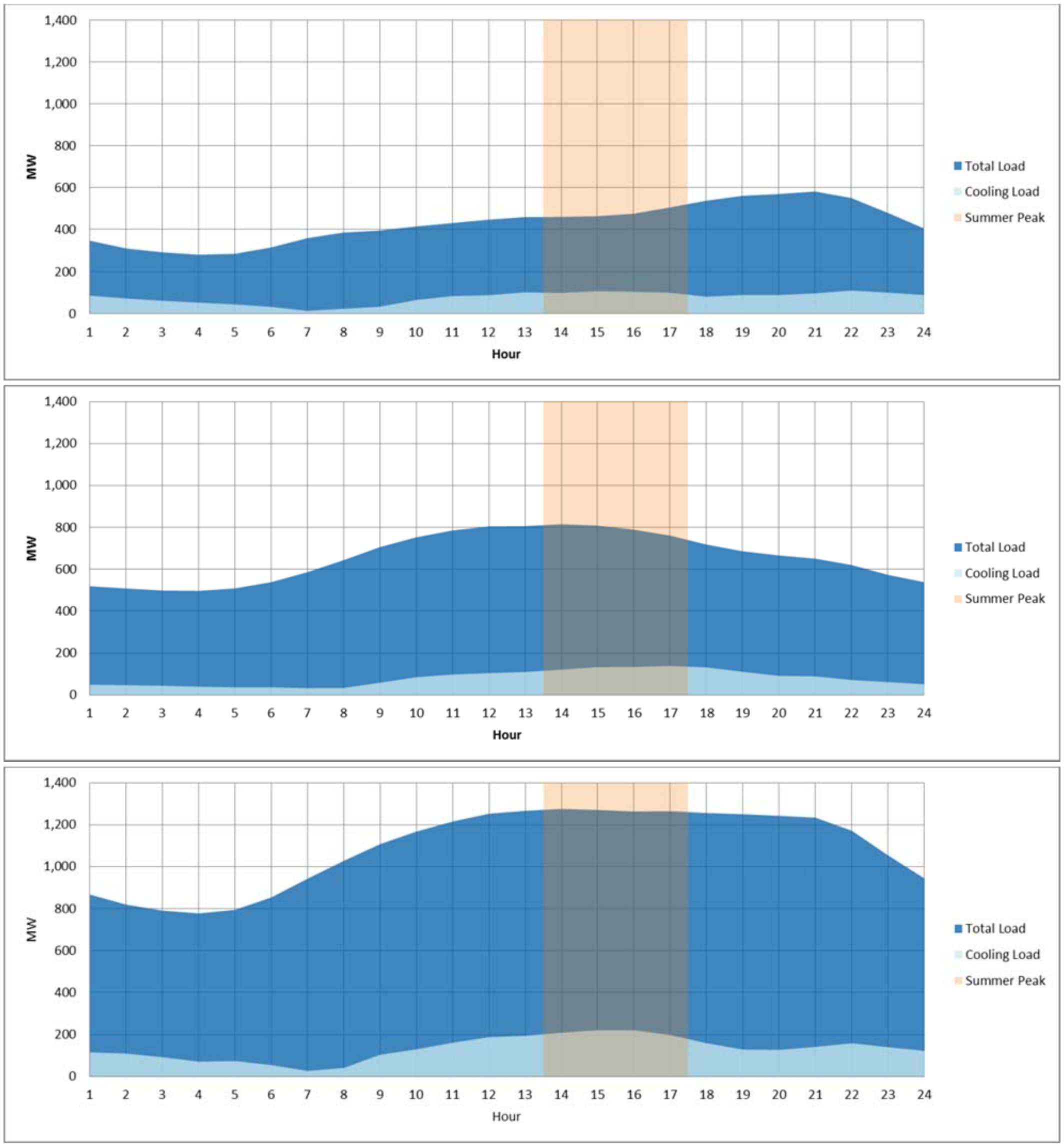
The data show that while the percentage of energy consumption attributed to cooling over the year and during summer weekdays is less than 20% for most utilities, the combined cooling energy consumption exceeds 25% of total electric consumption on the peak day and approaches 35% during the peak hour.

Sector Load

Cadmus received historical load data by sector for each of the electric utilities in New Hampshire: Public Service of New Hampshire (PSNH), New Hampshire Electric Co-op (NHEC), Liberty Utilities, and Unitil. We used these data to develop average load profiles for the residential and C&I sectors, and performed a weather regression analysis to identify the weather-dependent cooling load profile within each sector.

Figure 8 shows a comparison of the total and cooling load profiles for each sector for an average summer weekday.

Figure 8. Estimated NH Total and Cooling Load Profiles for Average Summer Weekday by Sector



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

The total residential load is shaped as expected, with lowest loads in the early morning hours and the highest loads in the evening hours, which are driven by the use of lighting and residential appliances. The C&I load is also lowest in the early morning hours, and has the highest loads during normal business hours. For both sectors, the cooling load is a relatively small percentage of the total load for an average summer weekday.

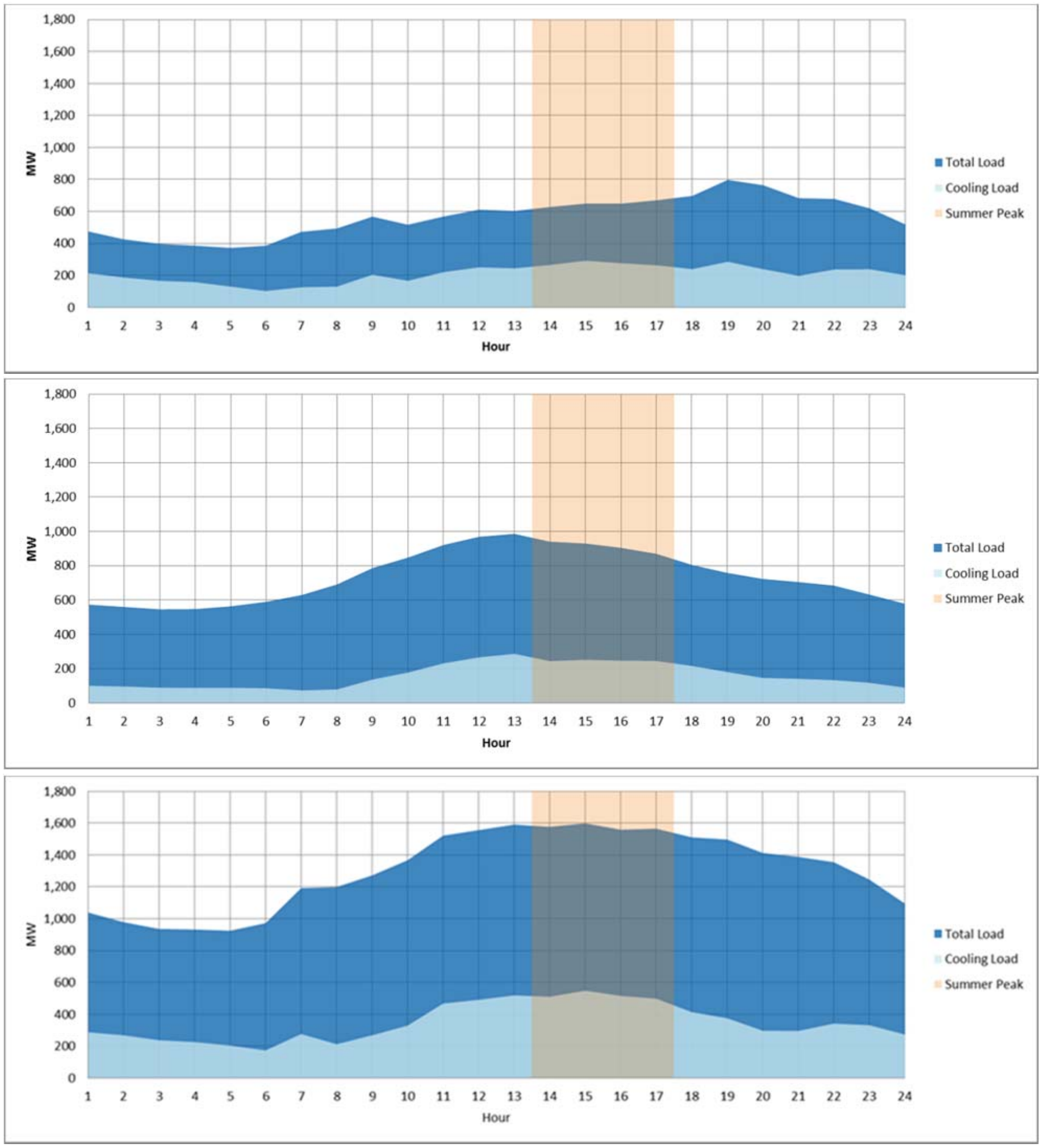
Figure 9 compares the total and cooling load profiles for each sector for the system peak day in 2012.

Figure 9. Estimated NH Total and Cooling Load Profile for Peak Day by Sector

Residential

C&I

Residential and C&I Combined



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

The peak day loads for both sectors are shaped similarly to the average summer weekday profiles, with higher total loads throughout the day due to increased cooling loads. The peak demand in the residential sector still occurs in the evening, and the peak demand for the C&I sector is just after noon.

Residential Cooling Equipment

The typical mechanical cooling equipment in the residential sector includes central air conditioning (CAC) systems, window or room air conditioning (RAC) units, and heat pump equipment. Since New Hampshire has a relatively cool climate compared to other regions in the US, as well as a population of vacation or second homes, there is also a sizable percentage of homes with no mechanical cooling equipment.

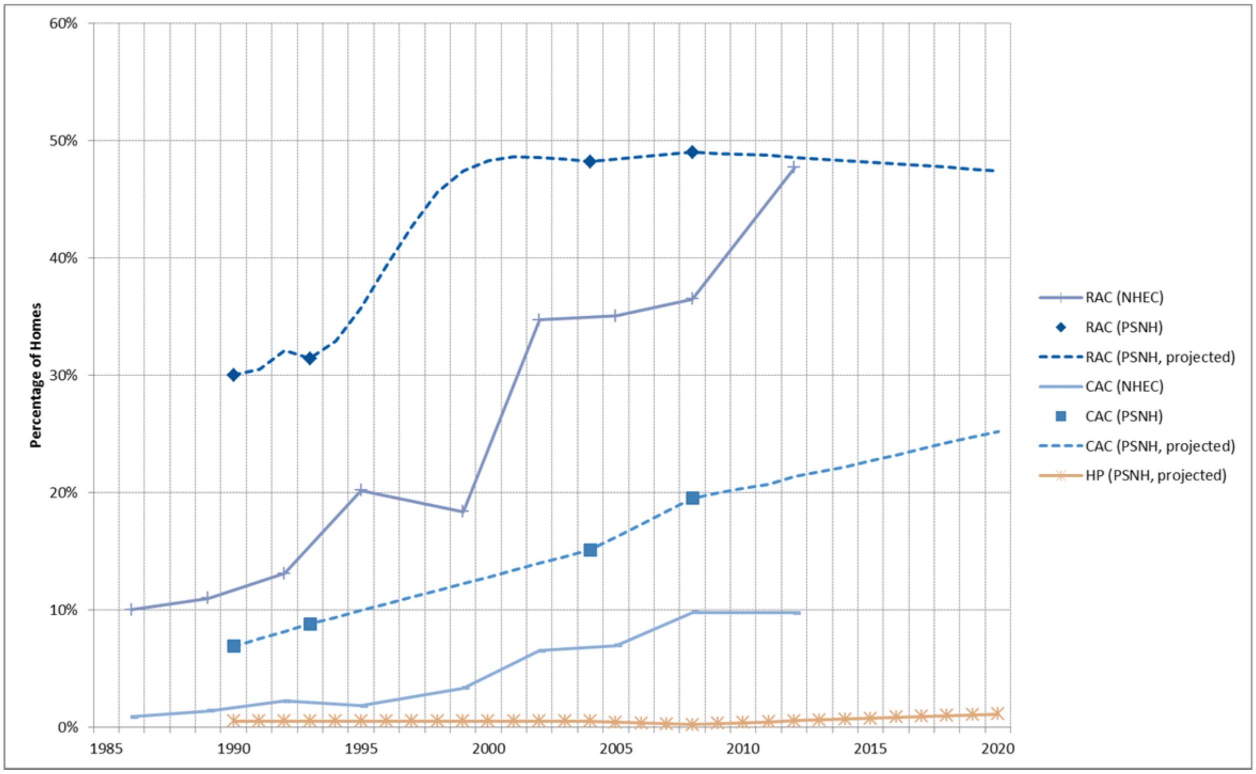
Cadmus reviewed customer survey data to assess the current and historical saturation of each cooling equipment type among residential homes in New Hampshire. Data sources included:

- ***E SOURCE Residential Energy End-Use Study: Appliance and Equipment Saturation – Cooling Equipment (July 2011):*** This study conducted by E SOURCE included a 2010 survey of 32,471 residential US customers on a variety of energy-related topics. The survey included 189 New Hampshire residents.
- ***PSNH Customer Survey Data:*** PSNH provided data from its periodic residential customer surveys for years 1990, 1993, 2004, and 2008. The 2008 survey included 1,885 PSNH customers.
- ***NHEC Customer Survey Data:*** NHEC provided data from its triennial residential customer surveys for years 1989, 1992, 1995, 1999, 2002, 2005, 2008, and 2012. The 2012 survey included 1,098 NHEC customers.

Figure 10 shows the trends in cooling equipment type for NHEC and PSNH customers based on survey data and projections from 1986 and through 2020. The survey data show increasing saturations of RAC and CAC systems for both companies, though PNSH projects decreasing percentage of homes with RAC equipment after 2008.[9]

[9] The saturation values are percentage of households with each equipment type. A decreasing *percentage* of homes with RAC does not necessarily mean a decreasing *number* of homes with RAC. The PSNH projections show continued increase in the percentage of homes with CAC, leaving a smaller share of the market for RAC.

Figure 10. Cooling Equipment in Residential Sector (PSNH and NHEC)



Source: NHEC and PSNH residential customer survey data

The figure shows that:

- The percentage of NHEC homes with RAC has historically been lower than the percentage of PSNH homes with RAC; however, the NHEC population caught up with PSNH in 2012, and almost 50% of homes in both territories have at least one RAC unit.
- The percentage of NHEC homes with CAC has historically been lower than the percentage of PSNH homes with CAC, and remained lower by 10% in 2012. PSNH projects that the percentage of homes with CAC will continue to increase, growing from 20% in 2008 to 25% in 2020. However, the latest surveys conducted for NHEC customers showed no growth in CAC saturation between 2008 and 2012.
- PSNH projected marginal increases in the population of homes with heat pump cooling systems, but expects that only 1% of homes will use heat pumps for space cooling in 2020.

Figure 11 shows the estimated percentage of homes with no cooling equipment from 1985 through 2020, based on customer surveys and projections performed by NHEC and PSNH. The percentage of homes with no cooling equipment is estimated as all homes with neither a RAC nor CAC cooling system.

Figure 11. Percentage of Homes with No Cooling Equipment

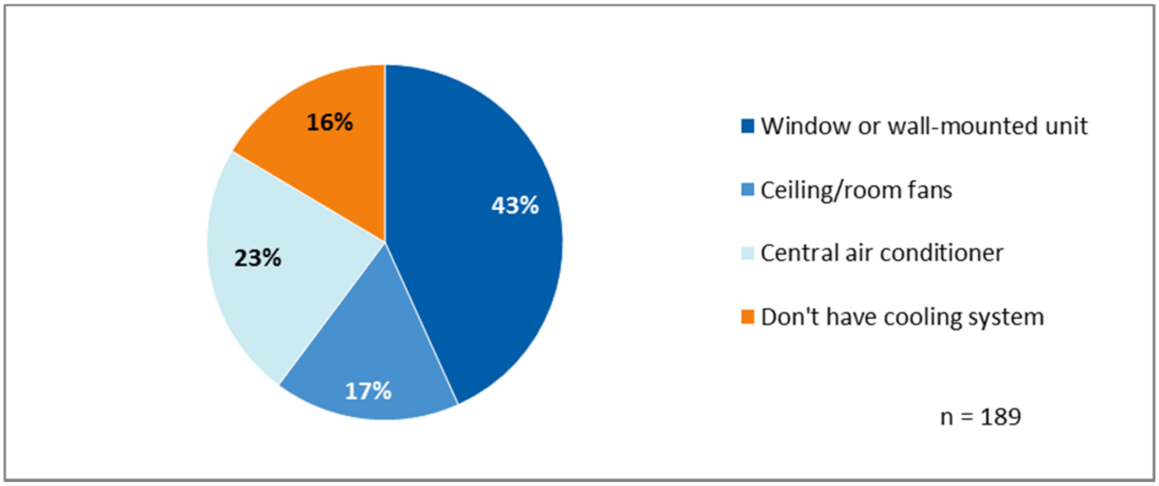
Source: NHEC and PSNH residential customer survey data

The data indicate that the percentage of homes with no mechanical cooling is rapidly shrinking. In 2000, 70% of NHEC homes and almost 40% of PSNH homes did not use mechanical cooling. Only eight years later, in 2008, less than 55% of NHEC homes and 30% of PSNH homes did not use mechanical cooling.

