FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

CONTRACT REPORT

A Comparison of Homes Built to the 2009 and 1984 Florida Energy Codes

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Table of Contents

EXECUTIVE SUMMARY

The purpose of this study is to determine if Florida homes built to the newer code deliver measureable energy savings compared to homes built to a much earlier energy code. This residential research study was focused on single-family detached homes. The new code group represented homes built to the 2007, with 2009 supplement, Florida energy code. The old code group were homes built to the June 1, 1984-1985 code period. The study makes no statistical attempt to determine to what extent homes are upgraded (or downgraded) with respect to energy efficiency over time. Therefore the energy evaluation is based on old code "as is" in which some homes may have replaced heating and cooling equipment, windows, completed air duct tightening and added attic insulation.

Homes were selected by researching public records then sending a mailed invitation to homeowners to participate in the study. A total of 78 homes were part of the study with 47 old code and 31 new code homes.

Each home had a full energy audit similar to an energy rating completed. Electric energy monitoring equipment was installed to measure whole house, outside condensing unit, air handler unit/heat, and domestic hot water energy use.

Monitored data indicates homes built to the 2009 Florida Energy Code are using 4.4% less energy for cooling than homes built to the 1984 code. They are using about 9% less for water heating. Space heating data size was smaller and, due to a mild winter, less reliable, however the newer homes that were monitored used 37% less energy for heating. Overall the combined heating, cooling and hot water energy use was 7% less for the new code homes using the available monitored data. Due to the smaller sample that had monitored data available for all seasons, the possible error of solely relying on monitored data is large. However looking at individual summer and winter months for monitored sites, the results are rather consistent for cooling and heating.

In order to further explore annual savings two methods were employed. The first method used monitored energy data to project missing data periods: heating and cooling projections were based on inside and outside temperatures and hot water projections were based on established monthly adjustment factors of water use and cold water temperature. The second method used utility bill data along with monitored data to estimate annual heating and cooling energy use of the participants.

Projections of missing months for cooling show a larger savings of 12.3% while space and water heating show lower savings at 20.5% and 5.2%, respectively. Overall, heating, cooling, and hot water energy use is 11.2% lower in new homes compared to old homes using monitored projections to create annual data.

Using utility bill analysis along with the monitored data, cooling savings for the new code homes are estimated at 12.8%, while for heating 38.9%, and water heating 5.2%, for an overall estimate of 13.0%. Because more homes are included with full annual billing energy data, the statistical

confidence is higher than solely relying on monitored data. As shown in Figures ES-1 and ES-2 and ES-3 the results are fairly consistent on a monthly basis as well.

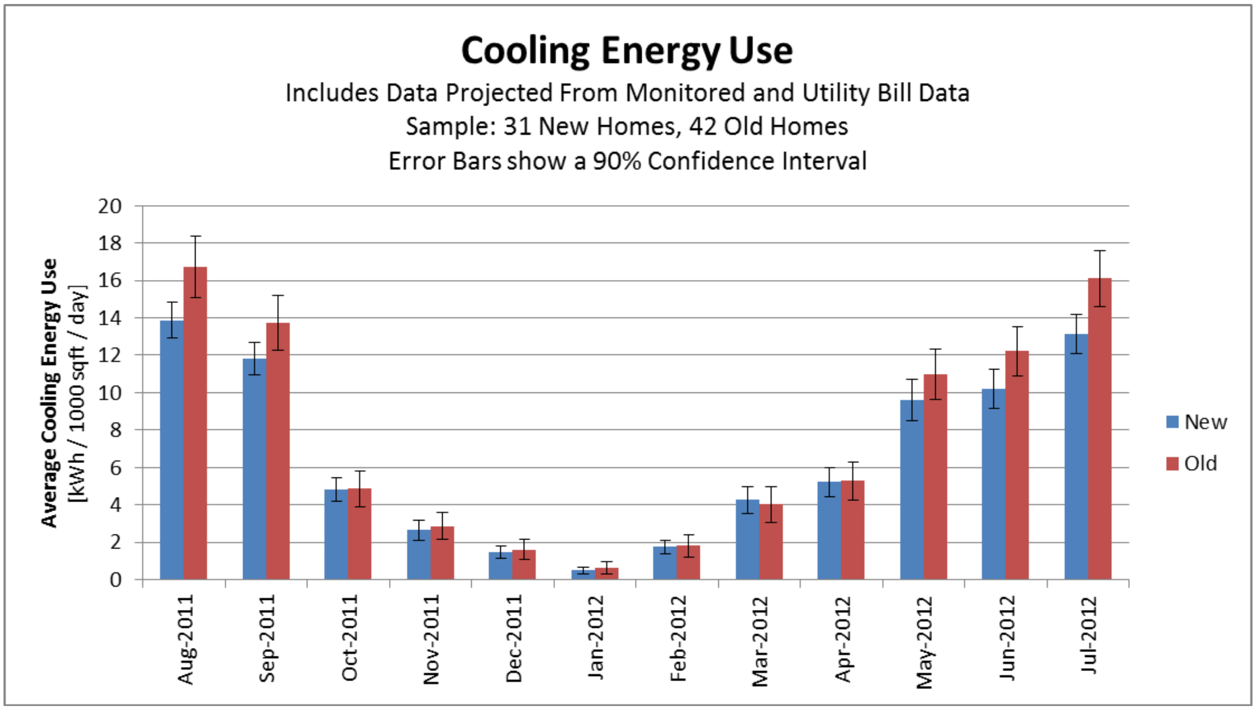


Figure ES-1. Monthly Cooling Energy Use Results, Utilizing Monitored and Utility Bill Data Projections.

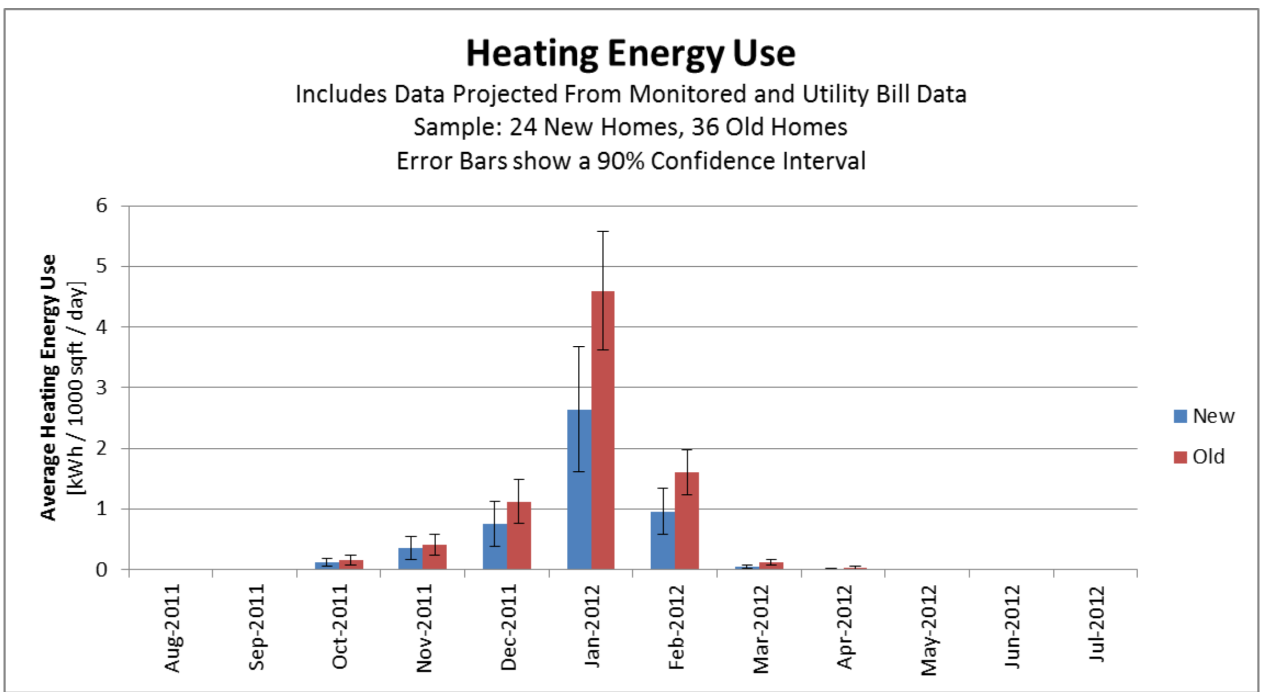


Figure ES-2. Monthly Heating Energy Use Results, Utilizing Monitored and Utility Bill Data Projections.

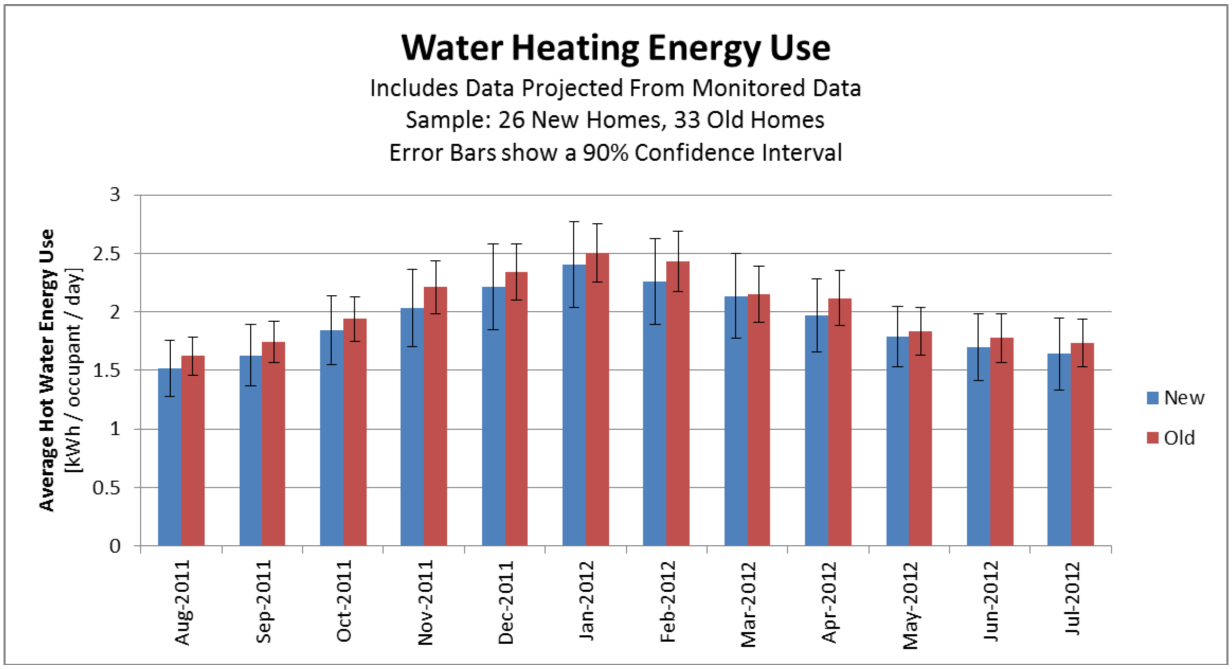


Figure ES-3. Monthly Hot Water Energy Use Results, Utilizing Monitored and Utility Bill Data Projections.

One of the key occupant influences on heating or cooling energy use is the thermostat set point. This study measured interior temperatures in the participant homes. Temperatures in old code homes averaged about 1 degree F higher during the summer and about 0.6 degrees colder during the winter. Relative humidity in old homes averaged 2%-5% higher than the new code homes but with a great deal of scatter among homes.

Simulation results [Fairey, 2009] indicated savings of about 50% of combined heating, hot water and cooling between the 1984 and 2009 energy code. We are estimating only 7% to 13% for the last year from the monitored homes. Some contributing factors to the difference between monitored and simulated are as follows: the unusually mild winter of 2011-2012; a noted interior temperature difference between new and old constructions, different internal loads, and the replacement of heating, cooling, and water heating equipment in the older code homes. In order to account for these factors, simulations were rerun making these adjustments and the predicted savings went from 50% to 9.4%, consistent with the monitored results. This simply means that over time, savings in new homes due to national equipment standard changes will be reduced with change-outs, and that occupants of newer, more efficient homes may keep thermostats at slightly more comfortable levels while using more “plug-load” energy.

The newer code homes had tighter envelopes, tighter ductwork and better return pathways when interior doors were closed than the older code homes. The average house tightness of old code homes was 9.07 ACH50 (n=47) compared to 5.66 ACH50 (n=31) for the new code group, indicating the 2009 homes are 37.6% tighter than the older 1985 era homes. Sixteen (34.0%) old code homes had return duct PPan average exceeding 3.0 pascals. Only one new code home (3.2%) exceeded 3.0 pascals on the return side. The old code group has 85% of homes with at least one room or more per home exceeding the pressure limit when closing a bedroom door, while the new code group had 63%.

Newer code homes were also inspected for compliance and enforcement. Energy code forms were collected and energy audit data was used to create EnergyGauge USA building files to calculate the audited building e-ratio. All of the homes in this sample had been permitted using the performance methodology even though a prescriptive alternative was available to builders. The performance method requires the permitted home to be built to an e-ratio of 0.85 or less compared to the reference home which has set efficiency levels. Twenty-eight of the 31 audited e-ratios were still at 0.85 or less, indicating a 90% e-ratio compliance rate.

While the e-ratio averages of the submitted and audited homes are nearly the same, significant differences between the proposed and audited values were observed on a house by house basis. Three houses had audited e-ratios that exceeded the maximum passing limit of 0.85. The audited e-ratio was lower (more efficient) or the same in 52% of the homes. The remaining 48% had audited e-ratios greater than the submitted form claimed.

The level of energy code compliance of 14 items covered in the performance summary report was determined for each new code home. On average, there was 16.4% non-compliance for the new code group. Non-compliance occurred most often in window (47%), domestic hot water heating (35%) and glass/floor ratio (28%) respectively. Many of the items noted as non-compliance would have a minor impact on the e-ratio.

1. Introduction

1.1 Purpose

The energy code has generally been made stricter over time. This study is to determine if homes built to the newer code deliver energy savings relative to homes built to a much earlier energy code. In other words does the energy code deliver?

1.2 Scope

The Florida Solar Energy Center conducted research into the effectiveness of the Florida energy code to reduce energy use in residential buildings. FSEC examined two groups of homes: those built to the 1984 energy code (June 1, 1984-1985) and those built to the 2007 with 2009 supplement energy code (March 1, 2009- March 14, 2012). Florida's energy code was started in 1979, but the 1984 year was chosen as a time five years later, when it was believed the acceptance of the energy code was realized by builders and jurisdictions. The Florida 2007 with 2009 supplement energy code (hereafter also called 2009 or new code) represented the latest Florida energy code when this project started. An equal sample of 44 homes of each code group was desired. A sample of 47 old code and 31 new code homes was obtained.

1.2.1 Broad Scope of Data Collection

The main goal is to determine if the annual energy use of the two home groups is different. Six categories of data collection were sought for each home in order to reach the goal:

1. Each home was audited for energy efficiency levels of envelope and equipment.
2. On-site measurements were made to ascertain normalized house air tightness and relative amount of duct leakage.
3. Permit information including energy code forms was sought for each new home in order to determine if the new home did comply with the new code.
4. Monitored electric space heating, air conditioning, hot water and total energy use data were collected.
5. Indoor temperatures were also collected to account for this key occupant-controlled characteristic.
6. Utility bill data for two years was sought for each customer in order to better estimate annual energy use.

In order to make a reasonable comparison study while still obtaining participants, FSEC limited the home selection as indicated in Section 3: Obtaining Homes.

1.2.2. Anticipated Issues and Limitations

There were a number of anticipated issues first discussed in the project work plan [Withers, et. al., 2010] that the researchers knew would need to be addressed through site selection and analysis:

1. Older homes will have newer HVAC systems that are more efficient than those installed at the time of construction.

2. Some older homes may have made other energy upgrades such as attic insulation, sealed ducts or new windows.
3. Some older homes may have added additions – some of which may not have been permitted or were permitted under newer codes.
4. Baseline energy use of the non-code plug and lighting loads will vary significantly due to occupancy and behavior.
5. Different number of occupants among the sample homes.
6. Different thermostat settings among the sample homes.

There were also some limitations to the study anticipated in the work plan:

- This study makes no attempt to statistically determine to what extent homes are upgraded (or downgraded) with respect to energy over time. That information likely varies by effort provided by utility and other outreach programs and may also be dependent on demographic factors such as income. Thus, the length of time that a code-level home stays at that level is not analyzed.

- The study will not account for variations under different code jurisdictions or geographic regions as the resources do not allow representative samples for each jurisdiction but rather just sample size based on a state-wide basis. In order to reduce climate-related factors, only one geographic region of the state is proposed covering Central Florida. Inclusion of which Central Florida homes were studied depended in part on finding participants.

- This study does not look at all home types. In order to keep sufficiently sized comparative samples, only single-family detached homes within the range of 1,500 to 2,300 square feet were used.

2. Background

2.1 History of Florida Residential Energy Code Compliance Requirements

In 1978, the State Energy Office under the Department of Administration issued Florida's first statewide building Energy Code. Modeled after ASHRAE Standard 90-75, this code became effective in 1979 and from that point forward, Florida has successfully managed a statewide residential Energy Code, which consistently receives high marks in U.S. Department of Energy national code studies.

A 2009 modeling study [Fairey, 2009] was commissioned by the Florida Department of Community Affair's Codes & Standards Section to determine the impacts of Florida's Energy Code over time and recommend possible changes that would increase residential efficiency. It examines each of the 15 residential Energy Code cycles that have occurred during the 30 year period and determines the relative change in Energy Code stringency and its impact on energy use and energy cost throughout the period. The study was revised to include Florida's 2009 supplement to its 2007 Energy Code.

EnergyGauge USA, Florida's current compliance software, was used to compare the changing levels over time. These results were combined with Florida's historical energy cost data and new home construction data to determine statewide energy use and cost changes across each Energy Code cycle and across all years since 1979. The change in median home size over the 30-year period is also considered by the analysis.

The major findings of the study were:

- Florida has had considerable success using its Energy Code since 1979, increasing efficiency requirements by more than 65% and cumulatively saving (estimated from simulations) Floridians more than 39 billion kWh of electricity – enough to power more than 3 million new Florida homes for a year. The cost savings have also been significant, estimated at almost \$4.7 billion, cumulatively. Compared to the 1979 Energy Code, the 67,000 new homes estimated to have been built during 2009 will realize annual cost savings of more than \$126 million per year.

- Florida's 2009 Energy Code will likely result in new homes that are about 17% more efficient than homes built to the standards of the 2006 IECC and about 3% less efficient than the 2009 IECC.

- "Other" residential energy uses, which have not been considered by Florida's Energy Code, constituted 28% of total home energy use in 1979. By 2009, the share of these "other" home energy uses had increased significantly to more than 55% of the total home energy use.

- Home sizes have consistently increased over time, from a median of 1736 ft^2 in 1979 to a median of 2344 ft^2 in 2009, taking back about 20% of the whole-home energy savings that would have been otherwise achieved.

The Fairey study does not evaluate compliance with the code. However, Florida Power and Light [FPL, 1995] studied homes built to the 1991 energy code in conducting its research for the BuildSmart program. It found that energy code submissions were usually submitted at a level that just passed code. Some audited homes tended to be built better than the code submission while 23% of audited homes were not in full compliance. FPL found that while 13% of the Central Florida homes were not in compliance, 28% of South Florida homes were not in compliance. FPL concluded, "For those homes that were not in compliance, the Code was exceeded by 5%."

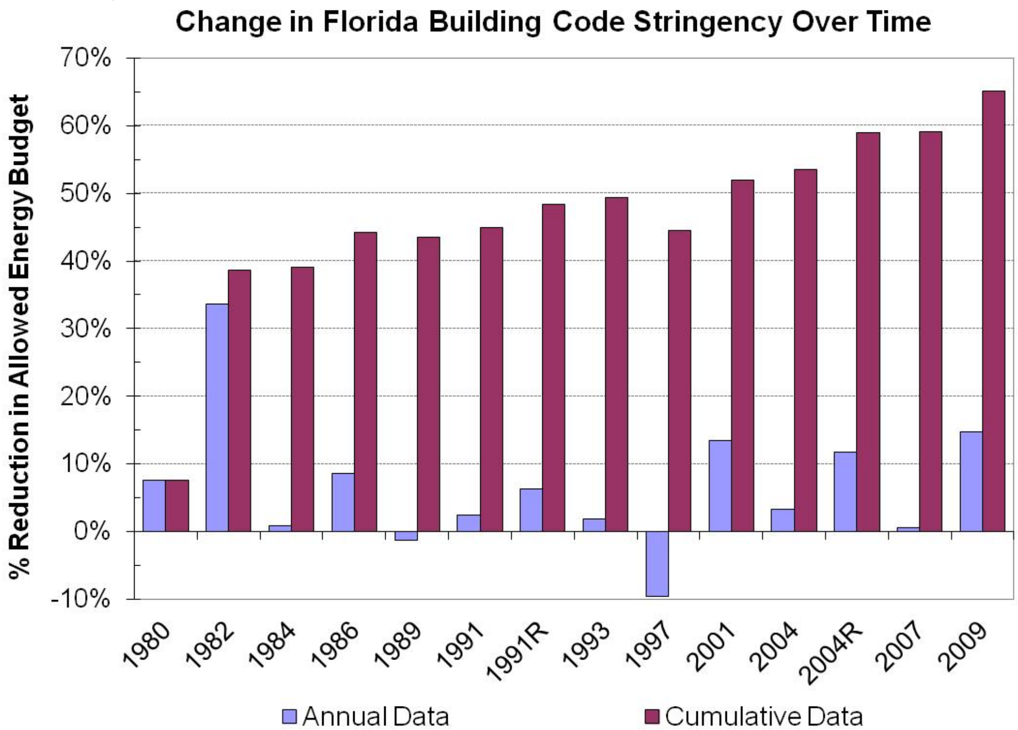


Figure 2-1. Florida Energy Code Stringency Levels 1979 -2009 (Fairey, 2009)

FPL's comparison of code baseline energy use with its metered data and the performance of certain efficiency measures led to some changes in Florida's energy code. For example, instead of assuming ducts to be fully sealed, the code now assumes leaky ducts unless tested to be airtight. Water heating loads were shown to be largely overestimated and were revised, and the credit for heat recovery units and ceiling fans were reduced. Light colored roofs were shown to be a significant energy saver and were provided credit in recent code editions.

The study also showed that many items given credit in the code showed up statistically significant to reducing energy use:

- High SEER equipment
- Reduced glass area
- Additional ceiling insulation
- Wood frame wall construction (higher R-value than block)

- Attic radiant barriers
- Heat pump versus electric resistance heat
- Heat recovery units
- Solar water heating systems.

FPL also recommended revising the heating baseline as their data tended to show less heating than projected by the code. Software licensed beginning with the March 2009 effective code date uses recently developed TMY3 meteorological data that represents 1970 -2000 weather data as opposed to the older TMY and TMY2 data used to derive earlier code multipliers. For most Florida cities, the newer data represent a warming trend with warmer winter temperatures which should predict less heating energy use.

3.0 Home Selection Process

The following steps were undertaken in order to find the Central Florida code effectiveness study homes.

1. Public databases in the selected region were searched for houses meeting key criteria:
   a. Year built (homes to be built under 1984 code or 2009 code)
   b. Conditioned square feet (homes must be between 1,500-2,300 square feet)
   c. Single family detached building
   d. Owner occupant (screen out new homes owned by builders or rental property)
2. Next, study participation invitations were sent to qualifying homes.
3. Staff received calls and messages from interested homeowners and discussed concerns and expectations. A database of interested parties with contact information was created.
4. Homeowner agreement contracts were sent to homeowners to read, sign, and return.
5. Energy code forms were requested from building departments of specific houses where homeowners agreed to participate in study. This involved identifying and contacting the jurisdiction the home was built in, of which, there were as many as five jurisdictions within a county with interested participants. Many jurisdictions required official records requests and in-person visits.
6. Energy audits were scheduled as signed agreements were returned.

Initially, east central Florida homes were solicited as our primary target due to their proximity to our location and significant population. The postcard shown in Figure 3-1 was sent to residents meeting the criteria of the study. Despite the initial amount of interest from potential participants in both the financial incentive as well as a free energy audit, the participation rate was below our goal. This required expanding our search area and continuing our mailing campaign as far west as Pinellas County. New code homes were particularly challenging to find given a substantial slowdown in construction that occurred through this building code era. A lower response rate for new code homes was also due to a higher rate of unoccupied homes than the old code group. A second canvassing went out to some areas in order to obtain an adequate representation of new code homes. Overall the participation rate was only about 0.3 percent of homes being solicited that became part of the study. The extended period required to obtain homes led to having less than a full year of monitored data on the majority of the homes obtained for the study.

Figure 3-1. Example of a study invitation postcard.

4.0 Data Collection

4.1 Energy Code Forms

All of the new homes in this study were discovered to have used Method A, also known as the performance-based method of compliance despite there being a simple to complete prescriptive method available. The form used in Method A is called **1100A-08**. The first page of this form can be seen in Figure 4-9. Code approved energy rating software is used to evaluate the energy use of the proposed “as-built” home which is compared to the “baseline” code home. The code form requires a ratio of as-built modified loads to total baseline loads to be less than 0.85, or 15% better than the baseline for the 2009 code.

Code forms were obtained after participants signed the agreement to participate in the study. Locating random permits prior to receiving an owner’s agreement to participate was not considered a successful procedure since most homes identified as potential candidates were not accessible. Thus the audit homes were found and then code forms retrieved to find any differences. Data that was input into the submitted code form was compared to the data collected during the energy audit.

The energy audit and code form data collection are discussed in further detail in Section 4.3.

4.2 Monitored Data

Monitored data was collected at each project house for the following parameters:

- Outdoor compressor electrical use
- Air handler electrical use
- Hot water electrical use (unless gas hot water)
- Total home electrical use
- Indoor air temperature
- Indoor relative humidity

Ideally one year of data would be collected for each home. However, the difficulty in obtaining customers (as indicated above), combined with some data logging issues described below, did not allow a full year of data for most homes before the project deadline. Monitoring initially was installed as early as May 2011 in the first houses and as late as May 2012 in the last houses. All homes had the instruments removed in August and September 2012 regardless of installation date.

In order to facilitate data collection within a modest budget, staff explored some new data loggers that promised the benefit of online tracking of data at a low cost. The Energy Detective “TED 5000” device (shown in Figure 4-1 with screen display in Figure 4-3 below) was touted as an accurate, real-time energy monitoring unit with remote viewing, and automated online data posting for four different channels in a cost-efficient and reliable device with a user-friendly interface. Initial evaluation of the TED monitoring system looked promising. However, in many home installations, issues arose. The issues included electronic line noise that could not be fully filtered, unresolved internal software code issues that made the device prone to data retrieval problems, and circuits with arc fault protection (as now required by the electric code in newer homes) would trip when the TED Gateway logger was installed. TED data quality problems persisted even after implementing suggestions from the manufacturer and their support team. This led to a change in equipment selection.

The research team identified Wattnode power meters combined with an Onset Computer Corp. HOBO 4-channel pulse datalogger model UX120-017 to be used in all new energy monitoring installations following the first 32 homes that were installed with TED 5000 systems. The new energy monitoring system consisted of two Wattnode power meters and an Onset Computer Pulse Data Logger. The pulse logger is a relatively new product that collects and stores the energy data, but does not have a means to send or download data through modem or internet. Unlike the TED systems, the Onset stores all data and no check can be made on the data without a site visit. The data was collected when the monitoring equipment was pulled out at the end of the project.

In addition to all new installations, 13 TED systems were replaced with the Wattnode/Onset datalogger systems. The breakdown of sites by type of dataloggers is listed in Table 4 -1.

Table 4-1. Number of homes by data logger/sensor type

	TED 5000	HOBO	TED Replaced with HOBO
Old code homes	32 initially (24 later)	18 initially (26 later)	8
New code homes*	8 initially (3 later)	26 initially (31 later)	5

**The total number of new code installations is 34, however, three of these homes were later disqualified after it was discovered that the homes had been permitted just prior to the 2009 code period.*

It should be noted that accuracy of energy measurements taken by a TED and by Wattnode/Onset system were checked against a calibrated Dranetz Power Platform 4300 power analyzer in an actual home installation before full-scale implementation in the study homes. In both cases each had accuracy within 2% agreement of the Dranetz, as the most extreme difference, and differences less than 1% for measurements of 3500 watts and greater, well within manufacturer claimed accuracy.

The Wattnode/Onset system shown in Figure 4-2 was installed inside an electric service panel. The power meters measure line voltage and current, then compute energy and output the data as a pulse signal. Each pulse is a specific amount of energy in watt hours that varies depending upon the current rating of current transducer (black sensors around line sets) used with the meter. The bottom left meter in Figure 4-2 measures whole house power while the meter directly on top of it measures condensing unit, air handler/heat, and domestic hot water energy. The white box towards the lower right collects energy data and stores up to 2-1/2 years of hourly data. Data logging equipment was programmed by connection to a laptop computer using HOBO Pro software. While connected to the computer, the logger was first configured for the Wattnode meter pulse output configurations and then verified to be working correctly (Figure 4-4).

Temperature and relative humidity were also monitored in each home using an Onset Computer Corp. HOBO U12-011 datalogger. Temperature and relative humidity measurements were stored at hourly intervals.

Figure 4-1. A TED energy data logger (gateway). The unit collects and stores data which can be accessed by internet using an ethernet connection. Current and voltage sensors called MTUs are located inside the electric service panel.

Figure 4-2. Wattnode power meters and Hobo data logger energy monitoring system after being installed in an electric panel by a licensed electrician.

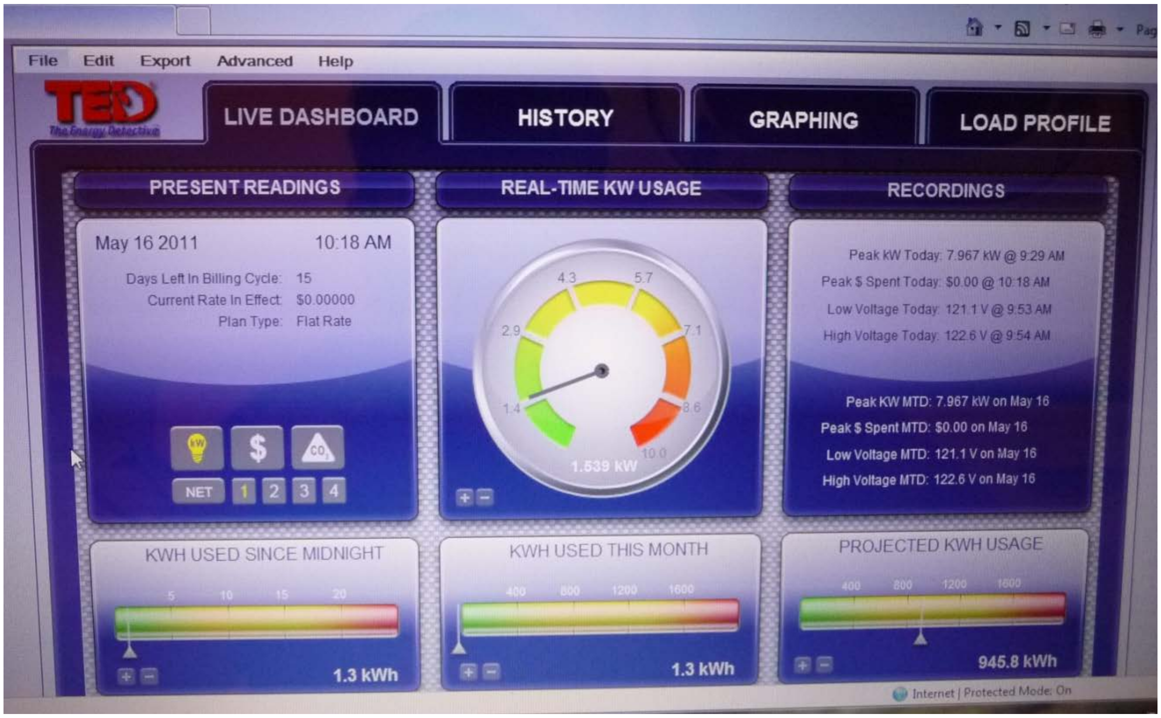


Figure 4-3. View of TED energy monitoring showing whole house power during an installation. This portal is used to look at live data and download stored data.


Figure 4-4. Laptop connected to installed Onset data logger is used to set up configurations and verify proper meter and logger operation.

Since data could not be accessed remotely after installation, it was very important to verify that the Wattnode and HOBO logger system was set-up correctly. It was also important to verify that it was measuring energy as expected before leaving the site. A procedure was written up and added to the test forms to document the serial number of loggers used, location placement and measured energy values observed during operation of cooling system, and hot water heater.

Once the logger was configured and connected to power meters, the air conditioner and hot water heater are operated. Pulses get sent to logger and recorded in real-time which are then verified to confirm that monitoring system is fully operational and logging data. A sample of the Energy Monitoring Notes and Verification form is shown in Figure 4-5 below.

Energy Monitoring Notes and Verification

Most installations should only require 2 Wattnode meters and one Onset pulse logger.
Note location of power meters and pulse logger in spaces below:

House meter (3D-240 P) location ________________________________.
Cond. Unit, AHU and DHW meter (3Y-208 P3) location________________________________.
Note if extra meter/logger combo needed and where located ________________________________.

Pulse logger serial number______________________and location__________________________.
Launch pulse logger with pulse count having pulse rate below (*sometimes this may need to be altered*):

Channel 1 =5 pulses/second (45kW w/100A ct); Channel 2 = 10 pulses/second (15kW w/50A ct)
Channel 3 = 10 pulses/second (15kW w/50A ct); Channel 4 = 10 pulses/second (9 kW w/30A ct)
Example: House meter at 3 pulse/sec.=27kW for one hour

Use the pulse factors below to convert pulses to watthours:

Meter type	With 30 amp CT (used on DHW)	With 50 amp CT (on Cond.Unit and AHU)	With 100 amp CT (on house line A and line B)
3D-240 P (house only)	0.750 Whr/pulse*	1.250 Whr/pulse*	**2.50 Whr/pulse**
3Y-208 P3	**0.250 Whr/pulse**	**0.417 Whr/pulse**	0.833 Whr/pulse*

* Do not use this CT with meter indicated.

Verify proper function of power meters and pulse logger using procedure below.
Connect laptop to pulse logger via HOBOWARE, count pulses/min. and convert to watts in table.

Energy Measurement	Start time	Stop time	Start pulse count	Stop pulse count	Pulse count/min.= (stop pulse-start pulse)/ elapsed min.	Whr/min = (Pulse count/min.) x (Whr/pulse factor)	Watts = (Whr/min.) x 60 min.
Whole House							
A/C Cond. Unit							X2=total
AHU							X2=total
Water Heater							X2=total
HOBO Temperature and RH logger							
T&RH Logger ID#						T&RH Logger location	

If wattage does not appear to be reasonable, then verify that pulse logger pulse/sec is set to appropriate value.

Launch HOBO to gather temperature and RH at hourly periods indefinitely.
Place HOBO on ground floor in central area as close to thermostat as possible. Make sure HOBO not near significant localized heat source such as above cooking appliances, stereo or TV. Locate above reach of small children. A high shelf location out of view is ideal.

Figure 4-5. Energy Monitoring Notes and Verification. This form was used to document the data logger serial number and site location as well as verify proper measurement and data logging of four energy channels.

Figures 4-6 and 4-7 show a portion of the screenshot during live monitoring of energy use. Since the pulse rate can be quite high, digital photos taken at prescribed time intervals were found to be very effective at quickly getting an accurate sample of four measurements simultaneously during the verification procedure.

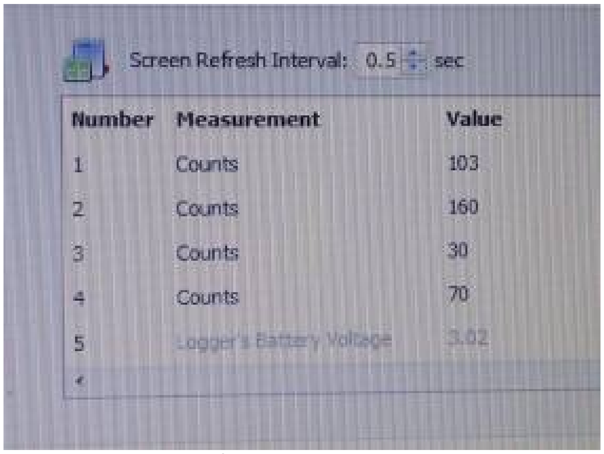


Figure 4-6. Photo of logger screen while connected to the laptop that shows initial pulse count at beginning of evaluation period.

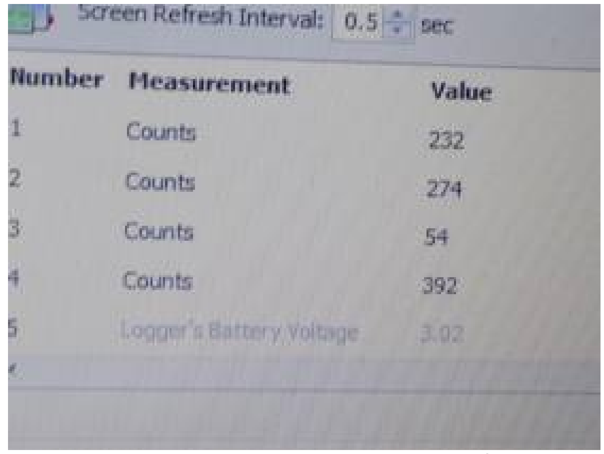


Figure 4-7. Shows the total pulse count after a two-minute period.

Using the form in Figure 4-5, the calculated wattage can be compared to estimated wattage of the air conditioning system, and to the stated wattage taken directly from the electric hot water heater nameplate with an example shown in Figure 4-8. The air conditioner wattage is estimated based on the nominal cooling capacity and efficiency as SEER (btu delivered / whr used). If there is not information stating SEER on site, then an estimate is typically used between 13-15 SEER to establish an expected boundary.

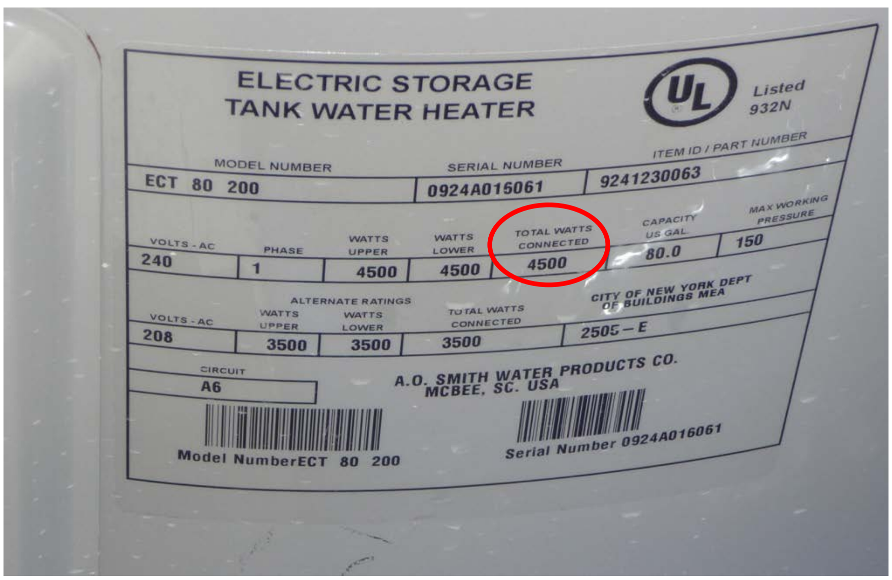


Figure 4-8. Water Heater Nameplate. This nameplate states that the total device wattage is 4,500 watts.

4.3 Audit Data

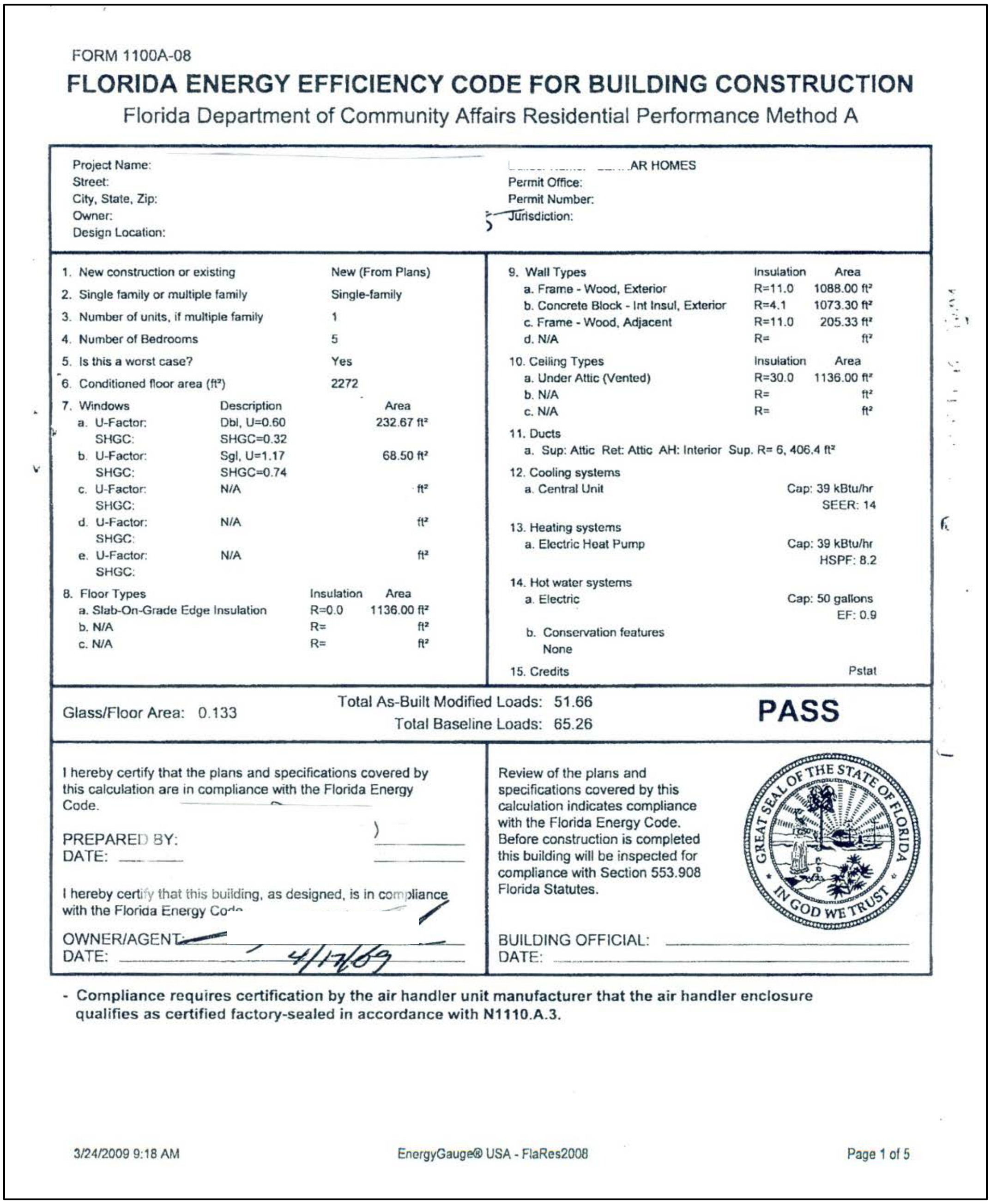
Each house had extensive information collected to be able to determine as many energy-code related characteristics as possible. The effort was nearly identical to completing a Florida Class 1 Energy Rating with the exception that a Pressure Pan duct test was done instead of the CFM25 duct test.

Specific details regarding general audit and code compliance data collection are provided here to provide a better understanding about how the level of non-compliance was determined for each new code house. Residential energy code compliance was evaluated by focusing on 14 primary areas that are summarized in the list below by items a.- n. to include the Glass/Floor Area ratio and e-ratio. Next to the itemized letters are numbers 4-15 in parentheses that appear just as they are shown on the first page of Form 1100A-08 (Figure 4-9).

a. (4.) Number of Bedrooms
b. (5.) Is this worst case?
c. (6.) Conditioned floor area (ft^2)
d. (7.) Windows
e. (8.) Floor Types
f. (9.) Wall Types
g. (10.) Ceiling Types
h. (11.) Ducts
i. (12.) Cooling Systems
j. (13.) Heating Systems
k. (14.) Hot Water Systems
l. (15.) Credits
m. Glass/Floor Area
n. e-ratio

The general method of evaluation of each of these primary items is discussed in detail below.

1.) <u>Correct Code Form</u>
Code Form 1100A-08 was the correct code form for the performance evaluation method of energy code compliance in the new code homes. The code form requires the ratio of as-built modified loads to total baseline loads to be less than 0.85, or 15% better than the baseline for the 2009 code. This value was referred to as the e-ratio. The lower the e-ratio the more efficient the home is relative to the baseline.



FORM 1100A-08

FLORIDA ENERGY EFFICIENCY CODE FOR BUILDING CONSTRUCTION

Florida Department of Community Affairs Residential Performance Method A

Project Name:	AR HOMES
Street:	Permit Office:
City, State, Zip:	Permit Number:
Owner:	Jurisdiction:
Design Location:	

1. New construction or existing		New (From Plans)	
2. Single family or multiple family		Single-family	
3. Number of units, if multiple family		1	
4. Number of Bedrooms		5	
5. Is this a worst case?		Yes	
6. Conditioned floor area (ft²)		2272	
7. Windows	Description		Area
a. U-Factor:	Dbl, U=0.60		232.67 ft²
SHGC:	SHGC=0.32		
b. U-Factor:	Sgl, U=1.17		68.50 ft²
SHGC:	SHGC=0.74		
c. U-Factor:	N/A		ft²
SHGC:			
d. U-Factor:	N/A		ft²
SHGC:			
e. U-Factor:	N/A		ft²
SHGC:			
8. Floor Types		Insulation	Area
a. Slab-On-Grade Edge Insulation		R=0.0	1136.00 ft²
b. N/A		R=	ft²
c. N/A		R=	ft²

9. Wall Types	Insulation	Area
a. Frame - Wood, Exterior	R=11.0	1088.00 ft²
b. Concrete Block - Int Insul, Exterior	R=4.1	1073.30 ft²
c. Frame - Wood, Adjacent	R=11.0	205.33 ft²
d. N/A	R=	ft²
10. Ceiling Types	Insulation	Area
a. Under Attic (Vented)	R=30.0	1136.00 ft²
b. N/A	R=	ft²
c. N/A	R=	ft²
11. Ducts		
a. Sup: Attic Ret: Attic AH: Interior Sup. R= 6, 406.4 ft²		
12. Cooling systems		
a. Central Unit		Cap: 39 kBtu/hr SEER: 14
13. Heating systems		
a. Electric Heat Pump		Cap: 39 kBtu/hr HSPF: 8.2
14. Hot water systems		
a. Electric		Cap: 50 gallons EF: 0.9
b. Conservation features None		
15. Credits		Pstat

Glass/Floor Area: 0.133

Total As-Built Modified Loads: 51.66
Total Baseline Loads: 65.26

PASS

I hereby certify that the plans and specifications covered by this calculation are in compliance with the Florida Energy Code.

PREPARED BY:
DATE:

I hereby certify that this building, as designed, is in compliance with the Florida Energy Code

OWNER/AGENT:
DATE: 4/17/09

Review of the plans and specifications covered by this calculation indicates compliance with the Florida Energy Code. Before construction is completed this building will be inspected for compliance with Section 553.908 Florida Statutes.

GREAT SEAL OF THE STATE OF FLORIDA IN GOD WE TRUST

BUILDING OFFICIAL:
DATE:

- **Compliance requires certification by the air handler unit manufacturer that the air handler enclosure qualifies as certified factory-sealed in accordance with N1110.A.3.**

3/24/2009 9:18 AM EnergyGauge® USA - FlaRes2008 Page 1 of 5

Figure 4-9. Example of form 1100A-08.

2.) <u>Number of Bedrooms</u>

This is a simple single value input regarding the number of bedrooms. If the code form differs from the built house, it was counted as non-compliance. A bedroom is a conditioned space of seventy square feet or more that has a door and a closet space. A "bedroom" used as an office or den space is considered a bedroom by Florida code. The number of bedrooms is used as a surrogate for occupants and effects the water heating gallons used per day in the simulation. As such the proportion of the water heating load relative to the total load will increase as bedrooms increase for a given sized home. Since many Florida homes are built with minimal efficiency water heating equipment, increasing bedrooms will often hurt the performance based code calculation (which needs to be 15% better that the baseline home), so omitting a bedroom could lead to a result of compliance when it should be non-compliant.

3.) Conditioned floor area (ft^2)

This is the total of all conditioned areas in the house. Floor area on code form that was more than 3% greater than the built house was noted as a non-compliance item. Increasing the floor area as well as the associated ceiling and roof areas will typically cause a decrease in the calculated e-ratio thus making a proposed home appear more efficient.

4.) Windows

The windows were evaluated by performance data. Performance inputs are the U-factor and the solar heat gain coefficient (SHGC); an example National Fenestration Rating Council tag is provided in Figure 4-10. The actual performance data was almost never available at the time the audit occurred. When actual window performance data was not available, the code form values were assumed as long as the values claimed were reasonable. The glass area was evaluated as a separate item as the Glass/Floor Area, which can make a large difference in meeting the code (see Figures 4-11 through 4-13)

Significant difference of other window input values were also evaluated and non-compliance qualified as:

i. Orientation is manipulated in a way to result in lower e-ratio, such as high % of glass on north and south sides instead of east and west.
ii. Shading input difference greater than 20% that favors lower e-ratio.

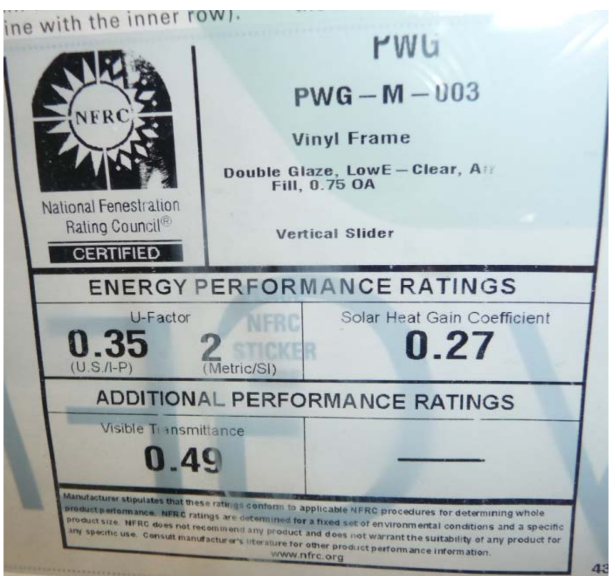


Figure 4-10. Example of an NFRC window rating tag showing U and SHGC values.

Figure 4-11. Window width measurement shown here. The type of window, height, orientation and shading related factors are also measured for every window and wall.

Figure 4-12. Significant of large single pane glass areas in this new code home (81) resulted in a high e-ratio.

Figure 4-13. New code home (45) with little shading, but less glass area on exposed east and west sides.

5.) Floor types

The type of floor and the R-value of floor were considered in this evaluation. Much of new Florida residential construction is slab on grade that usually does not have any added R-value. None of the homes in this study had evidence of insulation for slab on grade. Floor types may also be second story floors over unconditioned garage or cantilevered over outside space as well as raised floor over crawl space which do commonly have added insulation.

6.) Wall types

The type of wall construction was considered as well as the cavity R-value. Since the wall system is enclosed, there was no way to observe actual insulation in finished walls. The code form wall R-value was assumed correct unless site measurements show the R-value claimed is not plausible. The built home wall insulation is estimated based on construction type and measured wall thickness (see Figure 4-14). After subtracting the construction material from the total dimension, the space available for insulation can be known. Much of the new Florida exterior wall construction is eight inch concrete block. Consider the following example where a block wall was measured from interior finished surface to exterior stucco finished surface. If the construction material (interior gypsum board, concrete block and exterior stucco) add up to 9-3/8 inches and the measured wall thickness is 10 inches thick there is a 5/8 inch space for insulation. Foil-faced Polyisocyanurate that is 5/8 inches thick can provide an R-value of 4.1.

Figure 4-14 Exterior wall thickness measurement of an 8 inch masonry block wall.

7.) Ceiling Types

The R-value of insulation was the primary criteria for determining compliance. This applies to flat, vaulted ceiling areas, and on kneewalls. Areas of Ceiling Types were only noted as non-compliance if the difference from actual built house was great enough to result in a lower e-ratio. The attic inspection (see Figures 4-15 through 4-18) looked for variance in insulation thickness and noted compression and voids. The installation of the insulation system was rated as one of three different grades: I, II, or III.

Figure 4-15. Blown insulation in attic is about 11"-12" in most areas which is about R-38.

Figure 4-16. Some areas in this house were only 8"-9" thick (approximately R-30).

Figure 4-17. Photo shows an area of kneewall missing insulation in an old code home (H59).

Figure 4-18. This is same house in photo at left showing kneewall insulation in decent condition around the corner from the un-insulated kneewall (H59).

8.) Ducts

Duct compliance was primarily evaluated based on correct R-value and location of supply, return and air handler. The duct area was only considered if it was clearly understated compared to the built house and the understatement was enough to result in a lower e-ratio. ASHRAE standard 152 uses a duct surface area default of 27% of conditioned floor area, however, well-designed layouts can be about half of this. Decreased duct surface area in attic spaces clearly results in lower calculated energy use in Energy Gauge USA and can result in a lower e-ratio.

The field audit included attic and duct inspection (see Figures 4-19 through 4-22) but did not make an actual measurement of duct surface area. This is because attics are very difficult to navigate through and a hostile environment to make physical measurements of duct surface dimensions. Care must also be taken not to compress and diminish the effectiveness of installed ceiling insulation. The number of supply and return registers is counted and location of these and the AHU are noted on a floor plan. The e-ratios of the actual built home was evaluated using the duct area on the code form, except when the code form claimed a value that was not plausible. If a value was not plausible, the default surface area assumed by Energy Gauge USA was used.

Figure 4-19.Tag on flex duct located in attic indicates R-6.0 insulation.


Figure 4-20. Flex duct in attic used as return air transfer (jump duct) from bedroom to central space. Mastic was used to seal connections.


Figure 4-21. Many old code home had R-6.0 insulated ducts in attics and evidence of duct mastic applied at joints and connections such as this one with black mastic.


Figure 4-22. Duct inspection shows mastic and proper mechanical support was used on this new code system.

9.) <u>Cooling systems</u>

The primary item evaluated under cooling systems was the cooling efficiency based on the seasonal energy efficiency ratio (SEER). The model information of the outside and inside unit was collected on site and the data used to look up the rated efficiency. Figures 4-23 and 4-24 show model nameplate data taken from each house that was used to look up the Air-

Conditioning, Heating and Refrigeration Institute (AHRI) efficiency rating (Figure 4-25). This system at house 70 was a straight cool system with only SEER13 rating and electric strip heat (COP=1).

Figure 4-23. Photo of condensing unit tag. With model number listed at top of this 35.0 kbtu cooling system.

Figure 4-24. Photo of air handler unit tag with model number shown at the top. Below this tag was information indicating this system had 9.6kW of electric strip heat.


AHRI CERTIFIED™ www.ahridirectory.org

Certificate of Product Ratings

AHRI Certified Reference Number: 1105474 Date: 4/2/2012

Product: Split System: Air-Cooled Condensing Unit, Coil with Blower
Outdoor Unit Model Number: 4TTR3036A1
Indoor Unit Model Number: 4TEC3F36B1
Manufacturer: TRANE
Trade/Brand name: XR13

Manufacturer responsible for the rating of this system combination is TRANE

Rated as follows in accordance with AHRI Standard 210/240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump Equipment and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:

Cooling Capacity (Btuh):	35000
EER Rating (Cooling):	11.00
SEER Rating (Cooling):	13.00

* Ratings followed by an asterisk (*) indicate a voluntary rerate of previously published data, unless accompanied with a WAS, which indicates an involuntary rerate.

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AHRI Air-Conditioning, Heating, and Refrigeration Institute

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Figure 4-25. Model numbers from the outdoor and indoor unit are looked up on the AHRI directory of efficiency ratings to determine the heating and cooling efficiency. This unit is a straight cool system with strip heat so only the cooling is rated. This air conditioner has a 13.0 SEER rated efficiency.

10) Heating systems

Heating system code compliance was evaluated by different named ratings depending on the type of equipment and fuel used. Electric heat pumps were evaluated by the heating seasonal performance factor (HSPF). Electric resistance heat rating is known as the coefficient of performance (COP). Gas fuel based system efficiency is known as annual fuel utilization efficiency (AFUE).

11) Hot water systems

Electric and gas hot water system energy compliance were evaluated by the efficiency factor (EF). The location of the appliance is also noted. Figure 4-26 shows model number data taken from an electric domestic hot water (DHW) tank that is used to look up the efficiency rating using AHRI. Figure 4-27 shows the AHRI certificate stating the 40 gallon electric water heater has an EF=0.92.

Figure 4-26. Photo taken of the 40 gallon electric storage domestic hot water heater nameplate. The model number and manufacturer are looked up using the AHRI rating directory to determine the efficiency. The rating certificate is shown below.

AHRI CERTIFIED™
www.ahridirectory.org

Certificate of Product Ratings

AHRI Certified Reference Number: 2110411 Date: 4/2/2012 †Status: Active

Product: Residential Water Heaters
Model Number: ECT-40
Manufacturer: A.O. SMITH WATER PRODUCTS CO.
Trade/Brand name: A.O. SMITH

Rated as follows in accordance with Department of Energy (DOE) Water Heater test procedures as published in the latest edition of the Code of Federal Regulations, 10 CFR Part 430 and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:

Energy Factor:	0.92
First Hour Rating:	54.0 Gallons per hour

The following data is for reference only and is not certified by AHRI:

Energy Source:	Electric Resistance
Water Heater Type:	Storage
Rated Storage Volume:	40 Gals
Input:	4.5 kWh
Recovery Efficiency:	98 %
Heat Traps:	Yes

FootNote 17 - Insulation supplied for Inlet & Outlet connections.

† Models with an 'Active' status are those that are currently in production. Models with a 'Discontinued' status are those that the manufacturer has elected to stop producing, yet stock is still available. Models with an 'Obsolete' status are those that the manufacturer is required to stop manufacturing due to an AHRI certification program test failure.

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AHRI Air-Conditioning, Heating, and Refrigeration Institute

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Figure 4-27. AHRI rating indicates the electric DHW heater has an efficiency rating EF=0.92.

DHW conservation credits associated with insulated heat traps, tank insulation wrap, heat recovery unit, add-on dedicated heat pump and solar system were also noted.

12) <u>Credits</u>
There are several possible energy credits available. These are: programmable thermostat, ceiling fan cooling credit, whole house fan, and cross ventilation. If credits were claimed they were verified against audit data.

13) Glass/Floor Area
The glass /floor area was calculated by the total area of glass per area of conditioned space. The glass/floor area was noted as non-compliance in cases where the glass/floor area on form was different enough to result in a lower e-ratio.

14) e-ratio
E-ratios were calculated for all the new code homes. The e-ratio score was noted as non-compliance if the audited home e-ratio was greater than 0.85.

4.3.1 House Performance Testing

In addition to the previous mentioned measurements and observations, house performance testing was also completed on all old and new code homes. House tightness, relative duct tightness, and quality of return air balance were measured, and the air conditioning system was verified to be in working order.

<u>House Tightness</u>

The house tightness test followed test standard ASTM-779 method of measuring air leakage during depressurization only using a calibrated fan installed in an exterior doorway to measure the rate of air leakage into the home (Figure 4-28). This method tends to provide a more conservative evaluation of tightness compared to testing in both the pressurization and depressurization that averages the results. This occurs because depressurization will pull tighter on exhaust dampers, and jalousie- type windows. The depressurization method was used since pressurization can push movable barriers such as dampers more open than they would typically occur under more natural conditions, which can result in more elevated leakage measurements. Nearly all tests were completed by taking several measurements (multipoint); however four homes were tested using the single-point test method at 50 pascals due to limited test time.

The measured air pressure and fan flowrate results were entered into Energy Gauge USA to calculate:

1. House air leakage rate in cubic feet per minute when depressurized to 50 pascals (CFM50)
2. Normalized air leakage rate as air changes per hour at 50 pascals (ACH50). This is simply calculated by CFM50x60 / house volume (ft3).
3. Air flow equation variables C (flow coefficient) and n (flow exponent) as well as the correlation coefficient, r. All multipoint tests had correlation coefficients greater than 0.98 indicating a good quality test.

Figure 4-28. Blower Door set up in exterior door way in preparation for house tightness and duct pressure pan tightness testing.

Duct Tightness
The standard code approved method for measuring duct air tightness is by means of temporarily masking over duct grills and using a small calibrated fan to depressurize the duct to 25 pascals of pressure. This determines the leakage air flow rate at 25 pascals also known as CFM25. Due to the time involved, this method was only used in cases when a code form claimed the air tight duct credit. There was only one home where the code form claimed the tight duct credit and the CFM25 test method was used. It was found that this duct system was tight enough to earn the claimed the credit.

Another method, known as the pressure pan test or PPan in short, was used in all study homes as an alternative to the CFM25 test (Cummings et. al, 1993). This method used the blower door fan to depressurize the house to 50 pascals and then place a sealed pan over each grill to measure the pressure at the grill with reference to indoors. Photos of the measurement being taken are shown in Figure 4-29 and Figure 4-30. This method was chosen for three primary reasons:

1. Good diagnostic test- It is more informative about <u>where</u> the largest leaks exist in the system. This is helpful to see how the code may have impacted the return versus supply side differently and it is more informative to repair contractors to help prioritize and focus repair efforts.
2. Faster. It does not require large amount time required to seal grills and install a duct test fan. Some grills can be difficult to access in cases such as very high ceiling locations or when they are partially blocked by large furniture such as sofas, beds, dressing cabinets, and entertainment centers. The PPan test can be effectively completed by measuring most grills, and does not require measurement of every grill as long as measurements are taken at grills immediately nearest to those not measured.
3. Lower liability. Paint damage can result from paint from grills as the masking material is removed from the grills at the end of the CFM25 test. Interior finished surfaces can also be accidentally marred as a ladder is moved about to access several grills to seal and unseal them.


Figure 4-29. The pressure pan duct leakage test is used to indicate presence of significant air leakage near the supply and return grill measurements.


Figure 4-30. PPan measurement at a supply grill located in hall ceiling below attic space.

The air conditioning cooling performance was verified to be in working condition by measuring return air flow and the air temperature and relative humidity at the return and supply diffuser closest to the supply plenum. Airflow measurements were made using either the Energy Conservatory TrueFlow flow plate or a Shortridge FlowHood as seen in Figure 4-31 and Figure 4-32 respectively.

Figure 4-31. An airflow measuring plate sensor that measured air conditioner airflow is seen at the return intake. This was placed at the air handler inside the filter access slot when possible.

Figure 4-32. Airflows were also measured using a Flow Hood at return grills.

5.0 Energy Analysis Method

The goal of this project was to compare the annual energy use of space heat, space cool and DHW systems between the two code groups. All homes had energy monitoring equipment installed, however, no homes have a full year of collected data available. Therefore, a combination of monitored and utility bill data was used to derive annual energy use in each home. This section describes the energy analysis methodology that was used. Specific examples of energy data are shown to help describe how data was used and analyzed to determine annual energy use of space heat, space cool and DHW. Final results are not reported until Section 7.

5.1 Heating and Cooling Analysis

Heating and Cooling performance were measured by comparing the average daily energy use for each month from August 2011 to July 2012. For homes with incomplete data, the month was considered if at least 50% of the possible hourly data points were present. Heating for three homes with natural gas heating and one home with a wood pellet heater were not considered.

For months with insufficient data, a monthly projection based off of the monitored energy data and the difference between the outdoor temperatures and monitored indoor temperatures was used. If the monthly projection could not be produced, a monthly prediction based off of utility bill data gathered for each home was used. For example, Figure 5-1 shows an example of monitored energy use (blue diamond points) available only from November 2011-July 2012. Using regression analysis of daily monitored data, the energy use for the previous months (August 2011-October 2011) can be predicted as shown by the solid blue line. This process will be fully described in this section.

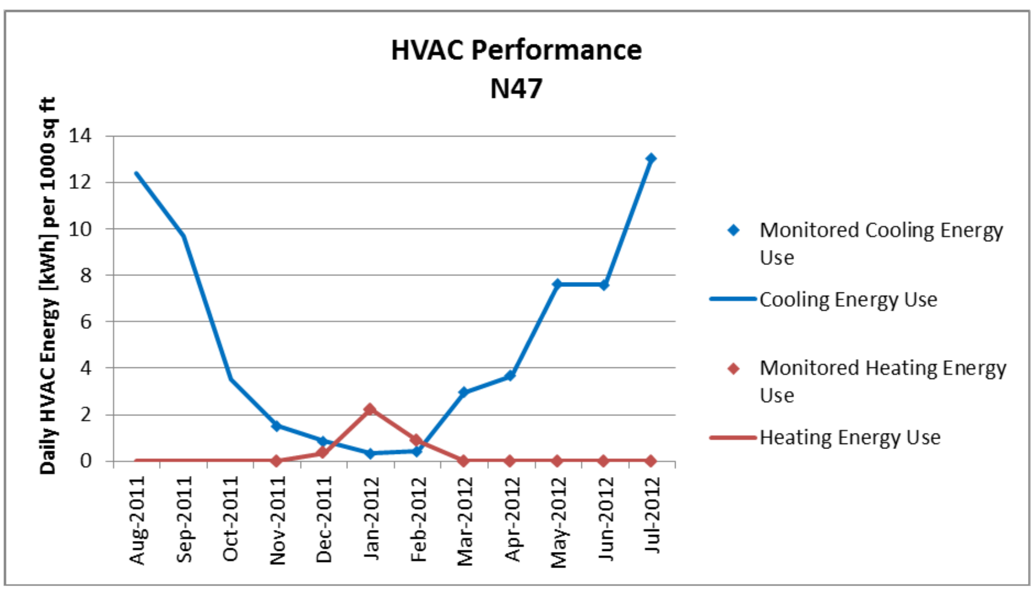

Figure 5-1. Chart of the final reported data for home 47. Note that this home only has monitored data from November 2011 to July 2012. Data before November 2011 has been projected (solid line) using one of the two methods described later in this report.

5.1.1 Assumptions and Normalization

Since the homes in the study ranged in size from 1300 to 2400 ft^2, cooling and heating data was normalized to account for floor area. Cooling and heating values were divided by the house area divided by 1000, to obtain energy values per 1000 ft^2 of house area.

$$\text{Normalized HVAC Energy} = \frac{\text{HVAC Energy}}{\left(\frac{\text{House Floor Area}}{1000}\right)} \tag{5-1}$$

Homeowners were asked about any significant vacations they took during the monitoring period. These periods were examined, and upon clear evidence of the home being vacant, all data for that home during that time period was discarded. Periods of house vacancy greatly alters the energy use of the home, skewing the prediction of missing home energy use and the overall reported energy use, for example, if new code homeowners took significantly fewer vacations than the old code homeowners, old homes would report an artificially high amount of energy use. Care was taken to identify any clear periods of vacancy lasting for more than one week. Short vacations or weekend trips were not considered.

Cooling and heating are usually done by the same equipment, therefore it was necessary to determine when the HVAC system was cooling or heating. To do this, a day's HVAC energy use during hours with an outdoor temperature greater than 65°F was compared to HVAC energy use during hours with an outdoor temperature below 60°F. The system was assumed to be cooling if more HVAC energy was consumed at temperatures above 65 °F, and assumed to be heating of more HVAC energy was consumed at temperatures below 60°F. Hourly energy data points and interior temperatures could also be examined as needed to differentiate between heating and cooling trends. Cooling energy use is greatest during the warmest afternoon hours of the day where heating energy use is more frequent during early morning periods.

One exception was days with no HVAC use. Most air handlers showed relatively constant stand-by power use, making the above method of determining heating or cooling irrelevant. In order to include and properly specify this data, days where the HVAC energy use was at or below this level were specified as cooling or heating days based on the average outdoor temperature for that day. Days with an average outdoor temperature above 65°F were considered cooling and below 60 °F were considered heating. For days between 60 and 65 °F, they took the same specification as the day before. For example, Feb 10-11 2011 have only standby HVAC energy use. The average outdoor temperature for Feb 10 was 67°F, so it was specified as a cooling day. The average outdoor temperature for Feb 11, however, was 63°F. Because it is between 60 and 65, it follows the same pattern as the day before it: cooling.

5.1.2 Monitored Data Projection

Cooling and heating energy use rely heavily on the difference between indoor temperatures and outdoor temperatures. This study utilized a model commonly used to assess building performance based on monitored data (Fels, 1986 and Kissock, 2003). The model assumes a linear relationship between the cooling and heating energy use of a home and the difference between indoor and outdoor temperatures (see Equation 5-2 below: m and b are constants determined by regression).

$$\begin{aligned} &\mathit{Daily\ Cooling\ or\ Heating\ Energy\ Use} \\ &\qquad = m \times (T_{outdoors} - T_{indoors})_{daily\ average} + b \end{aligned} \tag{5-2}$$

Using a least-squares regression between the HVAC energy and the temperature differential, the constants m and b can be determined to create a HVAC performance model.
Since the model accounts for temperature variations both inside and outside the home, it allows a researcher to compare the cooling and heating performance of buildings in different geographic areas or during different time periods. The model can also allow a researcher to project the energy use of a building for a period of time using only the indoor and outdoor temperatures for that time period.

For this study, two models were created for each home, one for cooling and one for heating. A least-squares linear regression was calculated with the dependent variable as the total daily cooling or heating energy and the independent variable as the difference between the daily average outdoor and indoor temperatures (see Figure 5-2).

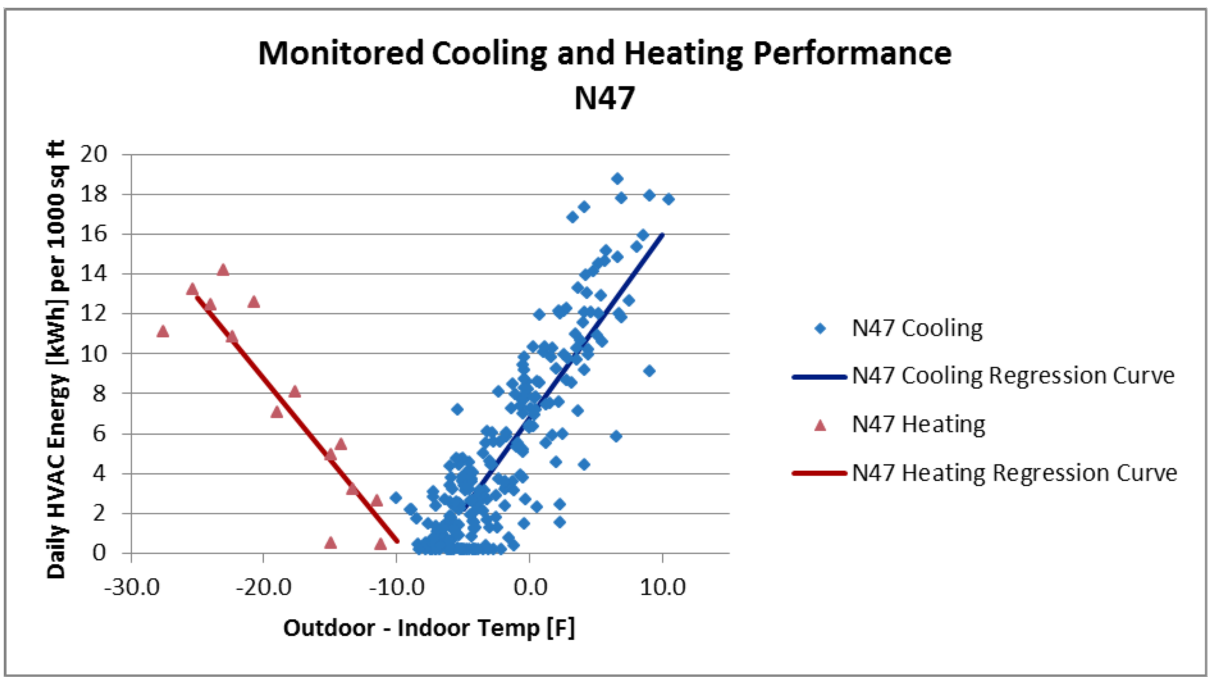

Figure 5-2. Chart showing the correlation between HVAC energy and the difference between indoor and outdoor temperatures. The regression curves are used to predict energy use values for missing months.

Days with no HVAC activity were not included in the regression calculation, because during periods where a homeowner has set the HVAC system not to run, the home's interior temperatures change slowly compared to the wide range of exterior temperatures. This is similar to a regression model used by the Princeton Scorekeeping Method (PRISM), which models cooling and heating use as the functions as shown in Figure 5-3 (Fels, 1986 and Kissock, 2003).

