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Central Electric Power Cooperative, Inc.
Manufactured Home Study
Final Report

February 23, 2012

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Executive Summary

Central Electric Power Cooperative, Inc. (CEPCI) started an energy efficiency research and development program for manufactured homes across their service territory in 2010. CEPCI received American Recovery and Reinvestment Act (ARRA) funding through the South Carolina Energy Office for this project. As part of this program, CEPCI has replaced 200 heating and air conditioning units, 200 roofs, performed weatherization measures on 79 customers, and provided 400 energy efficient appliances (2 appliances each) to 200 customers. In addition, CEPCI provided power monitors to a group of 300 homes. Manufactured home customers that were not selected for upgrades were selected to serve as a control group. GoodCents monitored 30 customers in the HVAC replacement group, 30 customers in the roof replacement group, 30 customers in the appliance replacement group, and 29 customers in both the weatherization group and control group for M&V and energy savings analysis.

GoodCents used a combination of HOBO data loggers and Watt's Up? Pro devices to record air conditioning and heating loads, as well as the appliance loads for the appliance replacement program.

Appliance Replacement

Each customer participating in the appliance replacement study received a combination of two of the following new ENERGY STAR appliances: a refrigerator, washing machine, dishwasher, or freezer. The original appliances were monitored for 2 months prior to replacement to allow for baseline data to be collected. The new energy efficient appliances were installed during the middle of February. All metering devices were removed at the end of April which provided over 2 months of post replacement data.

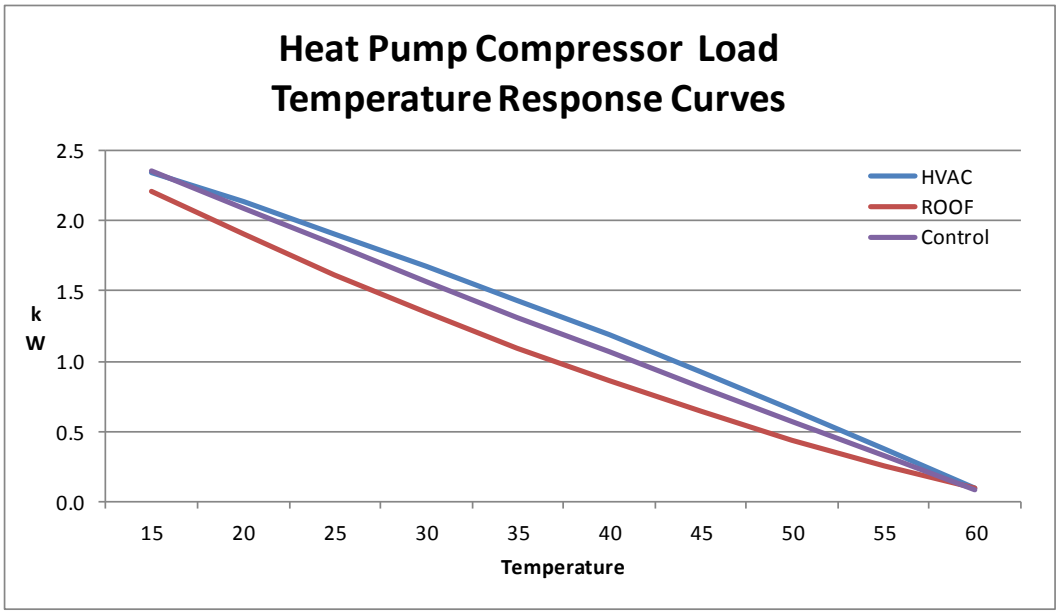
The following table shows a summary of energy savings resulting from the appliance replacement program.

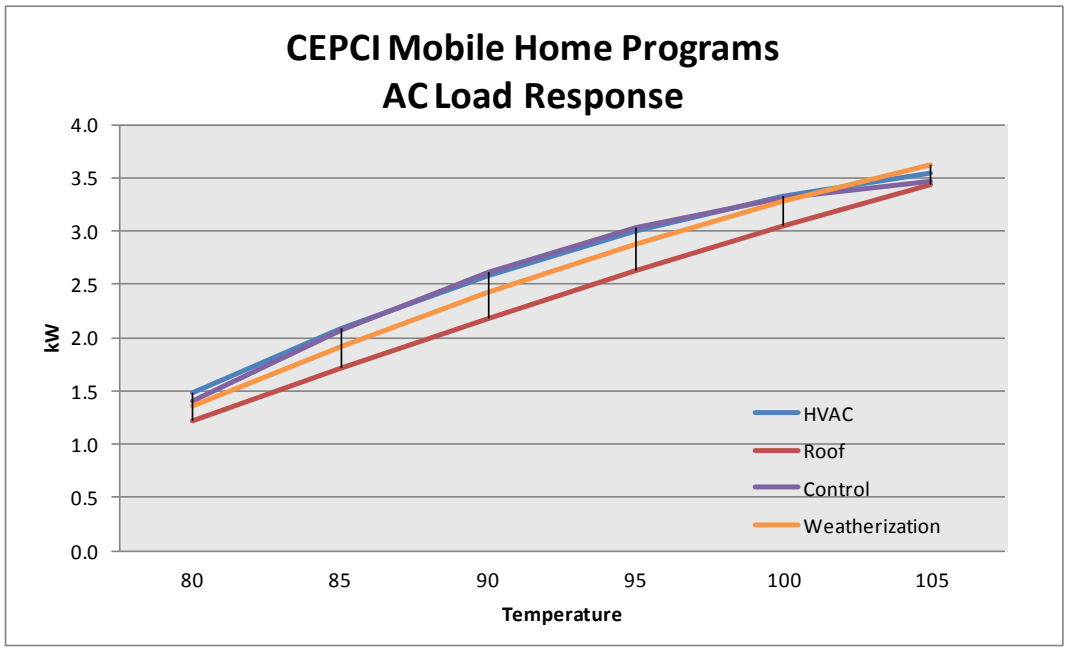
Summary Savings Table - All Appliance Replacement							
Appliance	Daily kWh Old Appliance	Daily kWh New Appliance	Daily kWh Savings	Percent Savings	Annual kWh Savings	Average Appliance Price	Estimated Years to Payback
Refrigerator	2.33	1.46	0.87	37.4%	319	$544.28	14
Freezer	1.37	1.07	0.20	14.6%	73	$325.27	17
Washer	0.32	0.20	0.12	36.6%	42	$368.88	35
Dishwasher	0.59	0.31	0.28	47.5%	102	$185.44	13

GoodCents found that dishwasher replacement produces the largest percent savings, at 47.5%, and has the shortest estimated years to payback, 13 years. Refrigerator replacement produces the second largest percent savings, 37.4%, and has the second shortest payback of 14 years. Freezers show a 14.6% savings, with a payback of 17 years. The longest payback is the washing machine, which would take 35 years and has an average savings of 36.6%. We are generally under-estimating the payback for washing machines since customers are probably using less hot water with the new washers, allowing their water heater usage to be less. This will reduce their water bill and their water heater kWh, neither of which were considered in this analysis.

Weather Sensitive Programs

Customers participating in weather sensitive programs (HVAC replacement program, the roof replacement program, the weatherization program) as well as the control group, have both their air conditioning compressor and their heat strips monitored. GoodCents provided heating and cooling load shapes for each customer group, as well as a peak day analysis for both the winter and summer seasons. GoodCents developed cross sectional models for each season and each customer group to show the load response to temperature. The weather response graphs are shown below.





GoodCents conducted a billing comparison and years to payback analysis in order to determine the savings resulting from each of the weather sensitive programs. The table below shows the average payback calculated for the HVAC replacement program.

	Years	N
Average Payback	10.72	145
Average Payback for Split Unit	11.21	82
Average Payback for Package Unit	9.04	19

Overall Total Number of Customers	Payback Range in Years
32	0 to 5
61	5 to 10
25	10 to 15
15	15 to 20
12	20 and Up

The average payback was 10.72 years (5,212 kWh per year) with 11.21 years for split units and 9.04 years for package units. Most customers showed a payback of less than 15 years. Few customers had a payback of more than 20 years. There were 33 customers that showed no payback; their usage was greater after the unit was replaced. This could be due to lifestyle or behavior change.

A total of 119 out of 182 Broad River, Mid-Carolina, and Horry Electric Cooperative roof replacement customers with available data showed positive payback. These customers averaged 24.23 years of annual energy savings (2,716 kWh on average at 11.62 cents per kWh) to pay back the average roof replacement cost of $6,333.00. Sixteen customers had a payback period less than 10 years and 28 customers had a payback between 10 and 15 years.

A total of 34 out of 65 Berkeley and Black River Electric Cooperative weatherization customers with available data showed positive payback. These customers averaged 10.65 years of annual energy savings (5,565 kWh on average at 11.62 cents per kWh) to pay back the average weatherization cost of $5,500. Six customers had a payback period less than 5 years and 15 customers had payback in less than 10 years.

CEPCI conducted a power monitor program in 2010 and 2011, allowing participants access to their home's energy use for one full year via an in-home display. Three electric cooperatives participated in this program, allowing for a total of 300 participants within the program. In Laurens Electric Cooperative, 44 out of 116 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 2.09 years of annual energy savings (1,851 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $189.

In Pee Dee Electric Cooperative, 32 out of 49 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 7.40 years of annual

energy savings (2,205 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $864.

In Edisto Electric Cooperative, 69 out of 125 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 1.56 years of annual energy savings (2,545 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $166. The payback for all 145 customers in all three electric cooperatives averaged 3.01 years of annual energy savings. Sixty customers had a payback period of less than one year.

GoodCents conducted regression analysis using the control group data to calculate energy savings. We found that if an average control group customer's heat pump was replaced with a higher efficiency heat pump, assuming normal weather, this customer would save about 1,466 kWh per year. If a control customer with an electric furnace replaced it with a high efficiency heat pump, they would see an annual kWh savings of 4,344. The roof replacement heat pump customers are saving 2,291 kWh annually when compared to the control group. The roof replacement electric furnace customers are saving 2,565 kWh annually. Weatherization customers are saving 179 kWh annually when compared to the control group.

Introduction

Central Electric Power Cooperative, Inc. (CEPCI) started an energy efficiency research and development program for manufactured homes across their service territory in 2010. CEPCI received a grant from the South Caroline Energy Office to complete this project. Funding was provided by the American Recovery and Reinvestment Act (ARRA). As part of this program, CEPCI has replaced 200 heating and air conditioning units, 200 roofs, performed weatherization measures on 200 customers, and provided 400 energy efficient appliances (2 appliances each) to 200 customers. In addition, CEPCI performed home energy audits on a group of 300 manufactured homes, which now serves as a control group.

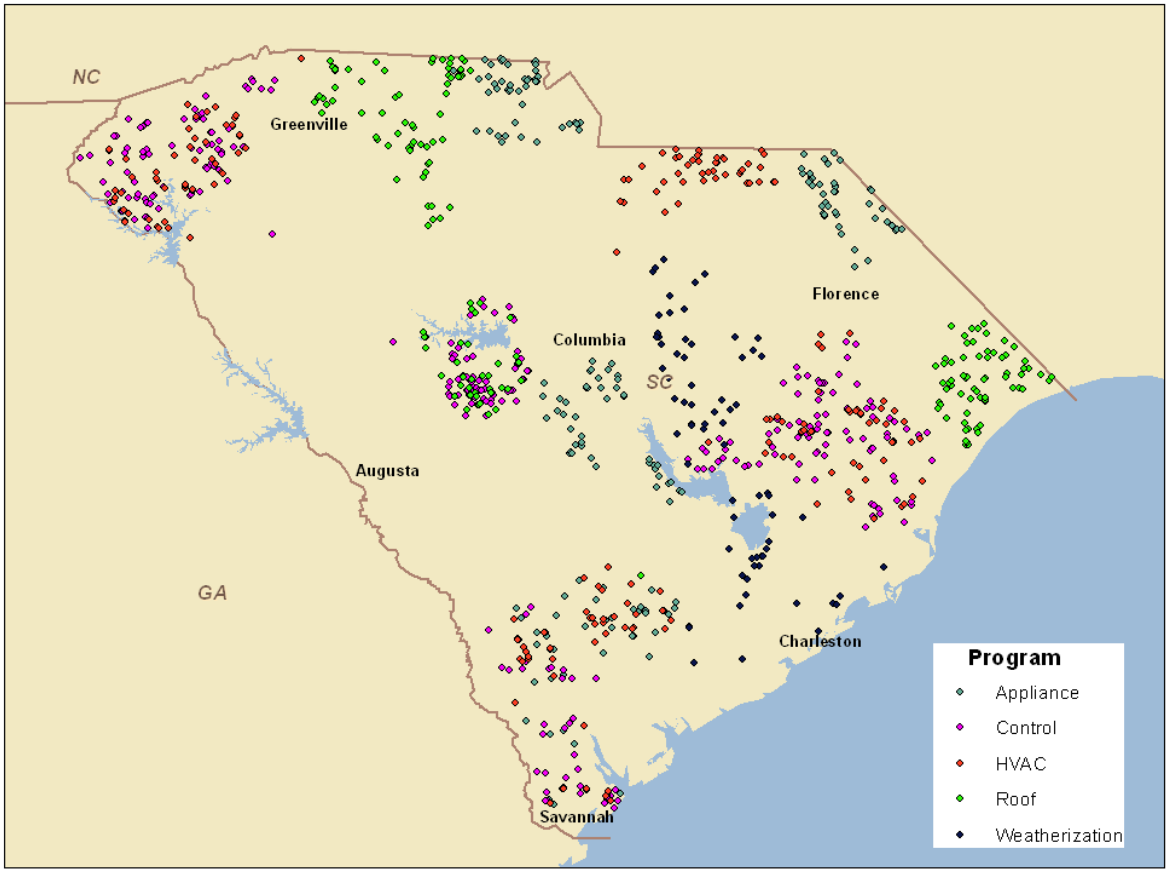
CEPCI hired an independent contractor to conduct quality assurance checks throughout the entirety of the Manufactured Home Research and Development Program. The contractor has held a residential building license for 27 years in the state of South Carolina. The contractor is a certified Home Energy Rater with the Residential Energy Services Network and a certified Building Performance Institute Building Analyst. Additionally, the contractor has an AP, Building Design and Construction certification from Leadership in Energy and Environmental Design.

The contractor was instrumental in providing exceptional customer service and quality assurance. He was able to quickly assess and provide CEPCI with eyes on the ground. The contractor visited and inspected 100% of the homes that received upgraded HVAC systems and roof replacements. The contractor visited and inspected 30% of the homes participating in the appliance replacement program. The contractor also evaluated 10% of the audits performed.

BPI audits were performed on 722 of the 1,480 homes in the study. This allowed CEPCI to have a complete understanding of the home and assist with the analysis of the project.

The following map shows the location of each home participating in the Manufactured Home Research and Development Program.

CEPCI Manufactured Housing Pilot Program Total Population



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CEPCI contracted with GoodCents to conduct measurement and verification (M&V) on the manufactured home energy efficiency program. The following report provides a detailed overview of the manufactured home energy efficiency program, the installation of monitoring devices on a sample of participants' homes, the data collected during the course of the one year-long study, and the energy savings resulting from each of the measures installed as part of the program.

The M&V Sample

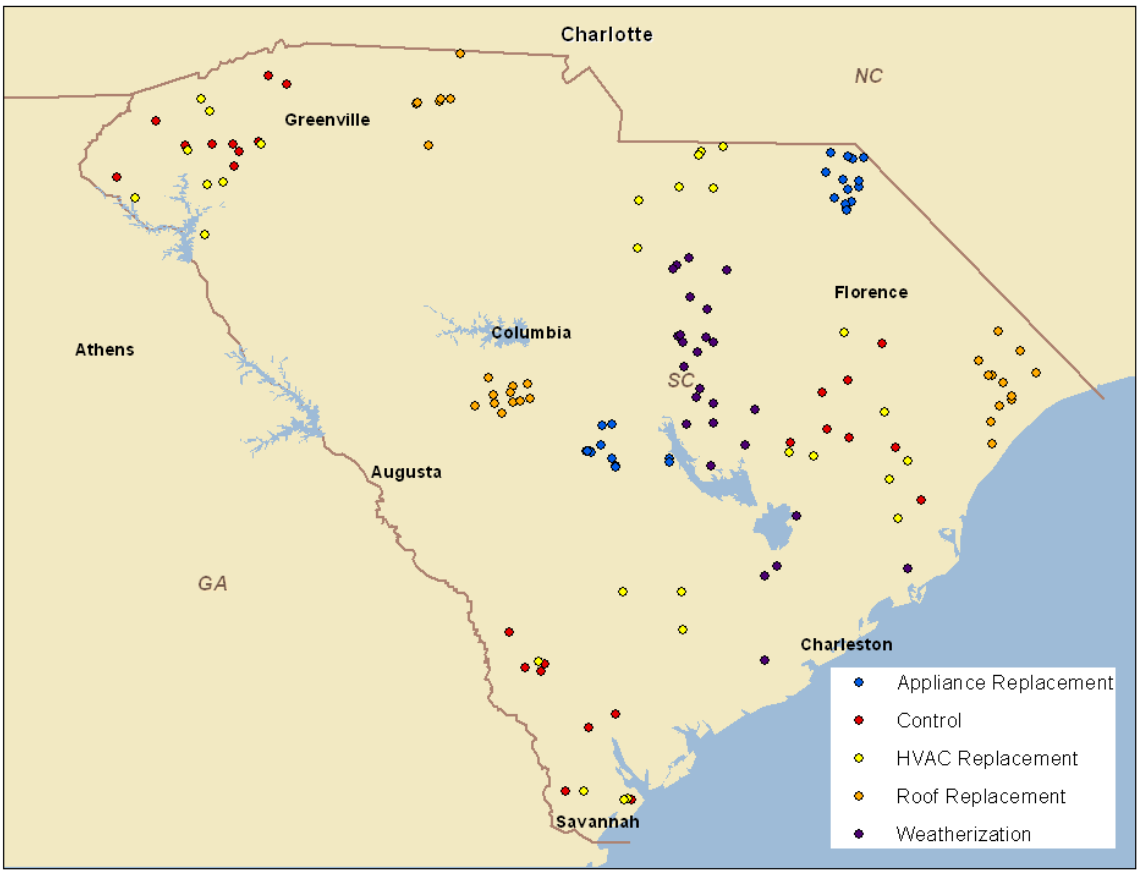
GoodCents determined that a sample of 30 M&V customers per energy efficiency measure was statistically significant for providing the energy savings resulting from the program. Control group and HVAC replacement customers were chosen to participate in the M&V portion of the program based on their electric cooperative, the size of their home, and the number of occupants within their home to ensure an accurate representation of the manufactured home population. The following table provides the allocation determined for the HVAC M&V sample.

Proposed Sample Allocation for CEPCI HVAC Program								
Distribution Cooperative	Number of HVAC Installs	M&V Allocation	Breakdown by Type & Occupancy					
			Single Wide			Double Wide		
			1-2 Occ	3-4 Occ	>= 5 Occ	1-2 Occ	3-4 Occ	>= 5 Occ
Blue Ridge	50	8	1	1	1	2	2	1
Santee	50	8	1	1	1	2	2	1
Lynches River	50	8	1	1		2	2	1
Palmetto	25	4	1			1	1	1
Coastal	25	3	1			1	1	
Total	200	31	5	3	2	8	8	4

Appliance customers were selected for M&V participation by CEPCI. Roof replacement customers were selected for M&V participation based on completion date. Weatherization customers were selected by best fit for M&V participation. Many customers participating in the weatherization customers were not eligible for M&V participation due to the lack of central air conditioning or the lack of a functioning air conditioning system.

As a part of the manufactured home study, 30 homes from each group were monitored for data collection and measurement and verification analysis. The map below shows the distribution of all 149 homes currently monitored throughout the service territory (30 Appliance Replacement, 29 Control, 30 HVAC Replacement, 30 Roof Replacement, and 29 Weatherization customers).

Distribution of M&V Customers



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Billing data is used to compare energy usage before the energy efficient measure was completed to heating and air conditioning data collected after the energy efficient measure for customers in the HVAC replacement, roof replacement, and weatherization groups. The appliance replacement customers were monitored for two months before and after the replacement, allowing for a direct comparison.

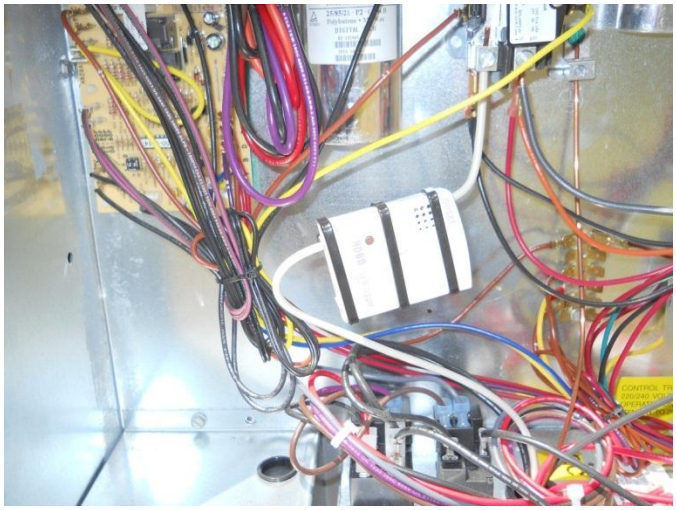
Monitoring Equipment

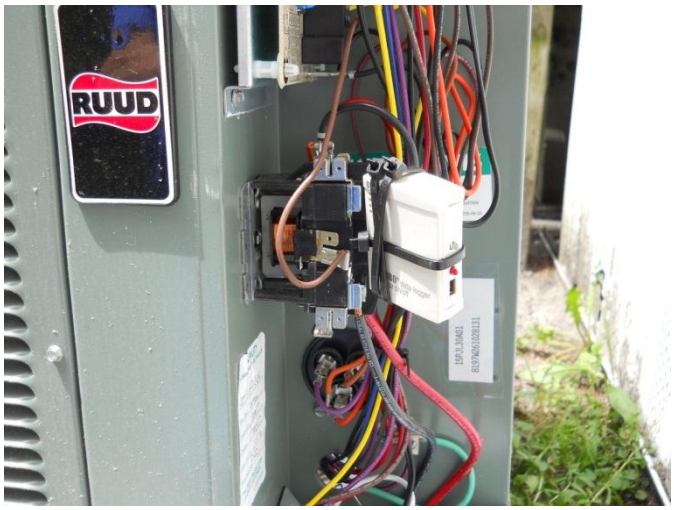
GoodCents selected two types of monitoring equipment to use for data collection. HOBO data loggers were used to monitor air conditioning and heating loads for the weather sensitive programs (HVAC replacement, roof replacement, weatherization, and control). Watt's Up? Pro devices were used to monitor the non-weather sensitive appliances.

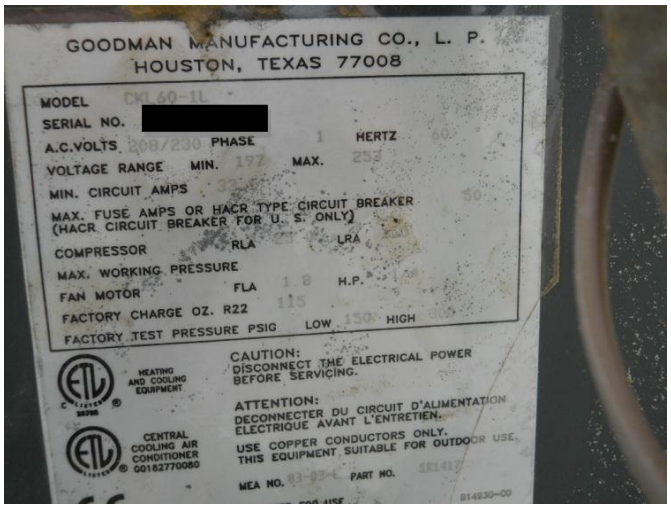
HOBO Data Loggers

HOBO meters were used to collect air conditioning and heating loads for M&V customers in the HVAC replacement group, the roof replacement group, the weatherization group, and the control group. Two HOBO devices were installed at each participants home; one on the compressor, the other on the heat strips.

HOBO meters allow for larger sample sizes and lower metering costs. HOBO meters are small data recorders that mount directly to the power leg on the air conditioning compressor. The HOBO meter senses the electrical field when the air conditioning compressor is turned on and then stores date and time stamps, as well as motor status. The meter stores an additional date and time stamp and motor status when the unit turns off. The pictures below show HOBO loggers installed at several customers' homes.