Details of Residential Equipment Saturations

Figure 12 shows the distribution of cooling system types in New Hampshire based on results of the E SOURCE *Residential Energy End-Use Study* (July 2011). The data show that in 2010, 66% of New Hampshire homes used mechanical cooling equipment, 17% used ceiling or room fans, and 16% had no cooling system.

Figure 12. Cooling Equipment Distribution in Residential Sector, 2010



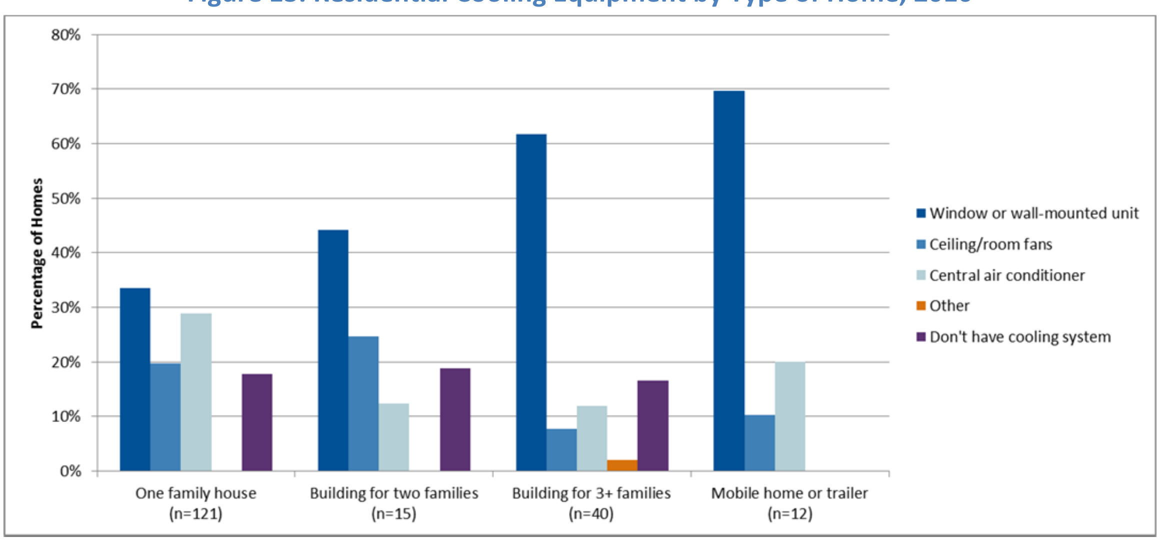
Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

These cooling equipment distributions are comparable to the distributions shown in NHEC and PSNH customer survey data, and are slightly more similar to the PSNH customer base.

The following figures show the distribution of cooling equipment by the type, age, size, and income of each home (based on New Hampshire residents' responses to the E SOURCE study).

Figure 13 shows the distribution of cooling equipment by home type. Single-family homes have a mixture of equipment types, but window or wall-mounted air conditioning units are increasingly dominant in multifamily buildings, mobile homes, and trailers. The percentage of homes with no cooling systems is balanced across single and multifamily residences.

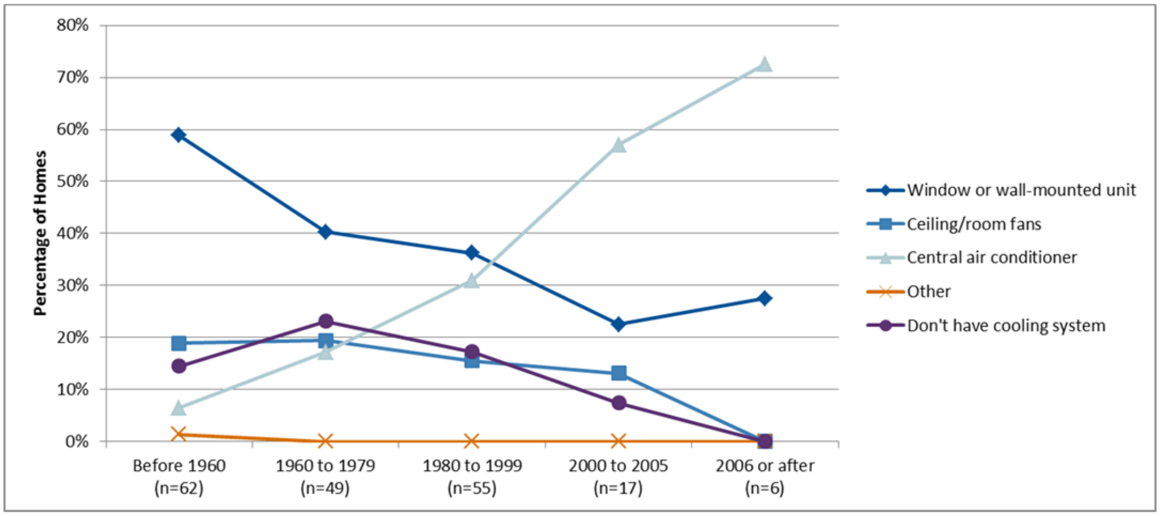
Figure 13. Residential Cooling Equipment by Type of Home, 2010



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Figure 14 shows the distribution of cooling system type by home age. The data show increasing saturation of CAC systems in newer homes and decreasing saturations of window/wall units and ceiling fans. For the 23 surveyed homes built after 2000, 61% had a CAC system, 24% used window/wall units, and only 5% reported having no cooling system.

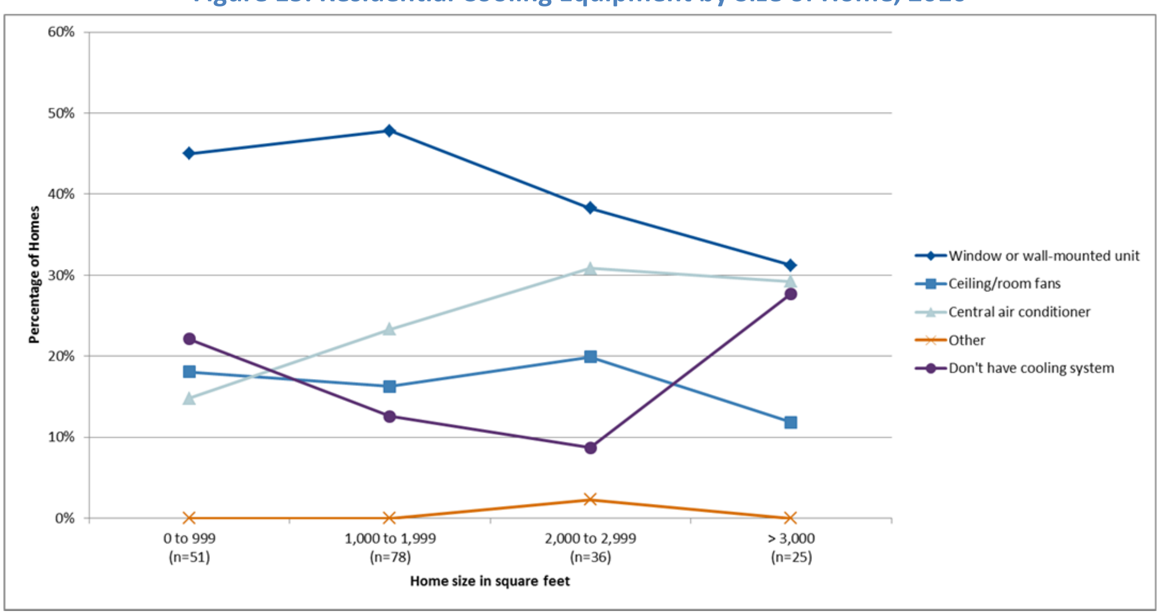
Figure 14. Residential Cooling Equipment by Age of Home, 2010



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Figure 15 shows the distribution of cooling system type by home size. The data suggest that smaller homes are more likely to use a RAC unit, but the distribution of cooling system types varies among large homes.

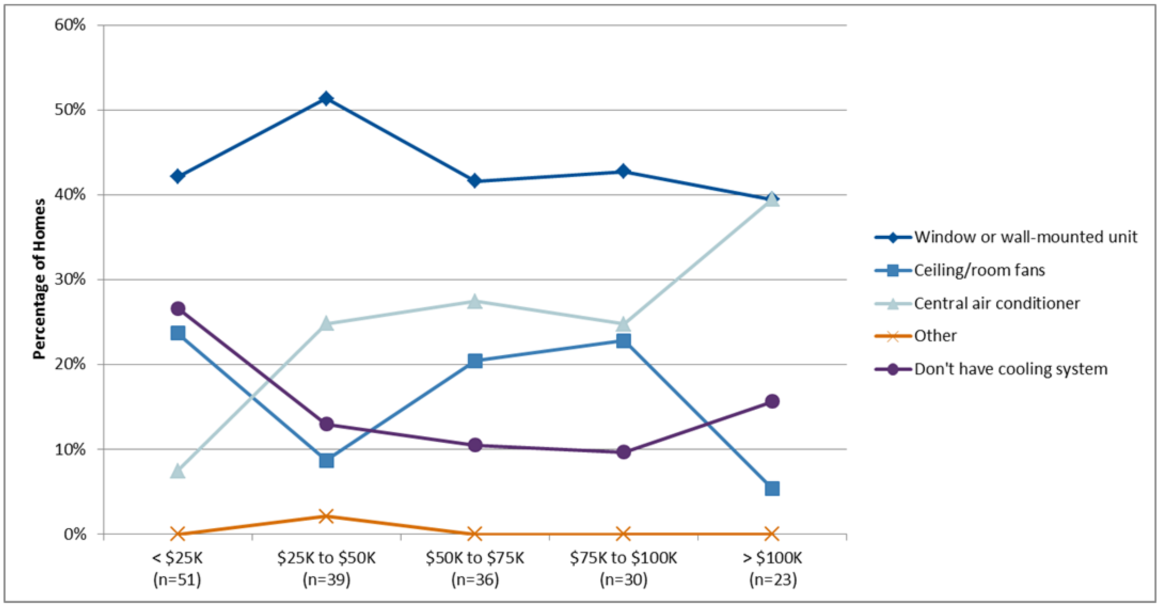
Figure 15. Residential Cooling Equipment by Size of Home, 2010



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Figure 16 shows the distribution of cooling system type by the household income. The data show that the percentage of homes with a RAC unit is highest among all income levels, but that higher income households are more likely to have a CAC system. Although the percentage of homes with RAC equipment in the lowest income level is comparable to other income levels, the lowest income households are also more likely to not use a cooling system compared to the other income levels.

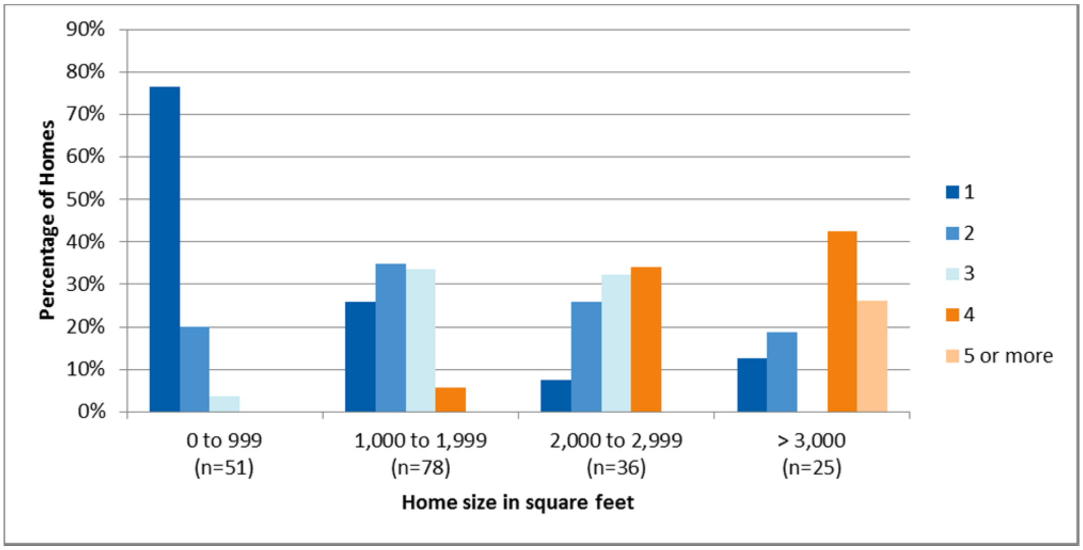
Figure 16. Residential Cooling Equipment by Income, 2010



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Figure 17 shows the percentage of RAC-cooled homes within each home size category, broken out by the total number of RACs. As expected, the data show that the smaller homes are more likely to have only one RAC unit, and the largest households typically have multiple units.

Figure 17. Number of Room Air Conditioning Units by Homes Size, 2010

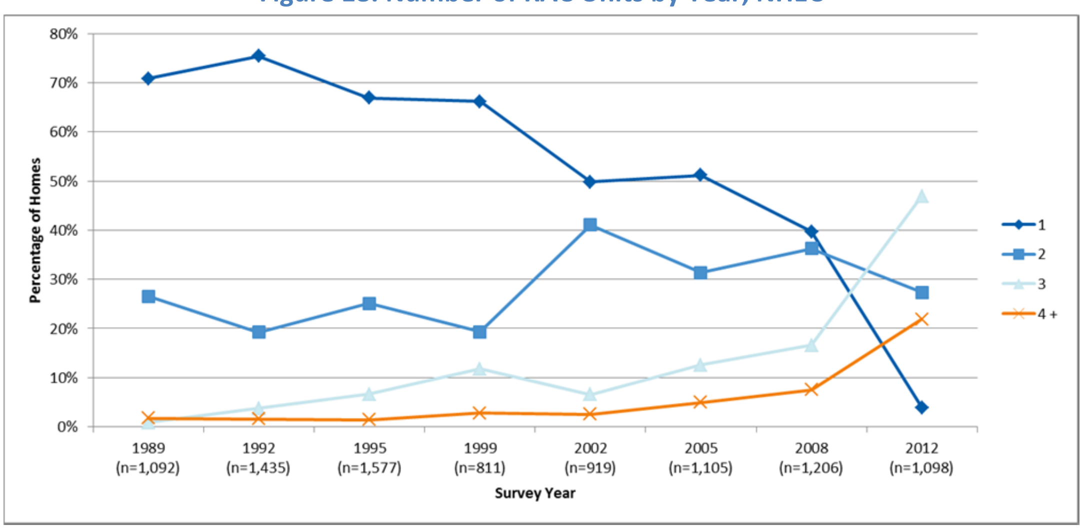


Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Across all home size categories, the E SOURCE survey data show that 36% of RAC-cooled homes have only one unit, 28% have two units, 22% of homes have three units, 12% have four units, and only 2% of homes have five or more RAC units. Based on these data, Cadmus calculated that the average RAC-cooled home in New Hampshire in 2010 has 2.2 RAC units.

Figure 18 shows the historical number of RAC units in NHEC homes that use RAC, based on NHEC customer surveys. The data show that the percentage of RAC-cooled homes with only one RAC unit is shrinking, and the percentage of homes with multiple units is increasing. Based on the NHEC survey data, Cadmus calculated that the average RAC-cooled home in the NHEC territory had 1.9 RAC units in 2008 and 2.9 RAC units in 2012.