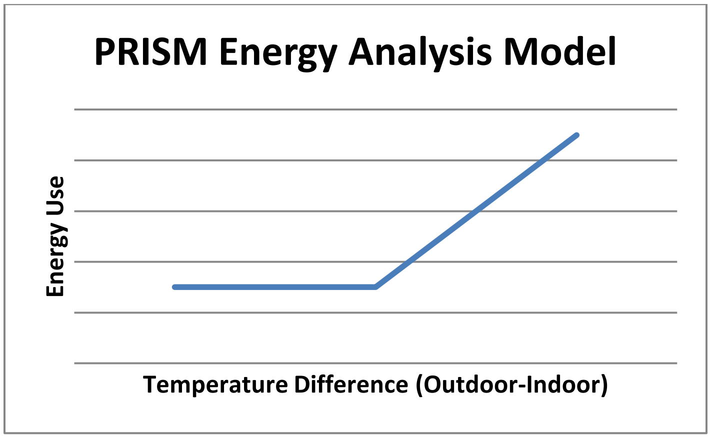

Figure 5-3. Conceptual cooling model of the Princeton Scorekeeping Method

For homes with sufficient data and correlation (more than 15 days of data and an R^2 value greater than 0.3), the resulting cooling or heating model was used to project the HVAC data for days not monitored, according to Equation 5-2. Months for which there was not enough monitored data used these projected values to create a monthly average seen as the solid green line in Figure 5-4.

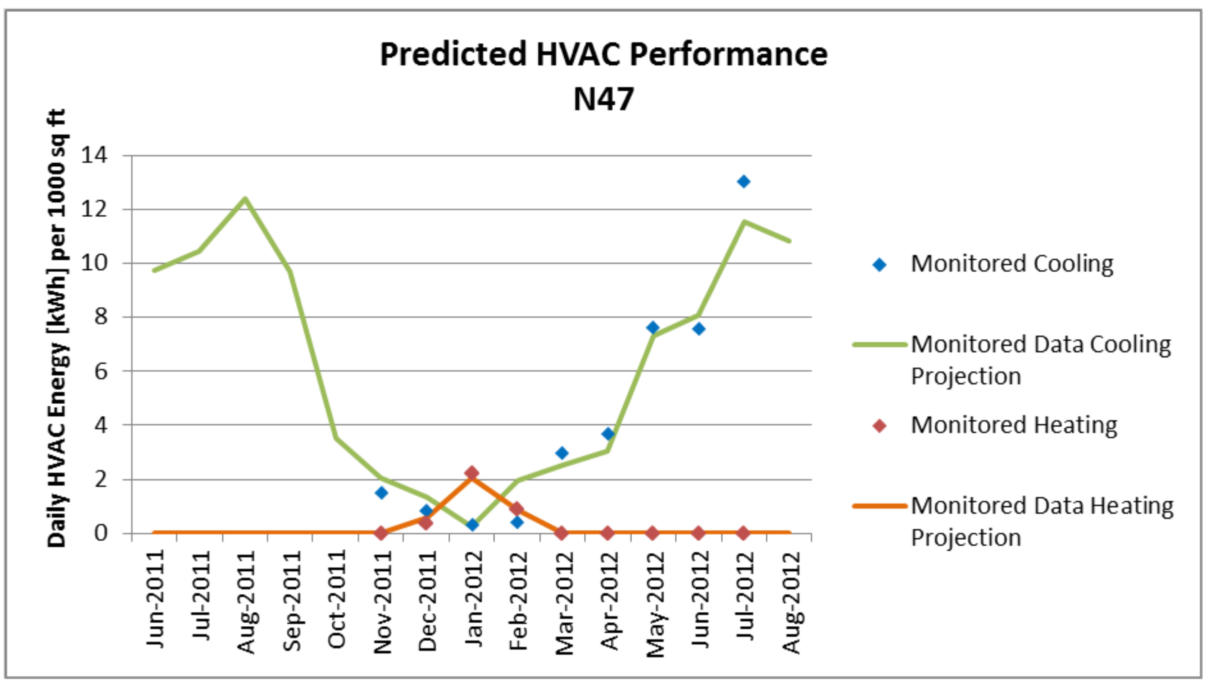

Figure 5-4. HVAC performance projected using a regression between monitored energy and the difference between indoor and outdoor temperatures.

5.1.3 Utility Bill Projection

For some homes with faulty data monitoring equipment or later installation of monitoring equipment, no monitored heating data is available. To adequately assess these homes, one to two years of energy bill data was collected from the homeowners' utility companies. A model similar in concept to the monitored data projection model above can be obtained by comparing the home's monthly electricity use to the cooling and heating degree days for the area. The cooling and heating degree days were based on 65°F.

Researchers used a multiple linear regression model, with area-normalized billing period energy use as the dependent variable and cooling degree days and heating degree days as the independent variables.

Occasionally, homes show a large discrepancy in the energy trend during the Christmas/New Year holidays. To account for this, a third variable, "Holiday," was included in an additional regression, which accounts for this unusual energy use. If the Holiday variable provided a statistically significant addition to the regression, namely if the t-statistic for the Holiday variable was above 1.3 (90% confidence level), the three-variable regression was used instead of the initial regression.

Figure 5-5 below shows the results of the multiple regression. This data did not show abnormal holiday use and was analyzed without the extra holiday variable.

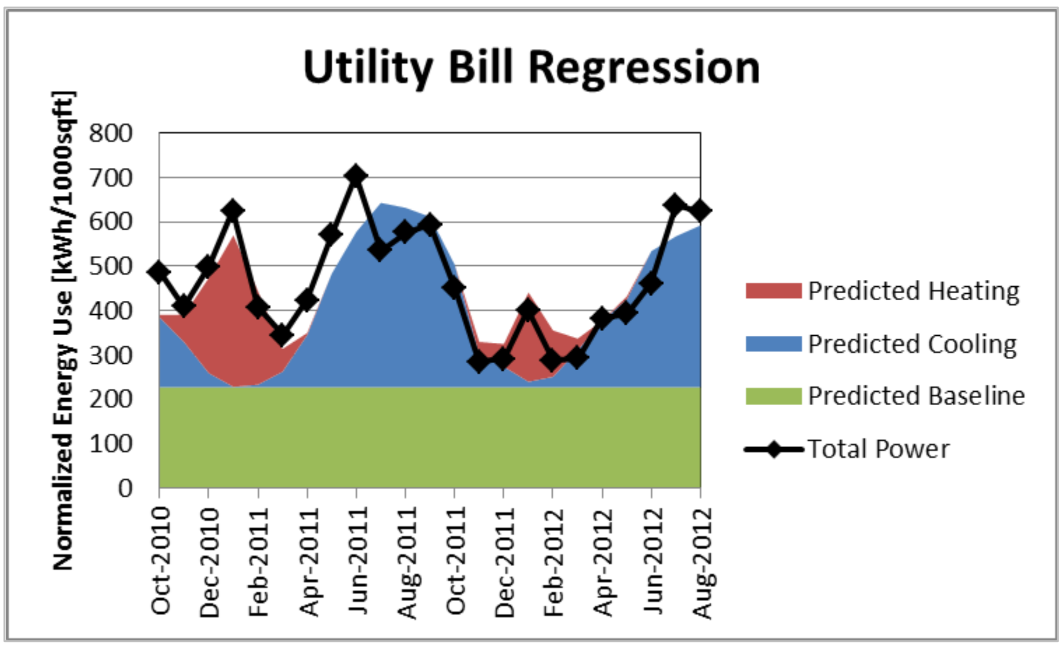

Figure 5-5. Results of multiple regression analysis on utility bill data using cooling degree days and heating degree days.

Using the relationship between cooling/heating degree days and cooling/heating energy use, a trend for the cooling and heating energy use is created below (Figure 5-6).

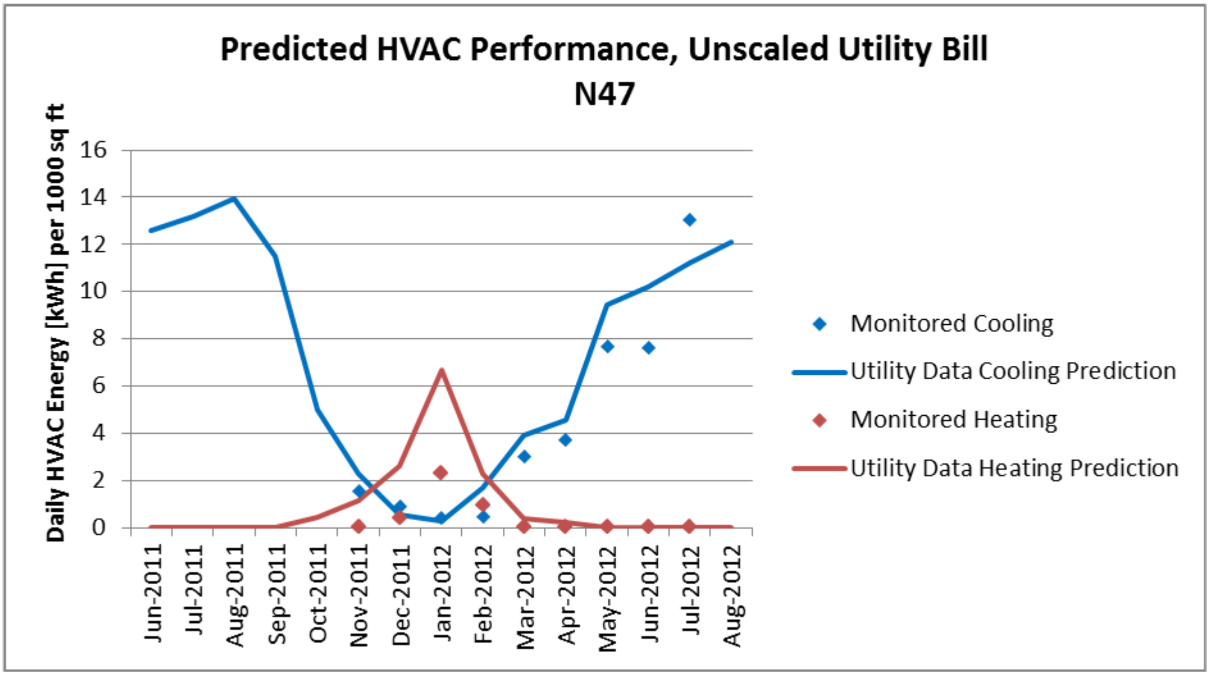

Figure 5-6. HVAC performance as predicted by utility bill analysis.

If monthly monitored values are available, the predicted values are compared to the monthly monitored values and a scaling factor between two is determined. Upon strong correlation (R^2>0.6), the predicted values are scaled and reported as the "Predicted HVAC Energy Use", as in Figure 5-7.

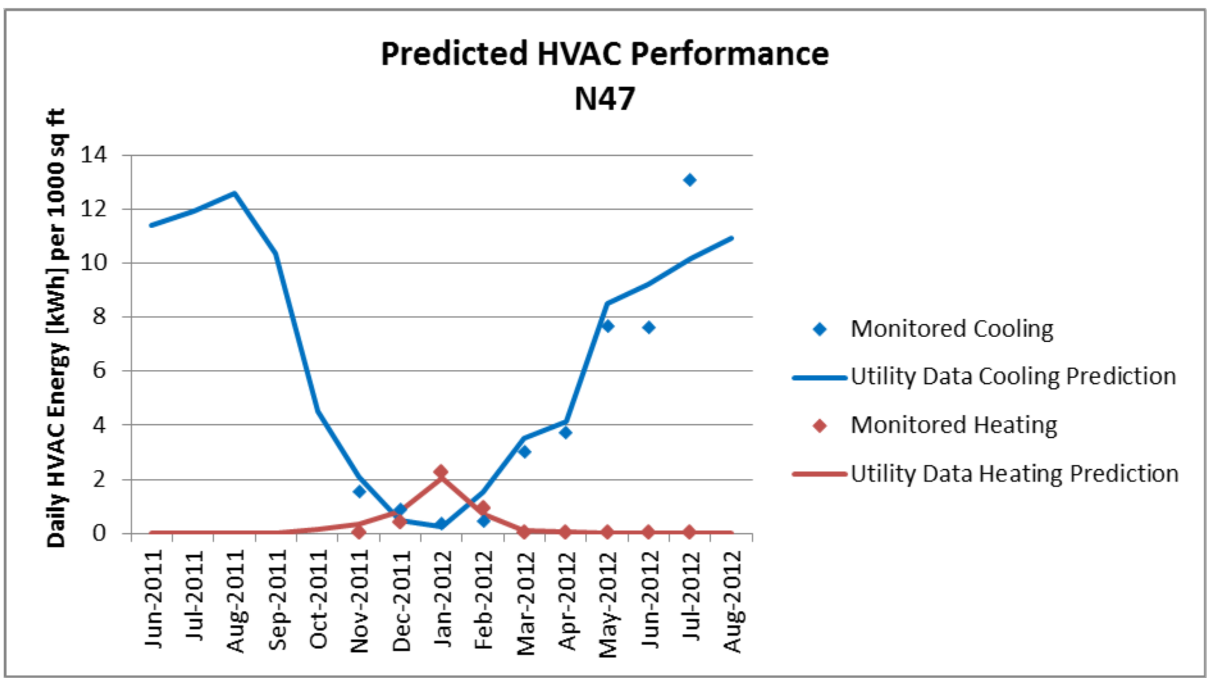

Figure 5-7. HVAC performance as predicted by utility bill analysis, after being scaled from a comparison between monitored data and predicted data.

5.1.4 Reported HVAC Energy Use

An annual cooling and heating energy use value is created using a combination of monitored data, the monitored data projection, and the utility bill projection. Monitored monthly data is always used when available. For months with no monitored data, the monitored cooling projection values are used. If there is no monitored cooling projection available, the values from the utility bill analysis are used instead. Table 5-1 shows the cooling energy analysis for House 47. House 47 has nine months of monitored data. The three missing months, August-October 2011, are filled in using the monitored data projection for cooling. Total monthly use is calculated for August 2011 to July 2012 by multiplying the daily average by the number of days in the month and an annual value is obtained from the summation of all months. The annual value can then be used to compare with other homes.

Table 5-1. Cooling Energy Analysis, House 47. The last column, Reported Cooling Energy Use, values use the Monitored Cooling Projection values for months with no monitored data.

Month	Monitored Cooling Energy Use [kWh/day/ 1000 ft^2]	Monitored Cooling Projection [kWh/day/ 1000 ft^2]	Utility Bill Predicted Cooling [kWh/day/ 1000 ft^2]	Reported Cooling Energy Use [kWh/day/ 1000 ft^2]
Aug-2011		**13.41**	12.6	**13.41**
Sep-2011		**10.58**	10.4	**10.58**
Oct-2011		**3.81**	4.5	**3.81**
Nov-2011	**1.41**	2.07	2.1	**1.41**
Dec-2011	**0.67**	0.78	0.5	**0.67**
Jan-2012	**0.10**	0.25	0.2	**0.10**
Feb-2012	**0.33**	1.85	1.5	**0.33**
Mar-2012	**2.95**	2.53	3.5	**2.95**
Apr-2012	**3.77**	3.25	4.1	**3.77**
May-2012	**7.61**	7.83	8.5	**7.61**
Jun-2012	**7.59**	8.25	9.2	**7.59**
Jul-2012	**13.01**	11.31	10.1	**13.01**
Annual Cooling Energy Use [kWh/1000 ft^2]				1984

5.2 Domestic Hot Water Analysis

Domestic Hot Water (DHW) performance was assessed by finding the average daily DHW use for the entire monitoring period and for each month. Homes with natural gas DHW (5 New, 5 Old), propane (1 New), integrated collector storage (ICS) solar systems (2 Old), or heat recovery units (3 Old) were not considered due to small sampling size and extra monitoring that would have been required.

Because DHW use is primarily a factor of the number of occupants of a home, the DHW use was normalized by dividing the energy use by the number of occupants (Equation 5-3).

$$Normalized\ DHW\ Energy\ Use = \frac{DHW\ Energy\ Use}{Number\ of\ Occupants} \qquad (5\text{-}3)$$

DHW use was projected for non-monitored months using an adjustment factor developed from Building America Benchmark definitions for domestic hot water. The factor is made of two components: the first accounts for the differences in energy required to heat the water entering the water heater due to different water mains temperatures, the second accounts for the change in hot water draw amounts due to the additional hot water needed to create the desired mix temperature for showers, baths, and sink use.

5.2.1 Mains Temperature Adjustment Factor

The monthly average mains temperatures were calculated using the following BA Benchmark definition:

$$T_{mains} = \left(T_{amb,avg} + offset\right) + ratio \times \left(\frac{\Delta T_{amb,max}}{2}\right) \times \sin\left(0.986 \times (day\# - 15 - lag) - 90\right) \quad (5\text{-}4)$$

where:

T_{mains}	=	mains (supply) temperature to DHW tank (°F)
$T_{amb,avg}$	=	annual average ambient air temperature (°F)
$\Delta T_{amb,max}$	=	maximum difference between monthly average ambient temperatures (°F)
0.986	=	degrees/day (360/365)
$day\#$	=	Julian day of the year (1–365)
$offset$	=	6°F
$ratio$	=	0.4 + 0.01 ($T_{amb,avg}$ – 44)
lag	=	35 – 1.0 ($T_{amb,avg}$ – 44)

The mains temperature adjustment factors, $F_{mains\ temp}$, were created by finding the difference between the supply temperature and the monthly average mains temperature, then dividing by the difference between the supply temperature and the annual average mains temperature (see Equation 5-5(5-5)). The supply temperature in homes for this study was assumed to be 130°F.

$$Mains\ Temp.\ Adjustment\ Factor = F_{mains\ temp} = \frac{T_{supply} - T_{mains,monthly\ average}}{T_{supply} - T_{mains,annual\ average}} \quad (5\text{-}5)$$

The mains temperature for the adjustment factor was calculated from climate data for Orlando Sanford Airport. The calculated mains temperatures are shown in Figure 5-8 and the calculated adjustment factors are shown in Table 5-2.

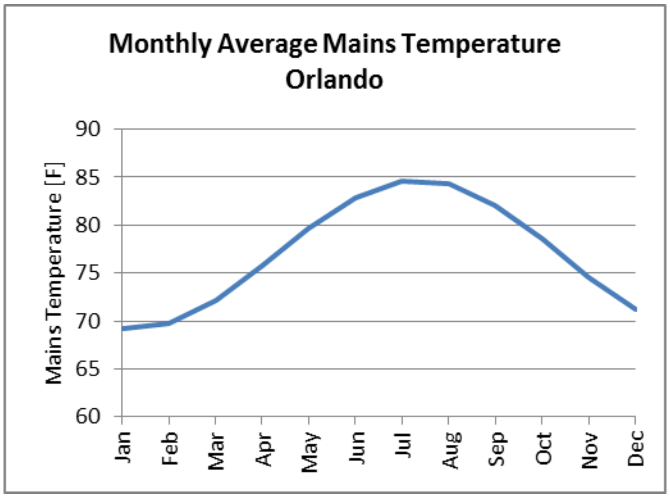

Figure 5-8. Water Mains Temperatures for Orlando Sanford Airport. These mains temperatures are used for all homes in the study because the differences between locations in Central Florida are small.

Table 5-2. Mains Temperatures and Adjustment Factors

Month	Mains Temperature [°F]	Mains Temperature Adjustment Factor
	T_{mains}	$F_{mains\ temp}$
Jan	69.3	1.15
Feb	69.7	1.14
Mar	72.1	1.09
Apr	75.7	1.03
May	79.7	0.95
Jun	82.9	0.89
Jul	84.6	0.86
Aug	84.3	0.86
Sep	82.1	0.91
Oct	78.5	0.97
Nov	74.6	1.05
Dec	71.2	1.11
Average	77.1	

5.2.2 Draw Adjustment Factor

Occupants tend to use more hot water during colder periods. Since shower, bath, and sink usage uses a mix of hot and cold water more hot water is needed during cold months to achieve the desired temperatures. Monthly averages for the daily hot water draw were determined using the 2010 Building America Benchmark documentation (Hendron, 2010). See Table 5-3 and Equation 5-6.

Table 5-3. Building America Benchmark Definition for Hot Water Usage.

End Use	Water Usage [gal]	Hot or Mix
Shower		Mix
Bath		Mix
Sink		Mix
Clothes Washer		Hot
Dishwasher		Hot

$$Average\ Daily\ DHW\ Use\ [gal] = (30 + 10 \times N_{br}) \times \left[\frac{T_{delivery} - T_{mains}}{T_{supply} - T_{mains}}\right] + (4.61 + 1.53 \times N_{br}) \qquad (5\text{-}6)$$

Where $T_{delivery}$ is the temperature occupants adjust the hot/cold mix of water for showers and sinks and is the number of bedrooms. This study assumes $T_{delivery}$ to be 105F. The draw adjustment factors, F_{draw}, were created by dividing each monthly average draw amount, $V_{monthly\ average}$, by the annual average, $V_{annual\ average}$, as in Equation 5-7. Table 5-4 shows the calculated draw schedule adjustments.

$$Draw\ Adjustment\ Factor = \frac{Monthly\ Average\ Draw\ [gal/day]}{Annual\ Average\ Draw\ [gal/day]}$$

$$F_{draw} = \frac{V_{monthly\ average}}{V_{annual\ average}} \qquad (5\text{-}7)$$

Table 5-4. Draw Schedule Adjustment Factors

Month	Total DHW Use [gal/day]	Draw Adjustment Factor
Jan	43.9	1.10
Feb	43.6	1.10
Mar	42.6	1.07
Apr	40.8	1.02
May	38.5	0.97
Jun	36.5	0.92
Jul	35.3	0.89
Aug	35.6	0.89
Sep	37.1	0.93
Oct	39.4	0.99
Nov	41.5	1.04
Dec	43.1	1.08
Average	39.8	

5.2.3 Overall DHW Adjustment Factor

To combine the two adjustment factors into an overall factor, consider average DHW energy use per day, Q, which can be expressed by Equation 5-8.

$$Q = V\rho C\,(T_{supply} - T_{mains}) \tag{5-8}$$

Where V is the volume of DHW drawn per day, ρ is the relatively constant density of water, and C is the relatively constant heat capacity of water.

Divide the monthly average DHW energy use per day, $Q_{monthly}$, by the annual average DHW energy use per day, Q_{annual}, to produce:

$$\frac{Q_{monthly}}{Q_{annual}} = \frac{V_{monthly\ average}}{V_{annual\ average}} \times \frac{T_{supply} - T_{mains,monthly\ average}}{T_{supply} - T_{mains,annual\ average}} \tag{5-9}$$

Substitute Equations 5-5 and 5-7 into Equation 5-9:

$$\frac{Q_{monthly}}{Q_{annual}} = F_{draw} \times F_{mains\ temp} \tag{5-10}$$

Defining the overall DHW adjustment factor as $F_{DHW} = \frac{Q_{monthly}}{Q_{annual}}$, the overall DHW adjustment factor is equal to the draw and mains temperature adjustment factors multiplied together (Equation 5-11).

$$F_{DHW} = F_{draw} \times F_{mains\ temp} \tag{5-11}$$

The overall and component DHW adjustment factors are shown in Table 5-5 and Figure 5-9.

Table 5-5. DHW Adjustment factors

Month	Draw Adjustment Factor	Mains Temperature Adjustment Factor	Overall DHW Adjustment Factor
	F_{draw}	$F_{mains\ temp}$	F_{DHW}
Jan	1.10	1.15	1.23
Feb	1.10	1.14	1.22
Mar	1.07	1.09	1.15
Apr	1.02	1.03	1.05
May	0.97	0.95	0.93
Jun	0.92	0.89	0.84
Jul	0.89	0.86	0.79
Aug	0.89	0.86	0.79
Sep	0.93	0.91	0.86
Oct	0.99	0.97	0.97
Nov	1.04	1.05	1.08
Dec	1.08	1.11	1.18

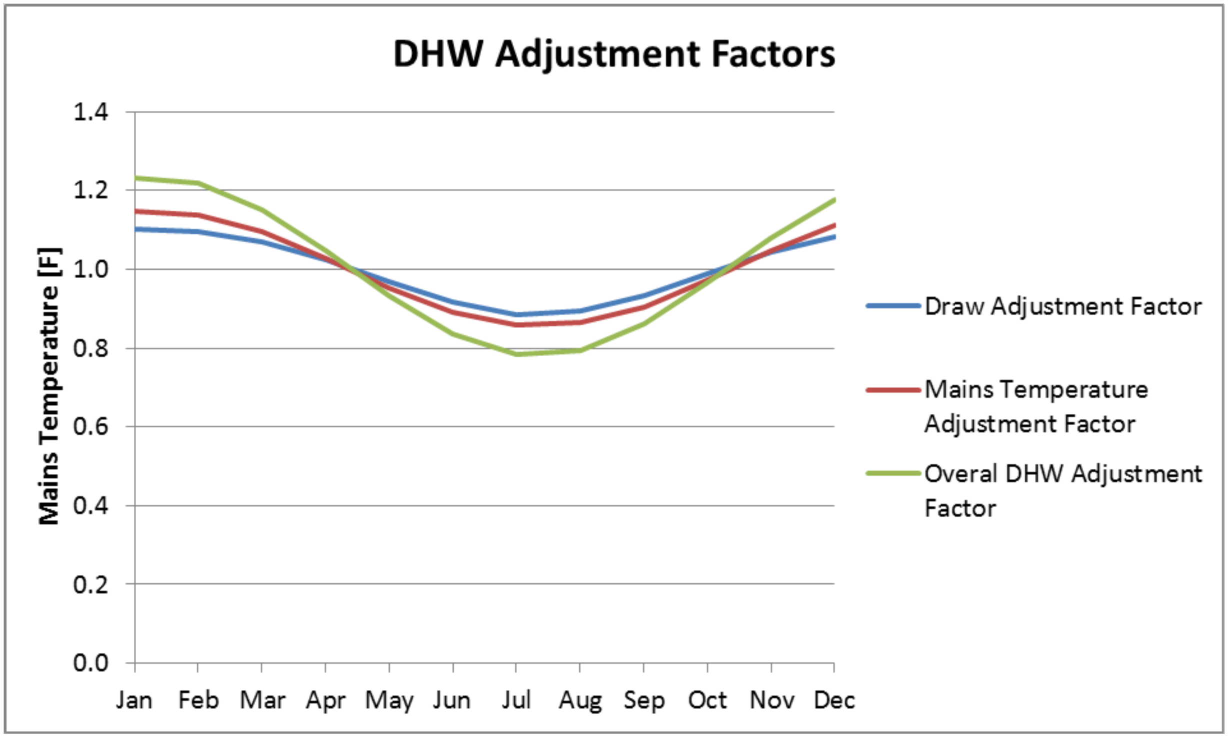

Figure 5-9. DHW Adjustment Factors, used to project DHW use for unmonitored months.

5.2.4 DHW Energy Use Projection

Since $Q_{monthly}$ is directly proportional to F_{DHW}, a scaling factor can be determined to project monthly DHW use from the overall adjustment factor (see Equation 5-12). The scaling factor is created using a least-squares linear regression with monitored monthly average energy use per day, $Q_{monthly}$, as the dependent variable and the corresponding DHW adjustment factors, F_{DHW}, as the independent variable. Although many homes have irregularities in DHW use due to vacations and visitors, the projection provides a reasonable estimate of DHW use in months that have not been monitored.

$$Q_{\text{monthly}} = (Scaling\ Factor) \times F_{DHW} \tag{5-12}$$

Figure 5-10 shows the projected hot water use for house 47 while Table 5-6 shows the projected hot water energy being used to create an annual hot water energy use value. House 47 has hot water measurements for November 2011 through July 2012. In order to obtain a full year, a scaling factor is created between the monitored data and the DHW adjustment factors. Each adjustment factor is multiplied by the scaling factor to get the DHW energy projection. Once the projected values are calculated, the three months for which there is no data are reported as the projected values, while the other nine months are reported with the monitored values. The average energy use per day for each month is then multiplied by the number of days in the month and summed to obtain an annual value.

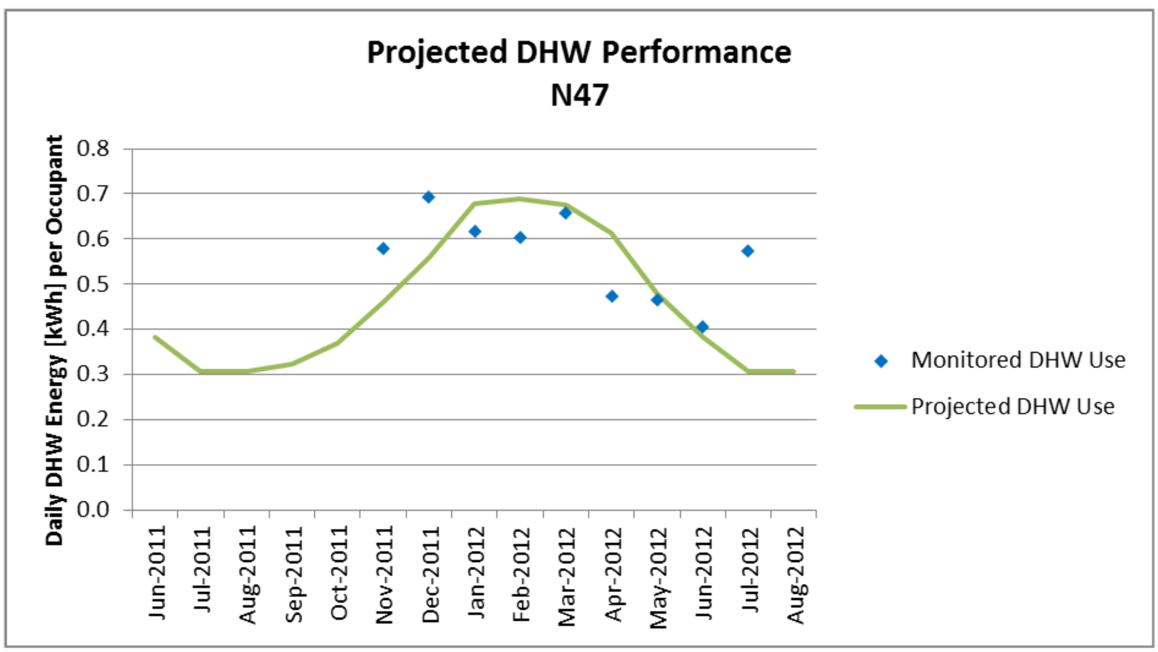

Figure 5-10. DHW performance, projected using the overall DHW adjustment factor.

Table 5-6. DHW Energy Analysis, Home 47. The final column, Reported DHW Energy Use, uses Monitored DHW Energy Projection values for months with no monitored data. Bold values denote the reported values

	Monitored DHW Energy Use [kWh/day/ occupant]	DHW Adjustment Factor	Monitored DHW Energy Projection [kWh/day/ occupant]	Reported DHW Energy Use [kWh/day/ occupant]
Aug-2011		0.79	**1.05**	1.05
Sep-2011		0.86	**1.14**	1.14
Oct-2011		0.97	**1.28**	1.28
Nov-2011	**1.44**	1.08	1.43	1.44
Dec-2011	**1.73**	1.18	1.56	1.73
Jan-2012	**1.54**	1.23	1.63	1.54
Feb-2012	**1.50**	1.22	1.62	1.50
Mar-2012	**1.64**	1.15	1.53	1.64
Apr-2012	**1.17**	1.05	1.39	1.17
May-2012	**1.16**	0.93	1.24	1.16
Jun-2012	**1.01**	0.84	1.11	1.01
Jul-2012	**1.42**	0.79	1.04	1.42
Annual DHW Use [kWh/occupant]:				490.83

6. Energy Code Score and Compliance Comparison

6.1 Introduction

This section will describe how the new home code compliance forms were compared to the site collected energy audit home data. All residential code forms for the new code homes in this study were available and copies were collected. The method of code compliance and energy use index (e-ratio) data collection will be discussed. Results of code compliance and comparisons between the submitted code form and audited e-ratios will also be discussed in this section.

All the new homes in this study used the Method A, also known as the performance-based method of compliance indicating a strong preference for this method of compliance. This method generally does not require prescriptive measures to be incorporated. Code approved energy rating software is used to evaluate the energy use of the proposed "as-built" home which is compared to the "baseline" code home that minimally passes.[1] The code form requires a ratio of as-built normalized modified loads [Fairey, 2000][2] to total baseline loads to be less than 0.85, or 15% better than the baseline for the 2007 code. This value is referred to as the e-ratio. The lower the e-ratio, the more efficient the home is relative to the baseline. Method A allows less efficient features to be compensated by more efficient features. For example, a house with less efficient wall envelope R-values can still pass with higher heating or cooling efficiency or higher performance windows

6.2 Code Compliance Results by Category

If each home was built and had audit data entered in software just as it was proposed on the code form, then the as-audited home e-ratio should match the submitted code form e-ratio. In real practice, the audit home e-ratio will vary from the submitted form depending upon the severity of under- and over-compliance compared to the submitted code form. The 31 new code homes available for this study had varying degrees of non-compliance as well as over-compliance. The general process and method of site collected data was previously discussed in Section 4.3 Audit Data portion of this report. As previously discussed, the residential energy code compliance was evaluated by focusing on 14 primary areas.

In addition to the 31 monitored new homes reported on in the rest of this report, twelve new homes outside of Central Florida were evaluated for compliance with the code. The selection of those homes is provided in another report [Withers, et. al, June, 2012]. These homes did not have full audits, monitoring, or many times any occupants. Individual results are shown in Table 6-1 for each house according to twelve of the fourteen individual evaluation criteria areas. Compliance in number of bedrooms and passing e-ratio score are not shown in Table 6-1. There was no non-compliance in the number of bedrooms claimed and only three houses had non-

[1] "As-built" and "baseline" have been replaced with the IECC language of "Proposed design" and "Standard reference design" respectively in the 2010 Florida energy code that took effect in March 2012.

[2] Fairey, P., et al., 2000. "The HERS Rating Method and the Derivation of the Normalized Modified Loads Method." FSEC-RR-54-00, Florida Solar Energy Center, Cocoa, FL. (http://www.fsec.ucf.edu/en/publications/html/FSEC-RR-54-00/)

compliance due to having audited e-ratio greater than 0.85. The summary of percent compliance is shown in the far right column. Generally 14 criteria were considered. In a few cases where construction was not completed or there was not access to a specific item, the compliance % is based on the total number of items that were able to be evaluated. Therefore there can be differing % non-compliance for different homes having the same number of non-compliance items. Non-compliance of 43 houses in Florida was found to average 16.6% with a range from lowest at 0% to the highest at 57%.

Using the data shown in Table 6-1, the number of times non-compliance occurred is shown in Figures 13 and 14 for each of the 12 categories. Non-compliance occurs most often in window (47%), domestic hot water heating (35%) and glass/floor ratio (28%) respectively. Then next three greatest areas of non-compliance occurred in Walls (26%), Ducts (19%) and Cooling and Heating each having 19% non-compliance.

The 12 non-compliance items shown in the top row of Table 6-1 are not weighted by energy impact, and are simply noted if the auditor found the building does not agree or match up with what is specified on the building's residential code form. Therefore, just because an item was found with a non-compliance (or found with a large frequency of occurrences with the 43 buildings) does not necessarily mean it is equal with another non-compliance item in the same house – regarding energy impact, etc. For example, while DHW was the 2nd most common occurring form of non-compliance, the actual impact on energy is likely modest since 93% (14/15) of the installed EF were within 0.02 of the claimed value and all were within 0.03 EF.

In instances where an item called out in the code form no longer has the manufacture label or specs listed in the home, the researchers focused on other areas of the specified item to quantify the item code form data with what was installed. Window non-compliance was related to window area, orientation or shading related errors. Window U value and SHGC labels are removed when the home is completed; however window performance data was available in about 3 houses. In those cases we did find that the installed performance data met or exceeded the claimed efficiency. The reason for wall non-compliance was usually related to over-stated R value on code forms or significant wall area errors. Non-compliance in cooling and heating was due to installation of lower efficiency equipment in half of the cases. Most of the time the SEER difference was about 1 SEER lower and HSPF about 0.3 lower. The other half of non-compliance in heating and cooling was noted for installation of significantly oversized equipment.

Table 6-1. Residential Compliance Summary Table

ID #	Wrong Code Form	Cond. Area ft²	Windows	Floor Types	Wall Types	Ceiling Type	Ducts	Cooling System	Heating System	DHW System	Credits	Glass/ Floor Area	Percent Non-Compliance
3													0.0%
5													0.0%
8													7.1%
12													14.3%
13													7.1%
17													0.0%
18													7.1%
20													14.3%
24													7.1%
29													42.9%
32													14.3%
42													0.0%
43													0.0%
44													21.4%
45													14.3%
46													7.1%
47													7.1%
48													0.0%
49													0.0%
57													14.3%
63													14.3%
64													7.1%
68													21.4%
69													35.7%
70													57.1%
71													21.4%
72													42.9%
74													21.4%
75													0.0%
80													0.0%
81													14.3%
82													28.6%
83													7.1%
84													42.9%
85													42.9%
86													28.6%
87													53.8%
88													42.9%
89													14.3%
90													7.1%
91													7.1%
92													9.1%
93													8.3%
Total	**4**	**3**	**20**	**2**	**12**	**4**	**8**	**7**	**7**	**15**	**2**	**12**	
%	**9.3%**	**7.0%**	**46.5%**	**4.7%**	**27.9%**	**9.3%**	**18.6%**	**16.3%**	**16.3%**	**34.9%**	**4.7%**	**27.9%**	**16.4%**

Figures 6-1 through 6-3 visually represent non-compliance items in the 43 homes. Figure 6-1 summarizes the number of non-compliance occurrences. Figure 6-2 shows each non-compliance category item (e.g. windows, DHW, etc.) as a percentage of occurrence within each inspection category, while Figure 6-3 provides the frequency distribution at different ranges for the forty-three homes based on the twelve inspection categories of audited items.

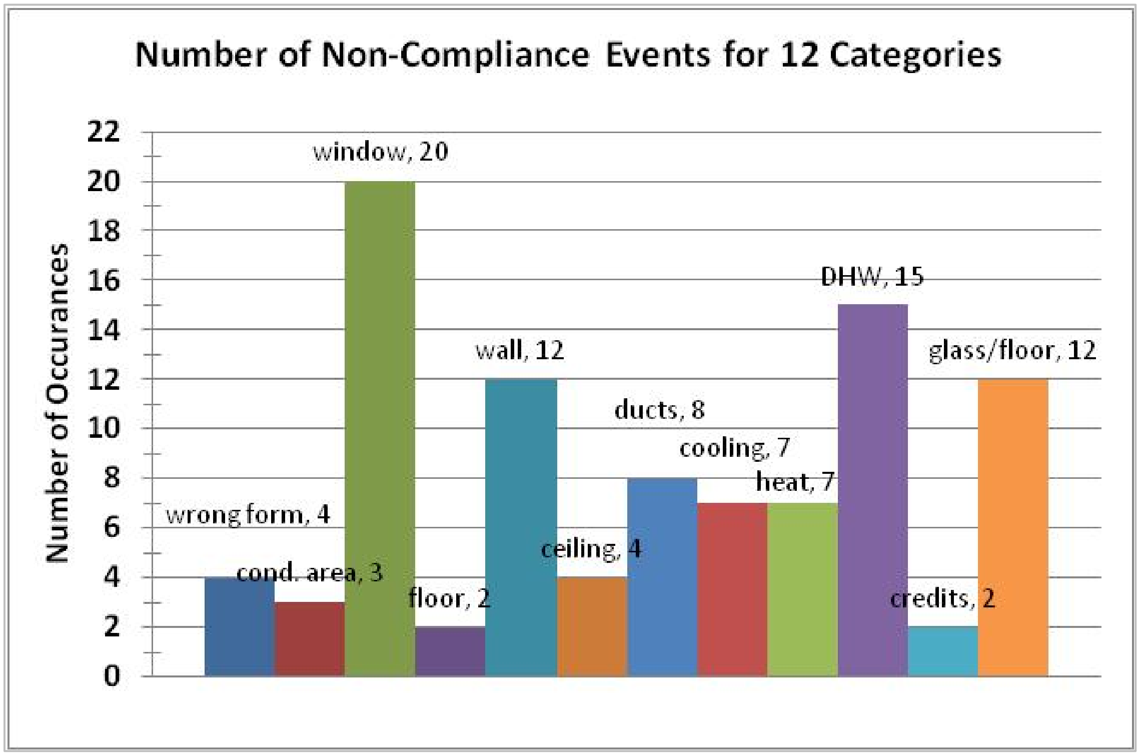

Figure 6-1. Number of homes where non-compliance was noted for each type of category.

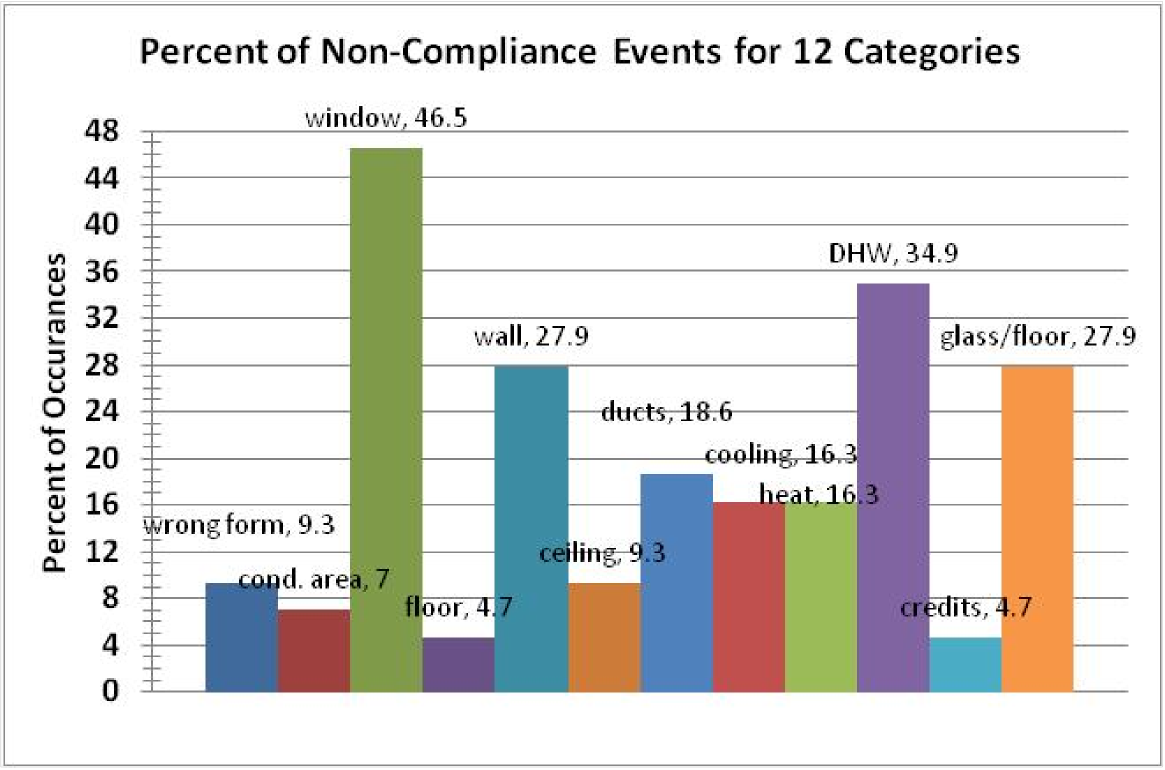

Figure 6-2. Amount of non-compliance (percent of homes) for each inspection category.

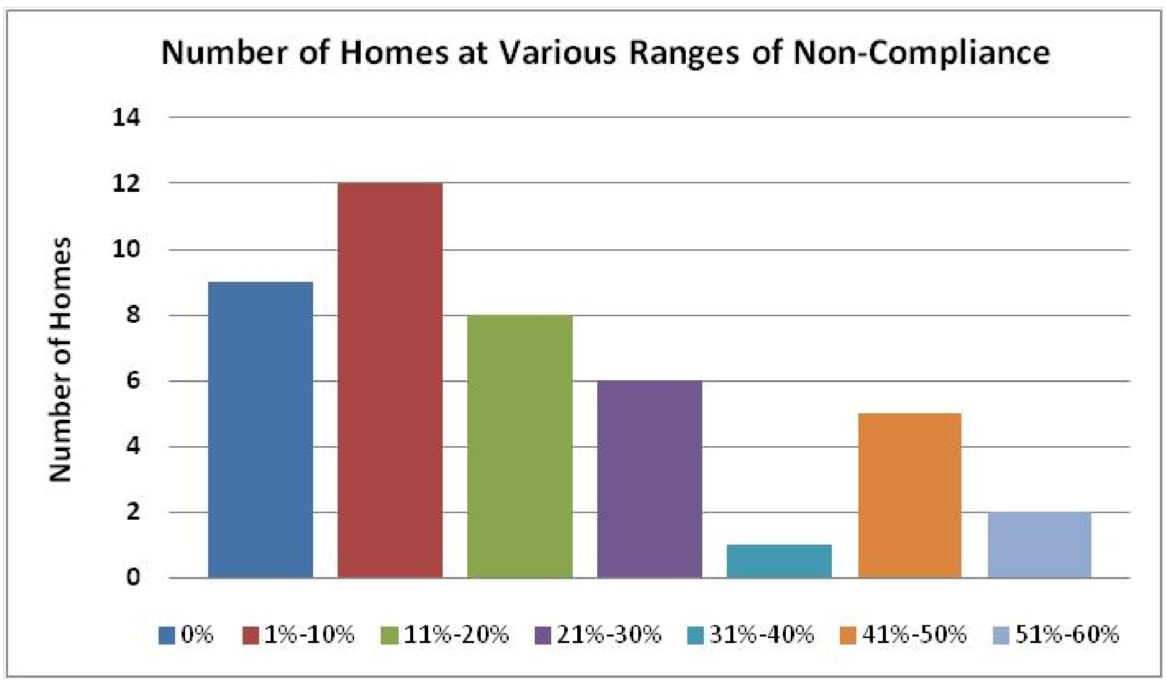

Figure 6-3. Frequency distribution at different ranges of non-compliance for 43 homes. The height of each bar is the number of homes that had the percentage of compliance issues shown on the x axis.

6.3. Code Compliance Results by E-Ratio

A comparison was made between the e-ratio on the as-submitted code forms and the site collected data (audited) in 31 homes. EnergyGauge USA was used to calculate the as-audited e-ratio. This is the same software that was used to calculate all submitted code forms and e-ratios. Table 6-2 summarizes the as-submitted e-ratio and audited e-ratio. By this measure 28 of the 31 homes met the calculated e-ratio for the energy code or a 90% state-wide compliance, The average submitted E-Ratio 0.80 and the average audited e-ratio of 0.81 were nearly the same.

Table 6-2. Comparison of Submitted and Audited E-Ratio (0.85 or lower required for passing)

House ID #	As submitted E-ratio	Audited E-Ratio
3	0.85	0.76
5	0.77	0.76
8	**0.95**	0.81
12	0.80	0.85
13	0.80	0.79
17	0.83	0.82
18	0.83	0.79
20	0.82	0.83
24	0.83	0.77
29	0.84	**1.03**
32	0.84	0.78
42	0.75	0.78
43	0.78	0.77
44	0.80	0.83
45	0.82	0.81
46	0.80	0.65
47	0.81	0.79
48	0.85	0.79
49	0.83	0.80
57	0.81	0.82
63	0.83	0.84
64	0.80	0.83
68	0.79	0.85
69	0.84	0.70
70	**0.94**	**1.05**
71	0.61	0.78
72	0.60	0.80
74	0.64	0.82
75	0.79	0.77
80	0.79	0.75
81	0.84	**0.91**
Std.Dev.	***0.073***	***0.076***
Mean	***0.80***	***0.81***
Median	***0.81***	***0.80***
Mode	***0.80***	***0.78***

While the averages are nearly the same, significant differences between the proposed and audited values can be observed on a house by house basis. Three houses had audited e-ratios that exceeded the maximum passing limit of 0.85 (in bold print). The audited e-ratio was lower (more efficient) or the same in 52% of the homes. The remaining 48% had audited e-ratios greater than submitted form claimed.

Most homes passed base on the e-ratio score for two primary reasons.

1. The proposed home was less than the required 0.85 e-ratio 87% of the time, thus giving some room to pass with some non-compliance. The item(s) not in compliance are often only significant enough to cause an increase of the e-ratio by a point or two. As an example consider that if the DHW EF of house 42 had an EF = 0.90 instead of 0.92, then the total house e-ratio would have been 0.79 instead of 0.78. Twenty-two of the thirty-one houses (71%) have e-ratios low enough to be able to pass with some relatively minor non-compliance items.
2. The second reason most homes pass e-ratio is due to over-compliance that occurs where more efficient features are installed in the home than the code form claimed. Houses with as-built e-ratios substantially lower than the as-submitted have resulted typically from greater efficiency heating and cooling equipment installed or more efficient envelope measures taken in the attic that were not in submitted code form. The more efficient attic measures have been R38 attic insulation instead of R30 and radiant barrier system installed that was not claimed on the code form.

Four homes had the older 600A-2004R code form submitted even though the permit date was after when the 2009 supplement code was in effect. Two of these have e-ratios greater than 0.85 that can be noticed in the preceding table. Three audited home e-ratios were greater than the maximum limit of 0.85. The two highest audited e-ratios occurred in house # 70 and 29 due to a number of failures to build what was submitted (category non-compliance of 57% and 43% respectively). The third home with a failing e-ratio=0.91, house 81, failed primarily due to fairly high window to floor area ratio with windows having very poor window performance and orientation.

6.3.1 Variance in Audited vs. Submitted E-Ratio

The data shown in Table 6-2 shows a very clear impact of very high non-compliance upon much higher as audited e-ratios. The data is shown below in Figure 6-4 as audited e-ratio vs. submitted code form e-ratio. All thirty-one homes can be seen as black dots. There are also 15 homes shown as a subgroup of the original 31 homes having red boxes around the dots. This subgroup of 15 homes is made up of homes that may or may not have non-compliance and did not have any over-compliance.

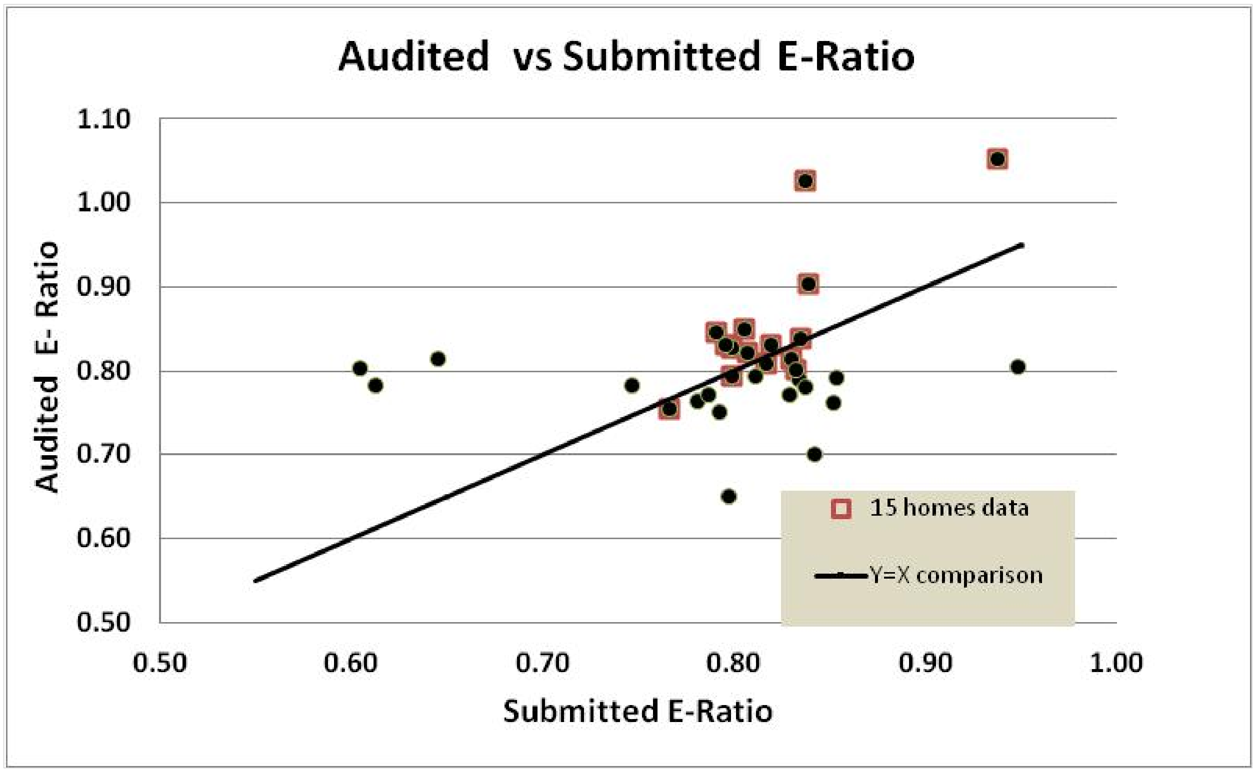

Figure 6-4. Audited E-Ratio shown at the Y-axis vs the Submitted E-Ratio on the X-axis.

If the audited homes are built exactly as the submitted code form claims, the audited and submitted E-ratios should practically be the same value. As one would suspect, the audited E-ratio may be higher or lower depending upon under- or over-compliance. Homes having the exact same audit e-ratio as the submitted form will have a data point resting on the dark reference line. Homes having significant under-compliance much greater than over-compliance relative to the claimed form will have points above the dark reference line. Those having significant over-compliance will tend to have points below the reference line.

Some of the more extreme departures from the reference line in Figure 6-4 can be explained.

Highest two audited e-ratios greater than 1.0 are houses #29 and 70 which both had non-compliance of 43% and 57% respectively. House 70 also had used the older code form which passed the house with 0.94. The point with highest submitted e-ratio of 0.95 was house 8 noted as the dot far below the reference line. This is because an old code form was submitted to pass the old code, but the audited home had been built with much more efficient features adequate to pass the 2007 code. The three dots having the lowest submitted e-ratios can be noticed substantially higher than the reference line indicative of significant non-compliance. These homes (71, 72, and 74) all had wall R value and window orientation issues much less efficient than claimed. Two of these homes (71 and 74) had 21% non-compliance while the third (72 with lowest e-ratio) had 43% non-compliance. It is reasonable to expect house 74 with twice the amount of non-compliance to be noticeably higher above the other two homes (71 and 74). The impact of non-compliance in house 72 is largely offset by over-compliance related to higher SEER, HSPF, and programmable thermostat credit.

6.4 Comparison of Categorical and e-ratio Compliance

It was found that 16 of the 31 homes had at least one or more items of over-compliance compared to items on the code forms. This does not mean that the 16 homes did not also have non-compliance, as many of them had both over-compliance and under-compliance.

The next two plots (Figures 6-5 and Figure 6-6) show the delta e-ratio (audited e-ratio – submitted e-ratio) vs. the percent of non-compliance. Recall that percent of non-compliance is calculated for this purpose as the number of categories with a less efficient audited value than provided on the code form divided by the number of categories inspected (Described fully in Section 4.3 also see Table 6-1 for category list). Figure 6-5 shows all 31 homes and has a poor coefficient of determination, R^2 =0.35. Figure 6-6 shows only the 15 homes having only non-compliance and no over-compliance items. The linear equation is very similar, however R^2 is much improved at 0.78.

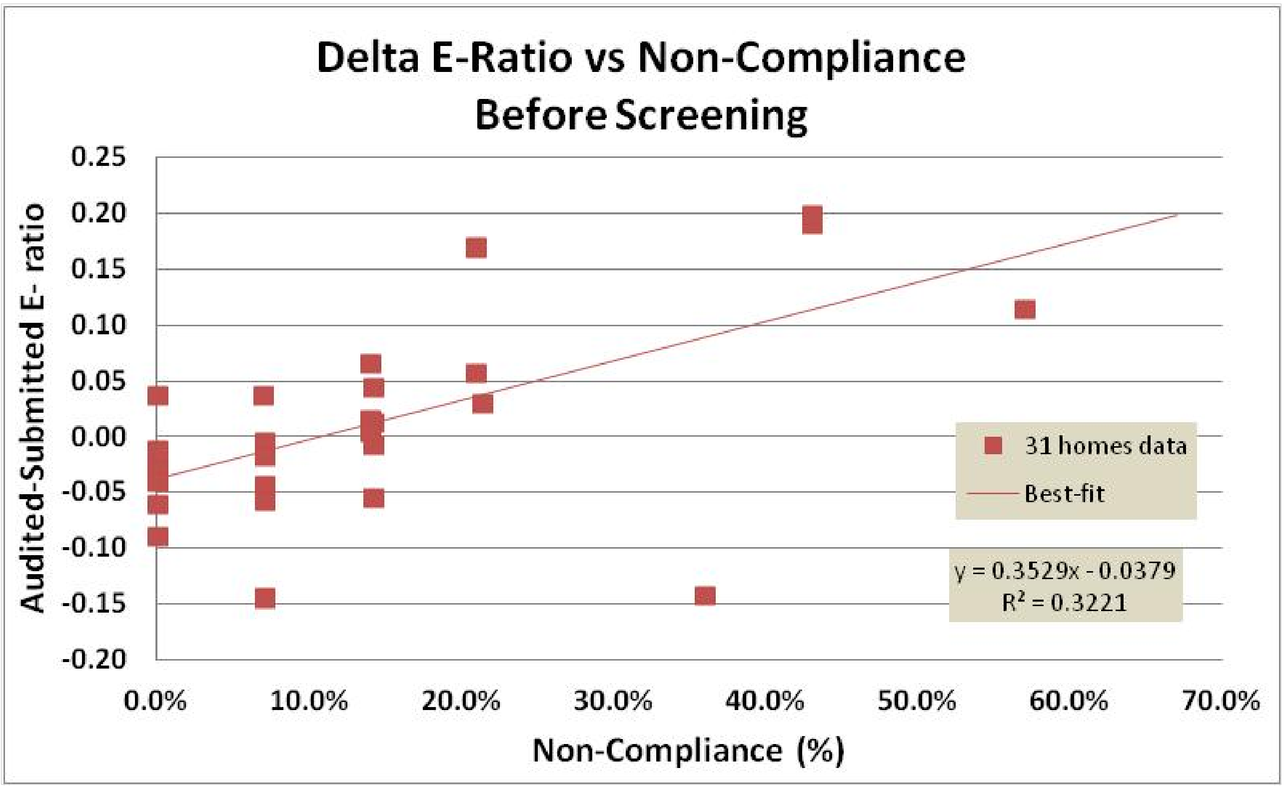

Figure 6-5. The difference between the audited and submitted e-ratios for 31 homes. Many of these homes have varying amounts of over-compliance as well as non-compliance.

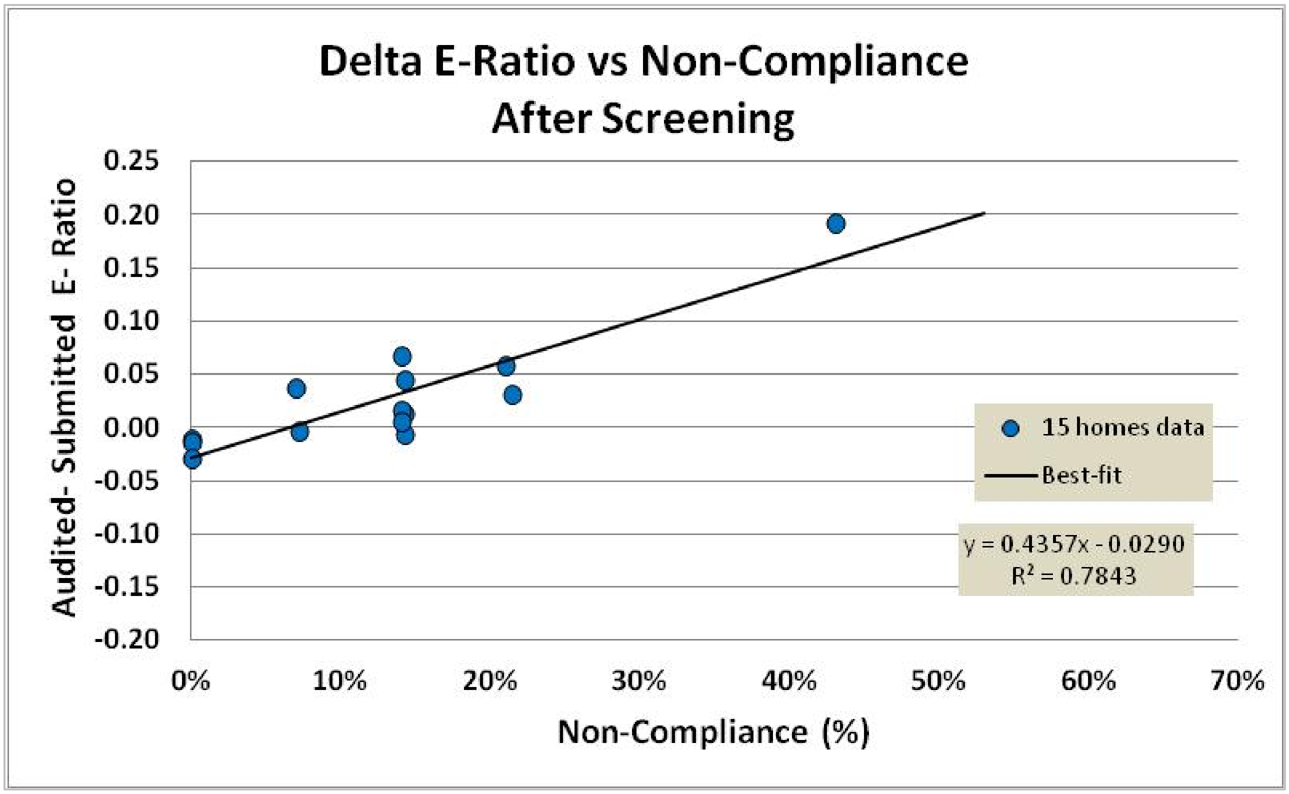

Figure 6-6. The difference between the audited and submitted e-ratios for 15 homes. Screening out the homes with over-compliance results in strong correlation.

Based upon the linear equation from Figure 6-6, this suggests there may be an increase in the built home e-ratio of 0.02 for every 5% of non-compliance. Actual impacts would of course vary on a case by case basis depending upon the severity of non-compliance. A home with only one non-compliance issue that had a central air conditioner installed with a SEER value one less than claimed on a code form would have a more significant increase in e-ratio than the same home having only one non-compliance issue of a DHW EF that is 0.02 lower than claimed. Both examples would be considered at about 7% non-compliance, but the space cooling inefficiencies carry much more weight in Florida code compliance.

7.0 Energy and House Characteristics Comparison

7.1 House Characteristics

It is important to identify home characteristics pertinent to Florida energy code to identify any potential biases between new and old homes. The detailed home audit performed on each home provides many data points for comparison, some of which have been extracted to show comparisons among key physical qualities shown in Table 7-1. Some of the notable findings are:

- On average the house floor areas have less than 1% difference, but the old code group had an average volume about 5% less due to higher ceiling heights in more of the new homes.
- Both groups had only two homes having 2 stories.
- The new code group had slightly more bedrooms and occupants on average.
- Attic R value improved by 29% from an average R24 to R31.
- While they only represented 2-3% of surface area adjacent to attic space, kneewall areas have decreased 42% and kneewall insulation R value has increased by 42%.
- Window performance has clearly become better, however, about 22% of the old code homes had at least double pane clear windows. The U and SHGC values claimed on new home code form was assumed unless audit found it to be implausible. Default window performance was assumed for the old code group except in a few cases where windows were replaced and had the NFRC rating tag available.
- Supply duct work remains largely in attics, but more air handlers are moving out of attics and to interior spaces.
- Heat pumps were significantly dominant in both groups.
- SEER rating of new code group was only about 9.3% higher.
- New code group has programmable thermostats 84% compared to old code 26%.
- There is little difference between the average DHW electric storage tank EF.
- Pool pumps were found in 55% of the old code homes compared to only 6% new code.

Table 7-1A. Key House % Characteristic for Each Code Group.

	New Homes	Old Homes
	Construction Type*	
% Wood Frame Homes	0%	23.4%
% Concrete Block Homes	100%	76.6%
Average Wood Frame Insulation Value [R]	--	11.2
Average Concrete Block Insulation Value [R]	4.73	4.74
	Heating System	
% Electric Heat Pump	90.3%	80.9%
% Electric Strip Heat	6.5%	12.8%
% Natural Gas Furnace	3.2%	4.3%
Average HSPF for Electric Heat Pumps	8.3	7.6
	Supply Duct Location	
% Attic	96.8%	91.5%
% Interior	3.2%	8.5%
	Air Handler Location	
% Garage	38.7%	38.3%
% Interior	58.1%	29.8%
% Attic	3.2%	27.7%
	Hot Water System	
% Electric (no HRU or ICS System)	83.9%	76.6%
% Propane or Natural Gas (no ICS System)	12.9%	10.6%
% Electric with Heat Recovery	0.0%	8.5%
% ICS Solar System	0.0%	2.1%
% Instantaneous (Gas or Electric)	5.3%	5.0%
	% of Homes with Select Appliances	
Programmable Thermostat	84%	26%
Pool Pump	6%	55%
Well Pump	0%	11%

* Construction type represents the dominant type of wall found in each home.

Table 7-1B. Key House Characteristics (continued).

	New Home Average	Old Home Average	New Home Range	Old Home Range
Occupants	2.7	2.2	1 to 5	1 to 4
Bedrooms	3.5	3.1	3 to 5	2 to 4
Stories	1.1	1.1	1 to 2	1 to 3
Floor Area [ft^2]	1829	1833	1350 to 2360	1067 to 2400
Wall Height [ft]	8.82	8.35	8 to 10	8 to 10
Volume [ft^3]	16137	15305	10800 to 22019	8536 to 20511
Attic Insulation [R]	31	24	30 to 38	11 to 48
Knee Wall Area [ft^2]	39	67	0 to 189	0 to 872
Knee Wall Insulation [R]	27	19	0 to 30	0 to 30
Roof Solar Absorptance	0.86	0.82	0.75 to 0.92	0.30 to 0.92
Wall Solar Absorptance	0.61	0.68	0.50 to 0.80	0.30 to 0.75
Window U-Value	0.66	1.02	0.37 to 1.20	0.29 to 1.20
Solar Heat Gain Coefficient	0.44	0.72	0.29 to 0.80	0.21 to 0.80
Single Pane Window Area [ft^2]	29	197	0 to 281	0 to 488
Double Pane Window Area [ft^2]	182	59	0 to 316	0 to 388
Total Window Area [ft^2]	213	261	127 to 319	111 to 488
Infiltration (ACH50)	5.6	9.1	3 to 11	4 to 18
A/C Efficiency [SEER]	14.1	12.9	13.0 to 15.3	10.0 to 15.8
Electric Heat Pump [HSPF]	8.3	7.6	7.7 to 8.8	6.5 to 9.0
Electric Water Heater Efficiency	0.92	0.92	0.86 to 0.93	0.88 to 0.93
Gas Water Heater Efficiency	0.66	0.64	0.59 to 0.83	0.59 to 0.82
Number of Ceiling Fans	3.3	4.1	0 to 8	0 to 7
% Fluorescent Bulbs	26	13	10 to 90	10 to 50

7.2 Space Heating

Heating performance showed considerable savings between new and old homes, totaling 37% savings of new homes over old. The heating results must be regarded with care, however, because the heating monitoring period, the winter of 2011-2012, was usually mild, causing much less heating energy use than expected. Some homes in the study appeared to use no heating energy at all. Figure 7-1 and Table 7-2 show the average monthly heating use for new and old. Consider that while 2009 and 2010 had considerably colder than normal winters in east central Florida, with about 900 HDD each (base 65^{o}F), 2011 had fewer than 300 HDD. Also significant was that the much of the cold weather was focused during just a couple periods between the end of December, 2011 through mid- January, 2012.

Monitored data was available for the entire heating season, although the sample size is significantly lower at the start of the heating season, because monitoring equipment was still being installed or replaced. The heating energy use was compared in three primary ways, 1) available monitoring data only, 2) projected annual heating based on regression analysis using monitored data, 3) projected annual heating based on monitored data and utility billing data.

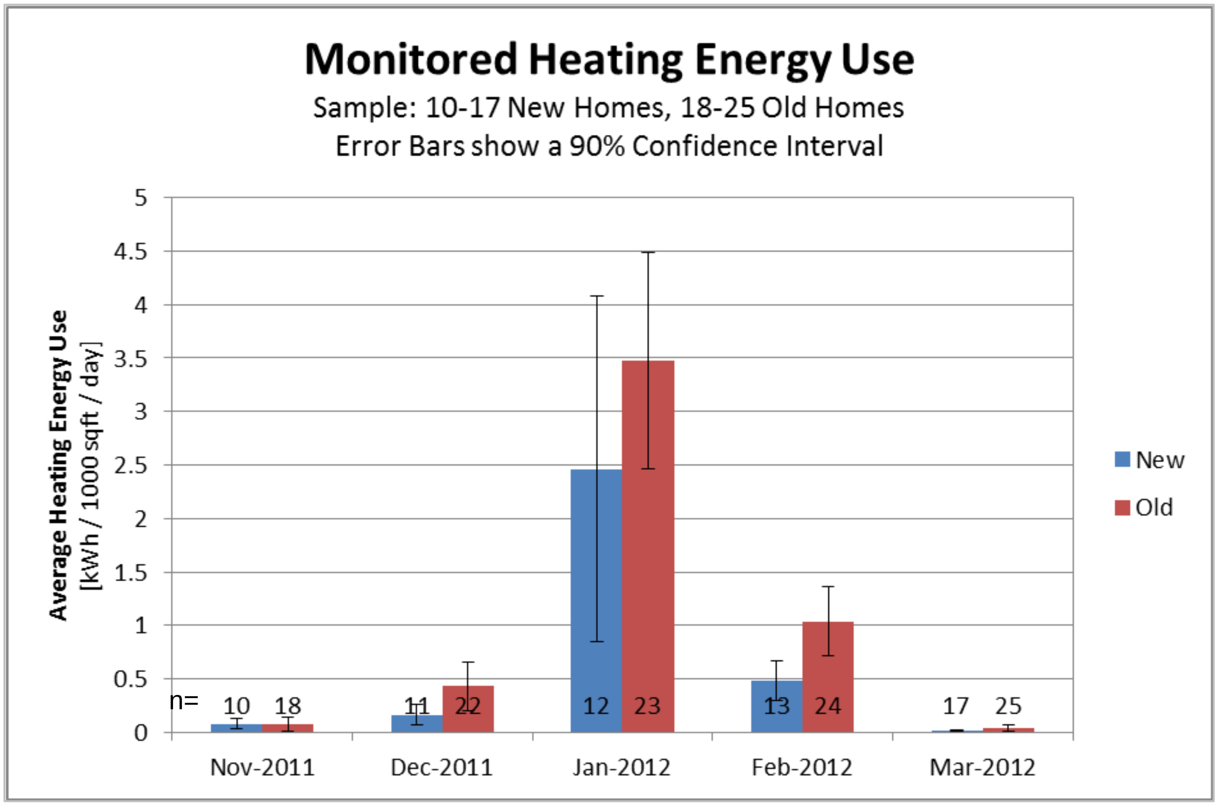

Figure 7-1. Monitored Heating Energy Use, Comparing New and Old Code Homes. Sample size is shown as a label at the base of each column.

Table 7-2. Monitored Heating Results and Confidence Intervals.

		Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	**Total Heating Season [kWh/1000ft^2]**
Mean [kWh/1000ft^2/day]	New	0.08	0.16	2.46	0.48	0.01	**98.2**
	Old	0.07	0.43	3.47	1.04	0.04	**154.6**
Margin of Error (Confidence Level 90%)	New	0.05	0.09	1.62	0.19	0.01	**60.2**
	Old	0.06	0.23	1.01	0.32	0.03	**50.6**
Sample Size	New	10	11	12	13	17	
	Old	18	22	23	24	25	
% New Less than Old		-6%	62%	29%	53%	67%	**36.5%**

The large margin of error is a result of the sporadic nature of heating during such a mild winter. Large variability in the heating data is to be expected because some homes will have very high heating use from electric strip heat, while some better insulated homes or homes with more cold-tolerant occupants will not use any heating.

7.2.1 Results Using Monitored Data Projections

Since many homes are missing data for the entire heating season, monitored data projections were incorporated into the following analysis. Projecting data for months with little or no monitored data available provides a larger sample size and allows annual values to be compiled and compared between homes. Homes with monitoring equipment installed in late January or February will still have a significant amount of heating data that can be utilized to project the data for the entire heating season, using the relationship between HVAC energy consumption and the difference in temperature between indoors and outdoors. The process of projecting heating or cooling data is described in detail in Section 5.1.2. For the analysis using monitored data projections, months with little or no monitored data used the projected data to create an entire year of data.