At the time of installation, a small audit is completed in order to gather nameplate information from the compressor and air handler, as well as any other pertinent customer information that may have an impact on the energy savings found. The air conditioning name plate information is then used to

determine the maximum kW load, or connected load, for each participant. The connected is load is then used to convert run time data into load data. The picture above on the bottom right shows the nameplate of an air conditioning unit participating in the program.

Watt's Up? Pro Devices

GoodCents installed Watt's Up? Pro devices on the existing appliances for customers participating in the appliance replacement program to gather data for two months. The devices were then moved to the new energy efficient appliances for the remainder of the program.

The Watt's Up? Pro simply plugs into an electrical outlet, and then allows for the appliance to be monitored to be plugged into the device itself. The Watt's Up? Pro allows the user to select the interval at which data is collected. The Watt's Up? Pro stores interval data internally, allowing data to be collected using a USB interface. A picture of the Watt's Up? Pro is shown to the right.

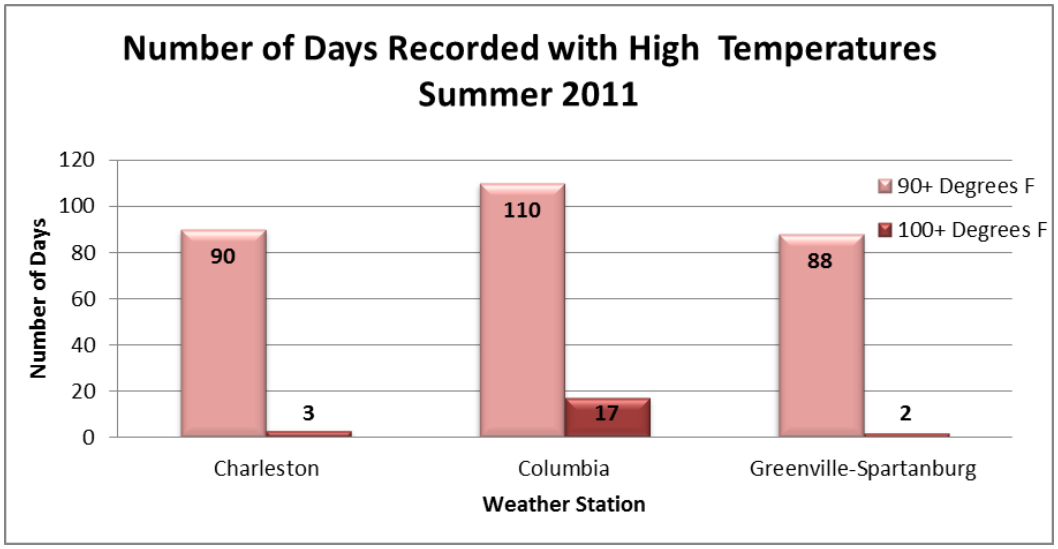
At the time of installation, a small audit is completed in order to gather appliance nameplate information.

Data Collection

Data collection for both the HOBO meters and the Watt's Up? Pro devices is manual. A technician collected data from each device on a 4 to 6 week rotation. The collected data files were sent to GoodCents headquarters for processing. The data is then reviewed and verified by GoodCents research analysts. The following report provides a summary of the data collected during the course of the program, as well as the energy savings resulting from each energy efficient measure included in the program.

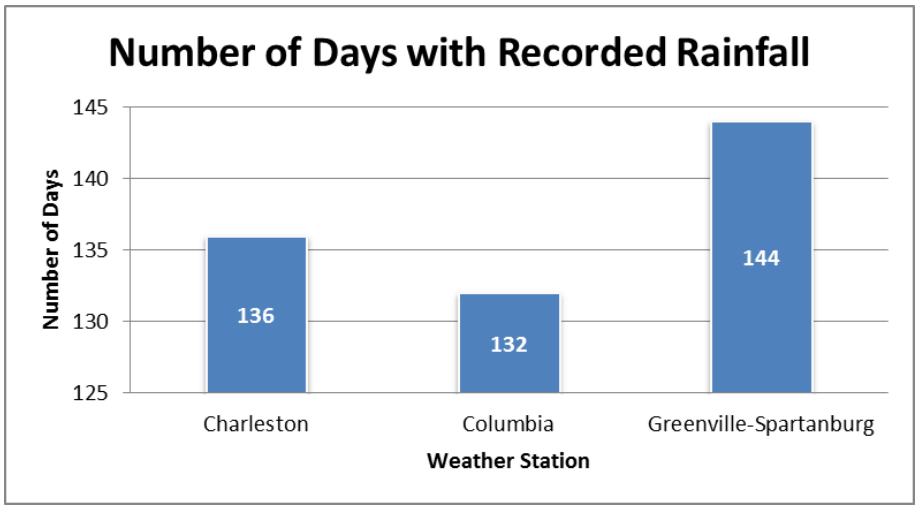
Weather Review

Manufactured Home program participants were located all across the state of South Carolina. Many of the energy efficient measures conducted as part of the program are weather sensitive. South Carolina experienced temperatures that were slightly cooler than normal in December of 2010 and January of 2011. However, South Carolina experienced a slightly warmer than normal summer in 2011. The following graph shows the number of days between October 2010 and October 2011 with recorded temperatures higher than 90 degrees F and 100 degrees F for three weather stations in South Carolina.



Columbia, South Carolina recorded 17 days with temperatures 100 degrees F or above during the summer of 2011.

Rainfall totals recorded in the first six months of 2011 were lower than normal. However, August and September recorded higher than normal rainfall amounts. The graph below shows the number of days between October 2010 and October 2011 with recorded rainfall.



The majority of energy efficient measures completed as part of the manufactured home study are weather sensitive. Therefore, the data collected was weather normalized to determine actual energy savings resulting from each of the weather sensitive programs.

Appliance Replacement Program

A total of 200 customers participated in the appliance replacement program, with 30 customers monitored for analysis. Each customer participating in the appliance replacement study received a combination of two of the following new ENERGY STAR appliances: a refrigerator, washing machine, dishwasher, or freezer. The original appliances were monitored for 2 months prior to replacement to allow for baseline data to be collected. The new energy efficient appliances were installed during the middle of February. All metering devices were removed at the end of April which provided over 2 months of post replacement data. The focus of this analysis is the energy savings that the new appliances provided.

The table below lists the 30 monitored appliance replacement customers, whether their home is single-wide or double-wide, their electric cooperative, whether they had a Watts Up? Pro or HOBO device installed on the appliance, the installation date of the monitoring equipment, which appliances were replaced, and the date of the replacement.

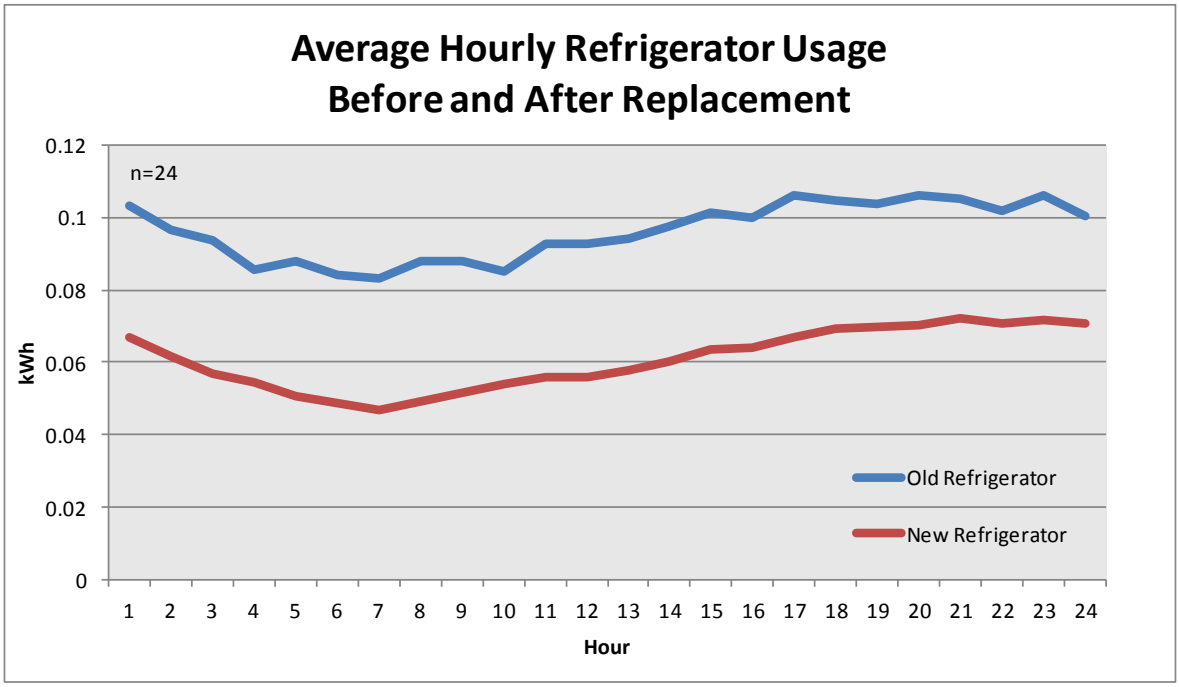
CEPCI MH Appliance Customers						
Sitename	Type	Cooperative	Device	Metering Device Install Date	Appliance Replaced	New Appliance Install Date
1	Single	Marlboro	Watts Up	12/10/2010	Fridge, Washer	2/18/2011
2	Double	Marlboro	Watts Up	12/10/2010	Fridge, Dishwasher	2/19/2011
3	Double	Marlboro	Watts Up	12/10/2010	Fridge, Washer	2/19/2011
4	Single	Marlboro	Watts Up	12/10/2010	Fridge, Freezer	2/18/2011
5	Single	Marlboro	Watts Up	12/10/2010	Fridge, Freezer	2/17/2011
6	Single	Marlboro	Watts Up	12/11/2010	Fridge, Freezer	2/19/2011
7	Single	Marlboro	Watts Up	12/11/2010	Fridge, Washer	2/18/2011
8	Single	Marlboro	Watts Up	12/11/2010	Fridge, Freezer	2/17/2011
9	Double	Marlboro	Watts Up	12/11/2010	Fridge, Washer	2/17/2011
10	Double	Marlboro	Watts Up	12/11/2010	Fridge, Washer	2/19/2011
11	Double	Marlboro	Watts Up	12/13/2010	Freezer, Washer	2/17/2011
12	Single	Marlboro	Watts Up	12/13/2010	Fridge, Freezer	2/17/2011
13	Double	Marlboro	Watts Up	12/13/2010	Freezer, Washer	2/18/2011
14	Single	Marlboro	Watts Up	12/13/2010	Washer, Freezer	2/18/2011
15	Double	Marlboro	Watts Up	12/13/2010	Fridge, Freezer	2/19/2011
16	Double	Tri-County	Watts Up/HOBO	12/14/2010	Fridge, Washer	2/15/2011
17	Single	Tri-County	Watts Up/HOBO	12/14/2010	Fridge, Washer	2/14/2011
18	Single	Tri-County	Watts Up	12/14/2010	Fridge, Washer	2/14/2011
19	Double	Tri-County	Watts Up	12/14/2010	Fridge, Washer	2/15/2011
20	Double	Tri-County	Watts Up	12/6/2010	Fridge, Freezer	2/14/2011
21	Double	Tri-County	Watts Up	12/6/2010	Washer, Freezer	2/15/2011
22	Double	Tri-County	Watts Up	12/6/2010	Fridge, Freezer	2/14/2011
23	Double	Tri-County	Watts Up	12/6/2010	Fridge, Freezer	2/14/2011
24	Double	Tri-County	Watts Up	12/7/2010	Fridge, Freezer	2/15/2011
25	Double	Tri-County	Watts Up	12/7/2010	Freezer, Dishwasher	2/15/2011
26	Double	Tri-County	Watts Up	12/7/2010	Fridge, Washer	2/16/2011
27	Double	Tri-County	Watts Up/HOBO	12/8/2010	Washer, Dishwasher	2/16/2011
28	Single	Tri-County	Watts Up/HOBO	12/8/2010	Fridge, Washer	2/16/2011
29	Single	Tri-County	Watts Up/HOBO	12/8/2010	Washer, Dishwasher	2/16/2011
30	Single	Tri-County	Watts Up	12/8/2010	Fridge, Washer	2/16/2011

Refrigerator Replacement

Of the 30 customers participating in the Appliance Replacement Program, 24 received a new refrigerator. The average refrigerator usage for the old refrigerator and the new refrigerator by day of the week is shown in the table to the right. The average daily usage has decreased by nearly 1 kWh since the old refrigerator was replaced by a new energy efficient refrigerator. The refrigerator usage continues to be relatively constant all week long, but is slightly higher on Sundays. This could be due to customers cooking and doing their grocery shopping on weekends, which leads to opening the door frequently and adding warm food to the refrigerator.

Average Refrigerator Use By Day of Week in kWh		
Day of Week	Old Refrigerator	New Refrigerator
Sunday	2.37	1.38
Monday	2.18	1.34
Tuesday	2.23	1.37
Wednesday	2.26	1.32
Thursday	2.24	1.31
Friday	2.23	1.27
Saturday	2.25	1.33
Average	**2.25**	**1.33**

The following graph shows the average hourly usage for the refrigerators in the homes of the appliance replacement group of customers before the appliance was replaced and after the appliance was replaced.



In the graph above, a decrease in usage is shown between the old refrigerator and the new energy efficient refrigerator. With the new energy efficient refrigerator, there is close to a 0.03 kWh reduction in usage per hour.

The table below shows the type, cubic feet, and daily kWh of both the old and new refrigerator, as well as the price of the new refrigerator. It also includes any savings in kWh from the new appliance and the payback in years.

Refrigerator Replacement Customer Table with Years to Payback Calculation											
Old Refrigerator					New Refrigerator					Results	
Refrigerator Type	Age	Cubic Feet	Icemaker	Daily kWh	Refrigerator Type	Cubic Feet	Icemaker	Daily kWh	Price	Daily Savings in kWh	Years to Payback (11.62 Cents per kWh with 3% Annual Increase)
TOP	> 10 years	18	N	1.12	TOP	18	Y	1.29	$ 500.68	-0.17	
TOP	> 10 years	18	N	2.86	TOP	18	Y	1.84	$ 500.68	1.02	10
TOP	> 10 years	16	Y	2.44	TOP	18	Y	0.95	$ 500.68	1.49	7
TOP	5 - 10 years	22	Y	1.71	TOP	22	Y	1.48	$ 500.68	0.23	32
SIDE-BY-SIDE	> 10 years	20	Y	4.23	SIDE-BY-SIDE	22	Y	1.60	$ 774.05	2.62	6
TOP	> 10 years	18	N	2.82	TOP	18	Y	1.10	$ 500.68	1.72	6
TOP	1 - 5 years	18	Y	2.18	TOP	18	Y	1.75	$ 500.68	0.43	20
TOP	5 - 10 years	18	N	1.03	TOP	18	N	1.26	$ 413.97	-0.23	
TOP	> 10 years	18	N	2.16	TOP	18	N	0.97	$ 413.97	1.18	7
SIDE-BY-SIDE	5-10 years	21	N	1.70	SIDE-BY-SIDE	22	Y	1.58	$ 774.05	0.11	60
TOP	> 10 years	14	N	2.46	TOP	18	N	1.26	$ 413.97	1.20	7
SIDE-BY-SIDE	> 10 years	22	Y	2.65	SIDE-BY-SIDE	22	Y	1.59	$ 774.05	1.06	14
SIDE-BY-SIDE	5 - 10 years	25	Y	2.56	SIDE-BY-SIDE	22	Y	1.58	$ 774.05	0.98	15
TOP	> 10 years		Y	0.84	TOP	18	N	1.15	$ 413.97	-0.32	
SIDE-BY-SIDE	> 10 years	19.6	Y	4.77	SIDE-BY-SIDE	22	Y	2.42	$ 774.05	2.34	7
TOP	> 10 years	18	N	1.93	TOP	18	N	0.98	$ 413.97	0.95	9
TOP	> 10 years	28	N	3.33	TOP	22	N	1.00	$ 413.97	2.34	4
TOP	> 10 years	15	N	1.51	TOP	18	N	1.07	$ 413.97	0.44	17
SIDE-BY-SIDE	> 10 years	20	Y	3.37	SIDE-BY-SIDE	22	Y	1.40	$ 774.05	1.97	8
SIDE-BY-SIDE	> 10 years	20	Y	2.78	SIDE-BY-SIDE	22	Y	1.62	$ 774.05	1.16	13
TOP	> 10 years	18	N	2.08	TOP	18	N	1.02	$ 413.97	1.05	8
TOP	> 10 years	14	N	1.88	TOP	18	N	1.38	$ 413.97	0.50	16
TOP	5 - 10 years	18	Y	1.50	TOP	18	Y	2.47	$ 500.68	-0.97	
TOP	> 10 years	16	N	2.13	TOP	18	N	2.24	$ 413.97	-0.11	
Average Daily kWh Before				2.33	Average Daily kWh After			1.46	Average Cost	Average Savings	Years to Payback
									$ 544.28	0.87	14

Several customers in this table received a new refrigerator that was smaller in cubic feet than their previous refrigerator, and therefore saw significant daily savings. On the other hand, a few customers went from models without an icemaker to a refrigerator with an icemaker. These customers often show very little daily savings because the increased efficiency of the new model is offset by the added demand brought on by adding an icemaker. The highest daily savings observed in the table above is 2.62 kWh. This customer's energy savings will equal the cost of the new refrigerator in just 6 years.

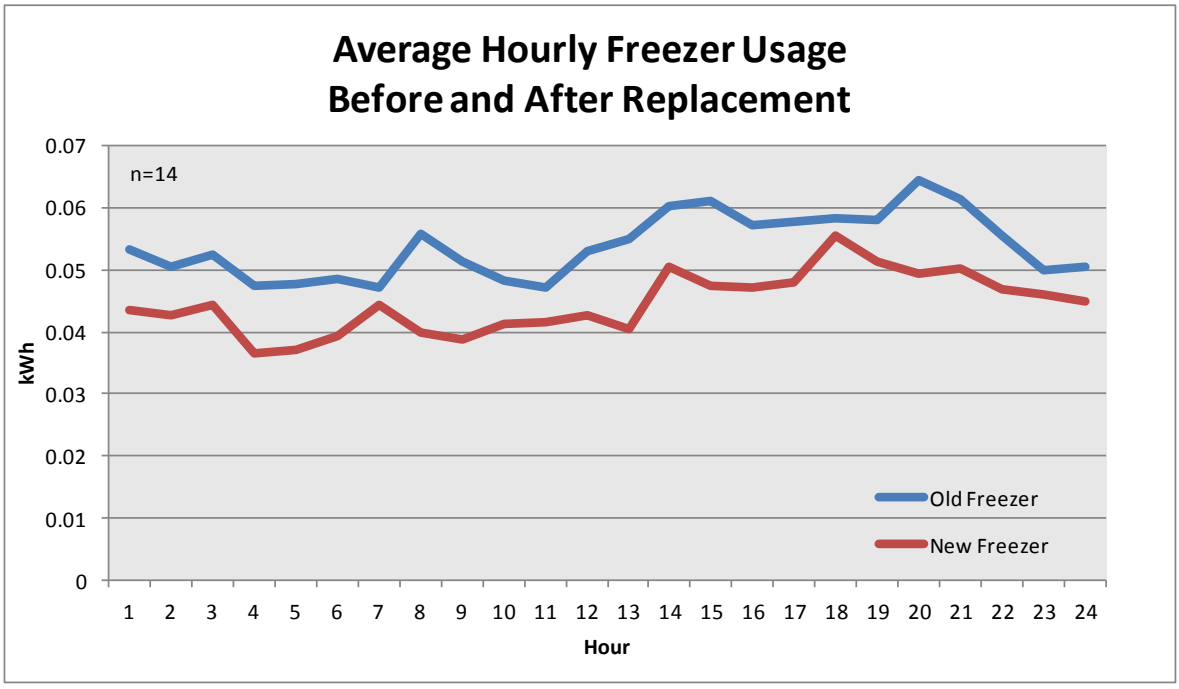
Freezer Replacement

Of the 30 customers participating in the Appliance Replacement Program, 13 received a new freezer. The average freezer energy usage found before and after the freezer replacement by the day of the week is shown in the below.

Average Freezer Use By Day of Week in kWh		
Day of Week	Old Freezer	New Freezer
Sunday	1.37	1.08
Monday	1.24	1.09
Tuesday	1.28	1.09
Wednesday	1.28	1.04
Thursday	1.30	1.09
Friday	1.32	1.04
Saturday	1.31	1.09
Average	**1.30**	**1.07**

An average decrease in average daily usage of 0.23 kWh occurred after the freezer was replaced with a more energy efficient model. Freezer usage, similar to refrigerator usage, is relatively constant all week long.

The graph below shows the freezer usage before and after the replacement of the appliance with a more energy efficient model.



The table below shows the freezer type, cubic feet and daily kWh before and after the replacement with the more energy efficient model. The table also shows daily savings in kWh and payback in years for the new appliance.

Freezer Replacement Customer Table with Years to Payback Calculation								
Old Freezer			New Freezer				Results	
Freezer Type	Cubic Feet	Daily kWh	Freezer Type	Cubic Feet	Daily kWh	Price	Daily Savings in kWh	Years to Payback (11.62 Cents per kWh with 3% Annual Increase)
CHEST	10	1.15	CHEST	15	0.97	$ 303.02	0.18	26
UPRIGHT	15	1.54	CHEST	15	1.39	$ 303.02	0.15	30
UPRIGHT	15	1.29	UPRIGHT	17	0.95	$ 458.76	0.34	23
Did not have old freezer			UPRIGHT	17	1.14	$ 458.76	-1.14	
CHEST	10	0.79	CHEST	15	0.97	$ 303.02	-0.18	
CHEST	7	0.66	CHEST	15	0.96	$ 303.02	-0.30	
CHEST	5	0.89	CHEST	15	0.99	$ 303.02	-0.11	
CHEST	10	1.56	CHEST	15	1.04	$ 303.02	0.52	12
CHEST	5.1	1.30	CHEST	15	1.01	$ 303.02	0.30	18
CHEST	15.3	3.38	CHEST	15	1.15	$ 303.02	2.23	3
CHEST	15	1.20	CHEST	15	1.27	$ 303.02	-0.07	
CHEST	5	1.16	CHEST	15	0.72	$ 303.02	0.44	13
CHEST	10	1.81	CHEST	15	1.27	$ 303.02	0.55	11
CHEST	7	1.03	CHEST	15	1.15	$ 303.02	-0.12	
Average Daily kWh		1.37	Average Daily kWh		1.07	Average Cost	Average Savings	Years to Payback
						$ 325.27	0.20	17

One customer in the table above received a chest freezer that was smaller than their original chest freezer. This customer showed the largest daily savings of 2.23 kWh. The difference in cubic feet was relatively minimal, 15.3 cubic feet vs. 15 cubic feet, however when combined with a more efficient appliance this could have made a big difference in the overall usage. For most customers, the new freezer did increase the size of their old freezer by 5 or 10 cubic feet. However, due to the efficiency of the new unit, most customers still show a daily savings overall. Six out of the fourteen freezer customers did not show savings with their new freezer.

Dishwasher Replacement

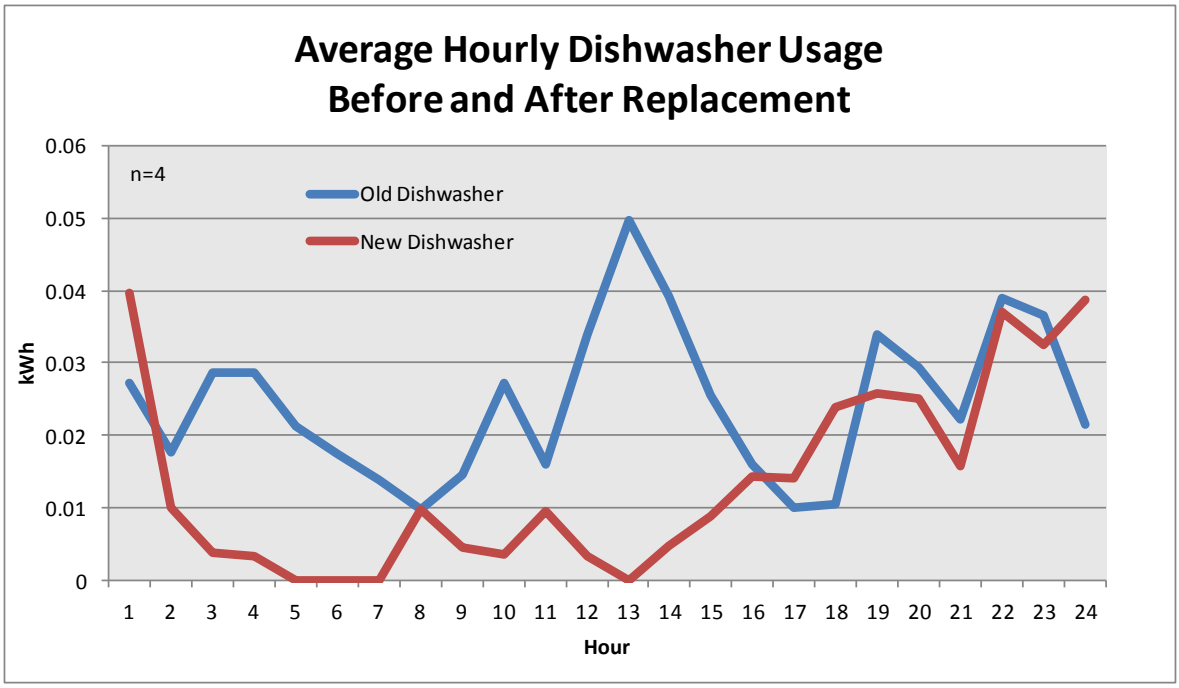
Only 4 customers received a new dishwasher. The average dishwasher usage by day of the week before and after the replacement of the dishwasher with the more energy efficient model is shown in the table below.