Figure 18. Number of RAC Units by Year, NHEC



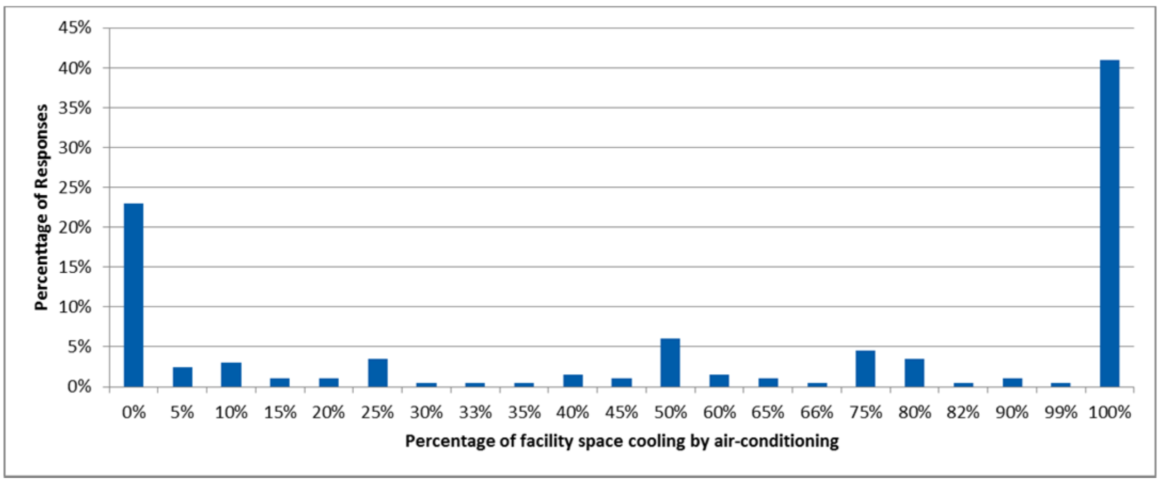
Source: NHEC Customer Survey Data

Commercial and Industrial Cooling Equipment

Typical mechanical cooling equipment in the C&I sector includes window air conditioners and packaged rooftop unit (RTUs) for small commercial buildings and central chiller plants, which distribute chilled water to air handlers for cooling in large commercial buildings. Industrial facilities typically use chillers for process cooling applications and smaller equipment— including window air conditioners, RTUs, and heat pumps for space conditioning.

Survey data collected by GDS Associates in 2008 show that almost one quarter of small commercial facilities do not use any air-conditioning equipment and less than half cool the entire building. Figure 19 shows unweighted percentages of space cooling for small commercial buildings indicated by 196 survey respondents.

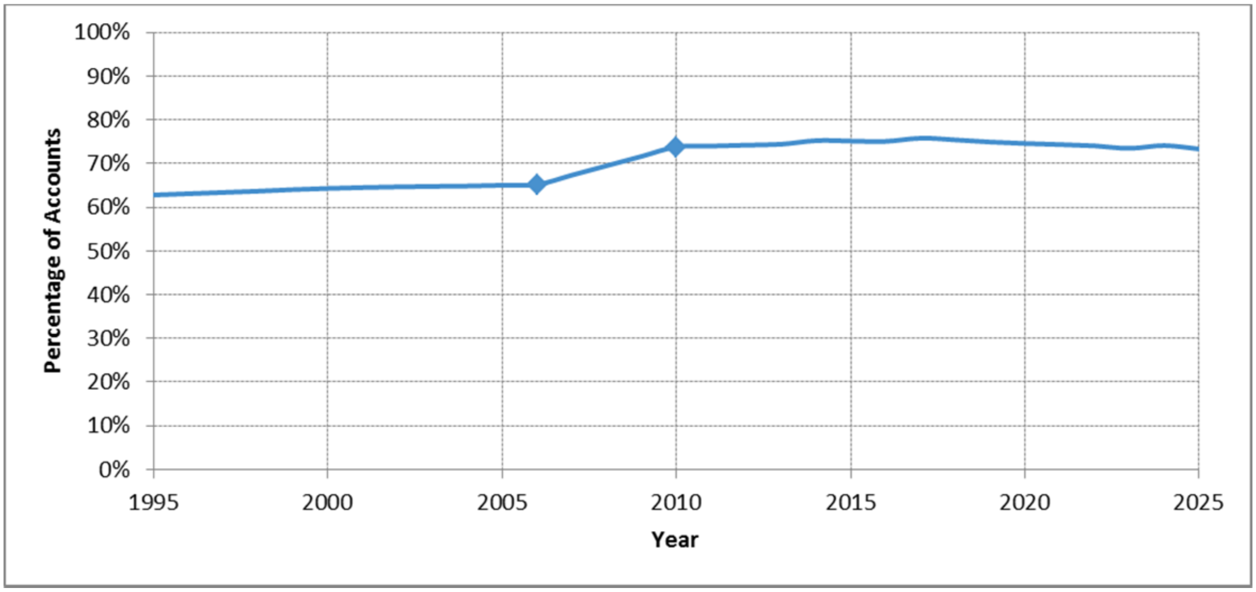
Figure 19. Space Cooling for Small C&I Buildings (based on 200 phone surveys)



Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

The survey data in Figure 19 is consistent with customer surveys collected by PSNH. Figure 20 shows the projected percentage of PSNH commercial accounts with cooling equipment, based on PSNH commercial load forecasting model which uses customer surveys conducted in 2006 and 2010 and projections for New England developed by the Energy Information Administration (EIA).

Figure 20. Cooling Equipment in Commercial and Industrial Sector, PSNH



SOURCE: PSNH commercial forecasting model

The PSNH survey data show that as of 2010, about 75% of commercial accounts use cooling equipment, and the projections indicate that this is not expected to increase in the near future.

Table 2 shows the distribution of air-conditioning equipment type among commercial buildings, derived from 152 responses to surveys conducted by GDS Associates for the NH potential study. The data confirm that the top three types of air-conditioning equipment for commercial buildings are central chillers, individual room or window air conditioners , and rooftop or packaged air conditioning units.

Table 2. Air Conditioning Equipment for Small Commercial

What type of air conditioning equipment is primarily used?	Warehouse	Retail	Grocery	Office	Lodging	Health	Education	Industrial	Restaurant	Other	Total	Percentage
Central chillers inside building	0	4	3	12	0	9	1	3	2	6	40	26%
Heat pumps for cooling	0	0	0	1	0	0	0	2	0	0	3	2%
Rooftop or packaged AC units	1	8	4	6	0	2	2	3	1	2	29	19%
Residential-type CAC	1	1	1	6	1	0	0	4	3	2	19	12%
Individual RACs (not heat pumps)	0	8	2	12	3	0	1	3	1	6	36	23%
District chilled water	0	0	0	1	1	1	0	1	0	2	6	4%
Don't Know	0	1	1	10	1	1	1	0	1	5	21	14%
Total	2	22	11	48	6	13	5	16	8	23	154	100%

Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

Table 3 and Table 4 show the saturation of HVAC controls equipment for small and large commercial buildings, respectively, based on the surveys conducted for the potential study. Small commercial customers were asked about the presence of programmable thermostats in their buildings, and large commercial customers were asked about the presence of energy management system (EMS) controls in their facilities.

Table 3. Saturation of Programmable Thermostats for Small Commercial Buildings

Do you have a programmable thermostat?	Warehouse	Retail	Grocery	Office	Lodging	Health	Education	Industrial	Restaurant	Other	Total	Percentage
Yes	0	0	1	1	0	0	n/a	3	0	1	6	11%
No	1	9	4	12	3	6	n/a	6	2	4	47	84%
Don't Know	0	0	0	2	0	0	n/a	0	0	1	3	5%
Total	1	9	5	15	3	6	n/a	9	2	6	56	100%

Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

Among small commercial buildings, only 11% of respondents indicated a presence of programmable thermostats for their building and 84% of respondents indicated no programmable thermostats.

Table 4. Saturation of HVAC Controls for Large Commercial Buildings

	Warehouse	Retail	Grocery	Office	Lodging	Health	Education	Industrial	Restaurant	Other	Total	Responses (N)
HVAC Controls	0	33%	33%	44%	8%	18%	79%	n/a	25%	48%	38%	94

Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

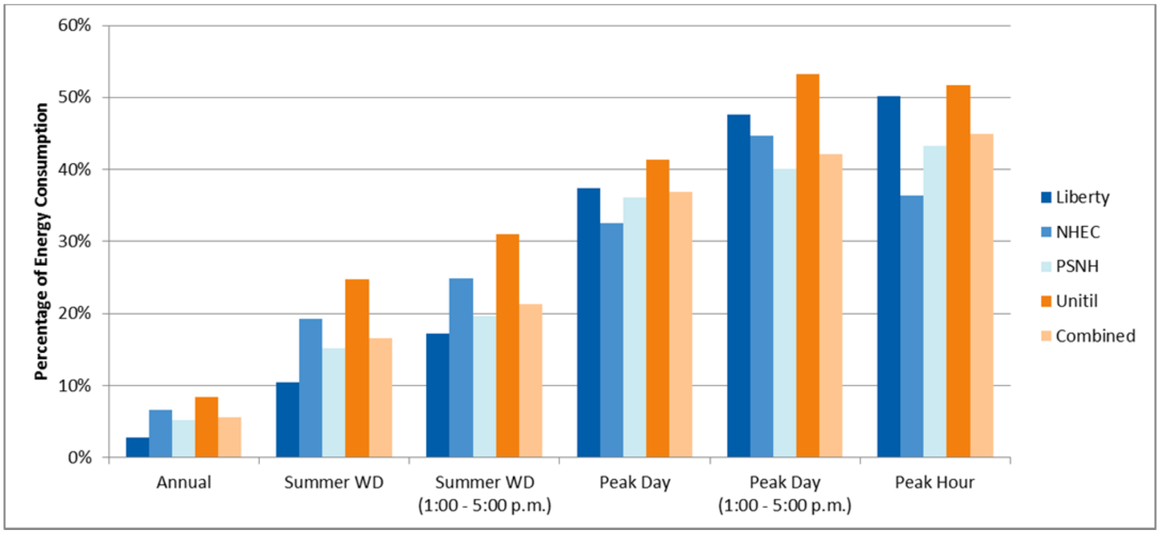
Among large commercial buildings, only 38% percent of respondents across all building types indicated having an HVAC control system such as an EMS or building management system (BMS).

Results

Residential

Cadmus' analysis of cooling loads in the residential sector revealed that the residential sector contributes only a small amount to the summer on-peak load, but may be a large contributor to load during peak days. Figure 21 shows the fraction of total residential energy consumption attributed to cooling for each utility and across all utilities for various summer periods.

Figure 21. Residential Cooling Consumption by Utility for Summer Periods, 2012



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

Cadmus' analysis of the system and sector electrical load and customer survey data revealed the following for the residential sector:

- Residential sector electric demand during summer weekdays peaks after the ISO forward capacity market (FCM) summer on-peak period. The highest loads in the residential sector occur between 6:00 p.m. and 10:00 p.m. (hours 19-22). This peak late in the day is driven by non-weather related loads, including lighting and appliances.[10]
- During the ISO-NE summer on-peak hours, the weather related (cooling) component of the summer residential load is 21% of the total summer residential load.
- The percentage of homes with mechanical cooling is increasing.[11] In 2000, only 30% of NHEC homes and less than 60% of PSNH homes used RAC or CAC cooling. Only eight years later, in 2008, more than 45% of NHEC homes and 70% of PSNH homes had either RAC or CAC systems.
- Within New Hampshire homes that use RAC units for cooling, the number of RAC units per home is increasing. Survey data from NHEC showed increasing quantities of RAC units in homes cooled by RACs.

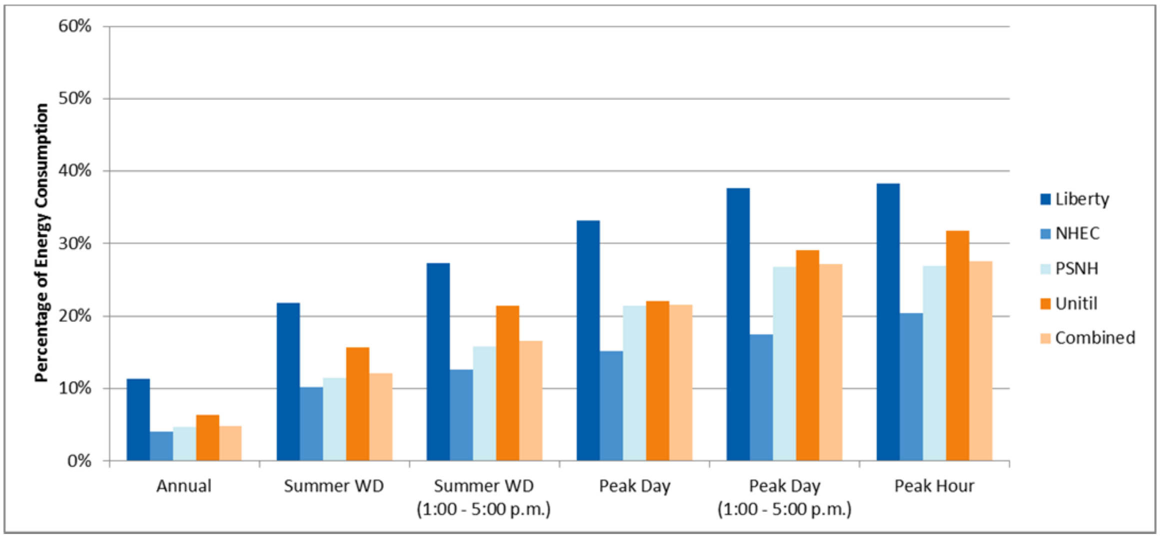
[10] Figure 8 shows an increase in the residential sector total load during the evening hours causing the residential sector peak during hours 19-21. Since the cooling load is shown to remain constant through this time, this evening spike in electric demand is driven by non-cooling loads.

[11] Although the statewide trends have shown growth in the saturation of RAC equipment through 2008, PSNH saw very little growth between 2004 and 2008 and projects an overall decrease in the percentage of homes in the future.

Commercial and Industrial

Cadmus' analysis of cooling loads in the C&I sector revealed that that cooling is a small contributor to the total C&I load during summer on-peak hours and on-peak days. Figure 22 shows the fraction of total C&I energy consumption attributable to cooling for each utility and across all utilities for various summer periods.

Figure 22. C&I Cooling Consumption by Utility for Summer Periods, 2012



Source: Cadmus weather-based load analysis using hourly model regression and utility load data

Cadmus' analysis of the system and sector electrical load and customer survey data revealed the following for the C&I sector:

- C&I sector electric demand during summer weekdays peaks just before the ISO-FCM on-peak period. The highest loads in the C&I sector occur between 11:00 a.m. and 2:00 p.m. This early peak in the summer is driven by building cooling loads.
- During the ISO-NE summer on-peak hours, the weather related (cooling) component of the summer C&I sector load is 17% of the total summer C&I sector load.
- The percentage of facilities with mechanical cooling systems is stable at 75% (based on PSNH survey data and EIA projections) and not expected to increase in the near future. It is expected that the C&I cooling market is saturated (i.e., those facilities without cooling equipment do not require cooling).
- A sizeable percentage of both small and large commercial facilities lack programmable controls system for their HVAC equipment. Based on surveys conducted for the 2009 NH potential study, less than 11% of small commercial buildings have programmable thermostats and less than 40% of large commercial buildings use a central HVAC control system.

TASK 2. RECOMMENDED PROGRAM ENHANCEMENTS

This section describes the objective, methods, and key results developed under Task 2. This included reviewing the results from Task 1, identifying opportunities to reduce energy consumption cooling load during peak periods, and recommendations for the New Hampshire programs to reduce cooling energy and demand.

Objective

This second task involved reviewing the current portfolio of New Hampshire core energy-efficiency programs for residential and C&I customer sectors, as well as developing recommendations to enhance the programs' electric energy and peak demand impacts through the inclusion of new measures or new program elements that will cost-effectively reduce electric air conditioning load.

The key result of this task is:

- Detailed recommendations to modify or expand the portfolio of existing core programs for residential and C&I customer sectors to promote the installation of cost-effective measures to reduce air conditioning peak demand and energy consumption.

Method

Cadmus used the findings from Task 1 and conducted a detailed review of the findings from the 2009 potential study to assess the opportunity to reduce both cooling load and overall energy and peak demand consumption for both the residential and C&I sectors. Using these findings along with our own experience with energy-efficiency technologies, we developed a set of recommendations for the New Hampshire programs to improve the reduction of electric energy consumption and summer peak load.

Efficiency Potential in New Hampshire

In 2008, the New Hampshire Public Utilities Commission commissioned an energy efficiency potential study to assess the additional opportunities for energy efficiency in New Hampshire. The study, completed in 2009, found that there is significant savings potential in New Hampshire through cost-effective electric, natural gas, and fuel-neutral efficiency measures and estimated that energy-efficiency measures could cost-effectively reduce the projected 2018 total electric energy consumption by more than 20% and reduce the projected 2018 electric peak demand by over 15%. The study estimated *potentially obtainable* total electric energy and demand reductions of 10.8% and 8.5%, respectively, of projected 2018 total electric sales.

The study estimated the potential energy and summer peak demand savings by sector. Table 5 shows the estimates of potentially obtainable electric energy and demand savings for each sector and the percentage of total savings attributed to each sector.