Heating data created from monitored data projections is shown in Figure 7-2 and Table 7-3. The total heating season value is created by multiplying each monthly average, which is the hot water energy use per day, by the number of days in the month, then summing each month. This annual value allows each house to be easily compared, and allows the heating energy use to be combined with other end uses to determine the overall performance and savings of heating, cooling, and water heating.

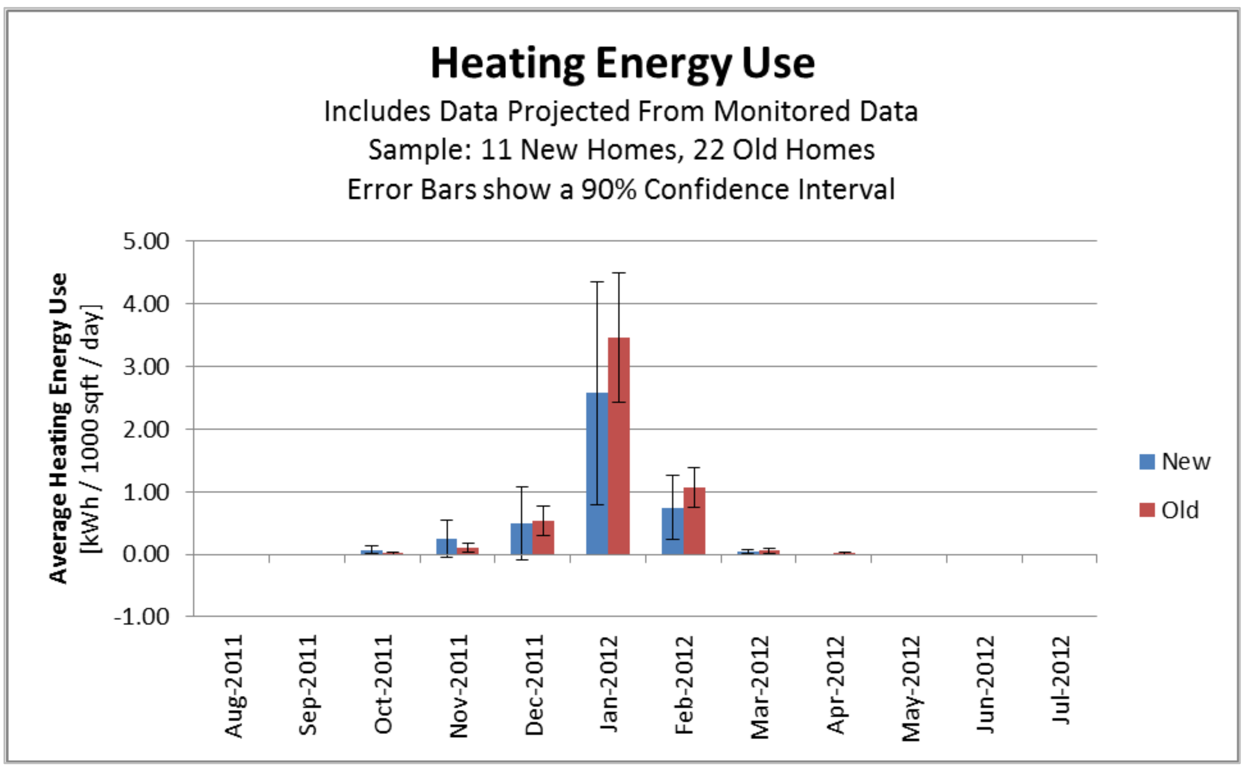

Figure 7-2. Heating Energy Use by Month, Utilizing Monitored Data Projections.

Table 7-3. Heating Energy Use and Confidence Intervals, Utilizing Monitored Data Projections.

		Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	**Total Heating Season [kWh/1000ft^2]**
Mean [kWh/1000ft^2/day]	New	0.06	0.25	0.50	2.56	0.74	0.04	0.00	127
	Old	0.01	0.10	0.53	3.45	1.06	0.06	0.02	160
Margin of Error (Confidence Level of 90%)	New	0.06	0.30	0.58	1.78	0.50	0.03	0.00	100
	Old	0.01	0.06	0.24	1.04	0.32	0.04	0.03	53
% New Less than Old		-380%	-151%	7%	26%	30%	38%	--	21%

Note that although utilizing monitored data projections increases the sample size of homes with heating energy use, the high data variability caused the margin of error to increase.

Similar to the results from purely monitored data, the results using monitored data projections shows new homes to use significantly less heating energy than old homes, although the savings is somewhat less, at 21%.

7.2.2 Results Using Monitored Data Projections and Utility Bill Predictions

Utility bill data projections, as described in Section 5.1.3, can be used to assess cooling and heating energy use when no monitored data is available, by using monthly energy bill data and the cooling and heating degree days for the monthly billing periods to project heating and cooling use.

For this analysis, homes with monitored data projections were unchanged, but homes that were not included with the monitored data projection analysis used utility bill projections if available. The results from the utility bill analysis, shown in Figure 7-3 and Table 7-4, increased the sample size by 13 and 14 for new and old homes respectively.

Although this method increases the sample size of the data, it decreases the accuracy of each home's reported data. Comparisons of utility bill data projections and monitored data showed that the projected cooling energy use was usually within 10-30% of the actual value, but showed that the projected heating results were often greatly overestimated, sometimes by factors of 2 to 10. Such a great overestimation is the result of a very mild winter. Previous studies on utility bill projection methods have shown the process to break down and greatly overestimate cooling energy for climates with very little cooling demand (Stram and Fels, 1986). Thus, these results should be regarded with caution.

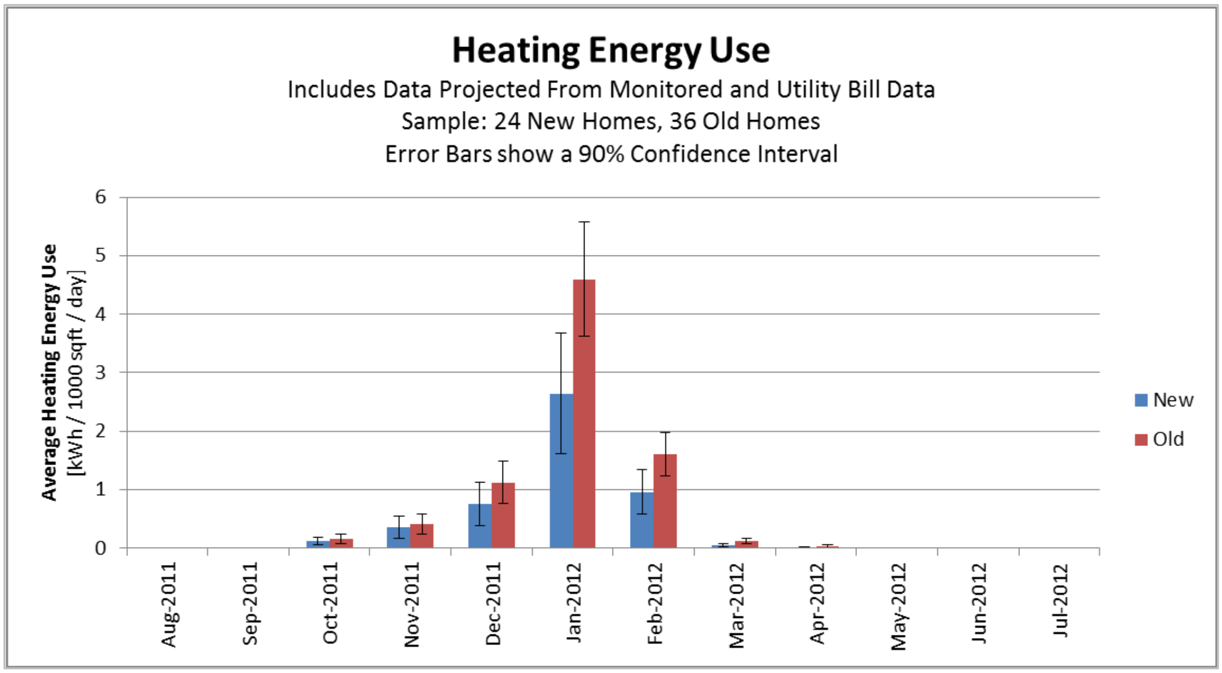

Figure 7-3. Heating Energy Use by Month, Utilizing Monitored and Utility Bill Data Projections.

Table 7-4. Heating Energy Use and Confidence Intervals, Utilizing Monitored and Utility Bill Data Projections.

		Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	**Total Heating Season [kWh/1000ft^2]**
Mean [kWh/1000ft^2/day]	New	0.12	0.36	0.76	2.64	0.96	0.05	0.01	**150**
	Old	0.16	0.41	1.12	4.60	1.60	0.12	0.03	**246**
Margin of Error (Confidence Level of 90%)	New	0.07	0.19	0.37	1.03	0.37	0.03	0.01	**63**
	Old	0.09	0.17	0.36	0.98	0.37	0.05	0.02	**62**
% New Less than Old		20%	12%	32%	42%	40%	56%	64%	**39%**

The margin of error in the data decreased dramatically, with such a large increase in sample size. Overall, this method showed 39% heating savings in new versus old homes.

Figures 7-4 and 7-5 give an idea of in the change in breadth and variability of the heating data from the data projections, as well as the impact of adding utility bill analysis for heat. Figure 7-4 shows a lot fewer homes with heating data, with a group of low-energy users and a group of higher energy users. Figure 7-5 shows many more data points, and continues the trend of highly variable heating use, with many more high energy users appearing, although these may be artificially created from the inaccuracy of the utility bill regression method. Ten of the twelve highest heating values come from homes with utility bill regression.

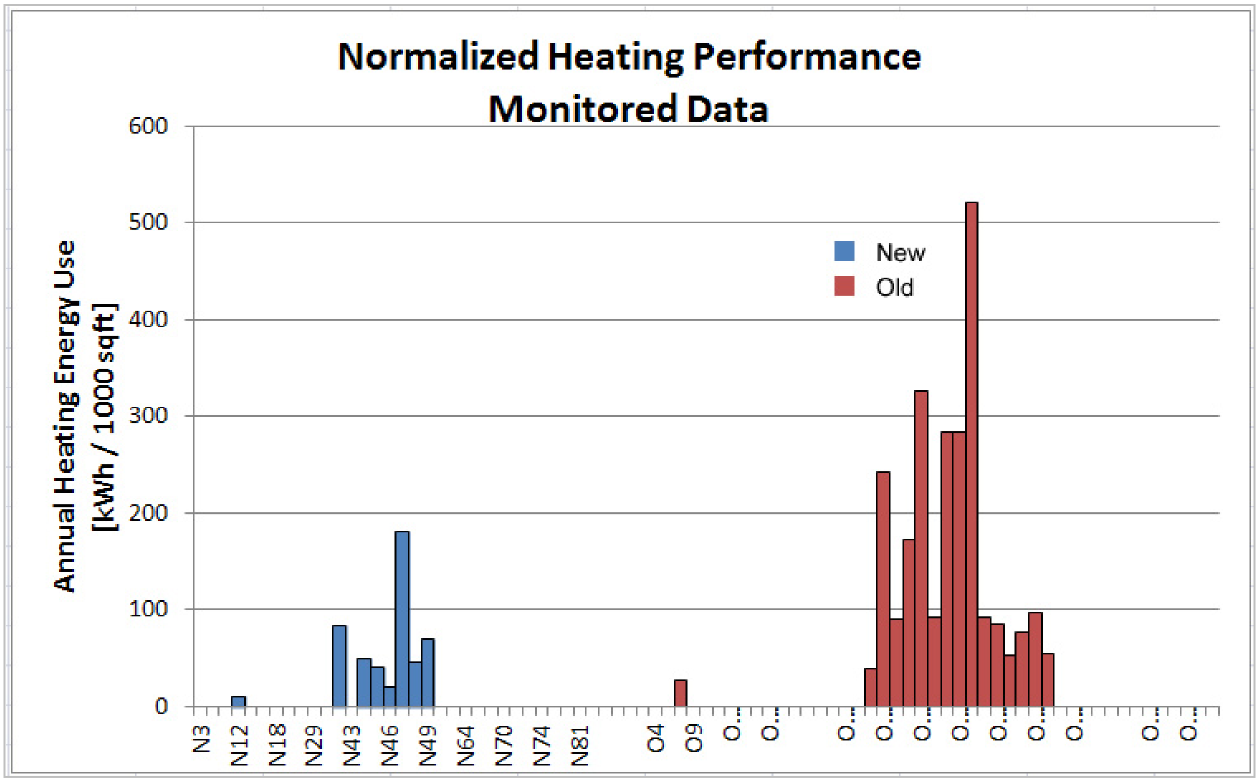

Figure 7-4. Monitored heating performance for each home, as calculated for November 2011 to Mar 2012.

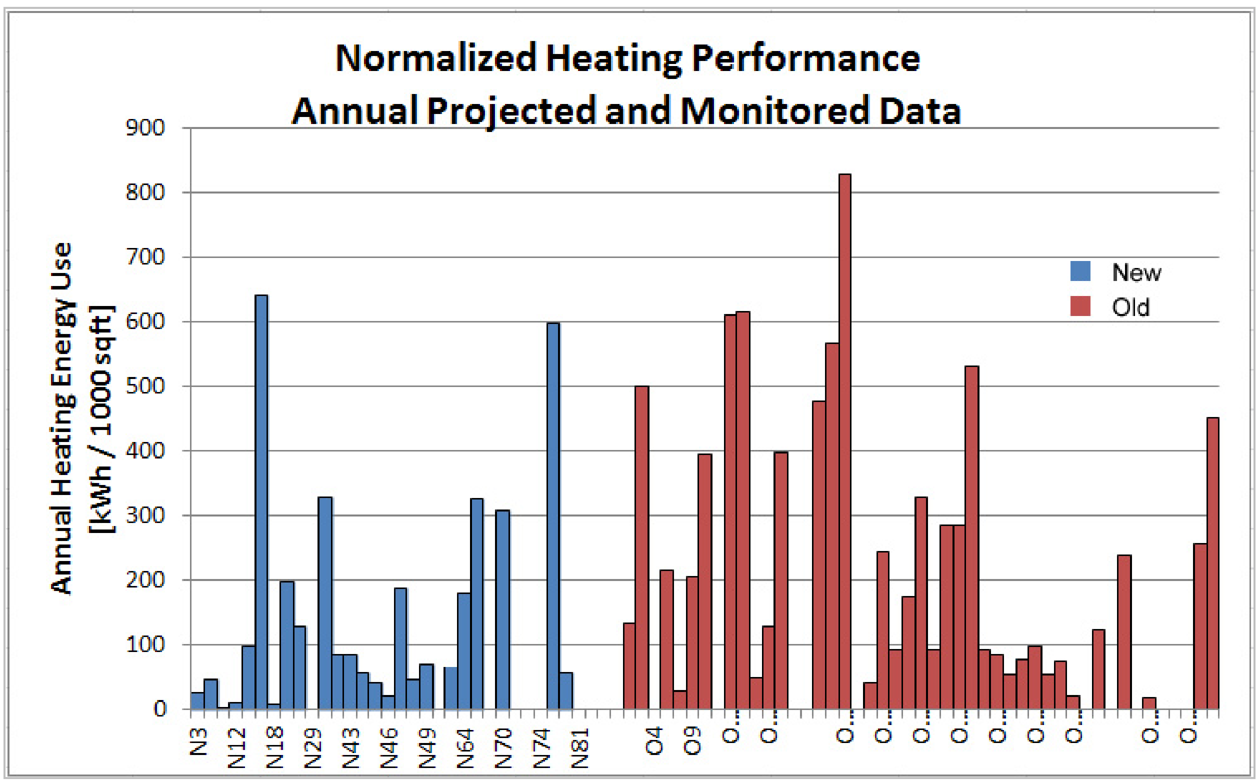

Figure 7-5. Annual Heating Performance for Each Home, Created with Monitored and Utility Bill Data Projections

7.3 Space Cooling

Cooling showed less significant energy savings between new and old homes. Although more cooling data was collected than heating, a full cooling season was not monitored. The monitored period of March 2012 through July 2012 showed new homes using 4.5% less cooling energy than old homes. Figure 7-6 and Table 7-5 show the cooling energy for March 2012 through July 2012. The peak months of summer show old homes using significantly more energy for cooling, as much as 14% more in July. However, during the more mild cooling months of March and April, new homes actually report more energy use. These unexpected results may be caused by a few factors in new homes. One factor may be related to having a lower thermostat set point, as suggested by the interior temperature analysis in Section 7.6. The other may be related to a slower rate of heat transfer of internal generated heat sources to outdoors during this cooler seasonal period due to improved envelope tightness and insulation.

Additionally, since the cooling data excludes August and September, which should have comparable cooling energy use to July, the impact of the higher savings during peak months may be underrepresented. Again, Section 5.0 explains the different analysis methods discussed below. The cooling energy use was compared in three primary ways, 1) available monitoring data only, 2) projected annual cooling based on regression analysis using monitored data, 3) projected annual cooling based on monitored data and utility billing data.

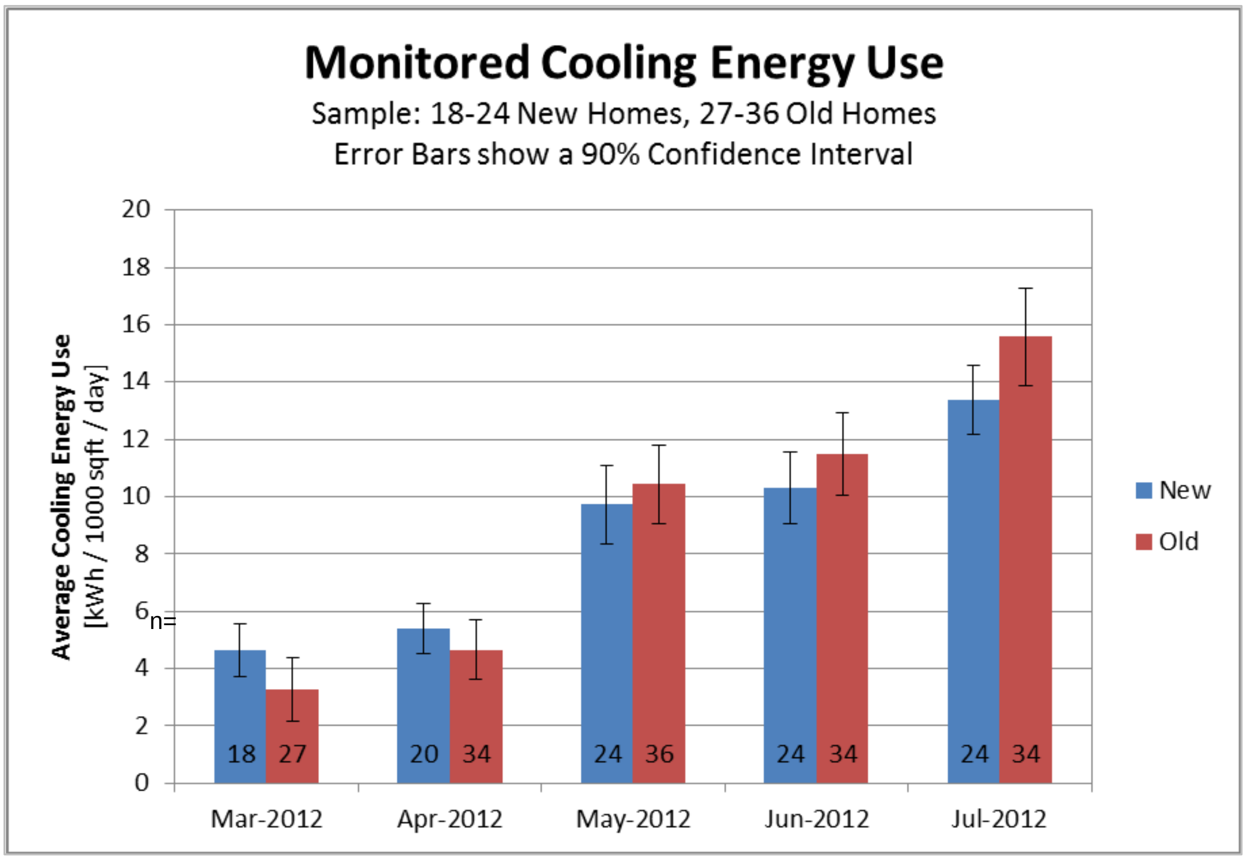

Figure 7-6. Monitored Cooling Energy Use, March 2012-July 2012.

Table 7-5. Monitored Cooling Results and Confidence Levels.

		Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	**Total Monitored Cooling Period [kWh/1000ft^2]**
Mean [kWh/1000ft^2/day]	New	4.6	5.4	9.7	10.3	13.4	**1331**
	Old	3.3	4.7	10.4	11.5	15.6	**1393**
Margin of Error (Confidence Level 90%)	New	0.94	0.87	1.36	1.25	1.20	**172**
	Old	1.11	1.03	1.38	1.46	1.70	**205**
Sample Size	New	18	20	24	24	24	
	Old	27	34	36	34	34	
% New Less than Old		-42%	-16%	7%	10%	14%	**4.5%**

7.3.1 Results Using Monitored Data Projections

Projected cooling energy use, shown in Figure 7-7 and Table 7-6, allows the annual cooling energy to be compared. Additionally, the sample size increased from 18-24 for new homes and 27-34 for old homes to 29 for new and 37 for old homes. Although the trend for the mild months still shows new homes using more energy than old homes, July, August, and September energy use push the overall savings up to 12.3%. Note that the margin of error is much less significant in the cooling data as the heating data. This is due to the more consistent use of electricity during a large cooling season, as well as the higher number of homes with sufficient heating data reported.

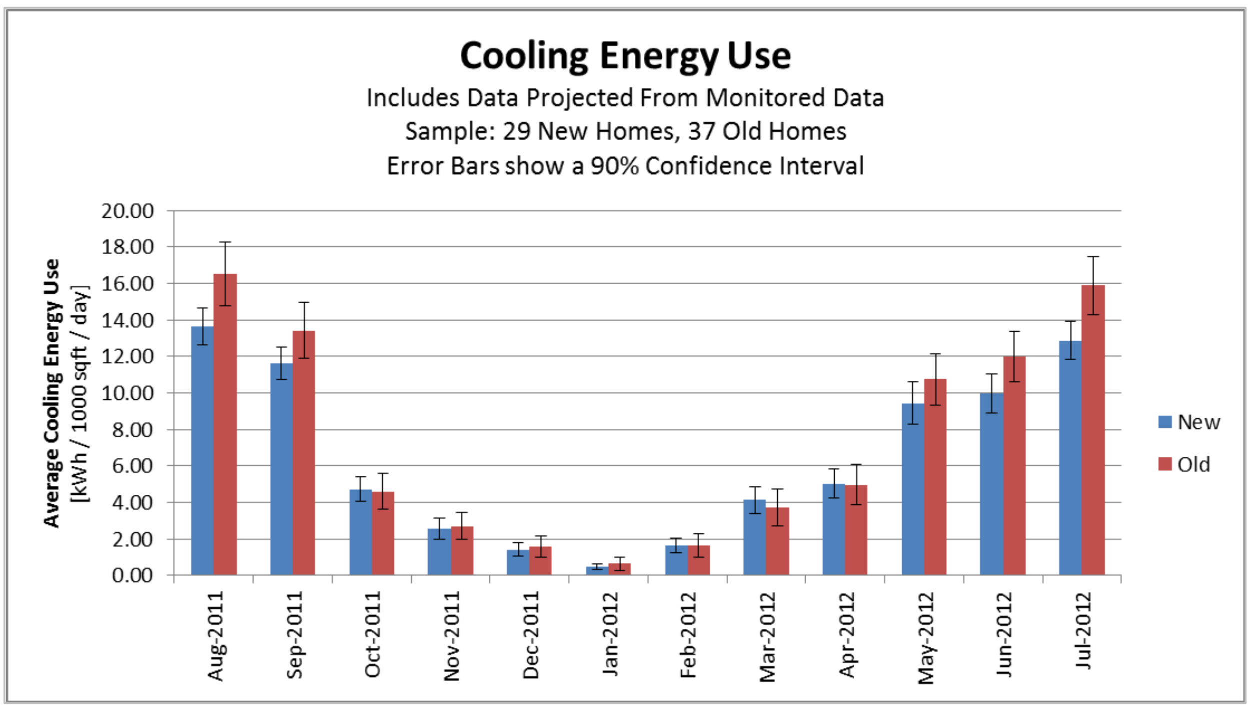

Figure 7-7. Cooling Energy Use by Month, Utilizing Monitored Data Projections.

Table 7-6. Cooling Energy Use and Confidence Intervals, Utilizing Monitored Data Projections.

		Aug 2011	Sep 2011	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	**Annual [kWh/ 1000ft^2]**
Mean [kWh/1000ft^2/day]	New	13.7	11.6	4.7	2.6	1.4	0.5	1.6	4.1	5.0	9.4	10.0	12.9	**2373**
	Old	16.5	13.4	4.6	2.7	1.6	0.6	1.6	3.7	5.0	10.7	12.0	15.9	**2707**
Margin of Error (Confidence Level of 90%)	New	1.00	0.89	0.66	0.59	0.38	0.17	0.39	0.75	0.79	1.14	1.07	1.05	**271**
	Old	1.74	1.51	0.98	0.76	0.58	0.37	0.63	1.01	1.08	1.39	1.40	1.58	**397**
% New Less than Old		17%	13%	-3%	5%	10%	25%	0%	-11%	-1%	12%	17%	19%	**12.3%**

7.3.2 Results Using Monitored Data Projections and Utility Bill Projections

Utility bill data projection allows for another two new homes and four old homes to be included in the analysis. The utility bill projections are expected to be up to 30% larger than the actual projection. Overall, the addition of utility bill data, as shown in Figure 7-8 and Table 7-7, shows savings near the projected annual savings of 12.8%.

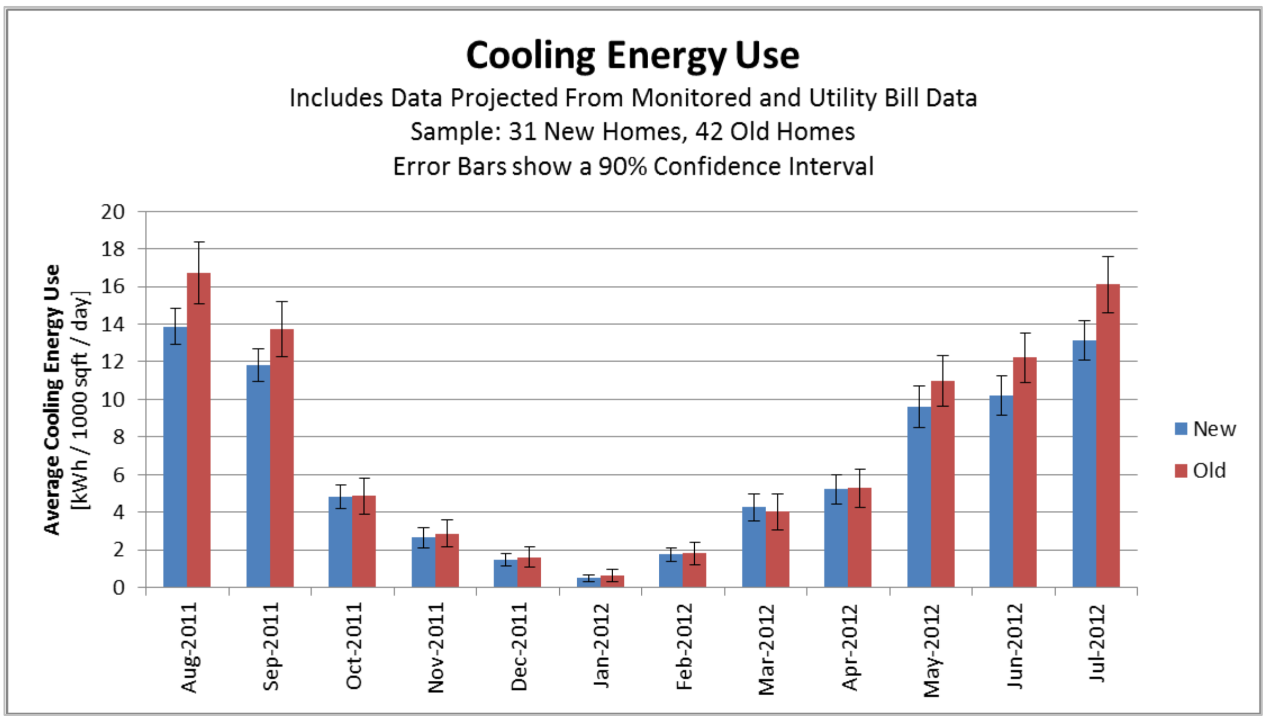

Figure 7-8. Cooling Energy Use by Month, Utilizing Monitored and Utility Bill Data Projections.

Table 7-7. Cooling Energy Use and Confidence Intervals, Utilizing Monitored and Utility Bill Data Projections.

		Aug 2011	Sep 2011	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	**Annual [kWh/ 1000ft^2]**
Mean [kWh/1000ft^2/day]	New	13.9	11.8	4.8	2.6	1.5	0.5	1.7	4.3	5.2	9.6	10.2	13.1	**2423**
	Old	16.7	13.7	4.8	2.9	1.6	0.6	1.8	4.0	5.3	11.0	12.2	16.1	**2778**
Margin of Error (Confidence Level of 90%)	New	0.97	0.87	0.62	0.56	0.36	0.16	0.38	0.72	0.77	1.09	1.03	1.04	**260**
	Old	1.64	1.46	0.94	0.72	0.53	0.33	0.58	0.94	1.01	1.33	1.34	1.50	**376**
% New Less than Old		17%	14%	1%	8%	9%	23%	4%	-6%	1%	13%	17%	18%	**13%**

Figures 7-9 and 7-10 give an idea of the variability and differences between the monitored data and the projected data. Both charts show the new homes to have less variable cooling energy use as well as less overall cooling energy use, however the pure monitored data has much fewer data points as well is skewed to favor the more mild summer months in which new homes tend to consume more energy than old homes.

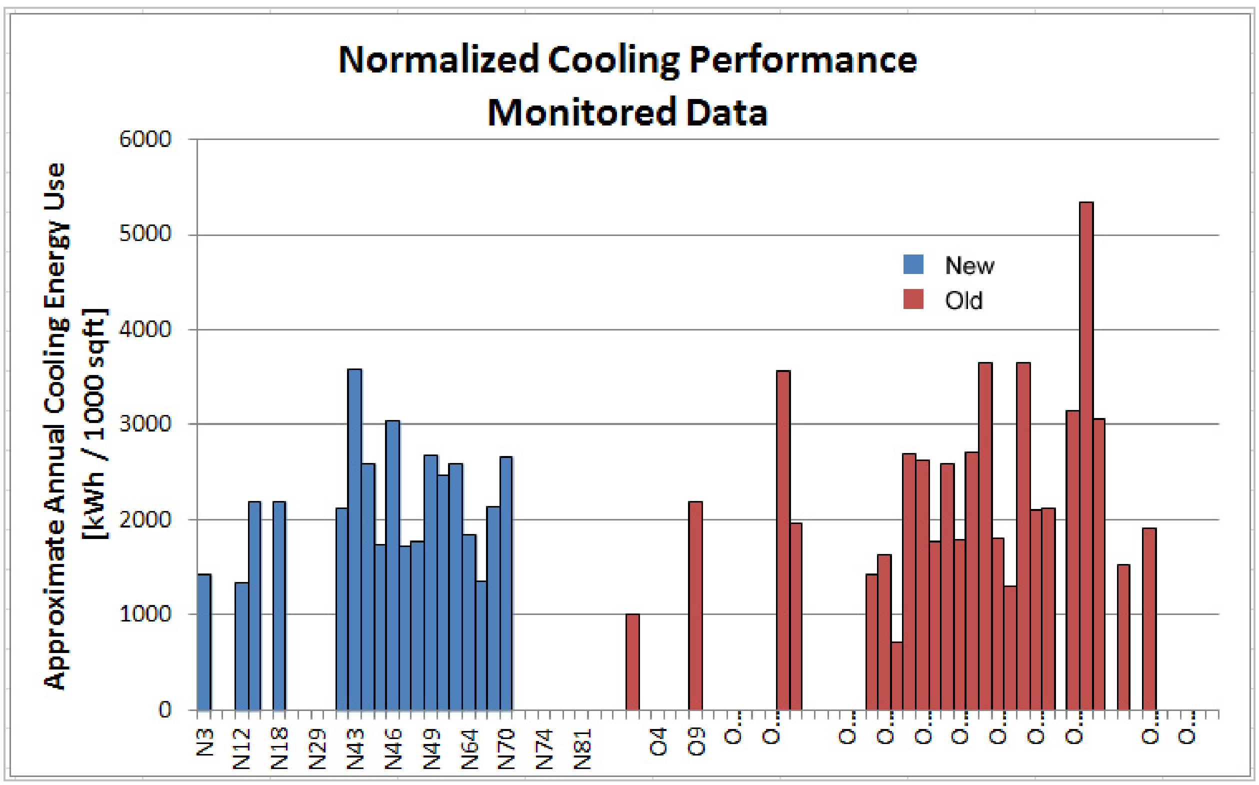

Figure 7-9. Monitored Cooling Performance for Each Home, Approximate Annual Value Calculated from March 2012 to July 2012 Data.

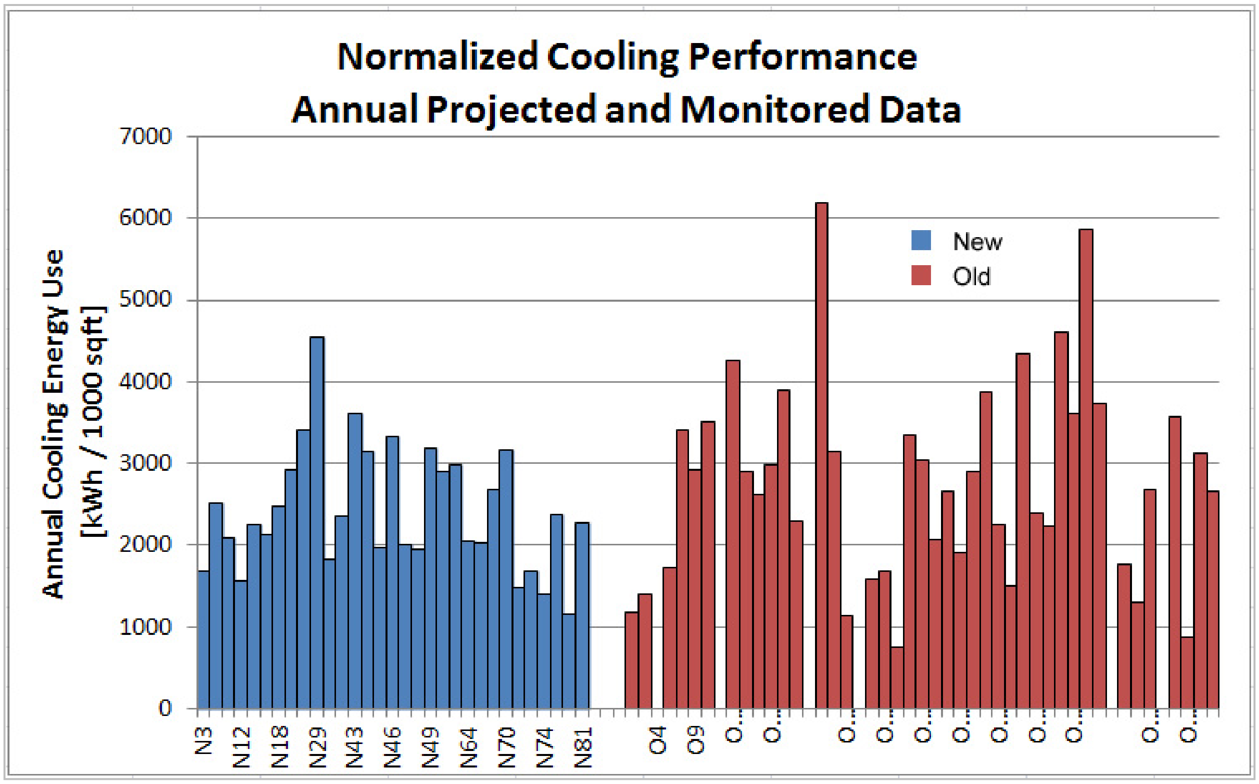

Figure 7-10. Annual Cooling Performance for Each Home, Created with Monitored and Utility Bill Data Projections.

7.4 Domestic Hot Water

Water heating showed new homes to have moderate savings over old homes. Sufficient water heating data for comparison was obtained for ten months, although the sample size is much greater at the end of the study. Initially, in November 2011, only roughly 30% of the 79 monitored homes provided data. By July 2012, over 60% of the monitored homes were providing data.

Monitored data measured from November 2011 through July 2012 (Figures 7-11 and Table 7-8) showed an average of 9% hot water savings, varying between 24% savings in November and 1.8% savings in June 2012.

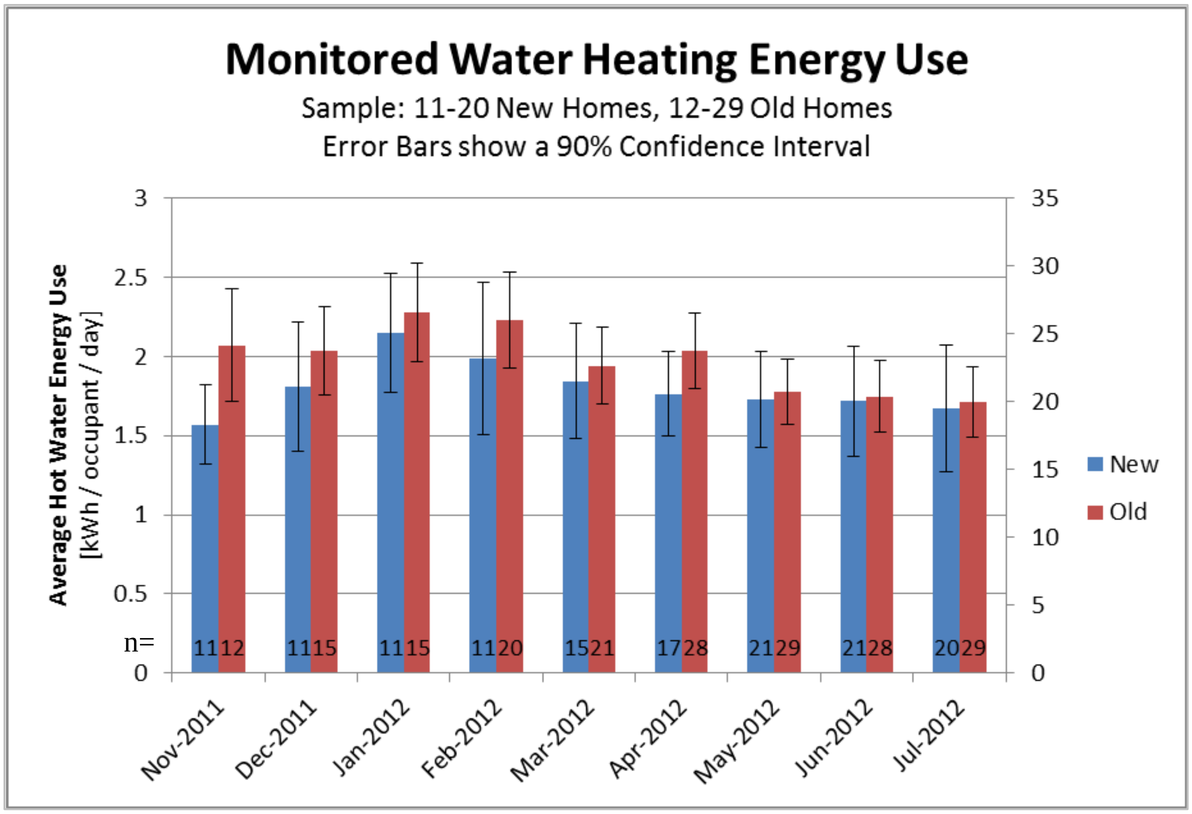

Figure 7-11. Monitored Hot Water Energy Use, Nov 2011-July 2012.

Table 7-8. Monitored Hot Water Results and Confidence Levels.

		Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	**Total Monitoring Period [kWh/occ.]**
Mean [kWh/ occupant/day]	New	1.57	1.81	2.15	1.99	1.85	1.76	1.73	1.72	1.67	494.5
	Old	2.07	2.04	2.28	2.23	1.94	2.04	1.78	1.75	1.71	542.5
Margin of Error (Confidence Level 90%)	New	0.25	0.41	0.37	0.48	0.37	0.27	0.30	0.35	0.40	97.1
	Old	0.35	0.28	0.31	0.31	0.24	0.24	0.21	0.23	0.22	72.6
Sample Size	New	11	11	11	11	15	17	21	21	20	
	Old	12	15	15	20	21	28	29	28	29	
% New Less than Old		24%	11.2%	5.7%	10.9%	4.8%	13.5%	2.6%	1.8%	2.3%	8.8%

7.4.1 Results Using Monitored Data Projections

The monitored water heating use was projected using adjustment factors based on the month, described in detail in section 5.1.2. The projected data increased the sample size from 11-21 in new homes and 12-29 in old homes to 26 in new homes and 33 in old homes. The resulting values, shown in Figure 7-12 and Table 7-9, show a more moderate hot water energy use savings of 5.2%, with monthly savings ranging between 8.0% in November and 0.8% in March.

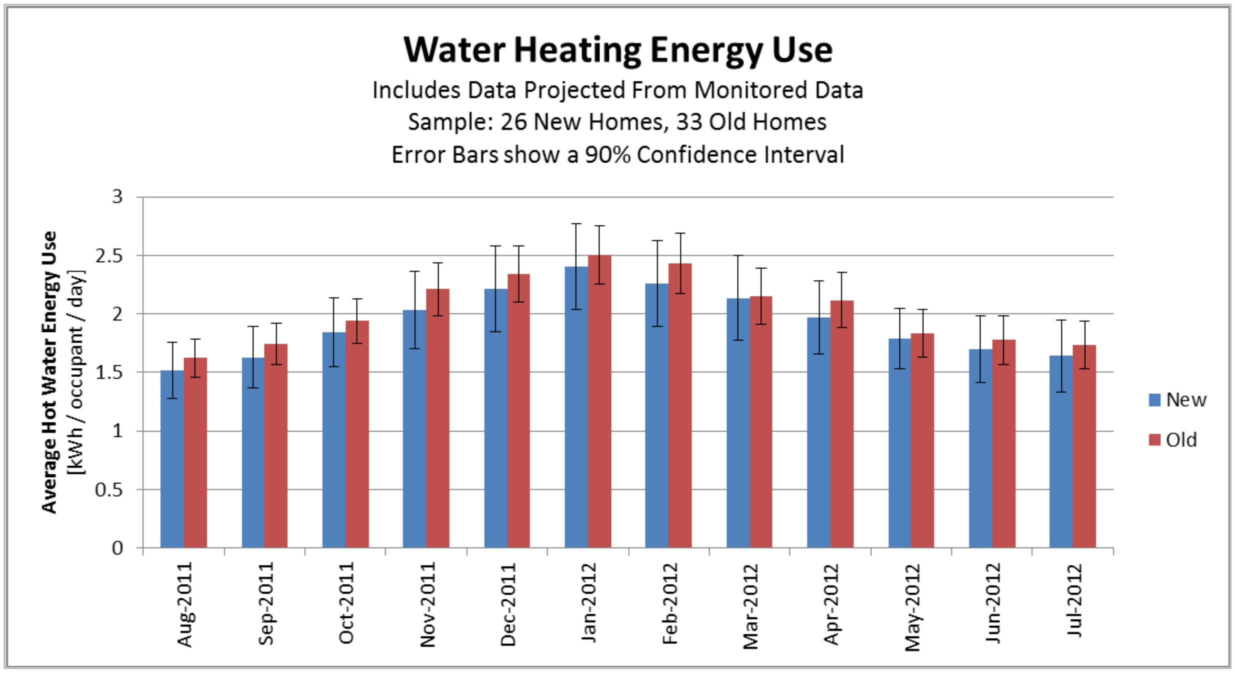

Figure 7-12. Hot Water Results Utilizing Monitored Data Projections.

Table 7-9. Hot Water Results and Confidence Levels, Utilizing Monitored Data Projections.

		Aug 2011	Sep 2011	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	**Annual** [kWh/ occ.]
Mean [kWh/ occupant/day]	New	1.52	1.63	1.84	2.03	2.22	2.40	2.26	2.14	1.97	1.79	1.70	1.64	**706**
	Old	1.62	1.74	1.94	2.21	2.34	2.50	2.43	2.16	2.12	1.84	1.78	1.74	**744**
Margin of Error (Confidence Level of 90%)	New	0.24	0.26	0.29	0.33	0.37	0.37	0.37	0.36	0.31	0.26	0.28	0.31	**114**
	Old	0.16	0.18	0.19	0.22	0.24	0.25	0.26	0.24	0.24	0.20	0.20	0.21	**79**
% New Less than Old		6.4%	6.5%	5.0%	8.0%	5.3%	3.9%	6.9%	0.8%	7.0%	2.7%	4.2%	5.4%	**5.2%**

Figure 7-13 below, showing the annual projected hot water energy use of each home, illustrates that hot water usage is highly variable from house to house, even after normalizing for occupants.

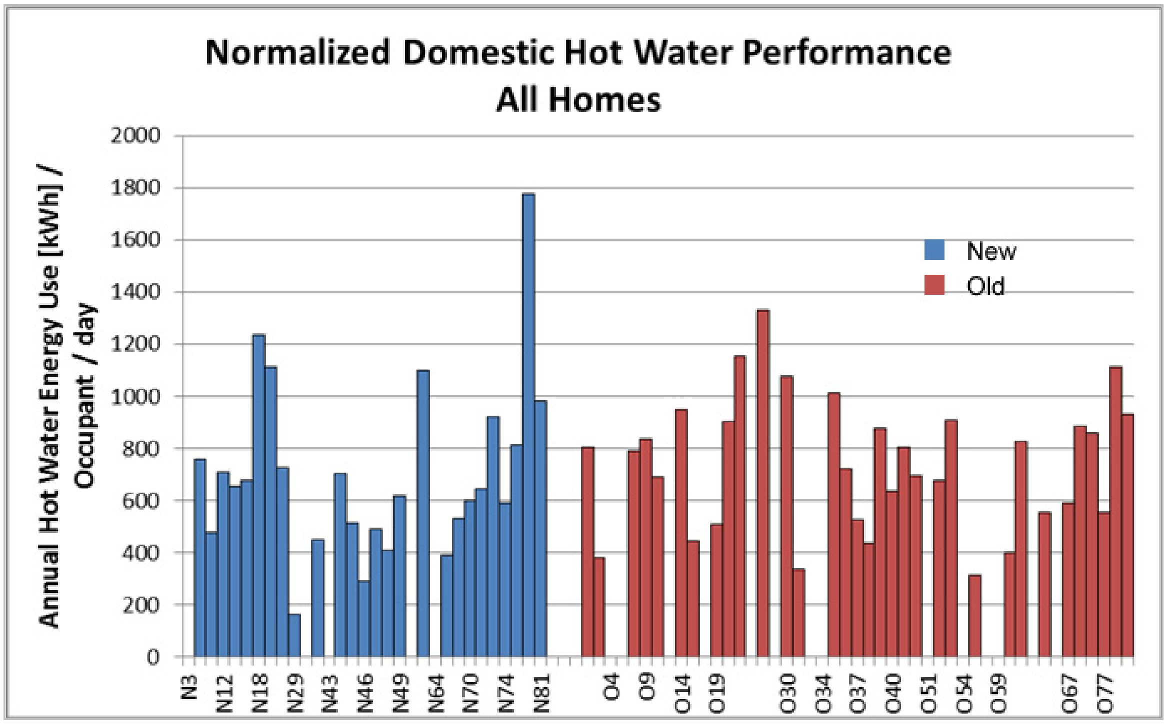

Figure 7-13 Hot Water Performance for Each House, Utilizing Monitored Data Projections.

7.5 Combined Heating, Cooling, and Domestic Hot Water

Monitored data showed moderate savings of new homes over old homes for cooling, heating, and hot water usage (see Figure 7-14 and Tables 7-10 and 7-11). Since only a partial year of hot water usage and a partial cooling season were recorded, an approximate value of the annual cooling, heating, and hot water energy was created by assuming the monitored hot water data represented 83% of the hot water usage (ten of twelve months) and the monitored cooling season represented 62.5% of the cooling season (five of eight months).

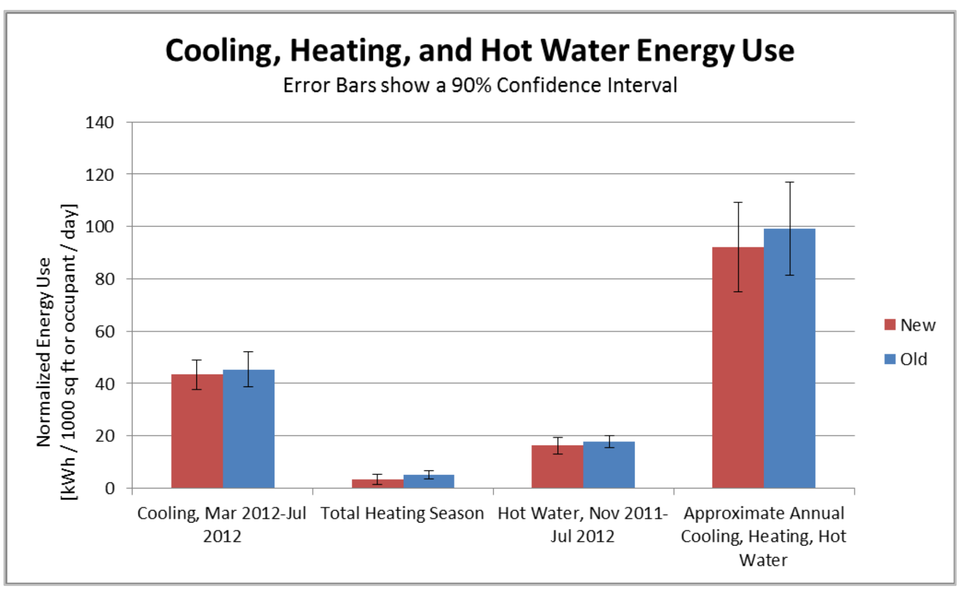

Figure 7-14. Overall Monitored Cooling, Heating, and Hot Water Energy Usage.

Overall, the monitored data showed a 4.4% decrease in cooling energy use of new homes, a 36.7% decrease in heating energy use, and an 8.9% decrease in hot water use. According to the annual approximation, the combined cooling, heating and hot water energy use savings is 7.0%.

Note that the margin of error (at a 90% level of confidence) of these savings values is very large. This is influenced by smaller sample size due to difficulties described previously in this report, and large variations in occupant behavior. From Table 7-1A, the savings of new homes over old from the approximate annual cooling, heating, and hot water energy use values results in a 7.0% savings of new over old, however within a 90% confidence level, the savings for Central Florida could be 25% greater or 34% lower.

Table 7-10. Percentage Savings of New Code Homes over Old Code Homes.

	Cooling	Heating	Hot Water	Cooling, Heating, and Hot Water
New Home Savings Over Old Homes	**4.4%**	**36.7%**	**8.9%**	**7.0%**
Positive Margin of Error	23.0%	44.7%	26.5%	25.3%
Negative Margin of Error	31.0%	88.3%	34.7%	34.4%

Table 7-11. Overall Monitored Cooling, Heating, and Hot Water Energy Usage.

		Cooling Energy, Mar 2012-Jul 2012 [kWh/1000 ft^2]	Total Heating Season [kWh/1000 ft^2]	Hot Water, Nov 2011-Jul 2012 [kWh/occupant]	Approximate Annual Cooling, Heating, Hot Water Energy [kWh/1000 ft^2 or occupant]
Mean	New	43.4	3.20	16.2	43.4
	Old	45.4	5.06	17.8	45.4
Margin of Error (Confidence Level of 90%)	New	5.62	1.95	3.19	5.62
	Old	6.68	1.65	2.39	6.68
Sample Size	New	18-24	10-17	11-20	
	Old	27-34	18-25	12-29	
% New Less than Old		4.4%	36.7%	8.9%	7.0%

7.5.1 Results Using Monitored Data Projections

In order to compare data for an entire year, a projection based on the relationship between the monitored cooling and heating energy use and the difference in temperature between indoors and outdoors was utilized. The monitored data projection method is described in Section 5.1.2. Additionally, utilizing monitored data projections increases the sample size, as shown in Table 7-12, producing more reliable averages for new and old homes. However, although the average values for all homes may be more statistically reliable, the data itself produced is less reliable when using projections, especially utility bill data projections.

Table 7-12. Sample Size for Three Data Analysis Methods.

	Cooling		Heating		Hot Water	
	New	Old	New	Old	New	Old
Monitored	18-24	27-34	10-17	18-25	11-20	12-29
Monitored with Monitored Projection	29	37	11	22	26	33
Monitored with Monitored and Utility Bill Projections	31	41	24	36	26	33

The results for heating, cooling, and hot water from these annual and monthly values are shown in Figure 7-15 and Tables 7-13 and 7-14 below. Cooling shows a larger savings of 12.3% while space and water heating show lower savings at 20.5% and 5.2%, respectively. Overall, heating, cooling, and hot water energy use is 11.2% lower in new homes compared to old homes using monitored projections to create annual data.

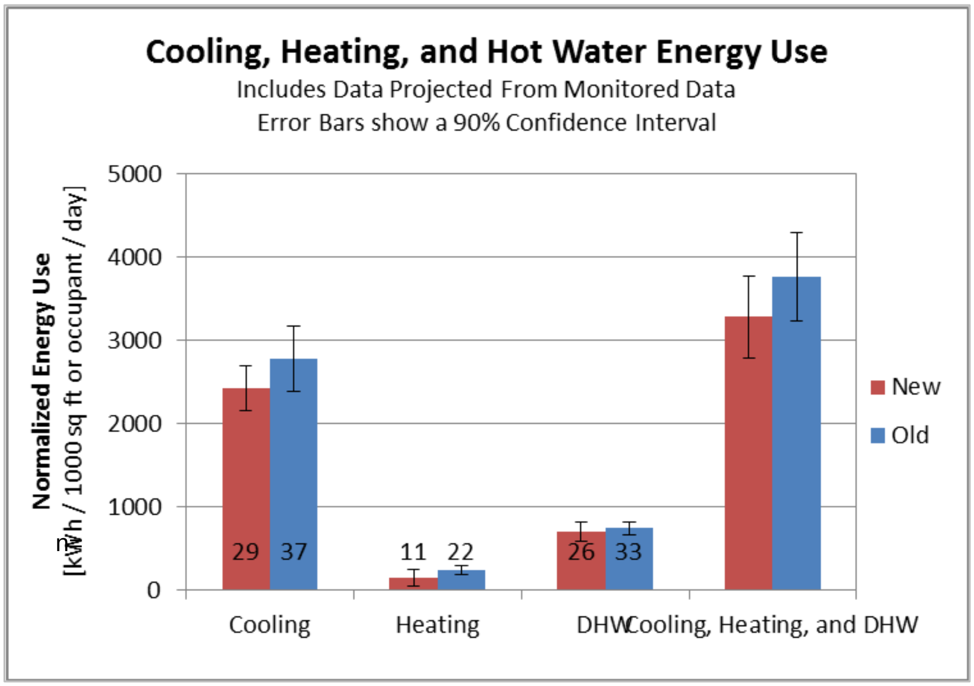

Figure 7-15. Overall Cooling, Heating, and Hot Water Energy Usage, Utilizing Monitored Data Projections.

Table 7-13. Overall Cooling, Heating, and Hot Water Energy Usage, Utilizing Monitored Data Projections.

		Annual Cooling Energy Use [kWh/1000 ft^2]	Annual Heating Energy Use [kWh/1000 ft^2]	Annual Hot Water Energy Use [kWh/occupant]	Annual Cooling, Heating, Hot Water Energy [kWh/1000 ft^2 or occupant]
Mean	New	2373	127	706	3206
	Old	2707	160	744	3611
Margin of Error (Confidence Level of 90%)	New	271	100	114	485
	Old	397	53	79	529
% New Less than Old		12.3%	20.5%	5.2%	11.2%

Table 7-14. Percent Savings and 90% Confidence Interval Error Values of New Code Homes over Old Code Homes, Utilizing Monitored Data Projections.

	Cooling	Heating	Hot Water	Cooling, Heating, and Hot Water
New Home Savings Over Old Homes	**12.3%**	**20.5%**	**5.2%**	**11.2%**
Positive Margin of Error	27%	133%	28%	31.0%
Negative Margin of Error	20%	67%	23%	23.1%

7.5.2 Results Using Monitored and Utility Bill Data Projections

Approximately half of the homes in the study had no monitored heating data, due to faulty equipment or late installation of equipment. For these homes, utility data was acquired and a utility bill projection was created. This method is often used to assess real home performance without the use of monitoring equipment. It can be used to compare different homes or to compare the performance of a home before and after a retrofit. From utility bill analysis done on homes with full heating or cooling data, the predicted cooling data was usually within 10-30% of the actual data, while the predicted heating use of homes was often greatly overestimated by the utility bill projection, especially for homes that appeared to have little or no heating use. Other research suggests that this method is inaccurate when predicting cooling or heating energy use during a small heating or cooling season (Stram and Fels, 1986). Thus, heating values from this analysis should be regarded with extreme care.

During a normal Central Florida heating season, researchers anticipate that this method would have worked well. With the extremely mild winter, however, this method appears to break down.

Figure 7-16 and Tables 7-15 and 7-16 show the results including homes with projected utility bill data in addition to the homes with monitored data and monitored projections.

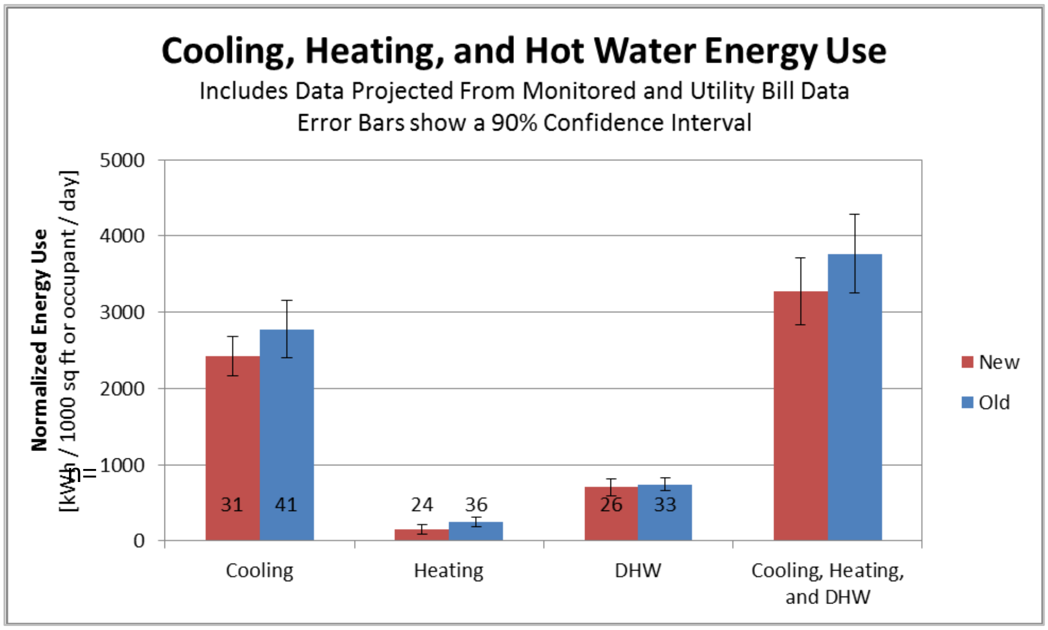

Figure 7-16. Overall Cooling, Heating, and Hot Water Energy Usage, Utilizing Monitored and Utility Bill Data Projections.

Table 7-15 Overall Cooling, Heating, and Hot Water Energy Usage, Utilizing Monitored and Utility Bill Data Projections.

		Annual Cooling Energy Use [kWh/1000 ft^2]	Annual Heating Energy Use [kWh/1000 ft^2]	Annual Hot Water Energy Use [kWh/occupant]	Annual Cooling, Heating, Hot Water Energy [kWh/1000 ft^2 or occupant]
Mean	New	2424	150	706	3280
	Old	2778	246	744	3768
Margin of Error (Confidence Level of 90%)	New	261	63	114	438.4
	Old	376.2	62	79	517.2
% New Less than Old		12.8%	38.9%	5.2%	13.0%

Table 7-16. Percent Savings and 90% Confidence Interval Error Values of New Code Homes over Old Code Homes, Utilizing Monitored and Utility Bill Data Projections.

	Cooling	Heating	Hot Water	Cooling, Heating, and Hot Water
New Home Savings Over Old Homes	**12.8%**	**38.9%**	**5.2%**	**13.0%**
Positive Margin of Error	24.5%	55.0%	28.4%	27.3%
Negative Margin of Error	18.7%	32.8%	23.0%	20.7%

The statistical margin of error is lowered greatly in the case of heating homes, as the sample size doubles for new homes and increases by 50% for old homes. However, the additional data is of uncertain accuracy. Ultimately, all data methods may not properly represent heating performance trends in Florida based on the 2011-2012 heating season.

The data show comparable values, although somewhat increased cooling savings than the other two methods. Note that the annual heating values are 20-60% larger than the monitored data and monitored data projection values. Overall, the combination of all three end uses shows a 13% savings in new homes versus old.

7.5.3 Baseline and Whole House Energy Use

Although not within the scope of this project, whole house energy use was measured and compiled in Table 7-17 and Figure 7-17. Overall, new homes used approximately 17.5% less energy than old homes.

Baseline energy, defined in this report as all energy use beside heating, cooling and hot water energy, is shown in Table 7-18. The baseline energy use was calculated for each hourly data point, compiled into a daily value, and averaged across the entire year. In this case, new homes without pools used about 10% more baseline electricity than old homes.

Table 7-17. Whole House Energy Use and Confidence Intervals

		Aug 2011	Sep 2011	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	**Annual** [kWh/ occ.]
Mean [kWh/ occupant/day]	New	52.2	40.7	29.2	25.7	25.3	25.5	23.7	30.7	31.2	38.1	39.8	46.2	**12475**
	Old	57.9	50.9	33.6	33.4	34.4	37.2	32.5	34.2	34.6	44.3	45.6	56.4	**15117**
Margin of Error (Confidence Level of 90%)	New		24.0	10.9	4.7	5.4	4.4	3.7	4.6	3.8	4.6	4.3	5.4	**2305**
	Old	20.6	13.9	4.8	4.9	3.6	4.3	3.0	4.1	3.9	4.9	4.9	6.5	**2424**
Sample Size	New	1	3	4	10	13	14	14	19	21	25	25	24	
	Old	5	6	14	18	24	24	26	26	35	35	33	33	
% New Less than Old		10%	20%	13%	23%	27%	31%	27%	10%	10%	14%	13%	18%	**17.5%**

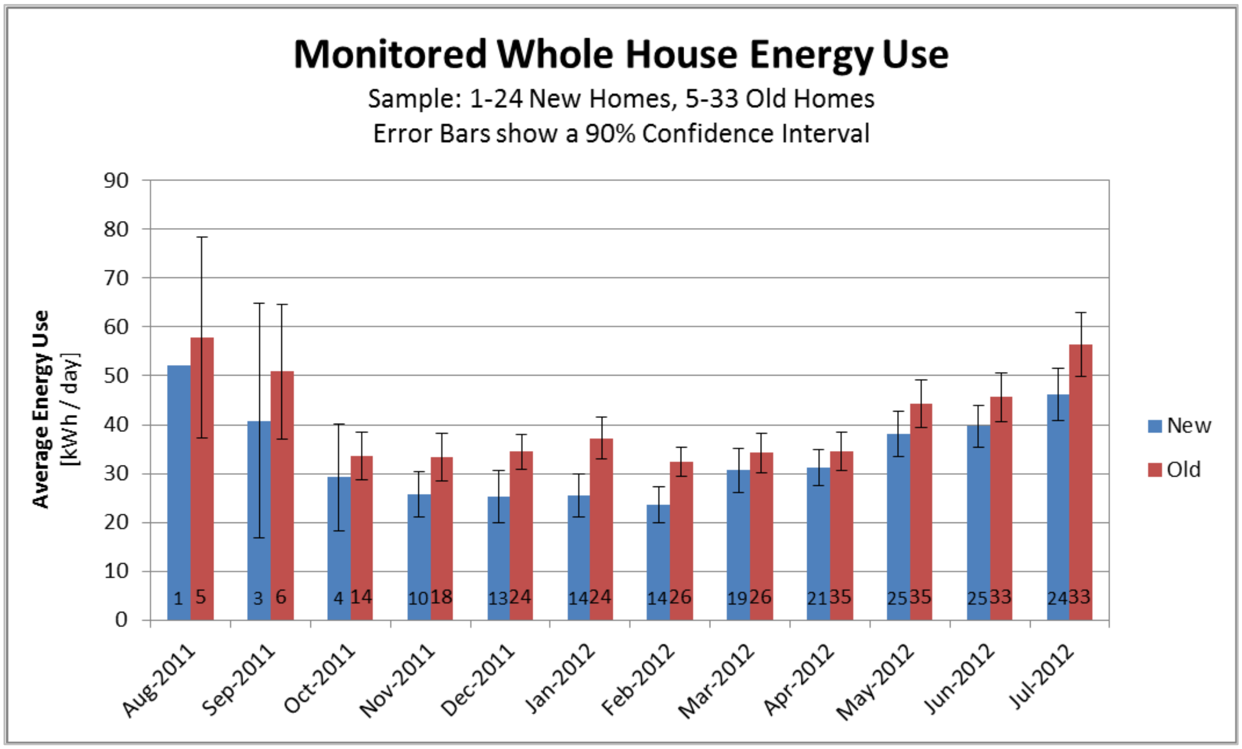

Figure 7-17. Monitored Whole House Energy Use, August 2011-July 2012.

Table 7-18. Average Baseline Energy Use.

	Daily Baseline Energy Use [kWh/day]		
	All Homes	Homes with No Pool	Homes with Pools Only
New	17.2	16.5	26.1
Old	22.9	15.0	29.0
New % Less than Old	25%	-10%	10%

The whole house energy use comparison is greatly affected by the presence of swimming pools: over half of the old homes had swimming pools while only two new homes had swimming pools. Based on baseline energy analysis, new homes with swimming pools use on average 3504 kWh/year more energy than new homes without swimming pools and old homes with swimming pools use on average 5110 kWh/year more than those without. The annual whole house energy use for homes without pools averages 12219 kWh/year for new homes and 12233 kWh/year for old homes, with a 0.1% difference between the two. Although new homes save 7-13% over old homes for cooling, heating and hot water, the 10% increase in baseline electricity use of new homes results in a comparable amount of whole house energy use.

7.5.4 HOBO vs. TED Comparison

As described in section 4.2, this study includes two types of data monitoring equipment. TED devices proved to be unreliable in most homes, and all but 20 were replaced (7 in new homes, 13 in old homes).

Although the TED monitoring units provided much difficulty in monitoring homes, some units did produce consistent data and others were not replaced to due to time constraints and homeowner availability. Since more TED units were kept in old homes compared to new homes, if TEDs reported systematically incorrect values, the comparison between new and old homes would be skewed. The results from all monitoring equipment were compared against the results from solely HOBO monitoring equipment in an effort to determine any difference in reported data between TED and HOBO data monitoring equipment. If a significant difference between the two were to appear, this would suggest the TED units are not measuring accurately.

The HOBO-only data did not look at data for 13 old homes and 7 new homes, although only one new TED-only home has data for cooling.

Cooling energy use based on data from all monitoring equipment in Table 7-19 barely differs from the cooling energy use reported by the HOBO dataloggers only, shown in Table 7-20. The only notable difference is that the only new TED home that reported cooling data was one of the lower energy users, although within the normal range of cooling energy use. The old home values, which should be more significantly affected by the absence of 12 sets of data showed only a very small change, giving no reason to suggest that the data collected by the TED units was inaccurate.

Table 7-19. Cooling Energy Use, All Data

		Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	Total Cooling Season [kWh / 1000 ft^2]
Monitored Cooling Energy Use [kWh/1000ft^2/day] (All Monitored Data)	New	4.64	5.4	9.72	10.3	13.4	1331
	Old	3.27	4.65	10.4	11.5	15.6	1393
Sample Size	New	18	20	24	24	24	
	Old	27	34	36	34	34	

Table 7-20. Cooling Energy Use, HOBO Data Only

		Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	Total Cooling Season [kWh / 1000 ft^2]
Monitored Cooling Energy Use [kWh/1000ft^2/day] (HOBO Data Only)	New	4.81	5.53	9.9	10.5	13.5	1354
	Old	3.09	4.3	10.5	11.6	15.8	1387
Sample Size	New	17	19	23	23	23	
	Old	24	30	30	30	29	

7.6 Interior Temperature and Humidity

Each house was installed with a temperature and relative humidity probe (Figure 7-18). The sensor has an accuracy of +/- 0.63F temperature and +/- 2.5% RH. The temperature logger was placed in central areas of the home in areas void of local heat sources generated from electronics, cooking, bathing or in direct air flow path directed from central heat and cool registers. The security of the logger and aesthetic of installation was another important factor in deciding on the best placement. It was desired to place the logger as close to the thermostat as possible. Since the logger was to remain in the same location for a year, there was not usually a good location next to the thermostat to place the logger. Loggers were often placed out or sight on shelves (Figure 7-19), cabinets or door bell chime enclosures.

Figure 7-18. Temperature and relative humidity datalogger.

Figure 7-19. Temperature datalogger being place on top of centrally located plant shelf.

Interior temperature and relative humidity were measured and stored for each hour of the day at each home. The hourly data from each home has been assembled to represent a daily 24 hour composite for each month. The mean, max and minimum are shown on the charts. The maximum and minimums represent a single home during the month for the hour indicated.

Temperatures in old code homes averaged about 1 degree F higher during the summer and about 0.6 degrees colder during the winter. Relative humidity in old homes averaged 2%-5% higher than the new code homes. Figures 7-20 shows the monthly average indoor temperatures of the two code periods. The trend downward can also be noticed in the plot of monthly outdoor temperatures shown in Figure 7-21.

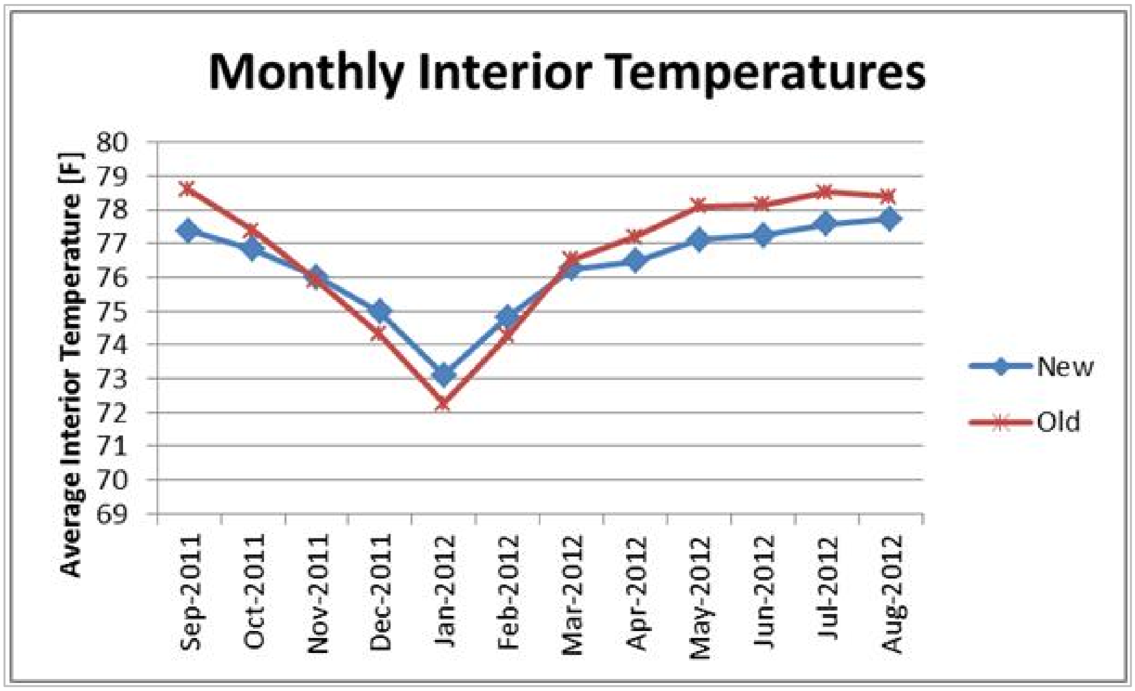

Figure 7-20. Average monthly indoor temperatures.