Average Dishwasher Use By Day of Week in kWh		
Day of Week	Old Dishwasher	New Dishwasher
Sunday	0.37	0.42
Monday	0.68	0.32
Tuesday	0.45	0.36
Wednesday	0.84	0.36
Thursday	0.53	0.30
Friday	0.82	0.32
Saturday	0.40	0.24
Average	**0.58**	**0.33**

Dishwasher usage has decreased on all days except for Sunday, where a slight increase is observed. This increase in usage is most likely due to a change in customer behavior. Overall, usage has decreased on average by 0.25 kWh.

The graph below shows the average dishwasher usage by hour before and after the dishwasher was replaced with a more energy efficient appliance. These

customers use their dishwasher more frequently during the afternoon and evening hours.



The table below shows the age of the dishwasher, the number of dishwasher loads per week, the daily kWh before the replacement, as well as the daily kWh after the dishwasher replacement. The table below also shows the daily savings in kWh and payback in years.

Dishwasher Replacement Customer Table with Years to Payback Calculation							
Old Dishwasher			New Dishwasher			Results	
Age	Number of Loads	Daily kWh	Dishwasher	Daily kWh	Price	Daily Savings in kWh	Years to Payback (11.62 Cents per kWh
> 10 years	4	0.35	GE	0.26	$ 185.44	0.09	31
Old Dishwasher Leaked, No Usage			GE	*0.22	$ 185.44		
> 10 years	5	0.83	GE	0.39	$ 185.44	0.44	9
No Old Dishwasher			GE	*0.36	$ 185.44		
Average Daily kWh		0.59	Average Daily kWh	0.31	$ 185.44	Average Savings	Years to Payback
						0.28	13
* Dishwasher data using HOBO meters contained some interference and required some estimation of connected load.							

Unfortunately, two of the four dishwashers do not have usage before their dishwasher was replaced because the old appliance was not in use; however, the two dishwashers that have both before and after usage show significant daily savings.

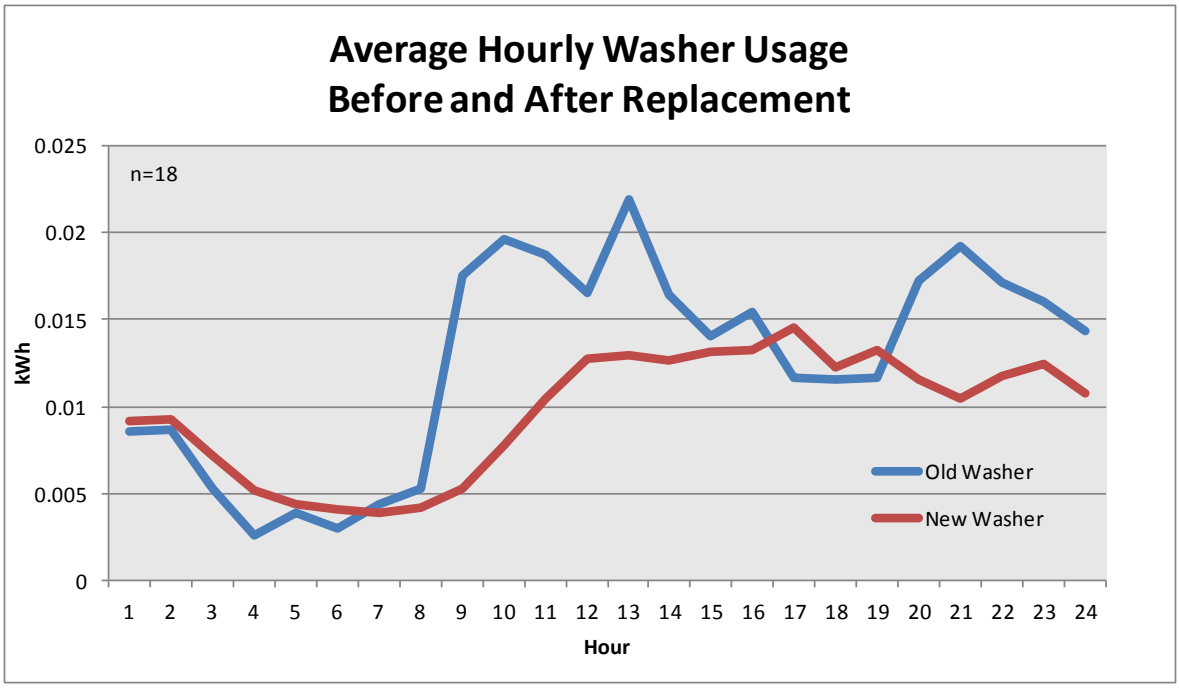
Washing Machine Replacement

Of the 30 customers participating in the Appliance Replacement program, 16 received a new washing machine.

The table to the right shows the average washer usage by day of the week for both the old washer and the new more energy efficient washer. The average washer usage has decreased by 0.06 kWh since the installation of the more energy efficient washer.

Average Washer Use By Day of Week in kWh		
Day of Week	Old Washer	New Washer
Sunday	0.23	0.21
Monday	0.27	0.25
Tuesday	0.23	0.24
Wednesday	0.34	0.23
Thursday	0.34	0.23
Friday	0.43	0.26
Saturday	0.29	0.25
Average	**0.30**	**0.24**

The following graph shows the average hourly washing machine usage before and after the replacement of the washing machine.



The washer usage in the graph above follows a similar pattern for both the old washer and the new washer; however the new washer has a lower peak in the early afternoon hour, which is when most of the washing machine usage is recorded. Washer usage is based on customer behavior and these customers do laundry most often in the middle of day and least often during the early morning hours.

The table below shows the age and daily kWh of the washer before replacement, as well as the typical number of loads per week, the device type, and daily kWh of the washer after it was replaced. The table also shows the daily savings in kWh and payback in years.

Washer Replacement Customer Table with Years to Payback Calculation								
Old Washer			New Washer				Results	
Age	Number of Loads per Week	Daily kWh	Washer Type	Device Type	Daily kWh	Price	Daily Savings in kWh	Years to Payback (11.62 Cents per kWh with 3% Annual Increase)
> 10 years	6	0.50	TOP	Watts Up	0.24	$368.88	0.25	24
> 10 years	3	0.58	TOP	HOBO	*0.12	$368.88	0.46	15
5 - 10 years	6	0.43	TOP	Watts Up	0.28	$368.88	0.15	34
> 10 years	4	0.21	TOP	HOBO	*0.21	$368.88	< 0.01	
5 - 10 years	8	0.26	TOP	Watts Up	0.18	$368.88	0.08	48
> 10 years	4	0.18	TOP	Watts Up	0.11	$368.88	0.07	51
5 - 10 years	3	0.28	TOP	Watts Up	0.13	$368.88	0.15	34
> 10 years	7	0.31	TOP	Watts Up	0.21	$368.88	0.10	44
> 10 years	*6	0.41	TOP	HOBO	*0.25	$368.88	0.16	33
5 - 10 years	3	0.28	TOP	Watts Up	0.11	$368.88	0.16	32
> 10 years	8	0.73	TOP	Watts Up	0.31	$368.88	0.42	16
> 10 years	8	0.41	TOP	Watts Up	0.20	$368.88	0.21	27
> 10 years	6	0.07	TOP	Watts Up	0.60	$368.88	-0.53	
> 10 years	4	0.15	TOP	Watts Up	0.12	$368.88	0.03	78
> 10 years	7	0.31	TOP	HOBO	*0.21	$368.88	0.10	43
> 10 years	5	0.31	TOP	HOBO	*0.07	$368.88	0.24	25
> 10 years	8	0.01	TOP	Watts Up	0.30	$368.88	-0.29	
> 10 years	4	0.24	TOP	HOBO	*0.01	$368.88	0.23	26
Average Daily kWh		0.32	Average Daily kWh		0.20	$368.88	Average Savings	Years to Payback
							0.12	35
* Washer data using HOBO meters contained some interference and required some estimation of connected load.								

Only 3 out of 18 customers did not see a daily savings after the replacement of their washing machine. Of the three customers that did not see any savings, one did not have any before usage and the other two had very low before usage. Therefore, they may have used their washing machine infrequently. The highest daily savings observed was 0.46 kWh.

Appliance Replacement Summary

The table below provides a summary of the daily kWh for the old appliance and the new appliance and the daily savings.

Summary Savings Table - All Appliance Replacement							
Appliance	Daily kWh Old Appliance	Daily kWh New Appliance	Daily kWh Savings	Percent Savings	Annual kWh Savings	Average Appliance Price	Estimated Years to Payback
Refrigerator	2.33	1.46	0.87	37.4%	319	$544.28	14
Freezer	1.37	1.07	0.20	14.6%	73	$325.27	17
Washer	0.32	0.20	0.12	36.6%	42	$368.88	35
Dishwasher	0.59	0.31	0.28	47.5%	102	$185.44	13

GoodCents found that dishwasher replacement produces the largest percent savings, at 47.5%, and has the shortest estimated years to payback, 13 years. Refrigerator replacement produces the second largest percent savings, 37.4%, and has the second shortest payback of 14 years. Freezers show a 14.6% savings, with a payback of 17 years. The longest payback is the washing machine, which would take 35 years and has an average savings of 36.6%. We generally under-estimating the payback for washing machines since customers are probably using less hot water with the new washers, allowing their water heater usage to be less. This will reduce their water bill and their water heater kWh, neither of which were considered in this analysis.

Weather Sensitive Programs

Energy savings results for the HVAC Replacement program, the Roof Replacement program, and the Weatherization program are dependent upon the weather; therefore, they are weather sensitive programs. Customers participating in each of the programs listed above, as well as the control group, have both their air conditioning compressor and their heat strips monitored. The following analysis shows the data collected for each group, the savings resulting from each energy efficient measure, a peak day analysis, and a summary of all the weather sensitive programs combined.

HVAC Replacement Program

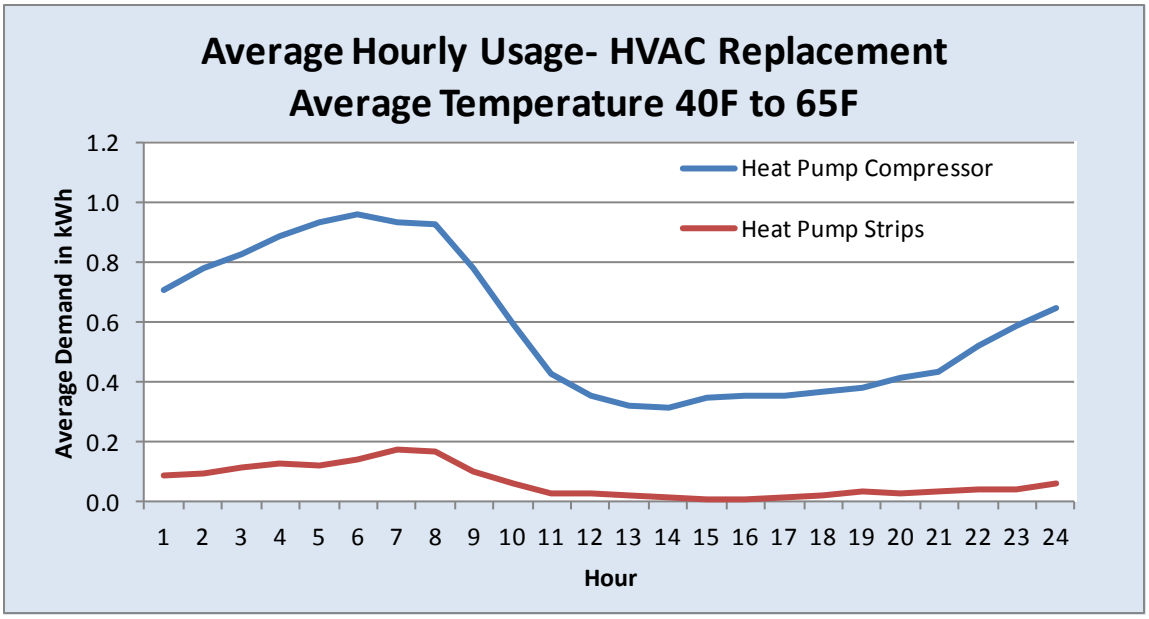
A total of 200 customers participated in the HVAC replacement program, with 30 monitored for analysis. Each customer had their duct work inspected and repaired, as well as received a new heat pump system.

The table to the right lists the 30 monitored heating and air conditioning customers, whether their home is single-wide or double-wide, their electric cooperative, the installation date of the monitoring equipment, and the number of occupants within the home.

CEPCI MH HVAC Customers				
Sitename	Type	Cooperative	Install Date	Occupants
1	Double	Blue Ridge	11/30/2010	3
2	Double	Blue Ridge	12/1/2010	1
3	Double	Blue Ridge	12/1/2010	6
4	Double	Blue Ridge	12/3/2010	4
5	Double	Blue Ridge	12/4/2010	2
6	Single	Blue Ridge	12/1/2010	1
7	Single	Blue Ridge	12/1/2010	5
8	Single	Blue Ridge	12/3/2010	3
9	Double	Coastal	11/30/2010	4
10	Double	Coastal	12/7/2010	3
11	Single	Coastal	11/30/2010	5
12	Double	Lynches River	11/23/2010	4
13	Double	Lynches River	11/24/2010	2
14	Double	Lynches River	12/1/2010	3
15	Double	Lynches River	12/1/2010	3
16	Double	Lynches River	12/1/2010	4
17	Single	Lynches River	11/23/2010	3
18	Single	Lynches River	12/1/2010	2
19	Double	Palmetto	12/7/2010	2
20	Double	Palmetto	12/7/2010	2
21	Double	Palmetto	12/16/2010	3
22	Single	Palmetto	12/7/2010	1
23	Double	Santee	11/29/2010	2
24	Double	Santee	11/29/2010	3
25	Double	Santee	11/29/2010	2
26	Double	Santee	11/30/2010	2
27	Double	Santee	12/8/2010	4
28	Single	Santee	11/24/2010	2
29	Single	Santee	11/24/2010	5
30	Single	Santee	11/29/2010	3

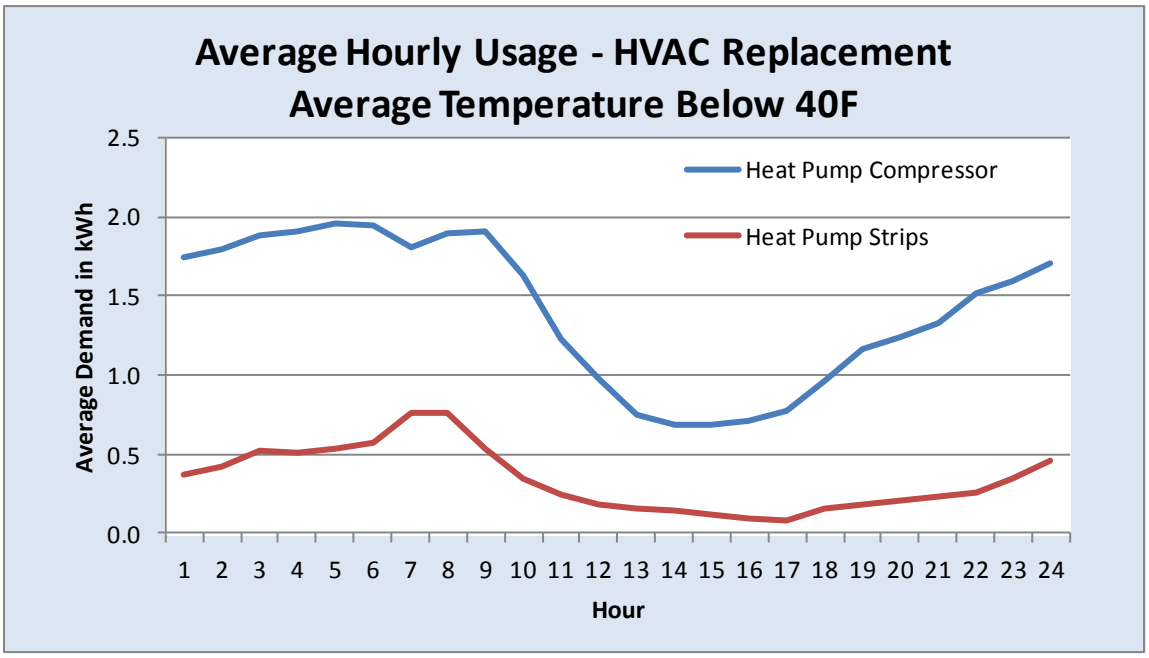
Heating

The graph below shows the average hourly heating usage when the average daily temperature is between 40 and 65 degrees Fahrenheit (F).

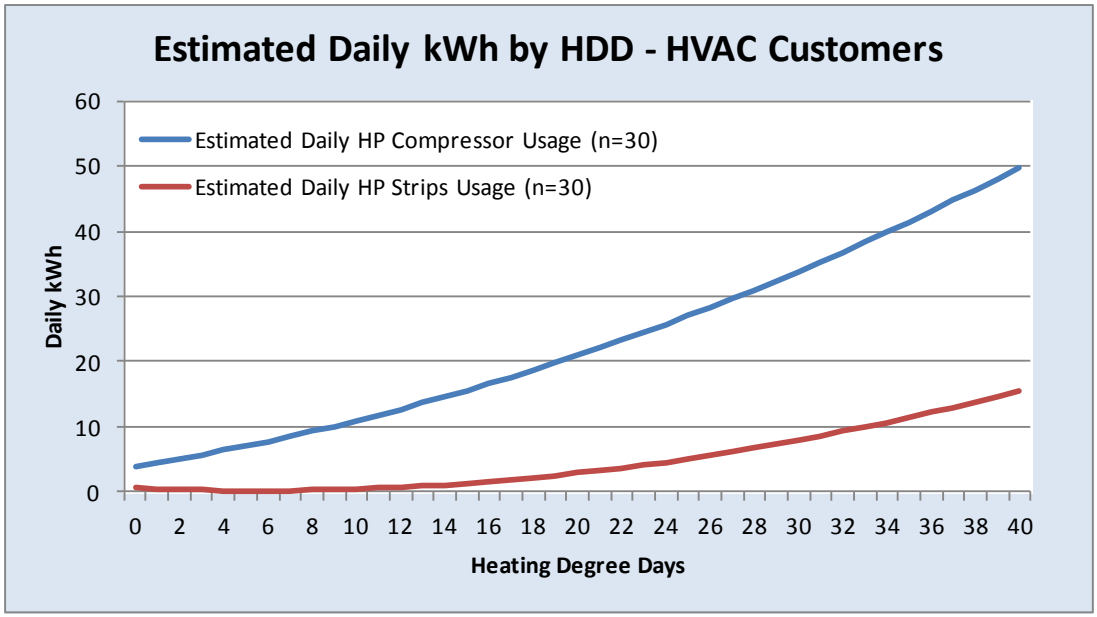


The greatest usage is shown in the early morning hours when temperatures are the coldest. Throughout the day, when temperatures warm up, both the heat strips and compressor usage gradually decrease and then increase again overnight.

The graph below shows the average hourly usage when the average daily temperature is less than 40F.



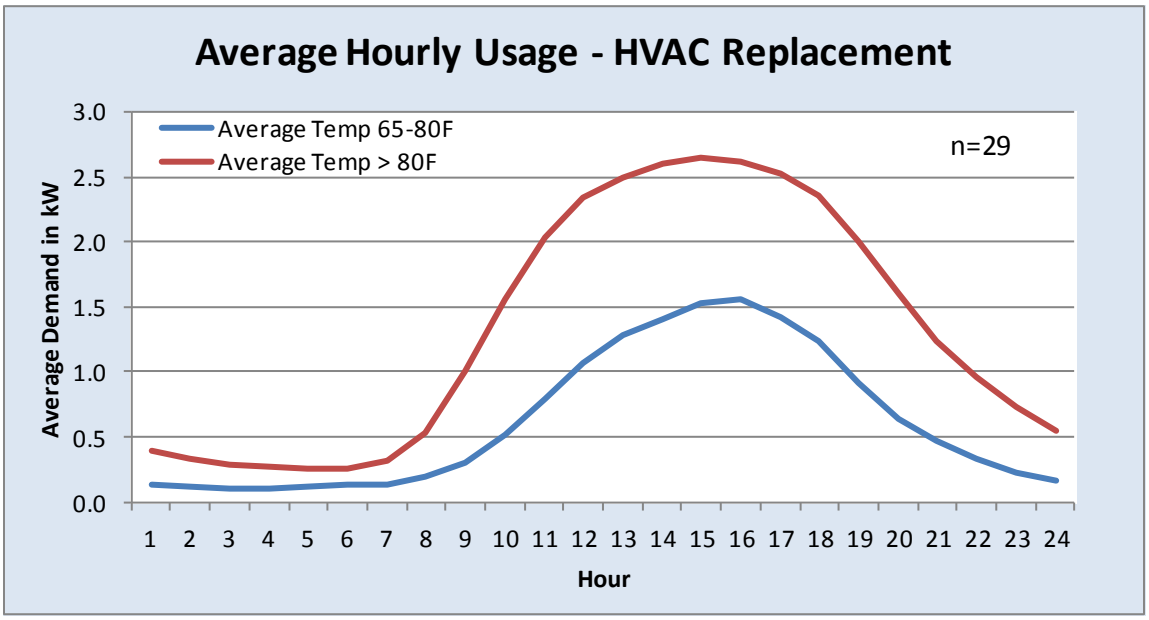
The highest usage still occurs in the early morning hours; however, an increase of a little less than 1 kWh per hour is observed on the compressor when compared to days when the average temperature is above 40F. Heat strip usage also increases by around 0.5 kWh.



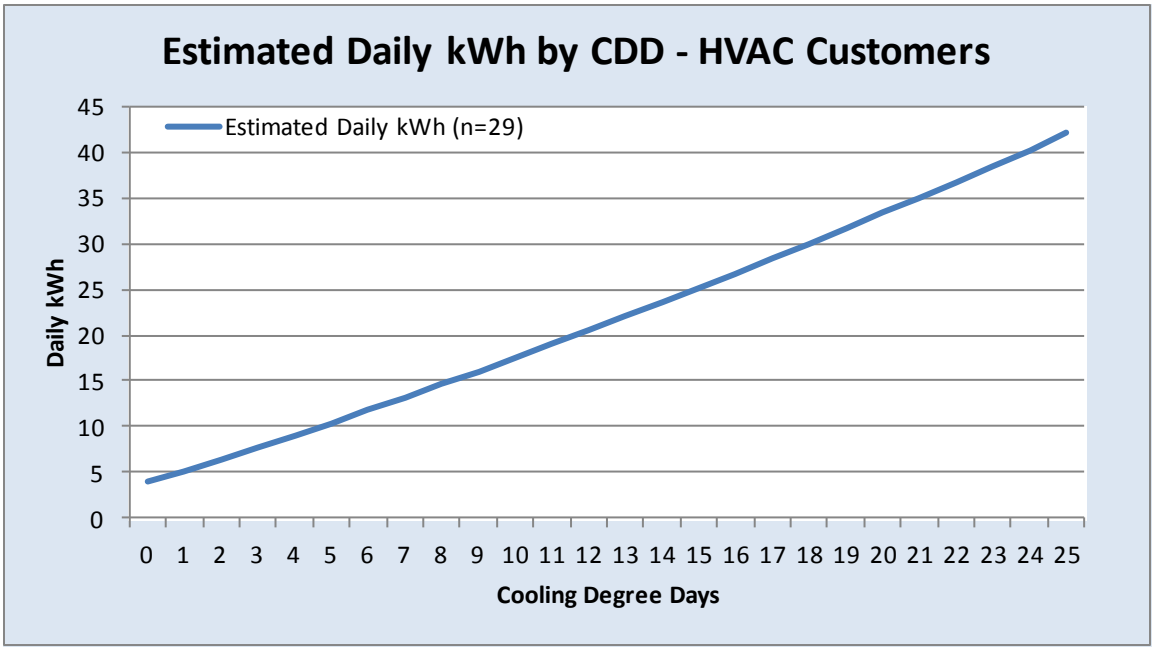
The graph above shows daily usage for all HVAC customers modeled by heating degree day (HDD). As the number of HDD increases, the heating usage also increases.