Table 5. Energy Savings Potential by Sector

Sector	Potential Electric Energy Savings (GWh)	% of Total Potential Energy Savings	Potential Summer Peak Demand Savings (MW)	% of Total Potential Summer Demand Savings
Residential	698	50%	26.3	10%
Commercial (Existing Buildings)	454	32%	132.3	52%
Commercial (New Construction)	38	3%	13.9	5%
Industrial	214	15%	81.9	32%
All Sectors	1,404	100%	254	100%

Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

The data show that the majority of electric energy savings are in the residential sector (50%) and within the commercial existing buildings market (32%). The majority of summer peak demand savings are in commercial existing buildings and industrial facilities. The data suggest that, to reduce total energy consumption, the energy-efficiency program should focus on opportunities in the residential and existing commercial buildings. However, to reduce peak load during the summer on-peak period, energy efficiency programs should focus on opportunities in the existing commercial and industrial facilities.

Results

Residential

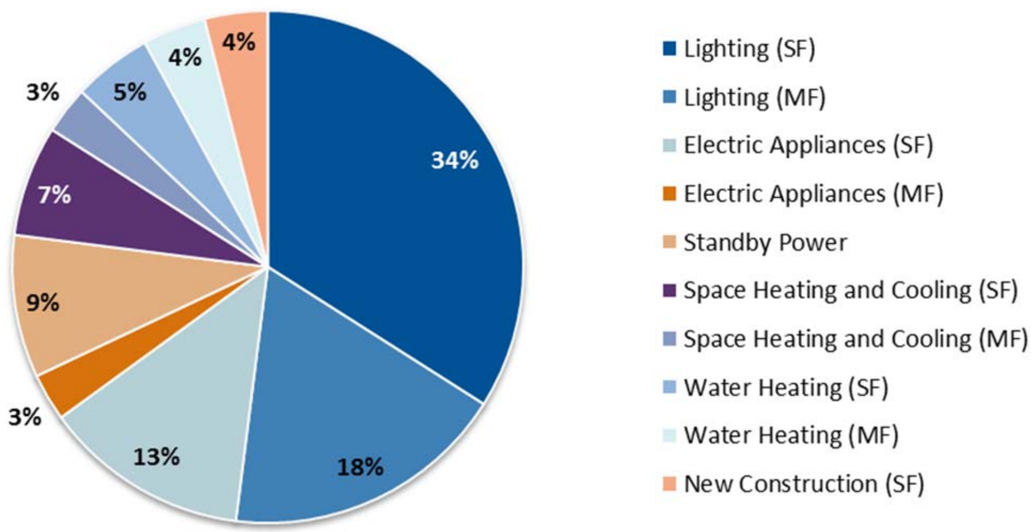
Cadmus' research under Task 1 revealed the following for the residential sector:

- Residential sector electric demand during summer weekdays peaks after the ISO-FCM on-peak period. The highest loads in the residential sector occur between 6:00 p.m. and 10:00 p.m. This late-in-the-day peak is driven by non-weather-related loads, including lighting and appliances.
- During the ISO-NE summer on-peak hours, the weather-related (cooling) component of the summer residential load is 21% of the total residential load.
- The percentage of homes in New Hampshire with mechanical cooling unit is increasing.[12] In 2000, only 30% of NHEC homes and less than 60% of PSNH homes used RAC or CAC cooling. Only eight years later, in 2008, more than 45% of NHEC homes and 70% of PSNH homes had either a RAC or CAC system.
- Within New Hampshire homes that use a RAC unit for cooling, the number of RAC units per home is increasing. Survey data from NHEC shows increasing quantities of RAC units in homes cooled by RACs.

[12] Although the statewide trends have shown growth in the saturation of RAC equipment through 2008, PSNH saw very little growth between 2004 and 2008 and projects an overall decrease in the percentage of homes in the future.

The New Hampshire Public Utilities Commission initiated an energy-efficiency potential study in 2008 (completed in 2009). The study found that there is significant savings potential in New Hampshire through cost-effective electric and natural gas efficiency measures. For the residential sector, the study showed a potential cost-effective reduction in electric consumption of more than 20% of projected 2018 total residential electric consumption. The study estimated that energy efficiency could cost-effectively reduce residential peak demand by less than 4%. Figure 23 shows the estimated maximum achievable potential by end use for the residential sector, based on that research.

Figure 23. Residential Maximum Achievable Residential Electric Savings Potential by End Use



SF = single-family homes; MF = multifamily homes

Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

Note: This study did not include the impact of EISA 2007 on lighting baselines, so the energy efficiency potential for the lighting end-use is overstated.

The data show that 52% of the savings potential is from lighting in single-family (SF) and multifamily (MF) buildings, 16% from electric appliances, and 9% from standby power. Energy-efficiency opportunities for heating and cooling equipment are only 10% of the total residential energy reduction opportunity.[13]

It is important to note that Figure 23 shows the end-use disaggregation of potential for reducing energy consumption, and does not necessarily correlate with summer peak demand reduction. For example, since residential lighting systems typically do not coincide with the ISO-NE summer on-peak period, lighting measures are less effective in reducing summer peak demand than measures that coincide with

[13] The NH potential study did not take into account changes in lighting baseline standard due to the Energy Information and Security Act of 2007 (EISA 2007), so the potential for lighting energy savings are overstated and the percentages of total potential for non-lighting end-uses are understated.

the summer on-peak period.[14] Thus, although space cooling measures are only 10% of the energy-efficiency potential, they are likely a higher percentage of the demand reduction potential.

New Hampshire Residential Energy Efficiency Programs

Cadmus reviewed the companies' 2013-2014 CORE New Hampshire Energy Efficiency Programs and the NHSaves.com Website to understand the existing program offerings for residential customers. Table 6 describes the energy-efficiency programs offered to New Hampshire residential customers in 2013-2014.

Table 6. New Hampshire Residential Efficiency Programs, Electric

Program	Utilities	End-Use	Description
ENERGY STAR® Homes Program	CORE	Multiple	Promotes energy efficient design and construction in residential new construction market.
Home Performance with ENERGY STAR® Program (HPwES)	CORE	Multiple	Improves efficiency within existing single-family and multifamily homes through weatherization, appliance, and lighting upgrades.
ENERGY STAR® Lighting Program	CORE	Lighting	Promotes saturation of energy efficient lighting through upstream and downstream actions.
ENERGY STAR® Appliance Program	CORE	Appliances	Promotes saturation of energy efficient appliances through marketing and mail-in rebates.
High Efficiency Heat Pump Program	NHEC	HVAC	Promotes the installation of high-efficiency air source and geothermal heat pump equipment for residential new construction
ENERGY STAR® Homes Program Enhancement: Geothermal and ASHP Option	PSNH	HVAC	Promotes the installation of high-efficiency air source and geothermal heat pump equipment for residential new construction
Residential Customer Engagement Pilot Program	PSNH	Multiple	Promotes energy efficiency behavior changes through energy savings reports and interactive website with energy savings tips.

Source: 2013-2014 CORE New Hampshire Energy Efficiency Programs, 2012.

The existing programs include incentives to address most areas of top electric energy-efficiency potential in the residential sector (lighting, electric appliances, and space heating and cooling), but may benefit from targeted strategies to reduce energy consumption for other key segments (multifamily lighting and standby power).

Although the energy-efficiency potential study showed lower opportunity for summer peak demand compared to the C&I sector, the programs may reduce summer peak demand in the residential sector through continued efforts to reduce cooling energy through home envelope improvements and cooling

[14] The New Hampshire CORE Residential ENERGY STAR® Lighting Program evaluation found a summer on-peak coincidence factor of 7.2% for residential for CFLs and 8.1% for residential interior fixtures.

equipment upgrades and expanded efforts to address residential loads that are coincident with the summer on-peak period.

The following sections provide recommendations to reduce electric energy and peak demand consumption in the residential sector through both cooling and non-cooling measures.

Recommended Residential Cooling Measures

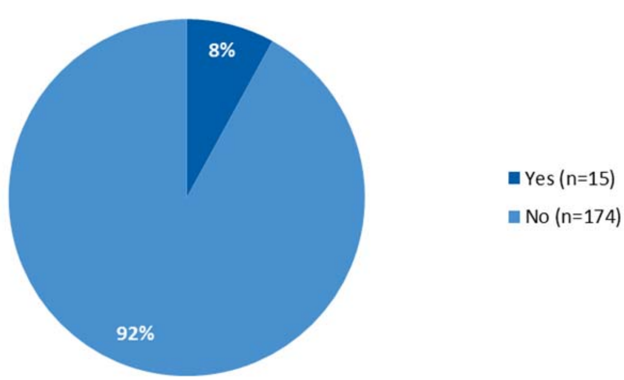
Cadmus recommends the following actions to reduce energy consumption and peak demand from residential cooling equipment:

- Encourage the installation of ductless heat pump air-conditioners in place of central or window air-conditioners.
- Ensure the programs capture opportunities to install the highest efficiency equipment for residential new construction and planned equipment replacement opportunities.
- Encourage the early replacement of existing inefficient air-conditioners.
- Encourage the installation of web-enabled programmable thermostats with central controls for demand response actions during summer peak periods.

Planned Actions for Residential Cooling Systems

The E SOURCE survey asked New Hampshire homeowners whether they planned to add or replace cooling equipment within the next 12 months. Figure 24 shows that only 8% of the homeowners responded affirmatively. While this may seem low, this is consistent with a typical 15-year equipment replacement cycle.

Figure 24. Residential Sector Plans to Add or Change Air Conditioning Equipment



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Early Replacement of Air Conditioners

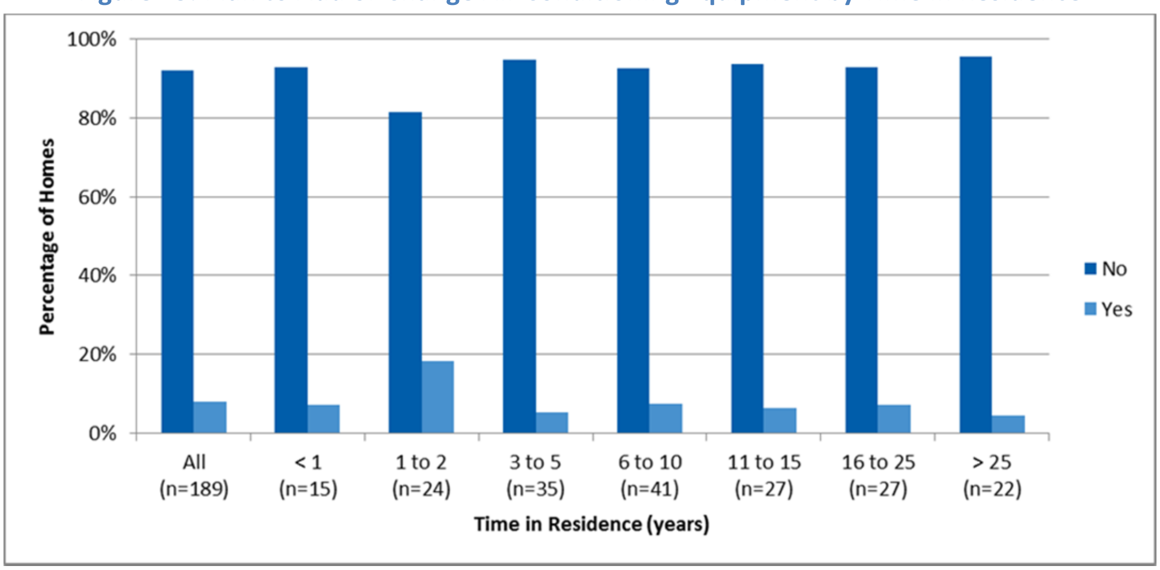
Since only a small fraction of NH residential households plan to replace their air-conditioning equipment, we recommend implementing an early replacement program to influence the remaining customers to replace their inefficient equipment sooner than they would have in absence of the program.

The baseline for replacing an air conditioner when it fails is the federal minimum of SEER 13. Installing a new SEER 14 unit, for example, saves approximately 7% over this baseline. The savings are small because the federal minimum increased from SEER 10 to SEER 13 in January 2006. However, the base of installed air conditioners is much less efficient for three reasons:

1) The weighted average of air conditions sold before January 2006 is SEER 10 or less (some units have lower than the federal standard SEER for the next two reasons);
2) Problems with initial installation, such as improper refrigerant charge and airflow, frequently cause units to operate less efficiently than their rated values, and
3) Equipment degradation over time can further reduce efficiency, including fouling of evaporator and condensing coils and refrigeration leaks.

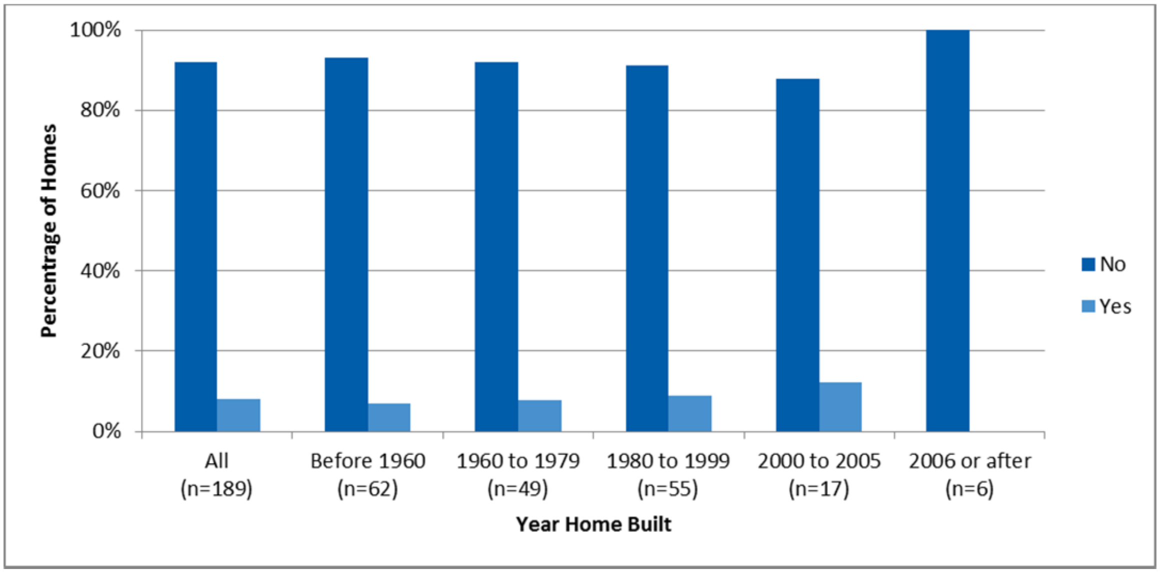
Figure 25 and Figure 26 show the responses indicating whether residents' planned to add or replace cooling equipment, by the amount of time they have lived in their residence and by the year the home was built, respectively. The figures show low percentages for all amounts of time and build dates. The findings were similar when compared for the home's air conditioning equipment type, age of home, and household income. The data show that for the utilities to increase the efficiency of the stock of air conditioners, they need to reach the 8% of households in the market for new air-conditioning equipment, annually.

Figure 25. Plan to Add or Change Air Conditioning Equipment by Time in Residence



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Figure 26. Plan to Add or Change Air Conditioning Equipment by Year Home was Built



Source: E SOURCE. *"Residential Energy End-Use Study."* July 2011.

Cadmus studied a tune-up program in Missouri and found that field efficiencies of poor but still operating units was in the range of SEER 8. Numerous programs across the country were designed to incentivize owners of older units to retire them prior to failure, which saves 30% or more of the unit energy use. Some programs recognize that owners will repair older, inefficient units to avoid the expense of a new unit; these programs offer higher incentives to encourage homeowners to replace rather than repair older units.

Ductless Mini-Splits

Ductless mini-spits are heat pumps and air conditioners that operate similarly to conventional split air conditioners and heat pumps, except that the evaporator coil is housed in a wall-mounted blower and there is no duct work. Where more cooling is needed, the mini-split only uses refrigerant lines to transport cooling, not ducts. Mini-splits work well as retrofit units and in hard-to-reach areas and they offer several advantages over conventional systems: (1) efficiency ratings exceed SEER 20, (2) they eliminate ducts and therefore duct losses, and (3) some models also provide heating and have the added benefit of offsetting electric or fossil fuel heating energy consumption.

The NH CORE Energy Efficiency Programs ENEGRY STAR® Appliance Program incents customers who are installing Room ACs, Central ACs or Air Source Heat Pumps and Mini Split systems to purchase and install the most efficient ENERGY STAR models.

Cadmus recommends that New Hampshire continue its air conditioner and heat pump programs; however, the programs should remain vigilant to avoid adding cooling load for spaces that wouldn't otherwise be cooled. This typically requires verification that in the absence of the programs, the same space would have been cooled with less efficient equipment. To maximize savings from ductless mini-split installations, we recommend that the target homes with existing electric resistance (ER) heating systems or installed where electric baseboard is present.