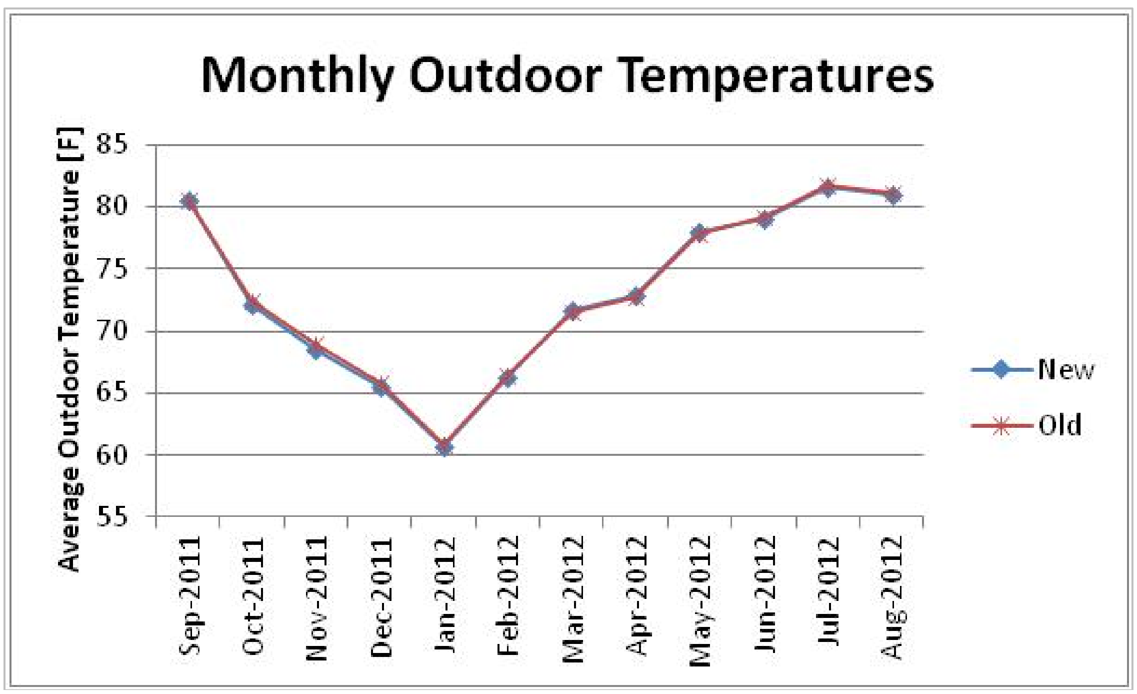

Figure 7-21. Average monthly indoor temperatures.

Figures 7-22 through 7-29 show a sample of plots representing months of 4 different seasons. Profiles for each month from August 2011- July 2012 are included in Appendix B.

7.6.1 Fall November 2011

Temperatures are nearly identical with diurnal amplitude within 74F-77 F range. Relative humidity is noticeably about 5% RH points higher in the old code homes.

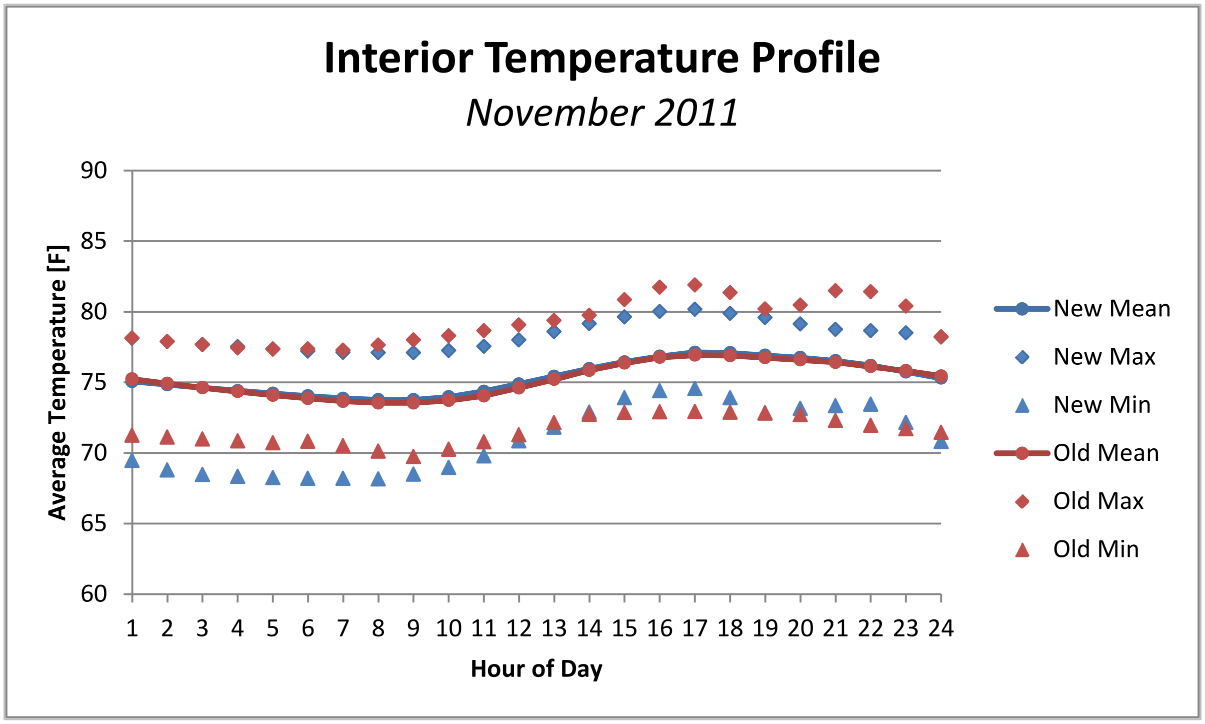

Figure 7-22. Interior Temperature Profile, November 2011

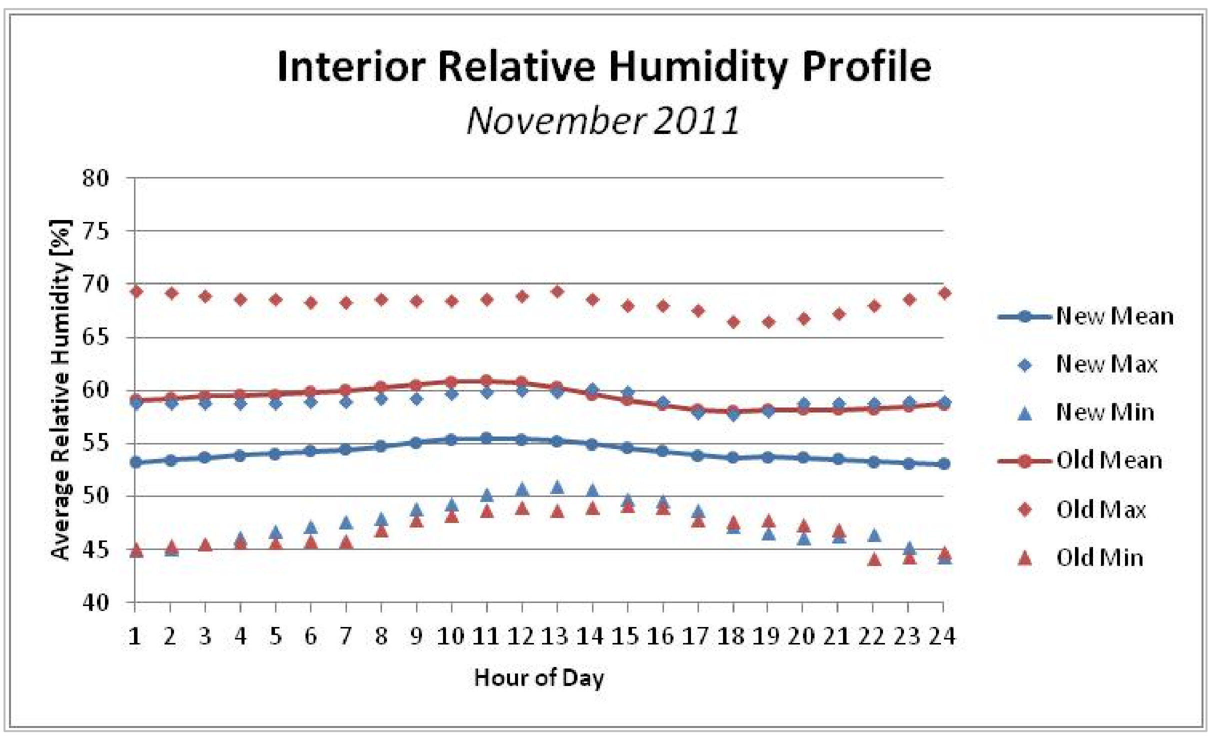

Figure 7-23. Interior Relative Humidity Profile, November 2011

7.6.2 Winter January 2012

Temperatures for the old code group are about 0.7 degrees colder with diurnal amplitude within 70°F-74° F range. Relative humidity is about 1% RH point higher in the old code homes.

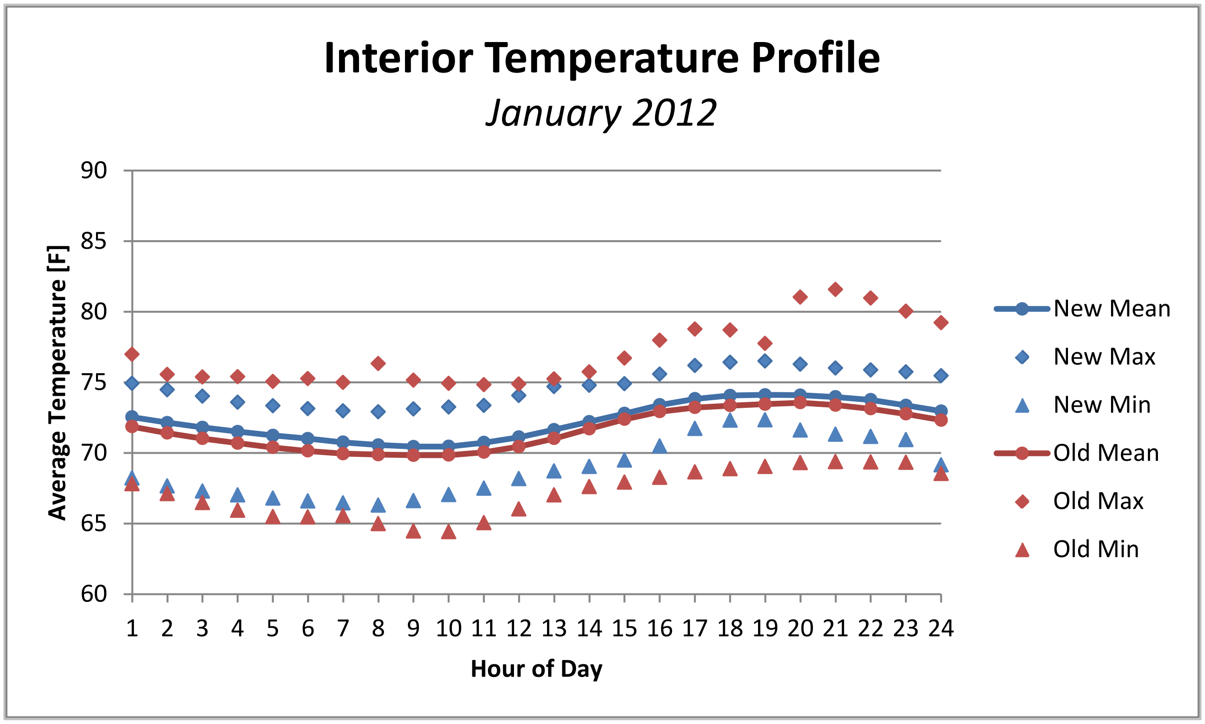

Figure 7-24. Interior Temperature Profile, January 2012.

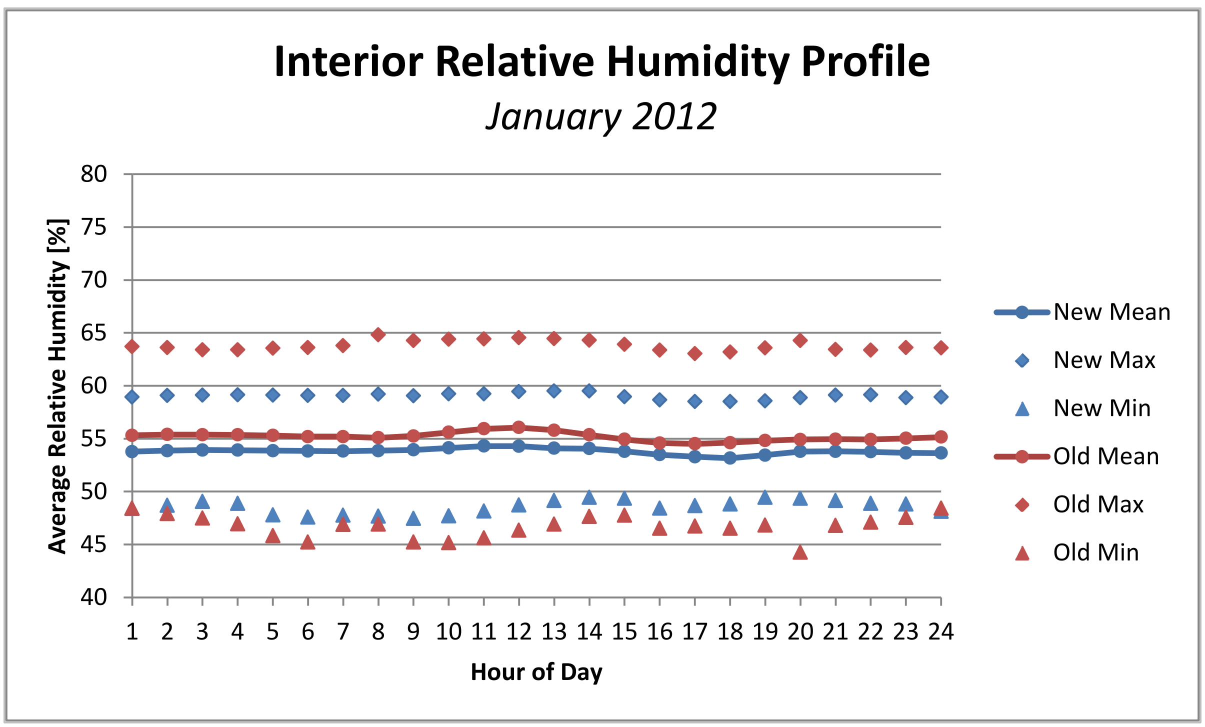

Figure 7-25. Interior Relative Humidity Profile, January 2012.

7.6.3 Spring April 2012

Temperatures for the old code group are about 0.8 degrees warmer with diurnal amplitude within 75°F-79° F range. RH is 4% higher in the old code homes in the late PM to early AM hours.

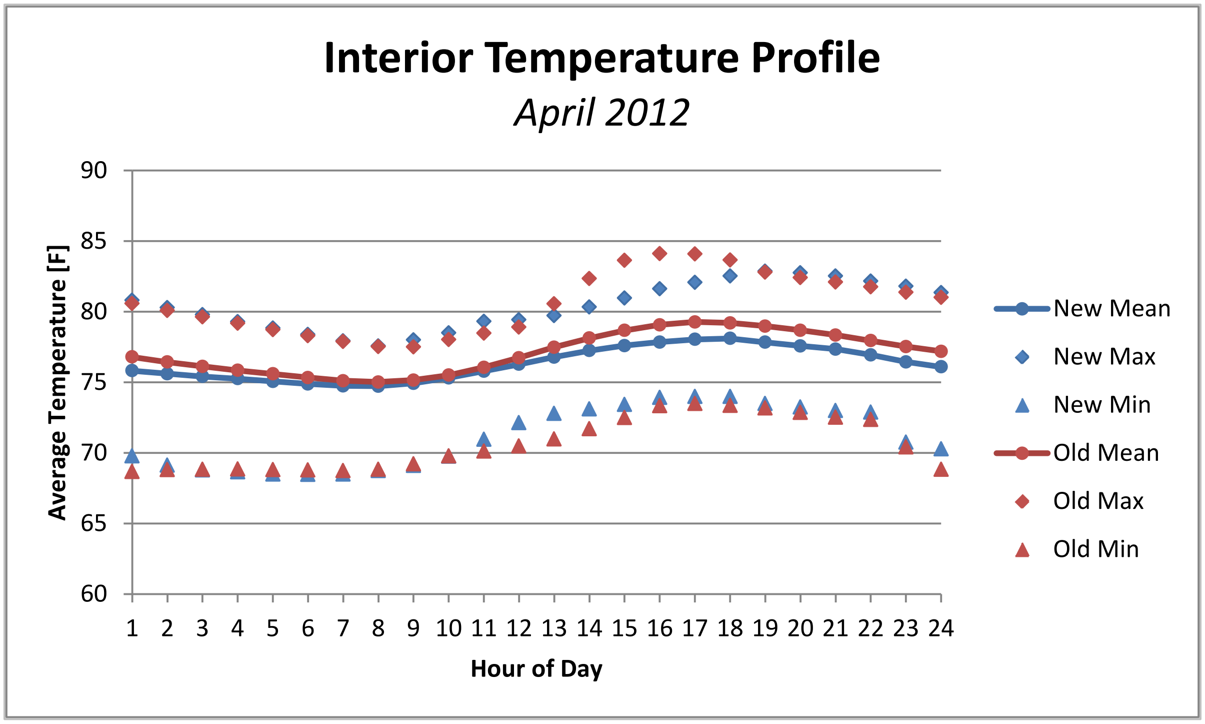

Figure 7-26. Interior Temperature Profile, April 2012.

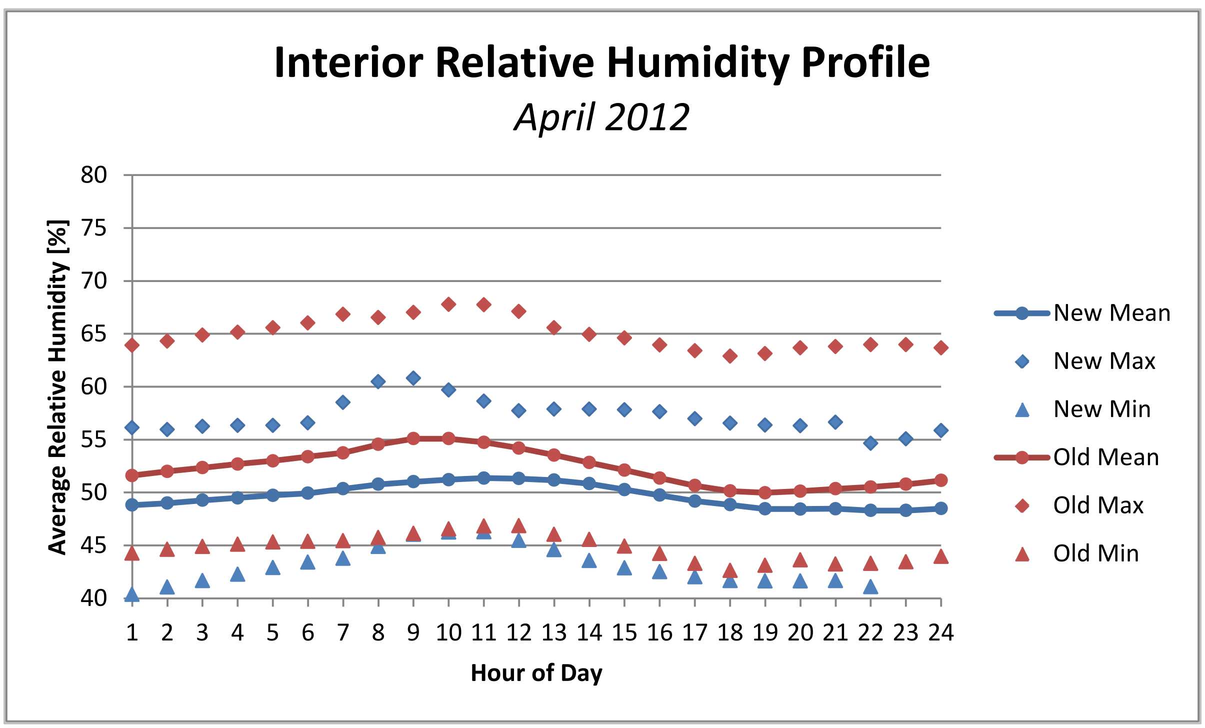

Figure 7-27. Interior Relative Humidity Profile, April 2012.

7.6.4 Summer July 2012

Temperature for the old code group is about 1.1 degrees warmer with diurnal amplitude within 76°F-80° F range. RH is about 3% points higher in the old code homes.

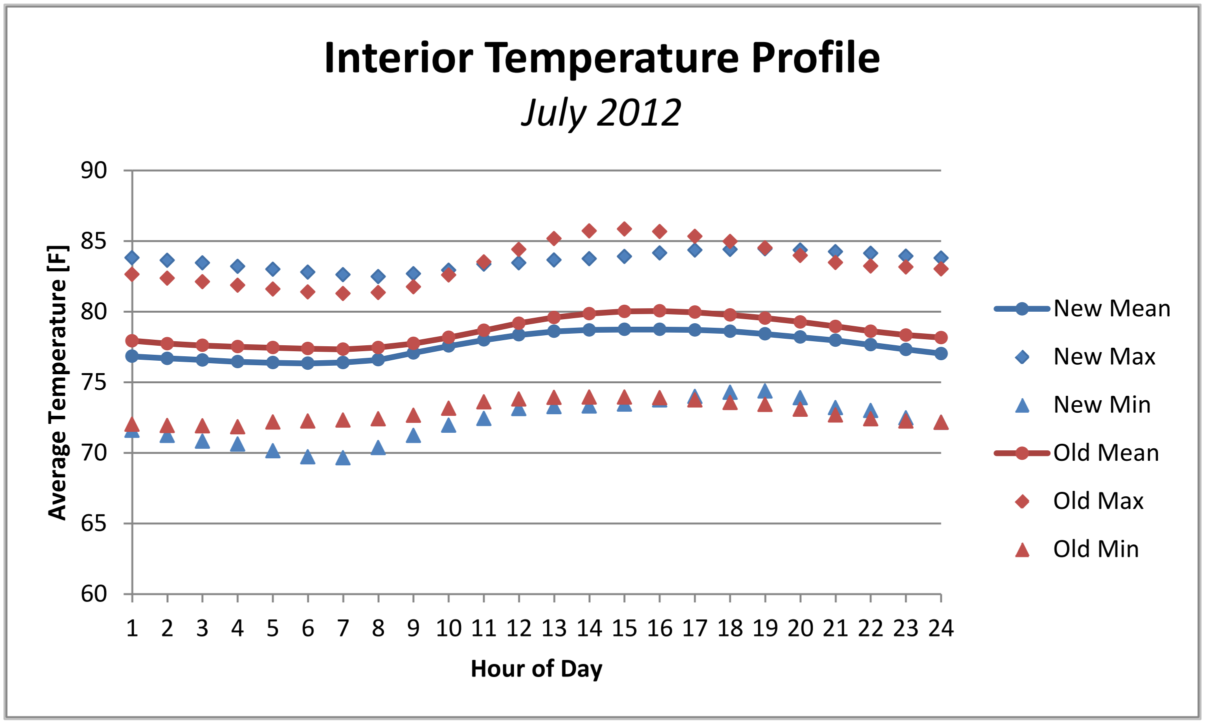

Figure 7-28. Interior Temperature Profile, July 2012.

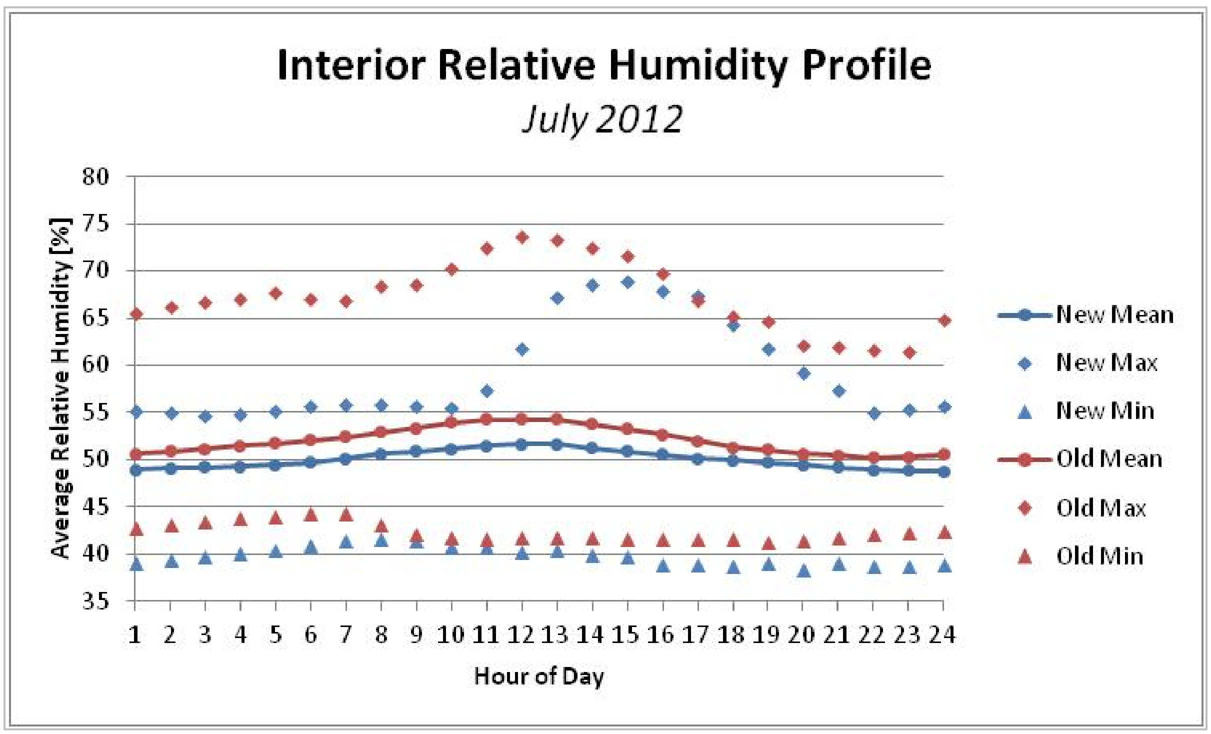

Figure 7-29. Interior Relative Humidity Profile, July 2012.

7.7 House Performance Test Results

Each home in the study had several performance-based tests completed. Measurements were made of house air tightness, as well as measurements designed to evaluate the general performance of the central air distribution system. The air distribution performance was evaluated by the pressure pan test (an indication of air tightness), pressure differentials across closed interior doors (to determine adequate return air distribution pathway) and cooling performance based on air temperature differential between return and supply as well as the return air flow rate.

7.7.1 House Tightness

The house tightness test followed test standard ASTM-779 method of measuring air leakage during depressurization only. This method tends to provide a more conservative evaluation of tightness compared to testing in both the pressurization and depressurization that averages the results. This occurs because depressurization will pull tighter on exhaust dampers, and jalousie-type windows. The depressurization method was used since pressurization can push movable barriers such as dampers more open than they would typically occur under more natural conditions, which can result in more elevated leakage measurements. Nearly all tests were completed by taking several measurements (multipoint); however four homes were tested using the single-point test method at 50 pascals due to limited test time.

The measured air pressure and fan flowrate results were entered into Energy Gauge USA to calculate:

1. House air leakage rate in cubic feet per minute when depressurized to 50 pascals (CFM50)
2. Normalized air leakage rate as air changes per hour at 50 pascals (ACH50). This is simply calculated by CFM50 / house volume (ft^3) x 60.
3. Air flow equation variables C (flow coefficient) and n (flow exponent) as well as the correlation coefficient, r. All multipoint tests had correlation coefficients greater than 0.98 indicating a good quality test.

Table 7-21 shows the comparison of house tightness data between the two different code groups. The average house tightness of old code homes was 9.07 ACH50 (n=47) compared to 5.66 ACH50 (n=31) for the new code group. This indicates that the 2009 homes are 37.6% tighter than the older 1985 era homes. It can also be stated that the older code group is 60.8% leakier than the new code [(9.07-5.64)/5.64].

Table 7-21. Comparison of House Tightness Data by Code Period.

Code Period	CFM50	ACH50	C	n	r
Old	2269	9.07	192.6	0.636	0.997
New	1484	5.64	105.4	0.691	0.998

The distribution charts (Figures 7-30 and 7-31) below show a clear shift in house airtightness towards tighter construction in the new code group compared to the older code group. While the total number of new code homes available for the study is less, the distribution shows that about

45% of very high leakage > 12 ACH50 has been shifted to ACH50 8.0 or less. Each plot shows the number of homes within a range of air tightness. At the top of each bar is the number of homes followed by the representative % of the total in the sample. The tightest old code home in the first bin 0.0-4.0 pascals had an ACH50=3.9 and had new windows installed as well as exterior paint and caulking.

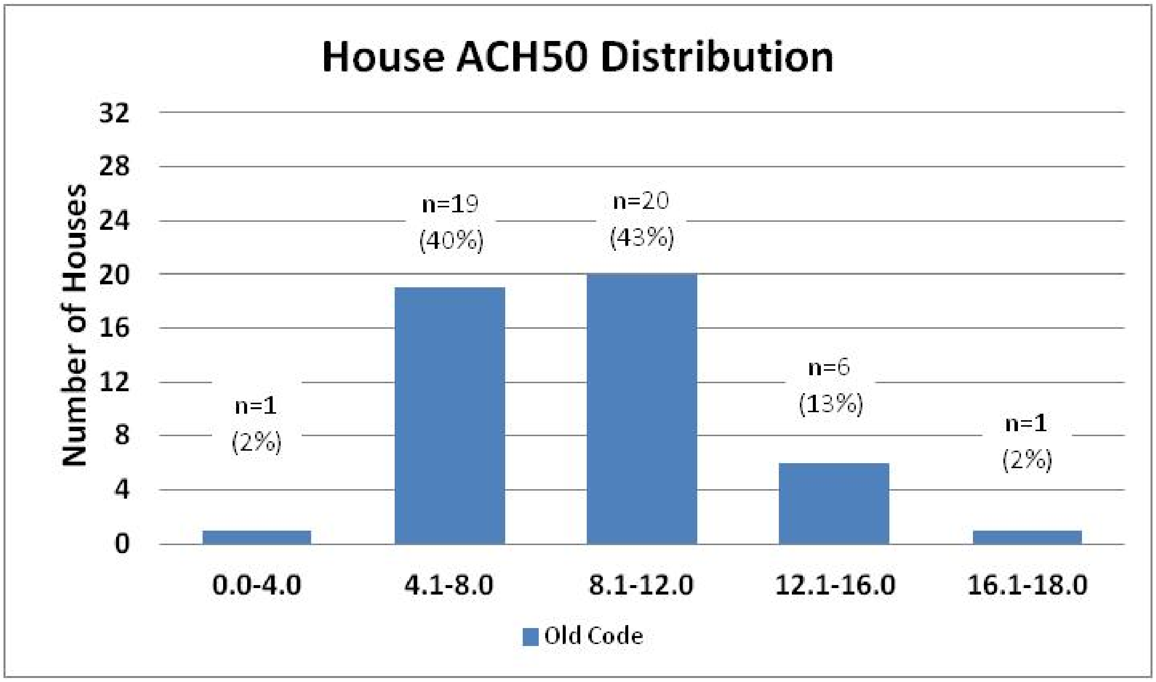

Figure 7-30. Normalized house leakage distribution for the old code group (n=47).

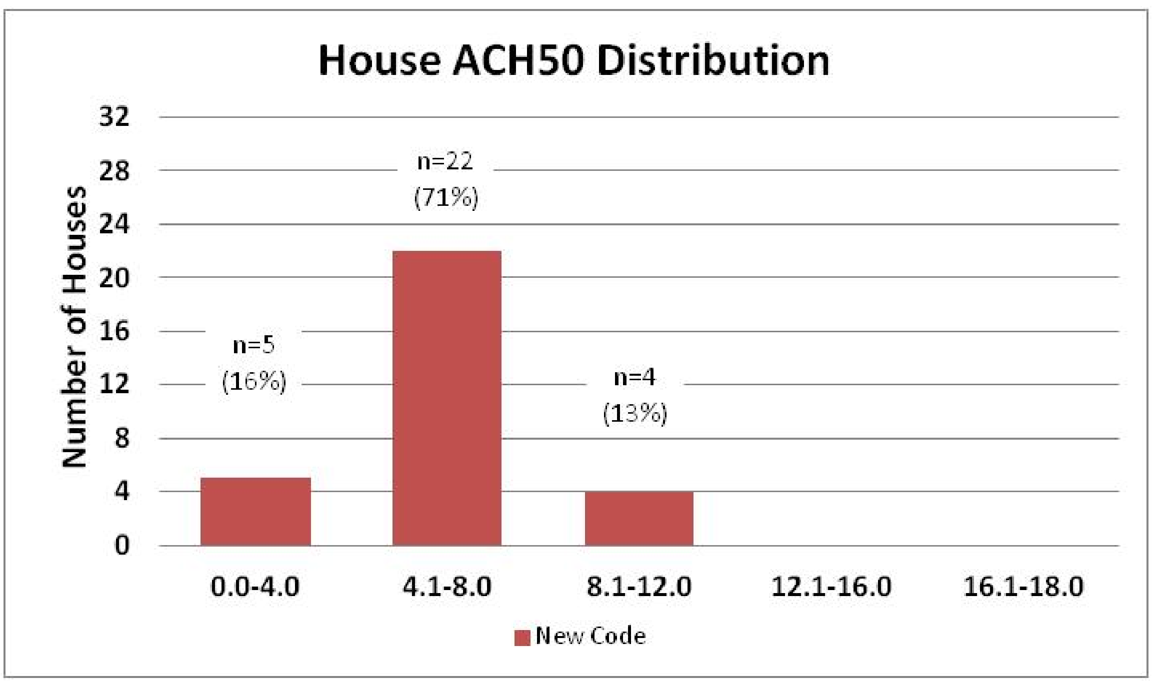

Figure 7-31. Normalized house leakage distribution for the new code group (n=31).

7.7.2 Duct Tightness

The standard code approved method for measuring duct air tightness is by means of temporarily masking over duct grills and using a small calibrated fan to depressurize the duct to 25 pascals of pressure. This determines the leakage air flow rate at 25 pascals also known as CFM25. Due to the time involved, this method was only used in cases when a code form claimed the air tight duct credit. There was only one home where the code form claimed the tight duct credit and the CFM25 test method was used. It was found that this duct system was tight enough to earn the claimed the credit.

Another method, known as the pressure pan test or PPan in short, was used in all study homes as an alternative to the CFM25 test. This method was chosen for three primary reasons:

1. Good diagnostic test- It is more informative about <u>where</u> the largest leaks exist in the system. This is helpful to see how the code may have impacted the return versus supply side differently and it is more informative to repair contractors to help prioritize and focus repair efforts.
2. Faster. It does not require large amount time required to seal grills and install a duct test fan. Some grills can be difficult to access in cases such as very high ceiling locations or when they are partially blocked by large furniture such as sofas, beds, dressing cabinets, and entertainment centers. The PPan test can be effectively completed by measuring most grills, and does not require measurement of every grill as long as measurements are taken at grills immediately nearest to those not measured.
3. Lower liability. Paint damage can result from paint from grills as the masking material is removed from the grills at the end of the CFM25 test. Interior finished surfaces can also be accidentally marred as a ladder is moved about to access several grills to seal and unseal them.

The PPan test does have some weaknesses as an air tightness measurement. The pressure readings are sensitive to the consistency of applied pressure to the pan during measurements as well as high wind fluctuations. Test personnel must be carefully trained to recognize these impacts and take quality measurements. PPan measurements in this study were taken among the same four trained members of the test / energy audit team. The other weakness in the PPan test is that it does not measure the absolute air tightness (total cumulative hole size) as does the CFM25 test. In general, higher PPan values correlate reasonably well with higher CFM25 out values, however the margin of error can be large enough in case by case comparisons of tight duct systems to be considered unsuitable in the Florida Energy Code for verifying substantially air tight duct systems. It should also be noted that this method only works for portions of duct systems located or able to communicate with unconditioned zones located outside the primary air barrier of the home such as attics, garages and crawlspaces. All of the study homes had significant portions of ducts in unconditioned space.

For those unfamiliar with this test method, it is described in more detail here. The test method requires the house to be depressurized or pressurized to 50 pascals with the central heat/cool system off and unsealed. A sealed pan with a pressure tap inserted into it is used to measure the pressure inside the grill with reference to the main body of the house. This is done by temporarily placing the pan over the grill applying a firm and steady pressure. Several seconds elapse to observe readings, and once steady results are observed the reading is recorded as pascals. The supply side PPan readings are averaged separately from the return side, then the average PPan reading is calculated as the average of the supply and return averages.

The measurement principle works based on the difference in pressure in the unconditioned zone where the ducts are located. The house is typically between -45 to -50 pascals with reference to the duct zone when the house is depressurized -50 pascals with reference to outdoors. A duct in a vented attic that was completely disconnected from the grill would have a pressure pan reading between -45 to -50 pascals. A supply duct not completely disconnected or return plenum having very large visible hole(s) may have PPan reading of 15-25 pascals. A very tight duct will have a PPan reading between 0 to 0.2 Pa.

The test results are reliable enough to compare the relative tightness of different duct systems and to determine the relative amount of leakage a duct system has. The following general characterizations in Table 7-B below are intended for the average PPan values of average supply and average return readings and are offered to assist in assessing the relative amount of leakage found in the tested duct systems. Average PPan value was calculated as follows:

$$\frac{(\textit{average supply PPan} + \textit{average return PPan})}{2}$$

The characterizations are not based on solid scientific basis as the testing cannot distinguish between several small cracks or one hole that is equal to the same cumulative amount of several cracks. As such, there may be exceptions to the specific statements below. It is however, very good at detecting the presence of significant leaks located in unconditioned spaces and there is reasonable confidence to trust this to utility repair programs which do use this methodology to determine whether or not to repair a duct system. Table 7-22 below is based on the authors' research experience and does not necessarily reflect that of any particular utility duct repair program.

Table 7-22. Duct Leak Characterization Using Average PPan Values.

PPan range (Pa)	General Characterization of Duct Leakage Based Upon Averaged PPan Values
0.00-0.30	Substantially to moderately tight; May have many very small cracks or seams not typically visible.
0.31-0.50	Typical new construction; not substantially tight, has many small cracks or seams, no large holes.
0.51-1.0	Common in new construction; Several small seams and some large cracks or seams.
1.1-3.0	Mechanical fastening integrity questionable; Visible sized holes plus several seams.
3.1-5.0	Partial mechanical integrity failure likely; visible sized hole(s) larger than preceding pressure range.
5.1-7.0	Partial mechanical failure present somewhere; Large visible hole(s) likely at return plenum.
7.1-15.0	Mechanical fastening failure but not 100% disconnect; Large hole(s) and/ or partial disconnect(s).

Table 7-23 below provides a comparison of averages between all homes in each code group for the average PPan values on the supply and return sides as well as the equally weighted average of the supply and return sides representing the whole duct system. The last two columns indicate the number of homes having average PPan on supply and return sides greater than 3 pascals, which is considered moderate leakage. Seven out of nine old code homes, noted as having substantial amounts of mastic, had whole duct average PPan less than 1.0. Two of these nine had a very large return leaks in the support plenums in the garage resulting in a PPan average of 2.5 pascals for one of them and 6.0 for the other system.

Table 7-23. Comparison of PPan Measurements by Code Period.

Code Period	Supply PPan avg.	Return PPan avg.	R&S Average	# homes with Supply avg. > 3Pa	# homes with Return avg. > 3Pa
Old	1.36	3.39	2.38	4 (8.5%)	16 (34.0%)
New	0.47	1.03	0.75	0	1 (3.2%)
% improvement	65%	70%	68%	100%	94%

The total house average PPan is shown in the next two charts (Figure7-32 and Figure 7-33) as the number of homes having duct tightness PPan values within various ranges. The ranges are not shown as equally separated ranges but rather at various ranges of tightness as characterized in the Table 7-22 preceding here. Figures 7-32 and Figures 7-33 show that 23% of the old code leakage exceeding 3.0 pascals has totally shifted to leakage less than 3.1 pascals in the new code group.

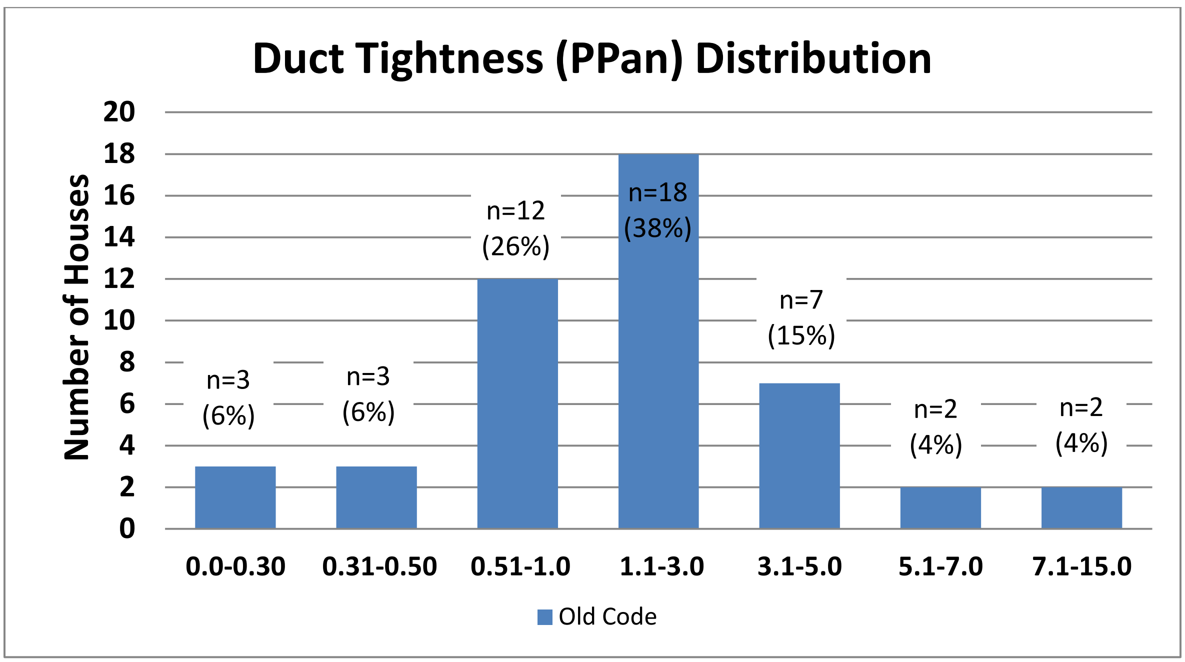

Figure 7-32. Duct leakage distribution for the old code group (n=47). (% may not add up to 100% due to rounding).

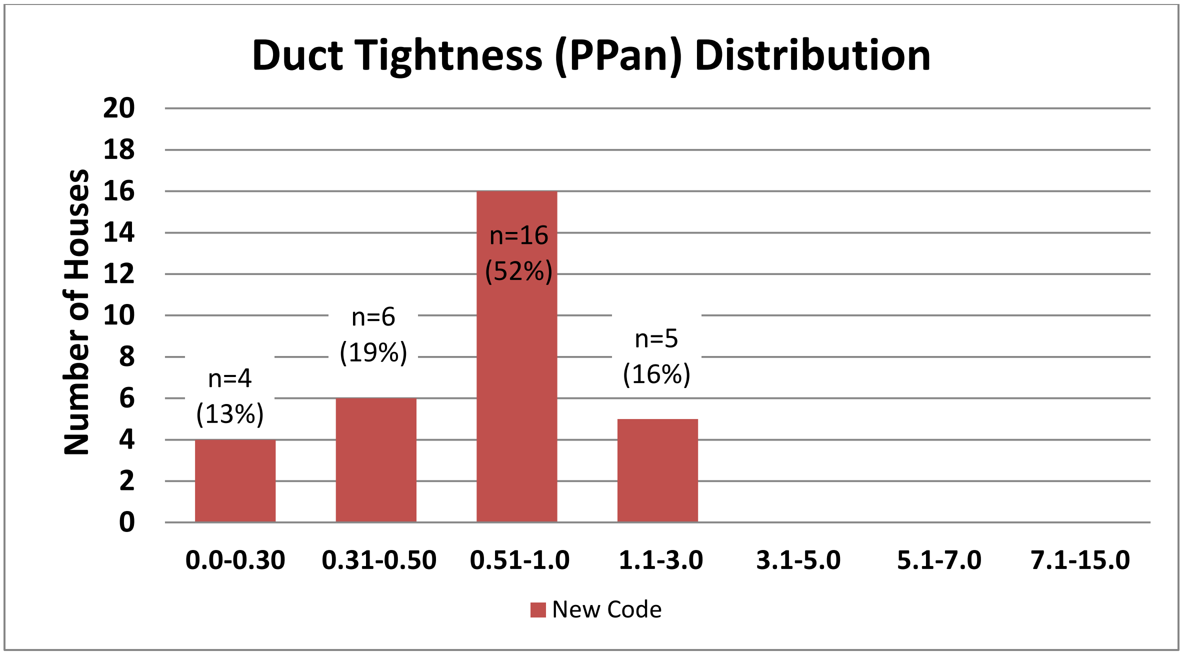

Figure 7-33. Duct leakage distribution for the new code group (n=31).

On average PPan values have decreased about 68% from old code to new code. This does not mean the total hole size has decreased by this amount, but does show that duct tightness has improved substantially from the old code to new code. The data also show that much of the improvement has occurred on the return side as a result of improved codes requiring mechanical and air sealing procedures as well as specific duct construction within located with air handler support platforms. The old code had four homes (8.5%) with supply PPan average exceeding 3.0 pascals and 16 (34.0%) homes with return PPan average exceeding 3.0 pascals. The new code number of homes exceeding 3.0 pascals was no homes on supply and only 1 home (3.2%) on the return side. This data shows a significant measureable improvement in duct tightness as a result of successful energy code improvements.

7.7.3 Return Air Balance

Florida building code addressed the need for adequate return air pathways for habitable rooms with closeable doors such as bedrooms beginning in March 2004 (Section 601.4 of the Mechanical Code (2004), "Balanced Return Air"). This requires that the magnitude of pressure from the room with reference to the main body of the home should not exceed 2.5 pascals (either positive or negative) while the central heating/cooling system is in operation. The intent is to decrease the energy load on the home and minimize potential for some indoor air environment problems that can arise due to depressurization of the central main body where centrally located return intakes are located (Cummings and Withers 2006), (Swami et al. 2006).

With the central cooling system on, each applicable interior door was closed and then the room pressure with reference to the main body was measured. Each measurement was done with only a single door closed at any given time.
On average the old code rooms had two rooms per house having pressure exceeding the 2.5 pascal limit. The new code group is half of this having one home per house on average that

exceeds the 2.5 pascal magnitude limit. The two charts below (Figure7-34 and Figure 7-35) show the distribution of homes having inadequate return air pathway for each code group. The old code group has 85% of homes with at least one room or more per home exceeding the pressure limit, while the new code group had 63%. The 2006 return air balance study completed on homes built just after the return air balance code began on homes built during 2004-2005 found that 27.5% of all rooms in 40 homes exceeded the pressure limit (Swami et al. 2006). By comparison, the new code group had 27/105 rooms (25.7%) in 31 homes that exceeded the limit. The new code has resulted in much better return air distribution, but shows there is still more room for improvement and that there is still about the same compliance since the code was enacted.

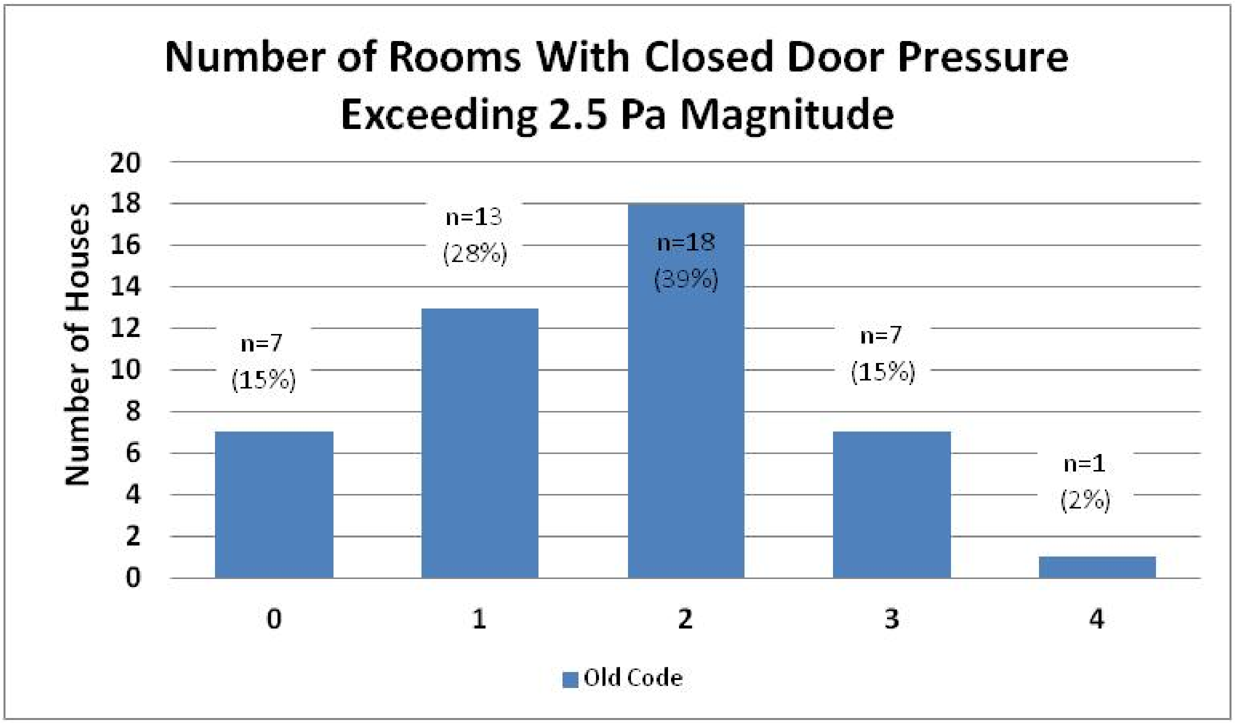

Figure 7-34. Distribution of homes having inadequate return air pathway for the old code group (n=46). (% may not add up to 100% due to rounding).

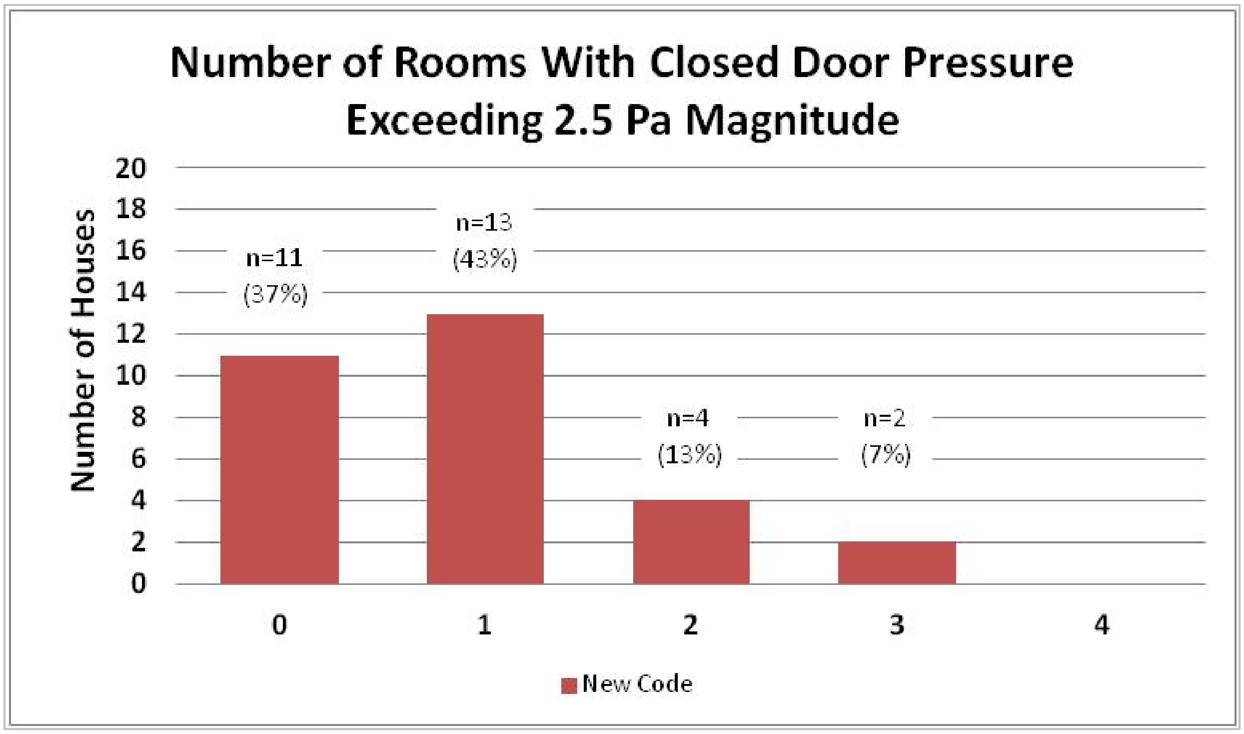

Figure 7-35. Distribution of homes having inadequate return air pathway for the new code group (n=30).

8.0 Conclusions

8.1 Energy Use Comparison

Monitored data indicates homes built to the 2009 Florida Energy Code are using 4.4% less energy for cooling than homes built to the 1984 code. They are using about 9% less for water heating. Space heating data size was smaller and, due to a mild winter, less reliable, however the newer homes that were monitored used 37% less energy for heating. Overall the combined heating, cooling and hot water energy use was 7% less for the new code homes using the available monitored data. Due to the smaller sample that had monitored data available for all seasons, the possible error of solely relying on monitored data is large. However looking at individual summer and winter months for monitored sites the results are rather consistent for cooling and heating.

In order to further explore annual savings two methods were employed. Missing heating and cooling data was projected from monitored data for each home based on inside and outside temperatures. Established monthly adjustment factors of water use and cold water temperature were utilized to derive missing hot water energy use data. The second method used utility bill analysis along with monitored data to estimate annual heating and cooling energy use of the participants.

Projections of missing months for cooling show a larger savings of 12.3% while space and water heating show lower savings at 20.5% and 5.2%, respectively. Overall, heating, cooling, and hot water energy use is 11.2% lower in new homes compared to old homes using monitored projections to create annual data.

Using utility bill analysis along with the monitored data, cooling savings for the new code homes are estimated at 12.8%, while for heating 38.9%, and water heating 5.2%, for an overall estimate of 13.0%. Because more homes are included, the statistical confidence is higher than the strictly monitored sites.

8.1.1 Discussion of Energy Use Results

The most problematic issue with the monitored data is the very mild heating season for which limited data was available. The heating degree days from winter period 2011-2012 were approximately 1/3 that in east central Florida compared to the very cold pervious two winter seasons occurring prior to this project monitoring period. Some of these Central Florida participants did not use any heating. Monitored data for the 2011-2012 winter season shows less heating use than would be predicted by standard utility bill analysis and temperature data. Having just short periods of cold temperature may not allow the building mass to cool down sufficiently for the building to require as much heat as projected.

Monitored cooling savings for the new homes are higher in peak summer months and actually show negative savings during mild March and April months. There is no conclusive reason why although personal operation of the home may be different between the groups. Perhaps one group is more comfortable using natural ventilation.

8.2 Temperature and Relative Humidity Measurements

One of the key occupant drivers for heating or cooling energy use is the thermostat set point. This study measured interior temperatures in the participant homes. Temperatures in old code homes averaged about 1 degree F higher during the summer and about 0.6 degrees colder during the winter. Relative humidity in old homes averaged 2%-5% higher than the new code homes.

8.2.1 Discussion of Temperature and Relative Humidity Measurements

A few possible explanations for the difference in temperature between old and new code homes are as follows. First, residents may keep their thermostat set point lower because it is more affordable in a tighter and better insulated home. Second, some new code home residents may set their thermostats a little lower to increase runtime and circulation for improved comfort. Lastly, old code homes, being leakier and less insulated on average are more susceptible to greater amplitudes in temperature swings resulting in higher average temperatures.

8.3 Simulated vs. Measured Energy Savings

Simulation results [Fairey, 2009] indicated savings of about 50% of combined heating, hot water and cooling between the 1984 and 2009 energy code. We are estimating only 7% to 13% for the last year from the monitored homes. Some contributing factors to the difference between monitored and simulated are as follows: the unusually mild winter of 2011-2012; a noted interior temperature difference between new and old constructions, different internal loads, and the replacement of heating, cooling, and water heating equipment in the older code homes. In order to account for the currently installed equipment in older homes, simulations were rerun with the average equipment efficiency found. For example, starting with the Tampa modeled 1984 code home [Fairey, 2009] modifications were made to include the typical equipment specifications for old homes: a 12.9 SEER/7.6 HSPF heat pump and a 0.92 EF electric resistance water heater. This brought the expected simulated savings down from 50% to 27.1% Then the winter season was reduced from a TMY3 (typical meteorological year weather data used in building energy simulation software) Tampa heating degree days of 647 to 359 by eliminating heating in all but January and February. This was done to the modeled 1984 and 2009 homes and the expected savings went from 27.1% down to 26.5%. The original model used a less efficient refrigerator and other appliance loads for the 1984 baseline. The model was based on 18.7 kWh/day of non cooling, heating and hot water energy use for 1984 and 17.22 kWh/day for 2009. This study found that to the contrary, the old homes without pools used 15 kWh/day and the new homes used 16.5 kWh/day (fairly close to the model). To make a modest adjustment, simulation runs for the 1984 home were run with the same 17.22 kWH/day value modeled for the 2009 home. Finally the 2009 home which had been modeled with a programmable thermostat and 78/80 F summer temperatures was changed to a constant 77 while the 1984 home remained at a constant 78. This brought the estimated savings down from 25.7% to 9.4% as shown in Table 8-1, in-line with the measured savings. This simply means that over time, savings in new homes due to national equipment standard changes will be reduced with change-outs, and that occupants of newer, more efficient homes may keep thermostats at slightly more comfortable levels while using more “plug-load” energy.

Table 8 -1 Simulated Energy Savings of Tampa Modeled Home Originally Used in Code Study

Simulated Home (Tampa)	1984 Combined Heating, Cooling and Water Heating Electrical Use kWh/yr	2009 Combined Heating, Cooling and Water Heating Electrical Use kWh/yr	2009 savings from 1984 kWh (%)
Original Code-level	12109	6061	6048 (49.9%)
Modify 1984 Equipment	8318	6061	2257 (27.1%)
Reduce Heating Season to Model Mild Winter	8155	5991	2164 (26.5%)
Reduce 1984 Internal Loads to Match 2009	8065	5991	2074 (25.7%)
Change 2009 Cooling Thermostat from Programmable 78/80 F to Constant 77 F	8065	7309	756 (9.4%)

8.4 Home Performance Test Results

The newer code homes had tighter envelopes, tighter ductwork and better return pathways when interior doors were closed than the older code homes. The average house tightness of old code homes was 9.07 ACH50 (n=47) compared to 5.66 ACH50 (n=31) for the new code group, indicating the 2009 homes are 37.6% tighter than the older 1985 era homes. Sixteen (34.0%) old code homes had return duct PPan average exceeding 3.0 pascals. The new code number of homes exceeding 3.0 pascals was only 1 home (3.2%) on the return side. 85% of old code homes had at least one room exceeding the pressure limit when closing a bedroom door, while the new code group had 63%.

8.4.1 Discussion of Home Performance Test Results

Although by simply measuring the homes in this study the cause and affect cannot be certain, the changes made to the Florida building code may be responsible for the improvements in the quality measurements made. Two key air distribution related changes were made to the Florida code over the years. One was that the return had to be ducted. Many times returns used portions of the building materials as part of the duct system. One common example is where the return pathway passes through the wall to an air handler that sits on top of a support platform in a garage or closet. Often, the wall used as part of the return was open to the attic and the system would pull some of the return air from the attic. The ducted return is designed to only pull air from the conditioned space.

The second significant change to the mechanical code addressed balanced return air pathways. It requires an adequate pathway for return airflow when interior doors to habitable rooms were closed. The doors proved enough of a barrier to create such a large negative pressure in the return zone of the house to pull in a large amount of air from outside, while the bedroom air would exfiltrate. The new code homes still have some issues with insufficient return air pathways but not as much as the older homes.

8.5 Residential compliance and code enforcement

All of the new code homes in the study were permitted using the performance method, which requires a 0.85 e-ratio, a ratio of the energy use of the proposed home compared to the baseline home using Florida energy code software. Ninety percent of the 31 audited homes were calculated to have met the 0.85 e-ratio. Four old code homes were submitted with the code forms that allowed for higher e-ratios (1.00), but only two of these ending up with higher than allowed ratios. However, homes were not built to the energy code specifications submitted that often. Some components exceeded their submitted efficiency and others fell short. Sixteen of the thirty-one audited homes had one or more components that exceeded the level submitted. Although many of these were minor, there were a couple cases of large violations that should have been flagged by building departments.

9.0 Acknowledgments

This project required various skills and services from a large number of individuals and organizations. The authors would first like to thank our sponsors at the Florida Department of Business and Professional Regulation which helped make this project possible. Thank you to all of the homeowners who welcomed us into their home and allowed the study to take place.

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Appendix A- Home Energy Charts