Cooling

The graph below shows the average hourly cooling usage when the average daily temperature is between 65 and 80 degrees Fahrenheit (F), as well as, above 80 degrees Fahrenheit (F).



The greatest usage is shown in the afternoon hours during the hottest part of the day. During the evening and overnight hours the usage gradually decreases as temperatures cool off.



The graph above shows daily usage for all HVAC customers modeled by cooling degree day (CDD). As the number of CDD increases, the cooling usage also increases.

We have included an analysis of savings using the control group as a baseline in the overall comparison section of the report.

Roof Replacement Program

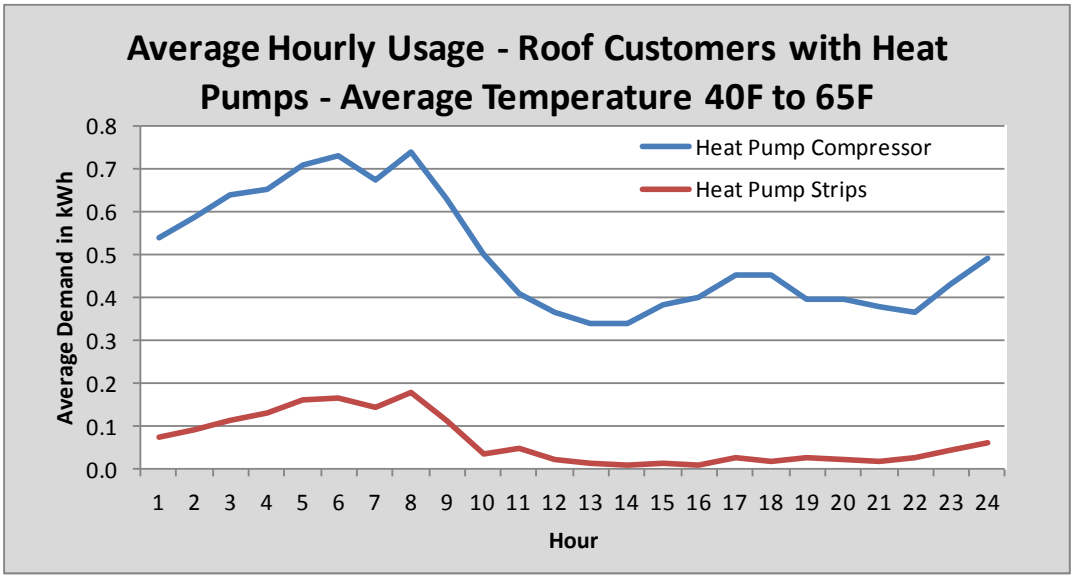
A total of 200 customers participated in the roof replacement program, with 30 monitored for analysis. Each customer received a new energy efficient roof. The table below lists the 30 monitored roof replacement customers, whether their home is single-wide or double-wide, their electric cooperative, the installation date of the monitoring equipment, and the number of occupants within the home.

CEPCI MH Roof Customers				
Sitename	Type	Cooperative	Install Date	Occupants
1	Double	Broad River	12/9/2010	3
2	Double	Broad River	1/25/2011	2
3	Single	Broad River	12/4/2010	2
4	Single	Broad River	12/4/2010	2
5	Single	Broad River	12/9/2010	2
6	Single	Broad River	12/9/2010	2
7	Single	Broad River	12/9/2010	5
8	Double	Horry	1/13/2011	2
9	Double	Horry	1/17/2011	4
10	Double	Horry	1/19/2011	3
11	Single	Horry	12/3/2010	5
12	Single	Horry	12/3/2010	1
13	Single	Horry	12/3/2010	3
14	Single	Horry	12/3/2010	1
15	Single	Horry	12/4/2010	3
16	Single	Horry	12/4/2010	2
17	Single	Horry	12/16/2010	3
18	Single	Horry	1/13/2011	2
19	Single	Horry	1/17/2011	2
20	Double	Mid-Carolina	12/16/2010	3
21	Double	Mid-Carolina	12/16/2010	3
22	Double	Mid-Carolina	12/21/2010	3
23	Single	Mid-Carolina	12/14/2010	4
24	Single	Mid-Carolina	12/15/2010	2
25	Single	Mid-Carolina	12/15/2010	2
26	Single	Mid-Carolina	12/16/2010	1
27	Single	Mid-Carolina	12/17/2010	1
28	Single	Mid-Carolina	12/21/2010	1
29	Single	Mid-Carolina	12/21/2010	2
30	Single	Mid-Carolina	1/25/2011	3

The analysis below separates out customers with heat pumps from customers with electric furnaces. Of the 30 roof customers monitored, 9 customers have heat pumps and 21 customers have straight cooling outdoor units and electric furnace heating systems.

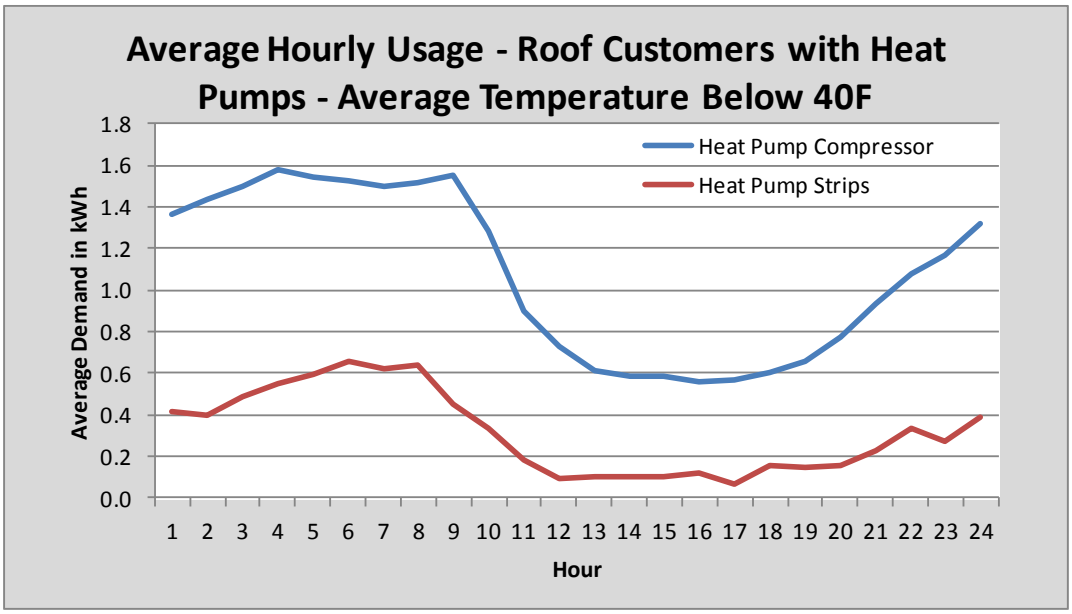
Heating

The following graph shows the average hourly heating usage of roof replacement customers with heat pumps when the average daily temperature is between 40 and 65 degrees (F).



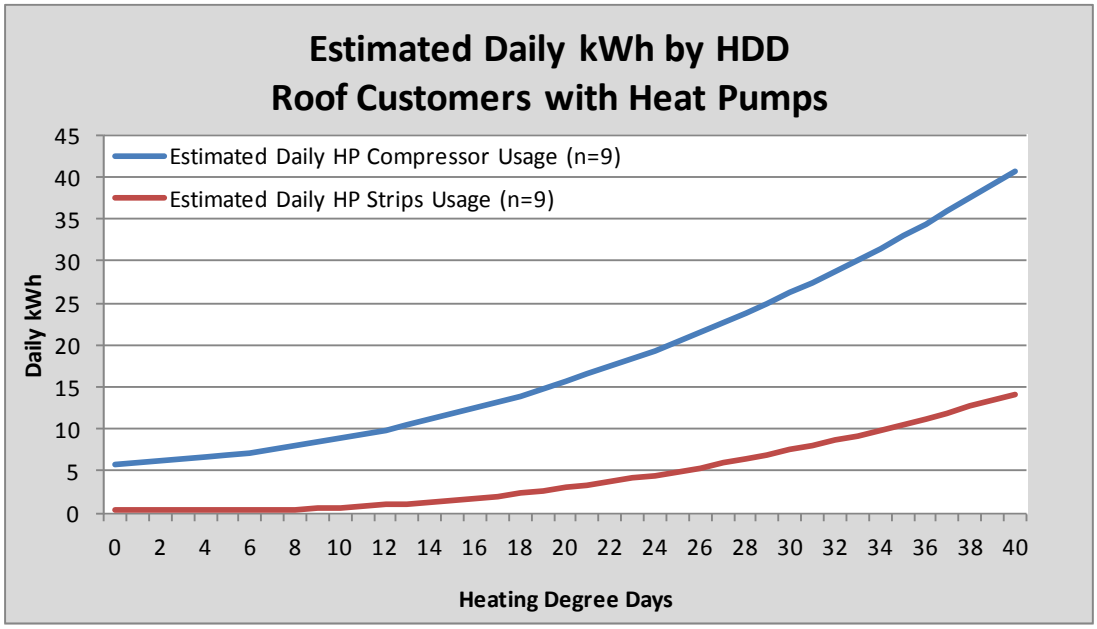
In the graph above, the highest usage is observed in the early morning hours when temperatures are the coldest, similar to the HVAC customers in the previous section. The heat strips follow a similar pattern, with usage close to zero in the afternoon and evening.

The following graph shows average hourly heating usage for an average daily temperature below 40F.

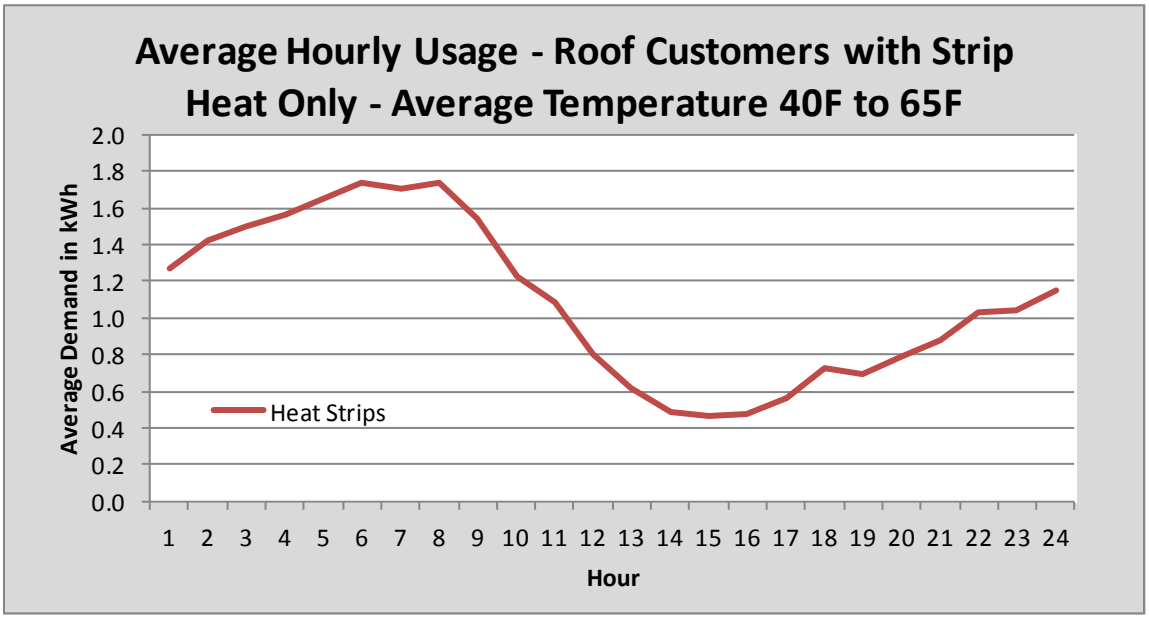


In the graph above, similar to the HVAC customers, the roof replacement customers show much greater usage, around 1.6 kWh, in the morning hours when temperatures are below 40F.

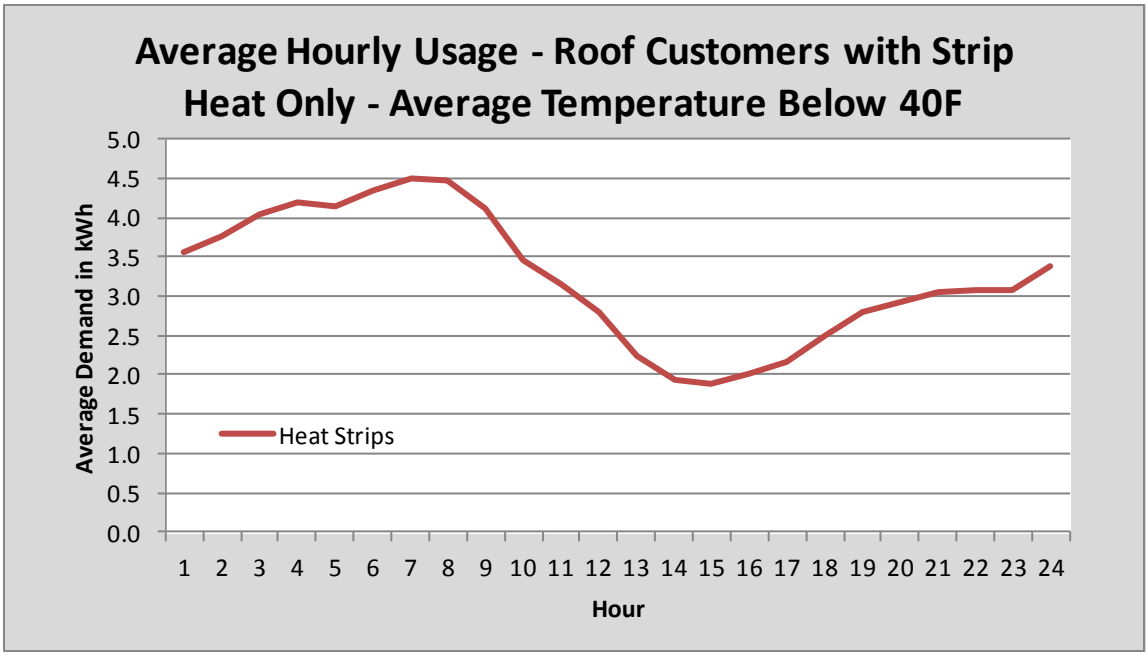
In the graph below, the daily usage for customers with heat pumps is modeled by HDD. As the number of HDDs increases, the usage also increases but at a slower rate than the HVAC customers.



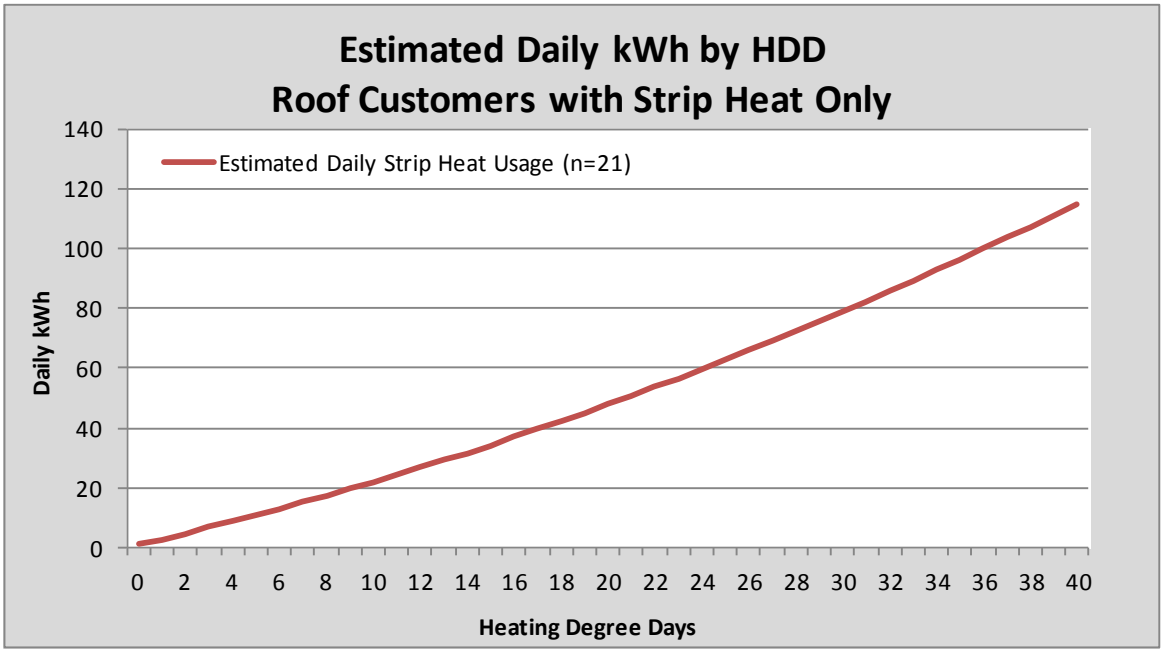
The following graph shows the average hourly heating usage of roof replacement customers with electric furnaces (strip heat only) when the average daily temperature is between 40 and 65 degrees (F).



With average temperatures between 40 and 65 degrees (F), the usage is highest during the overnight hours when temperatures are the coldest. The peak occurs in the early morning hours with usage around 1.7 kWh. As a comparison, in a previous version of this report in February, usage peaked closer to 3 kWh when there were fewer warmer days to moderate temperatures.



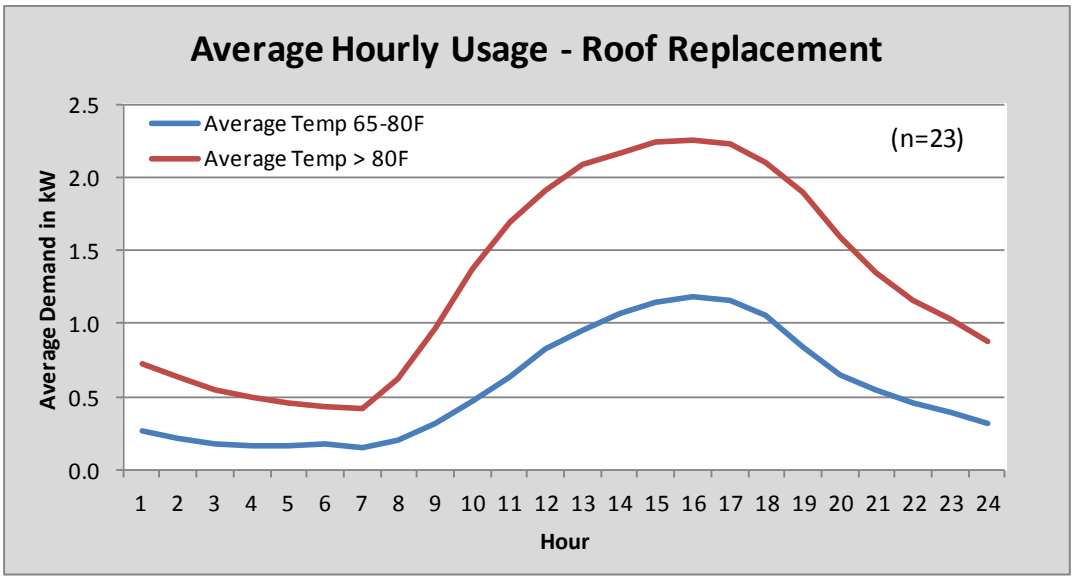
In the graph above, when temperatures are below 40 degrees (F), the highest usage is close to 4.5 kWh between 7 and 8 am. There is a decrease in heating in the afternoon hours, with hourly usage still around 2 kWh before beginning to rise again after the sun goes down.



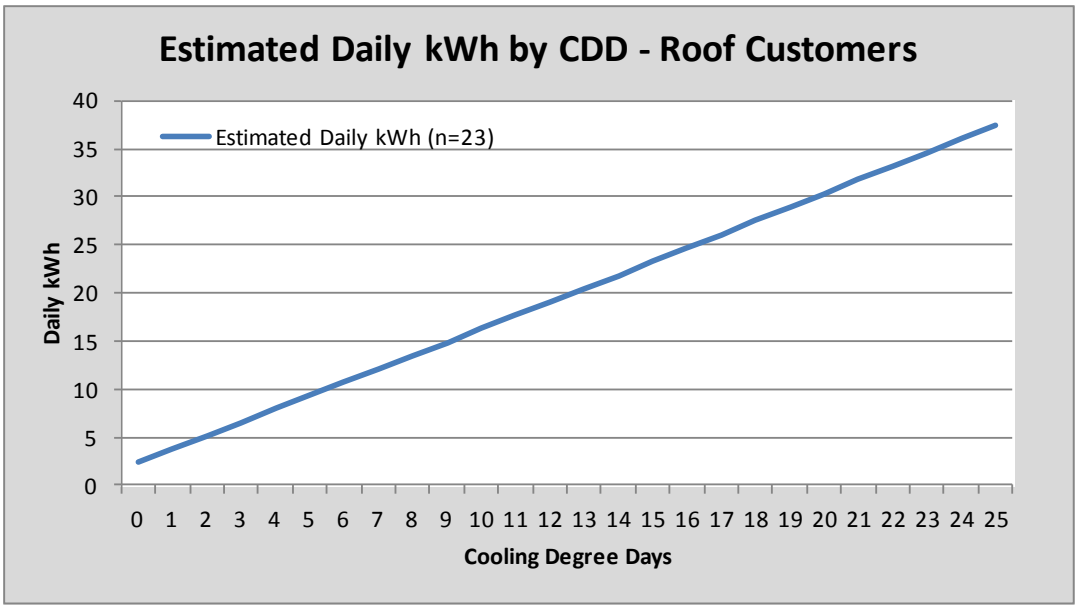
The graph above shows the daily usage modeled by HDD for the roof customers with resistance heat only. The usage by HDD rises steadily as the number of HDD increases.

Cooling

The following graph shows the average hourly cooling usage of roof replacement customers with heat pumps and central AC units when the average daily temperature is between 65 and 80 and above 80 degrees (F).



In the graph above, similar to the HVAC customers, the roof replacement customers show much greater usage when temperatures are above 80 degrees (F) during the afternoon hours. Usage decreases during the overnight hours when temperatures cool.



The graph above shows the daily usage modeled by CDD for the roof customers and is very similar to the daily usage for the HVAC customers. Air conditioning loads were modeled together for heat pumps and central AC units. The usage by CDD rises steadily as the number of CDD increases.

We have included an analysis of savings using the control group as the base in the overall comparison section of the report.

Weatherization Program

CEPCI and electric cooperatives, Berkeley and Black River, worked with community action groups to complete weatherization on participating manufactured homes. Several community action groups dropped out of the program, allowing only 79 homes to be completed with weatherization. GoodCents installed monitoring equipment on 29 of these homes for M&V analysis. Each customer received various home improvements including, duct sealing and repair, insulation upgrades, and HVAC repairs.

The table below lists the 29 monitored weatherization customers, whether their home is single-wide or double-wide, their electric cooperative, the installation date of the monitoring equipment, and the cost of the home improvement measures implemented in each home.