Web-Enabled Learning Thermostats, Centrally Controlled at Peak

Programmable thermostats are designed to reduce energy consumption by raising cooling set points and decreasing heating set points during user-chosen periods, typically when occupants are away from the building or sleeping, or when the thermostat detects no home occupancy. Energy savings accrue when the building temperature is allowed to float upwards in summer and downwards in winter, which reduces the cooling or heating energy consumption.

Cooling savings occur when: (1) the building thermostat setting is higher than normal, and (2) the cooling system stays off for a relatively long period of time. No savings occur during mild temperatures or when the HVAC system is off for only short periods. For example, during mild temperatures, the air conditioner might only operate for 10 minutes per hour. An increase in the set point by a few degrees for two hours would deliver very little savings. When the occupant re-sets the temperature to the comfort zone, the HVAC system operates longer to bring the home back down to the desired temperature.

Cadmus has conducted numerous thermostat studies in states including Illinois, Maryland, Missouri, and is currently conducting a pilot study for Liberty Utilities' natural gas customers in New Hampshire. In a recent analysis of metering data, Cadmus determined three main types of thermostat operation:

1. ***Regular set points:*** Residents set their thermostat to change temperature on a regularly scheduled basis. This group consisted of 43% of the 91 metering participants.
2. ***Manual but changing set points:*** Residents set their thermostat inconsistently by manually controlling the system either on their manual thermostat or directly by disconnecting their air conditioning from the thermostat, throughout the summer. This group consisted of 22% of the 91 metering participants.
3. ***Constant set point:*** Residents used thermostat settings nearly constant throughout the cooling season. This group consists of 35% of the 91 metering participants.

The energy used for these three types of thermostat operation varied, but was more a function of the occupied cooling set point than their set back behavior. While there were limitations to cooling savings from programmable thermostats, there are possible additional gains from learning thermostats. Also, web-enable thermostats offer the ability to control demand manually via phone applications and without the need for complex load switches or radio signal strategies.

The PSNH Website currently advertises the Heat Smart Load Control Program for heat pumps and electric hot water heaters. Cadmus recommends initiating a pilot program for the cooling season that combines the benefits of learning thermostats with the ability to control them centrally to reduce peak load. With user permission, the units can easily be controlled using Web protocols. PSNH can employ various strategies, from changing set points for short intervals to raising set points: this will depend on program design, outdoor temperatures, and the temperature of the house when each peak event occurs.

Recommended Residential Non-Cooling Measures

Cadmus' load research and the NHPUC's potential study show that cooling consumption and potential savings are a small component of overall use. Therefore, we broadened our view of potential savings measures to include both cooling and non-cooling measures.

Cadmus also identified a number of energy-efficiency measures that are not cooling related but will serve to reduce electric energy consumption and peak load. These include:

- Heat pump water heaters
- Showerheads and aerators
- ENERGY STAR® Dehumidifiers
- Clothes washers (education)
- Advanced power strips
- Computer power management (as a pilot)

Heat Pump Water Heaters

A HPWH reduces the electric water heating consumption (when replacing a standard electric water heater) through improved water heating efficiency, but does not impact the home's consumption of hot water. Since the consumption of hot water is unchanged, the runtime of any hot water circulating pumps is also unchanged.

HPWHs installed in a conditioned space may impact the heating and cooling loads in that space, impacting the home's heating and/or cooling systems. HPWHs reduce space cooling load, resulting in saving for electric cooling equipment. HPWHs increase heating load, resulting in increased heating fuel consumption and heating equipment runtime.

A Cadmus study of HPWH installations found that the average savings from noon to 8:00 p.m. (hours 13-20) was just over 200 watts per unit. [15] With a differential cost (at failure) of $500, the payback for these units is relatively short, and an incentive may increase the number of installations. Because most water heaters are replaced on failure under short notice, we recommend working through trade allies and distributors to have plumbers, plumbing supply houses, and other contractors stock these units.

LED/ CFL Lighting

We understand that the utilities currently already offer rebates for efficient bulbs, including a coupon to obtain an LED bulb for $10. Newer technology lighting products, like LEDs, are also offered via the online

[15] Cadmus. "United Illuminating Heat Pump Water Heater Pilot: Impact and Customer Acceptance Study." June 2010.

and hard copy lighting catalogs. Recognizing that the EISA law reduces the wattage of existing incandescent lights, upgrading from the new incandescent or halogen bulbs to ENEGRY STAR CFLs or LED will still encourage customer to purchase these more efficient bulbs.

Showerheads and Aerators

Efficient showerhead and aerators can reduce hot water use and associated electricity consumption for homes with electric hot water heaters. Since a typical hot water heater can consume 4.5 kW during recovery, water savings measures can deliver large peak savings even with a low coincidence factor. Based on a direct metering study of end-uses in 150 homes, Cadmus found that the average household HW consumption was lower than assumed in most technical reference manuals (TRMs) causing TRM savings to be over-stated. However, potential savings are still high enough to warrant consideration to promote this measure. Cadmus found annual energy savings of roughly savings 337 kWh per showerhead. [16]

We recommend marketing low-flow showerheads and aerators to homes with electric water heating systems to reduce annual energy consumption and demand during both summer and winter on-peak periods.

Dehumidifiers

An estimated 19% of US homes have a dehumidifier, equipment that can account for a substantial portion of residential energy use. The annual electricity consumption of a dehumidifier can be 1,000 kWh or more, which is twice the consumption of an ENERGY STAR refrigerator.

Figure 27 shows the daily electricity use versus water removal from a 2012 Cadmus study.[17] Average use was between 3 and 6 kWh per day, and one malfunctioning unit used 14 kWh per day without the owner noticing.

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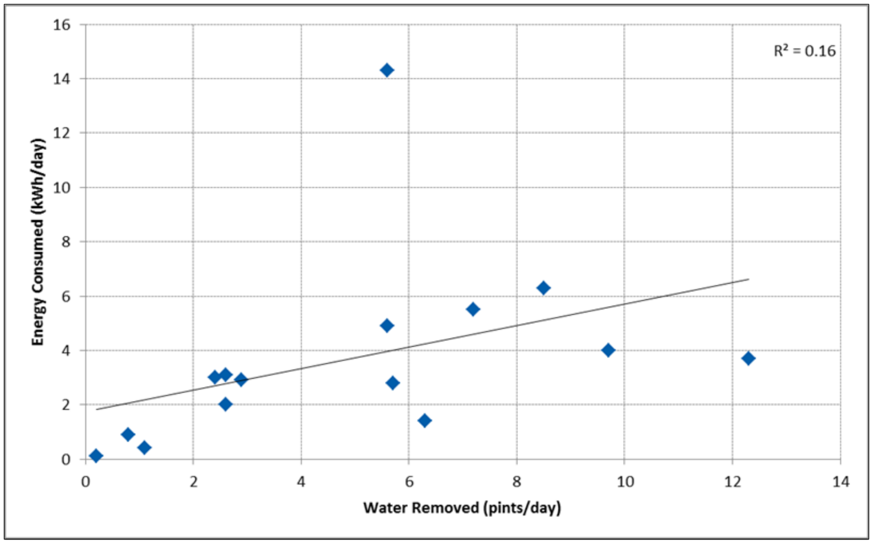
[16] Cadmus metering study of hot water uses, Detriot Edison and Consumers Energy, 2013.

[17] Korn, David and L. Mattison (The Cadmus Group, Inc.). "Dehumidifiers: A Major Consumer of Electricity." Paper presented at the American Council for an Energy Efficient Economy Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, August 12 – 17, 2012.

Figure 27. Daily Electricity Use of a Dehumidifier



Source: Korn, David and L. Mattison. "Dehumidifiers: A Major Consumer of Electricity." Paper presented at the ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, 2012.

Table 7 shows that the energy factor (EF), measured in liters of water removed per kWh consumed, has risen substantially. The figure also shows that new ENERGY STAR® units remove up to 85% more water per unit energy consumption. Cadmus also determined that many units were achieving much lower energy factors in the field due to cooler temperatures in basements and malfunctioning humidity sensors.

Table 7. Efficiency Standards for Dehumidifiers, Energy Factor (liters/kWh)

Current				Effective October 2012			
Federal Standard		ENERGY STAR V 2.1		Federal Standard		ENERGY STAR V 3.0	
≤ 25 pints/day	1.0	≤ 25 pints/day	1.2	≤ 35 pints/day	1.35	< 75 pints/day	1.85
> 25 to ≤ 35	1.2	> 25 to ≤ 35	1.4				
> 35 to ≤ 54	1.3	> 35 to ≤ 45	1.5	> 35 to ≤ 45	1.5		
		> 45 to ≤ 54	1.6	> 45 to ≤ 54	1.6		
> 54 to < 75	1.5	> 54 to < 75	1.8	> 54 to < 75	1.7		
≥ 75	2.25	≥ 75	2.5	≥ 75	2.5	≥ 75 to ≤ 185	2.8

Source: NARA 2010[18] and EPA 2011b[19]

Cadmus recommends that dehumidifiers be included in all energy audits, and that the unit power is spot measured as is done with some refrigerator programs. Inefficient or malfunctioning units could be covered by a relatively large rebate that would incent the homeowner to purchase of a new ENERGY STAR dehumidifier. This rebate should include a brochure that educates the homeowner on dehumidifier set points.

Clothes Washers

Clothes washers are rated according to their modified energy factor (MEF). MEF is the quotient of the capacity of the washer divided by the total amount of energy it consumes per cycle. MEF is expressed in cubic feet per kilowatt hour per cycle (ft^3/kWh/cycle). The higher the MEF value, the more efficient the clothes washer is. The water factor (WF), expressed in gallons per cubic foot per cycle (gallons/ft^3/cycle), is the quotient of total weighted per-cycle water consumption divided by the capacity of the clothes washer. A lower WF means less water, and therefore less water heating energy, is consumed per cycle.

MEF and WF are used to determine the federal standard for minimum allowable clothes washer efficiency, as well as being used by ENERGY STAR and by the Consortium for Energy Efficiency (a membership group of utilities) to set the voluntary energy-efficiency standards. In recent years, the efficiency ratings of available washers have increased substantially. The minimum MEF for ENERGY STAR qualification was raised three times between 2006 and 2011, going from 1.42 ft^3/kWh/cycle to 2 ft^3/kWh/cycle.[20]

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[18] [NARA] National Archives and Records Administration. 2010. *Department of Energy, 10 CFR 430, Energy Conservation Program for Consumer Products: Test Procedures for Residential Dishwashers, Dehumidifiers, and Conventional Cooking Products (Standby Mode and Off Mode); Proposed Rule.* http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/dw_dehum_ccp_tp_nopr.pdf

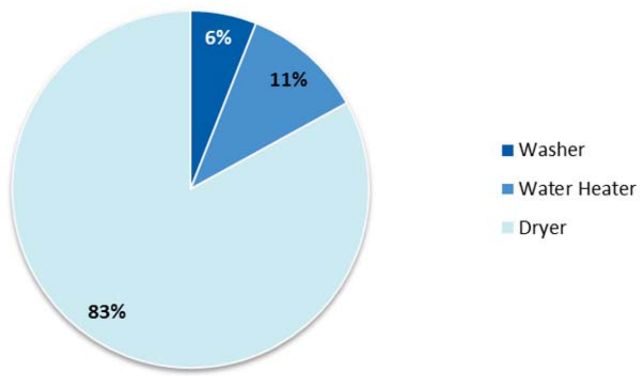
[19] [EPA] U.S. Environmental Protection Agency. 2011. ENERGY STAR Dehumidifier specification V3.0. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/dehumid/ES_Dehumidifiers_Final_V3.0_Eligibility_Criteria.pdf

[20] Korn, David and L. Mattison. "Do Savings Come Out In The Wash? A Large-Scale Study of Residential Laundry Systems." Home Energy (January/February 2012).

The conventional wisdom is that clothes washers save energy by reducing the use of hot water: however, in reality this is only partially true. We found that on average, on 13% of the water consumed by clothes washers is hot water. The speed of the spin cycle determines the moisture content of the clothes and the amount of energy needed to dry them. Energy savings are from the reduction in clothes *dryer* energy, therefore moisture sensors are critical.

Figure 28 shows the percentage of energy consumed by each component of the laundry system for a typical clothes washer cycle.

Figure 28. Energy Consumption by a Laundry System



Source: Korn, David and L. Mattison. "Do Savings Come Out In The Wash? A Large-Scale Study of Residential Laundry Systems." Home Energy (January/February 2012).

Under the ENERGY STAR® Appliance Program, customers who purchase an energy-efficient, ENERGY STAR-rated clothes washer between January 1, 2013 and December 31, 2013, may redeem a $30 mail-in rebate. Cadmus recommends that New Hampshire include education in its clothes washer rebate program that encourages users to properly use their clothes washer spin setting, reduce hot water usage, use their dryer moisture sensor, and use their equipment during off-peak hours. We also recommend educating consumers on the energy and cost savings from line-drying clothes, especially during the hottest summer days.

Advanced Power Strips

Advanced power strips (APSs), commonly called SmartStrip, have the capability to eliminate passive standby power from connected electronics peripherals. Passive standby energy is consumed when a product is turned off and in standby mode. The most popular APS products use a technology referred to as control or master functionality, in which a subset of outlets on the power strip are controlled by a master outlet. When that outlet is turned off, the controlled outlets are turned off as well. These types of APS products typically have several outlets that are always on and dedicated for set-top boxes, routers, and other devices that require consistent power. This ensures that the user experience is not compromised.

In addition to control type APS products, a new technology with occupancy sensing capability is beginning to enter the market. This technology differs from control products because it eliminates both passive and active standby power. Active standby power occurs when a product is still on, but is not in use. An example is a person leaving a TV on while they sleep at night. Occupancy sensing APSs have an infrared sensor that is connected to the APS and monitors motion in the room. When there is no motion for a specific amount of time, the APS turns off. There are controls on occupancy sensing APSs that allow products to be left on for extending periods of time, such as set-top boxes and routers.

APS technology is not for everyone. In order to get the full benefit of having an APS installed, homeowners need to have several electronic peripherals. If a homeowner has only a TV, they would only get minimal to no energy savings from an APS. If a homeowner has a gaming console, DVD player, home theater system, and other devices, they would be able to get high potential energy savings from their connected equipment. APS technology works best for those that have gaming consoles, audio visual equipment, and who still use older electronic technology with higher standby consumption.

Energy savings from APS technology varies based on the amount of connected devices and their efficiency. Reports completed by the New York State Energy Research and Development Authority, along with the Northeast Energy Efficiency Partnerships' *APS Data Working*, claim that an APS can save 75 kWh annually and have a measure life of 10 years. These savings are derived from master/slave configurations that do not eliminate active standby power. A new generation of APS devices that eliminate passive *and* active standby power have been reported to save between 200 kWh and 700 kWh through field testing.

The New Hampshire CORE programs offer incentives for SmartStrip through the ENERGY STAR® Appliances program. We recommend that the utilities develop a pilot for this technology to conduct field-tests of the reduction and explore methods improving the uptake and usage of SmartStrips to reduce residential plug load.

Computer Power Management

Computer power management, which automatically places inactive computers in a low-power sleep mode, can save up to $50 per desktop in energy costs, annually. Unlike for commercial computers in a server/client environment, residential computers are put to sleep by the operating system features in both PC and Mac systems. We recommend that the utilities address this measure through education in connection with other plug load efforts.

Commercial and Industrial

Energy Use and Potential Savings

Cadmus' research under Task 1 revealed the following for the C&I sector:

- C&I sector electric demand during summer weekdays peaks just before the ISO-FCM on-peak period. The highest loads in the C&I sector occur in the hours between 11:00 a.m. and 2:00 p.m. This early peak in the summer is driven by building cooling loads.

- During the ISO-NE summer on-peak hours, the weather-related (cooling) component of the summer C&I sector load is 17% of the total C&I sector load.
- The percentage of facilities with mechanical cooling systems is stable at 75% (based on PSNH survey data and EIA projections) and not expected to increase in the near future. It is expected that the C&I cooling market is saturated (i.e., those facilities without cooling equipment do not require cooling).
- A sizeable percentage of both small and large commercial facilities lack programmable controls system for their HVAC equipment. Based on surveys conducted for the 2009 NH potential study, less than 11% of small commercial buildings have programmable thermostats and less than 40% of large commercial buildings use a central HVAC control system.

The NH energy-efficiency potential study found that there is significant savings potential in New Hampshire through cost-effective electric and natural gas efficiency measures. For commercial and industrial buildings, the study showed a potential cost-effective reduction in electric consumption of more than 10% of projected C&I 2018 total electric consumption. The study estimated that energy efficiency could cost-effectively reduce commercial and industrial peak demand by up to 11% and 16%, respectively.