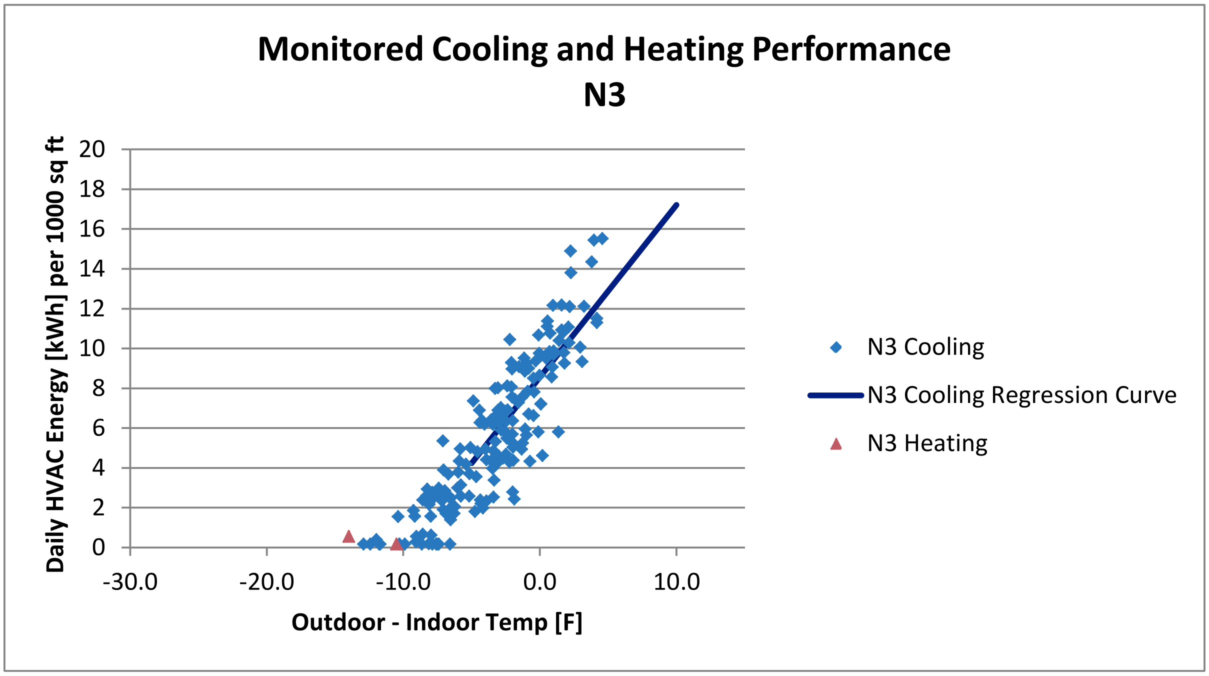


Figure A-5 Monitored Cooling and Heating Performance, N3

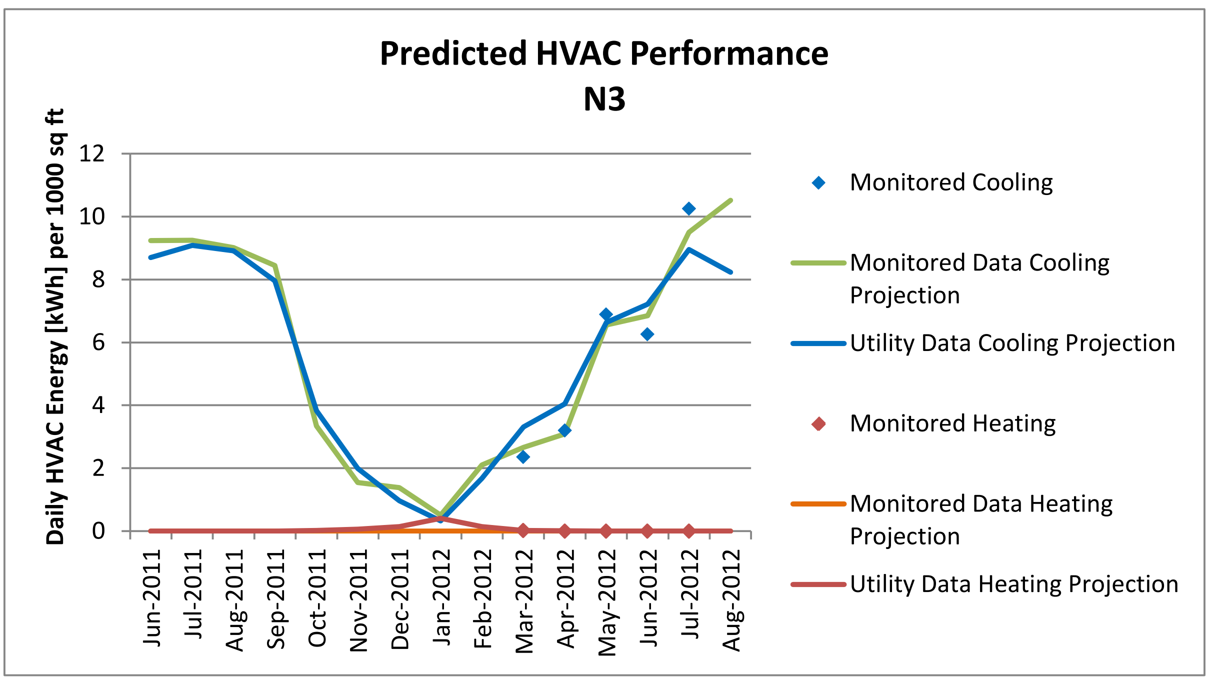


Figure A-6 Predicted HVAC Performance, N3

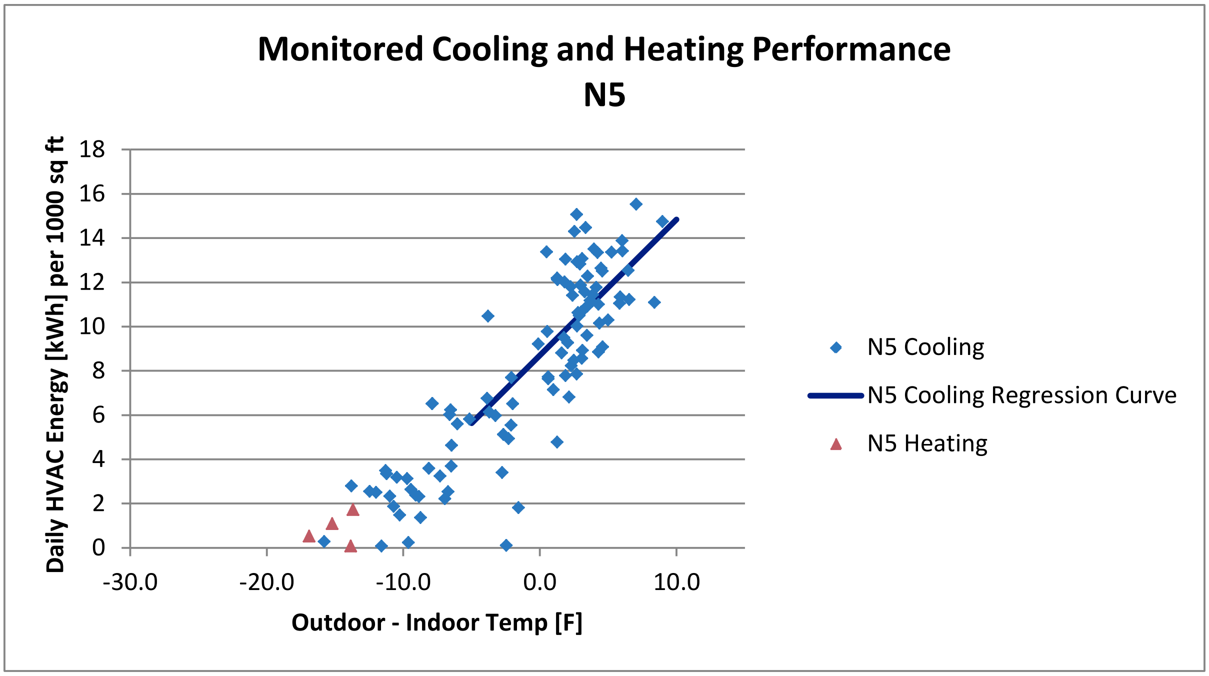


Figure A-7 Monitored Cooling and Heating Performance, N5

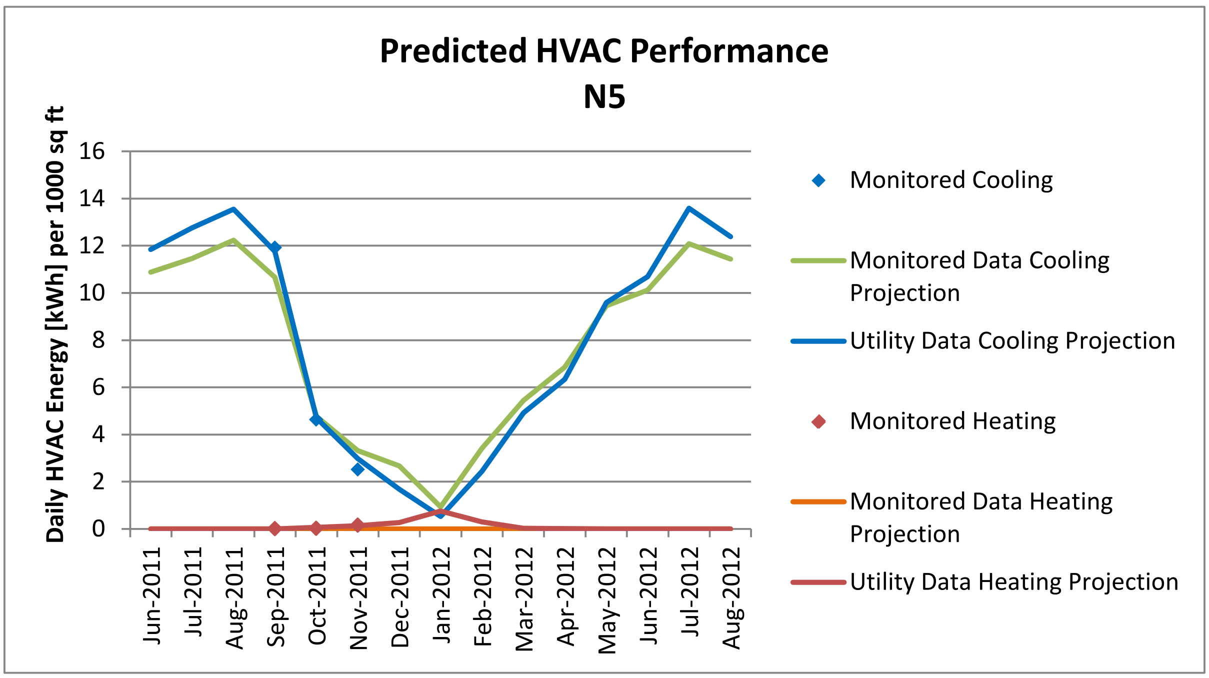


Figure A-8 Predicted HVAC Performance, N5

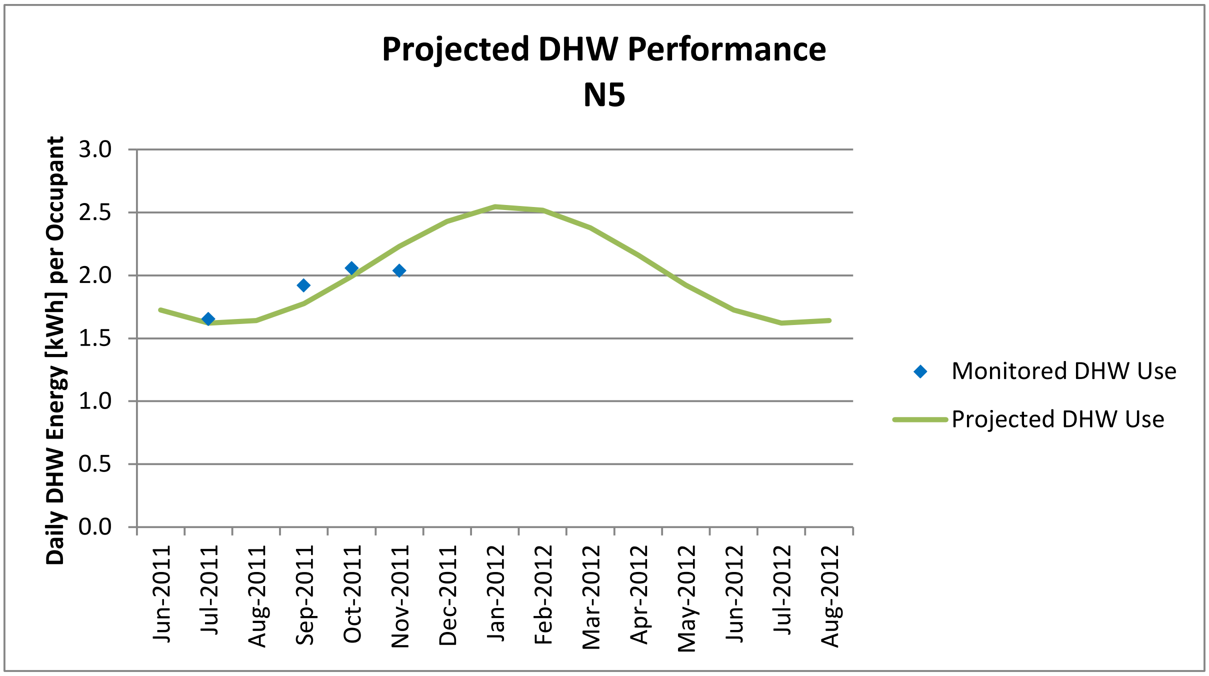


Figure A-9 Projected DHW Performance, N5

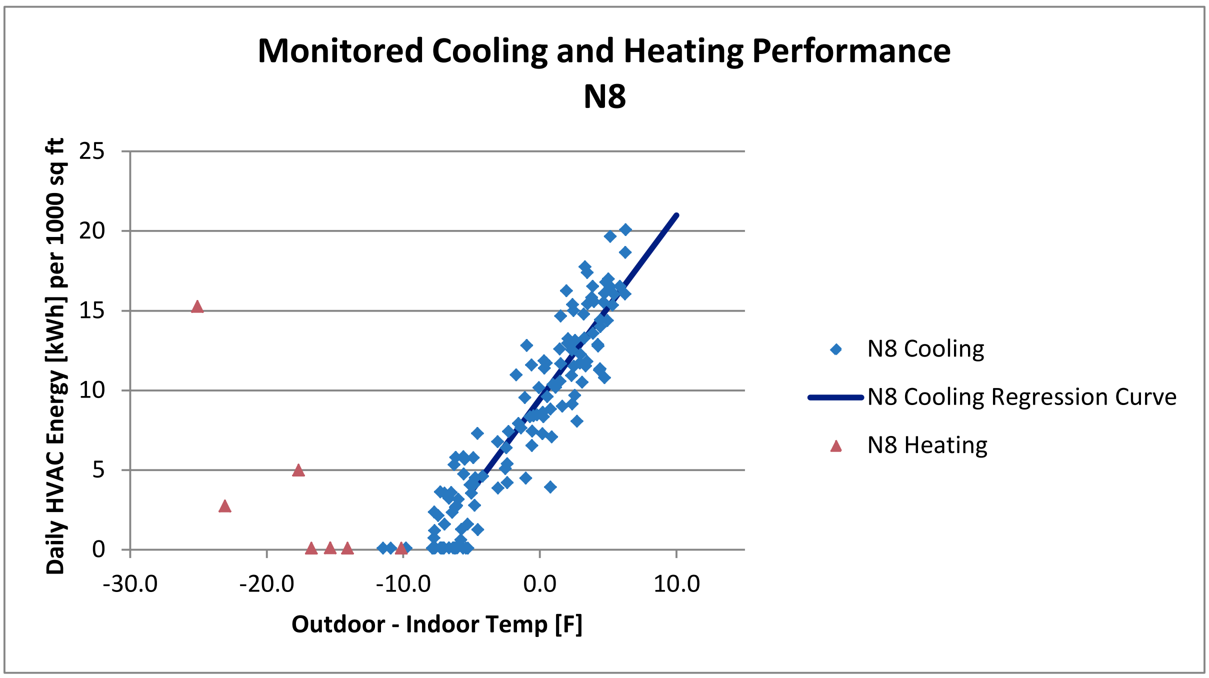


Figure A-10 Monitored Cooling and Heating Performance, N8

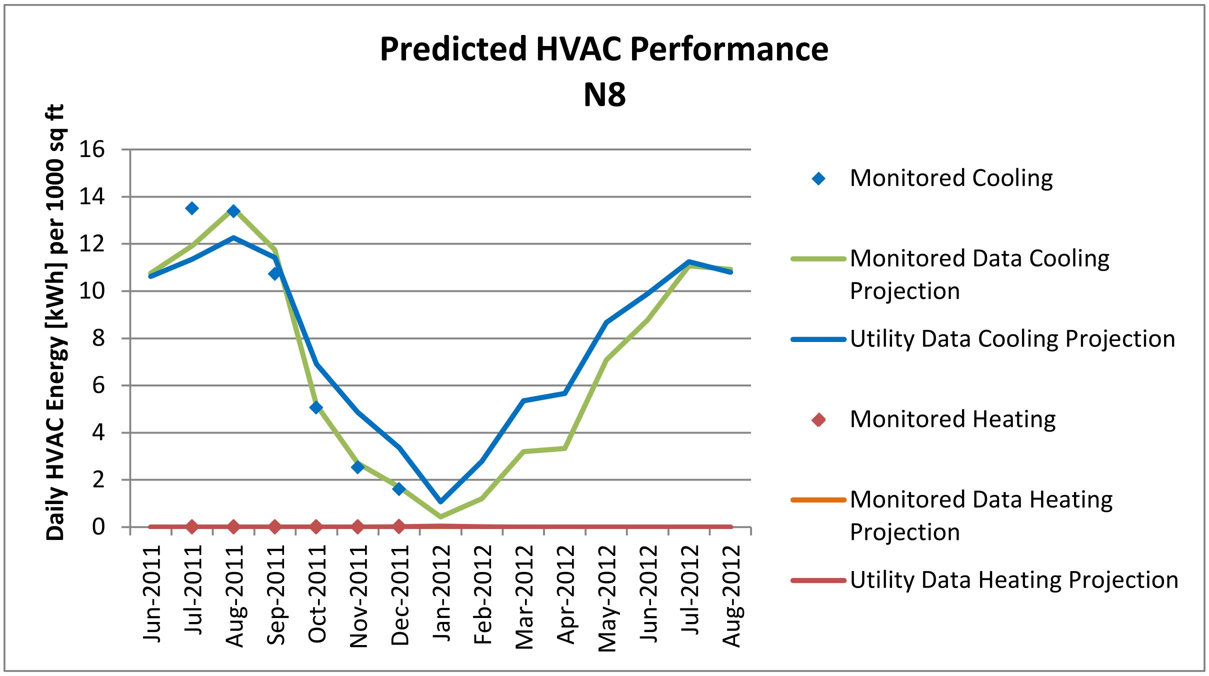


Figure A-11 Predicted HVAC Performance, N8

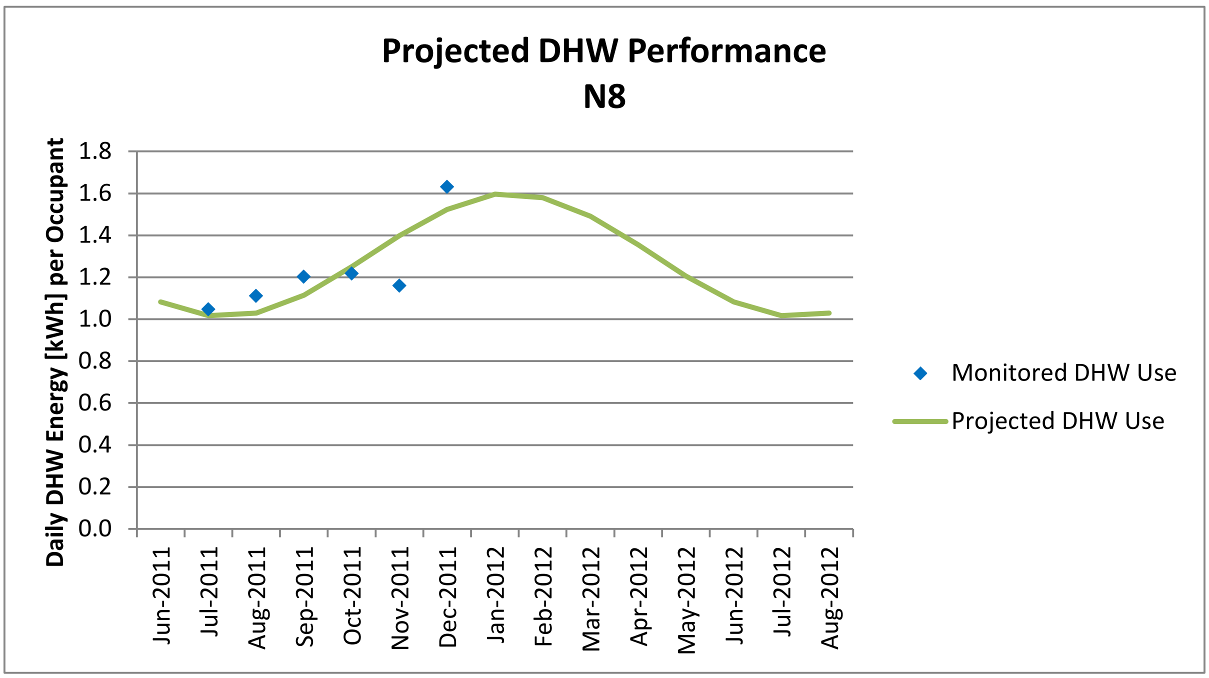


Figure A-12 Projected DHW Performance, N8

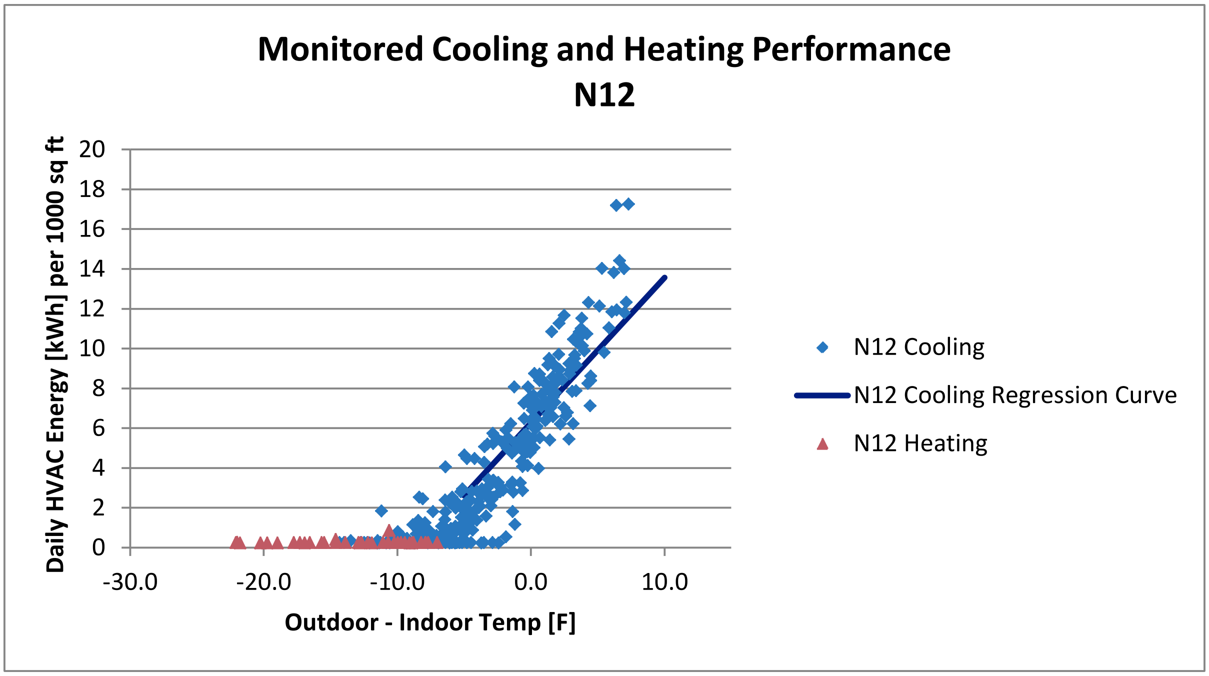


Figure A-13 Monitored Cooling and Heating Performance, N12

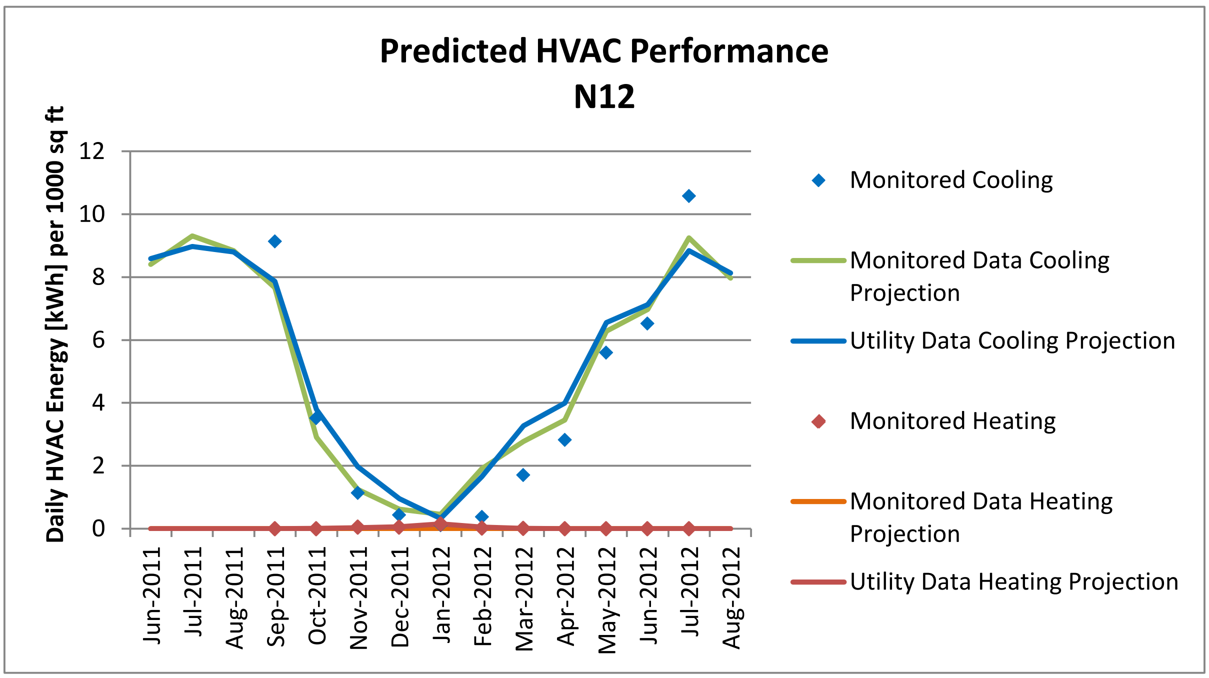


Figure A-14 Predicted HVAC Performance, N12

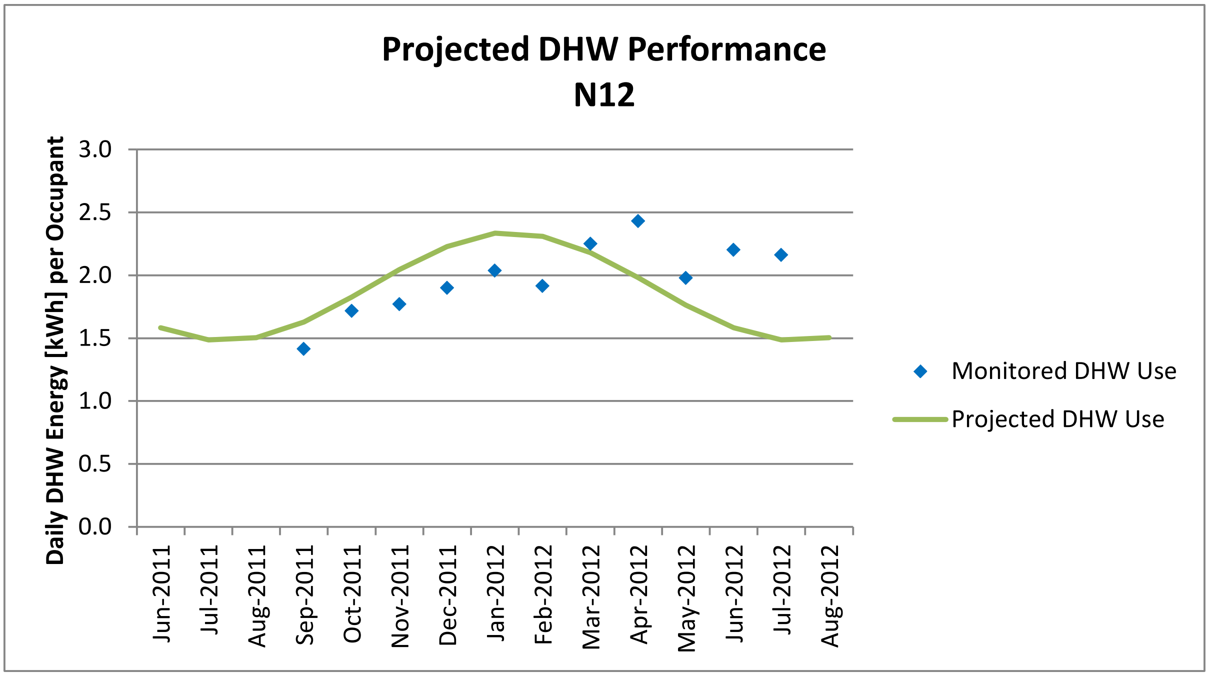


Figure A-15 Projected DHW Performance, N12

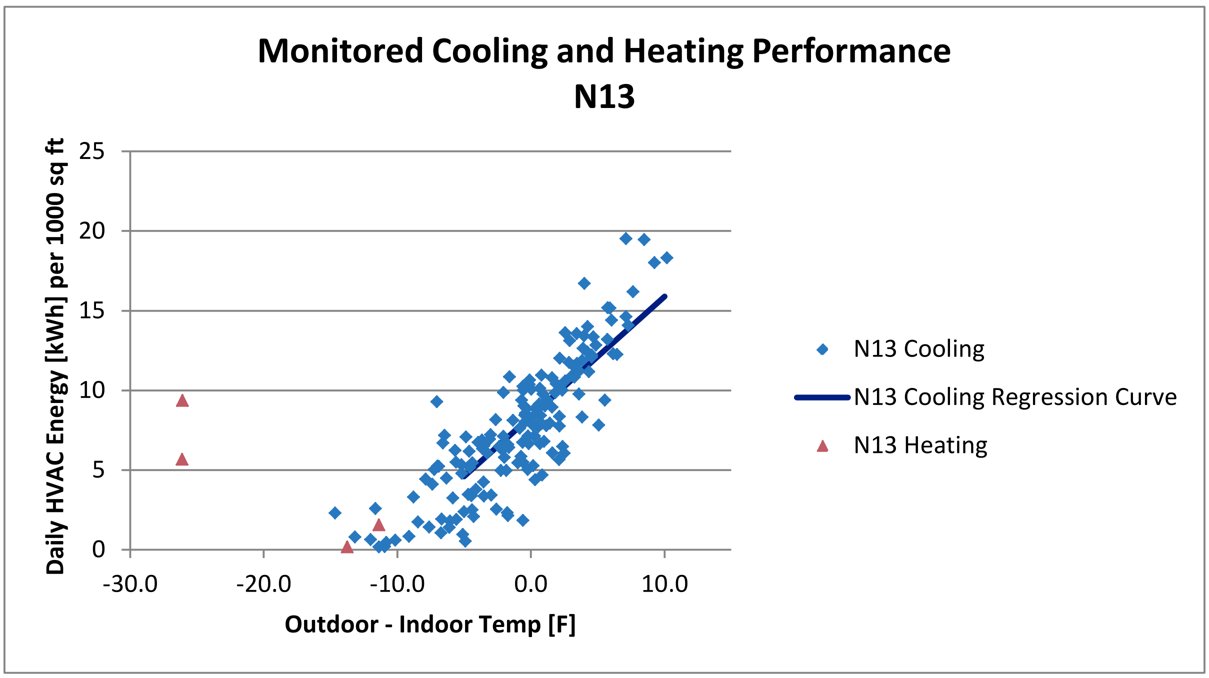


Figure A-16 Monitored Cooling and Heating Performance, N13

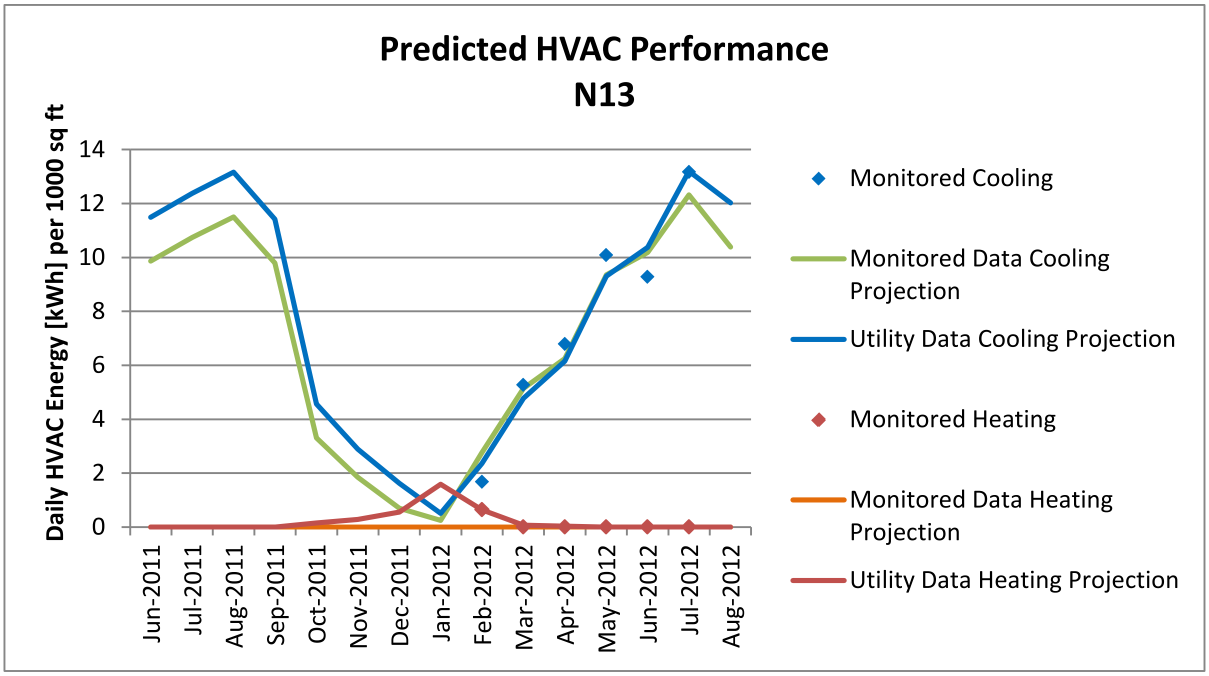


Figure A-17 Predicted HVAC Performance, N13

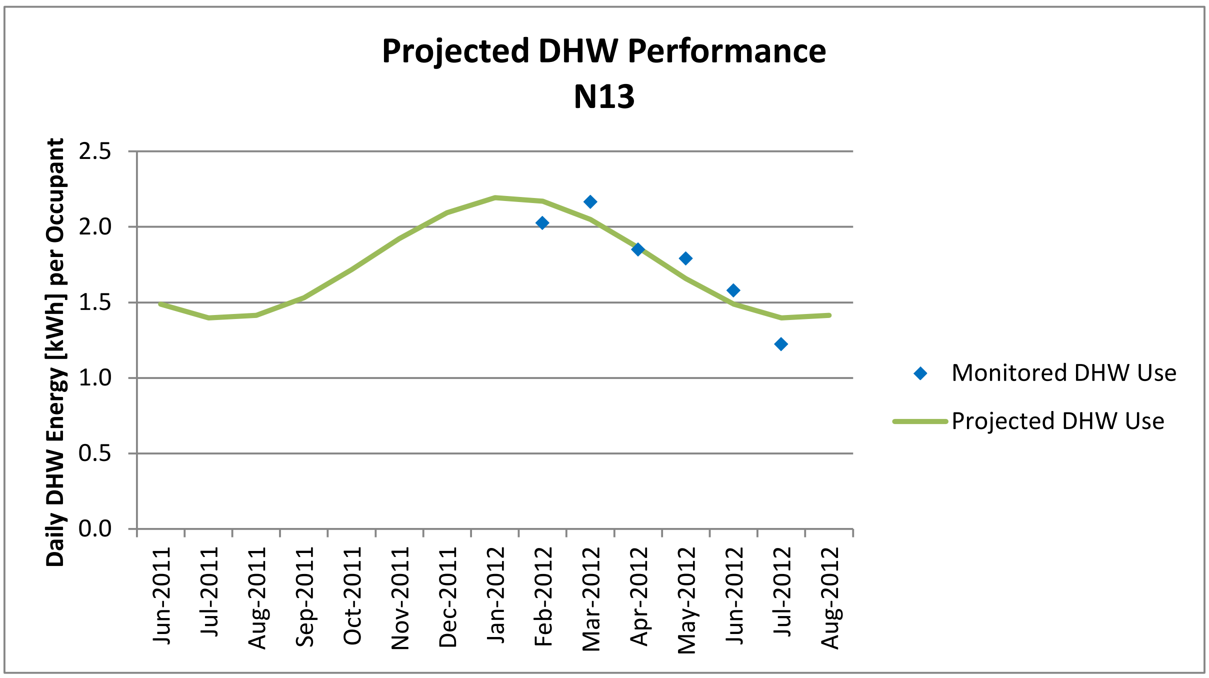


Figure A-18 Projected DHW Performance, N13

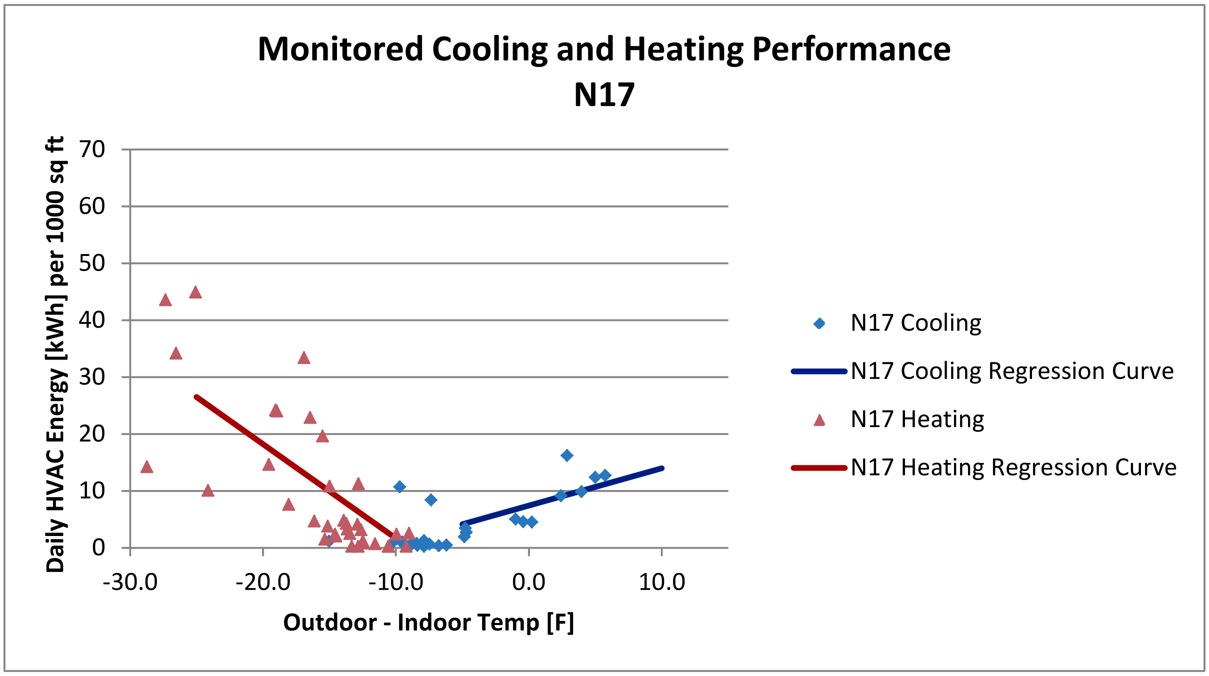


Figure A-19 Monitored Cooling and Heating Performance, N17

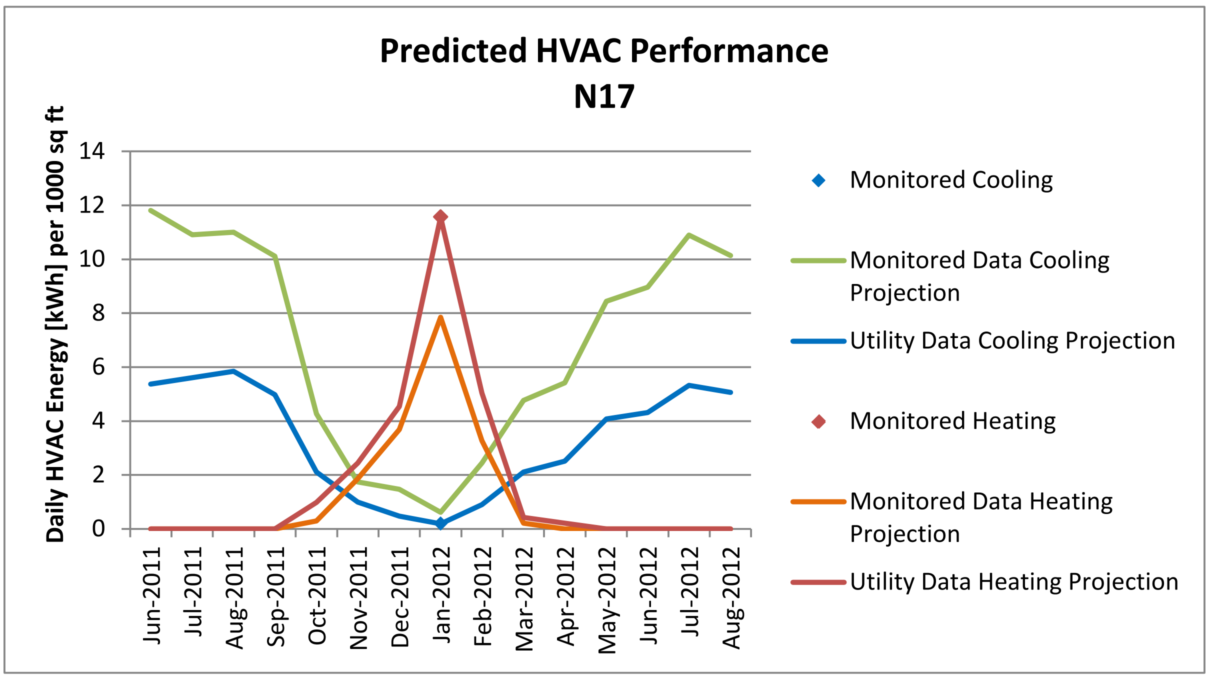


Figure A-20 Predicted HVAC Performance, N17

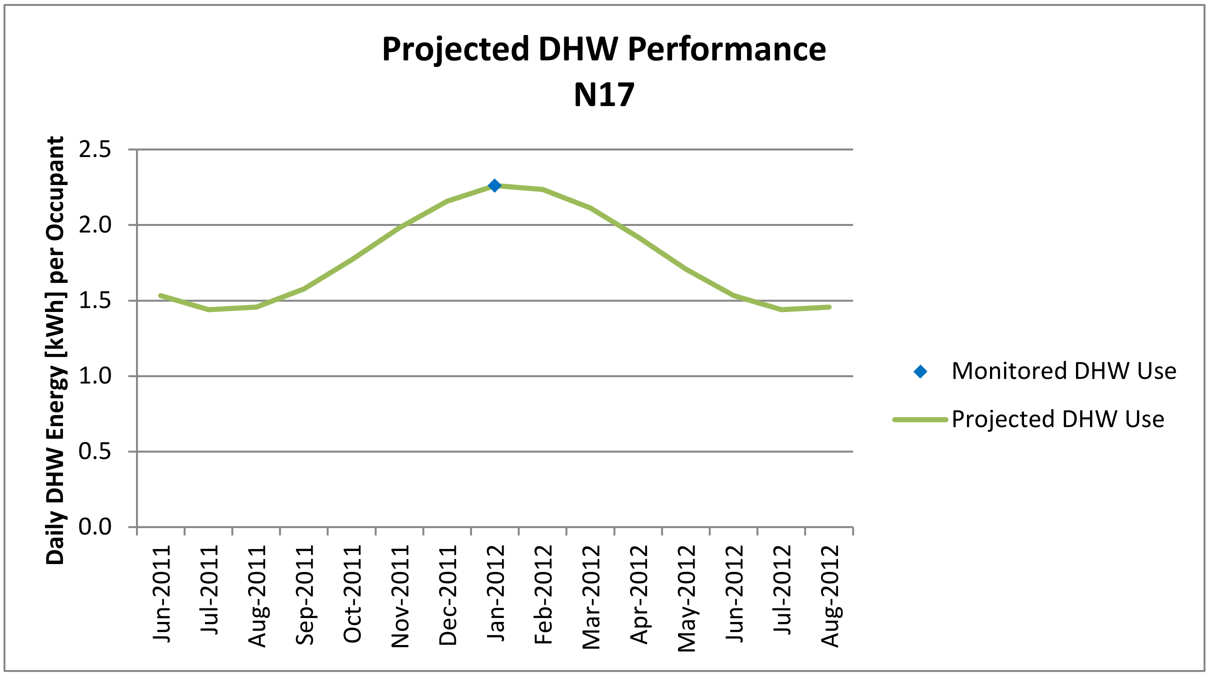


Figure A-21 Projected DHW Performance, N17

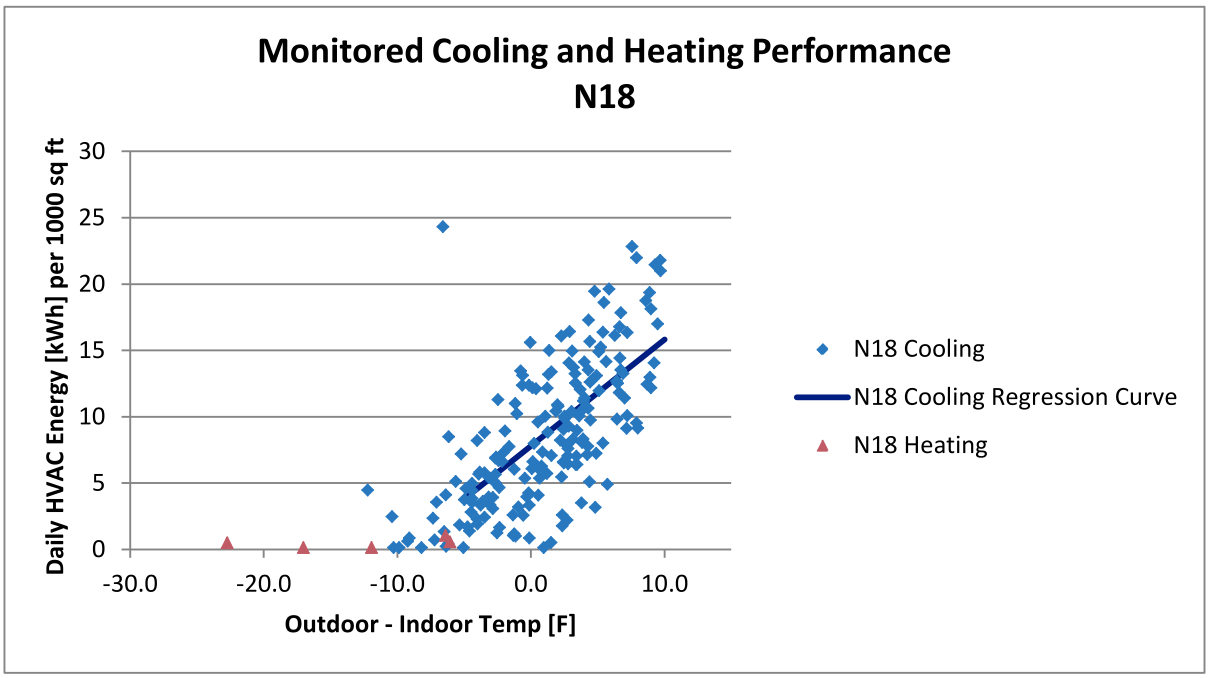


Figure A-22 Monitored Cooling and Heating Performance, N18

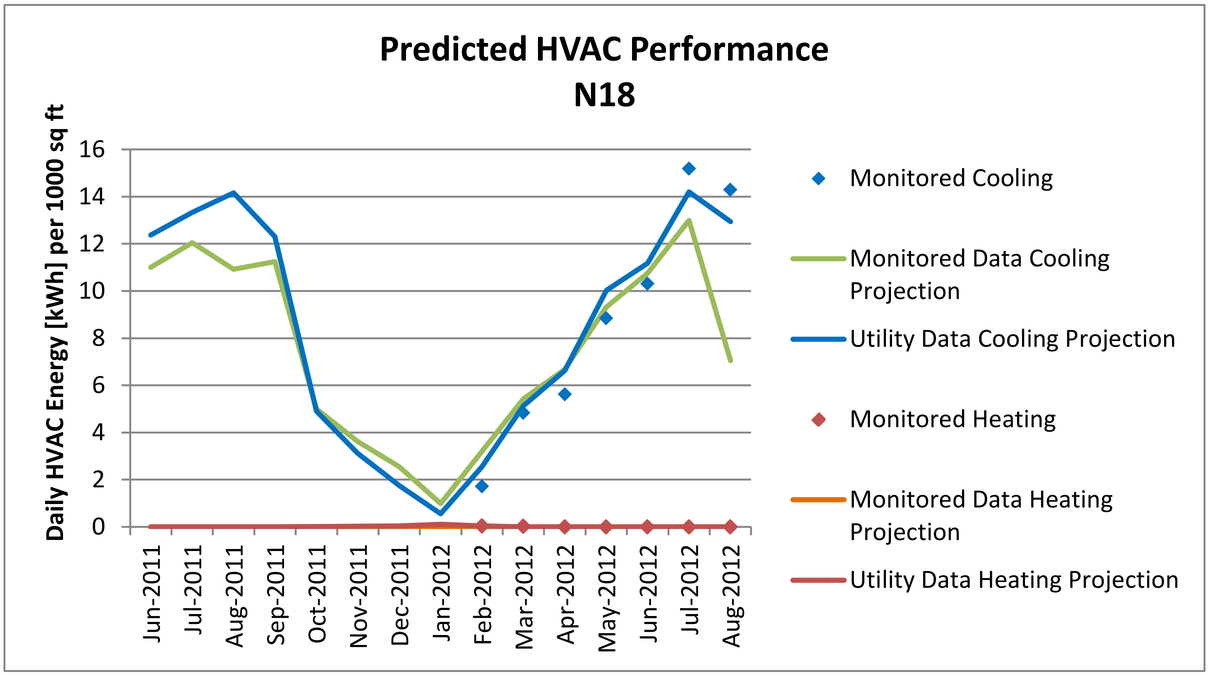


Figure A-23 Predicted HVAC Performance, N18

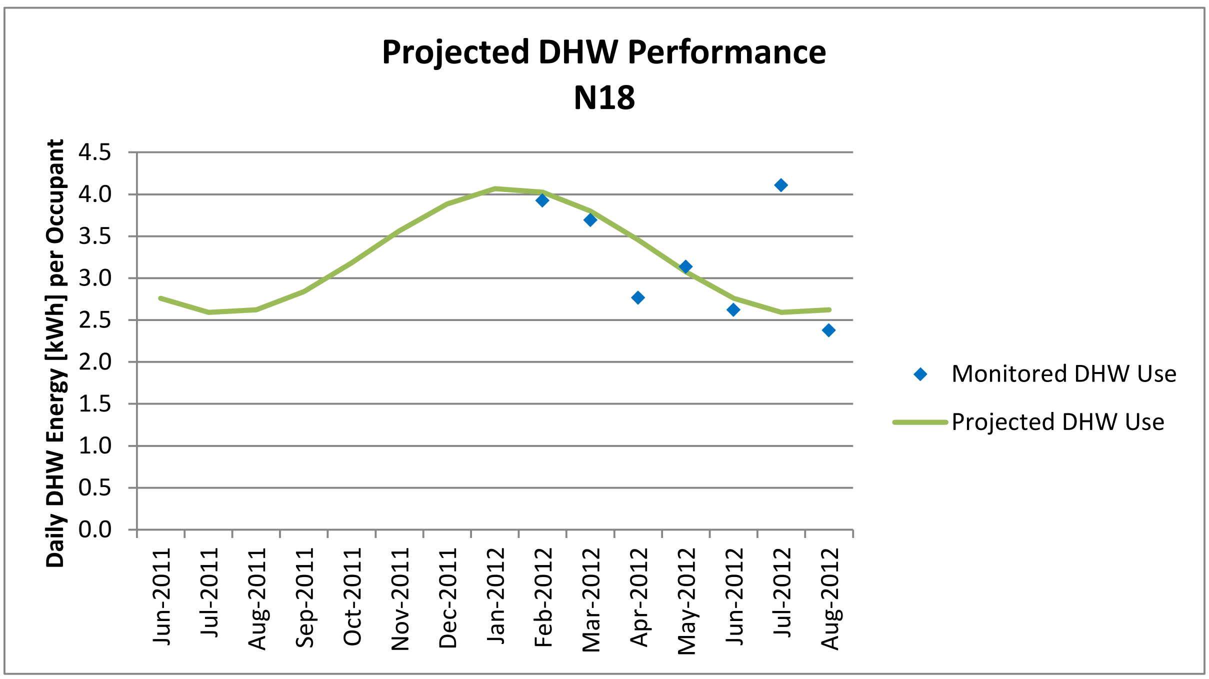


Figure A-24 Projected DHW Performance, N18

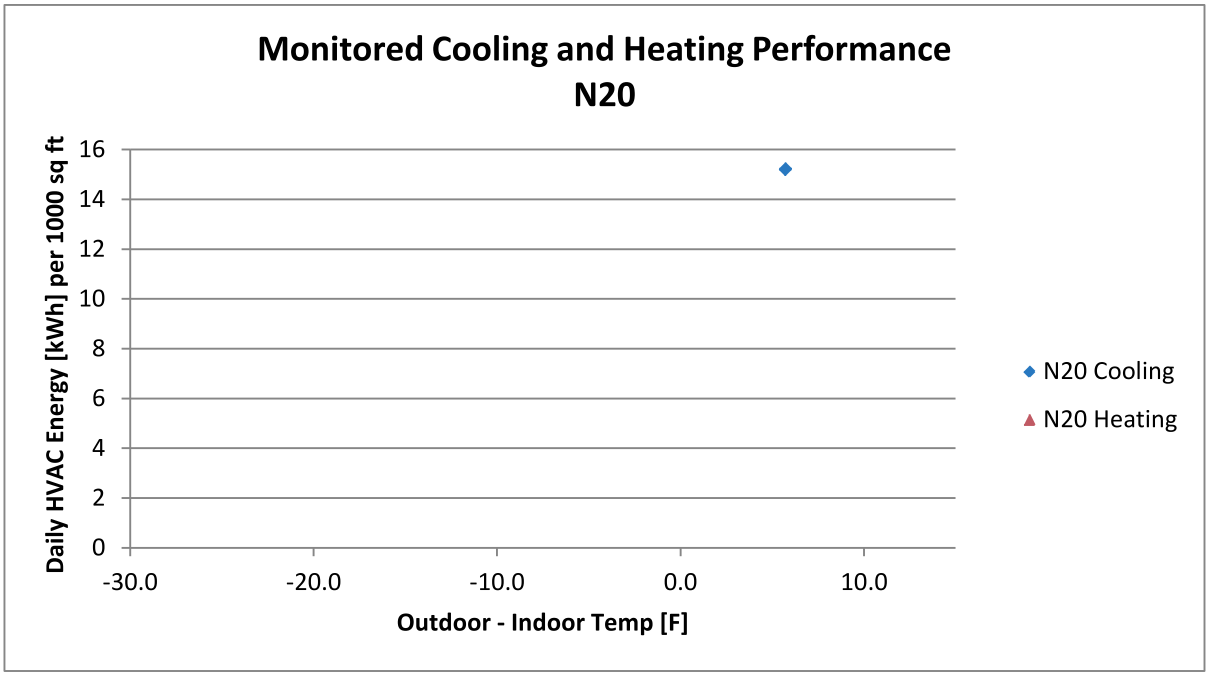


Figure A-25 Monitored Cooling and Heating Performance, N20

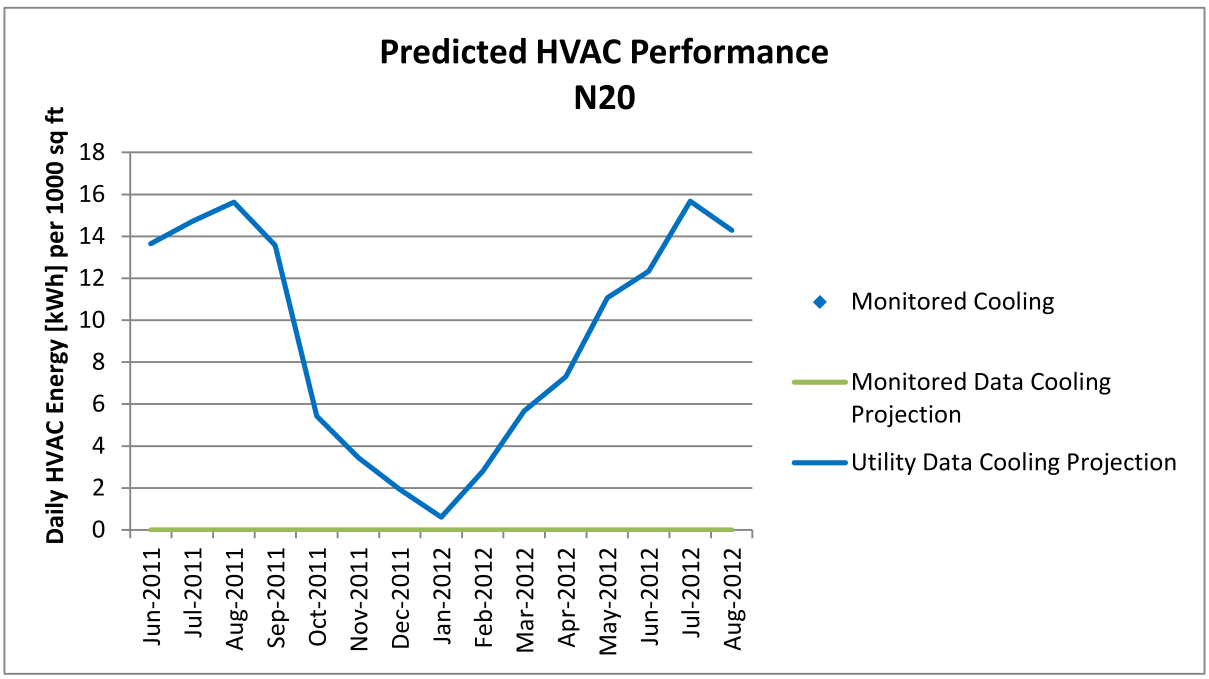


Figure A-26 Predicted HVAC Performance, N20

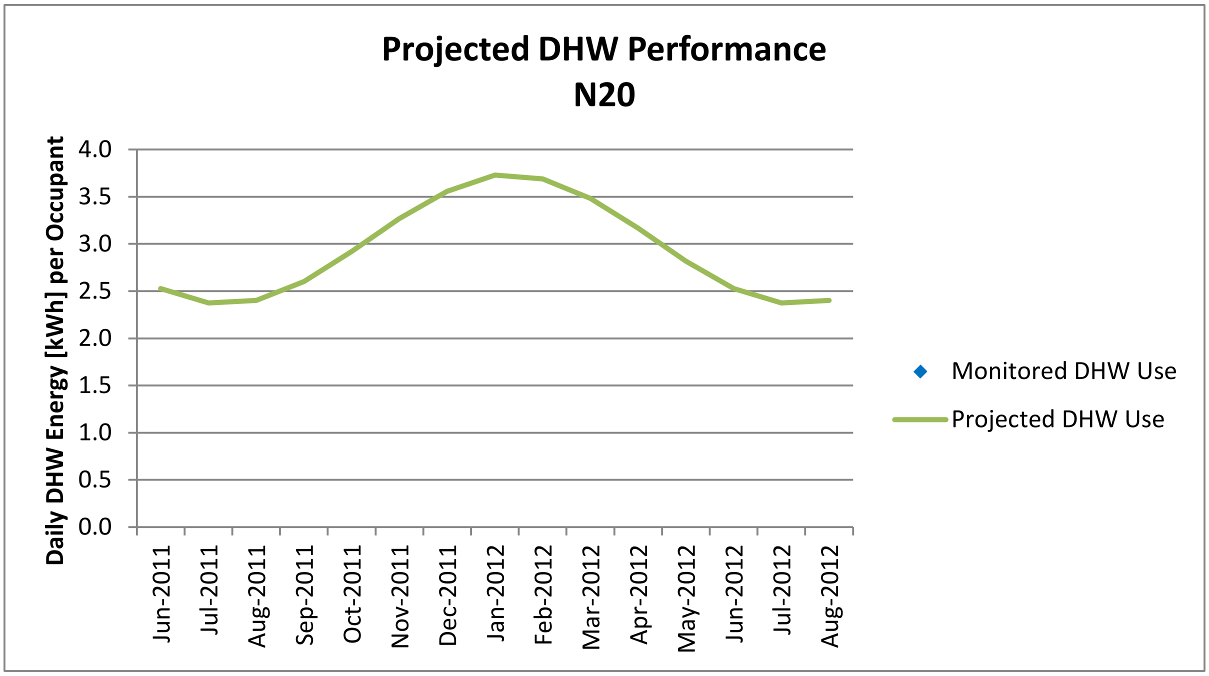


Figure A-27 Projected DHW Performance, N20

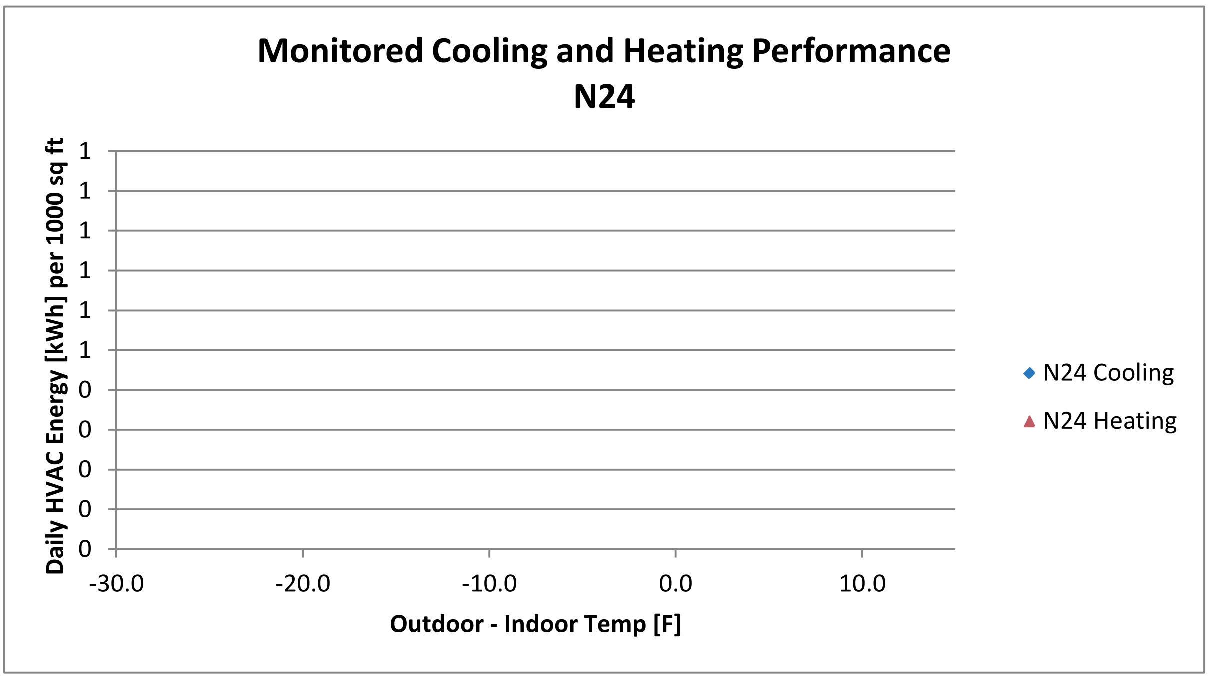


Figure A-28 Monitored Cooling and Heating Performance, N24

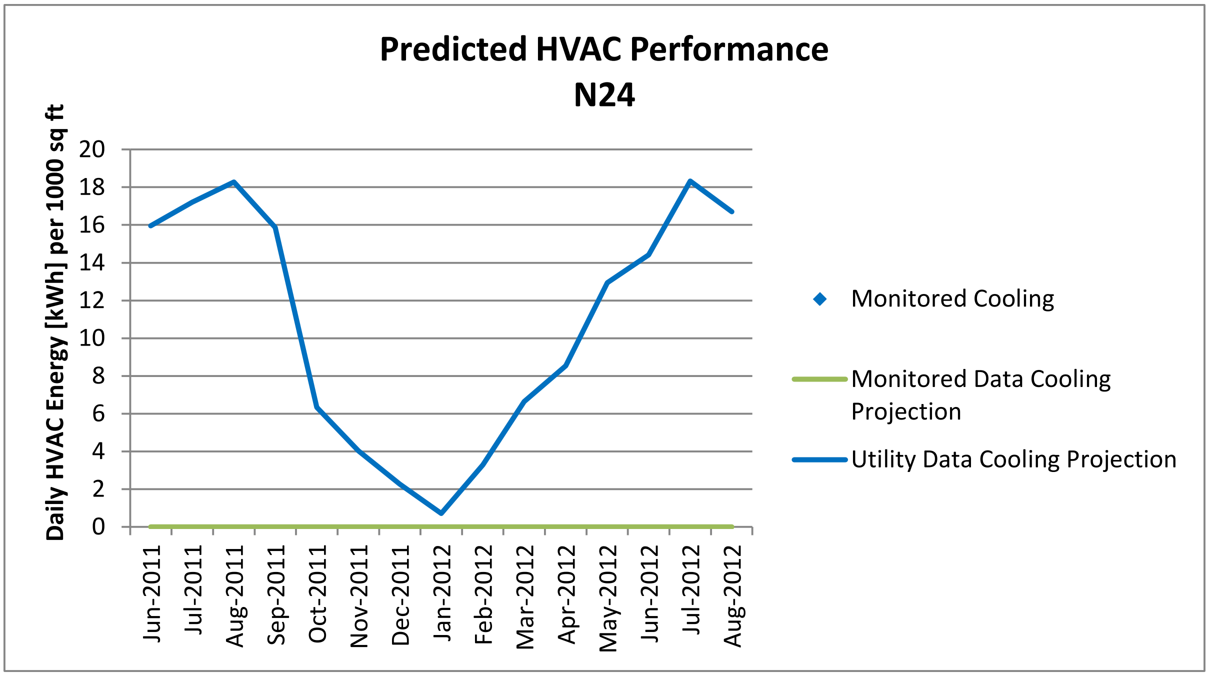


Figure A-29 Predicted HVAC Performance, N24

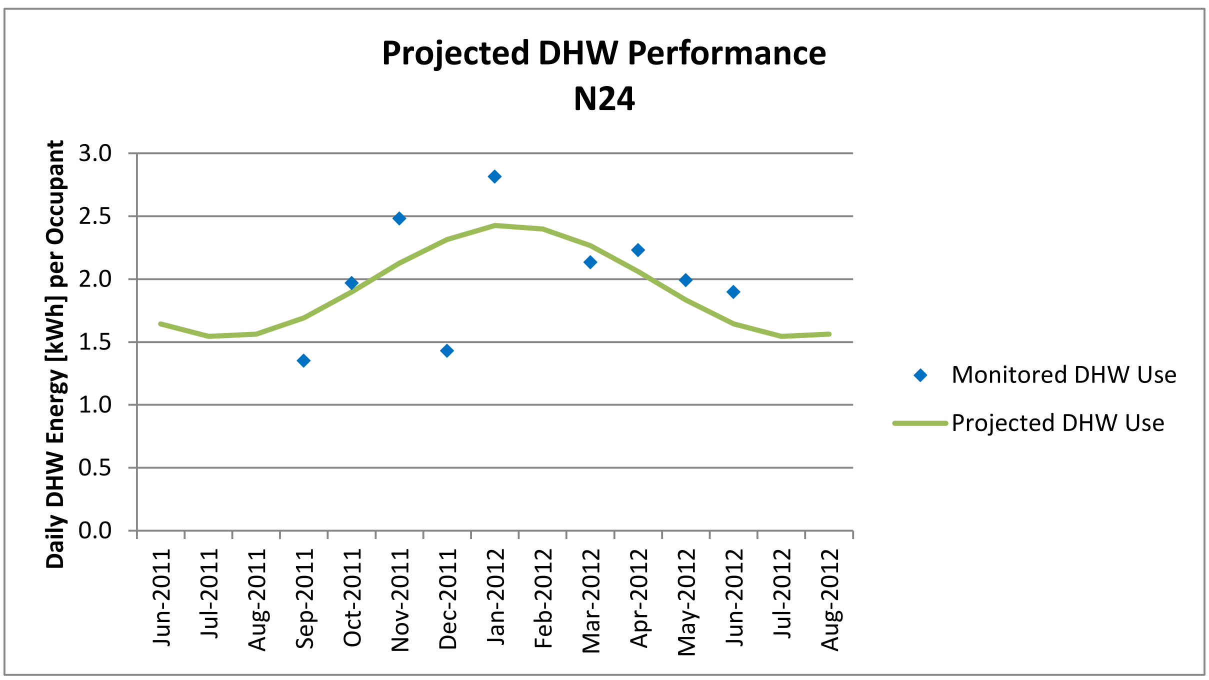


Figure A-30 Projected DHW Performance, N24

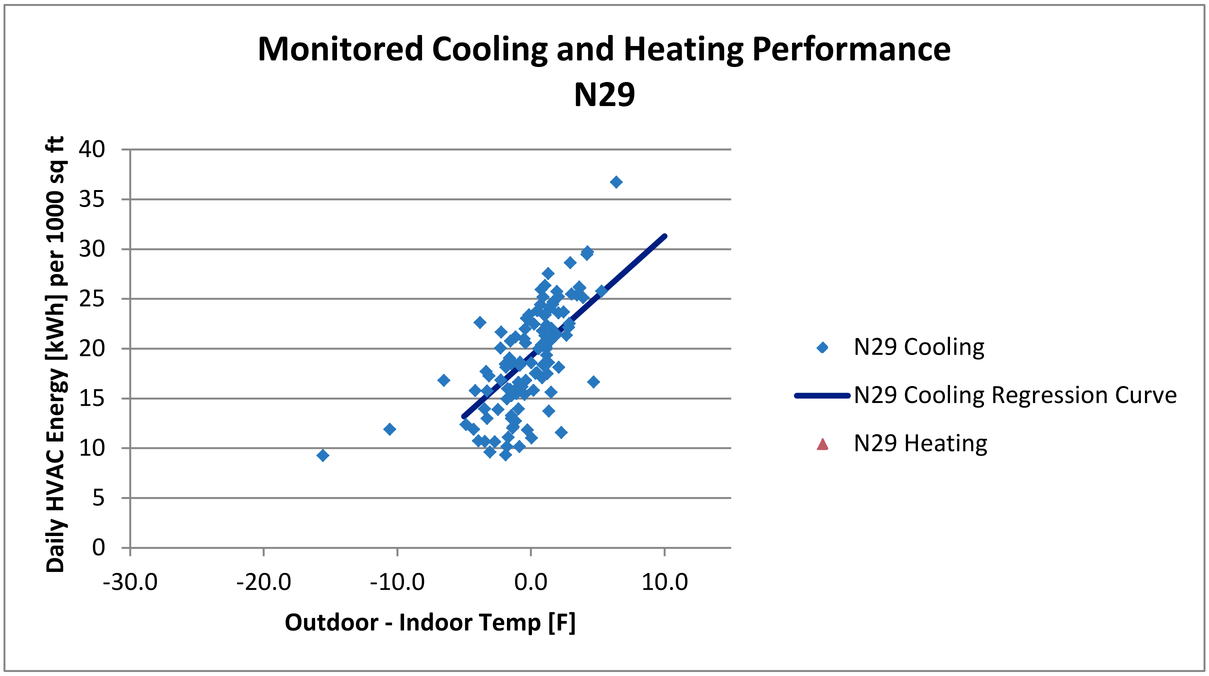


Figure A-31 Monitored Cooling and Heating Performance, N29

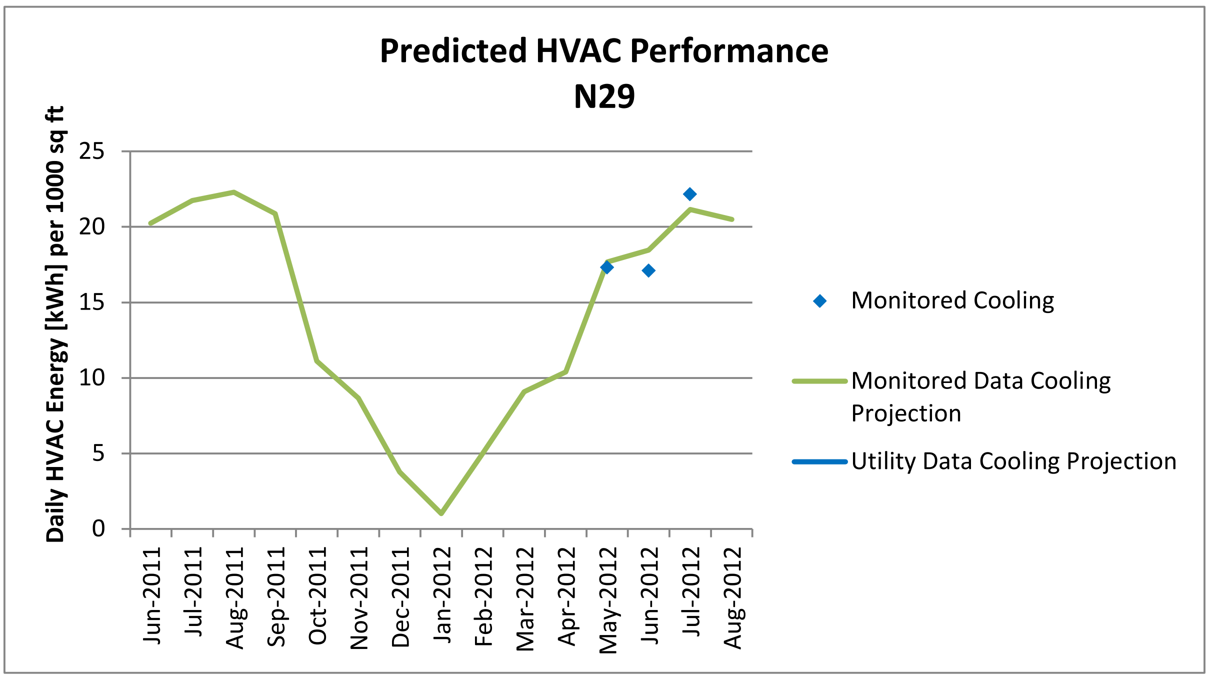


Figure A-32 Predicted HVAC Performance, N29