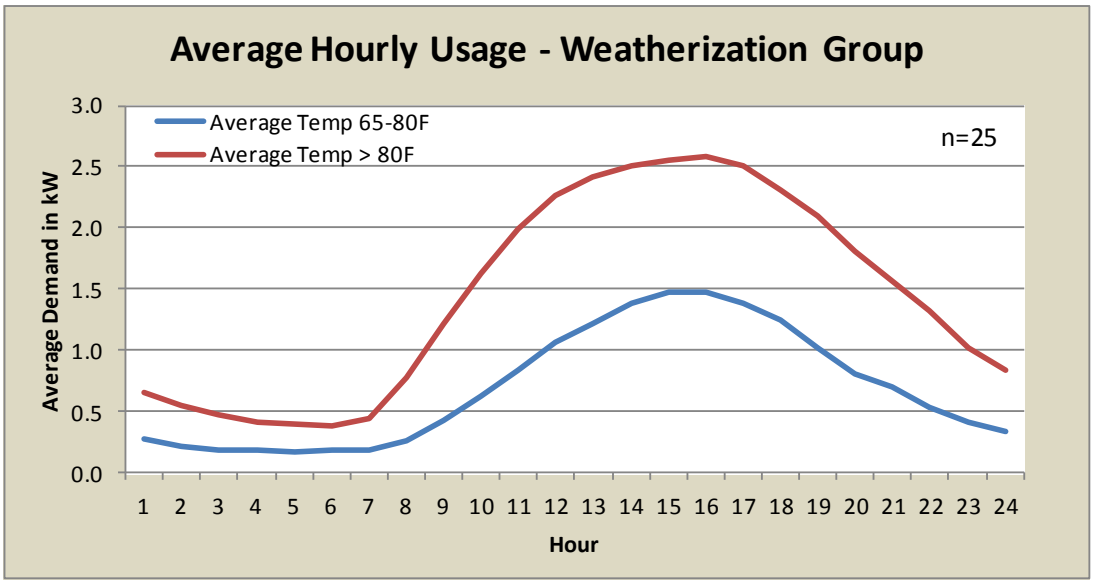
CEPCI MH Weatherization Customers				
Sitename	Type	Cooperative	Install Date	Weatherization Price
1	Double	Black River	5/9/2011	$5,845.73
2	Single	Black River	5/6/2011	$2,806.16
3	Double	Black River	5/10/2011	$2,326.37
4	Single	Black River	5/9/2011	$5,505.52
5	Single	Black River	5/9/2011	$6,830.43
6	Single	Black River	4/12/2011	$6,881.19
7	Single	Black River	3/29/2011	$3,204.23
8	Single	Black River	4/11/2011	$3,646.47
9	Single	Black River	4/11/2011	$1,129.01
10	Double	Black River	4/11/2011	$3,472.65
11	Double	Black River	4/12/2011	$4,182.42
12	Single	Black River	4/12/2011	$5,116.15
13	Double	Black River	4/12/2011	$4,847.29
14	Double	Black River	3/29/2011	$5,226.48
15	Single	Black River	3/29/2011	$3,660.20
16	Double	Black River	4/13/2011	$4,494.82
17	Single	Black River	4/13/2011	$3,938.07
18	Single	Black River	4/13/2011	$4,620.99
19	Double	Black River	4/14/2011	$2,682.06
20	Single	Black River	4/14/2011	$3,824.58
21	Double	Black River	4/14/2011	$4,695.39
22	Single	Black River	4/15/2011	$3,803.45
23	Double	Black River	4/15/2011	$7,987.15
24	Single	Black River	4/14/2011	$5,097.24
25	Double	Berkeley	5/23/2011	$5,500.00
26	Double	Berkeley	5/23/2011	$5,500.00
27	Double	Berkeley	5/24/2011	$5,500.00
28	Double	Berkeley	5/24/2011	$5,500.00
29	Single	Berkeley	5/24/2011	$5,500.00

Heating

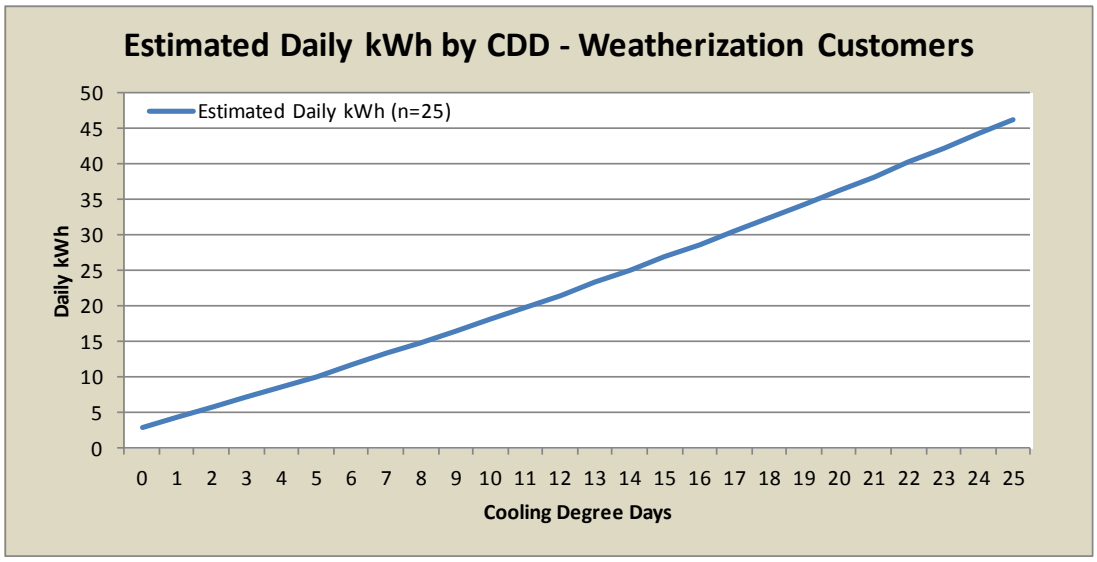
The weatherization and HOBO logger installations were not completed on these homes until the spring of 2011. Therefore, heating (winter) data was not collected on these customers.

Cooling

The following graph shows the average hourly cooling usage of the weatherization customers with heat pumps and central AC units when the average daily temperature is between 65 and 80 and above 80 degrees (F).



In the graph above, the weatherization customers show similar usage to the roof replacement customers, with usage around 3.0 kWh.



The graph above shows the daily usage modeled by CDD for the weatherization customers. Air conditioning loads were modeled together for heat pumps and central AC units. The usage is slightly

lower for the weatherization customers than it is for the HVAC and roof customers. The usage by CDD rises steadily as the number of CDD increases.

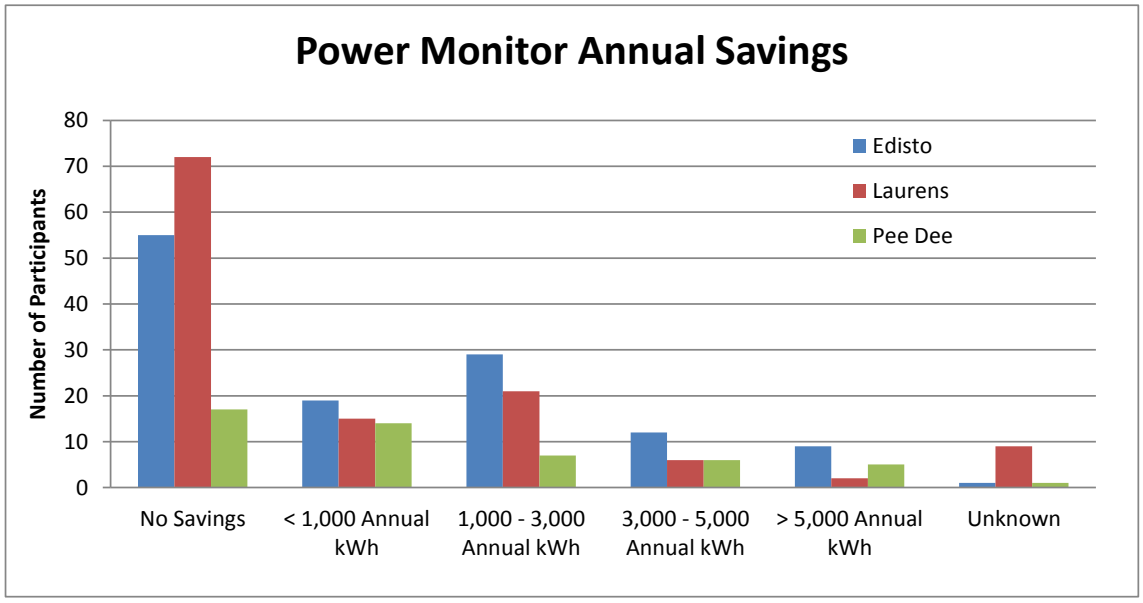
Power Monitor Program

CEPCI conducted a power monitor program in 2010 and 2011, allowing participants access to their home's energy use for one full year via an in-home display. Three electric cooperatives participated in this program, allowing for a total of 300 participants within the program. Edisto Electric Cooperative provided 125 participants, Laurens Electric Cooperative provided 125 participants, and Pee Dee Electric Cooperative provided 50 participants. The goal of this program was to allow customers to see how reducing their energy use can translate into savings.

The average power monitor cost for Edisto Electric Cooperative was $166.00. The average power monitor cost for Laurens Electric Cooperative was $189.00. The average power monitor cost for Pee Dee Electric Cooperative was $864. Installation dates ranged between December of 2010 and March of 2011.

Billing data was collected for the Power Monitor Program participants. GoodCents compared weather normalized monthly usage before the power monitor was installed to weather normalized monthly usage after the power monitor was installed.

The following graph shows a histogram of Power Monitor participants and the resulting annual savings.



The majority of customers did show some savings while participating in the Power Monitor program. Several customers showed a significant amount of annual savings. However, a large number of customers showed no savings.

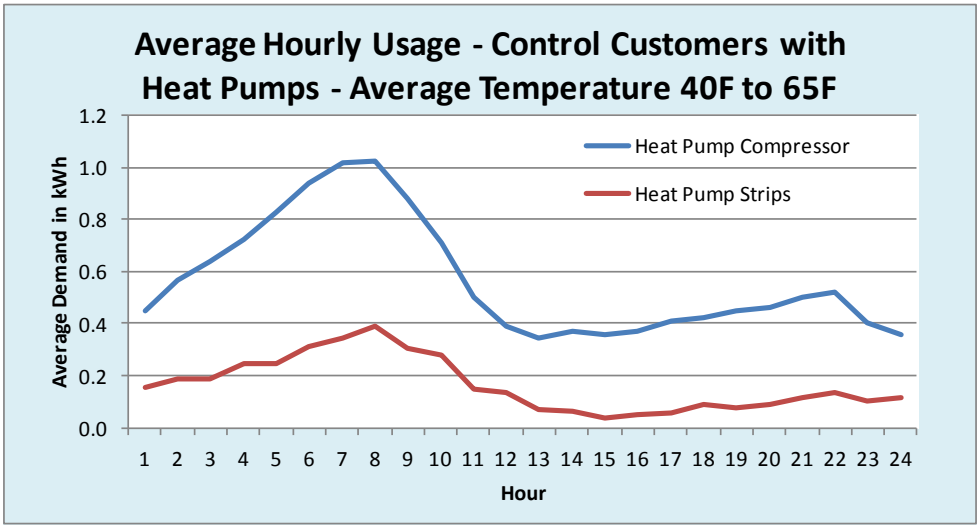
Control Group

A sample of 29 customers was randomly selected to serve as the control group, based on their electric cooperative, home size, and occupancy. These customers applied for the energy efficiency program, but were not selected for participation. The AC compressor and heat strips at each customer's home are monitored using HOBO devices. These customers were given an incentive for their participation in the program. The table below lists the 29 monitored control group customers, whether their home is single-wide or double-wide, their electric cooperative, the installation date of the monitoring equipment, and the number of occupants within the home.

CEPCI MH Control Customers				
Sitename	Type	Cooperative	Install Date	Occupants
1	Double	Blue Ridge	1/13/2011	2
2	Single	Blue Ridge	1/14/2011	2
3	Double	Blue Ridge	1/14/2011	2
4	Single	Blue Ridge	1/15/2011	4
5	Double	Blue Ridge	1/15/2011	1
6	Double	Blue Ridge	1/17/2011	3
7	Single	Blue Ridge	1/17/2011	2
8	Double	Blue Ridge	1/17/2011	2
9	Double	Blue Ridge	1/19/2011	2
10	Double	Blue Ridge	1/19/2011	2
11	Double	Palmetto	1/6/2011	1
12	Double	Palmetto	1/6/2011	3
13	Single	Palmetto	1/6/2011	2
14	Double	Palmetto	1/7/2011	4
15	Double	Palmetto	1/7/2011	4
16	Single	Palmetto	1/7/2011	2
17	Double	Palmetto	1/7/2011	5
18	Double	Palmetto	1/10/2011	2
19	Double	Palmetto	1/24/2011	2
20	Double	Santee	1/7/2011	2
21	Double	Santee	1/7/2011	2
22	Double	Santee	1/7/2011	3
23	Double	Santee	1/7/2011	4
24	Single	Santee	1/6/2011	2
25	Single	Santee	1/6/2011	6
26	Double	Santee	1/6/2011	2
27	Single	Santee	1/6/2011	4
28	Double	Santee	1/12/2011	4
29	Single	Santee	1/17/2011	1

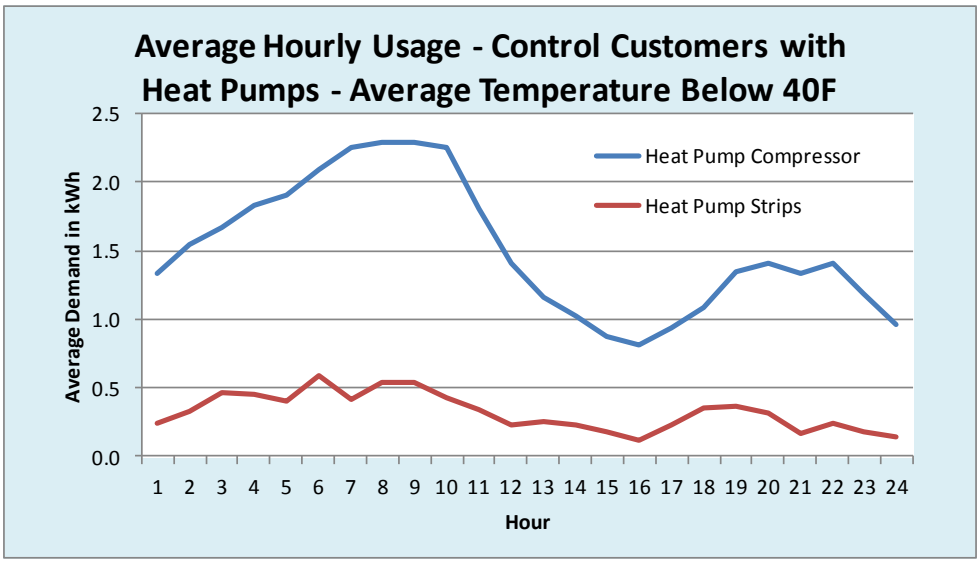
Heating

The following graph shows the average hourly heating usage of control customers with heat pumps when the average daily temperature is between 40 and 65 degrees (F).

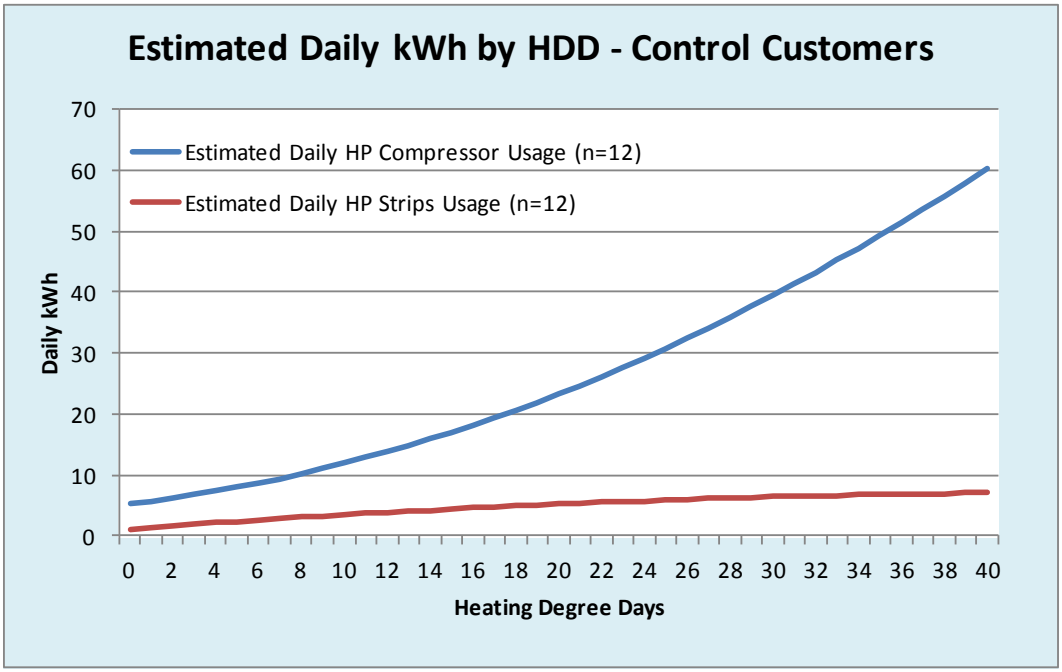


In the graph above, the highest usage is observed in the early morning hours when temperatures are the coldest, similar to both the HVAC and roof customers in the previous sections. The heat strips follow a similar pattern, with usage close to zero in the afternoon and evening before beginning to rise again after the sun has set.

The following graph shows average hourly heating usage for an average daily temperature below 40 degrees (F).

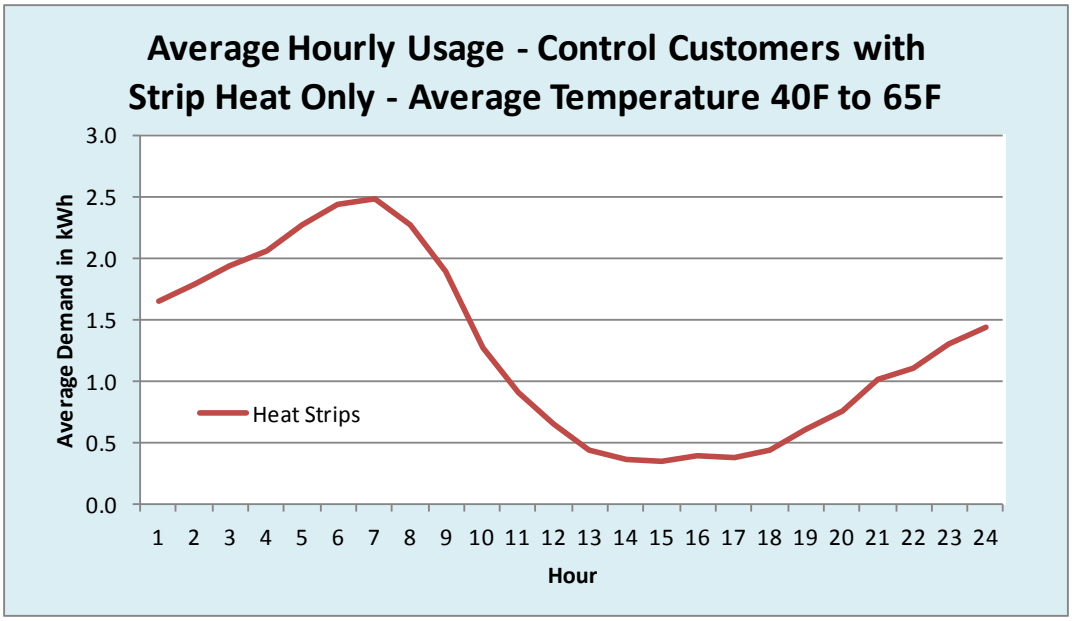


In the graph above, the control customers show much greater usage, around 2.2 kWh, in the morning hours when temperatures are below 40 degrees (F). In comparison, the roof replacement customers showed usage around 1.6 kWh in the morning hours at temperatures below 40 degrees (F).

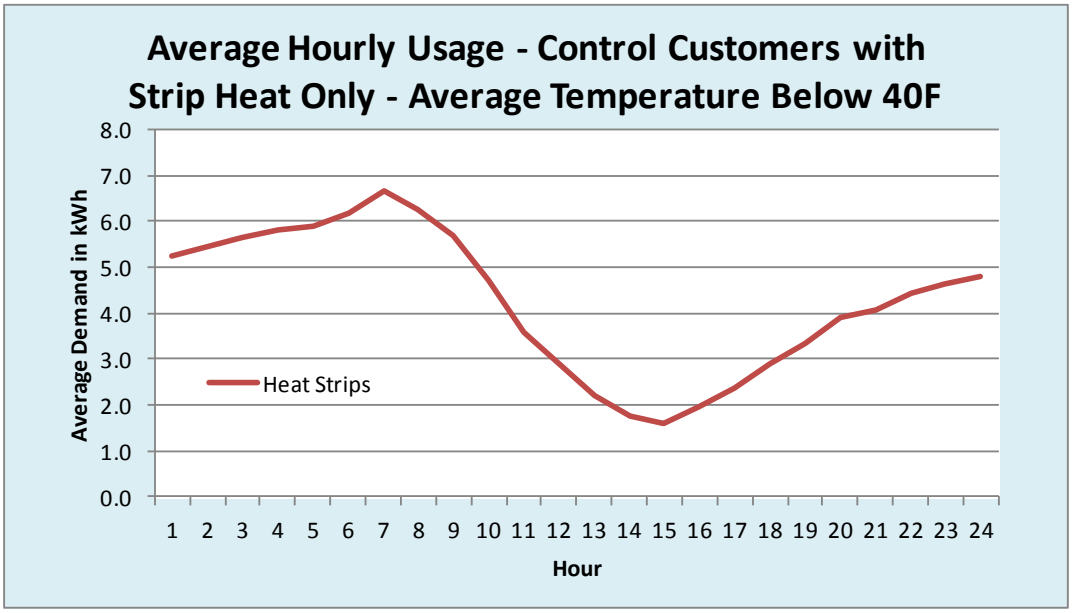


In the graph above, the daily usage for customers with heat pumps is modeled by HDD. As the number of HDDs increases, the usage also increases but at a faster rate than both the HVAC and roof replacement customers.

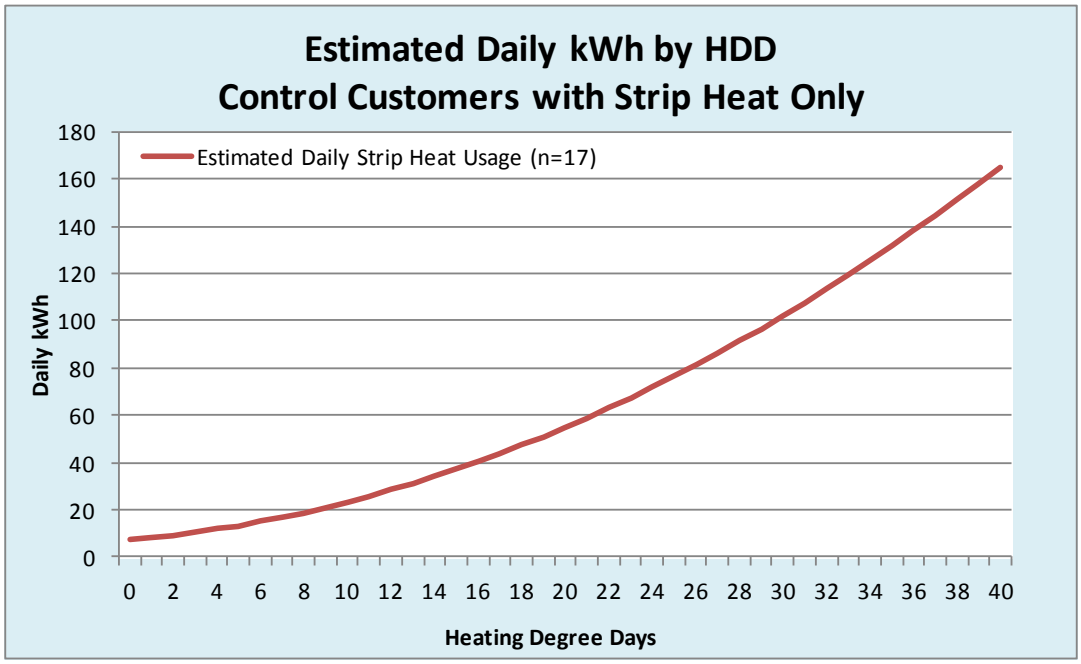
The following graph shows the average hourly heating usage of control group customers with electric furnaces (strip heat only) when the average daily temperature is between 40 and 65 degrees (F).



With average temperatures between 40 and 65 degrees (F), the usage is highest during the overnight hours when temperatures are the coldest. The peak occurs in the early morning hours with usage around 2.5 kWh.