Statewide and across all sectors, the majority of the opportunity to reduce summer peak demand is within existing commercial and industrial facilities. Fifty-two percent of the demand reduction opportunity is in the existing commercial building market and 32% is within industrial facilities.

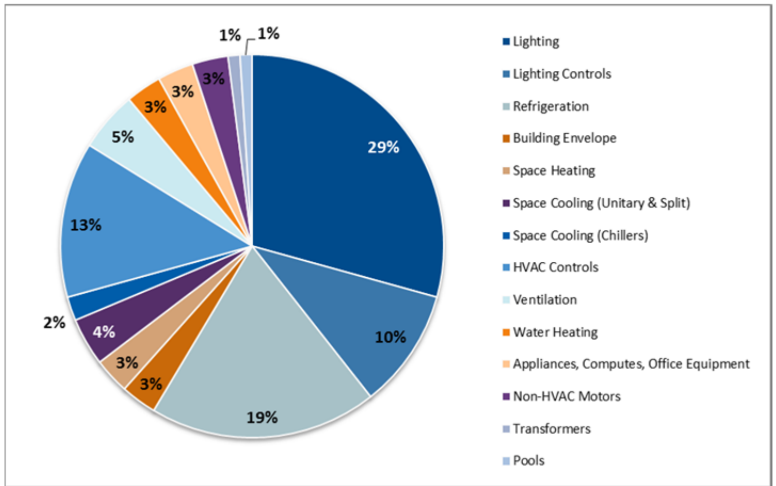
Figure 29 shows the estimated maximum achievable energy savings potential by end use for the C&I sector based on that research.

Figure 29. Maximum Achievable Commercial and Industrial Electric Savings Potential by End Use

Commercial (Existing Buildings)

32% of total potential annual electric energy savings

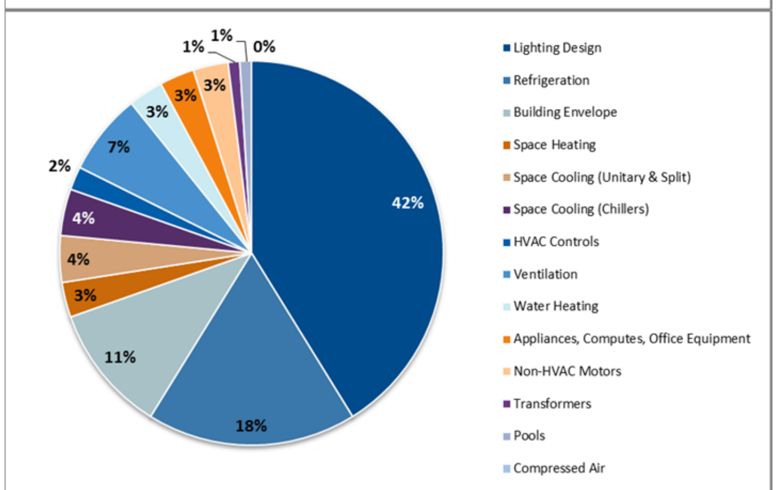
52% of potential summer on-peak demand savings



Commercial (New Construction)

3% of total potential annual electric energy savings

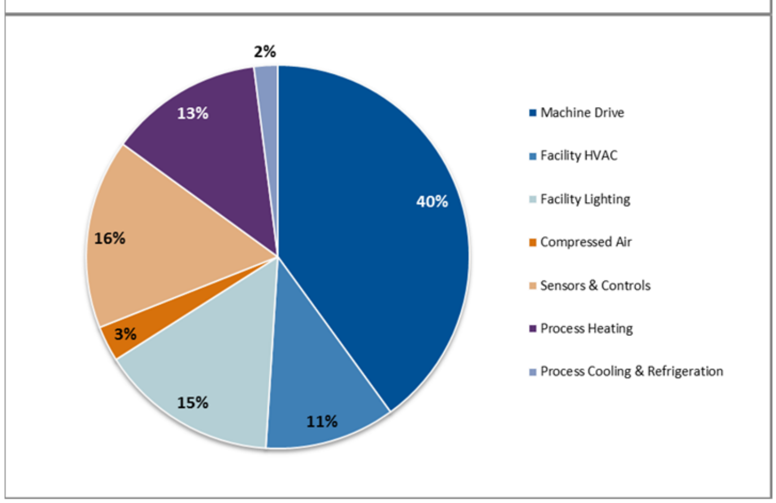
5% of potential summer on-peak demand savings



Industrial

15% of total potential annual electric energy Savings

32% of total potential summer on-peak demand savings



Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.
Note: This study did not include the impact of EISA 2007 on lighting baselines, so the energy efficiency potential for the lighting end-use is overstated.

The data show that 39% of the energy savings potential is from lighting measures, 29% from cooling and ventilation measures, and 19% from refrigeration measures. Energy-efficiency opportunities identified for cooling include HVAC controls, space cooling equipment, and building envelop measures that reduce cooling loads. It is important to note that high energy savings potential does not necessarily translate to high summer peak demand savings potential. Although this chart highlights end-uses with the highest energy-efficiency potential, some end-uses with low energy-efficiency potential may make large contributions to summer peak demand reduction.

New Hampshire Commercial and Industrial Energy Efficiency Programs

Cadmus reviewed the companies' 2013-2014 CORE New Hampshire Energy Efficiency Programs and the NHSaves.com Website to understand the existing program offerings for commercial and industrial customers. Table 8 describes the energy-efficiency programs offered to New Hampshire commercial and industrial customers in 2013-2014.

Table 8. New Hampshire C&I Energy Efficiency Programs

Program	Customer Requirements	Utilities	Description
Large Business Energy Solutions Program	Average demand > 200 kW	CORE	Promotes energy efficiency installations for new construction, major renovation, failed equipment, and retrofit markets for large customers.
Small Business Energy Solutions Program	Average demand < 200 kW	CORE	Promotes energy efficiency installations for new construction, major renovation, failed equipment, and retrofit markets for small-to-medium sized customers.
Smart Start	Commercial & Municipal	NHEC, PSNH	Promotes implementation of energy efficiency measures for commercial and municipal customers through on-bill financing. The programs pay up-front costs (purchase and installation) and recoup payment through monthly charges on the customer's electric bill.
C&I RFP Program for Competitive and Economic Development	Average annual demand > 350 kW	PSNH	Promotes market development in the EE industry by encouraging third parties to competitively bid on EE programs. The program aims to capture large C&I customers not already participating in the EE programs.
CHP Pilot		Unitil	Promotes Combined Heat and Power (CHP) installations to reduce electric energy and demand requirements.

Source: 2013-2014 CORE New Hampshire Energy Efficiency Programs. 2012.

The existing programs include prescriptive incentives to address the areas of top electric energy efficiency in commercial buildings (lighting systems and controls), and they offer technical support and custom incentives for all customers to address any end-use. However, the programs may benefit from more prescriptive options for efficiency opportunities in the commercial refrigeration and industrial markets, two areas of large energy-efficiency opportunity, as well as targeted strategies to achieve the efficiency and demand reduction potential highlighted for these key segments: C&I HVAC controls, C&I refrigeration, and industrial machine drives.

The following sections provide recommendations to reduce electric energy and peak demand consumption in the residential sector through both cooling and non-cooling measures.

Recommended Commercial and Industrial Cooling Measures

Cadmus recommends the following cooling-related measures to reduce summer cooling energy consumption and peak load:

- Building HVAC system retro-commissioning and controls
- Variable speed drives for data center CRACs
- Interval data billing analysis

HVAC Retro-Commissioning and Controls

The retro-commissioning (RCx) process improves existing building equipment and system operation and performance. RCx can resolve issues that began during a building's design and construction, as well as issues that developed over time during a building's use. RCx is a systematic process of investigating, analyzing, and optimizing the performance of building systems through identifying and implementing low- and no-cost facility improvements to ensure their continued performance. This process can generate ongoing energy and cost savings and lead to increased building efficiency.

Utility RCx programs typically target small- to medium-sized commercial and institutional facilities, aiming to achieve cost-effective energy savings through system optimization.

Cadmus recommends that the utilities offer a RCX pilot, potentially in conjunction with interval billing analysis (discussed below in the Recommended Commercial and Industrial Non-Cooling Measures section).

Variable Speed Drives on Computer Room Air Conditioners

Like virtualization, implementing variable speed drives (VSDs) in large data centers is becoming much more common. A recent Uptime Institute survey[21] indicated that 62% of larger companies had implemented or planned to install VSDs compared to only 21% of smaller companies.

Table 9 shows Cadmus' examination the cost-benefit analysis for a large scale VSD implementation project hows a Cadmus worked with eBay to examine the benefit/cost of a large scale VSD implementation.

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[21] Stansberry, Matt, and Julian Kudritzki. "Uptime Institute 2012 Data Center Industry Survey." 2012.

Table 9. Example Cost-Effectiveness of Computer Room Air Conditioner Variable Speed Drives

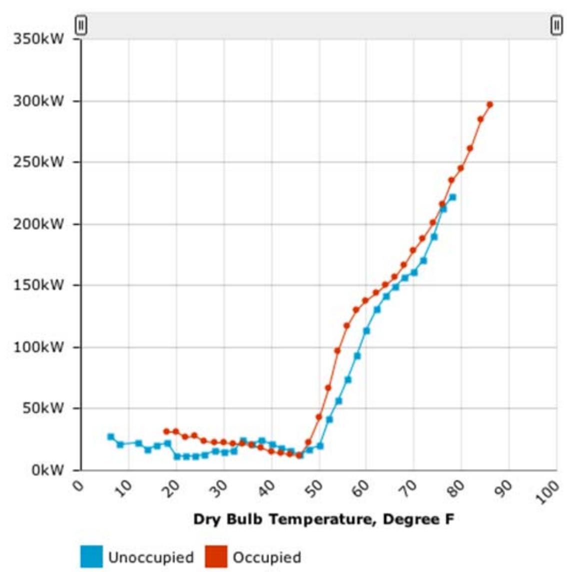
Type of Fan	Power (HP)	Efficiency	Hours of Use	Number of Units	Energy Use (kWh)
Constant Speed	10	90%	8760	83	6,026,685
Variable Speed	10	95%	8760	83	1,663,675
Energy Savings (kwh)					4,363,010
Energy Savings ($) at 6.5 cents per kWh					$ 283,596
VSD Equipment Costs					$ 341,960
Harmonic Transformer Costs					$ 338,984
VSD Installation Costs					$ 69,056
Payback					2.64
Potential incentive at 11 cents per kWh					$ 479,931
Actual incentive limited to 50% of costs or $300,000					$ 300,000
Payback with Incentive					1.59

A simple prescriptive incentive could be developed for CRAC VSDs based on the fan horsepower and an assumed conservative fan speed reduction.

Interval Data Billing Analysis

There are numerous electricity savings opportunities in most commercial buildings. Several recent software offerings allow for remote analysis of large commercial buildings at the account level. These analyses can detect unusual loads and potential problems in buildings that, if corrected, can reduce consumption and peak load. Figure 30 shows an example of a temperature response curve from one of these software offerings.

Figure 30. Commercial Building Temperature Response Curve from Remote Billing Analysis Software



Source: Sample building analysis chart from FirstFuel Rapid Building Assessment (RBA) report.

Recommended Commercial and Industrial Non-Cooling Measures

Cadmus also recommends a number of energy-efficiency measures that are not cooling related, but will served to reduce electric energy consumption and peak load. These include:

- Lighting systems and controls
- Prescriptive refrigeration
- Computer power management
- Variable speed drives
- Advanced power strips
- Emergency generator block heaters

Prescriptive Refrigeration

The potential study identified large opportunity for energy savings from refrigeration systems in commercial and industrial buildings. The Small Business Energy Solutions (SBES) program includes refrigeration controls, motors, and economizers; however, the Large Business Energy Solutions (LBES) program does not appear to include prescriptive refrigeration. This may be because refrigeration is thought of as a custom measure for larger sites.

Table 18 shows the saturation and remaining opportunity for various C&I refrigeration efficiency measures based surveys conducted by GDS Associates for the NH potential study.

Table 10. Saturation and Remaining Opportunity for C&I Refrigeration Efficiency

Sector	Measure	Saturation	Remaining Factor	Responses (N)
Large C&I	Refrigeration Economizer	0%	100%	37
	Evaporator Fan Motor Controls	0%	100%	46
	HE Evaporative Fan Motors	17%	83%	47
	Door Heater Controls	8%	92%	12
	Discuss Compressor	19%	82%	54
	Scroll Compressor	19%	82%	54
	Floating Head Pressure Control	20%	80%	40
	HE Design for large refrigeration freezer systems	14%	86%	49
	LED lighting retrofits in refrigeration end-use/display cases	2%	98%	97
Small C&I	Commercial Ice Makers	16%	84%	21
	Evaporator Fan Motor Controls	6%	94%	7
	HE Evaporative Fan Motors	2%	98%	2

Source: GDS Associates. "*Additional Opportunities for Energy Efficiency in New Hampshire.*" 2009.

The data show saturation levels less than 20% for all identified refrigeration efficiency measures, highlighting significant opportunity to improve efficiency in this market. Cadmus has observed that these measures work well for consumption savings and some peak savings. We recommend that utilities offer prescriptive measures for a variety of customer sectors and sizes ideally through a targeted refrigeration efficiency program such as the EnergySmart Grocer program.[22]

Computer Power Management

Computer power management, which automatically places inactive computers in a low-power sleep mode, can save up to $50 per desktop in energy costs, annually. For a number of years, utilities have offered an incentive between $6 and $15 per computer that is managed. The incentive pays for the customers' costs for available network software that quickly and easily activates sleep settings on all the computers in an organization. Cadmus recommends that New Hampshire adopt some of the following best practices of these programs:

- Require a minimum projected average annual savings per computer. This can be generated before activating power management by many of the network software solutions. Other utilities have required 100 to 125 kWh per year per computer in savings before offering the incentive.
- Pay only a percentage of the per-license fee for the software.
- Offer the incentive only for desktops (not laptops).
- Provide a list of approved vendors.

Table 11 outlines more information on existing computer power management programs.

[22] http://www.energysmartgrocer.org/

Table 11. Program Offerings for Computer Power Management

Utility	Incentive Amount	Minimum Average Annual Savings (kWh) per Computer	Approved List of Vendors
Austin Energy	Up to 50% of installed cost	120	No
Avista	$10 per computer	100	No
BC Hydro	$6 per computer or 75% of license cost - whichever is less	None	No
Idaho Power	$10 per computer	None	No
Manitoba Hydro	Up to 100% of installed cost; $15 per license	None	Yes
Modesto Irrigation District - Water and Power	$10 per computer	None	No
Pacific Gas and Electric	$15 per desktop computer (does not allow laptop computers)	None	Yes
Pacific Power	$7 per computer, up to 100% of software cost	None	No
Riverside Public Utilities	$15 per computer	None	No
Sacramento Municipal Utility District	$10 per license	None	No
San Diego Gas and Electric	$15 per desktop computer (does not allow laptop computers)	None	No
Silicon Valley Power	Up to 80% of project cost, $15 per desktop computer (does not allow laptop computers)	125	No
Southern California Edison	$15 per desktop computer (does not allow laptop computers)	None	No
Turlock Irrigation District Water and Power	$10 per desktop computer (does not allow laptop computers)	None	No

Variable Speed Drives

Cadmus reviewed the NH CORE program offerings for VSDs. It is well designed and does an excellent job of screening out systems that would deliver low savings (e.g., inlet vane dampers with forward curved fans). It appears that condenser water pumps are not included; however, PSNH may have intended that are included under the term "*chilled water pump.*" This should be clarified in future program offerings. Cadmus recommends that the utilities include this program in outreach to larger sites, in order to take advantage of savings. It should also be included in any retro-commissioning efforts.

Advanced Power Strips

See the residential Advanced Power Strips section for a discussion of advanced power strips. Cadmus recommends that the utilities offer a pilot for this technology that is adapted to the business environment.

Emergency Generator Block Heaters

During energy audits, Cadmus has frequently noted block heater loads of roughly 10 kW—even for emergency generators that are located in a conditioned space. We recommend that the utilities offer a pilot program to incent the addition of thermostats to these heater circuits to eliminate unnecessary heating, especially during peak summer periods. Implementing thermostats on 100 block generators could save 1 MW of peak load.

TASK 3. ANCILLARY ELECTRIC SAVINGS

This section outlines the objective, methods, and key results developed under Task 3, including identifying and quantifying the electric impacts of various non-electric energy-efficiency measures implemented through the New Hampshire programs.