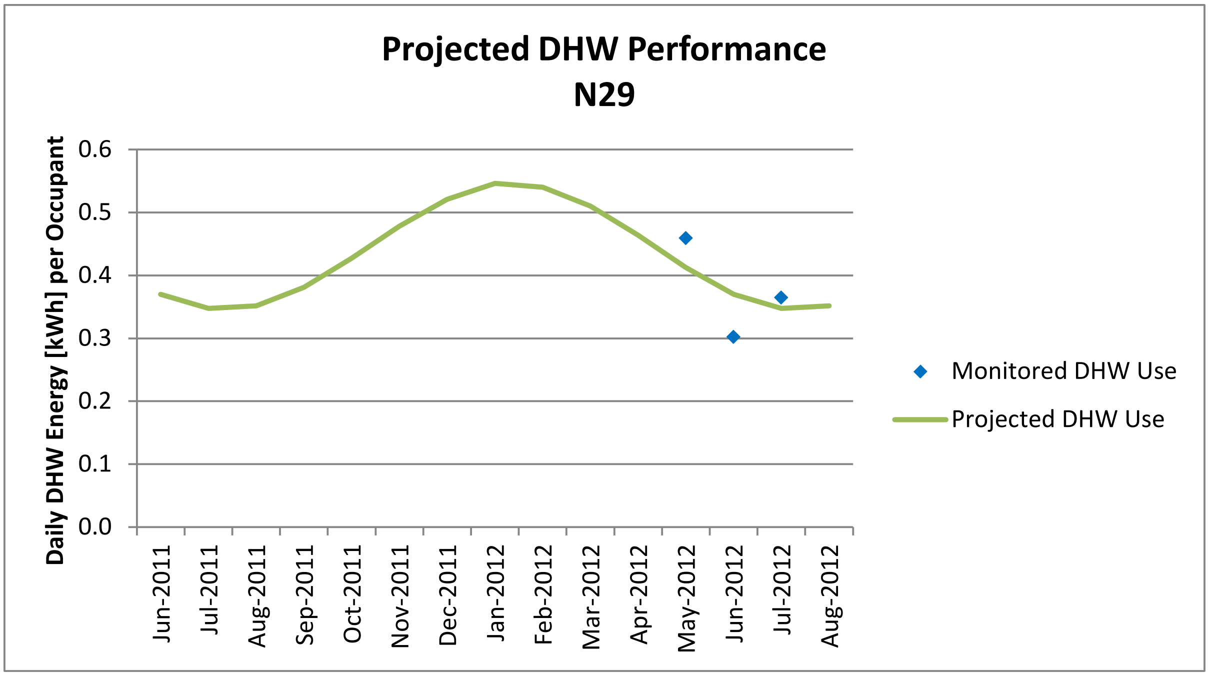


Figure A-33 Projected DHW Performance, N29

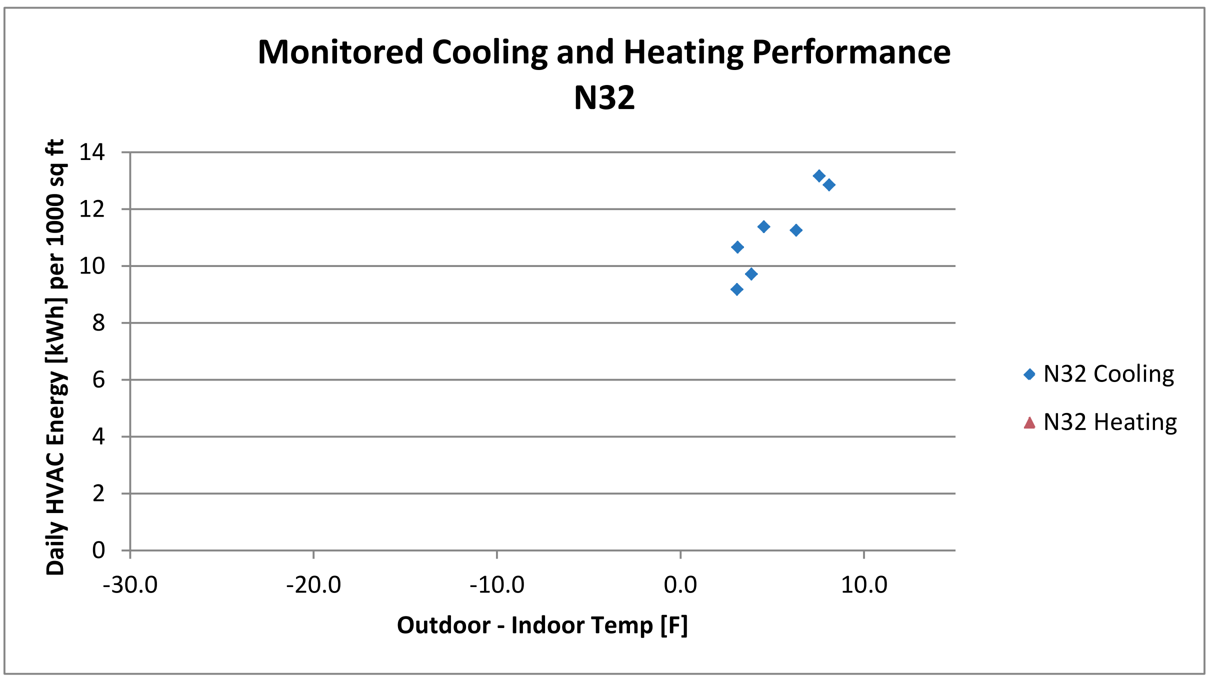


Figure A-34 Monitored Cooling and Heating Performance, N32

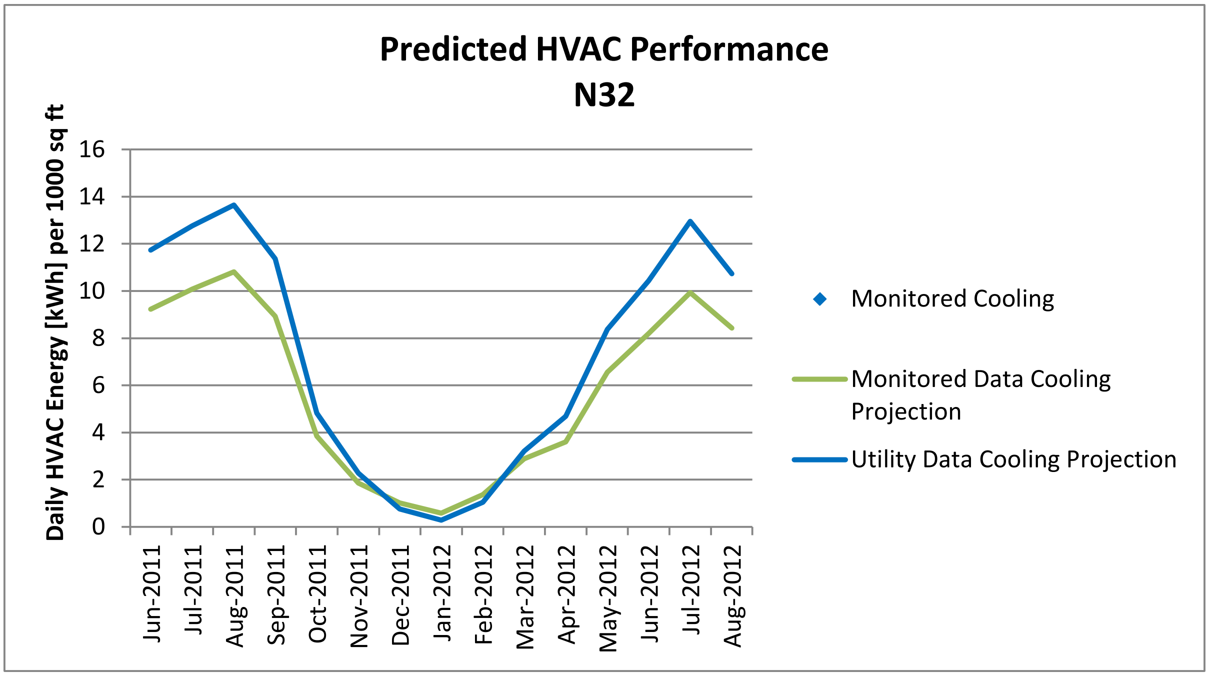


Figure A-35 Predicted HVAC Performance, N32

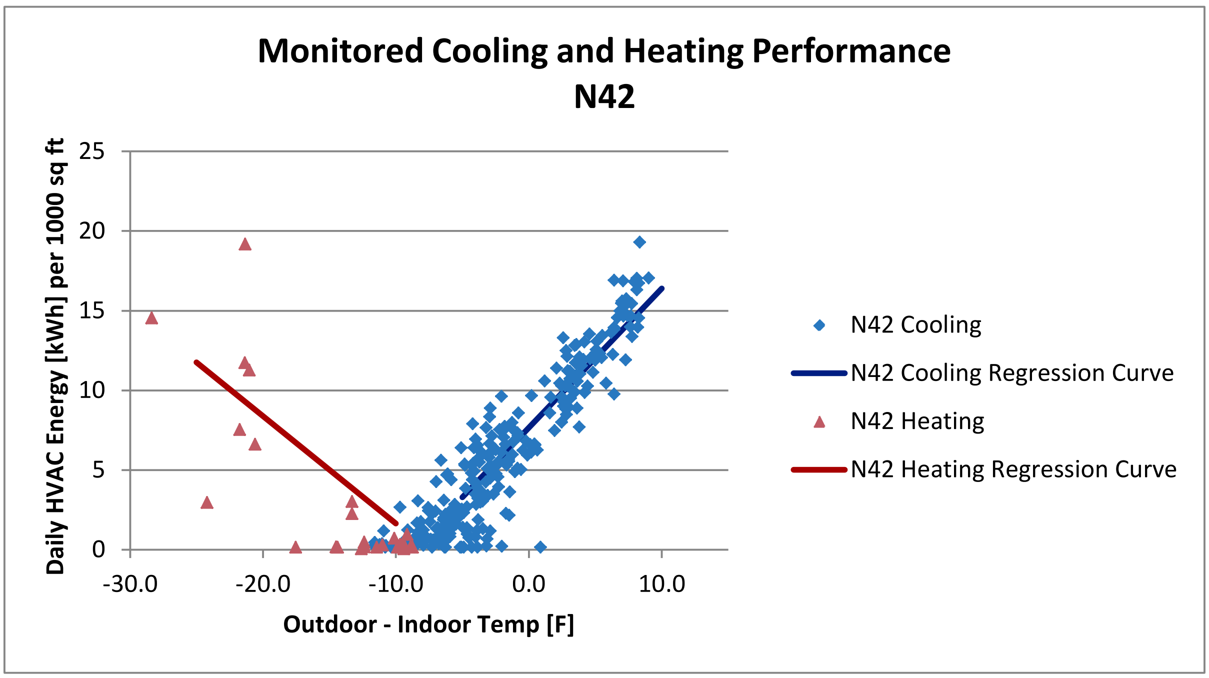


Figure A-36 Monitored Cooling and Heating Performance, N42

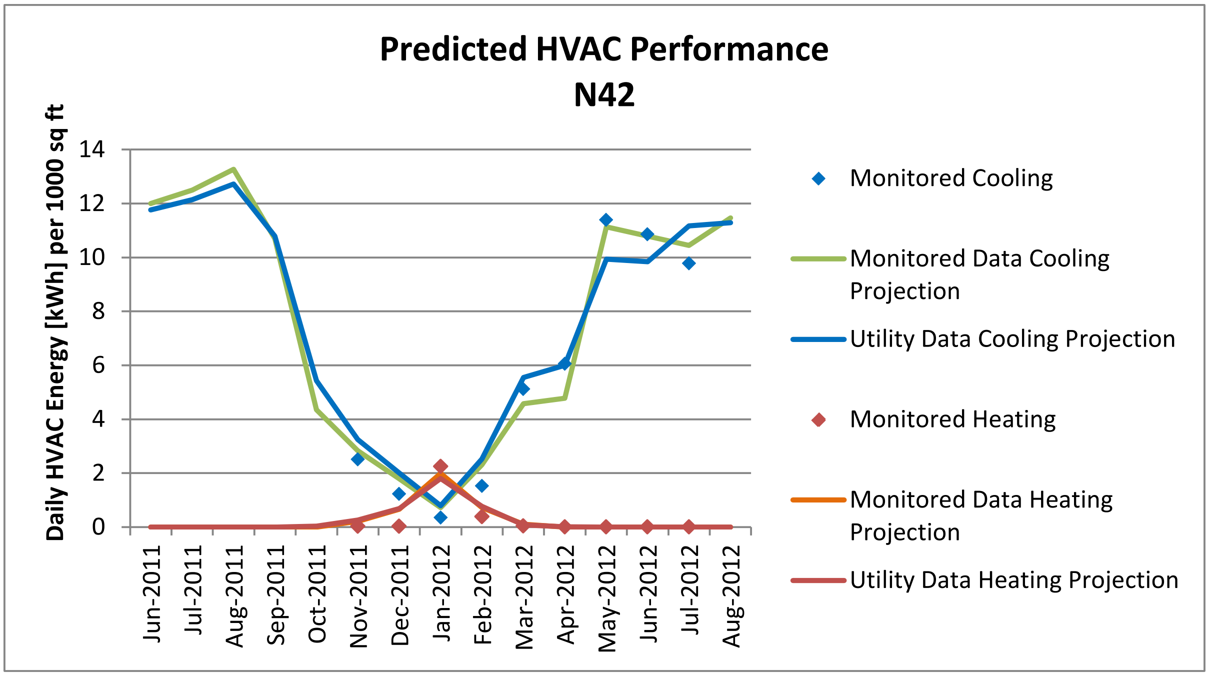


Figure A-37 Predicted HVAC Performance, N42

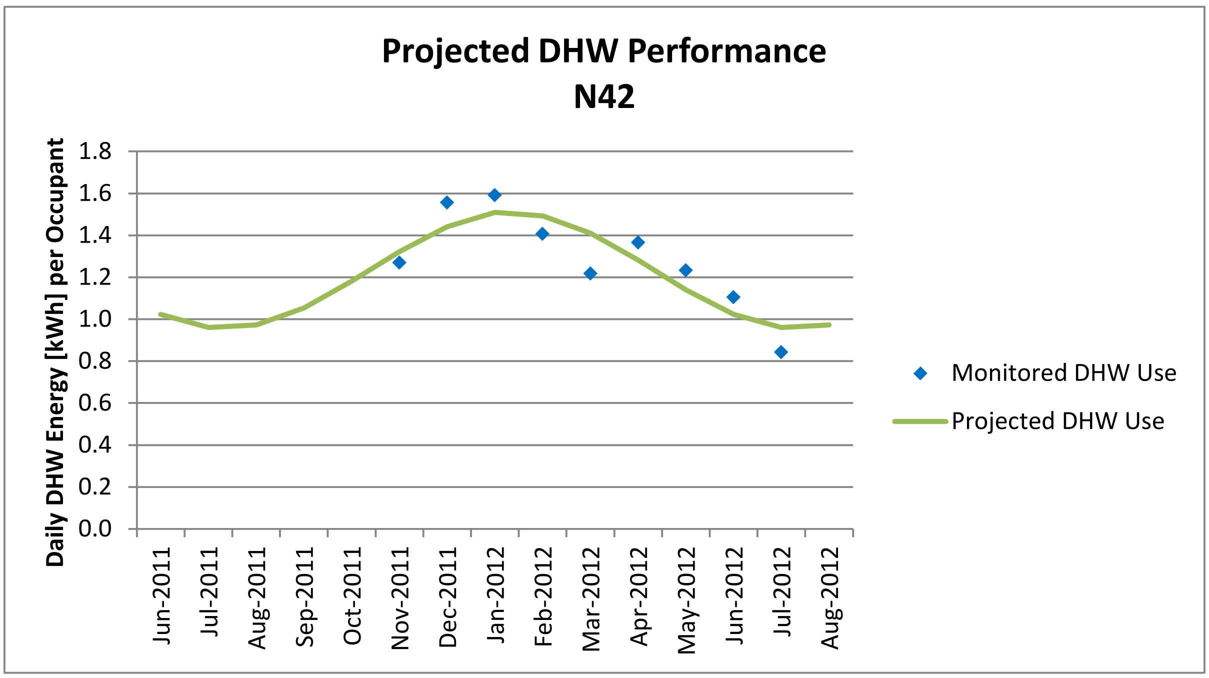


Figure A-38 Projected DHW Performance, N42

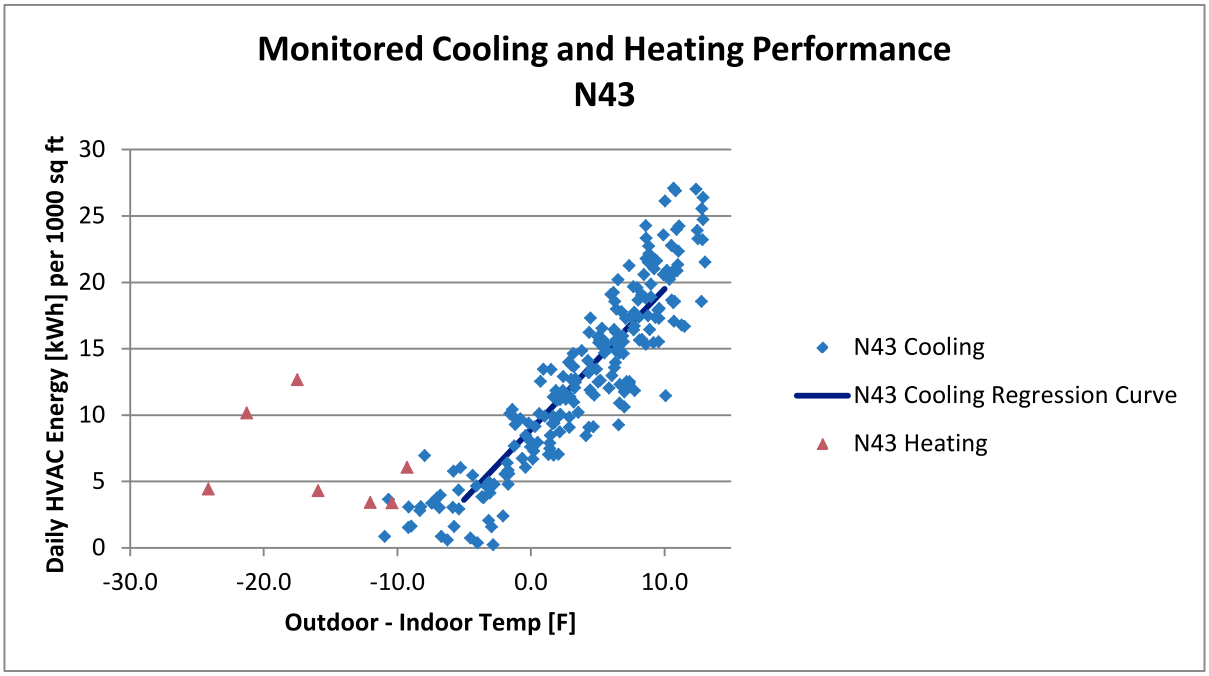


Figure A-39 Monitored Cooling and Heating Performance, N43

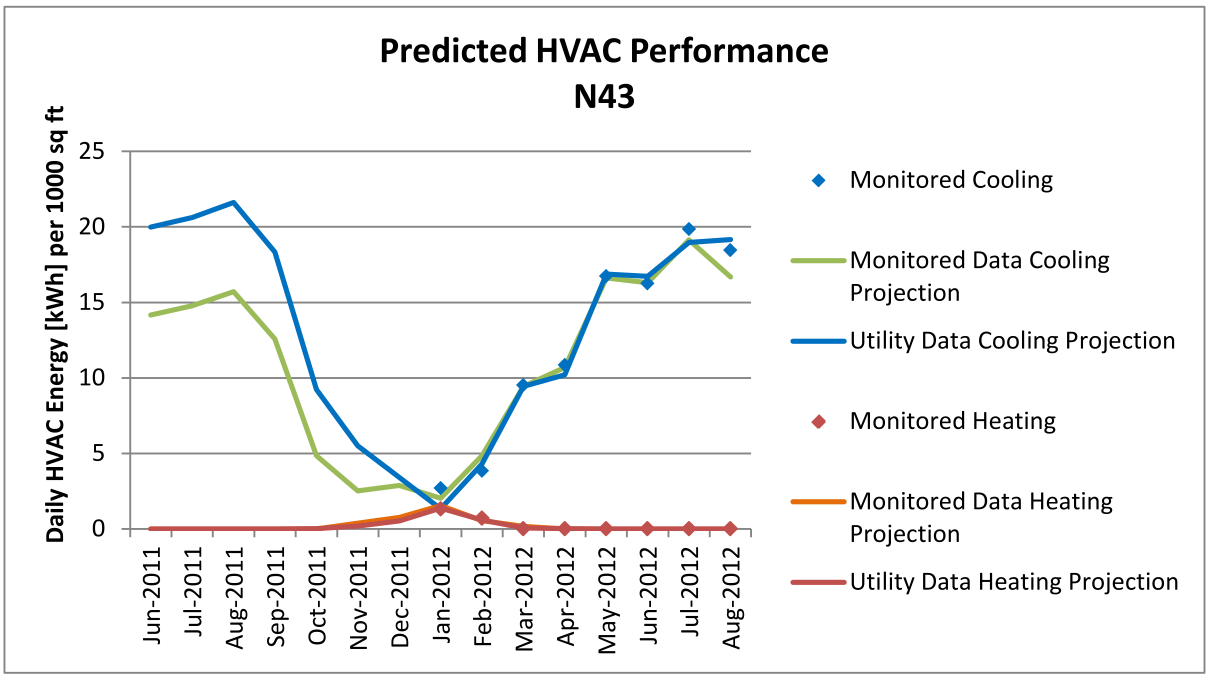


Figure A-40 Predicted HVAC Performance, N43

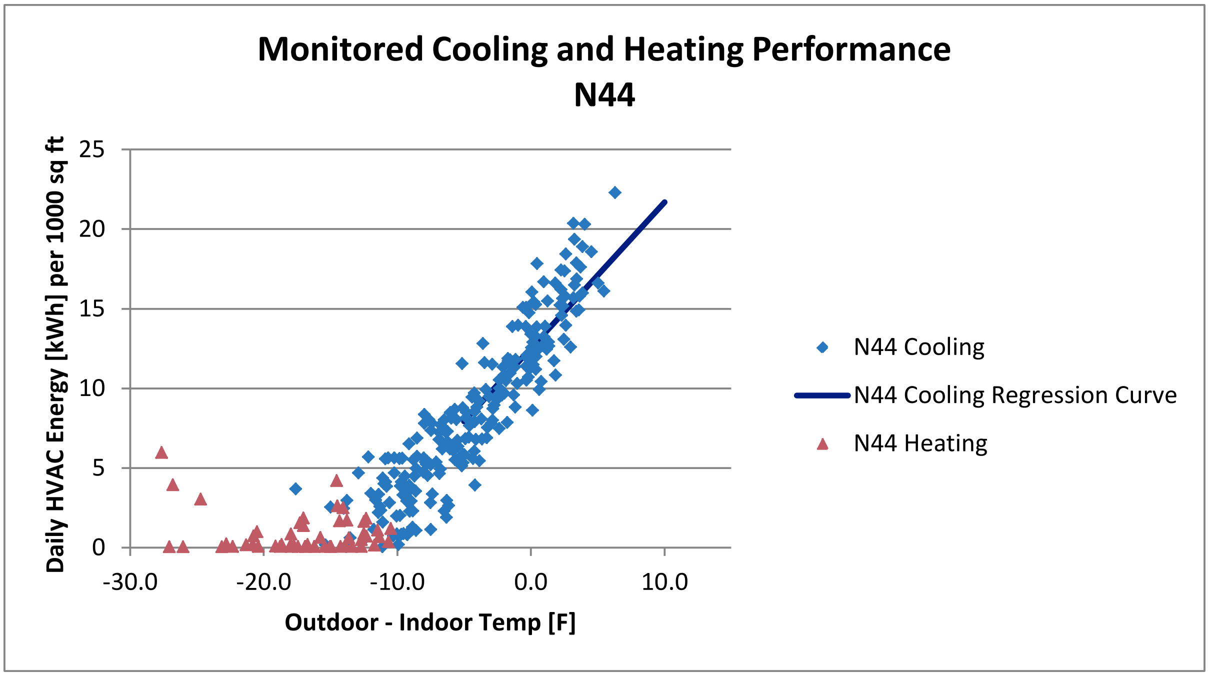


Figure A-41 Monitored Cooling and Heating Performance, N44

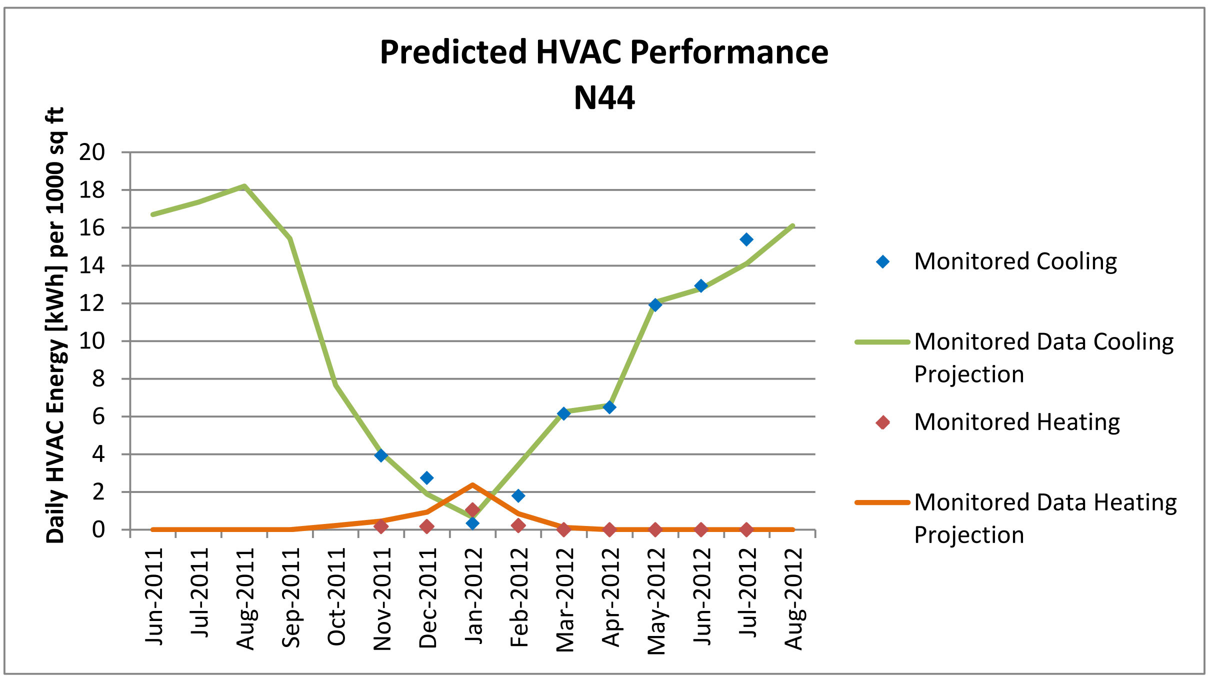


Figure A-42 Predicted HVAC Performance, N44

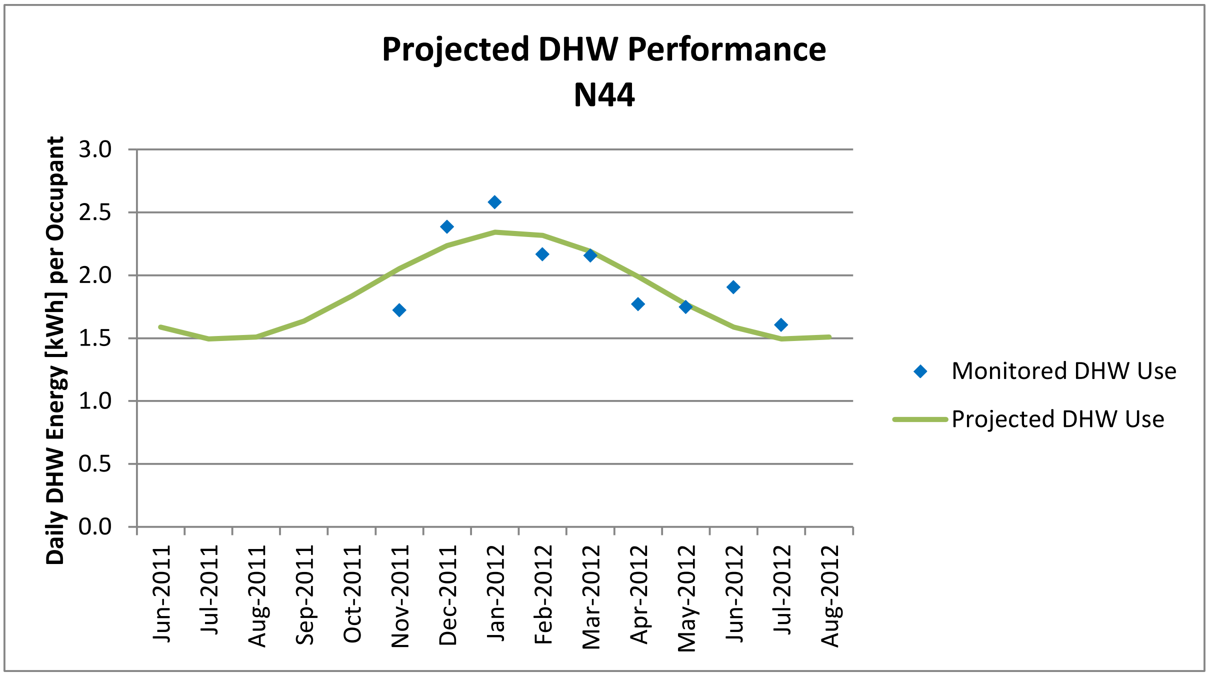


Figure A-43 Projected DHW Performance, N44

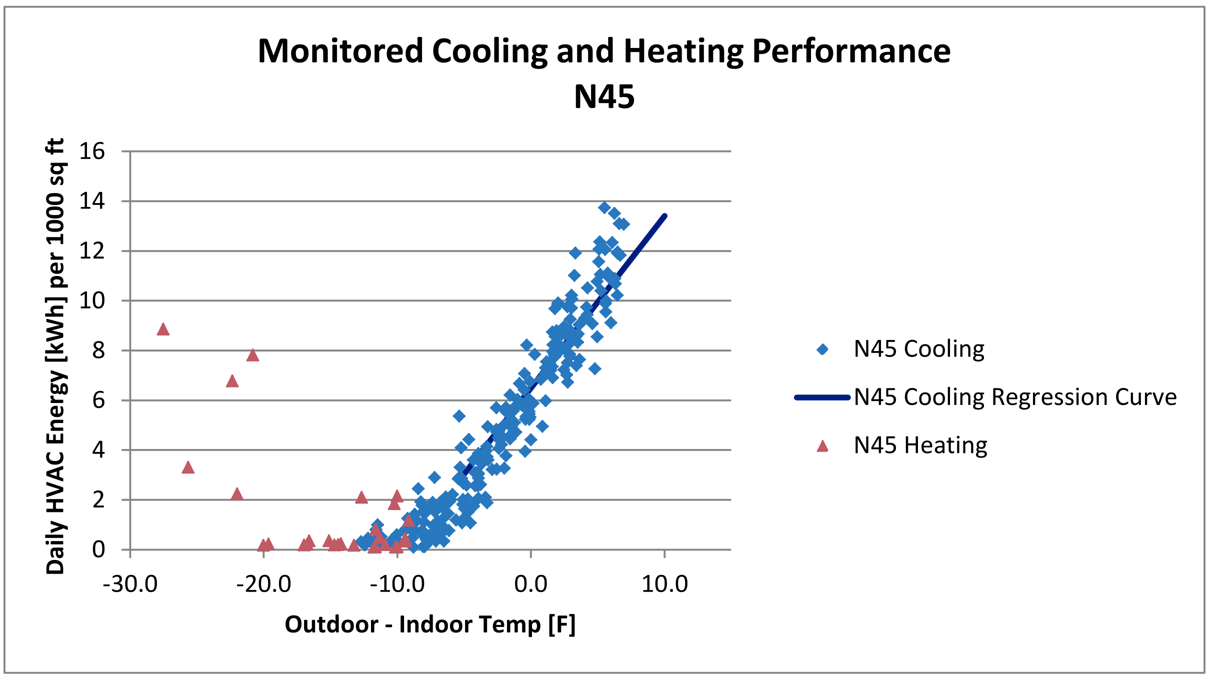


Figure A-44 Monitored Cooling and Heating Performance, N45

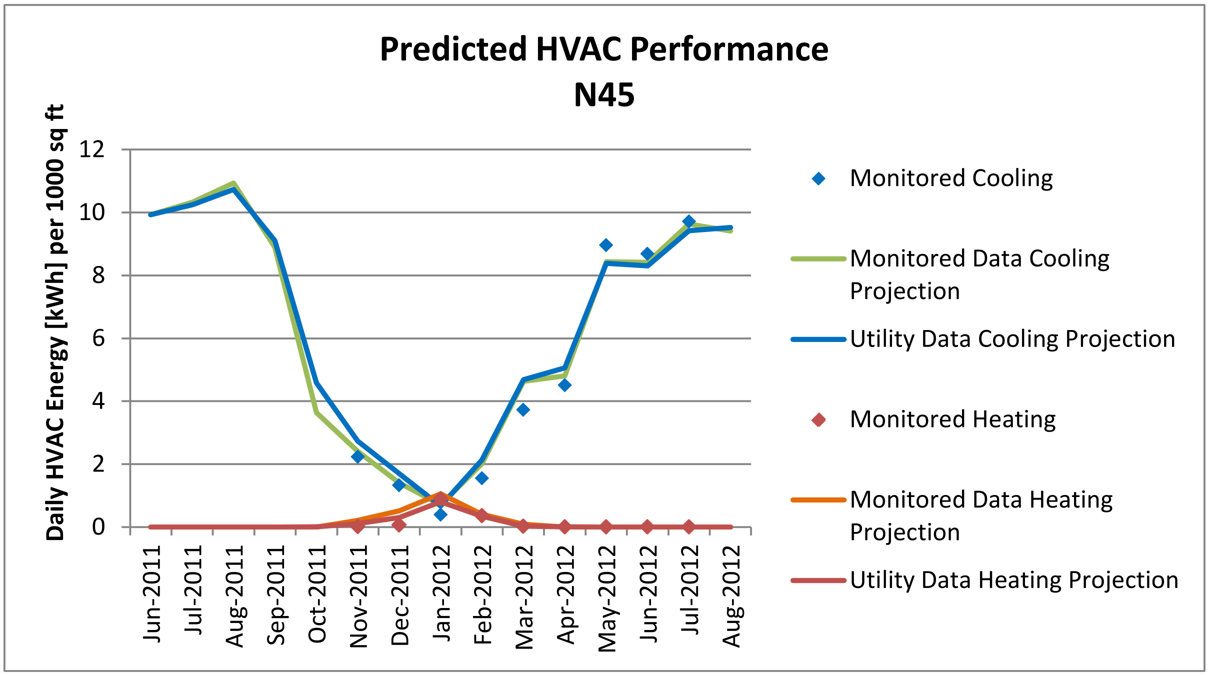


Figure A-45 Predicted HVAC Performance, N45

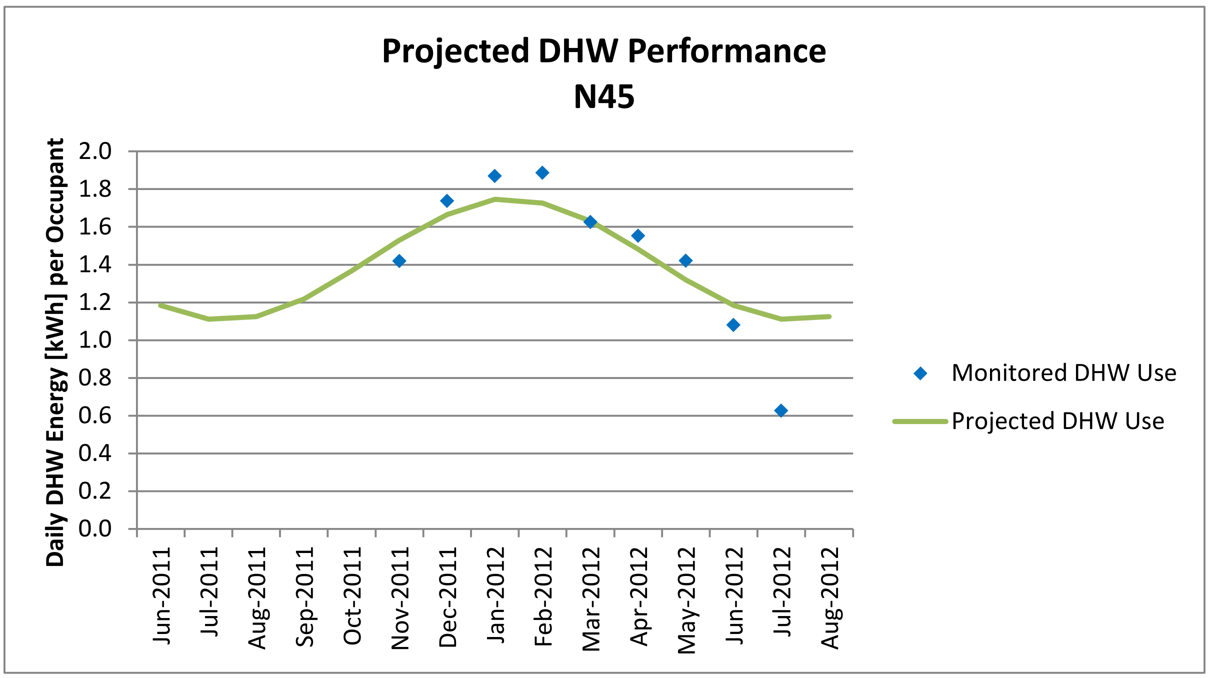


Figure A-46 Projected DHW Performance, N45

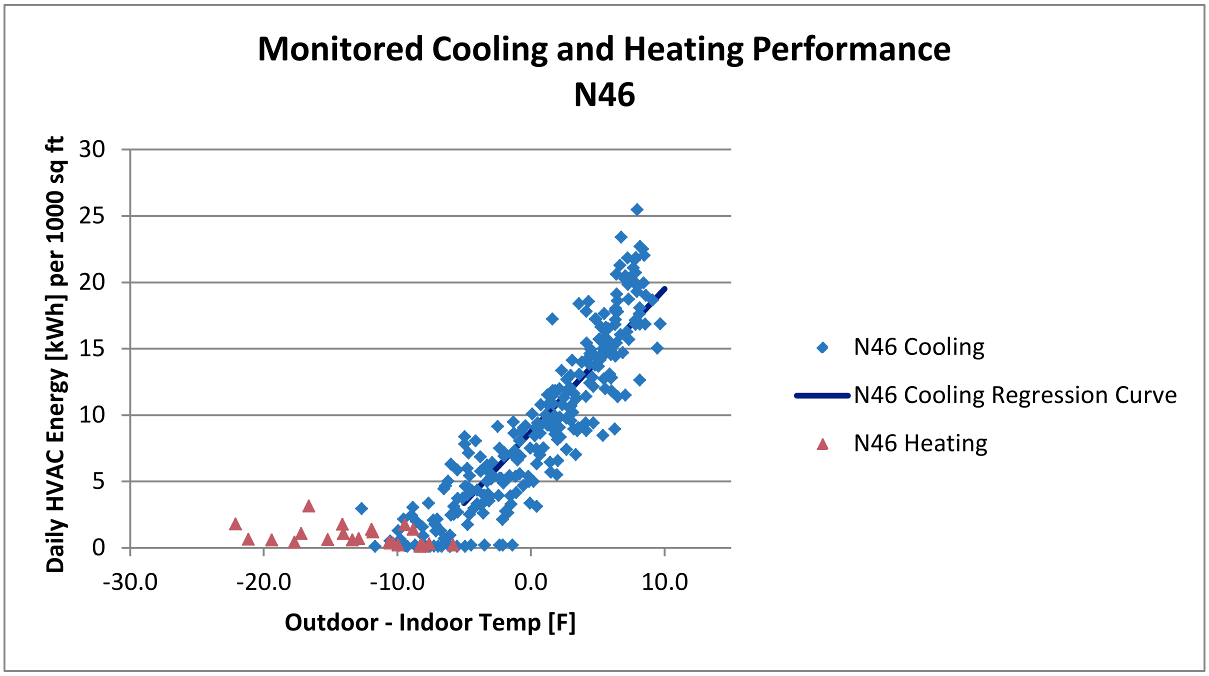


Figure A-47 Monitored Cooling and Heating Performance, N46

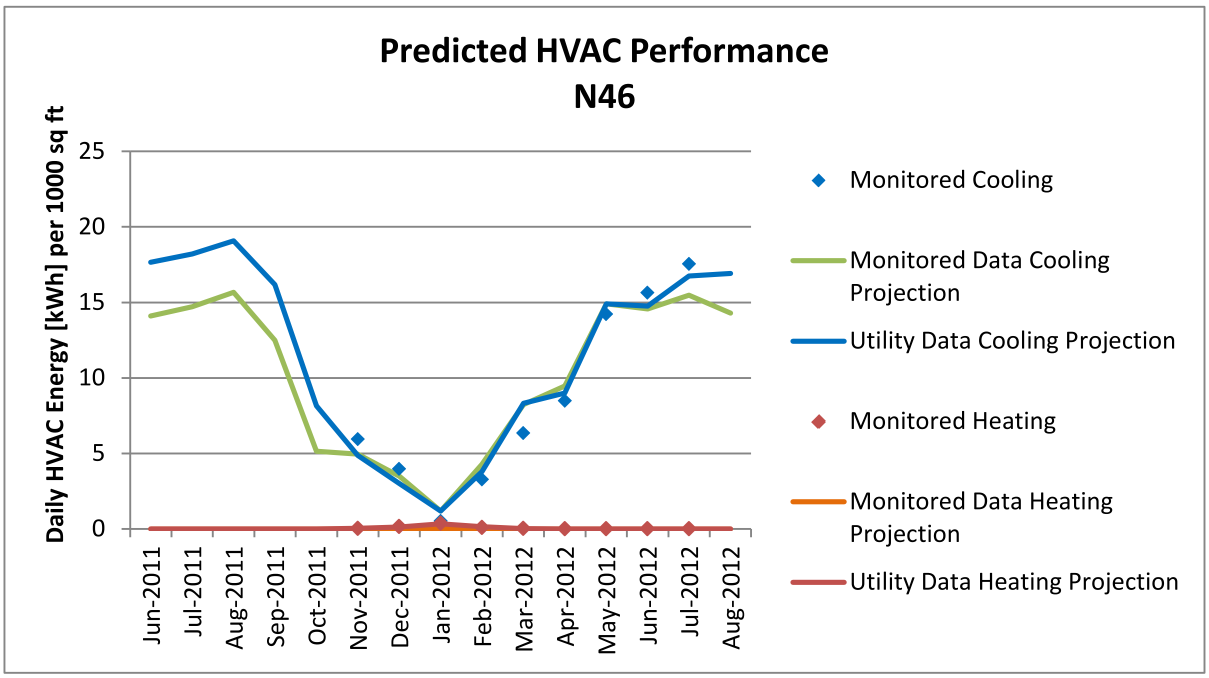


Figure A-48 Predicted HVAC Performance, N46

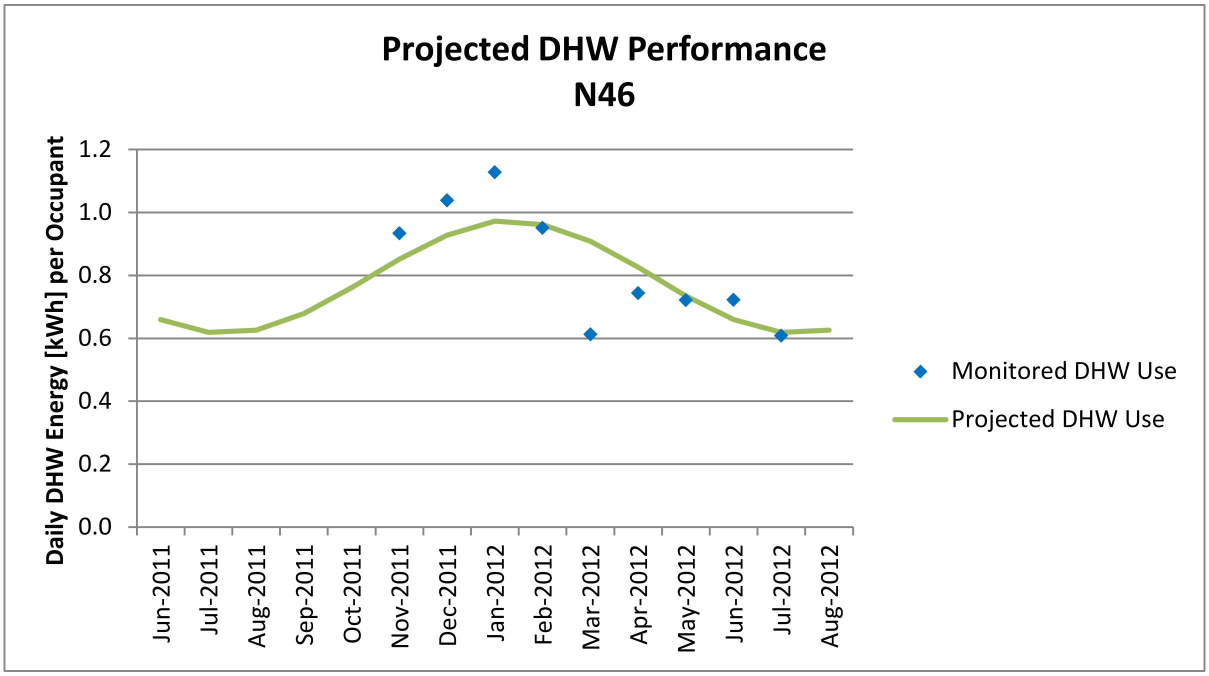
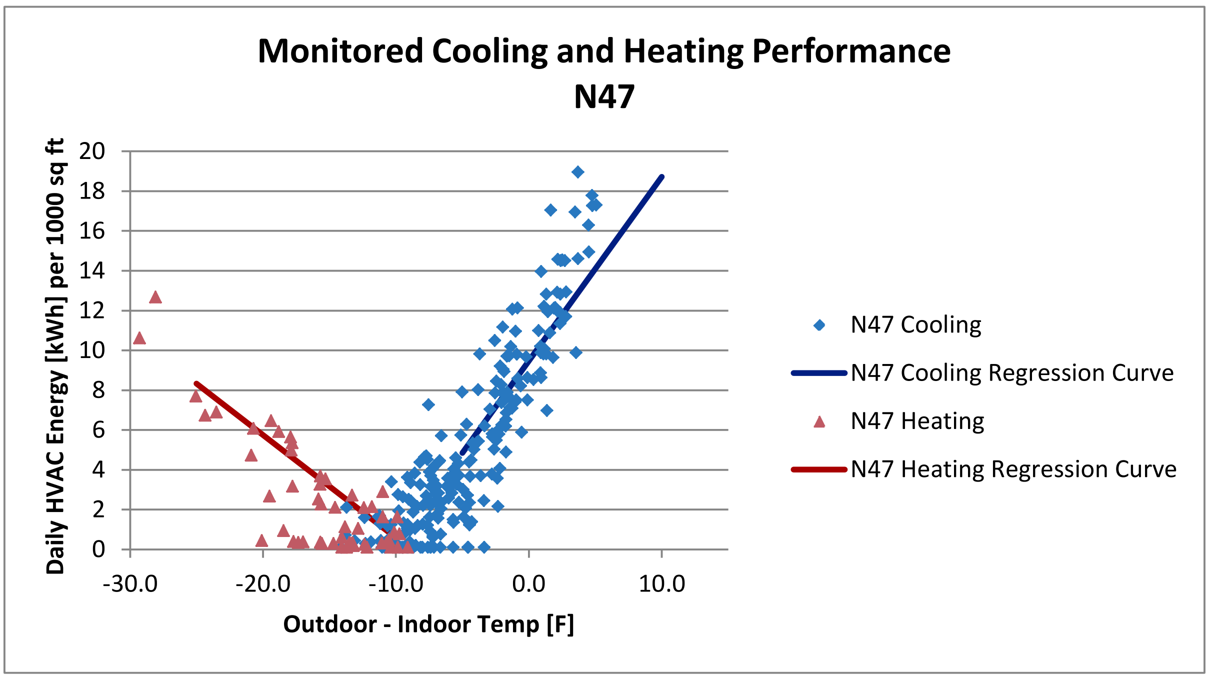


Figure A-49 Projected DHW Performance, N46



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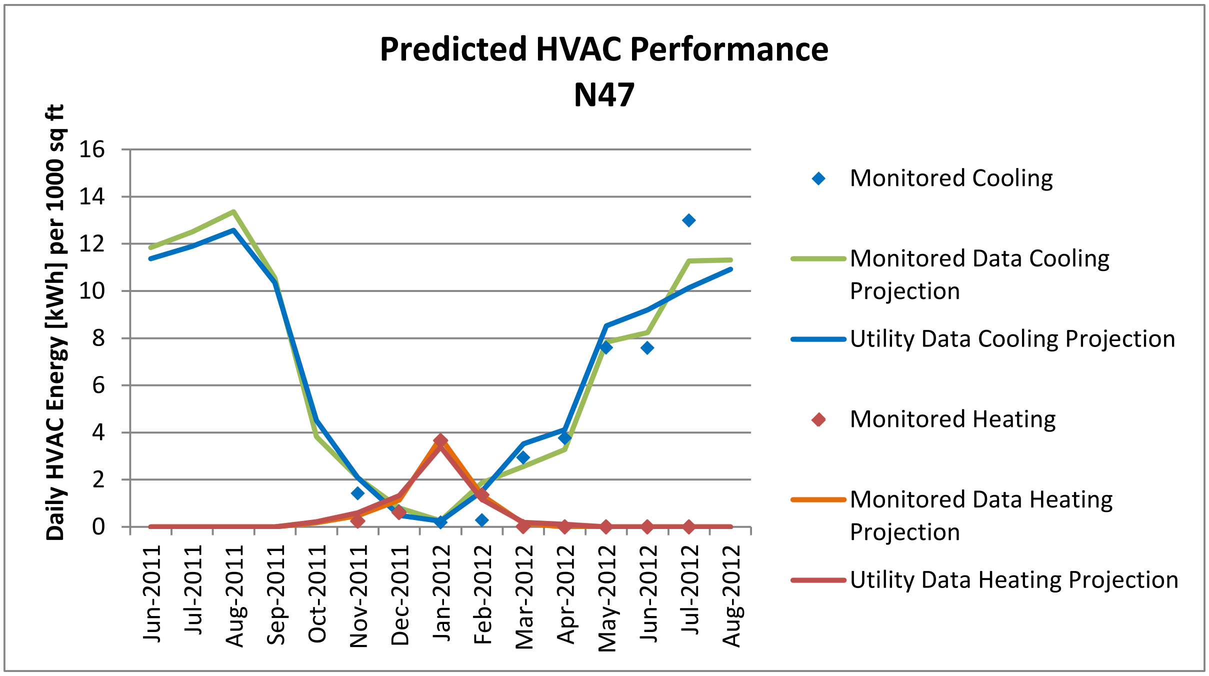

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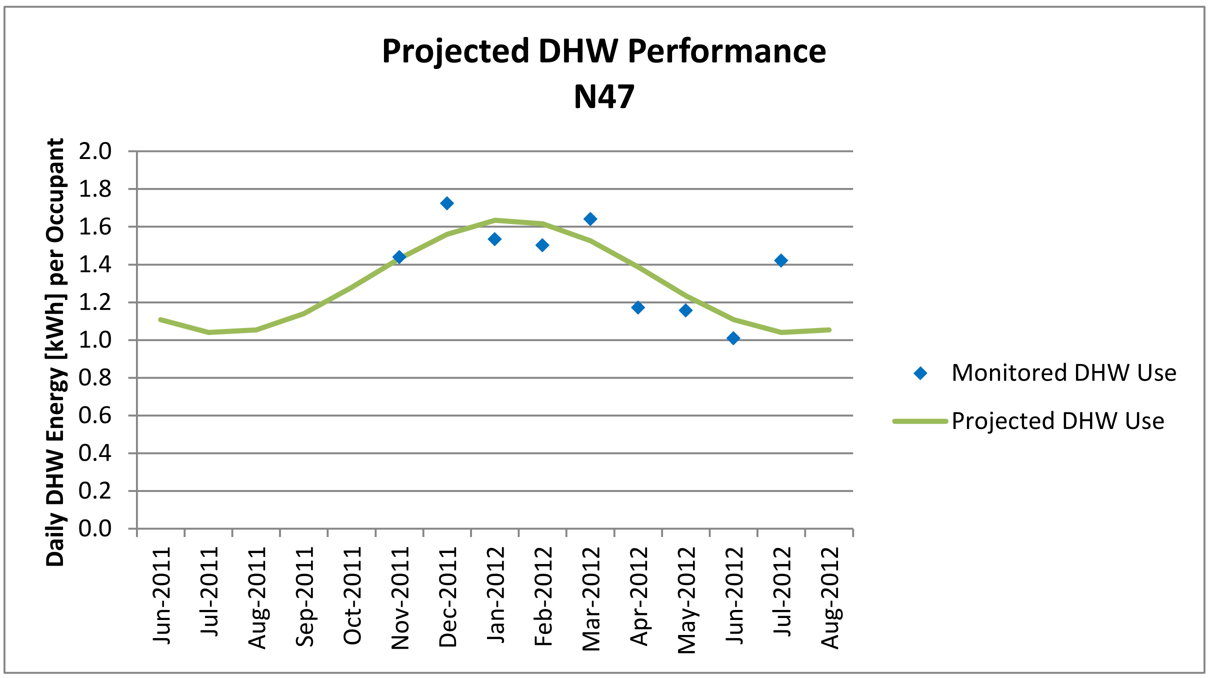

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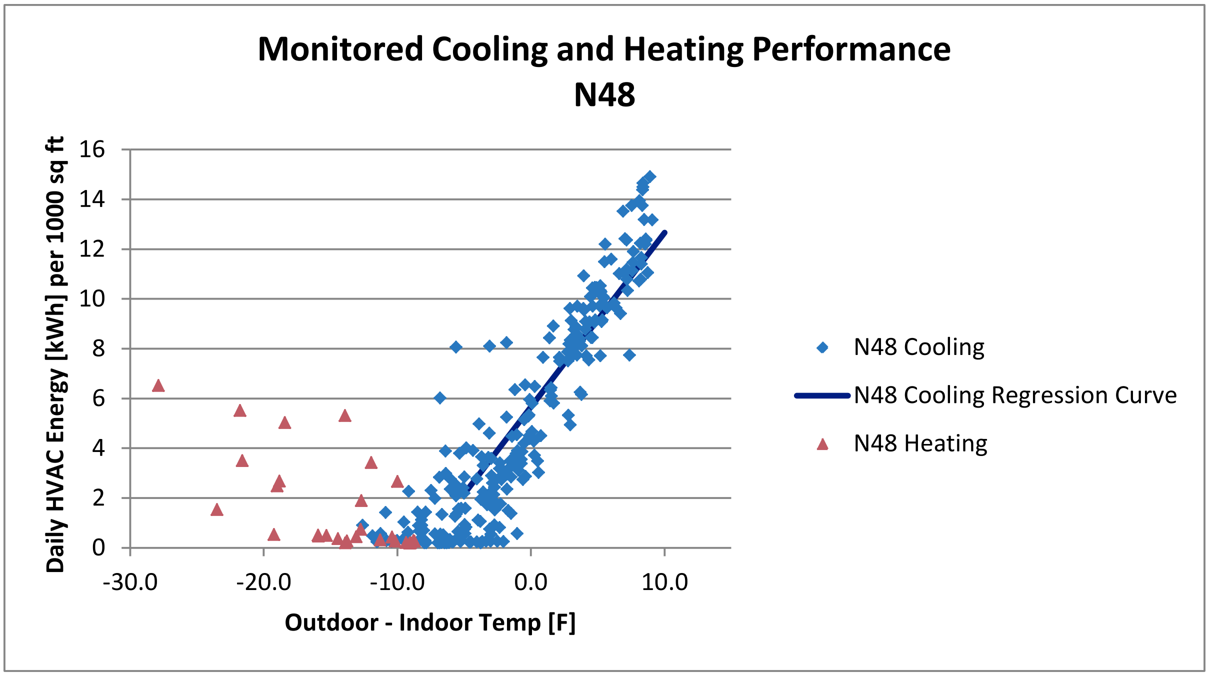
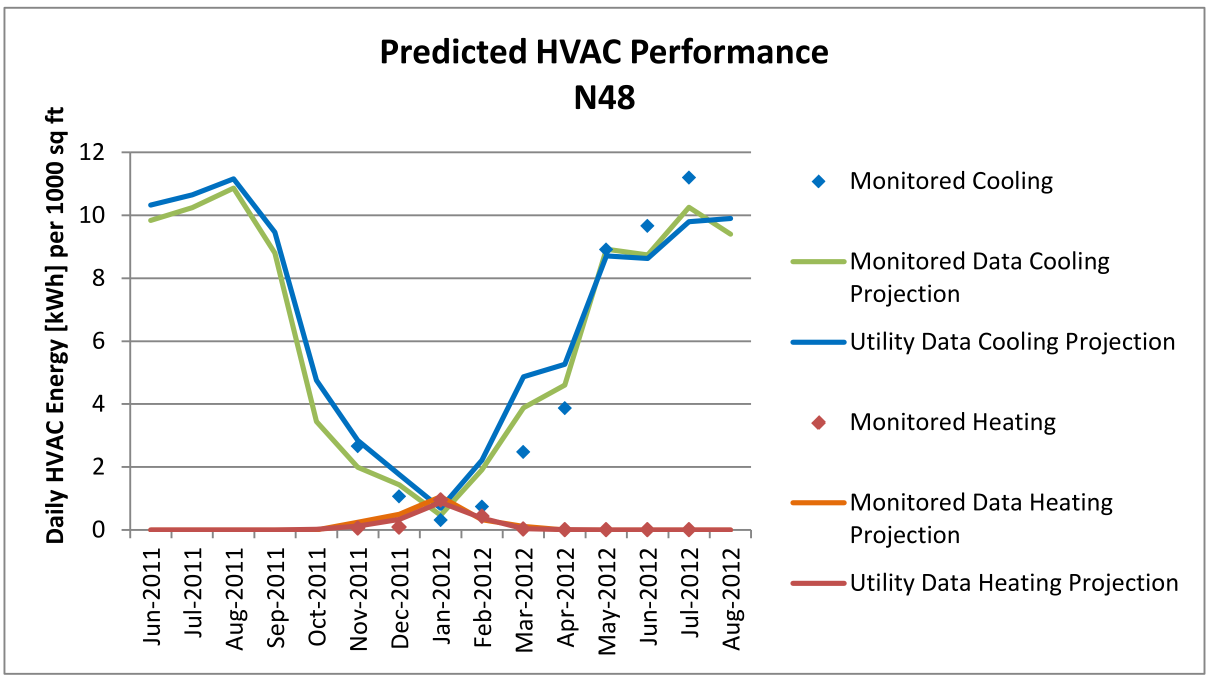


Figure A-53 Monitored Cooling and Heating Performance, N48



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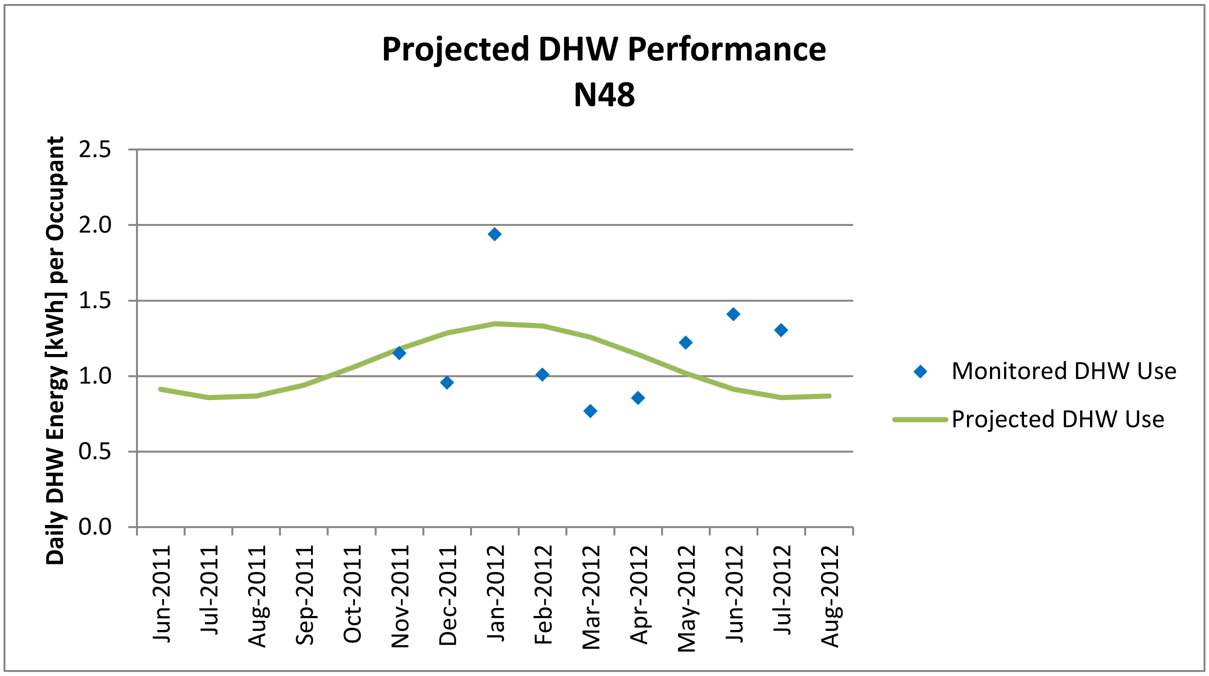

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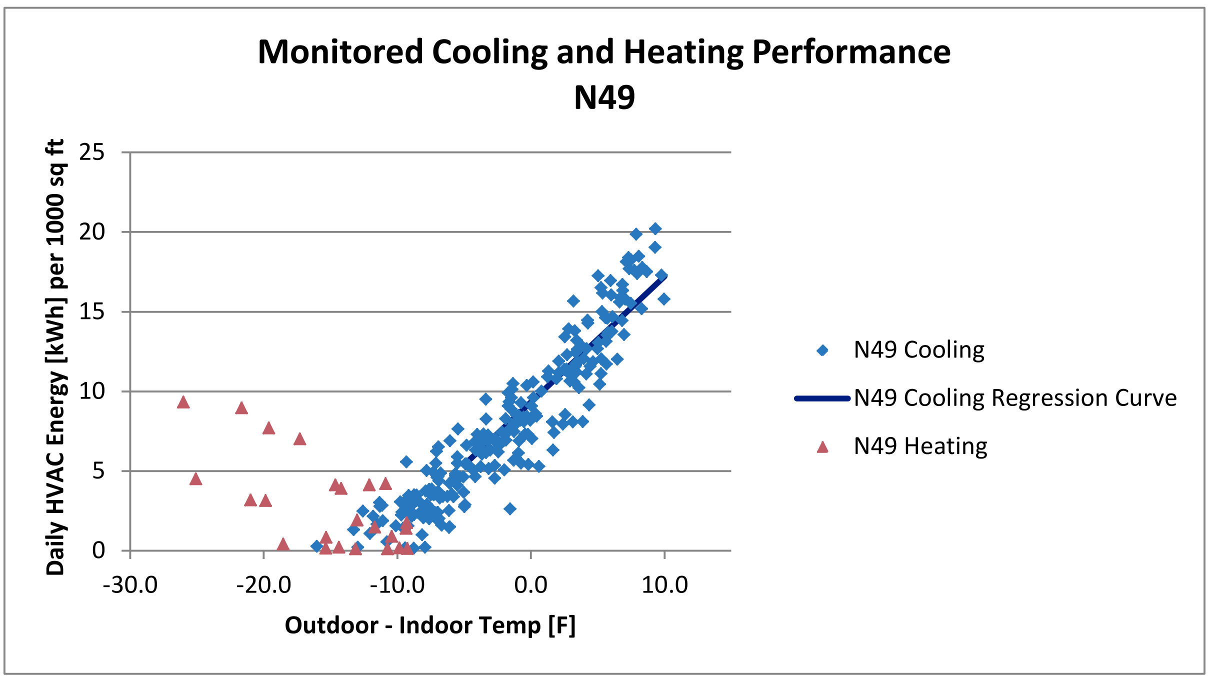

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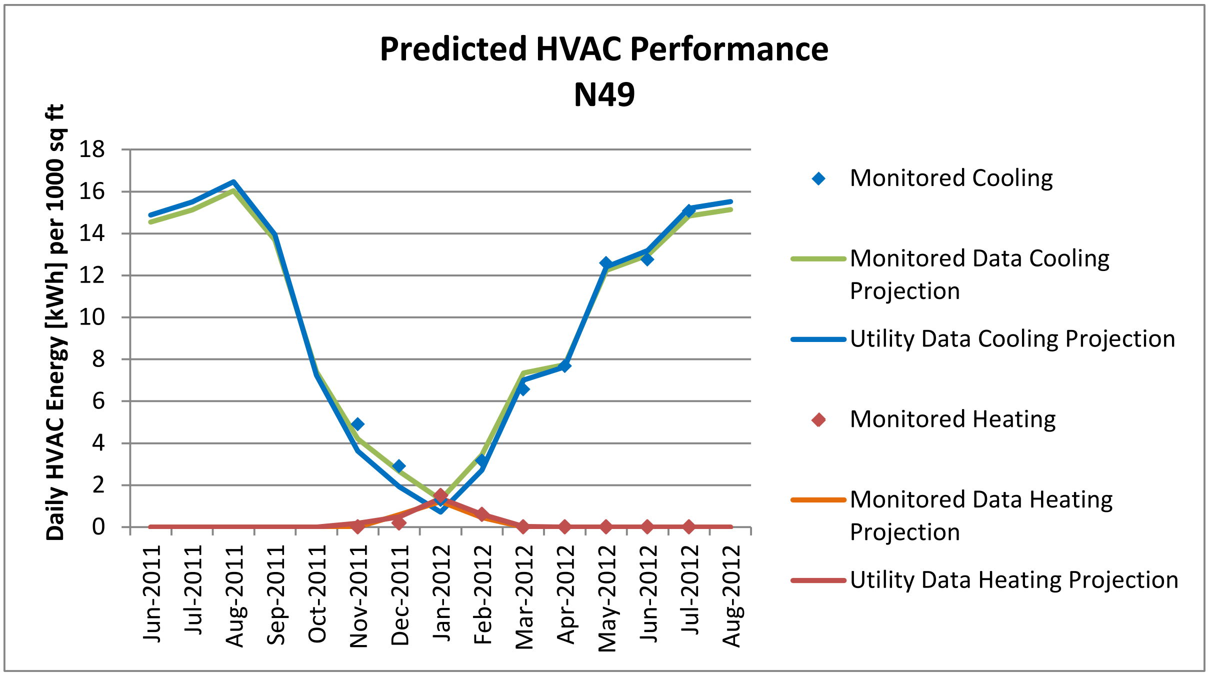


Figure A-57 Predicted HVAC Performance, N49

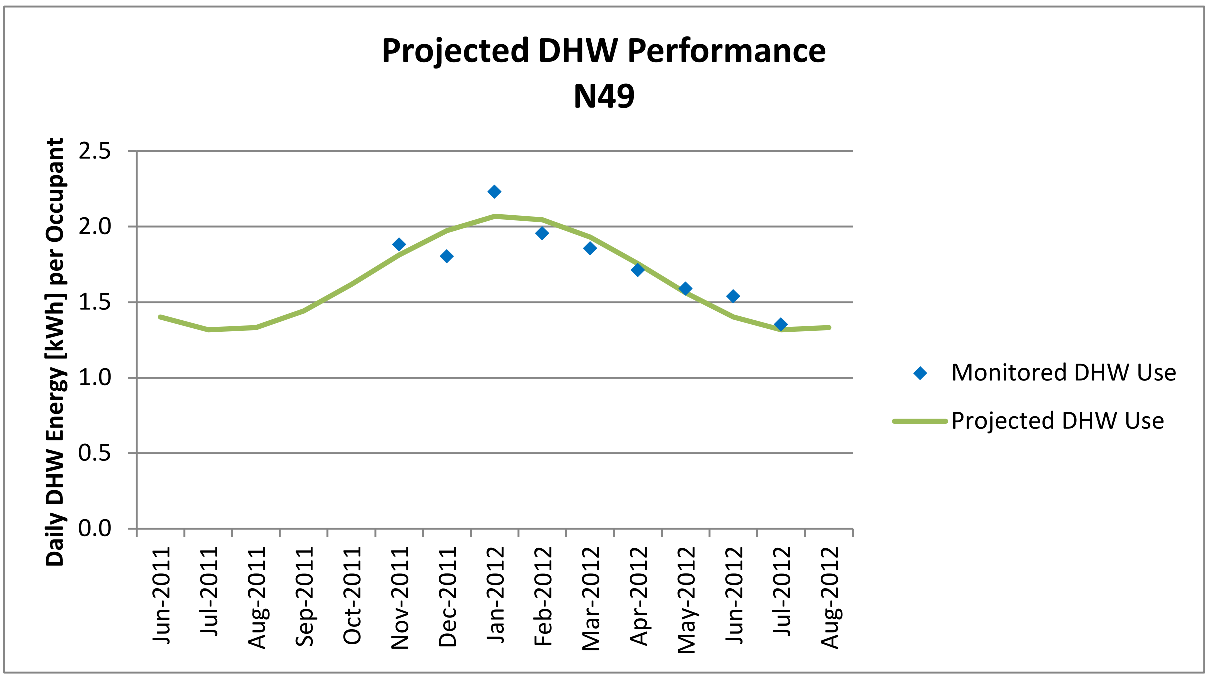
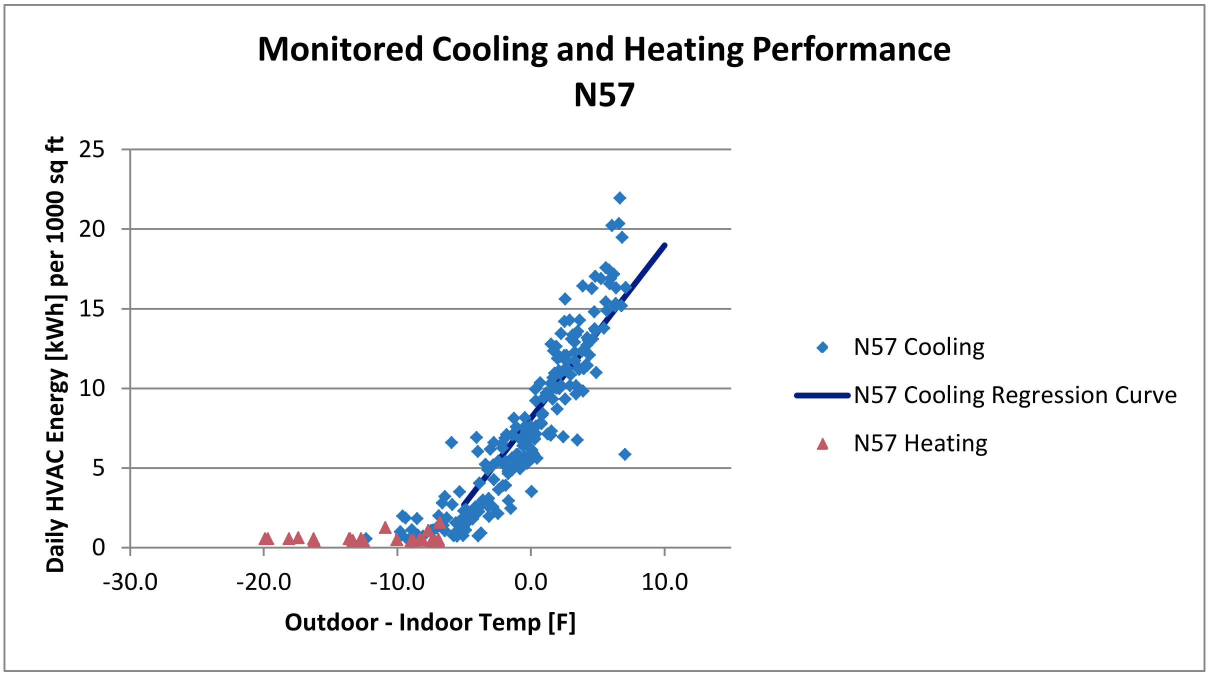


Figure A-58 Projected DHW Performance, N49



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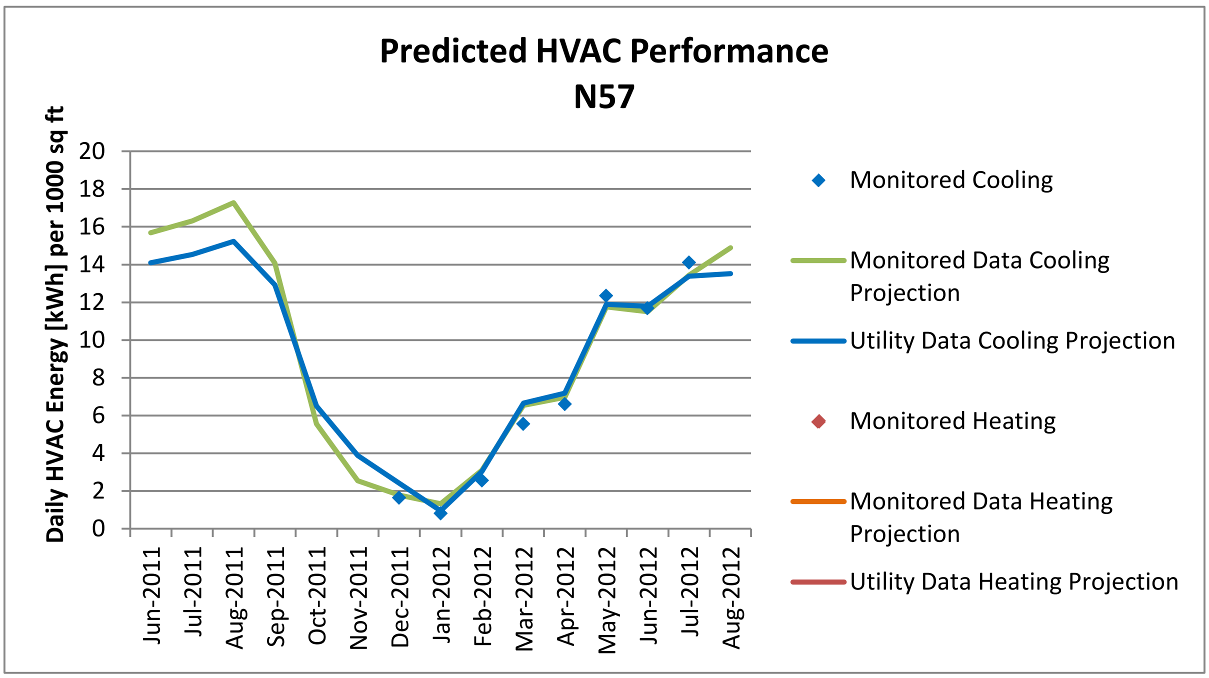