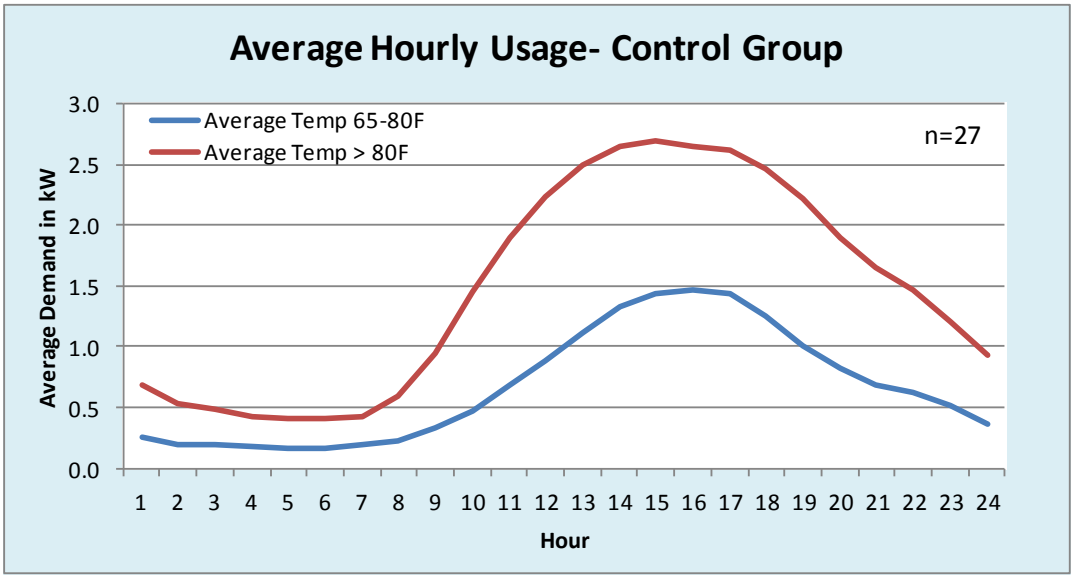
In the graph above, when temperatures are below 40 degrees (F), very high usage is observed between 7 and 8 am at close to 7.0 kWh. In comparison, the roof replacement customer's highest usage is 4.5 kWh and occurs at a similar time in the day. Both the roof replacement and the control group customer's usage decreases in the afternoon to a little less than 2.0 kWh before increasing again overnight.



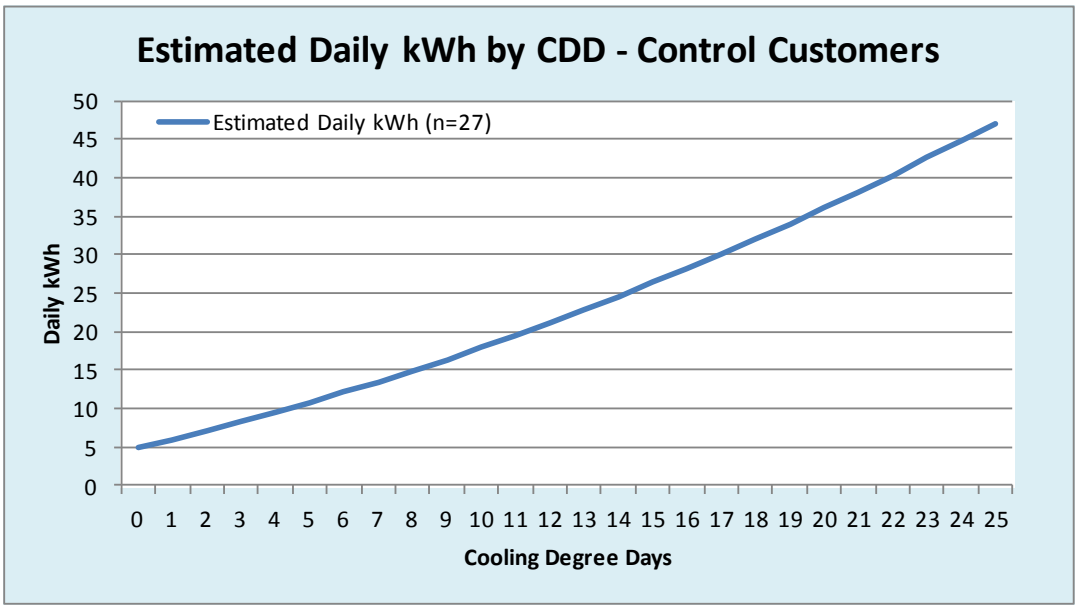
The graph above shows the daily usage modeled by HDD for the control customers with resistance heat only. The usage by HDD rises steadily as the number of HDD increases.

Cooling

The following graph shows the average hourly cooling usage for the control group customers when the average daily temperature is between 65 and 80 and above 80 degrees (F).



In the graph above, the control group shows greater cooling usage, around 3.5 kWh, in the afternoon hours when temperatures are above 80 degrees (F). In comparison, the roof replacement customers and HVAC customers showed usage around 3.0 kWh in the afternoon hours at temperatures above 80 degrees (F).



The graph above shows the daily usage modeled by CDD for the control customers. Air conditioning loads were modeled together for heat pumps and central AC units. The usage is higher for the control customers than it is for the HVAC and roof customers. On a hot summer day the average control group

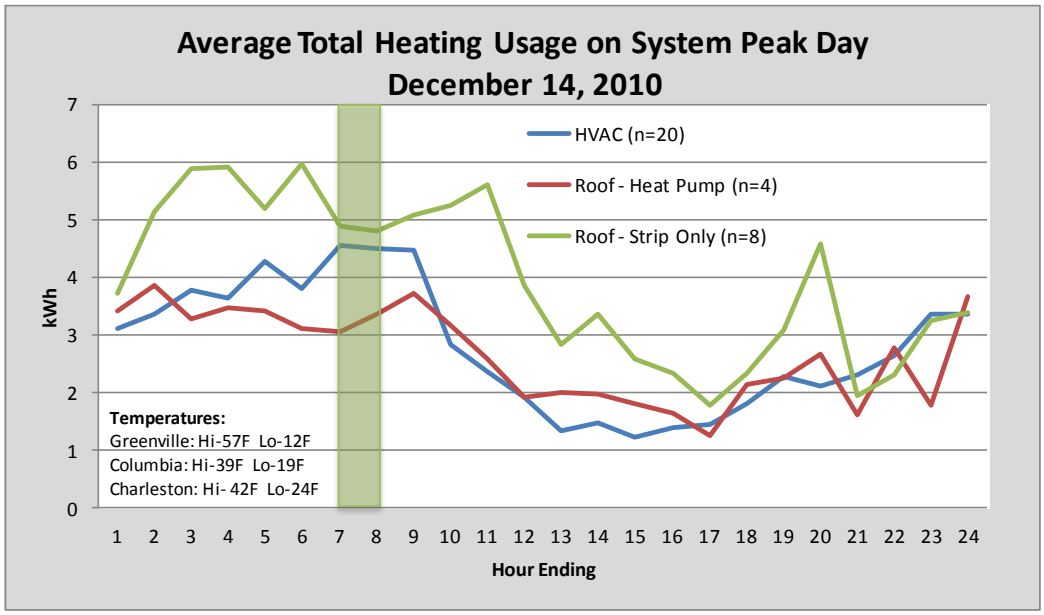
customer will use about 15 more kWh than the average member of the HVAC replacement or Roof Replacement groups. The usage by CDD rises steadily as the number of CDD increases.

Overall Comparison of Weather Sensitive Programs

The following section provides a direct comparison of the data collected and savings found for each of the weather sensitive programs, as well as a system peak analysis.

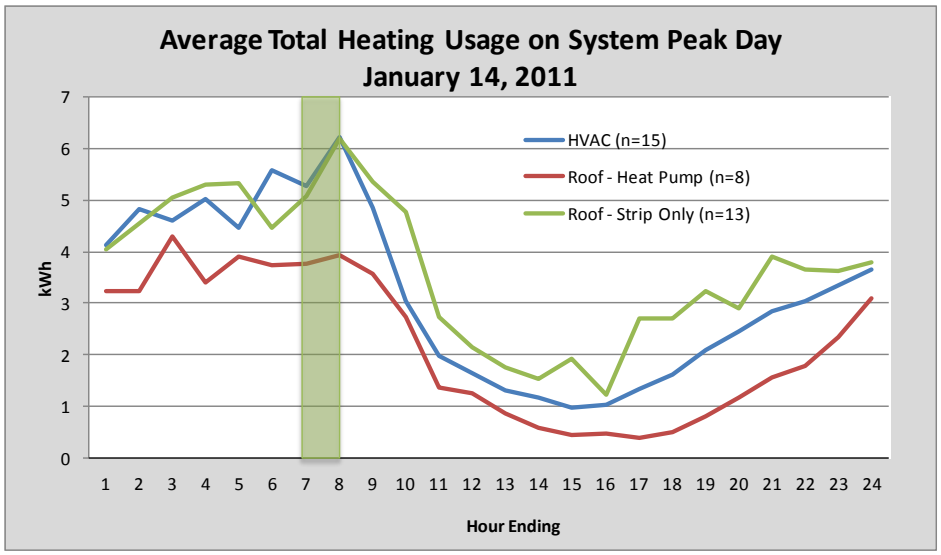
System Peak Analysis – Winter Season

The graphs below show average heating and appliance loads on the peak days recorded in December of 2010, and January, February and March of 2011.



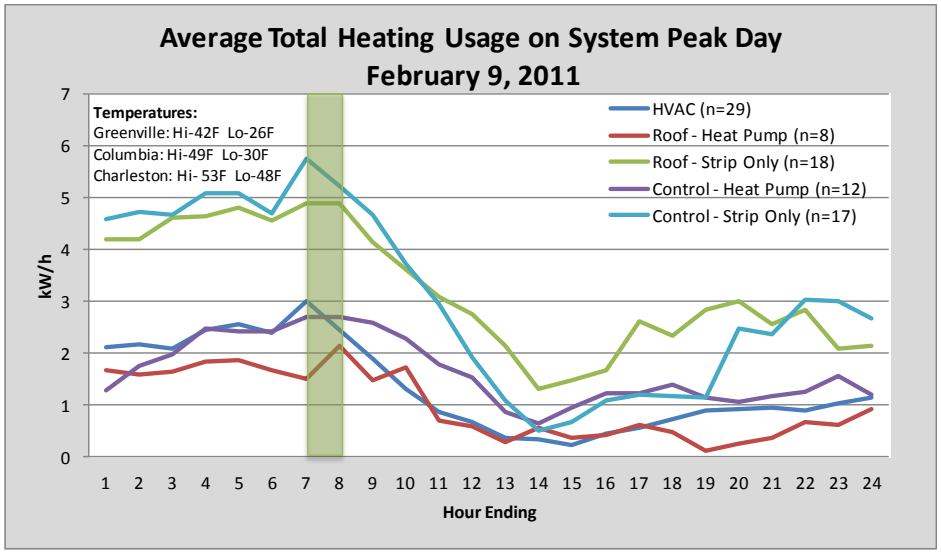
The graph above shows the average heating usage for each customer group on the peak day in December. This peak occurred on December 14th during hour ending 8. During the month of December, monitoring equipment was still being installed; therefore, data is only available for a select number of customers.

The following graph shows the average usage on the January peak day, January 14th, for each customer group. This peak also occurred during hour ending 8.



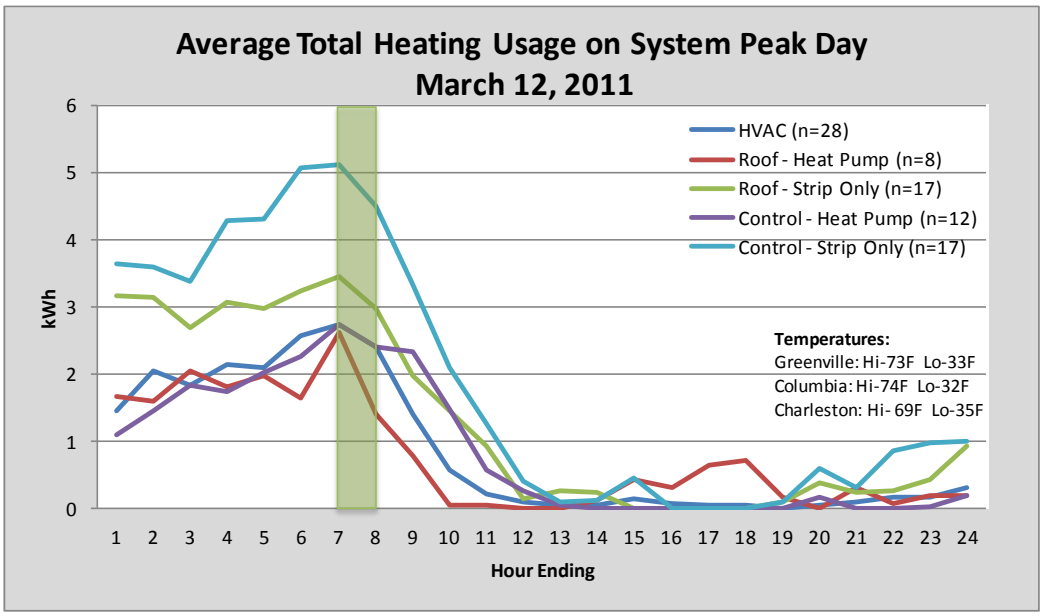
In the graph above, the average heating usages peak during hour ending 8. HVAC replacement customers averaged over 4 kWh during this hour and roof replacement customers using strip heat only averaged over 6 kWh during this hour.

The following graph shows the average usage on the February peak day, February 9th, for each customer group. This peak also occurred during hour ending 8.



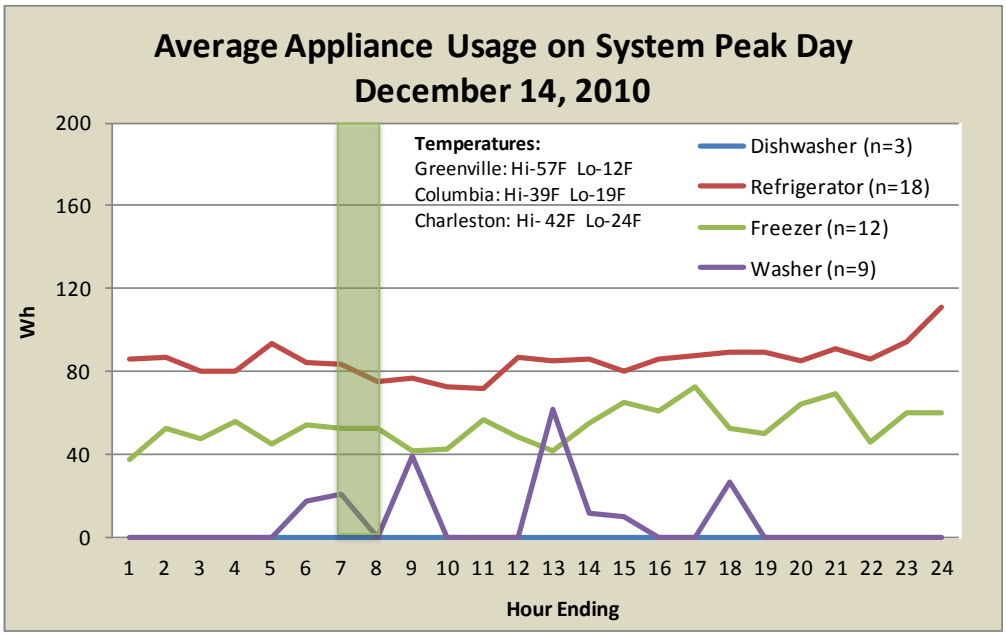
In the graph above, the average heating usages peak around hour ending 8. The HVAC replacement customers and control heat pump customers averaged around 3 kWh during this hour. Roof replacement customers using strip heat only and control customers using strip heat only averaged closer to 5 kWh during this hour.

The graph below shows the average usage on the March peak day, March 12th for each customer group. This peak also occurred during hour ending 8.



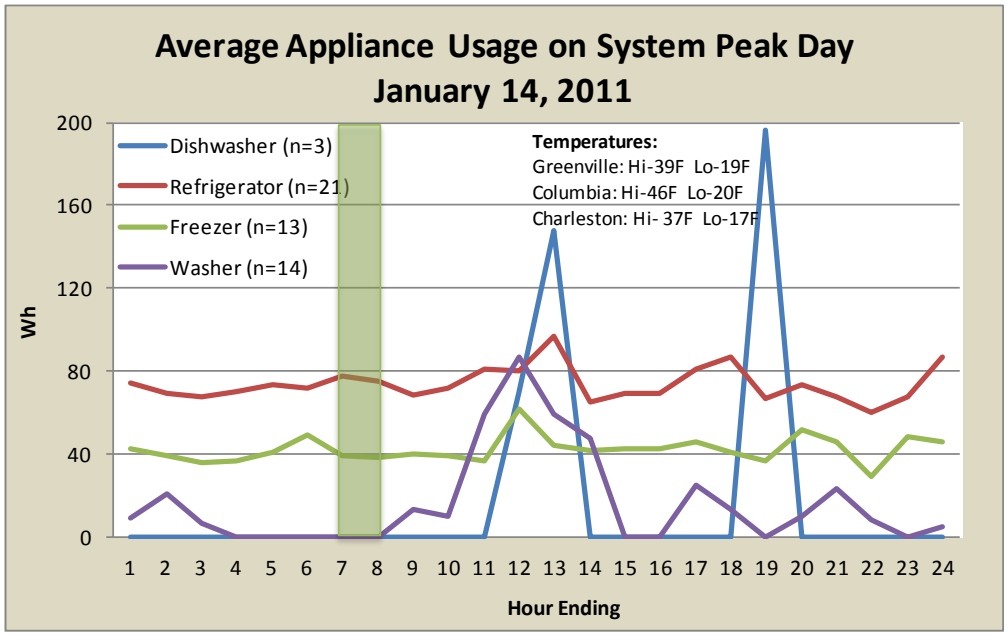
Since temperatures are beginning to moderate in early March, heating usage is beginning to decrease for most customers. Unlike the February system peak day, the roof replacement customers with strip heat only show much lower usage than control customers with strip heat only.

The graph below shows appliance usage on the December peak day of December 14th.

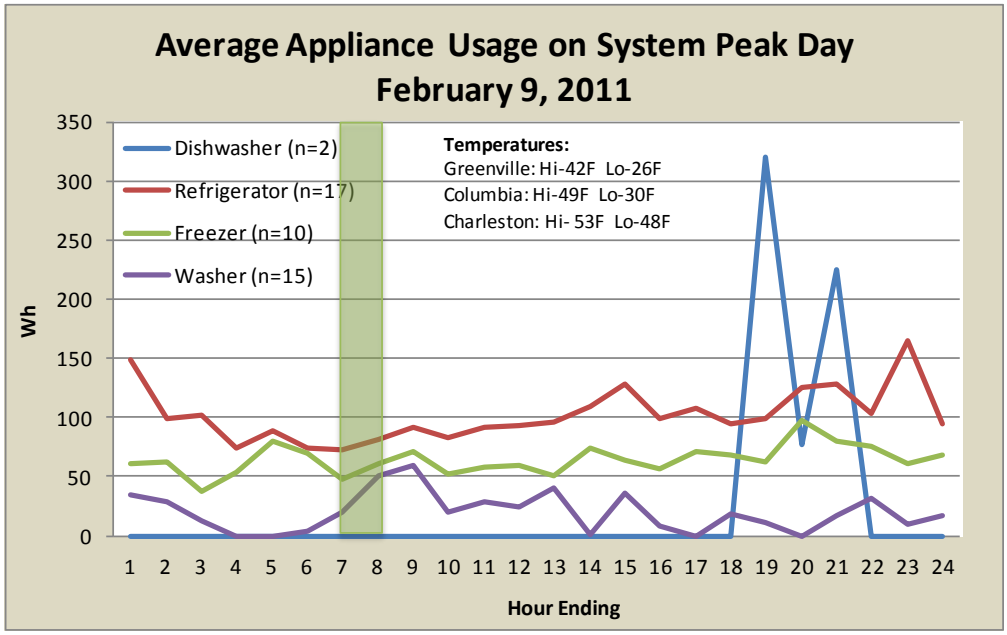


All three of the dishwasher customers did not wash any dishes on this day which is why usage remains at zero. Usage for all other appliances follows a normal pattern.

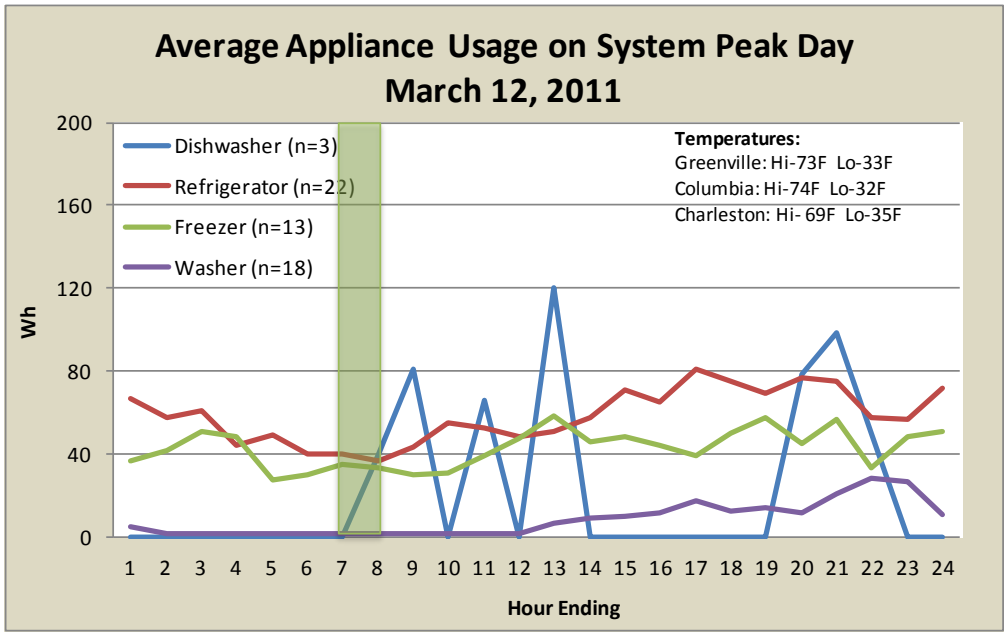
The graph below shows appliance usage for all customers on the January peak day of January 14th.



The graph below shows appliance usage for all customers on the February peak day of February 9th.



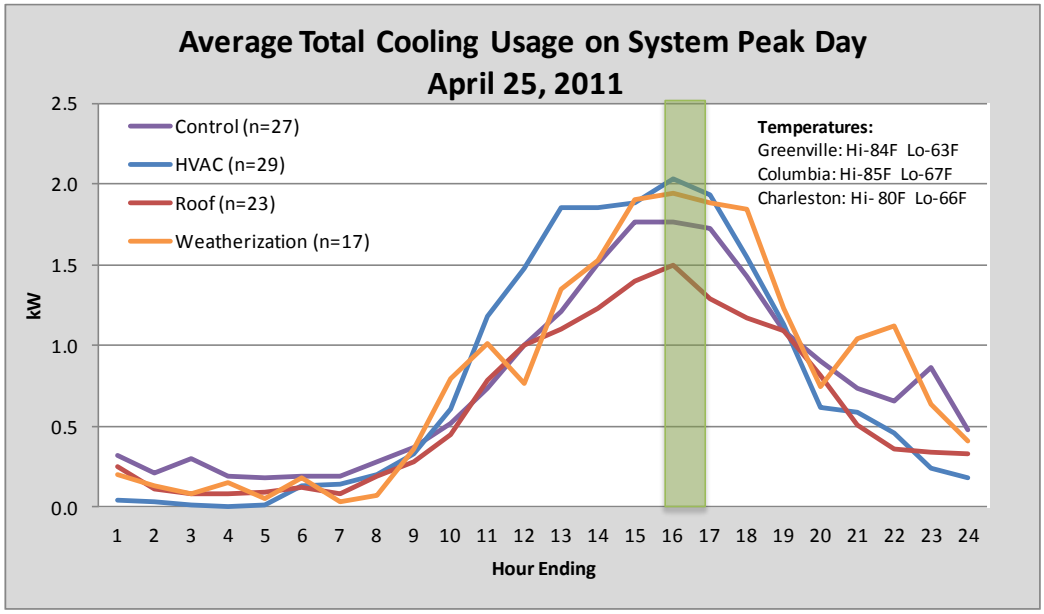
The graph below shows the appliance usage for all customers on the March peak day of March 12th.



In the graph above, all of the appliances had been replaced with the more energy efficient model. The graph shows that usage greatly decreased after the replacement, with each appliance showing lower usage during the peak at hour ending 8.