Objective

Order 25,402 directs the New England M&E team to: "*develop estimates for the ancillary electricity savings associated with non-electric savings of various measures used in the HPwES program*." The Order further states that: "*ancillary electric savings from non-electric energy efficiency measures have not been quantified sufficiently*" and notes that existing estimates of such savings vary widely.

Under this task, Cadmus reviewed secondary data to develop quantitative estimates of the ancillary electric energy savings associated with weatherizing homes and from replacing HVAC and DHW systems promoted by the ENERGY STAR Appliance Program.

Method

Under this task, Cadmus used results from the 2009 HPwES impact evaluation, New Hampshire resident and utility customer survey data, and data collected from other Cadmus evaluations to develop estimates for the electric energy and demand impacts on auxiliary heating and cooling equipment due to the installation of HPwES non-electric measures.

Identify Electric Impacts

Cadmus first reviewed the potential interactive impacts of various heating, cooling, and domestic hot water (DHW) energy-efficiency measures on a household's electric equipment, and determined that the energy consumption of ancillary electric equipment is impacted only by measures that affect the home's heating, cooling, or DHW loads. Ancillary electric equipment such as furnace or air handling fans and boiler pumps are not impacted by measures which only address equipment efficiency and do not also reduce the total load.

Heating, cooling, and DHW loads, or the household's demand for heating and cooling energy, are driven by multiple household characteristics, including: envelope properties such as insulation levels, air leakage rates, and windows; internal loads such as lighting and plug loads; and occupant behavior such as occupancy rates and thermostat set points. Energy efficiency measures to reduce heating, cooling, and hot water loads must address one or more of these characteristics to impact the loads, or total demand for useful heating, cooling, and DHW energy.

Energy-efficiency measures which impact household heating, cooling, or DHW loads save energy by reducing requirements for useful energy from the equipment serving that load. In addition, load reductions may have ancillary electric impacts due to reduced equipment runtime or may impact other local equipment used to serve those loads or provide additional comfort. Table 12 shows the direct impacts and potential interactive electric impacts achieved by reductions in heating, cooling, and hot water loads.

Table 12. Direct and Ancillary Energy Impacts for Home Heating, Cooling, and DHW Load Reduction

Load	Direct Impacts	Potential Ancillary Impacts, Electric
Heating	Heating system fuel consumption	(1) Run time for heating system equipment, including furnace fans (for furnace heating systems), boiler pumps (for hot water boiler systems), or pumps (for ground or water source HP systems) (2) Use of local electric heating equipment, such as space heaters
Cooling	Cooling system fuel consumption	(1) Run time for cooling system equipment, including air handling fans (for CAC systems) or pumps (for ground or water source HP systems) (2) Run time of local cooling equipment, such as ceiling and floor fans
Domestic hot water	DHW system fuel consumption	None

Energy efficiency measures which improve the efficiency of heating, cooling, and DHW equipment save energy by using less energy to serve the same home demands for useful heating, cooling, and DHW energy. These measures – such as a high efficiency furnace, boiler, water heater, or air-conditioner – do not impact ancillary equipment because all equipment is still serving the same heating, cooling, and DHW loads.

Table 13 shows the expected summer and winter electric impacts for various categories of energy-efficiency measures implemented through the HPwES and ENERGY STAR® Appliances programs, followed by a discussion of the potential electric impacts for each measure category.

Table 13. Summary of Potential Summer and Winter Electric Impact by Measure Type

Measure Category	Description of Impact	Summer Electric Impact	Winter Electric Impact
Weatherization	Envelope improvements reduce the home's heating and cooling loads, impacting heating and cooling energy consumption. Non-electric heating systems benefit from reduced equipment runtime.	Y	Y
Non-Electric Heating Equipment	Improvements in heating equipment efficiency do not impact heating load; the equipment runtime is independent of equipment efficiency. Heating equipment does not operate in the summer.	N	Y*
Non-Electric Cooling Equipment	Improvements in cooling equipment efficiency do not impact cooling load; the equipment runtime is independent of equipment efficiency. Cooling equipment does not operate in the winter.	Y	N
Non-Electric DHW Equipment	Improvements in DHW equipment efficiency do not impact DHW load; DHW consumption and equipment runtime is independent of equipment efficiency.	N	N
Heat Pump Water Heater	Ancillary heating and cooling savings may be realized if the HPWH is in a conditioned (heated, cooled, or dehumidified) space.	Y	Y
Programmable Thermostat	Thermostats facilitate changes in heating and cooling loads.	Y/N**	Y/N**

* Ancillary electric impacts occur for upgrades to electric equipment ancillary to the non-electric heating system, such as furnace fan upgrade to ECM.

** Electric energy savings occur due to programmable thermostats only if the thermostats are used to reduce the home heating and/or cooling loads. Since energy savings are based on user behavior, impacts vary and may increase system consumption.

Weatherization Measures

The implementation of measures such as insulation and air sealing improve a home's envelope and typically results in reduced heating and cooling loads. Lower heating and cooling loads results in reduced heating and cooling fuel consumption and equipment run time.

Weatherization measures achieve electric savings through reduced demand on electric heating systems, reduced run time requirements for ancillary electric equipment on non-electric heating systems, reduced demand on cooling systems, and potential reduction in usage of secondary heating and cooling equipment such as electric heaters and ceiling or floor fans.

Non-Electric Heating Equipment

Measures that replace existing or standard-efficiency heating equipment with high-efficiency heating equipment reduce energy consumption through improved system efficiency, but have no impact on the home's heating load. Since the high-efficiency equipment is serving the same heating load as the baseline equipment, the system runtime is unchanged. Since the home heating load is unchanged, ancillary electric consumption in the home is also unaffected.

Electric savings for non-electric heating equipment is only achieved through direct efficiency improvements in the heating system equipment. This includes:

- ***Furnace fans:*** High-efficiency furnaces typically have high-efficiency furnace fans that use less energy compared to baseline furnace fans.

Since heating equipment does not operate during the summer or impact cooling load, there are no summer electric impacts for high-efficiency heating equipment.

Boiler Reset Controls

Boiler reset controls reduce heating fuel consumption by reducing the hot water set point when heating or hot water demand is low, effectively improving the efficiency of the existing HW boiler system. The controls do not impact on the home's heating or hot water load.

The run time for circulator pumps for hot water boiler heating systems is driven by the home or space heat load, not by the system hot water temperature or heating system efficiency, so there are no additional electric savings due to the implementation of boiler reset controls.

Cooling Equipment

Measures that replace existing or standard-efficiency cooling equipment with high-efficiency cooling equipment reduce energy consumption through improved system efficiency, but typically have no impact on the home's cooling load. Since the high-efficiency equipment is serving the same cooling load as the baseline equipment, the system runtime is unchanged. Since the home heating load is unchanged, ancillary electric consumption in the home is also unaffected.

Since cooling equipment does not operate in the winter or impact heating load, there are no winter electric impacts for high-efficiency cooling equipment.

Non-Electric Water Heating Equipment

Measures that replace existing or standard-efficiency water heating equipment with high-efficiency water heating equipment reduce fuel consumption through improved water heating system efficiency, but do not impact the home's consumption of hot water. Since the consumption of hot water is unchanged, the runtime of any hot water circulating pumps is also unchanged.

Heat Pump Water Heaters

A HPWH reduces the electric water heating consumption (when replacing a standard electric water heater) through improved water heating efficiency, but does not impact the home's consumption of hot water. Since the consumption of hot water is unchanged, the runtime of any hot water circulating pumps is also unchanged.

HPWHs installed in a conditioned space may impact the heating and cooling loads in that space, impacting the home's heating and/or cooling systems. HPWHs reduce space cooling load, resulting in saving for electric cooling equipment. HPWHs increase heating load, resulting in increased heating fuel consumption and heating equipment run time. HPWHs installed in an un-conditioned (not heated or cooled) space reduce the dehumidification load in that space, and may consequently decrease the energy consumption of a dehumidifier that is operated in the same space.

Programmable Thermostats

Programmable thermostats facilitate changes in a home's heating and cooling load through changing the home's heating and cooling set points and schedules. Depending on the user behavior, these changes may reduce a home's heating and cooling loads, resulting in reduced heating and cooling fuel consumption and equipment runtime.[23]

Quantify Ancillary Electric Impacts

Based on our review of the potential electric impact from various heating, cooling, and DHW measures, Cadmus developed estimates for the following electric energy and demand impacts:

- Weatherization impacts on heating equipment:
  - Furnace or air handling fans
  - Boiler hot water circulation pumps
- Weatherization impacts on cooling equipment:
  - Central air-conditioning systems
  - RAC systems
- High-efficiency furnaces with ECMs
- Heat Pump Water Heaters replacing electric water heaters

Weatherization Measures – Heating Season Impacts

Air Handling Fans

Air handling fans, more typically called furnace fans, drive heated and cooled air over a heat exchanger or evaporator cooling coil, through a home's duct systems and into occupied spaces, then draws air from the space through return ducts and returns the air to the furnace and cooling coil. The fans usually turn on after the heating and cooling system has operated for seconds or minutes to avoid sending unconditioned air to living spaces. It usually stay on for seconds or minutes after the furnace or air conditioner shuts off to avoid wasting heat or cooling capacity.

Homeowners have two options for operating their air handling fans: 1) continuous mode, usually labeled "*On*" on their thermostat, or 2) heating mode, usually labeled "*auto*" on their thermostat.

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[23] Note that use of programmable thermostats may also increase heating and cooling loads, resulting in increased system consumption and runtime.

Weatherization measures, such as insulation and air sealing, reduce a home's heating load by reducing conductive and infiltration-driven heat losses. For a non-modulating burner where the fan is operated in auto mode, weatherization will cause the fan run time to be reduced, and some electric savings will be realized. In our previous studies in other northern climates, Cadmus has found that roughly 90% of homeowners operate their fans in auto mode. A Wisconsin study[24] found that four of 31 homeowners operate their fans continuously, with an additional fan operating all winter. Cadmus used that 90% value to calculate savings for this report.

Air Handler Fan Savings

Cadmus used the following formulas to determine the electric impacts of weatherization measures on furnace fans.

Heating Consumption (kWh/year) = Average Watts * Operating Hours / 1,000

Savings (kWh/year) = Heating Consumption (kWh/year) * Savings % * % Fans in Auto Mode

Table 14 outlines the parameters we used to calculate furnace fan savings from weatherization measures, including the values and sources for each value.

Table 14. Parameters for Furnace Fan Savings due to Weatherization

Parameter	Description	Value	Source
Average Watts	Average power for a furnace fan	385 W	In a current study of 40 furnaces in Wisconsin, Cadmus found an average power draw of 385 watts.
Operating Hours	Furnace fan operating hours during heating season	1,350 hours	Cadmus determined an average seasonal run time of 1,350 hours in heating mode in current study of furnaces in Wisconsin. We also conducted a 2012 logging study in Massachusetts, which has a milder climate than New Hampshire, and found an average heating mode run time of 1,200 hours, which is consistent with the 1,350 hours for New Hampshire (a less mild climate).
Savings Percent	Percentage reduction in heating energy due to HPwES weatherization measures	18%	In our study of New Hampshire HPwES weatherization savings, Cadmus estimated a savings of roughly 18.3% of heating energy.
% Fans in Auto Mode	Percentage of furnace fans operated in AUTO mode	90%	In previous studies in other northern climates, Cadmus determined that roughly 90% of homeowners operate their fans in auto mode.

[24] State of Wisconsin, Department of Administration, Division of Energy, Residential Programs. "Electricity Use by New Furnaces, A Wisconsin Field Study." October 2003.

Boiler (Hot Water Circulation) Pumps

Boiler pumps, also called circulation pumps, circulate hot water from a boiler through the heating system, which is typically made of fin tube radiators, then back to the boiler. The boiler is set to a high point, up to 180 °F, and has a large dead band between 10 °F and 40 °F. The boiler only fires when the circulation water temperature drops below the lower temperature band. The boiler pump, however, typically operates for as long as the call for heat lasts.

Cadmus used the following formulas to determine the electric impacts of weatherization measures on boiler pumps.

Heating Consumption (kWh/year) = Average Watts * Operating Hours / 1,000

Savings (kWh/year) = Heating Consumption (kWh/year) * Savings %

Table 15 outlines the parameters we used to calculate boiler pump savings from weatherization measures, including the values and sources for each value.

Table 15. Parameters for Boiler Pump Savings due to Weatherization

Parameter	Description	Value	Source
Average Watts	Average power for a circulation pump for HW boiler heating system	36 W	In a recent potential study in Massachusetts, Cadmus determined that the average size of boiler pump motors was 1/25 horsepower. Allowing for 70% efficiency and a loading of 85% calculates to an input of 36 watts.
Operating Hours	Boiler pump operating hours	1,358 hours	Cadmus' recent study of boiler pumps determined an average run time of 1,350 hours for Electronically Commutated motor boiler pumps.
Savings Percent	Percentage reduction in heating energy due to HPwES weatherization measures	18%	In our study of New Hampshire HPwES weatherization savings, Cadmus estimated a savings of roughly 18.3% of heating energy.

Steam Boilers

Cadmus calculated no savings for the homes using steam boilers since these systems use no ancillary electric equipment.

Weatherization Measures – Cooling Season Electric Impacts

Our general method for calculating the percentage of cooling energy saved by weatherization is to run a general simulation model. This percentage will be less than the 18% estimated for heating, because a portion of cooling load is not impacted by weatherization, including solar gain from windows, latent and sensible heat load from occupants and cooking, and sensible heat load from lighting and appliances.

Due to the high saturations of CAC and RAC equipment and low saturation of mini-splits or heat pump systems for residential cooling in New Hampshire, we calculated impact of weatherization on CAC and RAC systems only.

Central Air Conditioners

Cadmus calculated savings from CACs based on the portion of cooling consumption (conductive and convective heat gain) that can be attributed to weatherization. We determined the base load from a published value of 385 full load cooling hours for the Town of Concord, which calculates to 1,050 kWh per year. Roughly 40% of the energy can be influenced by weatherization, and based on our building simulation for heating, 18% of that energy is saved through weatherization. The net average savings per house with CAC is 76 kWh.

Cadmus used the following formulas to determine the electric impacts of weatherization measures on CAC systems in New Hampshire.

Savings (kWh/year) = CAC cooling energy * %Cooling from Wx * Savings %

Table 15 outlines the parameters we used to calculate central air conditioning system savings from weatherization measures, including the values and sources for each value.

Table 16. Parameters for CAC Savings due to Weatherization

Parameter	Description	Value	Source
CAC cooling energy	Average cooling load for NH residential home with CAC	1,050 kWh/year	The base load based on a published value of 385 FLCH for Concord, NH is 1,050 kWh per year.
%Cooling from Wx	Percentage of home cooling load impacted by weatherization characteristics	40%	Based on Cadmus Manual J model
Savings Percent	Percentage reduction in heating energy due to HPwES weatherization measures	18%	In our study of New Hampshire HPwES weatherization savings, Cadmus estimated a savings of roughly 18.3% of heating energy.

Room Air Conditioners

Cadmus calculated no savings for homes with less than one RAC per every 750 square feet,[25] assuming that the air conditioner is cooling less than full load, that the run time is driven by user behavior, and that weatherization does not necessarily reduce run time. For the portion of houses with less than one RAC per every 750 square feet, we calculated savings based on published full load cooling hours, an EER of 9.9, and an assumed average capacity of 8,000 Btu/h.

25 While this method does not account for exact sizing of air conditioners, and RACs commonly come in sizes ranging from 5,000 to 8,000 Btuh or less and provide 0.75 to nearly 1.2 tons of air conditioning, an average RAC serving a space less than 750 square feet is likely not fully meeting the cooling load.

Cadmus used the following formulas to determine the electric impacts of weatherization measures on RAC units and RAC-cooled homes in New Hampshire.

RAC per unit cooling consumption (kWh/year) = RAC size / RAC EER * NH FLCH / 1000

Savings per RAC (kWh/year) = RAC per unit cooling consumption * %Cooling from Wx * Savings %

Savings per RAC home (kWh/year) = Savings per RAC (kWh/year) * RAC per home

Table 15 outlines the parameters we used to calculate room air conditioning unit and system savings from weatherization measures, including the values and sources for each value.

Table 17. Parameters for RAC Savings due to Weatherization

Parameter	Description	Value	Source
RAC Size	Average capacity (Btu/h) of RAC unit	8,000 Btu/h	Assumed
RAC EER	Average EER for existing RAC system	9.9	Average shipment weighted EER 2005 - 2013[26]
NH FLCH	Full load cooling hours for Concord, NH	385	ENERGY STAR® calculator
%Cooling from Wx	Percentage of home cooling load impacted by weatherization characteristics	40%	Based on Cadmus Manual J model
Savings Percent	Percentage reduction in heating energy due to HPwES weatherization measures	18.3%	In our study of New Hampshire HPwES weatherization savings, Cadmus estimated a savings of roughly 18.3% of heating energy.
RAC per home	Percentage reduction in heating energy due to HPwES weatherization measures	2.2	Average value for NHEC and PSNH in 2012

No Mechanical Cooling

Cadmus calculated no savings for the portion of homes shown in saturation studies to have no air conditioners.