Figure A-60 Predicted HVAC Performance, N57

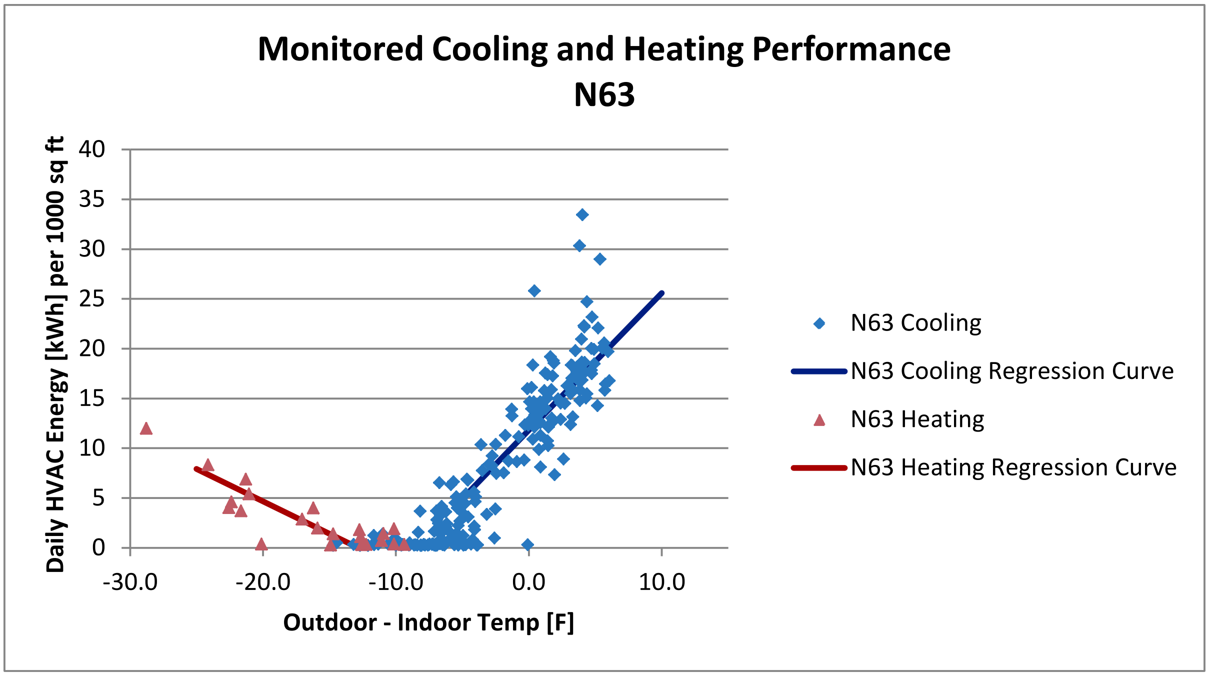


Figure A-61 Monitored Cooling and Heating Performance, N63

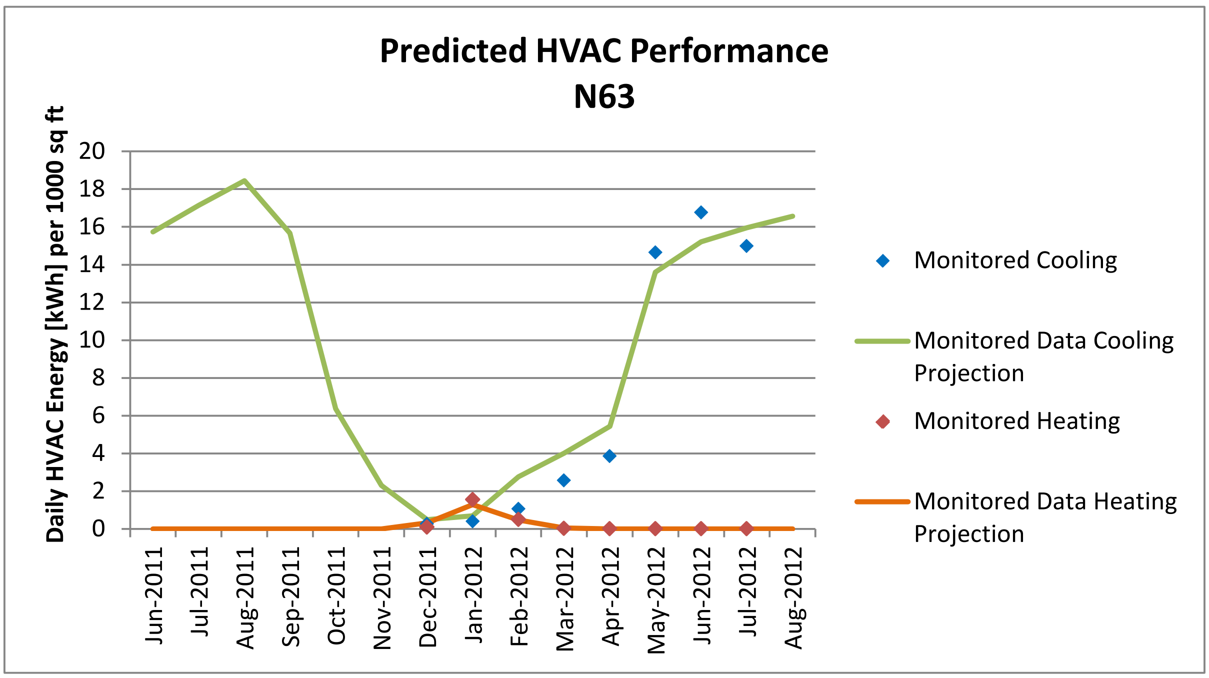


Figure A-62 Predicted HVAC Performance, N63

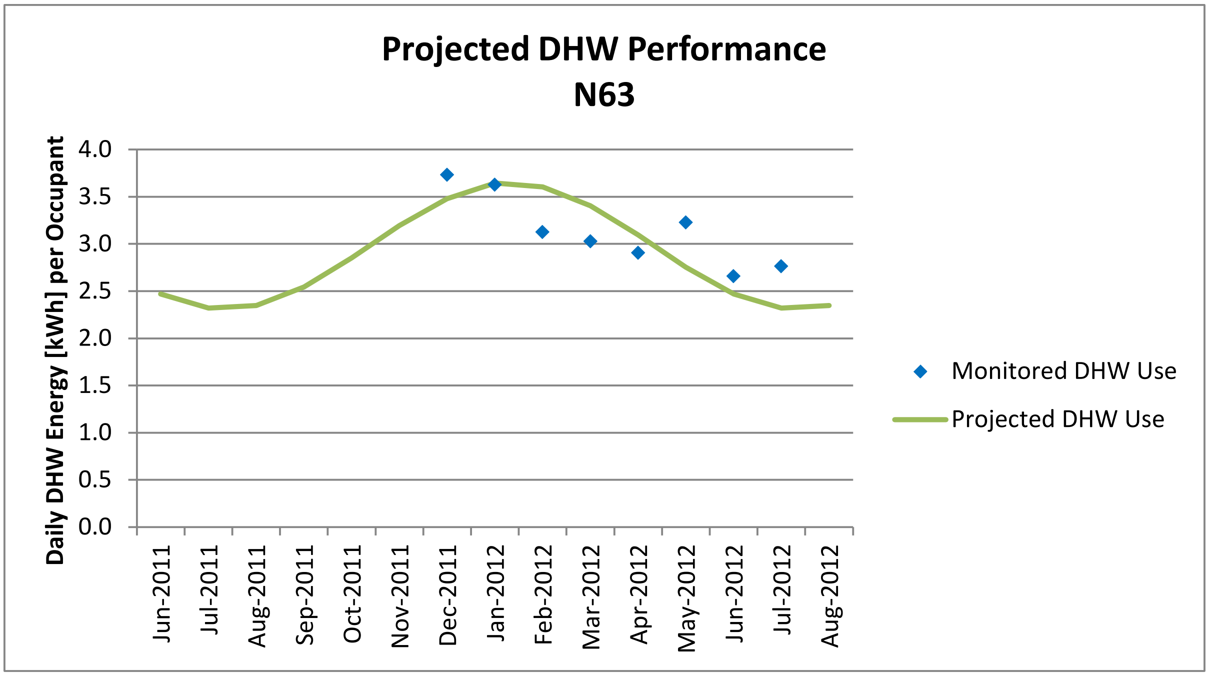


Figure A-63 Projected DHW Performance, N63

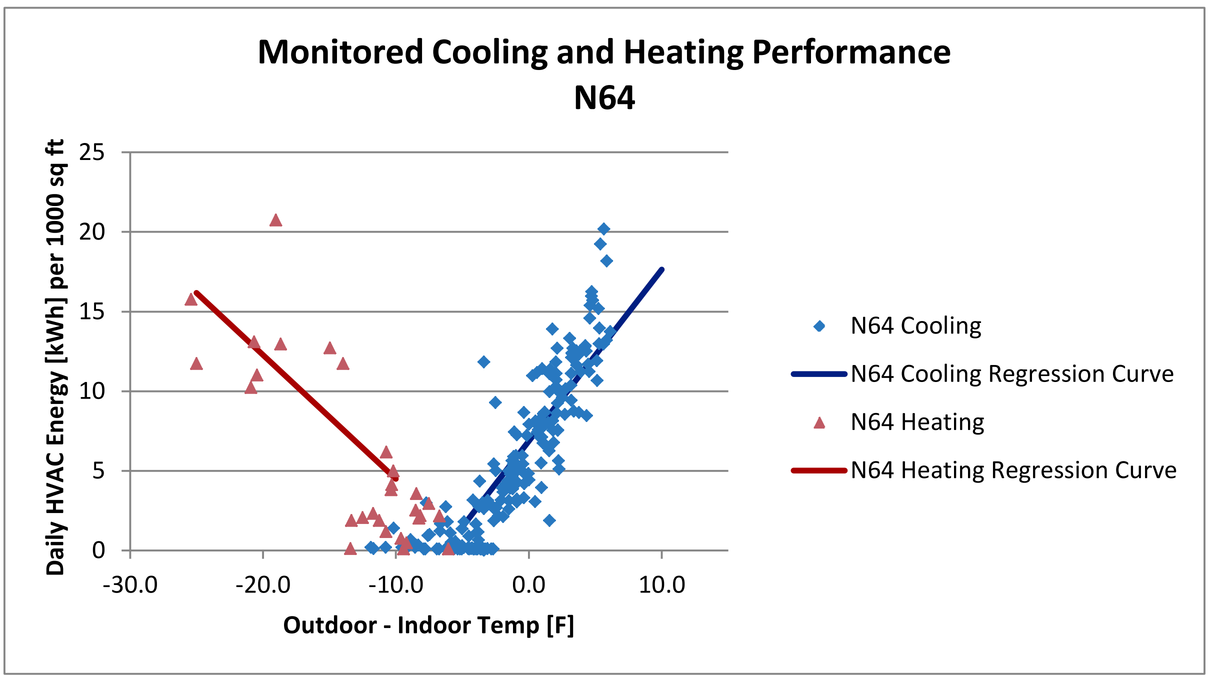


Figure A-64 Monitored Cooling and Heating Performance, N64

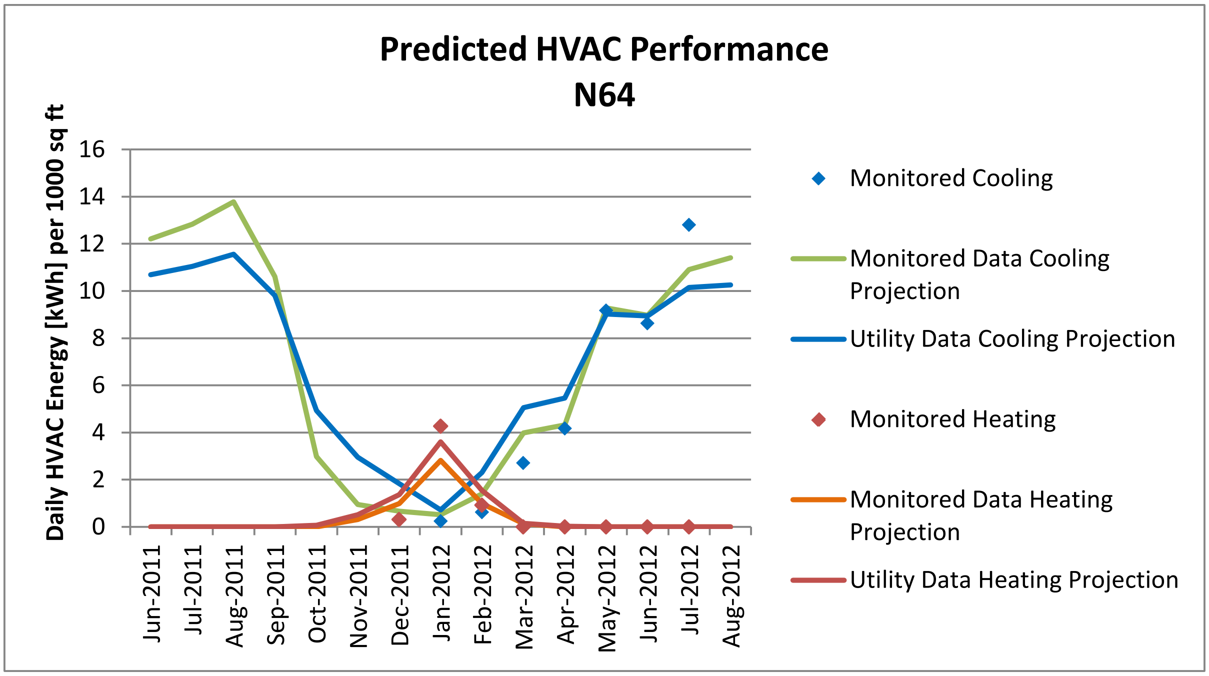


Figure A-65 Predicted HVAC Performance, N64

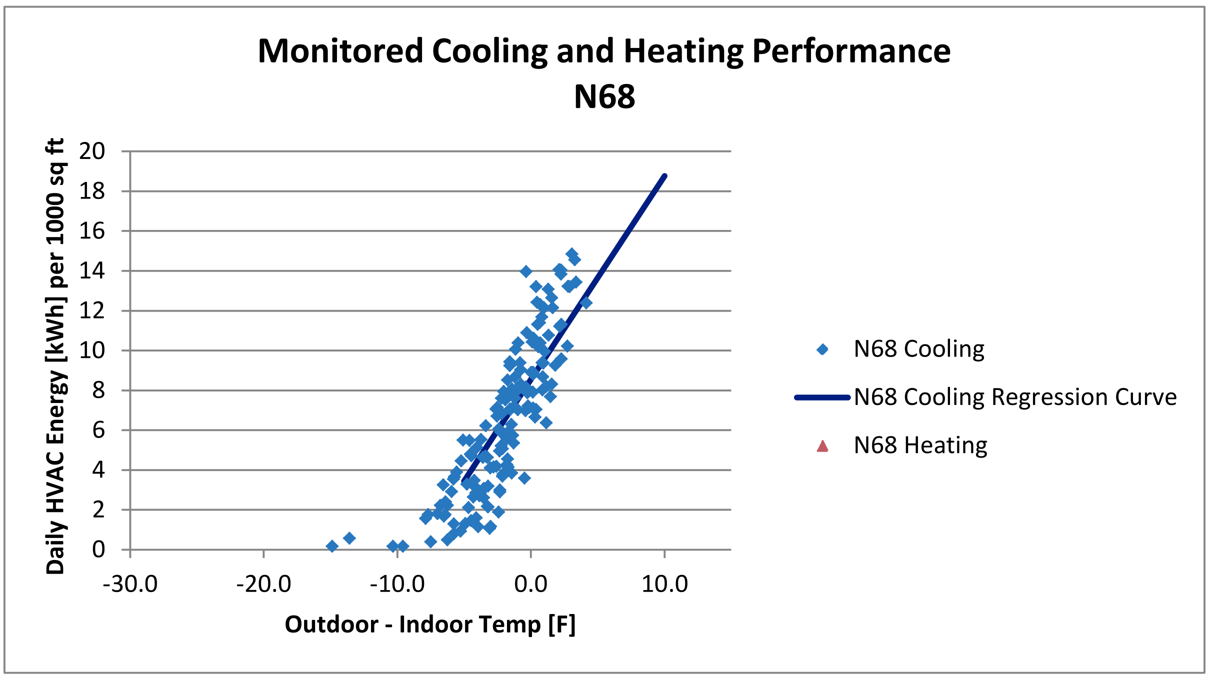


Figure A-66 Monitored Cooling and Heating Performance, N68

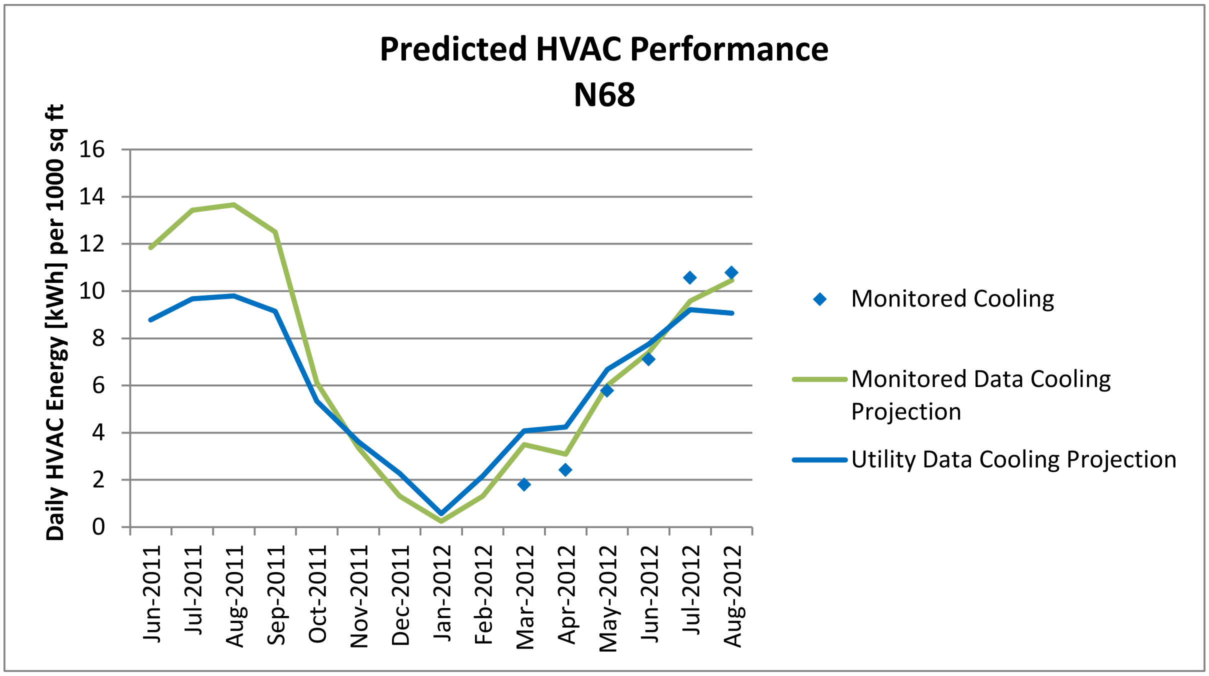


Figure A-67 Predicted HVAC Performance, N68

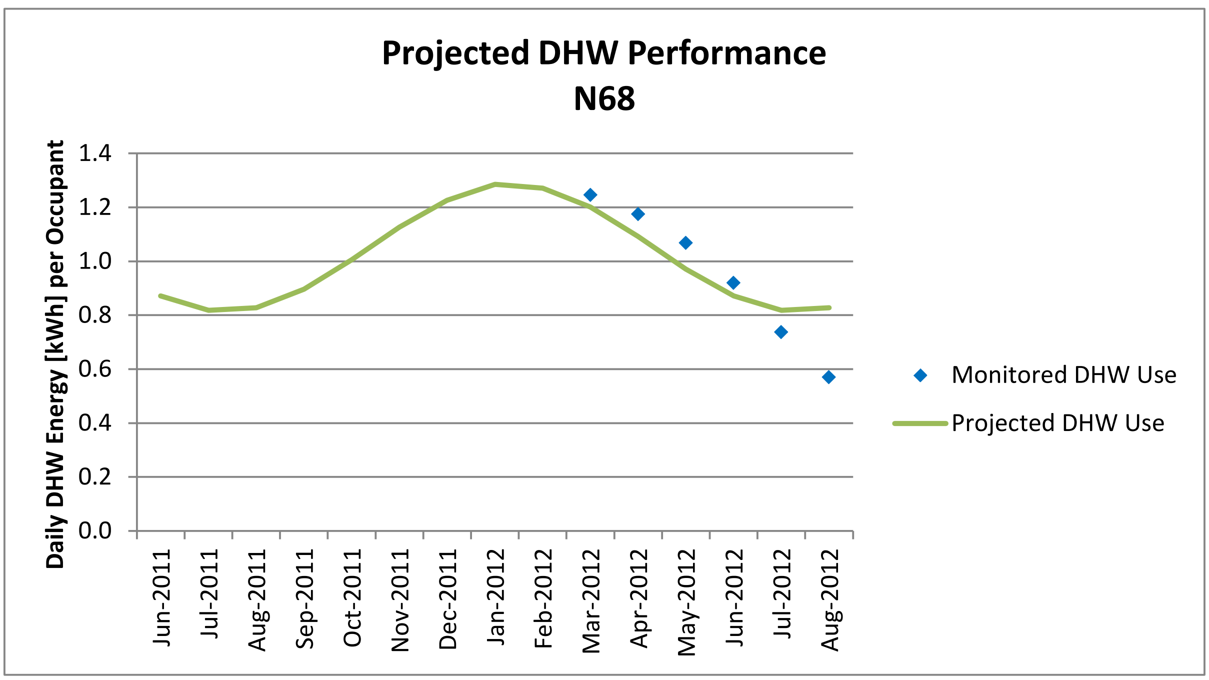


Figure A-68 Projected DHW Performance, N68

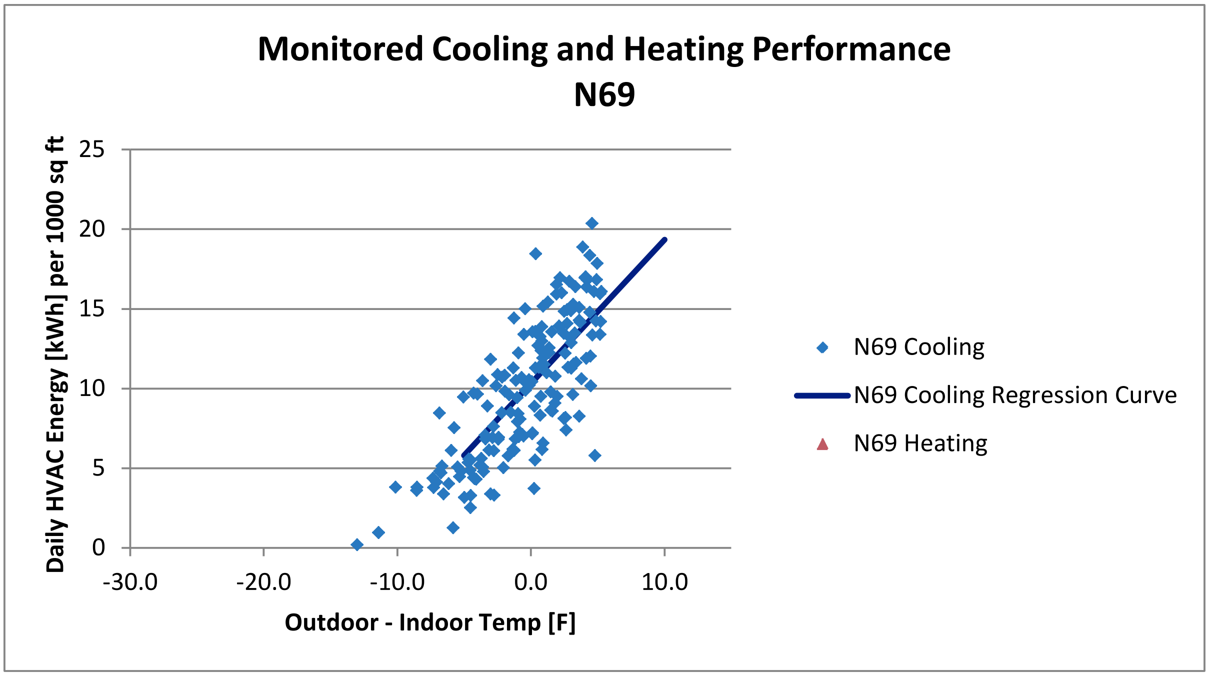


Figure A-69 Monitored Cooling and Heating Performance, N69

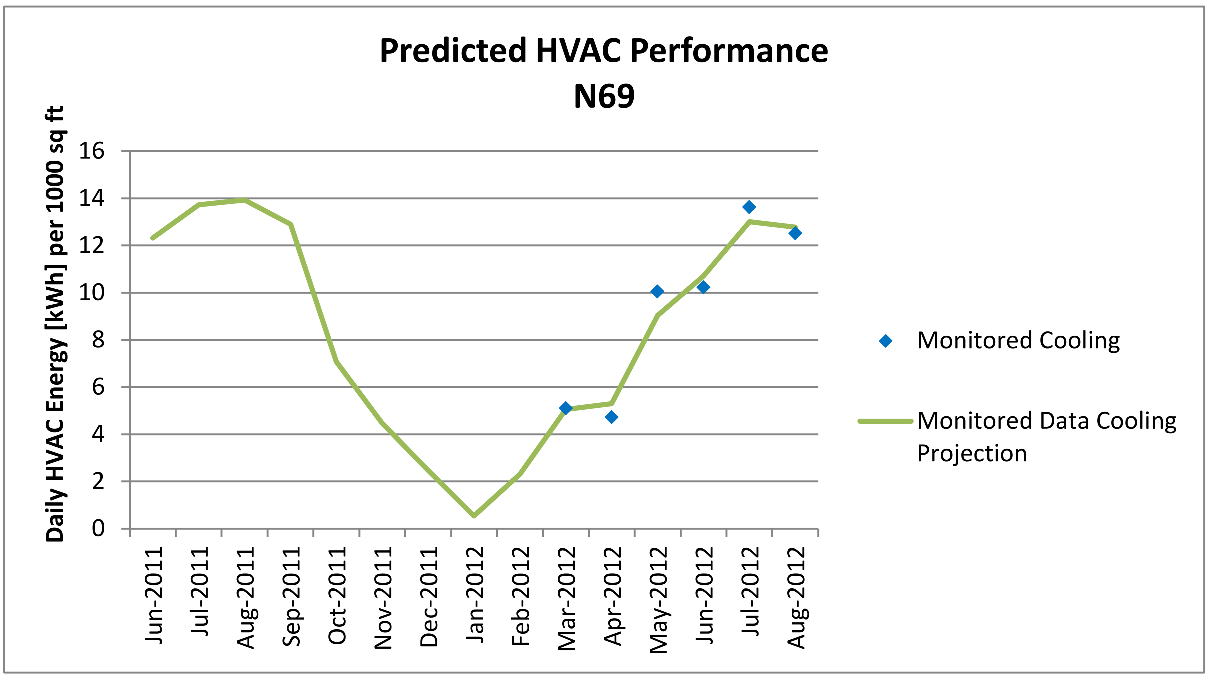


Figure A-70 Predicted HVAC Performance, N69

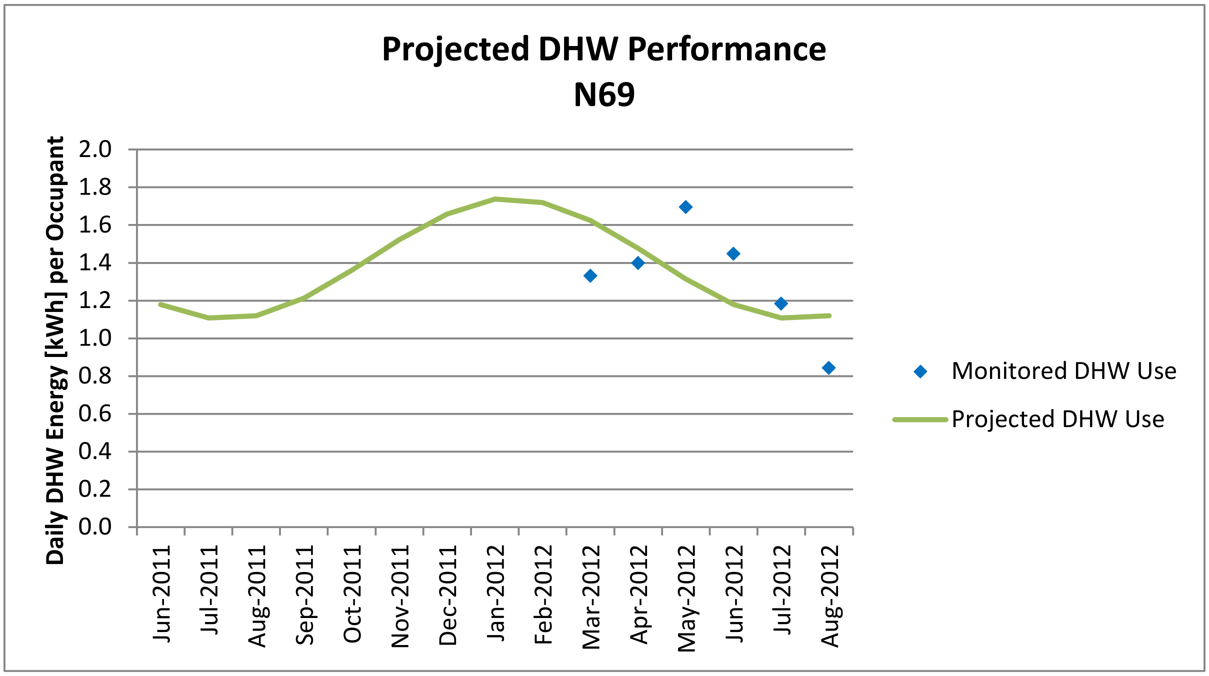
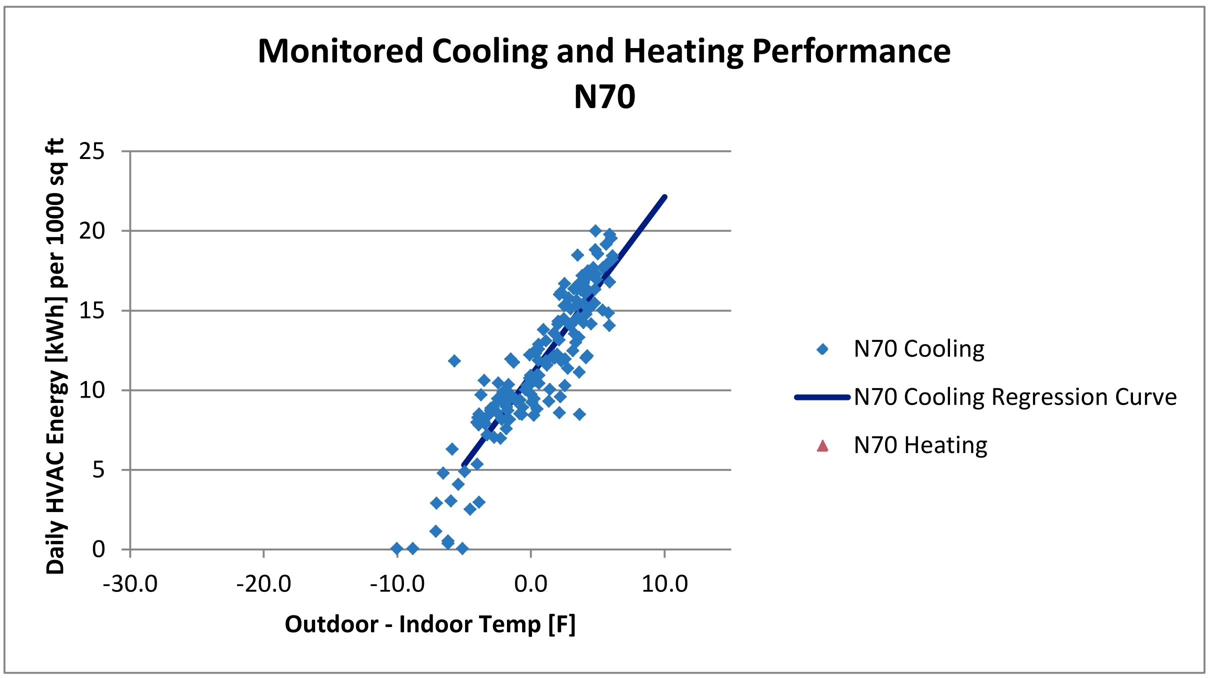


Figure A-71 Projected DHW Performance, N69



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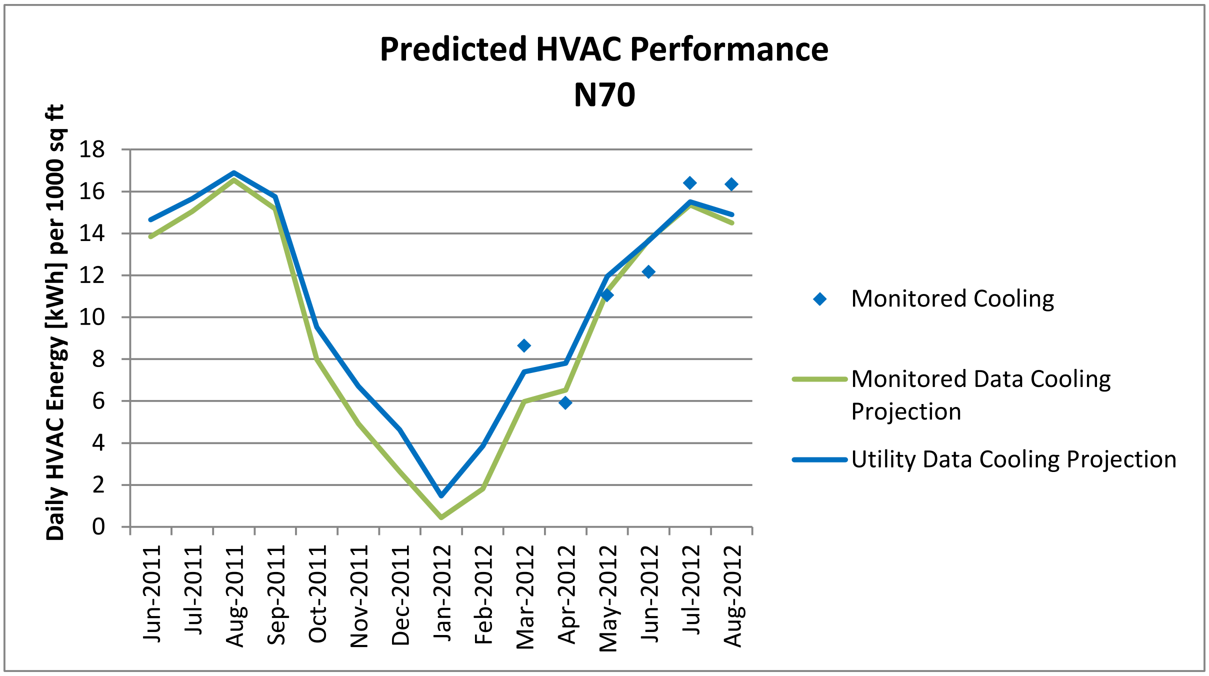