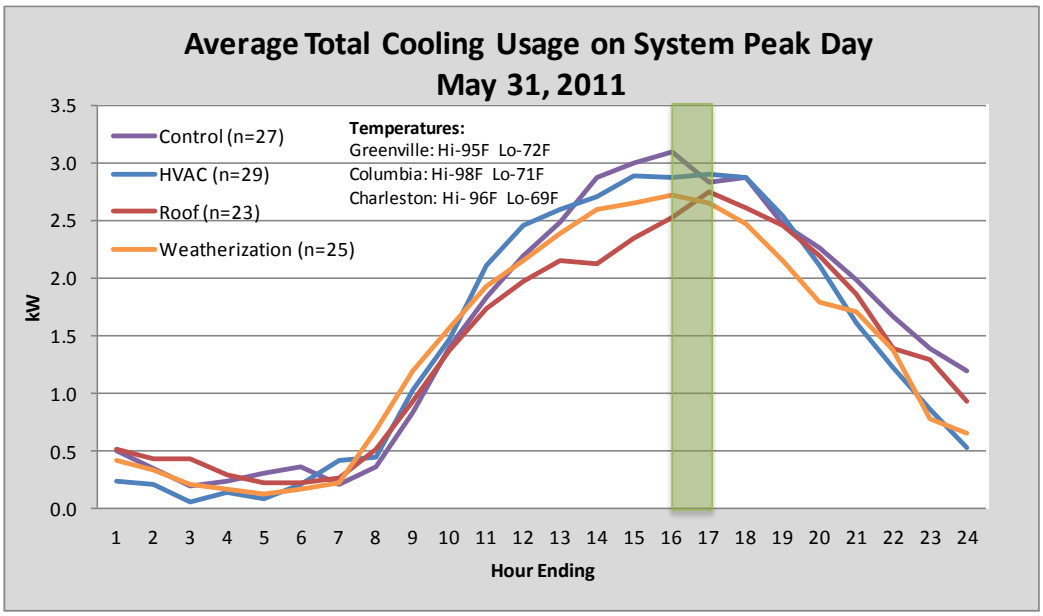
System Peak Analysis – Summer Season

The graphs below show average cooling loads on the peak days recorded in April through September of 2011.

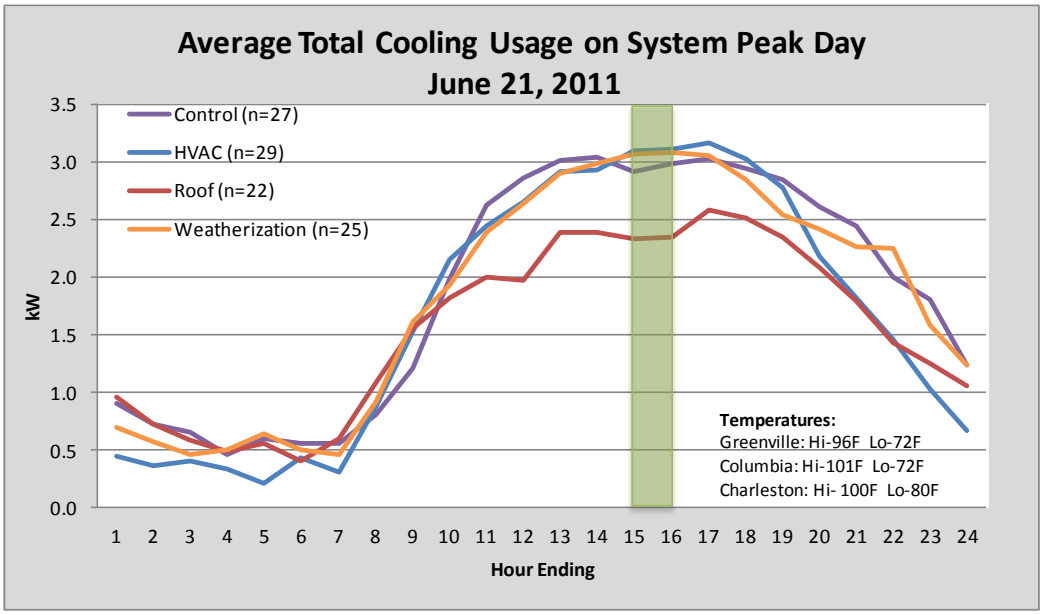


The graph above shows the average usage on the April peak day, April 25th, for each customer group. The system peak for April occurred during the hour ending 17. The HVAC replacement customers and weatherization customers averaged around 1.8 kW during this hour. Control customers averaged around 1.6 kW and the roof replacement customers were the lowest averaging around 1.3 kW during this hour.

The graph below shows the average usage on the May peak day, May 31st for each customer group. This peak also occurred during hour ending 17.

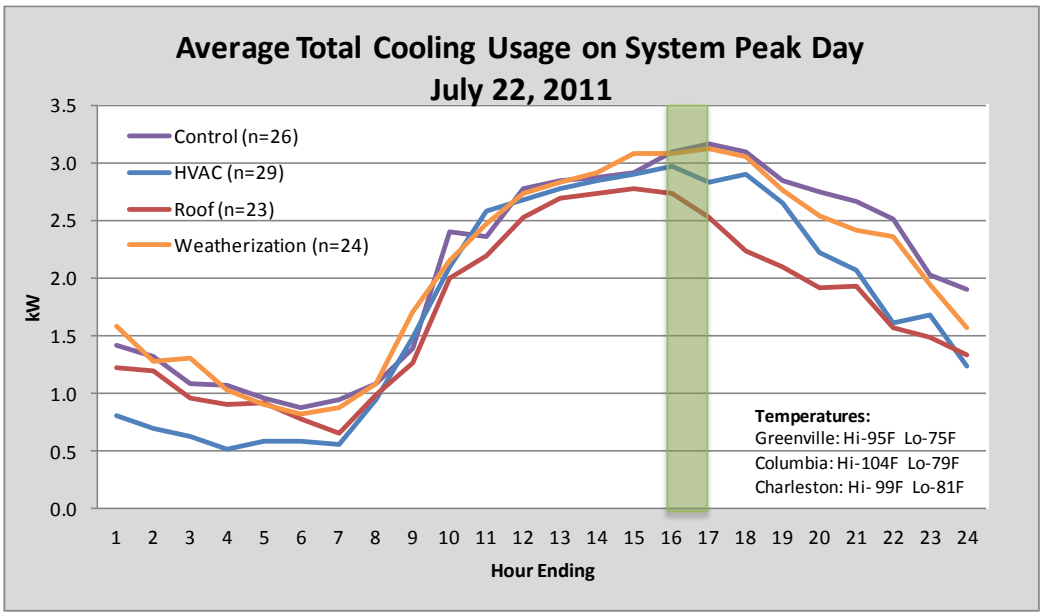


All of the customer groups averaged cooling usage between 2.5 and 3.0 kW.



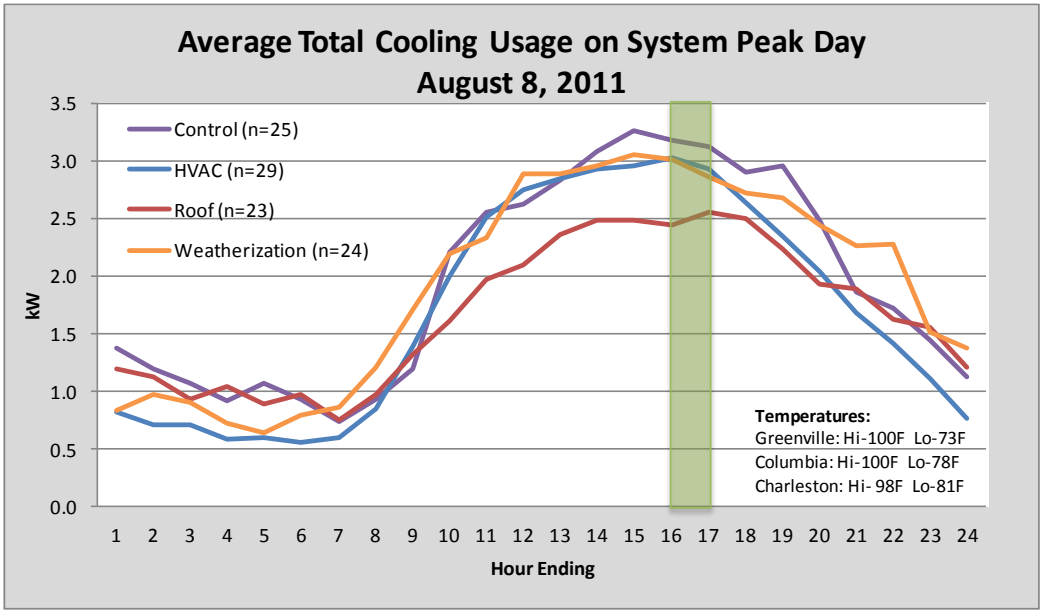
The graph above shows the average usage on the June peak day, June 21st, during hour ending 16, for each customer group. Again, all of the customer groups averaged cooling usage between 2.25 and 3.25 kW.

The graph below shows the average usage on the July peak day, July 22nd, during hour 17, for each customer group.



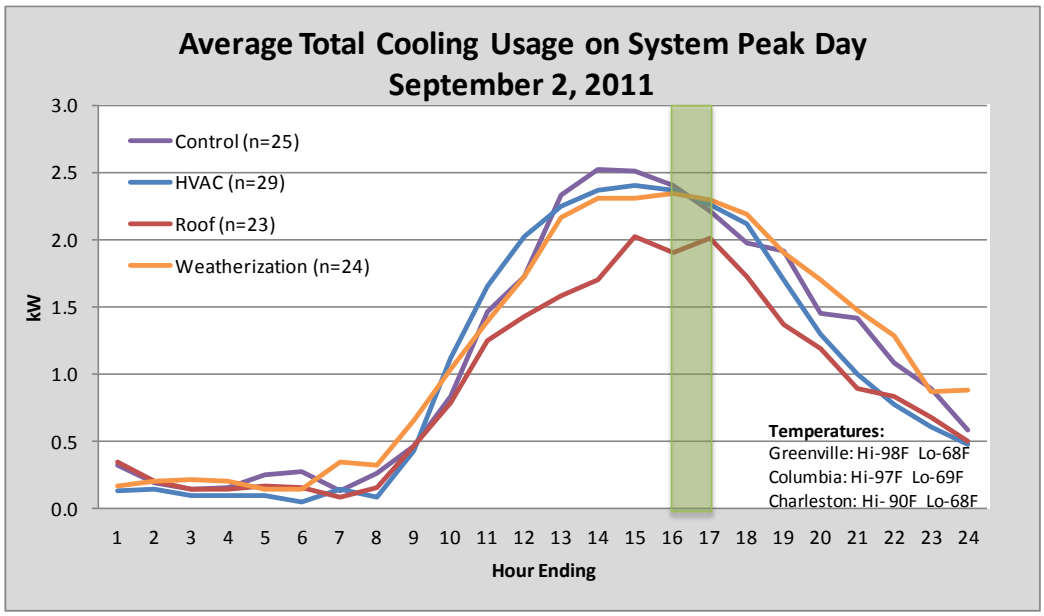
Demands at the hour of the system peak in July were between 2.5 and 3.2 kW on average.

The graph below shows the average usage on the August peak day, August 8th, during hour 17, for each customer group.



The cooling demands in August at the system peak were similar to those seen in July.

The graph below shows the average usage on the September peak day, September 2nd, during hour 17, for each customer group.



Cooling demands at the hour of the system peak in September declined to an average of about 2.3 kW due to the milder conditions during the month.

Winter Heat Pump Load Temperature Response Analysis

The following table and graphs show the results of a cross sectional analysis of the mobile home programs and the average response to temperature for the heat pump customers with compressor, heat pump strips, and total heat.

A cross sectional model uses all heat pump customer data and is used to develop the average heat pump response at a given temperature for an average customer. It can be used to model any size customer given an input maximum equipment demand. The maximum hourly demand for the heating equipment being modeled is used to improve the statistical fit and in effect normalize each customer's usage. The heat pump compressor and the heat pump strips have a different load response to temperature; therefore, it is appropriate to model the equipment separately.

An optional methodology is to model each customer independently and then to average the regression coefficients to get an average customer model. The cross sectional model produces a better response curve and tighter model fit because of the much larger amount of input data and is not as subject to large outliers when compared to the individual models.

The regression model used to estimate the quadratic response curves is shown below.

$$\boldsymbol{HPComp_{(i,t)} = intercept + maxhpcomp_i * temperature + (maxhpcomp_i * temperature)^2}$$

$$\boldsymbol{HPStrip_{(i,t)} = intercept + maxhpstrip_i * temperature + (maxhpstrip_i * temperature)^2}$$

Where:

i = individual heat pump customers

t = the air temperature at the closest weather station

hpstrip, hpcompmax = the maximum hourly demand for each customer for temperatures below 65 degrees

HPComp(i,t), HPStrip(i,t) = the average mean load at a given temperature for each heat pump customer

A compressor and strip heat model were developed for the HVAC replacement customers, the roof replacement customers, and the control group customers, allowing for a total of six models to be developed. The models were estimated using only data when the outside air temperature was below 65 degrees.

The SAS statistical output is shown below for a representative model, roof customers and heat pump compressor.

Please note in the regression output below:

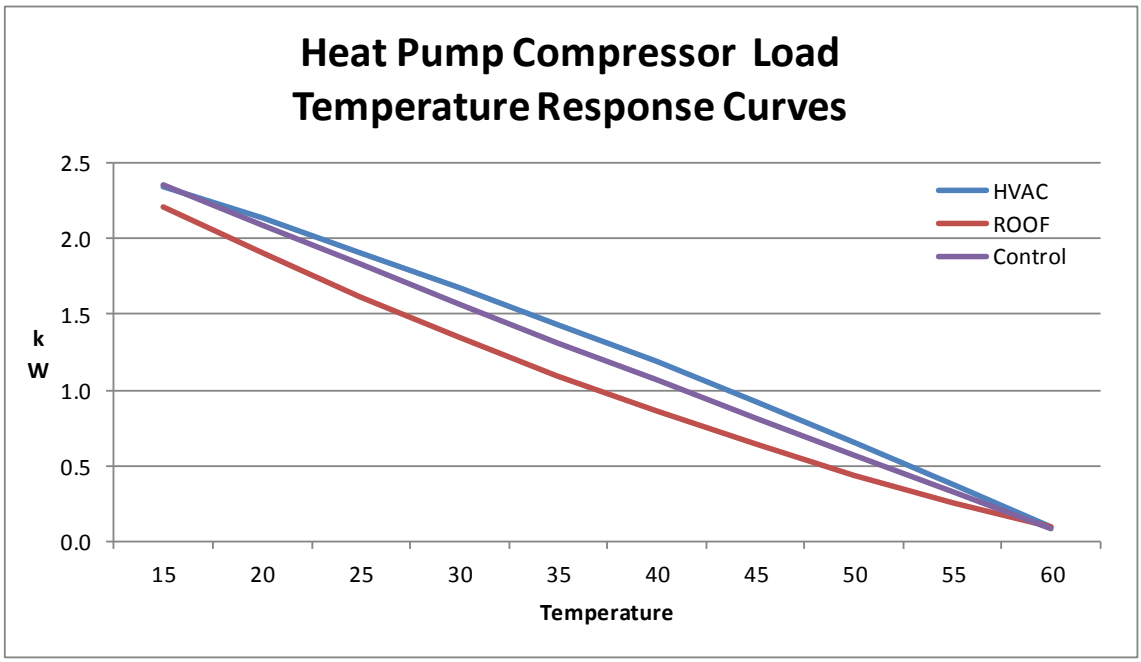
sysmax = maxhpcomp(i)*temperature

sysmax2 = sysmax*sysmax

```
The REG Procedure
Model: MODEL1
Dependent Variable: HPComp(i,t)

                             Analysis of Variance

                                    Sum of           Mean
Source                   DF        Squares         Square    F Value    Pr > F

Model                     2      184.24080       92.12040    1047.15    <.0001
Error                   432       38.00399        0.08797
Corrected Total         434      222.24479


Root MSE              0.29660    R-Square     0.8290
Dependent Mean        0.86919    Adj R-Sq     0.8282
Coeff Var            34.12385

                         Parameter Estimates

                      Parameter       Standard
Variable      DF       Estimate          Error    t Value    Pr > |t|

Intercept      1        0.09043        0.02656       3.40      0.0007
sysmax         1        0.01186        0.00109      10.84      <.0001
sysmax2        1     0.00004854     0.00000978       4.96      <.0001
```

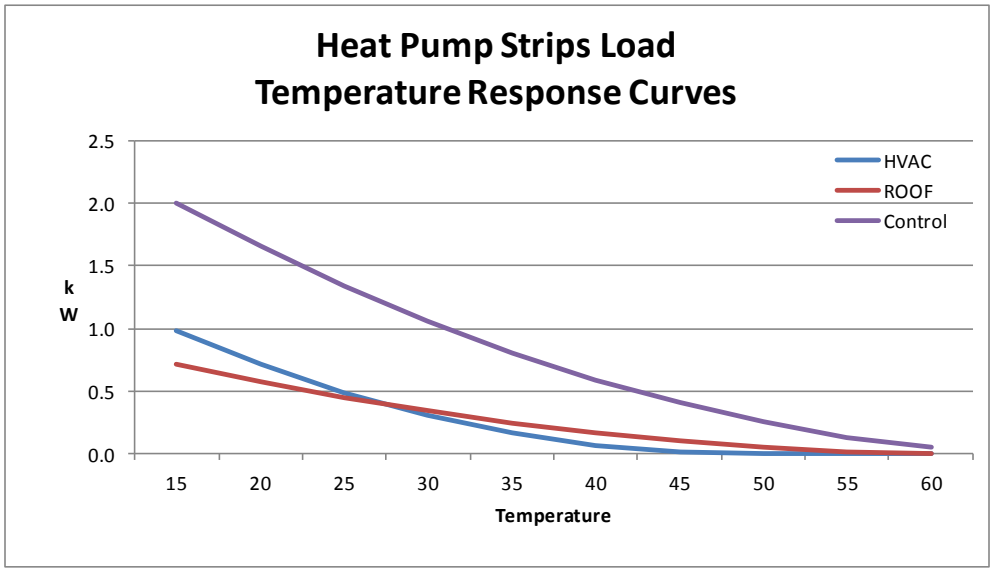
The model results were used to develop the table and graphs below.

CEPCI Mobile Home Comparison of Programs Heat Pump Load-Temperature Response Curves Heating Season									
Temperature	Compressor kW			Strip Heat kW			Total Heat kW		
Degrees F	HVAC	ROOF	Control	HVAC	ROOF	Control	HVAC	ROOF	Control
15	2.35	2.21	2.35	0.98	0.72	2.00	3.33	2.93	4.35
20	2.13	1.90	2.09	0.72	0.58	1.65	2.85	2.48	3.74
25	1.91	1.62	1.83	0.49	0.46	1.34	2.40	2.07	3.17
30	1.68	1.35	1.57	0.31	0.34	1.06	1.98	1.69	2.63
35	1.44	1.09	1.32	0.17	0.25	0.81	1.60	1.34	2.12
40	1.18	0.86	1.06	0.07	0.17	0.59	1.25	1.03	1.65
45	0.93	0.64	0.81	0.01	0.10	0.41	0.94	0.74	1.22
50	0.66	0.44	0.57	0.00	0.05	0.25	0.66	0.49	0.82
55	0.38	0.26	0.32	0.00	0.01	0.14	0.38	0.27	0.46
60	0.09	0.09	0.08	0.00	0.00	0.05	0.09	0.09	0.13



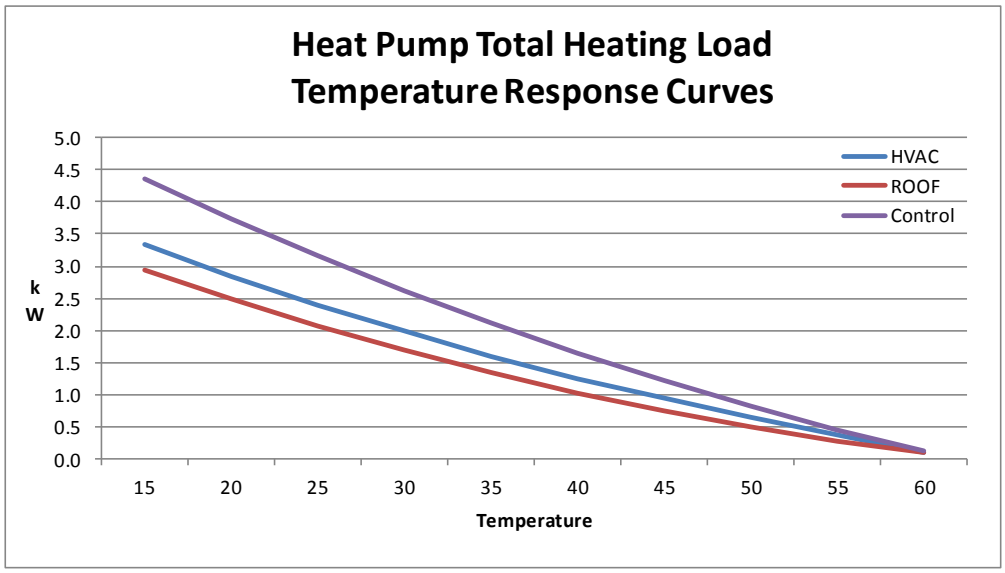
The graph above shows the temperature response curves for the heat pump compressor load.

The graph below shows the temperature response curves for the heat pump strips load.



The temperature response curves appear to be more linear for the heat pump compressor; while, the temperature response curves for the heat pump strips decrease more rapidly as the temperature increases. The HVAC and roof replacement heat pump customers use much less energy for heat strips than the control group heat pump customers.

The graph below shows the temperature response curves for the total heat pump heating load for each weather sensitive program.



At very cold temperatures the total heating load response is 1.42 kW and 1.02 kW less for the roof and HVAC heat pump customers respectively when compared to the control group customers with heat pumps.

Summer AC Compressor Load Temperature Response Analysis

The following table and graph shows the results of a cross sectional analysis of the mobile home programs and the average response to temperature for the air conditioner compressor. The regression model used to estimate the quadratic response curves is shown below.

The regression model used to estimate the quadratic response curves is shown below.

$$\boldsymbol{ACComp_{(i,t)} = intercept + maxACcomp_i * (temperature - setpoint) + (maxACcomp_i * (temperature - setpoint))^2}$$

Where:

i = individual heat pump or AC customer

t = the air temperature at the closest weather station

maxACcomp(i) = the maximum hourly demand for each customer for temperatures above 80 degrees

ACComp(i,t) = the average mean load at a given temperature for each heat pump or AC customer

setpoint = thermostat audit data collected at each site

A compressor model was developed for the HVAC replacement customers, the roof replacement customers, and the control group customers, allowing for a total of four models to be developed. The models were estimated using only data when the outside air temperature was great than or equal to 80 degrees.

The SAS statistical output is shown below for a representative model, HVAC Replacement Customers and AC compressors.