Furnace with Electronically Commuted Motor (ECM)

The Wisconsin study conducted by Focus on Energy "ECM Furnace Impact Assessment Report Final Report: January 12, 2009" found the average savings from installation of an ECM motors is 733 kWh. This study used meter data to estimate savings when the ECM operates in continuous mode, cooling mode, and heating mode. The study used survey responses to determine behavioral changes due to

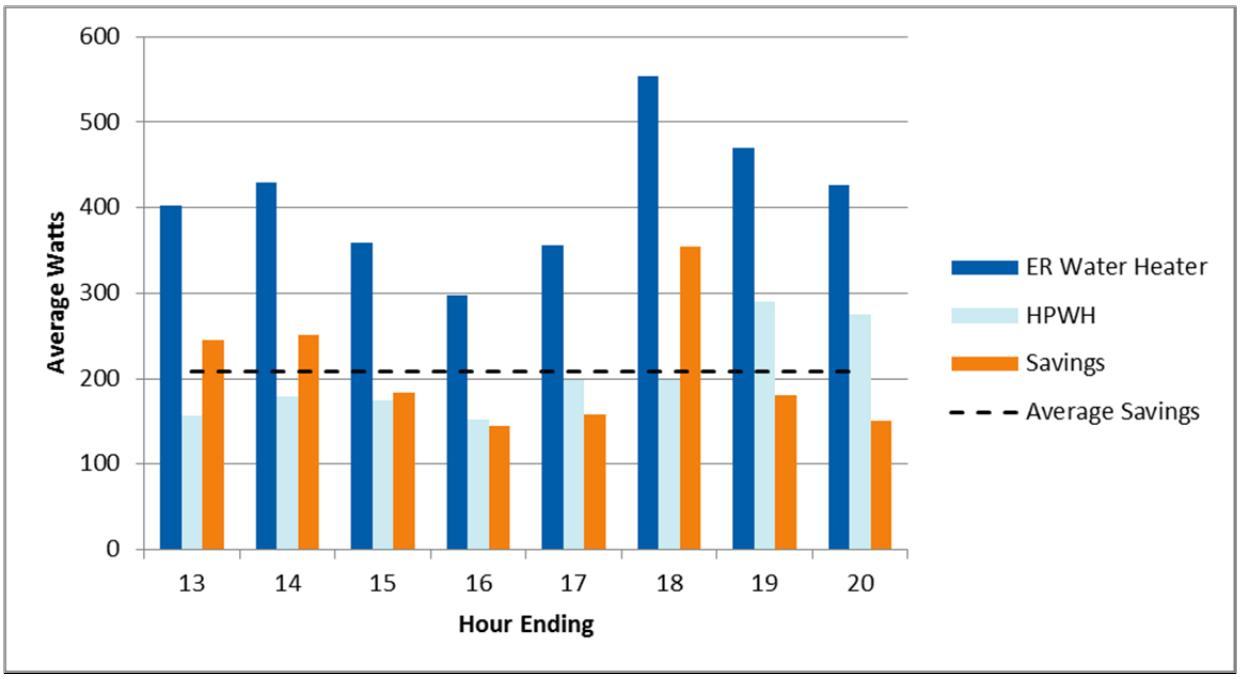
26 https://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/clothesdryers_tsd/clothesdryers_roomac_preanalysis_app8h.pdf

installation of an ECM and to determine the operation of the fan. The survey responses were used to develop the weighted average savings value of 733 kWh. Cadmus considers this the current best estimate of ECM savings.

Heat Pump Water Heaters

New heat pump water heaters (HPWH) use approximately half the energy of baseline electric water heaters. Since water heating accounts for 15% to 20% of most homes' electricity use, it could account for substantial savings. In a 2010 study, Cadmus found that HPWH saved an average of 961 kWh per year. Many HPWHs can also be programmed to not use electric resistance, and they can potentially replace a dehumidifier as well. The peak for a HPWH replacing an electric water heater savings are shown in Figure 31.

Figure 31. Peak Savings for a Heat Pump Water Heater



Source: Cadmus. *"United Illuminating Heat Pump Water Heater Pilot: Impact and Customer Acceptance Study."* June 2010.

Programmable Thermostats

In recent studies in Illinois in which Cadmus reviewed homes where summer space temperatures and air conditioning power usage was logged, we found correlation with set points and power usage as would be expected but no savings associated with the use of regular programmed set points.[27] The primary reason was that the homes with regular set points also had lower set points. As discussed under Task 2,

[27] Cadmus. Unpublished client memorandum for Illinois utility. February 2013.

we believe that web-enabled thermostats offer demand control advantages, and may offer savings, but this is best discovered with a pilot program.

Early Replacement Air-Conditioners

Table 18 shows the potential savings per unit to replace air conditioners prior to failure. The savings assume an average air conditioned size of 10,000 Btuh and average existing unit efficiency of SEER = 8.

Table 18. Calculated Savings for Early Replacement of Residential Central Air Conditioners

Parameter	Value	Source
Cooling consumption for existing AC	1,278 kWh/year	Cadmus used the published base load value of 385 full load cooling hours for the Concord, NH, and calculated this value based a SEER under 9 for older units.
SEER for new units	14	This value will depend on final program design and could be the federal minimum of 13 or higher. This value varies for existing programs across the U.S.
Cooling consumption for new AC	821 kWh/year	Cadmus used the published base load value of 385 full load cooling hours for the Concord, NH, and calculated this value based a SEER of 14 for new units.
Savings	457 kWh/year	Difference between energy consumption for existing and new unit

Results

Cadmus used secondary data to develop estimates of the electric energy and demand impacts of HPwES weatherization measures as well as the following residential HVAC measures: high-efficiency furnace with ECM, heat pump water heater, and early-replacement CAC. A summary all inputs and assumptions used in these calculations is provided in Appendix A.

Table 19 shows the estimated energy and demand impacts of weatherization measures on auxiliary electric heating system equipment and for typical cooling system equipment.

Table 19. Electric Impacts from Weatherization

Equipment Impact	Description of Impact	Annual kWh	Summer On-Peak kW	Winter On-Peak kW
Furnace fan	Reduced fan operation based on heating load reduction from weatherization measures	86	0	TBD
HW boiler circulation pump(s)	Reduced boiler pump operation based on heating load reduction from weatherization measures	9	0	TBD
Steam boiler	n/a	0	0	0
Average Heating System	*Average heating season electric impact of weatherization measures for non-electric heating system*	*55*	*0*	TBD
CAC	Reduced CAC cooling energy based on cooling load reduction from weatherization measures	77	TBD	0
RAC (per unit)	Reduced per unit RAC cooling energy based on cooling load reduction from weatherization measures	23	TBD	0
RAC (per home)	Reduced household RAC cooling energy based on cooling load reduction from weatherization measures and average units per RAC-cooled home	50	TBD	0
Average Cooling System	*Electric impact of weatherization measures for average residential cooling energy*	*34*	TBD	*0*

Table 20 shows the estimated energy and demand impacts of several DHW, furnace, and air conditioning related measures.

Table 20. Electric Impacts from HVAC and DHW Equipment

Measure	Description of Impact	Annual kWh	Summer On-Peak kW	Winter On-Peak kW
Furnace with ECM	Reduced electricity requirements for fan ECM compared to existing fan motor	733[28]	0	TBD
HPWH	Reduced electricity requirement for hot water consumption compared to standard electric heater	961[29]	0.184	0.268
Early Replacement CAC	Reduced electricity requirement for CAC cooling compared to existing inefficient CAC system	457	TBD	0

28 PA Consulting Group. "ECM Furnace Impact Assessment Report." January 2009.

29 Cadmus. "United Illuminating Heat Pump Water Heater Pilot: Impact and Customer Acceptance Study." June 2010

APPENDIX A – SAVINGS INPUTS AND ASSUMPTIONS

Parameter	Description	Value	Unit	Source	Notes
PctLoadReduction_Wx	Percentage reduction in heating energy due to HPwES weatherization measures	18%	%	[1]	In the previous study Cadmus estimated a savings of roughly 18 percent of heating energy.
FurnaceFan_AvgPower	Average power for a furnace fan	385	W	[unpublished]	Fan size varies with furnace capacity. In a recent study of 40 fans, Cadmus engineers found an average power draw of 385 W.
FurnaceFan_Hours	Annual furnace fan operating hours	1,350	Hours	[unpublished]	Cadmus found an average seasonal runtime of 1,350 hours in heating mode in an ongoing study in a northern climate. A logging study in Massachusetts, a milder climate than New Hampshire, last year, found an average heating mode run time of 1,200 hours, consistent with the 1,350 we are using here for New Hampshire.
FurnaceFan_PctAuto	Percentage of furnace fans operated in AUTO mode	90%	%	[2]	In previous studies in other northern climates, Cadmus has found that roughly 90% of homeowners operate their fans in “auto” mode.
BoilerPump_AvgPower	Average power for a circulation pump for HW boiler heating system	36	W	[unpublished]	In a recent potential study in MA, Cadmus found that the average size of boiler pump motors was 1/25 HP. Allowing for 70% efficiency and a loading of 85%, this is an input of 36W.
BoilerPump_Hours	Annual boiler pump operating hours	1,358	Hours	[3]	During a recent study by Cadmus of boiler pumps we found an average run time of 1,300 to 1,350 hours for ECM boiler pumps.
NH_CoolingkWh	Average cooling load for NH residential home	1,050	kWh	n/a	The base load based on a published value of 385 FLCH for Concord, NH is 1,050 kWh per year.
NH_CoolingkWh_old	Average cooling load for NH residential home with old (SEER=9) cooling system	1,279	kWh	n/a	The base load based on a published value of 385 FLCH for Concord, and lower SEER (10) for older units
PctCoolingLoad_Wx	Percentage of home cooling load impacted by weatherization characteristics	40%	%	[unpublished]	Roughly 40% of the energy can be influenced by weatherization. This value was determined using a Cadmus model and Manual J.
NH_FLCH	Full load cooling hours for Concord, NH	385	hours	n/a	The base load based on a published value of 385 FLCH for Concord
CAC_AvgSEERnew	Average SEER for new CAC system	14	SEER	n/a	Higher than federal minimum for a potential AC program

CAC_AvgSEERold	Average SEER for existing CAC system	9	SEER	n/a	Very worst units are SEER 8 but this is for tune up programs.
RAC_AvgEER	Average EER for existing RAC system	9.9	EER	n/a	Average shipment weighted EER 2005 - 2013
RAC_AvgSize	Average size (Btu/h) of RAC unit	8,000	Btu/h	n/a	Assumed
NH_RAC_AvgQty	Average number of RAC units per home for RAC-cooled homes	2.2	n/a	NH customer survey data	Average value for NHEC and PSNH in 2012
CoolingEqpt_PctCAC	Percentage of NH homes with CAC cooling	23%	%	NH customer survey data	Average value for NHEC and PSNH in 2012
CoolingEqpt_PctRAC	Percentage of NH homes with RAC cooling	43%	%	NH customer survey data	Average value for NHEC and PSNH in 2012
CoolingEqpt_PctNone	Percentage of NH homes with no cooling system	34%	%	NH customer survey data	Average value for NHEC and PSNH in 2012
HeatingEqpt_PctFurnace	Percentage of NH homes with furnace heating system	60%	%	NH customer survey data	Average value for NHEC and PSNH in 2012
HeatingEqpt_PctBoilerHW	Percentage of NH homes with HW boiler heating system	36%	%	NH customer survey data	Average value for NHEC and PSNH in 2012
HeatingEqpt_PctBoilerSteam	Percentage of NH homes with steam boiler heating system	4%	%	NH customer survey data	Average value for NHEC and PSNH in 2012
RAC_SummerCF	Summer on-peak coincidence factor for residential RAC	0.143	n/a	[4]	The study determined a residential AC summer on-peak coincidence factor of 0.143 for Concord, NH.

[1] Cadmus. “Impact Evaluation: New Hampshire Home Performance with ENERGY STAR® Program.” June 2011.

[2] State of Wisconsin, Department of Administration, Division of Energy, Residential Programs. “Electricity Use by New Furnaces, A Wisconsin Field Study.” October 2003.

[3] Cadmus. “*Impact Evaluation of the 2011-2012 ECM Circulator Pump Pilot Program*.” October 2012.

[4] RLW Analytics. “*Final Report, Coincidence Factor Study, Residential Room Air Conditioners*.” June 2008.

APPENDIX B – HOURLY MODEL ESTIMATION

The New Hampshire electric utilities provided historical hourly electric load data for the residential, commercial, and industrial customer classes. Cadmus combined these data into residential and commercial (C&I) sectors and developed hourly weather normalization regression models to determine the base load, cooling, and heating components of demand for each utility customer class.

We downloaded actual hourly weather data for the Concord, New Hampshire, weather station to obtain hourly temperatures coincident with the electric load data and developed heating degree hours (HDH) of bases 0 to 85, and cooling degree hours (CDH) of base h to 85.

We used these electric load and weather data to estimate hourly model specifications for each utility customer sector (s) and hour (t) and for each heating (h) and cooling (c) reference temperature:

$$kW_{std} = \alpha_{sthc} + \beta_{sth} * AVGHDH_{thd} + \delta_{stc} * AVGCDH_{tcd} + \varepsilon_{sthcd} \qquad \text{(Eq. 1)}$$

Where:

- α is the intercept or base load demand for each rate schedule (s), hour (t), each heating reference temperature(h) and cooling reference temperature (c)
- *kW* is the actual demand
- *AVGHDH* is the daily heating degree hours (base h)
- β is the heating demand per heating degree hour of base h
- *AVGCDH* is the cooling degree hours (base c)
- δ is the cooling demand per cooling degree hour of base c
- ε is the error of the model estimation

We developed models using the formula in equation 1 for each combination of customer sector (s), hour (t), day (d), heating reference temperature (h) and cooling reference temperature (c), where:

- Customer sector s=1, 2, 3, ….., 8
- Hour t=1,2,3,….,24
- Day d=1,2,3,….,n
- Heating reference temperature h=0,1, 2, 3,….,85
- Cooling reference temperature c=h, h+1,h+2,…, 85

Once all of the models were estimated for each sector, hour, and heating and cooling reference temperature ranges, we selected the model with the highest R-squared value for each hour representing the best fit to the actual hourly demand. After this step, we have the following information for the final 24 best hourly models for each sector: best model intercept, heating slope, heating reference temperature, cooling slope, and cooling reference temperature.

The final best-fit set of models for each sector predicts the hourly electric load based on weather, using the formula:

$$kWpred_{st} = \alpha_{st} + \beta_{st} * \overline{AVGHDH}_{th} + \delta_{st} * \overline{AVGCDH}_{tc} \quad \text{(Eq. 2)}$$

Where:

- α is the intercept or base load demand for each rate schedule (s), hour (t)
- kWpred is the model predicted demand
- AVGHDH is the average daily heating degree hours (best base h)
- β is the heating demand per heating degree hour of best base h for sector s and hour t
- AVGCDH is the average cooling degree hours (best base c)
- δ is the cooling demand per cooling degree hour of best base c

To disaggregate the predicted base load, heating, and cooling demand estimates for each sector (s) and each hour (t), we split the model into three components:

$$Base\ Load\_pred\ kW_{st} = \alpha_{st} \quad \text{(Eq. 3)}$$

$$Heating\_pred\ kW_{st} = \beta_{st} * \overline{AVGHDH}_{th} \quad \text{(Eq. 4)}$$

$$Cooling\_pred\ kW_{st} = \delta_{st} * \overline{AVGCDH}_{tc} \quad \text{(Eq. 5)}$$

To disaggregate the load into each component, we multiply the load by the associated average degree days for any hour or time period. We combined the components to determine the total predicted hourly demand for any hour or time period as follows:

$$Total\_predkW = Base\ Load\_pred\ kW + Heating\_pred\ kW + Cooling\_pred\ kW \quad \text{(Eq. 4)}$$

We used the models to predict hourly total demand and hourly cooling demand and then summed the total energy and cooling energy for the following periods:

- Annual (8,760 hours)
- Summer weekdays (Hours 1-24 on weekdays in June-August)
- Summer on-peak hours (Hours 14-17 on weekdays in June-August)
- Peak day (Hours 1-24 on the peak day)
- Peak day on-peak hours (Hours 14-17 on the peak day)
- Peak hour (Hour 17 on the peak day)