Please note in the regression output below:

Acmnattemp = ACComp(i,t)

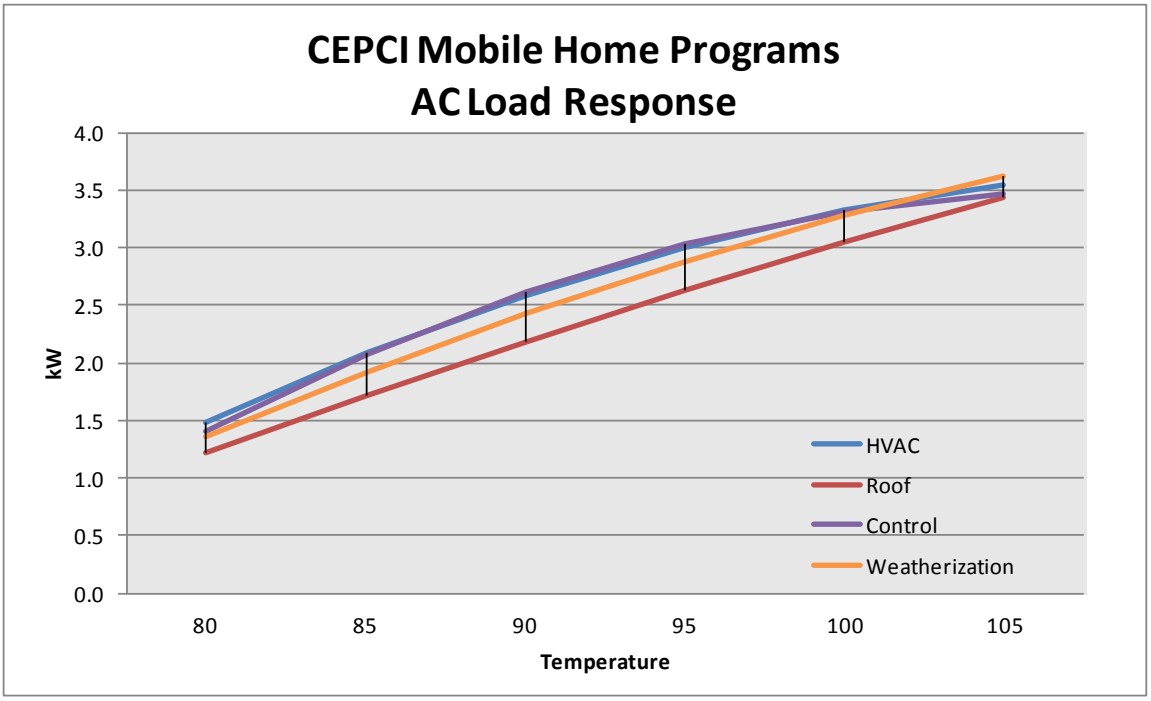
Sysmax = maxACComp(i) * (temperature - setpoint)

sysmax2 = sysmax * sysmax

```
The REG Procedure
Model: MODEL1
Dependent Variable: acmnattemp

Number of Observations Read                          659
Number of Observations Used                          622
Number of Observations with Missing Values            37


                            Analysis of Variance

                                   Sum of           Mean
Source                    DF      Squares         Square    F Value    Pr > F

Model                      2    195.49208       97.74604     325.38    <.0001
Error                    619    185.94915        0.30040
Corrected Total          621    381.44122


Root MSE              0.54809    R-Square     0.5125
Dependent Mean        1.87004    Adj R-Sq     0.5109
Coeff Var            29.30905


                        Parameter Estimates

                      Parameter       Standard
Variable      DF       Estimate          Error    t Value    Pr > |t|

Intercept      1        0.59841        0.08942       6.69      <.0001
sysmax         1        0.02729        0.00344       7.93      <.0001
sysmax2        1    -0.00003446     0.00003026      -1.14      0.2553
```

The model results were used to develop the table and graphs below and assumed a 4 kW maximum load AC compressor and a thermostat set point of 74.2 degrees for all programs.

CEPCI Mobile Home Comparison of Programs Normalized for Comparison to 4 kW Connected Load Thermostat Setting 74.2 Degrees Summer Season				
Temperature	**AC Compressor kW**			
Degrees F	**HVAC**	**Roof**	**Weatherization**	**Control**
80	1.48	1.21	1.36	1.40
85	2.08	1.71	1.92	2.07
90	2.59	2.19	2.43	2.62
95	3.00	2.63	2.89	3.03
100	3.32	3.05	3.28	3.32
105	3.55	3.44	3.62	3.47



The analysis above suggests little difference between the HVAC and roof programs as compared to the control group when looking at peak AC compressor demand response to temperature. The roof customers load response is consistently lower than that of the other groups.

Billing Comparison

Several of the electric cooperatives involved in the HVAC replacement program provided monthly billing data for program participants to GoodCents for analysis. A sample of these customers has their heating and cooling systems monitored with HOBO data loggers. For these individuals, the amount of energy used to heat or cool the home was compared to the total billed energy for that billing period. In the following sample calculation a customer from Palmetto Electric Cooperative's billed energy is compared to their metered HVAC usage. The following table shows the billing records for this home during the months when the new heat pump was monitored. The month that the loggers were installed is omitted because the HOBO devices were installed in the middle of a billing cycle.

Meter Read Date	Days in Billing Cycle	Billed kWh
1/16/2011	31	1547
2/16/2011	31	1347
3/16/2011	28	869
4/16/2011	31	974
5/16/2011	30	1086
6/16/2011	31	1426

The next step in the analysis is to sum the heat pump compressor and heat strip usage during these periods. In this calculation, HVAC usage from the current read date is included and the usage from the previous read date is not.

The following table shows the compressor usage (AC) and heat strip usage (AHU) in this home over the same period.

Meter Read Date	Days in Billing Cycle	AC	AHU
1/16/2011	31	678.3	31.2
2/16/2011	31	416.6	15.0
3/16/2011	28	209.8	1.3
4/16/2011	31	297.0	0.2
5/16/2011	30	511.2	0.0
6/16/2011	31	1053.3	0.0

Using the information presented in the tables above, the metered HVAC energy is compared to the billed energy and the percentage of the billed energy used for heating and cooling is calculated.

Meter Read Date	Billed kWh	Metered HVAC kWh	Percent of Billed Energy
1/16/2011	1547	709.5	46%
2/16/2011	1347	431.6	32%
3/16/2011	869	211.1	24%
4/16/2011	974	297.2	31%
5/16/2011	1086	511.2	47%
6/16/2011	1426	1053.3	74%

As the table above shows, this customer uses a considerable amount of energy for air conditioning, but heats their home conservatively. This calculation was performed for each customer whose available billing data overlapped the period that the home's heat pump was being metered. The following table presents the average percentage of billed energy used for heating and cooling, by electric cooperative, for each billing month that data was available.

Comparsion of Metered HVAC Energy to Billed Energy by Month		
Billing Month	Cooperative	Percent of Billed Energy Used for HVAC
February	Blue Ridge	53%
March	Blue Ridge	38%
April	Blue Ridge	39%
May	Blue Ridge	34%
June	Blue Ridge	38%
July	Blue Ridge	50%
August	Blue Ridge	53%
September	Blue Ridge	39%
January	Palmetto	52%
February	Palmetto	48%
March	Palmetto	31%
April	Palmetto	24%
May	Palmetto	42%
June	Palmetto	58%
January	Santee	52%
February	Santee	49%

During months with extreme temperatures, homes are using around half of their billed energy for the month on heating and cooling. During the milder, shoulder months, this ratio is much lower.

The table below shows the percent of billed energy used for HVAC for the Roof replacement customers with metered HVAC data and available monthly billing data.

Comparsion of Metered HVAC Energy to Billed Energy by Month		
Billing Month	Cooperative	Percent of Billed Energy Used for HVAC
January	Broad River	47%
February	Broad River	66%
March	Broad River	57%
April	Broad River	43%
May	Broad River	41%
June	Broad River	48%
July	Broad River	45%
August	Broad River	48%
September	Broad River	33%

Years to Payback Analysis

Billing data provided by each electric cooperative was also used to determine energy savings resulting from the replacement of the HVAC units. The electric cooperatives ranged from providing 3 months of billing data since the replacement to 12 months of billing data. GoodCents used all of the provided audit data, cost data, and billing data to determine the number of years required to pay back the cost of replacing the HVAC unit. All costs were determined using an average utility rate of $0.1186 per kWh with a 3% increase per year. Each HVAC replacement was assigned the same cost of $4,850. The following methodology was used to determine the years to payback for each participating customer.

- Determine the number of heating degree days (HDD) and cooling degree days (CDD) recorded at the closest of six South Carolina weather stations during each customer's billing cycle. (Previous month's reading date included, current month's reading date not included).
- Create regression models for each customer's billed kWh as a function of the HDD and CDD. The intercept of the regression models is used as a baseline monthly kWh. The baseline is an estimate of the kWh that a customer would use in a month when no heating or cooling was required.
- Determine a daily baseline usage for each customer by dividing the monthly baseline by the average number of days in each billing cycle. This number is then multiplied by the actual number of days in each billing cycle to get a baseline kWh for that specific billing period.
- Determine the weather dependent kWh for each billing cycle by finding the difference between the billed kWh and baseline kWh.
- Calculate the weather dependent kWh per degree day for each month. Calculate an average weather dependent kWh per degree day for the 'before' period and for the 'after' period.
- Compare the 'before' weather dependent kWh per degree day to the 'after' weather dependent kWh per degree day.

- Calculate the kWh savings per degree day taking the difference between the 'before' and the 'after' weather dependent kWh per degree day.
- Calculate the years to payback using the 30 year average number of degree days for the closest weather station, the total invoice cost, the average utility rate of 11.62 cents per kWh, and the calculated kWh savings.

HVAC Replacement Program Payback Analysis

The table below shows the average payback in years due to the HVAC replacement for all four electric cooperatives, as well as broken out by split and package unit.

	Years	N
Average Payback	10.72	145
Average Payback for Split Unit	11.21	82
Average Payback for Package Unit	9.04	19

Overall Total Number of Customers	Payback Range in Years
32	0 to 5
61	5 to 10
25	10 to 15
15	15 to 20
12	20 and Up

The average payback was 10.72 years (5,212 kWh per year) with 11.21 years for split units and 9.04 years for package units. Most customers showed a payback of less than 15 years. Few customers had a payback of more than 20 years. There were 33 customers that showed no payback; their usage was greater after the unit was replaced. This could be due to lifestyle or behavior change. A larger version of this table can be found in the appendix with each individual customer's output including cooling type, payback, and annual kWh savings by individual.

Roof Replacement Program Payback Analysis

The table below shows the average payback in years due to the Roof replacement for all three electric cooperatives.

	Years	N
Average Payback	24.23	119
Average Payback for Mid-Carolina	21.45	50
Average Payback for Horry	21.44	24
Average Payback for Broad River	28.79	45

Overall Total Number of Customers	Payback Range in Years
16	0 to 10
28	10 to 15
20	15 to 20
27	20 to 30
28	30 and Up

The average payback in years resulting from the roof replacement for all three electric cooperatives was calculated for customers with available billing data using the methodology above. A total of 119 out of 182 customers with available data showed positive payback. These customers averaged 24.23 years of annual energy savings (2,716 kWh on average at 11.62 cents per kWh) to pay back the average roof replacement cost of $6,333.00. Sixteen customers had a payback period less than 10 years and 28 customers had a payback between 10 and 15 years. The complete analysis with each individual customer's calculation is found in the appendix.

Weatherization Program Payback Analysis

The table below shows the average payback in years due to the Weatherization for Berkeley and Black River Electric Cooperatives.

	Years	N
Average Payback	10.65	34
Average Payback for Berkeley	11.89	18
Average Payback for Black River	9.25	16

Overall Total Number of Customers	Payback Range in Years
6	0 to 5
15	5 to 10
7	10 to 15
3	15 to 20
2	20 to 30
1	30 and Up

The average payback in years due to the weatherization program for Berkeley and Black River Electric Cooperative customers was calculated for customers with available billing data using the methodology above. A total of 34 out of 65 customers with available data showed positive payback. These customers averaged 10.65 years of annual energy savings (5,565 kWh on average at 11.62 cents per kWh) to pay back the average weatherization cost of $5,500. Six customers had a payback period less than 5 years and 15 customers had payback in less than 10 years. The complete analysis with each individual customer's calculation is found in the appendix.

Power Monitor Program Payback Analysis

The table below shows the average payback in years due to the Power Monitor program for Edisto, Laurens and Pee Dee Electric Cooperatives.

	Years	N
Average Payback	3.01	145
Average Payback for Edisto	1.56	69
Average Payback for Laurens	2.09	44
Average Payback for PeeDee	7.40	32

Overall Total Number of Customers	Payback Range in Years
60	< 1
31	1 to 2
30	2 to 5
13	5 to 10
11	10 and Up

In Laurens Electric Cooperative, 44 out of 116 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 2.09 years of annual energy savings (1,851 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $189.

In Edisto Electric Cooperative, 69 out of 125 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 1.56 years of annual energy savings (2,545 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $166.

In Pee Dee Electric Cooperative, 32 out of 49 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 7.40 years of annual energy savings (2,205 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $864.

The payback for all 145 customers in the three electric cooperatives averaged 3.01 years of annual energy savings. Sixty customers had a payback period of less than one year. The complete analysis with each individual customer's calculation is found in the appendix.

Energy Savings Analysis

Using heating and AC load data collected on a sample of customers from each group and the control group allows for a more rigorous analysis of savings associated with each program. In general, the kWh savings estimates calculated using the metered data were similar in magnitude to that calculated above using statistical modeling of billing data and weather data.

A separate quadratic regression model was developed for daily compressor usage and the daily strip heat usage for each group in the 'Weather Sensitive Programs' section. Roof replacement and control group customers with heat pumps were analyzed separately from those with electric furnaces. The following table contains the regression equations for HVAC customer's compressor and strip heat loads.

Regression Coefficients - HVAC Replacement Group			
Heat Source	Intercept	β1 (HDD)	β2 (HDD^2)
Compressor	3.972	0.546	0.015
Heat Strips	0.600	-0.146	0.013

A sample calculation for an HVAC customer's compressor load on a day with 15 HDD is shown below.

$$\boldsymbol{Daily\ Compressor\ Usage = Intercept + \beta_1 * HDD + \beta_2 * HDD^2}$$

$$\boldsymbol{Daily\ Compressor\ Usage = 3.972 + 0.546 * 15 + 0.015 * 15^2}$$

$$\boldsymbol{Daily\ Compressor\ Usage = 15.54\ kWh}$$

A separate quadratic regression model was developed for each group in the "Weather Sensitive Programs" section for daily compressor usage once summer season was collected. The following table contains the regression equation for HVAC customer's compressor load.

Regression Coefficients - HVAC Replacement Group			
Cooling	Intercept	β1 (CDD)	β2 (CDD^2)
Compressor	5.313	1.251	0.032

A sample calculation for an HVAC customer's compressor load on a day with 15 CDD is shown below.

$$\boldsymbol{Daily\ Compressor\ Usage = Intercept + \beta_1 * CDD + \beta_2 * CDD^2}$$

$$\boldsymbol{Daily\ Compressor\ Usage = 5.313 + 1.251 * 15 + 0.032 * 15^2}$$

$$\boldsymbol{Daily\ Compressor\ Usage = 31.28\ kWh}$$

Using the 30-year normal number of HDD and CDD for Columbia, SC and the number of days in each month, an average number of HDD and CDD per day was calculated for each month during the course of the program (December 2010 through November 2011). The regression equations for each group were

then applied to estimate the daily heating and cooling load for that month. This daily heating and cooling load was multiplied by the number of days in the month to return an estimated monthly heating or cooling usage. During winter months for customers with heat pumps, the monthly compressor load and monthly heat strip load were summed to produce an estimate of the monthly heating energy. Comparing the monthly heating or cooling energy of the control group to the experimental groups provides an estimate of the savings produced by each measure.

The table below shows the monthly savings if an average control group customer's heat pump was replaced with a higher efficiency heat pump.

Monthly Savings Estimates if Heat Pump is Replaced with Higher Efficiency Heat Pump						
Month	30 Year Normal HDD	30 Year Normal CDD	Control with Heat Pump		HVAC Replacement	
			Heating kWh	Cooling kWh	Heating kWh	Cooling kWh
December	552	5	785	158	638	127
January	628	2	897	155	749	124
February	485	4	690	142	557	114
March	321	20	490	174	363	146
April	131	69	295	224	206	205
May	23	206	215	402	151	393
June	1	388	193	681	138	656
July	0	515	199	910	142	858
August	0	467	199	820	142	781
September	8	296	198	531	140	518
October	121	76	292	236	203	218
November	325	15	490	164	366	136

Total kWh Savings			
Month	Heating kWh Savings	Cooling kWh Savings	Total kWh Savings
December	147	31	177
January	148	31	179
February	132	28	160
March	126	28	154
April	89	19	108
May	64	9	73
June	55	25	80
July	57	52	109
August	57	39	96
September	57	13	70
October	89	19	107
November	124	28	152
	1146	**319**	**1466**

Assuming normal weather, this customer would save about 1,466 kWh.

The table below shows the monthly savings if a control customer with an electric furnace replaced it with a high efficiency heat pump. Notice that the cooling kWh numbers for control with heat pump are the same as the cooling kWh estimates for control with electric furnace. This is because air conditioning loads were modeled together for heat pumps and central AC units.

Monthly Savings Estimates if Electric Furnace is Replaced with High Efficiency Heat Pump						
Month	30 Year Normal HDD	30 Year Normal CDD	Control with Strip Heat		HVAC Replacement	
			Heating kWh	Cooling kWh	Heating kWh	Cooling kWh
December	552	5	1445	158	638	127
January	628	2	1733	155	749	124
February	485	4	1257	142	557	114
March	321	20	748	174	363	146
April	131	69	371	224	206	205
May	23	206	247	402	151	393
June	1	388	220	681	138	656
July	0	515	227	910	142	858
August	0	467	227	820	142	781
September	8	296	226	531	140	518
October	121	76	362	236	203	218
November	325	15	759	164	366	136

Total kWh Savings			
Month	Heating kWh Savings	Cooling kWh Savings	Total kWh Savings
December	807	31	837
January	984	31	1015
February	699	28	727
March	385	28	412
April	165	19	184
May	95	9	105
June	83	25	107
July	85	52	136
August	85	39	124
September	86	13	98
October	159	19	177
November	393	28	421
	4025	**319**	**4344**

A total annual kWh savings of 4,344 is estimated for this type of customer. This compares to the average savings estimate calculated from the HVAC replacement group using billing data of 5,113 kWh.

The table below shows the monthly savings between the control customers with heat pumps and the roof replacement customers with heat pumps.

Monthly Savings Estimates from Roof Replacement - Heat Pump Customers						
Month	30 Year Normal HDD	30 Year Normal CDD	Control with Heat Pump		Roof Replacement with HP	
			Heating kWh	Cooling kWh	Heating kWh	Cooling kWh
December	552	5	785	158	497	82
January	628	2	897	155	585	78
February	485	4	690	142	435	74
March	321	20	490	174	300	103
April	131	69	295	224	208	168
May	23	206	215	402	197	359
June	1	388	193	681	190	610
July	0	515	199	910	196	791
August	0	467	199	820	196	723
Setember	8	296	198	531	190	482
October	121	76	292	236	212	180
November	325	15	490	164	299	94

Total kWh Savings			
Month	Heating kWh Savings	Cooling kWh Savings	Total kWh Savings
December	287	75	363
January	312	76	389
February	255	68	323
March	190	71	261
April	86	56	142
May	18	43	62
June	3	71	74
July	3	119	122
August	3	97	100
September	8	49	58
October	81	57	137
November	191	70	261
	1438	**853**	**2291**

The roof replacement heat pump customers are saving 2,291 kWh when compared to the control group. This compares favorably with savings estimates calculated using billing data for the roof customers of 2,073 kWh.

The table below shows the monthly savings between the control customers with strip heat and the roof replacement customers with strip heat.

Monthly Savings Estimates from Roof Replacement - Electric Furnace Customers						
Month	30 Year Normal HDD	30 Year Normal CDD	Control with Strip Heat		Roof Replacement with Strip Heat	
			Heating kWh	Cooling kWh	Heating kWh	Cooling kWh
December	552	5	1445	158	1294	82
January	628	2	1733	155	1507	78
February	485	4	1257	142	1132	74
March	321	20	748	174	704	103
April	131	69	371	224	284	168
May	23	206	247	402	73	359
June	1	388	220	681	31	610
July	0	515	227	910	30	791
August	0	467	227	820	30	723
September	8	296	226	531	44	482
October	121	76	362	236	264	180
November	325	15	759	164	716	94

Total kWh Savings			
Month	Heating kWh Savings	Cooling kWh Savings	Total kWh Savings
December	151	75	226
January	226	76	303
February	125	68	193
March	44	71	114
April	86	56	142
May	174	43	217
June	189	71	260
July	197	119	315
August	197	97	294
September	182	49	232
October	98	57	154
November	44	70	113
	1712	**853**	**2565**

The roof replacement electric furnace customers are saving 2,565 kWh.

The table below shows the monthly cooling savings for the weatherization customers during the months of March through November.

Monthly Cooling Savings - Weatherization Customers				
Month	30 Year Normal CDD	Control Group Cooling kWh	Weatherization Cooling kWh	Cooling kWh Savings
March	20	174	112	62
April	69	224	180	44
May	206	402	391	11
June	388	681	693	-12
July	515	910	923	-13
August	467	820	835	-14
September	296	531	536	-5
October	76	236	192	44
November	15	164	102	62
		Cooling kWh Savings		**179**

The savings found for weatherization customers is only 179 kWh.

Conclusions

CEPCI implemented an energy efficiency research and development program for manufactured homes across their service territory in 2010. As part of this program, CEPCI replaced 200 HVAC units, 200 roofs, performed weatherization measures on 79 customers, and provided 400 energy efficient appliances (2 appliances each) to 200 customers. CEPCI provided power monitors to a group of 300 customers and conducted home energy audits on a group of 300 manufactured homes.

GoodCents was contracted to conduct measurement and verification on the Manufactured Home Research and Development Program. GoodCents monitored 30 customers in the HVAC replacement group, 30 customers in the roof replacement group, 30 customers in the appliance replacement group, and 29 customers in both the weatherization group and control group in order to determine the energy savings provided by the program.

Each customer participating in the appliance replacement study received 2 new ENERGY STAR appliances, a refrigerator, washing machine, dishwasher, or freezer. The original appliances were monitored for 2 months prior to replacement to allow for baseline data to be collected. The new energy efficient appliances were installed during the middle of February. All metering devices were removed at the end of April which provided over 2 months of post replacement data.

GoodCents found that dishwasher replacement produces the largest percent savings, at 47.5%, and has the shortest estimated years to payback, 13 years. Refrigerator replacement produces the second largest percent savings, 37.4%, and has the second shortest payback of 14 years. Freezers show a 14.6% savings, with a payback of 17 years. The longest payback is the washing machine, which would take 35 years and has an average savings of 36.6%. We are generally under-estimating the payback for washing machines since customers are probably using less hot water with the new washers, allowing their water heater usage to be less. This will reduce their water bill and their water heater kWh, neither of which were considered in this analysis.

Customers participating in weather sensitive programs (HVAC replacement program, the roof replacement program, the weatherization program) as well as the control group, have both their air conditioning compressor and their heat strips monitored. GoodCents provided heating and cooling load shapes for each customer group, as well as a peak day analysis for both the winter and summer seasons. GoodCents developed cross sectional models for each season and each customer group to show the load response to temperature.

GoodCents conducted a billing comparison and years to payback analysis in order to determine the savings resulting from each of the weather sensitive programs. The average payback was 10.72 years (5,212 kWh per year) with 11.21 years for split units and 9.04 years for package units. Most customers showed a payback of less than 15 years. Few customers had a payback of more than 20 years. There were 33 customers that showed no payback; their usage was greater after the unit was replaced. This could be due to lifestyle or behavior change.

A total of 119 out of 182 Broad River, Mid-Carolina, and Horry Electric Cooperative roof replacement customers with available data showed positive payback. These customers averaged 24.23 years of annual energy savings (2,716 kWh on average at 11.62 cents per kWh) to pay back the average roof replacement cost of $6,333.00. Sixteen customers had a payback period less than 10 years and 28 customers had a payback between 10 and 15 years.

A total of 34 out of 65 Berkeley and Black River Electric Cooperative weatherization customers with available data showed positive payback. These customers averaged 10.65 years of annual energy savings (5,565 kWh on average at 11.62 cents per kWh) to pay back the average weatherization cost of $5,500. Six customers had a payback period less than 5 years and 15 customers had payback in less than 10 years.

CEPCI conducted a power monitor program in 2010 and 2011, allowing participants access to their home's energy use for one full year via an in-home display. Three electric cooperatives participated in this program, allowing for a total of 300 participants within the program. In Laurens Electric Cooperative, 44 out of 116 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 2.09 years of annual energy savings (1,851 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $189.

In Pee Dee Electric Cooperative, 32 out of 49 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 7.40 years of annual energy savings (2,205 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $864.

In Edisto Electric Cooperative, 69 out of 125 customers with available data showed positive payback. The average payback in years due to the Power Monitor program was calculated for customers with available billing data using the methodology above. These customers averaged 1.56 years of annual energy savings (2,545 kWh on average at 11.62 cents per kWh) to pay back the average power monitor cost of $166. The payback for all 145 customers in all three electric cooperatives averaged 3.01 years of annual energy savings. Sixty customers had a payback period of less than one year.

GoodCents conducted regression analysis using the control group data to calculate energy savings. We found that if an average control group customer's heat pump was replaced with a higher efficiency heat pump, assuming normal weather, this customer would save about 1,466 kWh per year. If a control customer with an electric furnace replaced it with a high efficiency heat pump, they would see an annual kWh savings of 4,344. The roof replacement heat pump customers are saving 2,291 kWh annually when compared to the control group. The roof replacement electric furnace customers are saving 2,565 kWh annually. Weatherization customers are saving 179 kWh annually when compared to the control group.