Figure A-73 Predicted HVAC Performance, N70

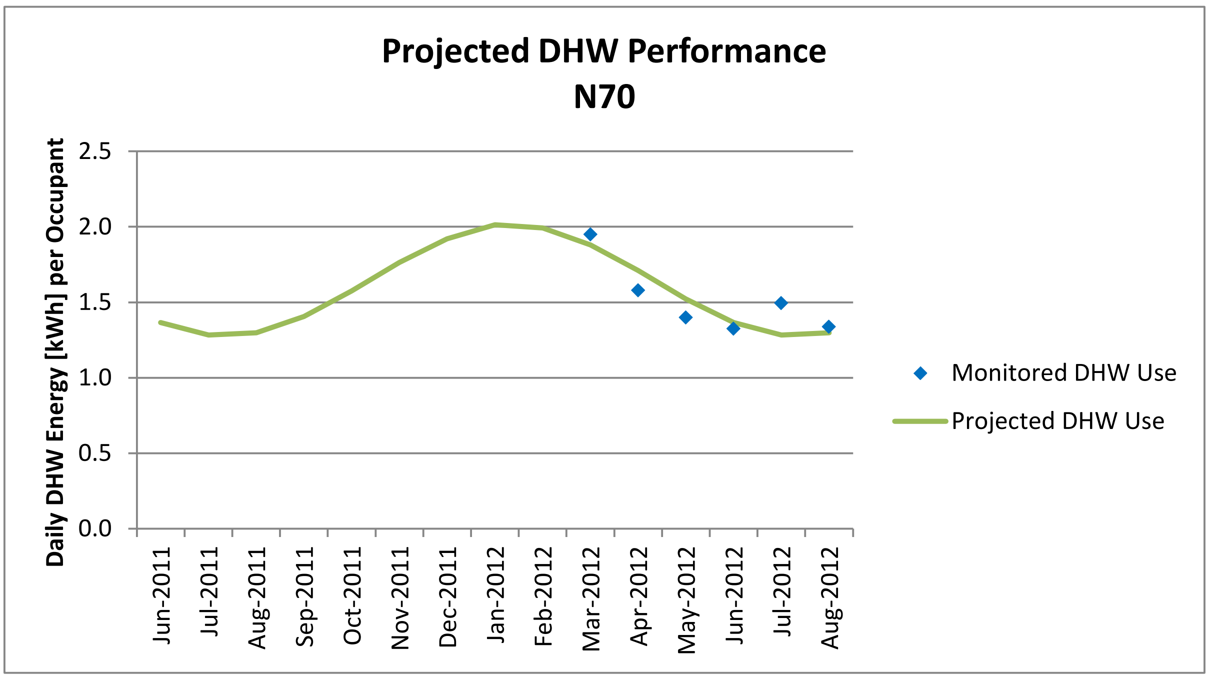

Figure A-74 Projected DHW Performance, N70

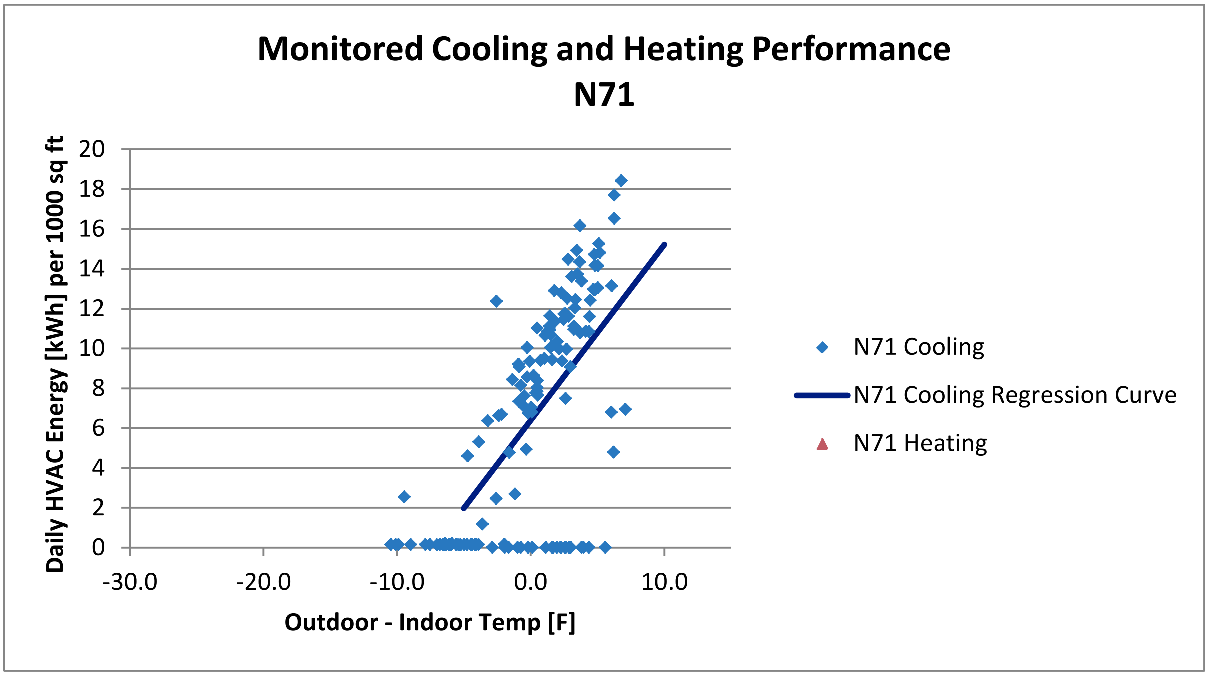

Figure A-75 Monitored Cooling and Heating Performance, N71

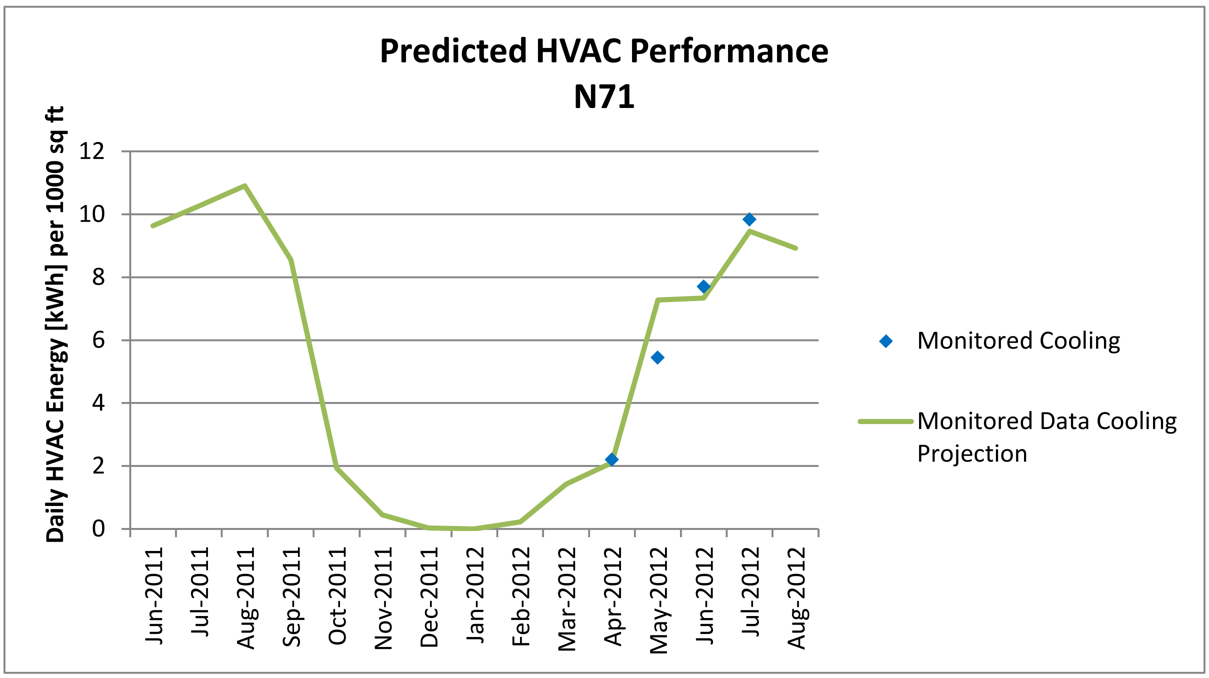

Figure A-76 Predicted HVAC Performance, N71

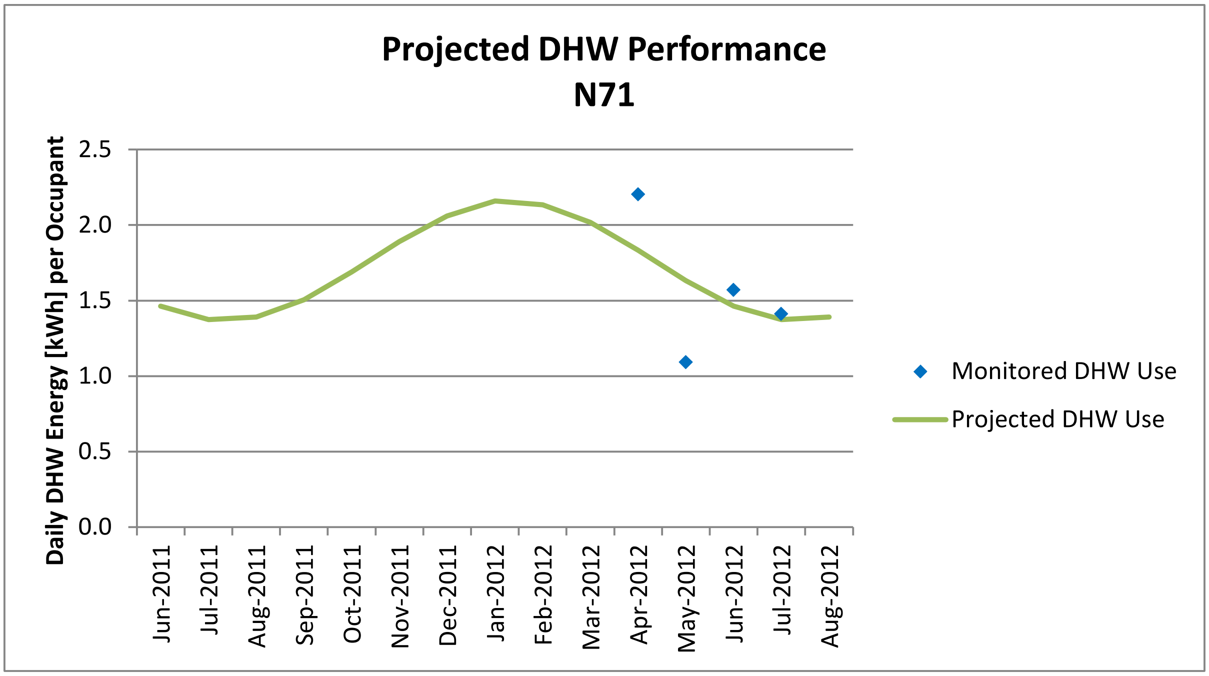

Figure A-77 Projected DHW Performance, N71

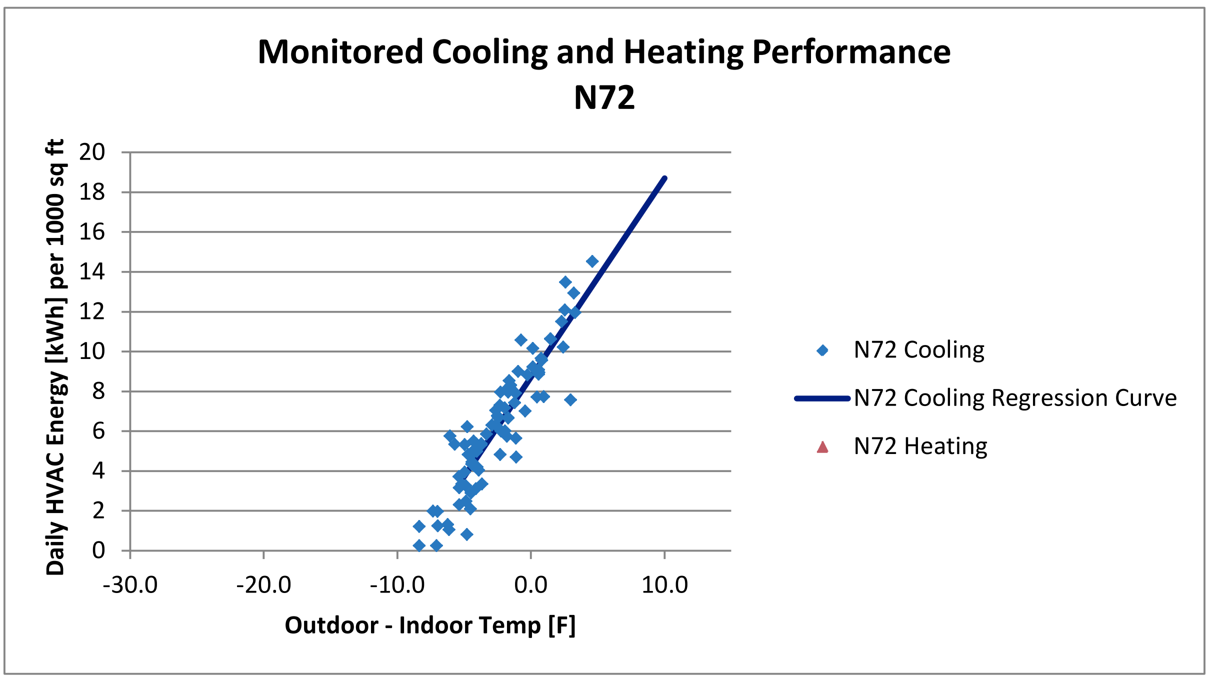

Figure A-78 Monitored Cooling and Heating Performance, N72

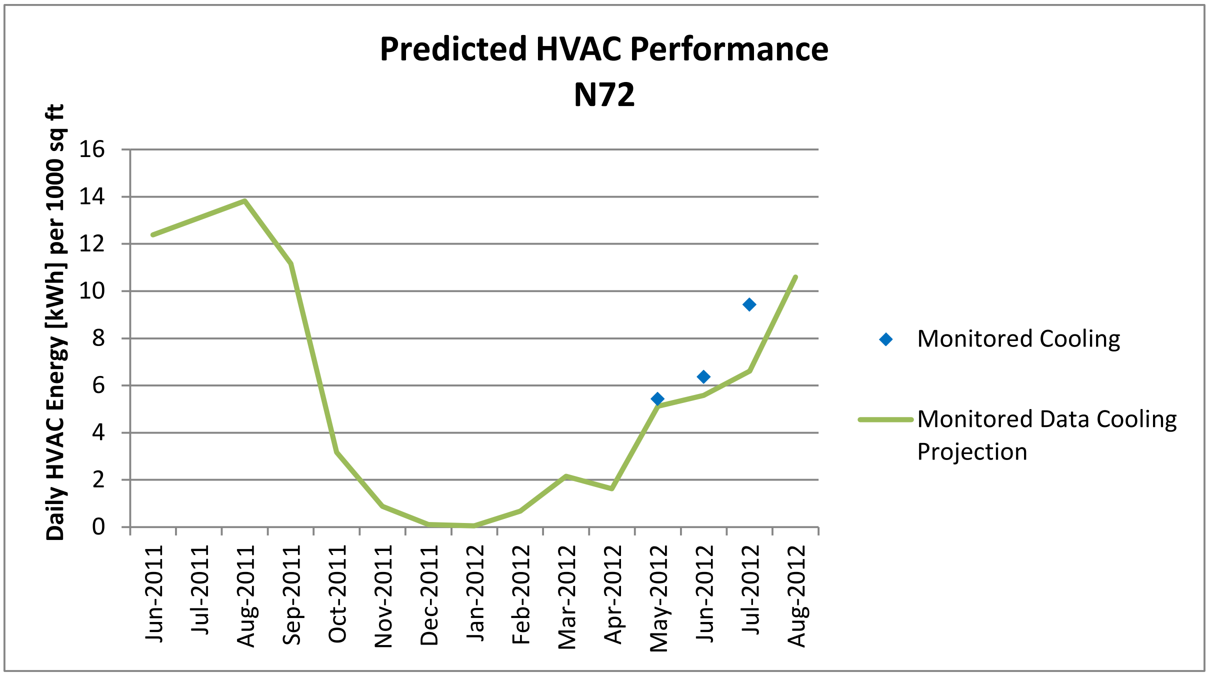

Figure A-79 Predicted HVAC Performance, N72

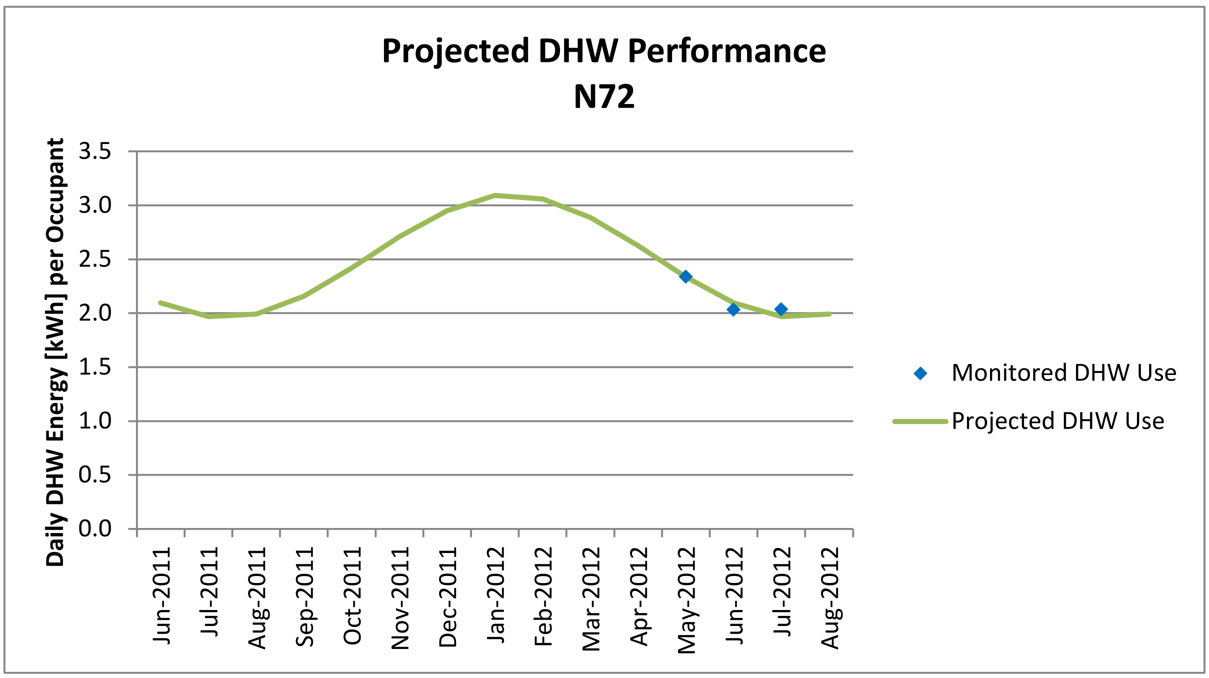

Figure A-80 Projected DHW Performance, N72

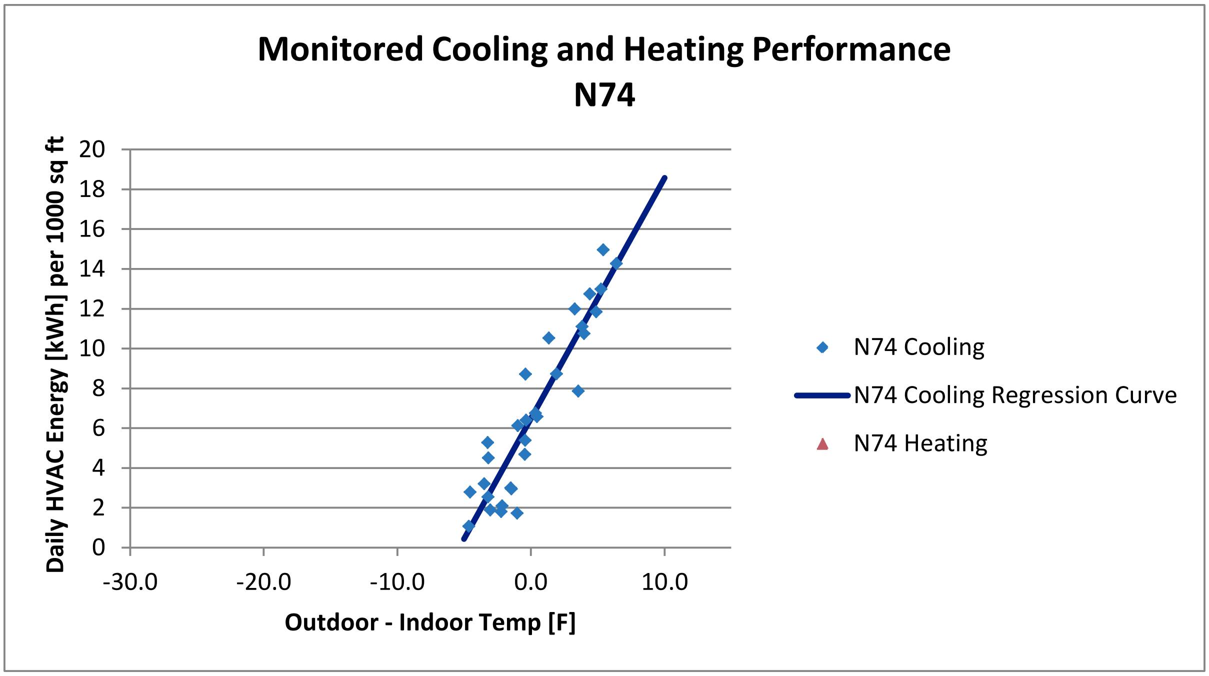

Figure A-81 Monitored Cooling and Heating Performance, N74

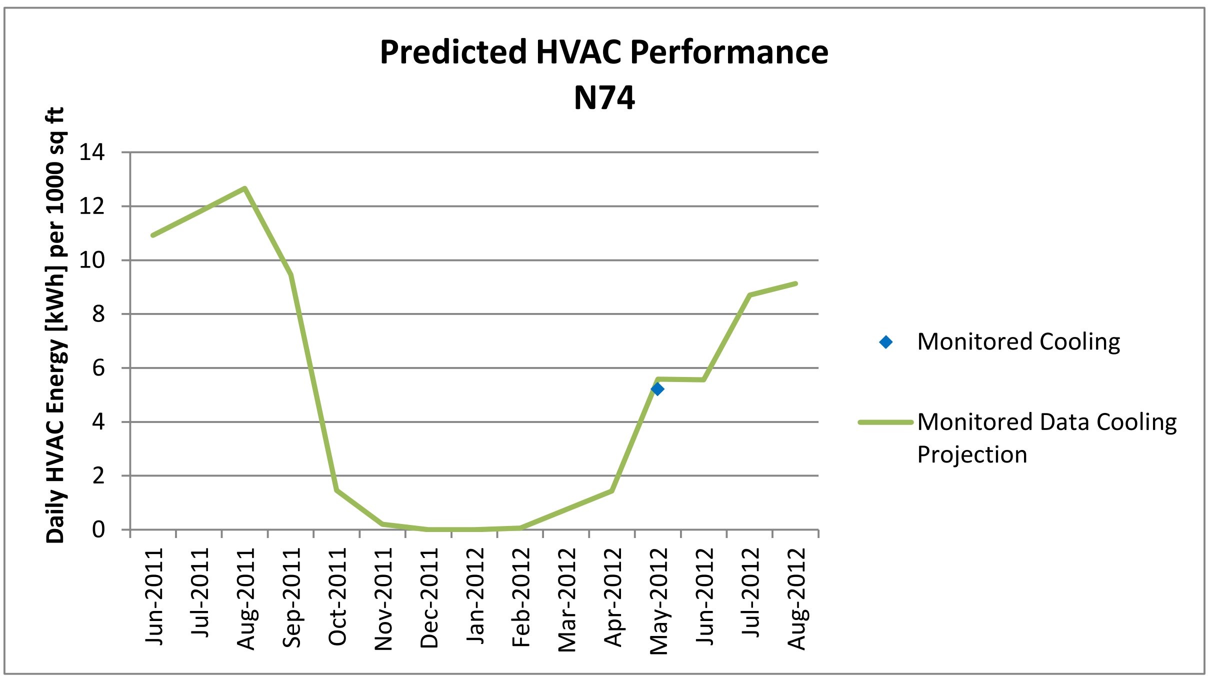

Figure A-82 Predicted HVAC Performance, N74

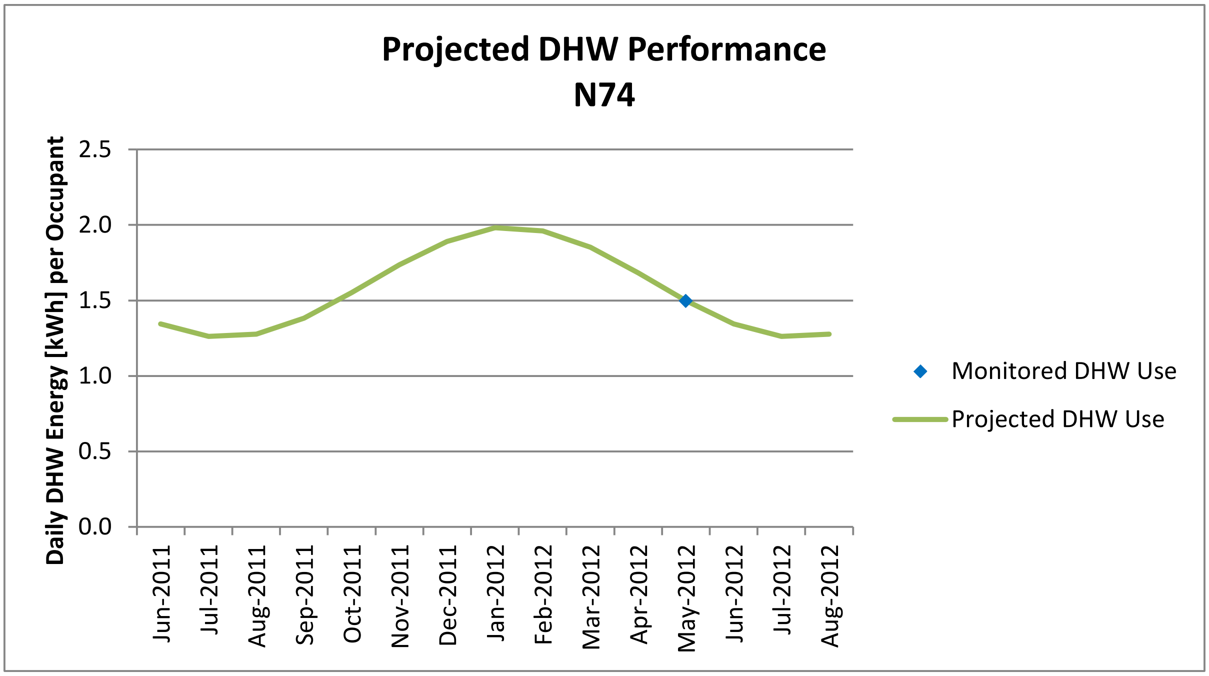

Figure A-83 Projected DHW Performance, N74

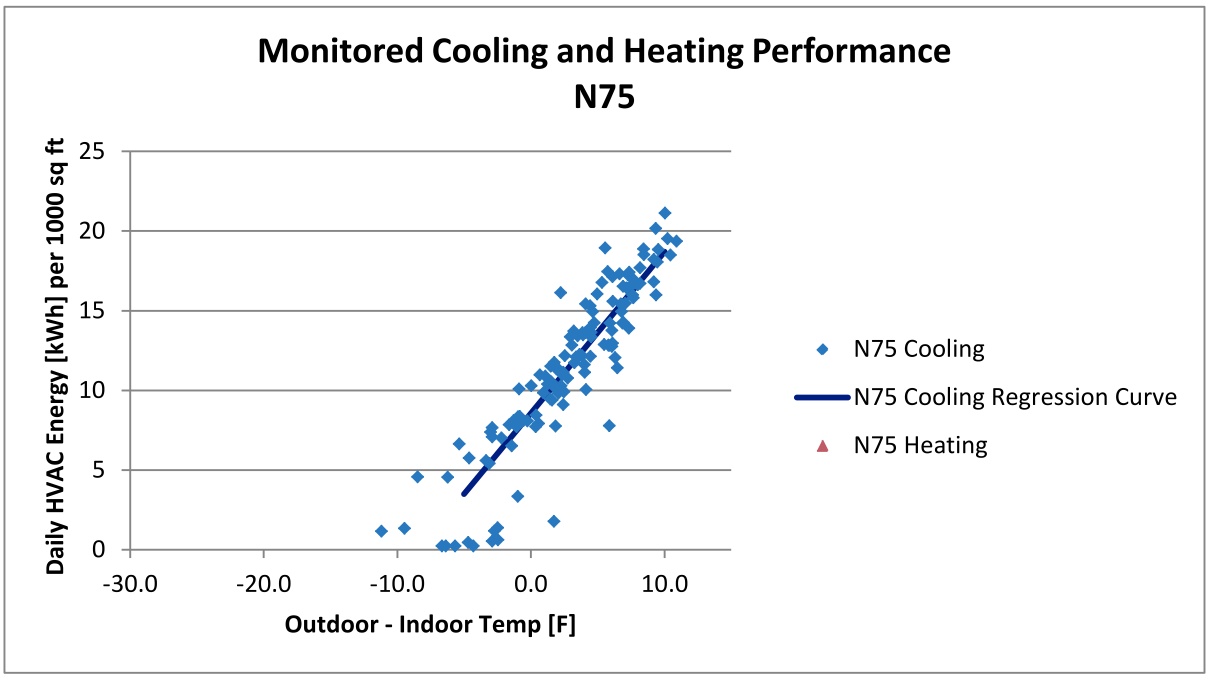

Figure A-84 Monitored Cooling and Heating Performance, N75

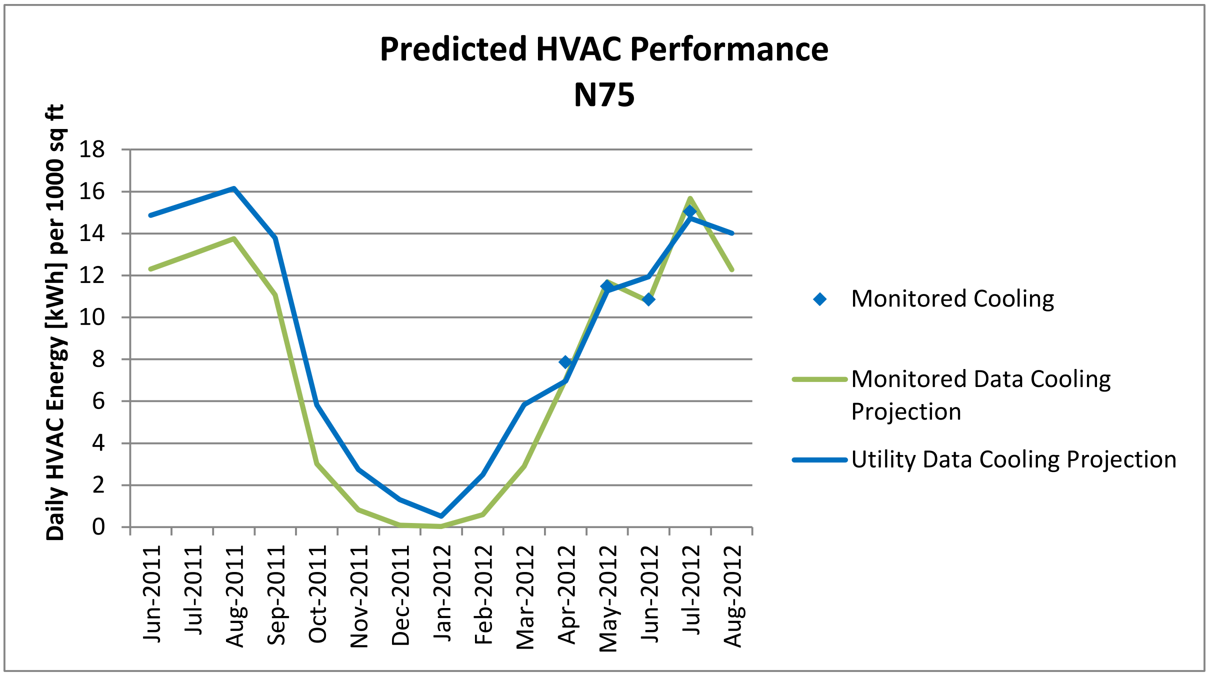

Figure A-85 Predicted HVAC Performance, N75

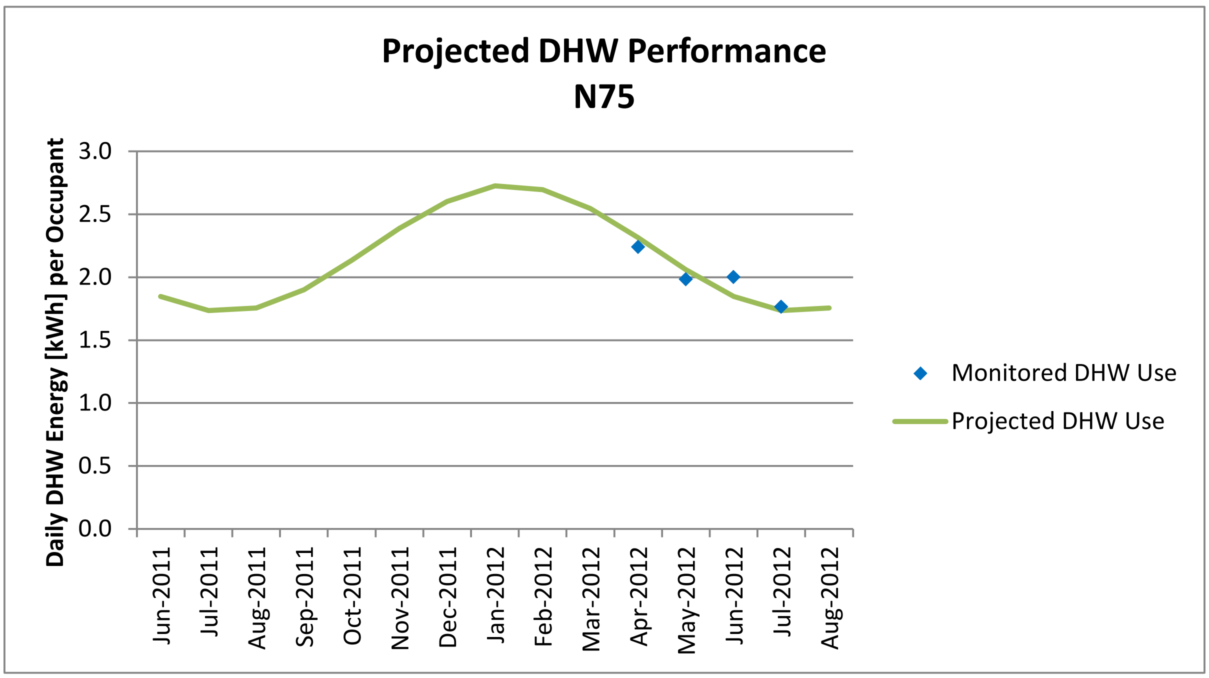

Figure A-86 Projected DHW Performance, N75

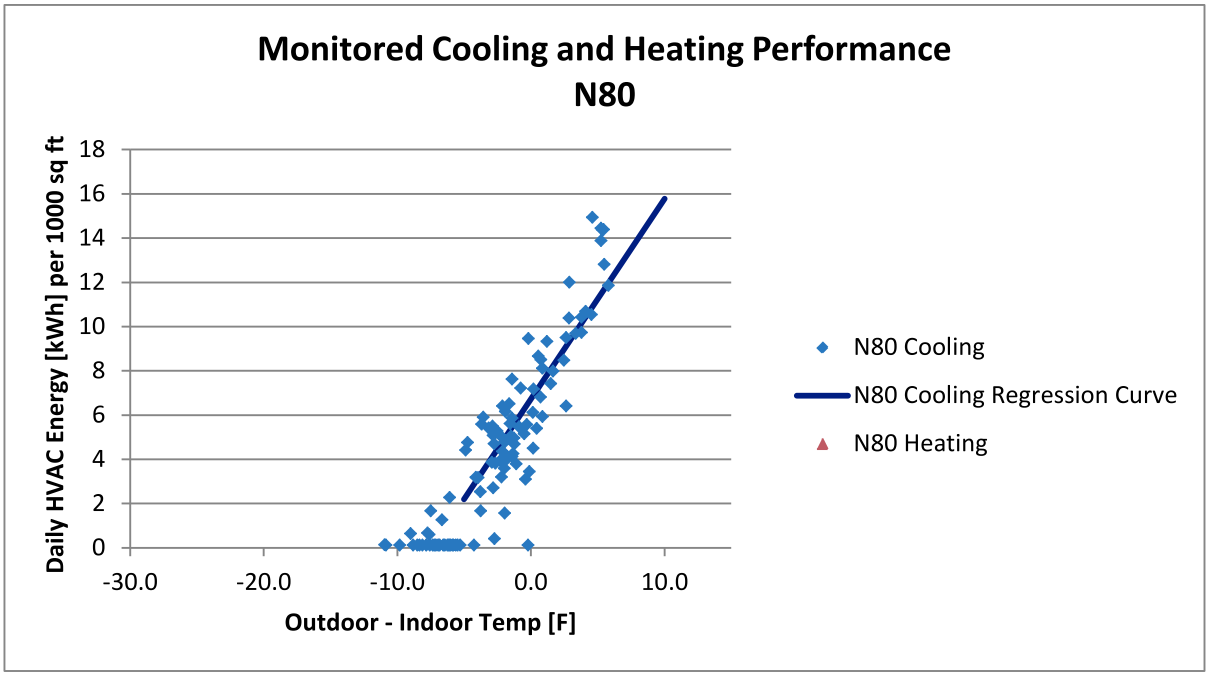

Figure A-87 Monitored Cooling and Heating Performance, N80

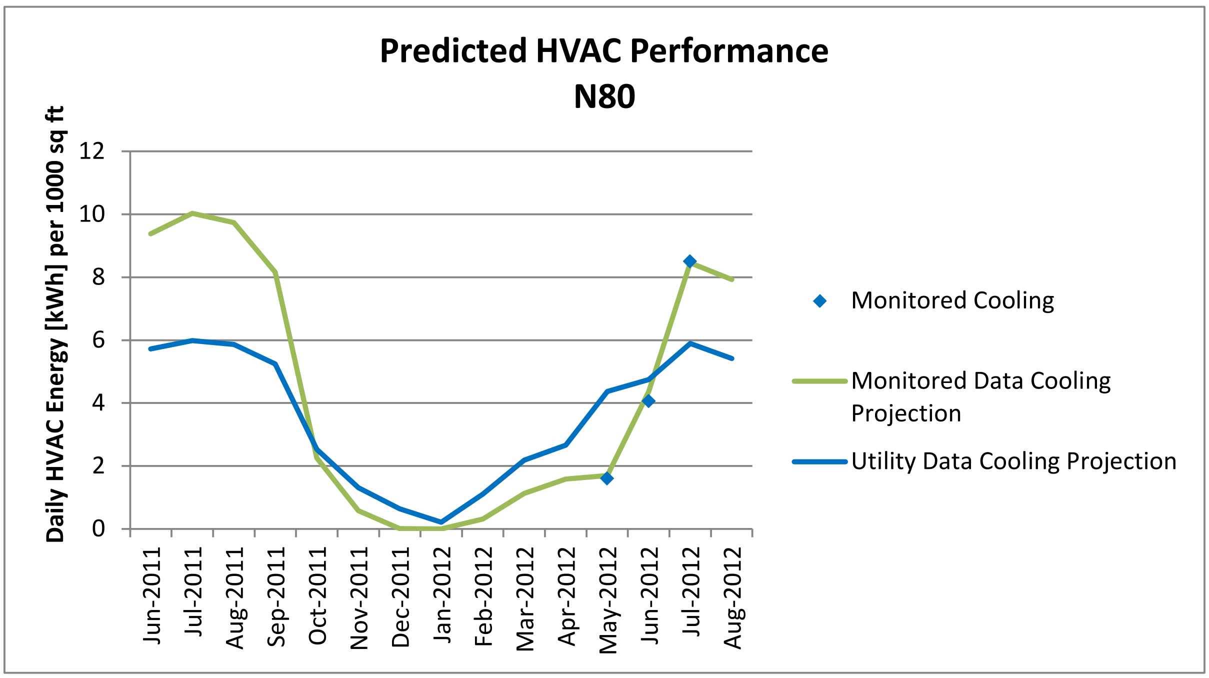

Figure A-88 Predicted HVAC Performance, N80

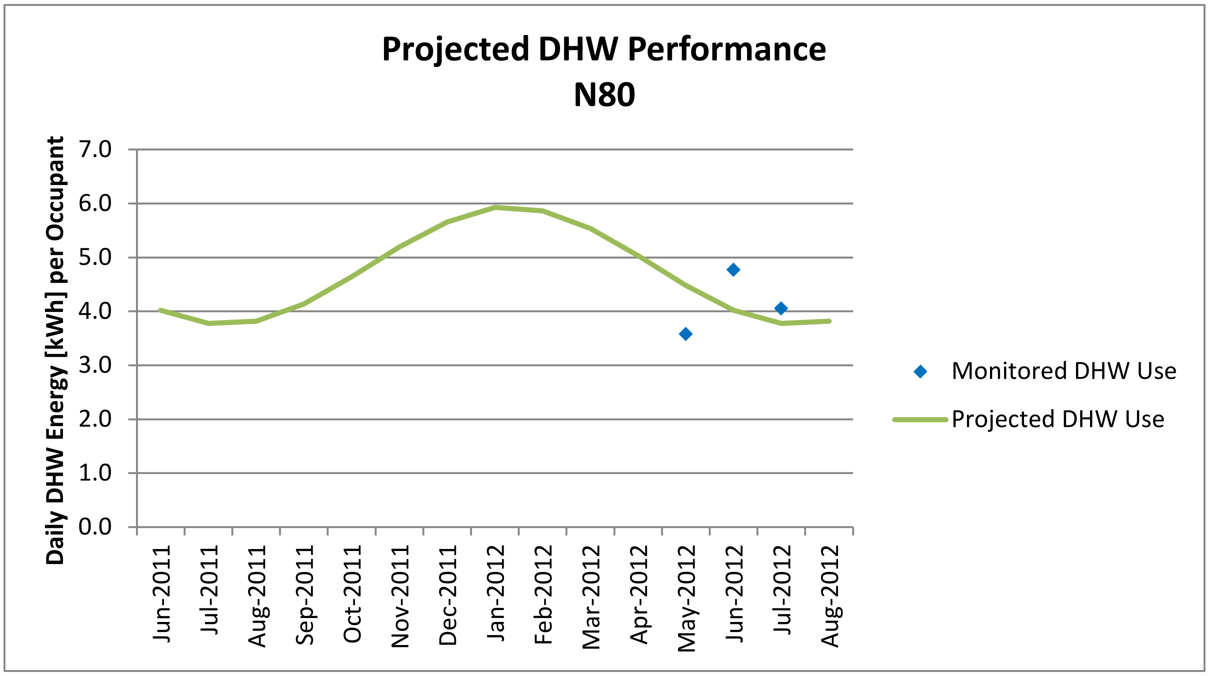

Figure A-89 Projected DHW Performance, N80

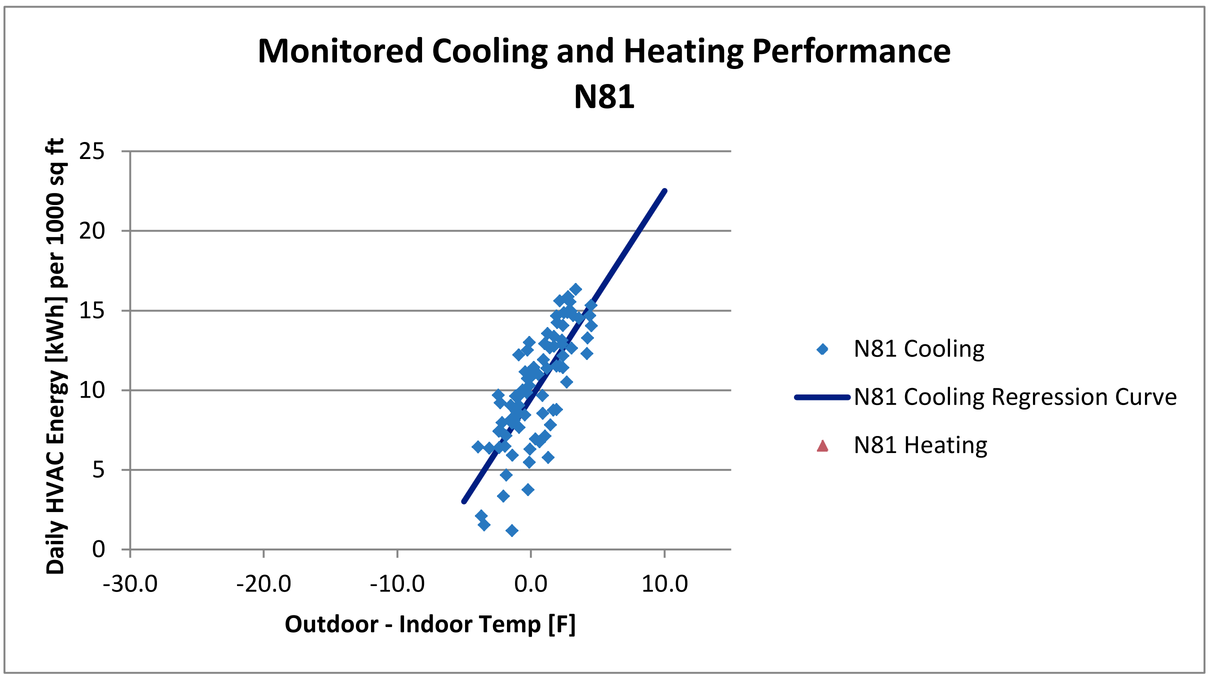

Figure A-90 Monitored Cooling and Heating Performance, N81

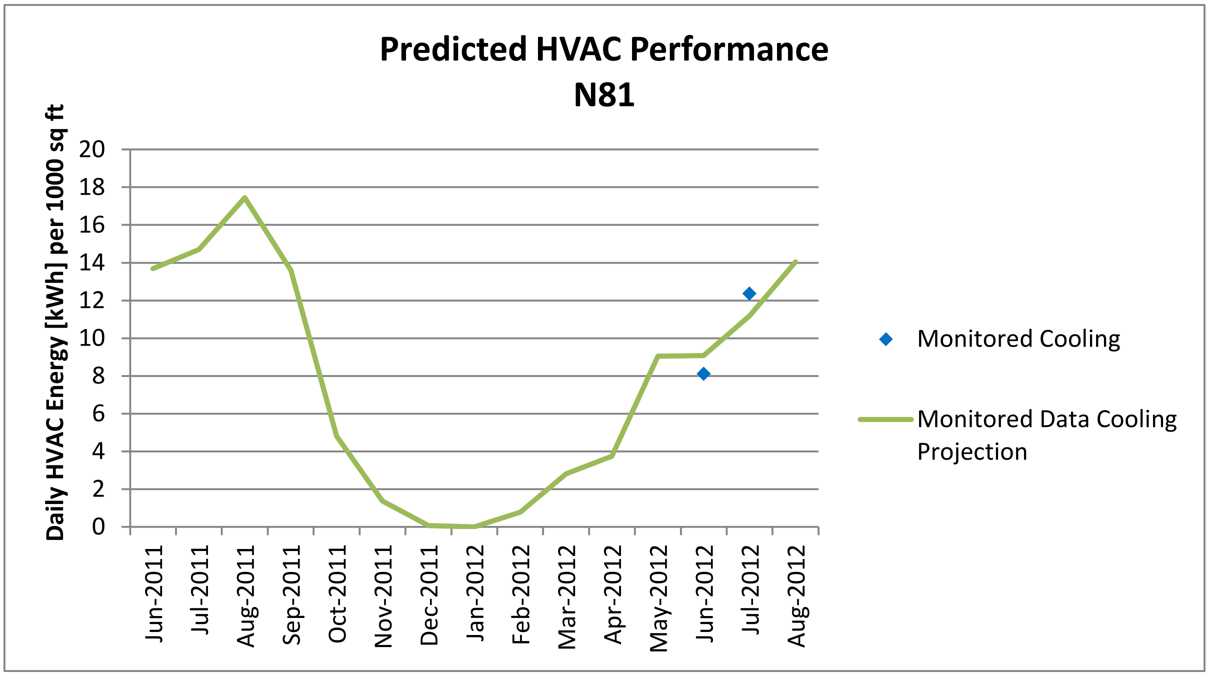

Figure A-91 Predicted HVAC Performance, N81

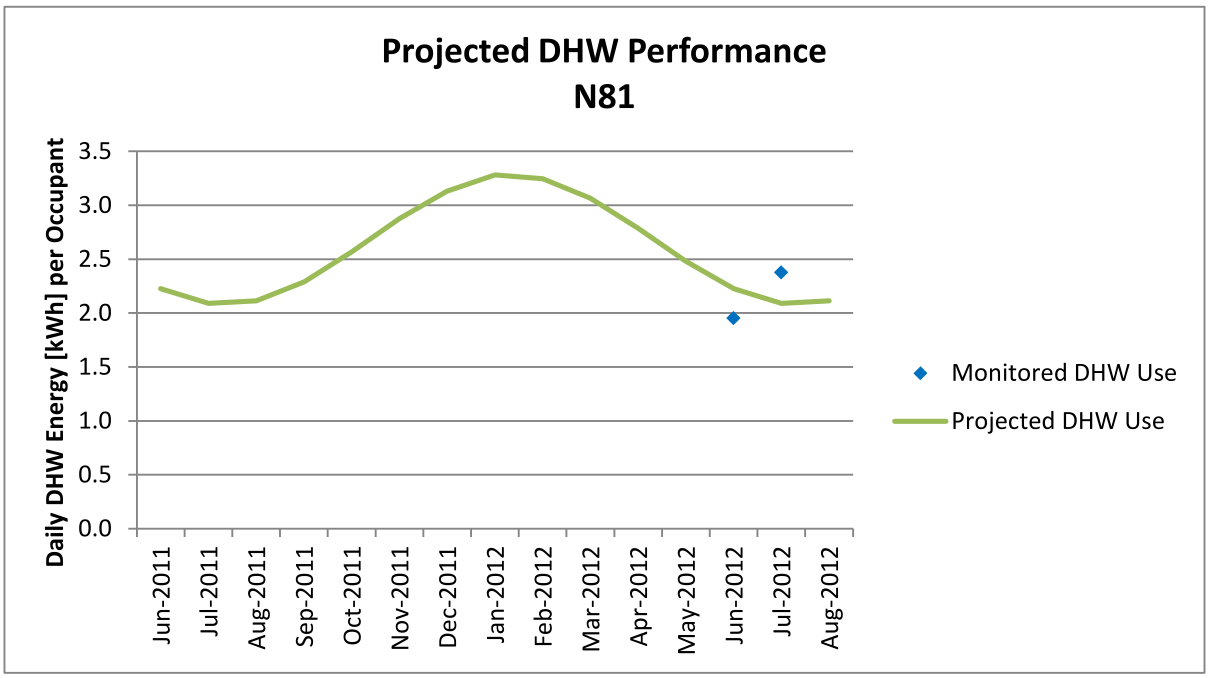

Figure A-92 Projected DHW Performance, N81

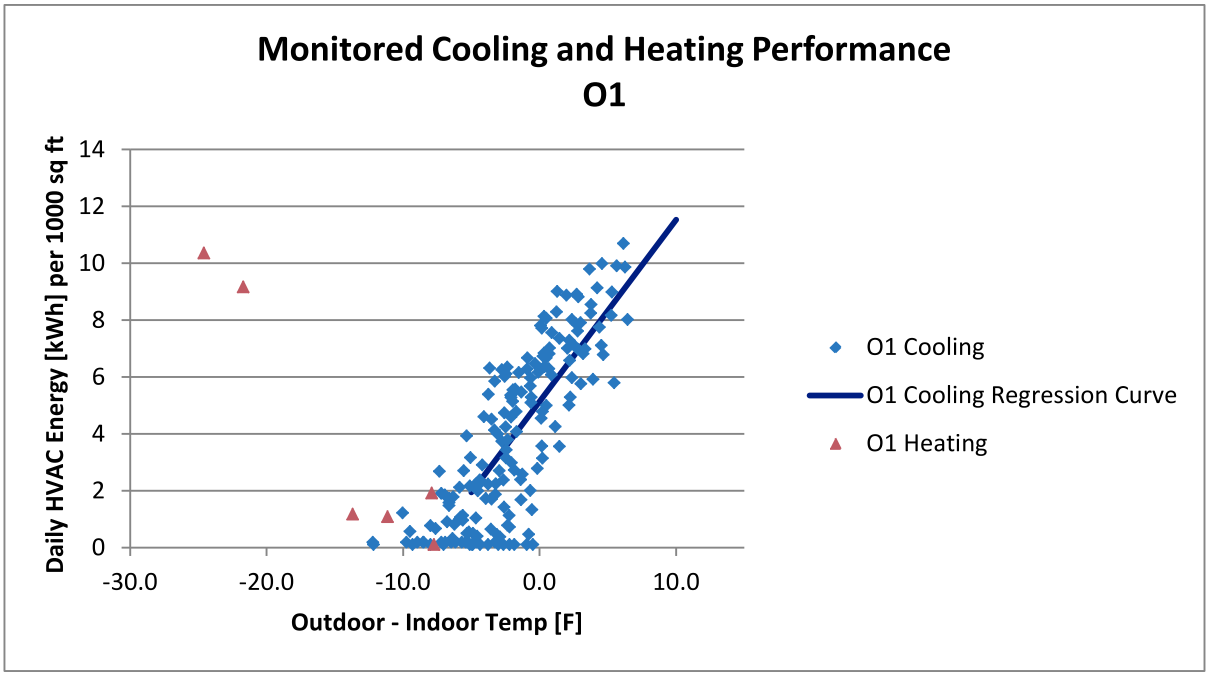

Figure A-93 Monitored Cooling and Heating Performance, O1

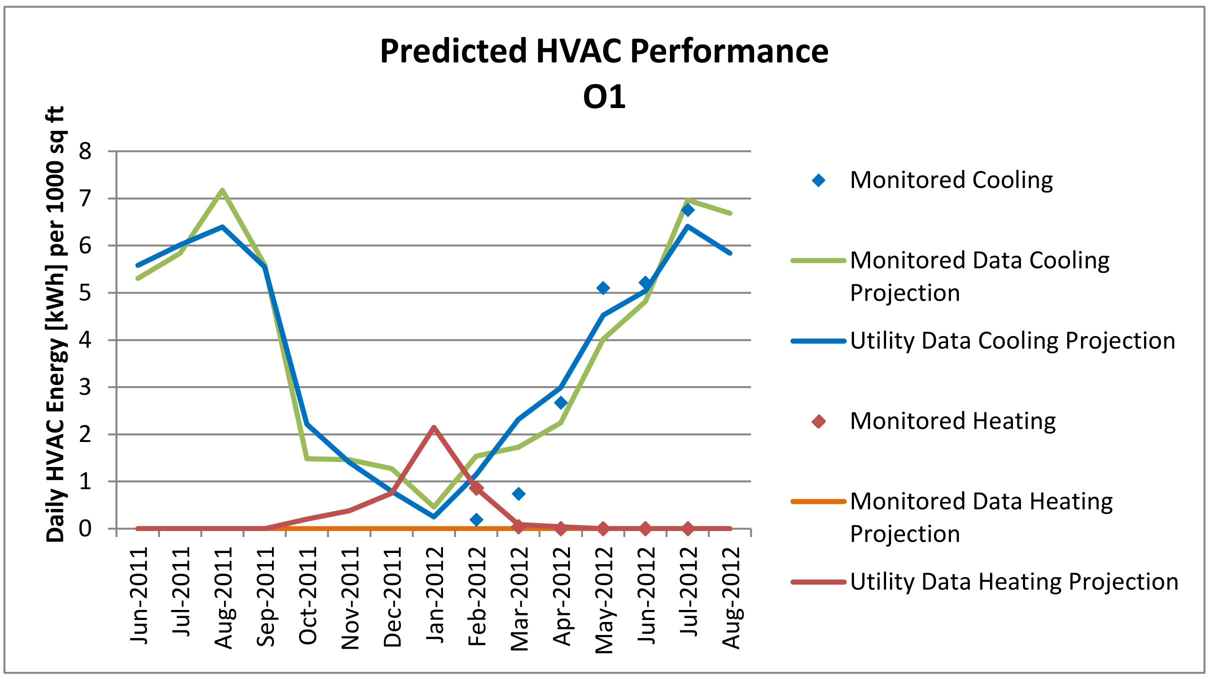

Figure A-94 Predicted HVAC Performance, O1

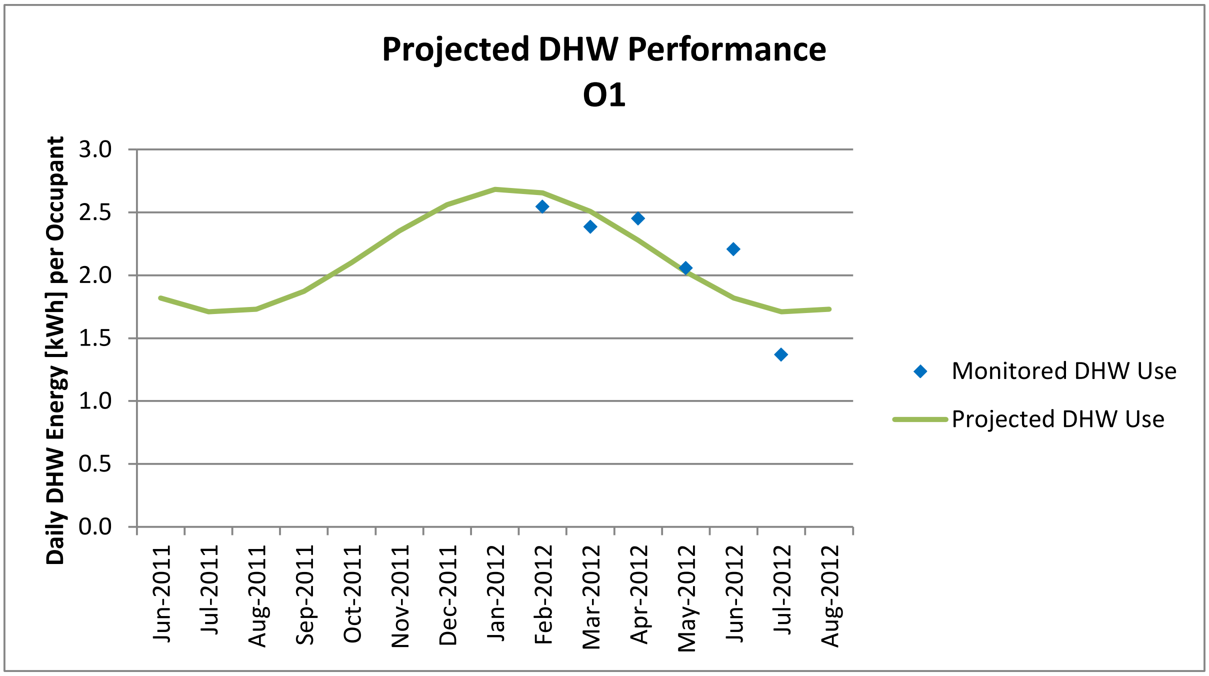

Figure A-95 Projected DHW Performance, O1

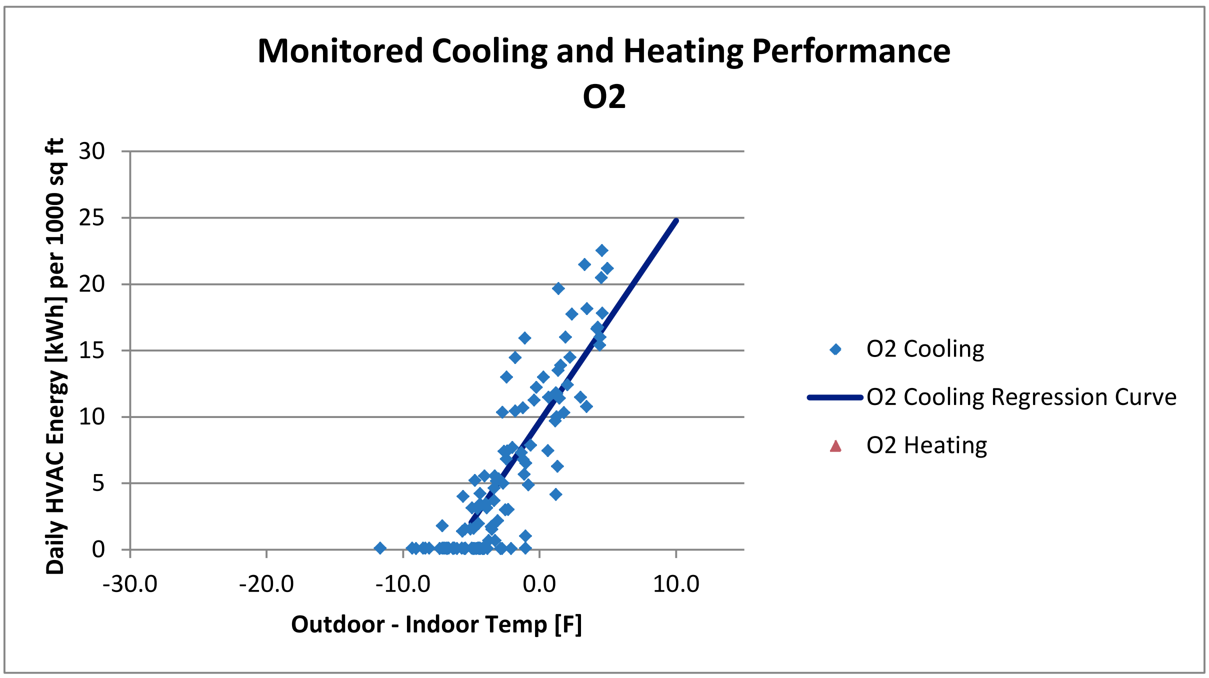

Figure A-96 Monitored Cooling and Heating Performance, O2

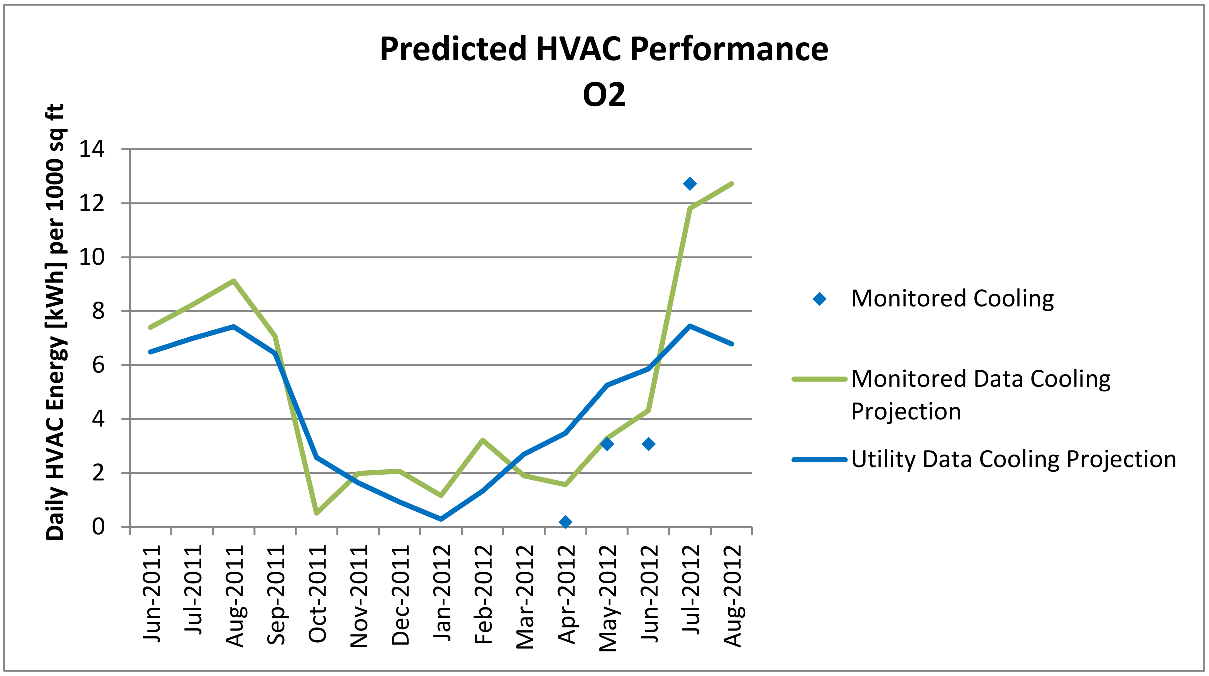

Figure A-97 Predicted HVAC Performance, O2

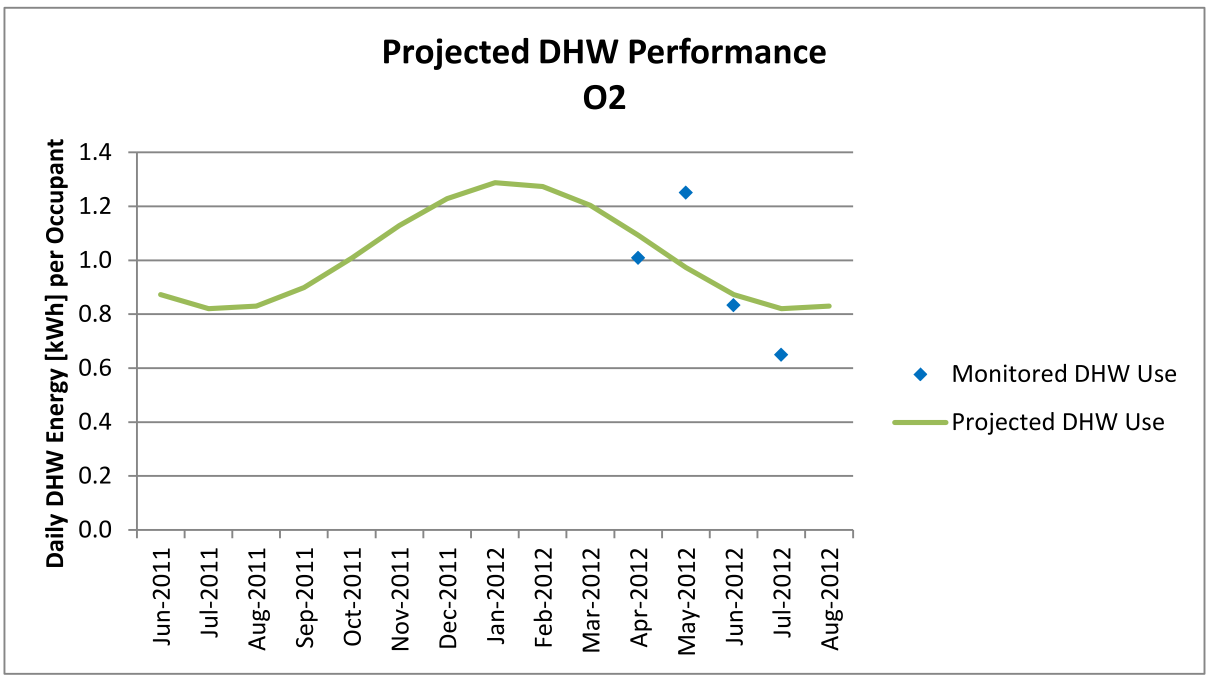

Figure A-98 Projected DHW Performance, O2

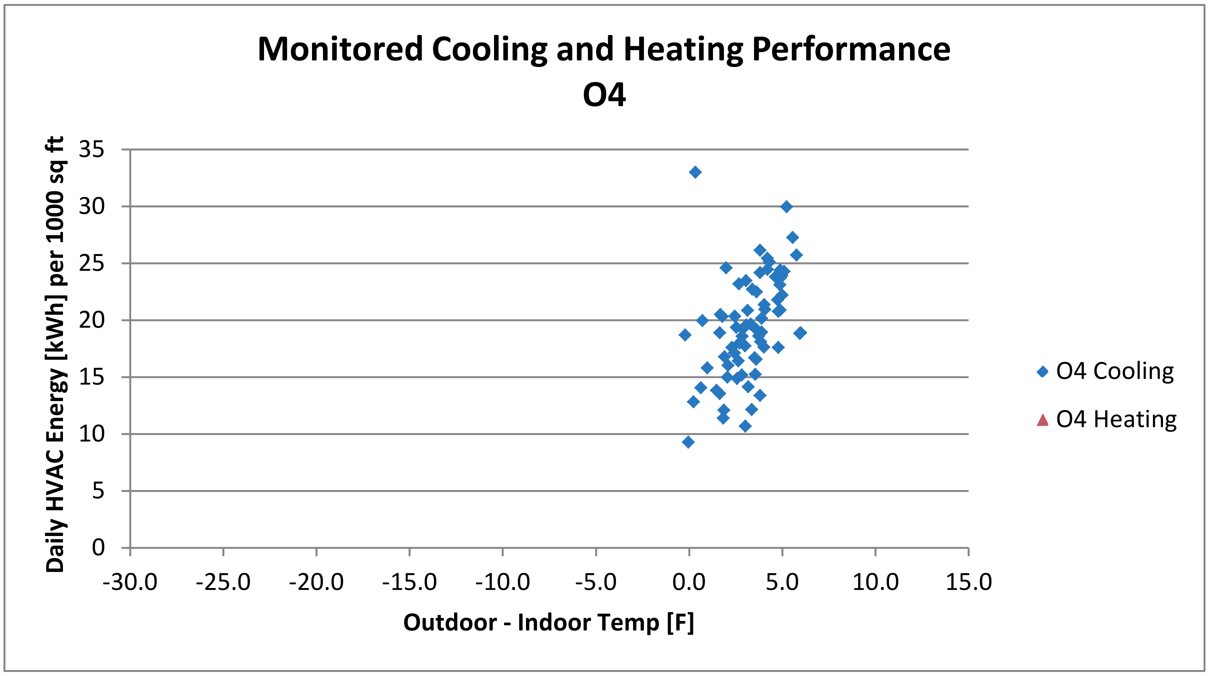

Figure A-99 Monitored Cooling and Heating Performance, O4

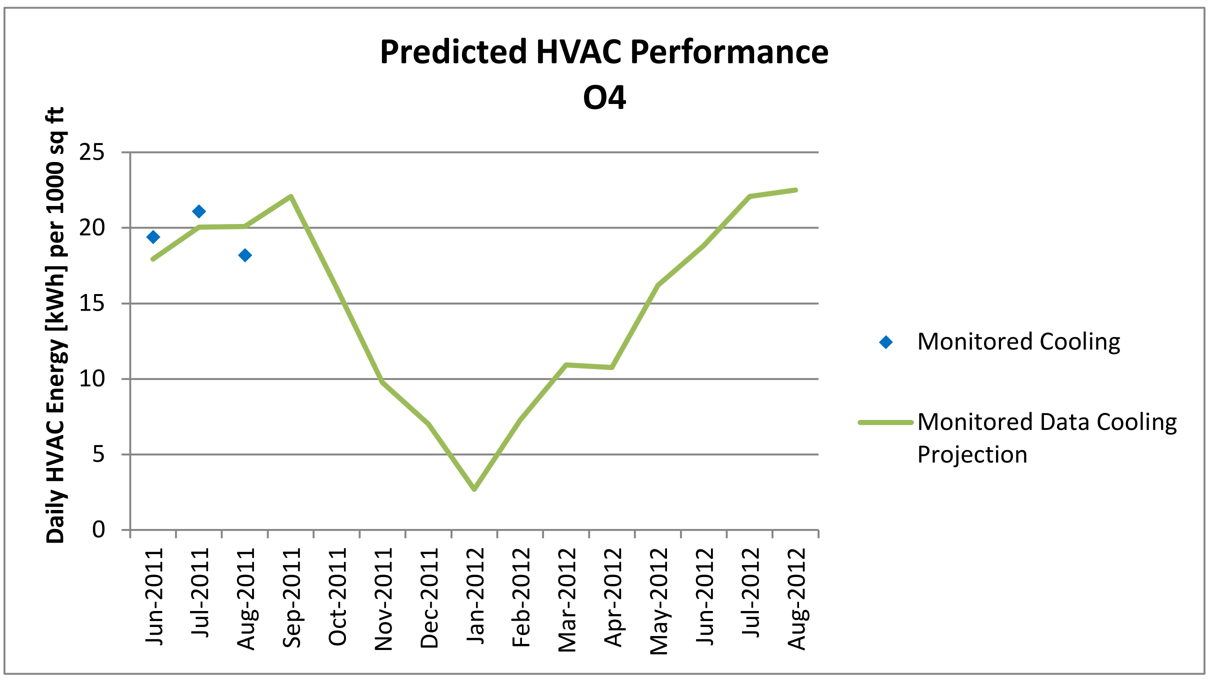

Figure A-100 Predicted HVAC Performance, O4

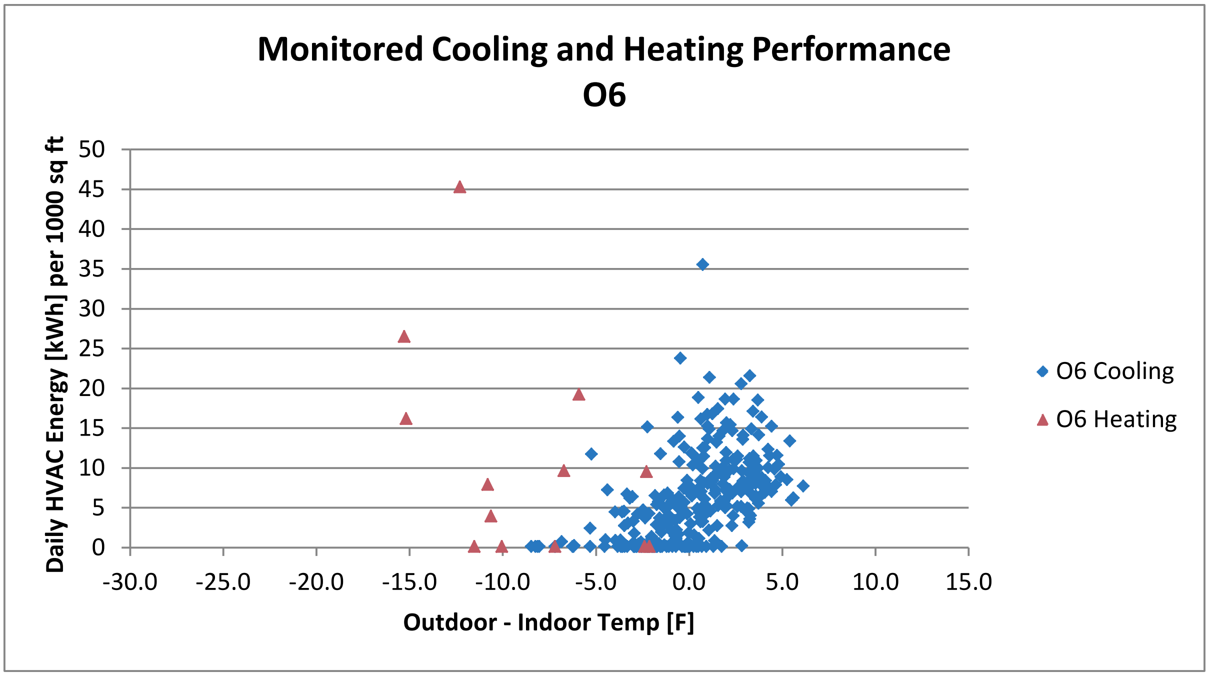

Figure A-101 Monitored Cooling and Heating Performance, O6

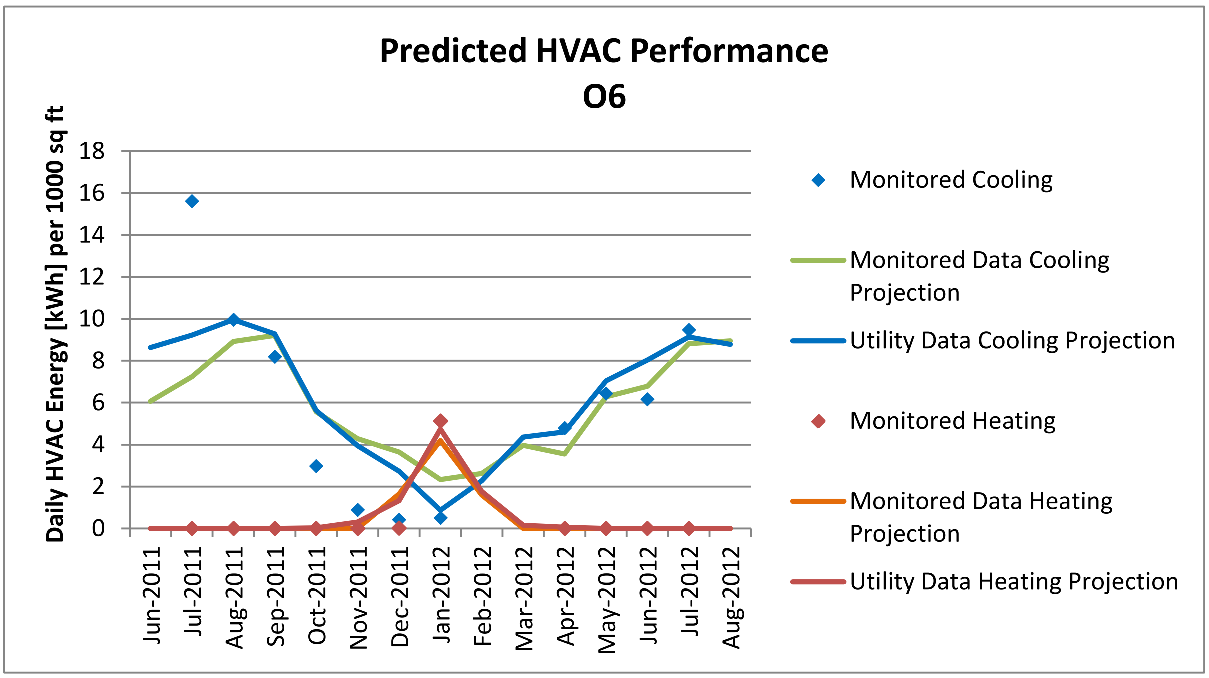

Figure A-102 Predicted HVAC Performance, O6

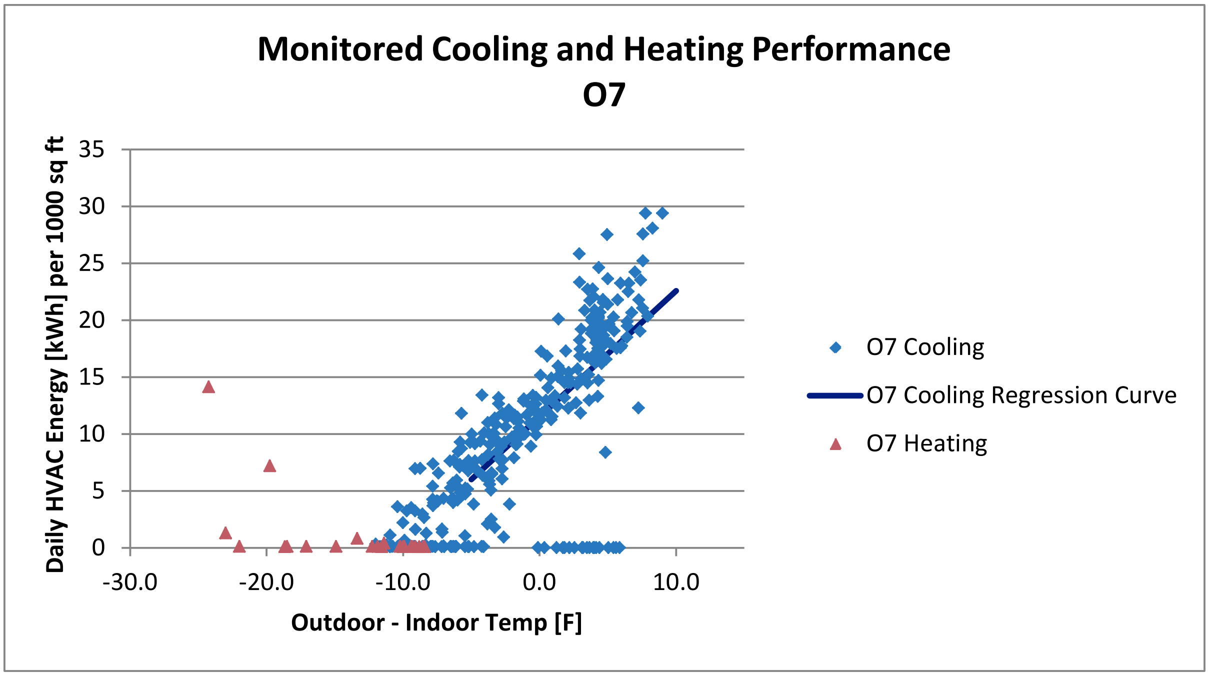

Figure A-103 Monitored Cooling and Heating Performance, O7

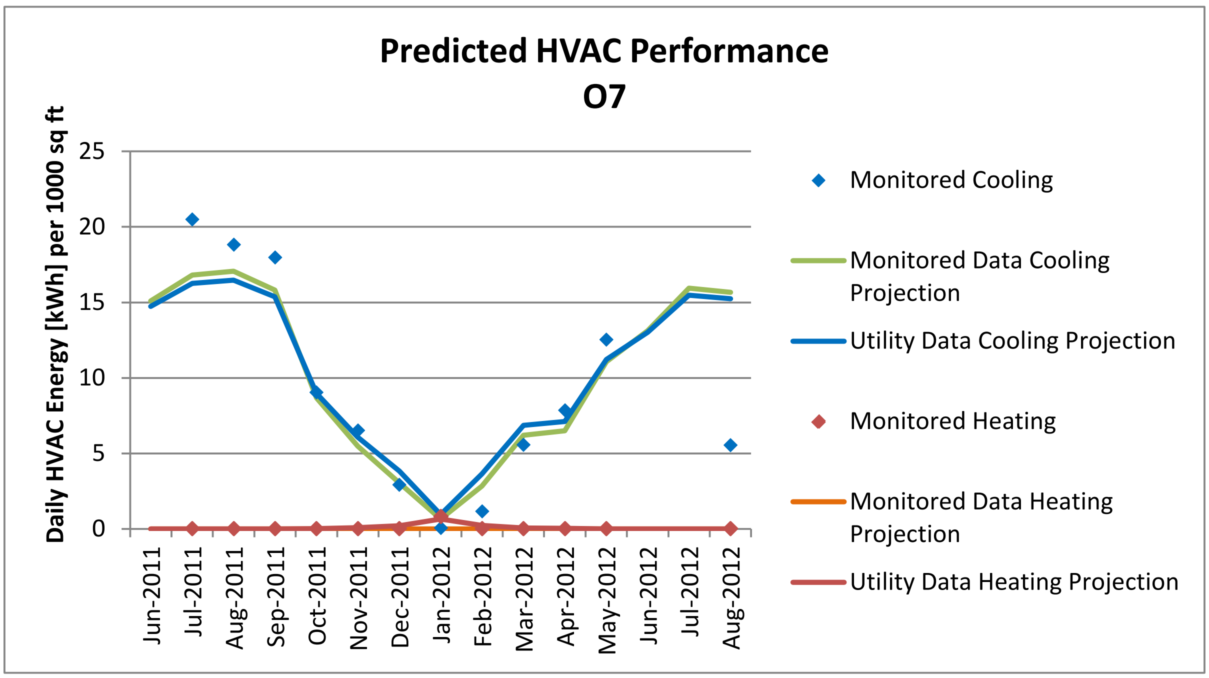

Figure A-104 Predicted HVAC Performance, O7

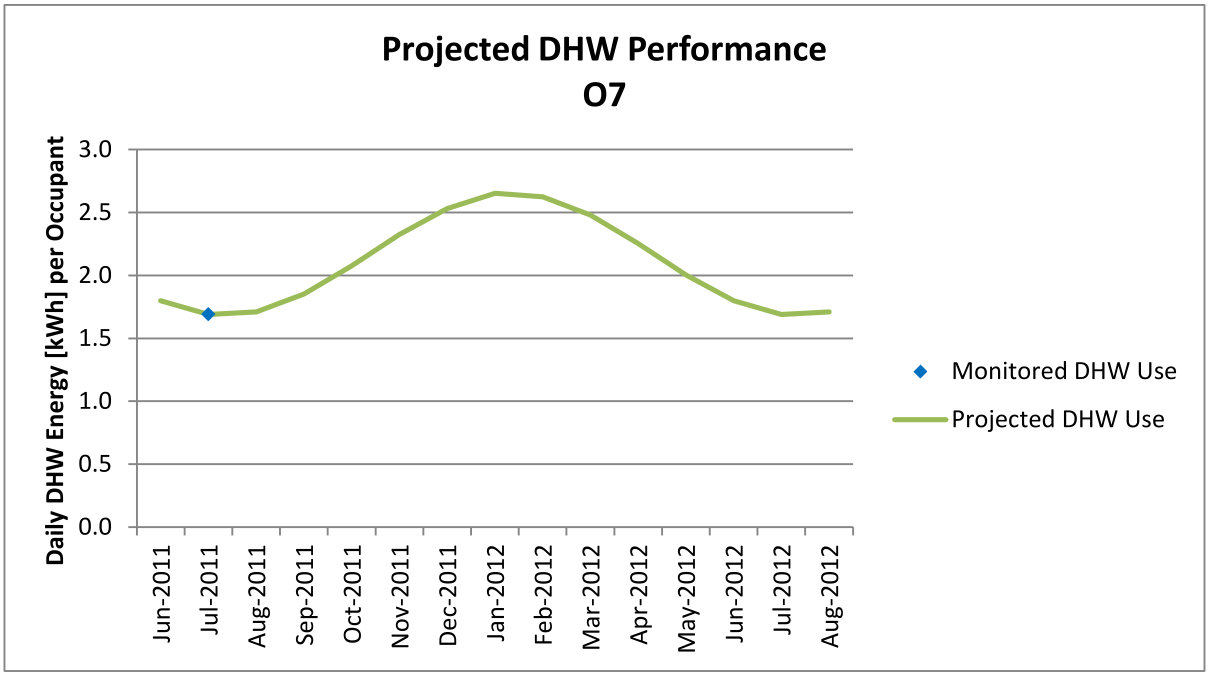

Figure A-105 Projected DHW Performance, O7

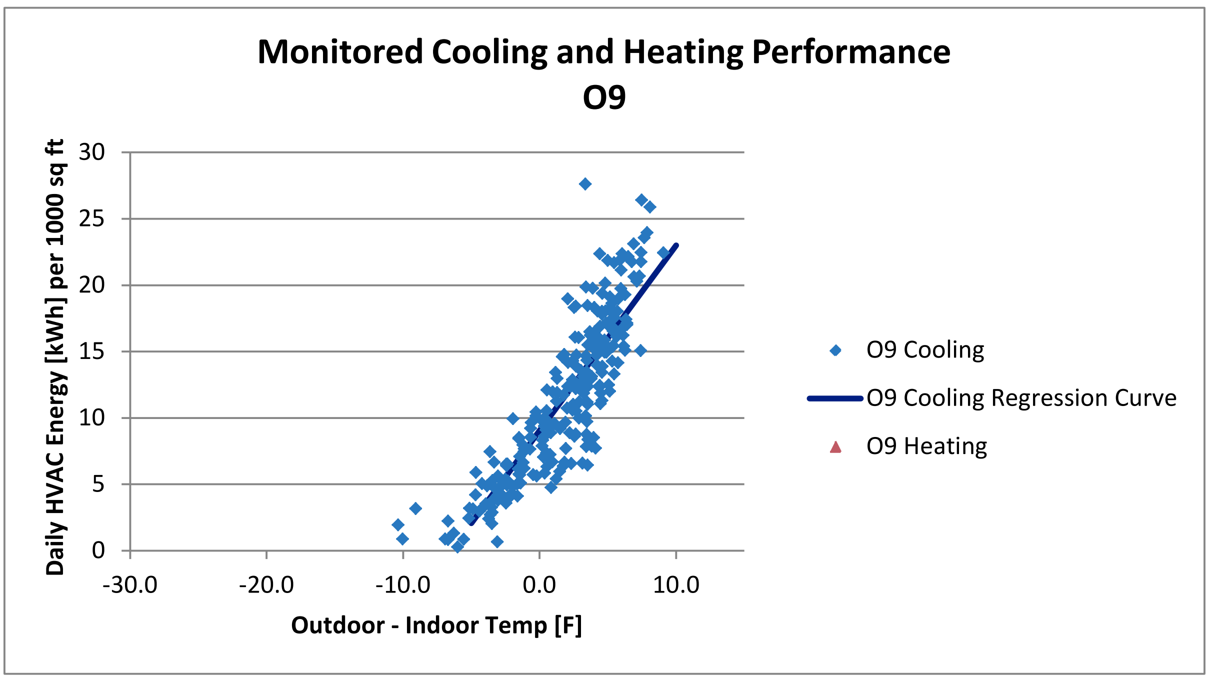

Figure A-106 Monitored Cooling and Heating Performance, O9

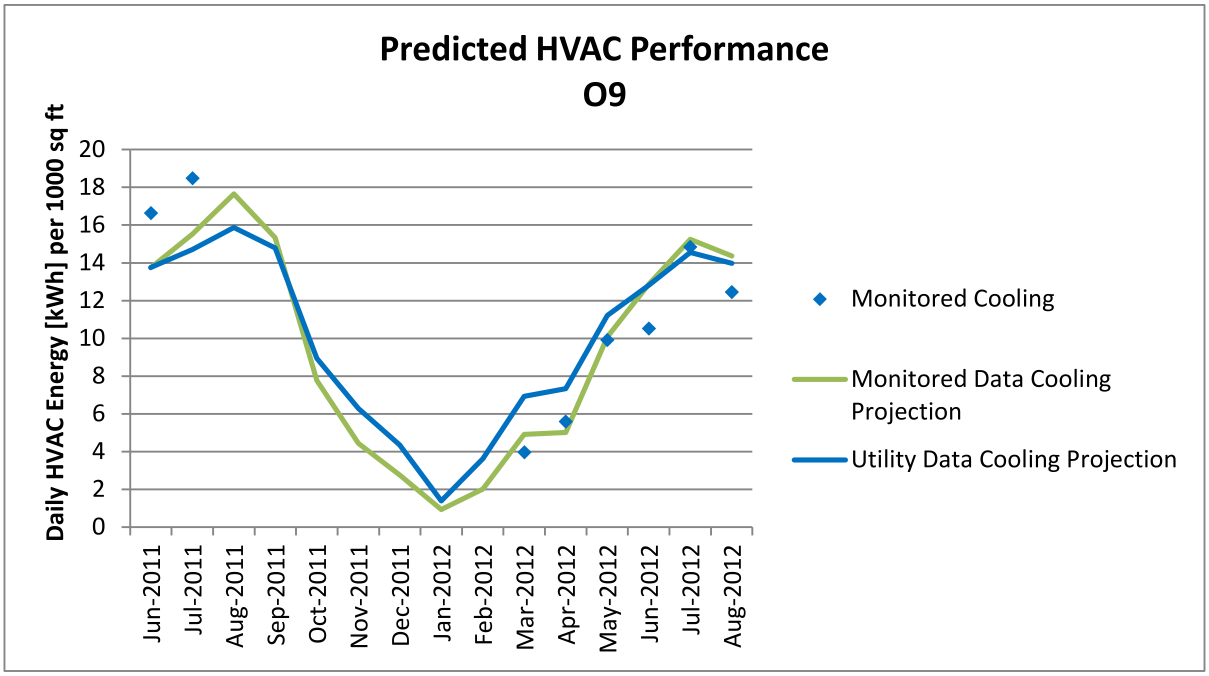

Figure A-107 Predicted HVAC Performance, O9

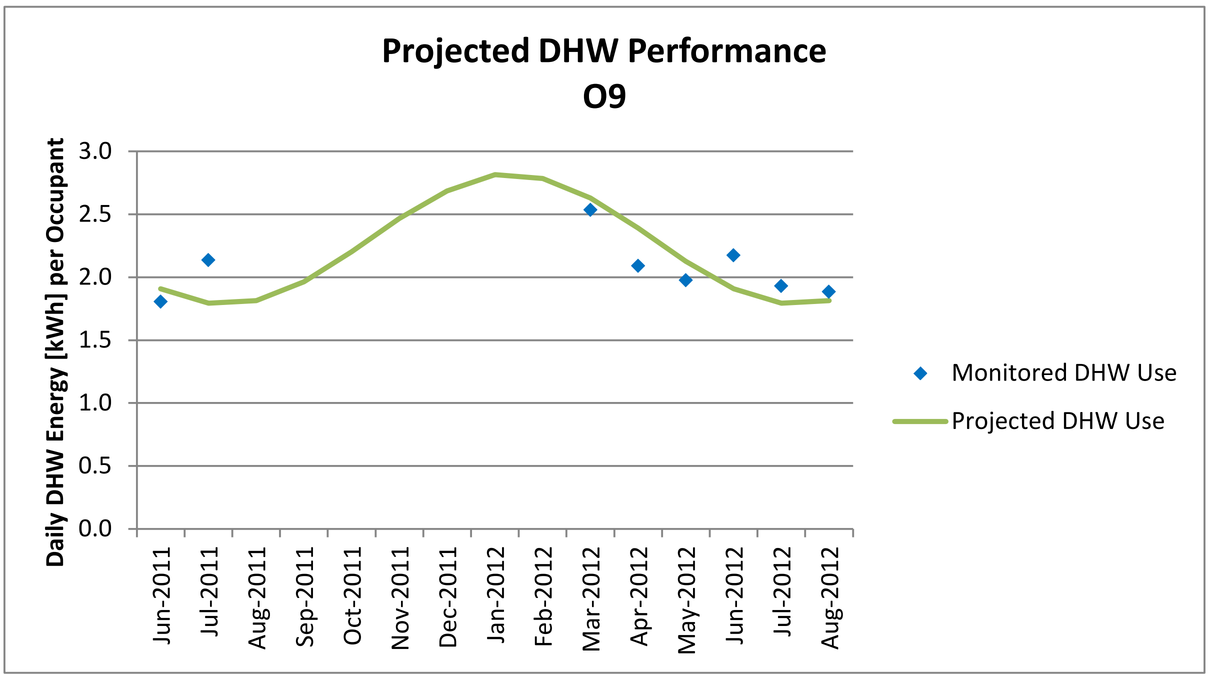

Figure A-108 Projected DHW Performance, O9

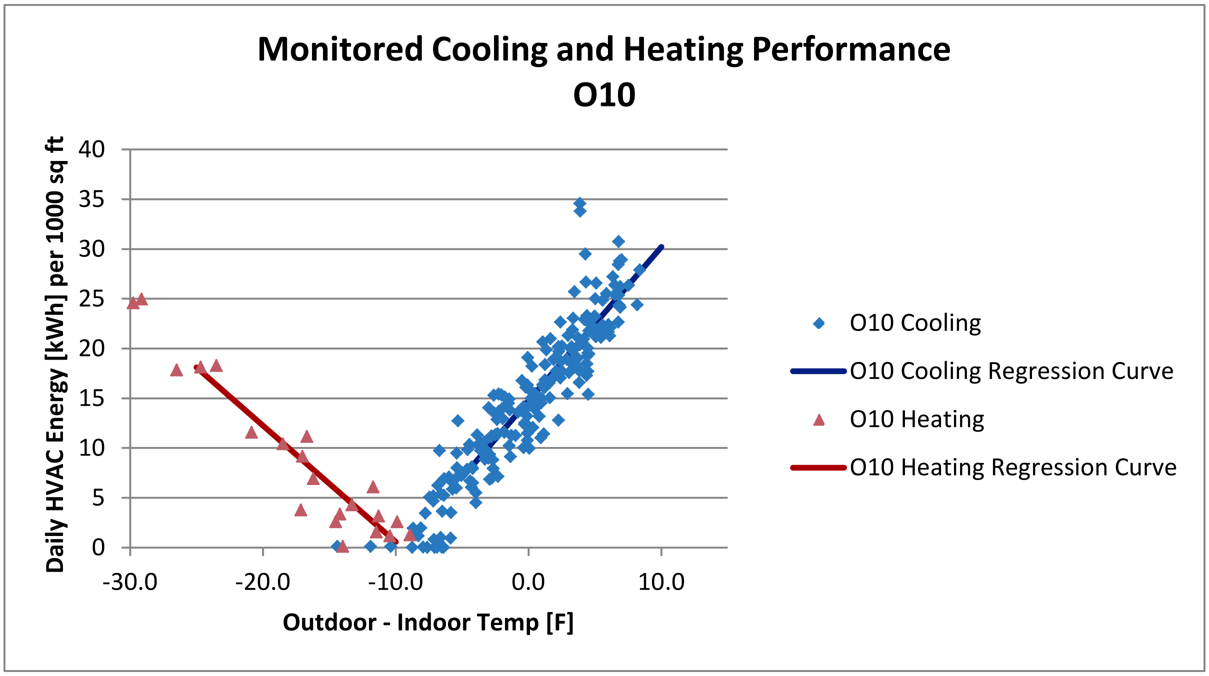

Figure A-109 Monitored Cooling and Heating Performance, O10

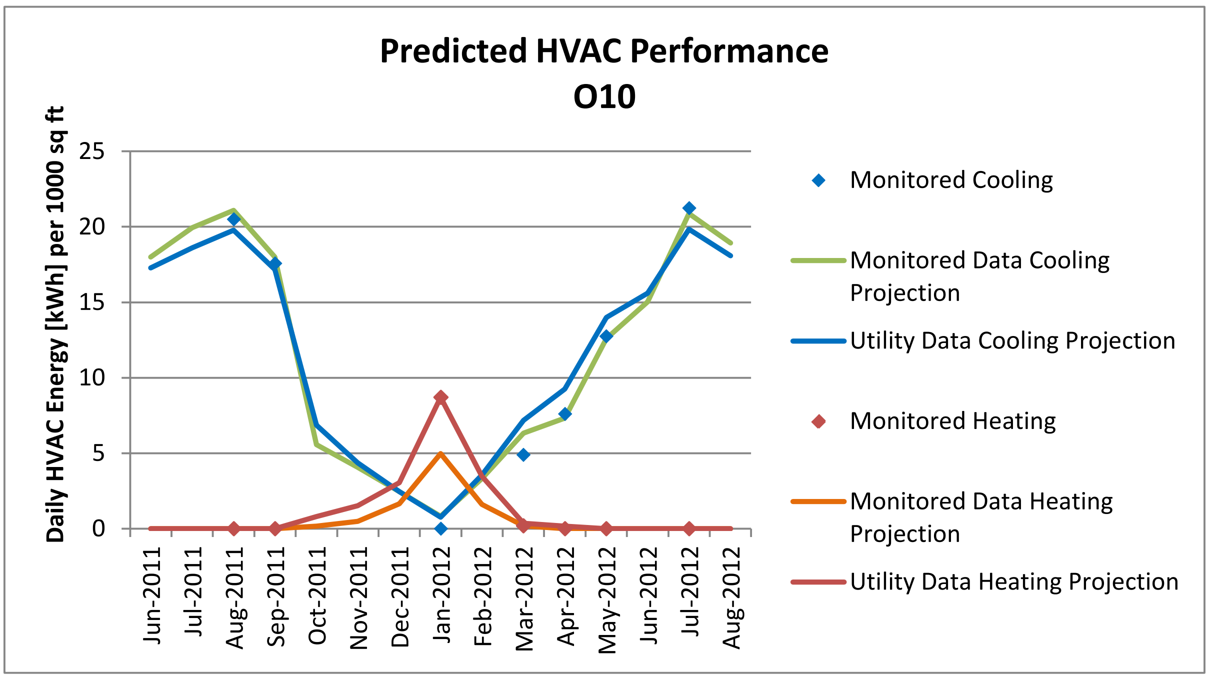

Figure A-110 Predicted HVAC Performance, O10

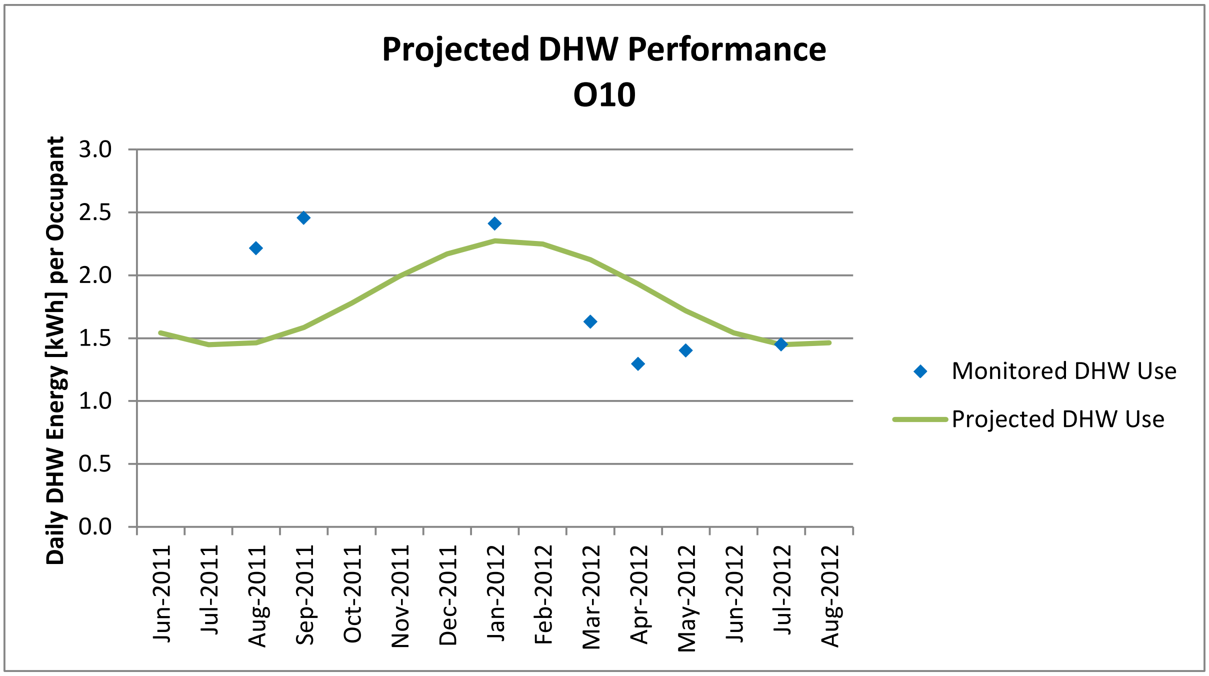

Figure A-111 Projected DHW Performance, O10

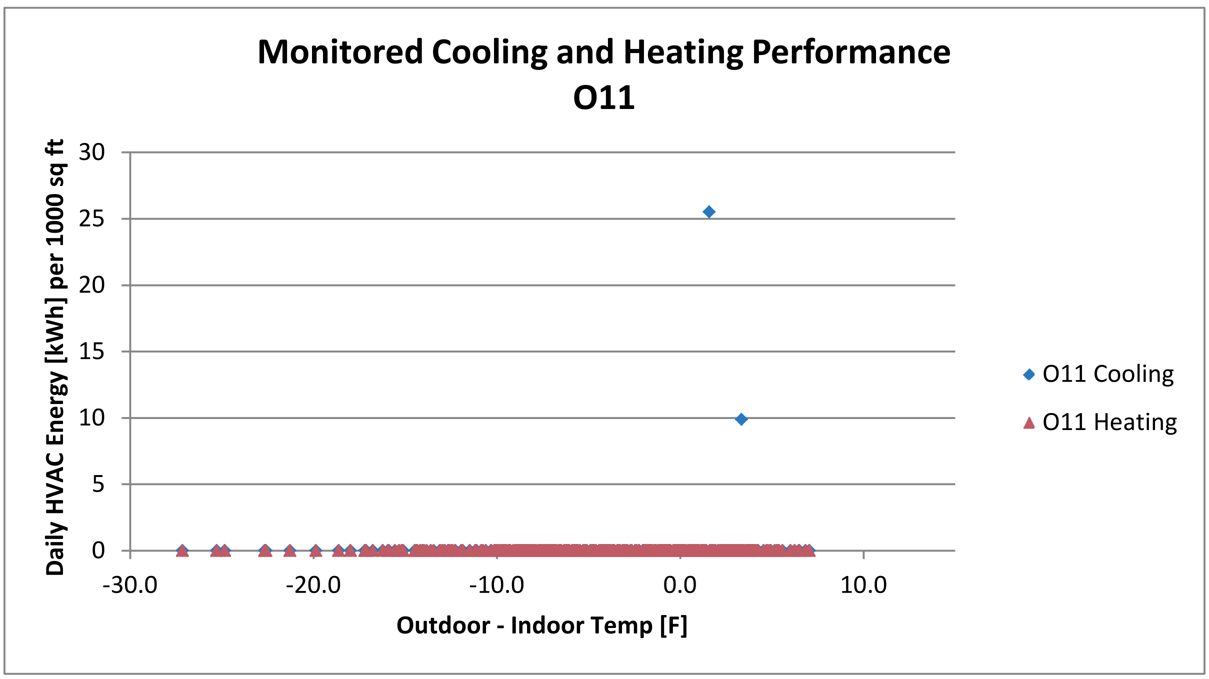

Figure A-112 Monitored Cooling and Heating Performance, O11

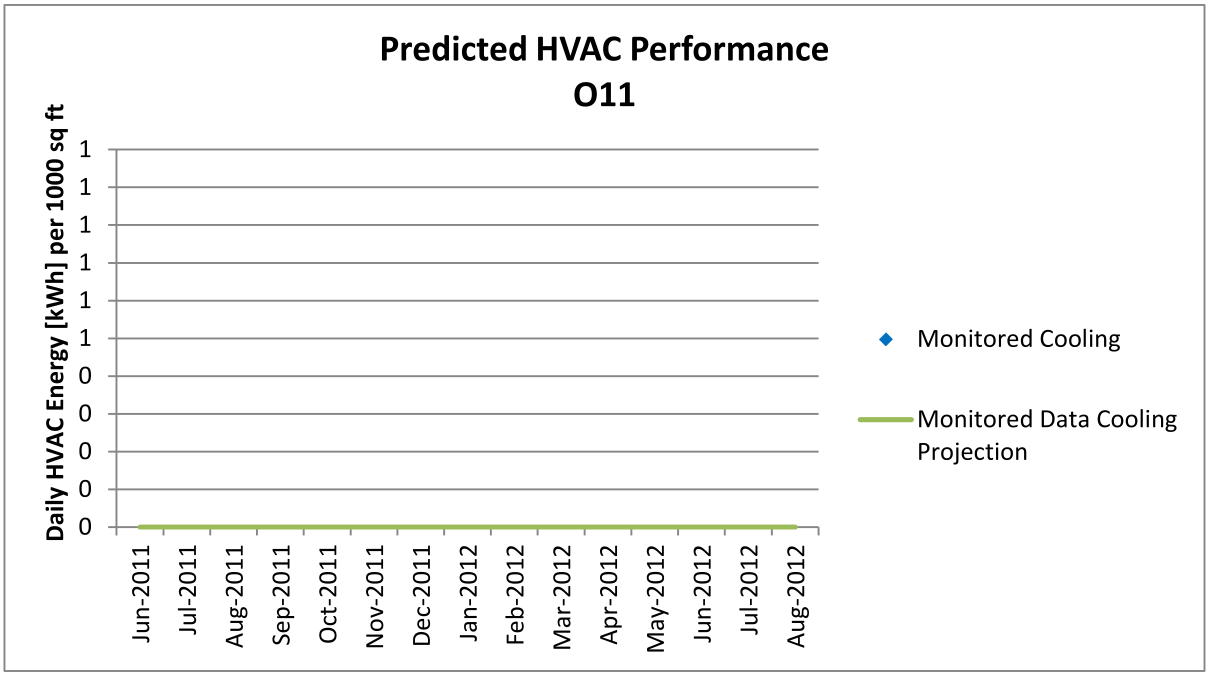

Figure A-113 Predicted HVAC Performance, O11

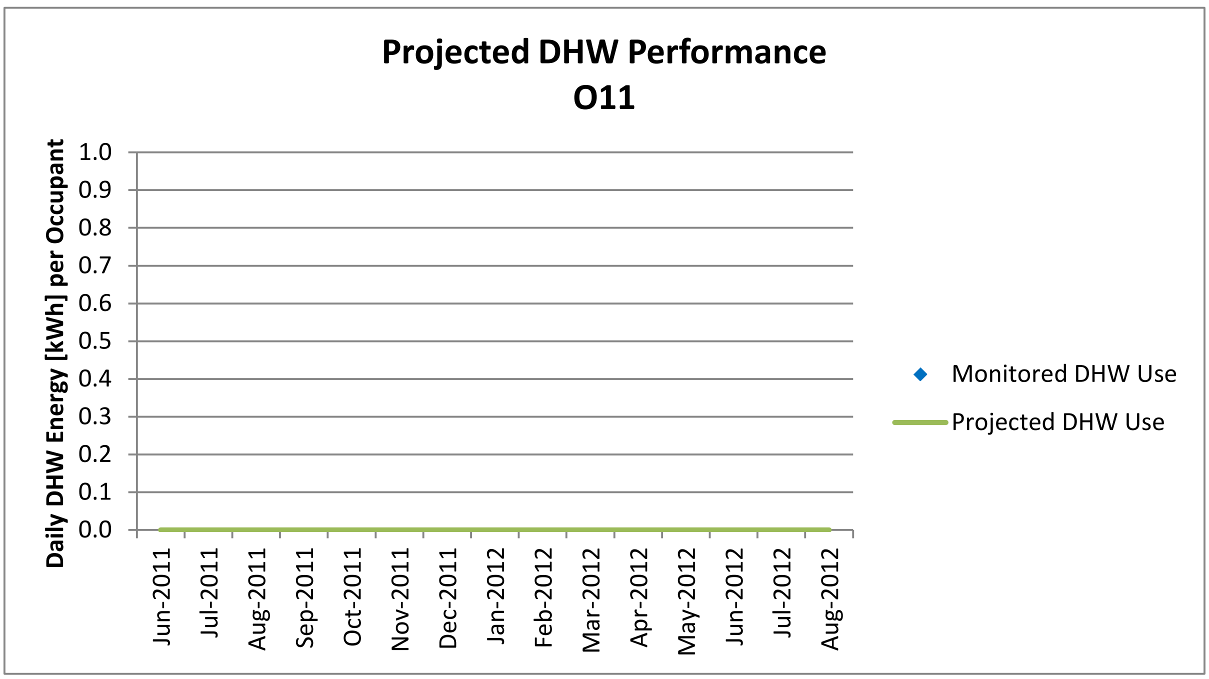

Figure A-114 Projected DHW Performance, O11

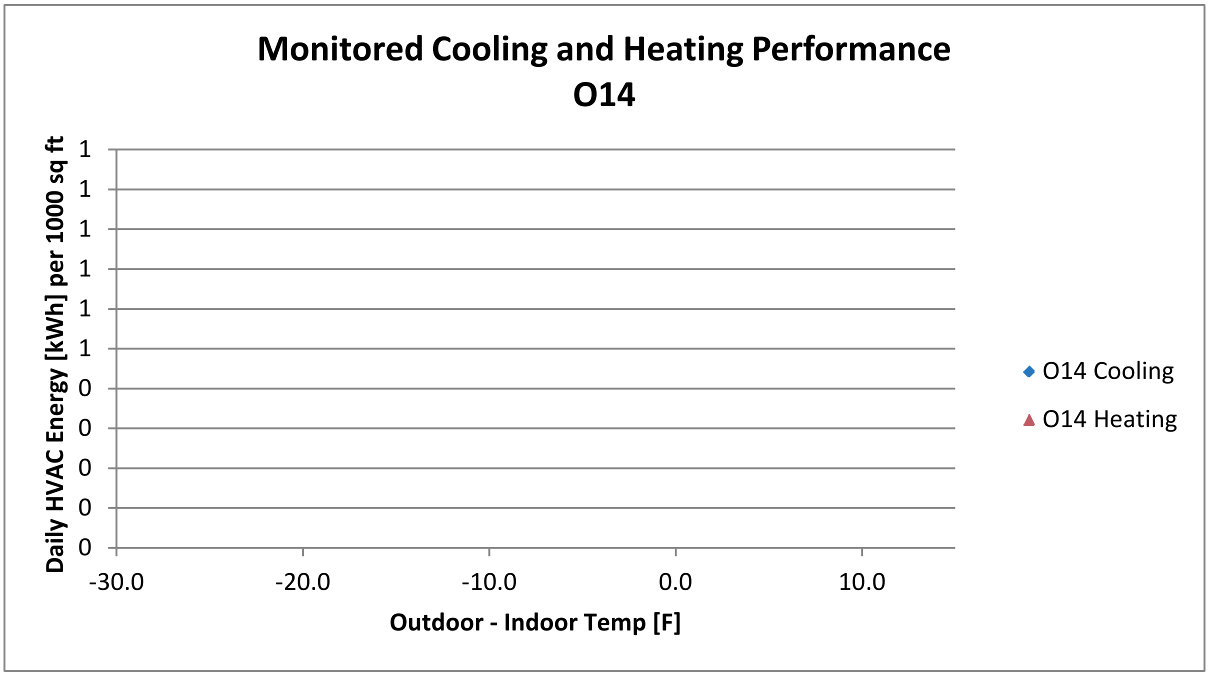

Figure A-115 Monitored Cooling and Heating Performance, O14

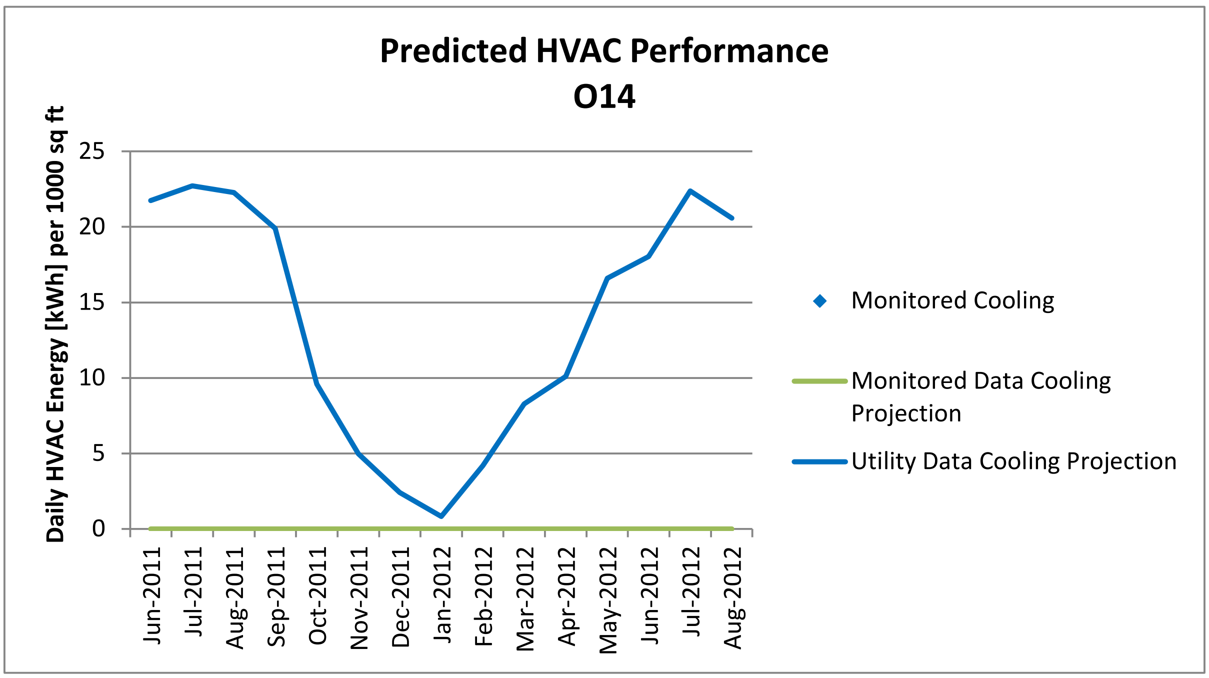

Figure A-116 Predicted HVAC Performance, O14

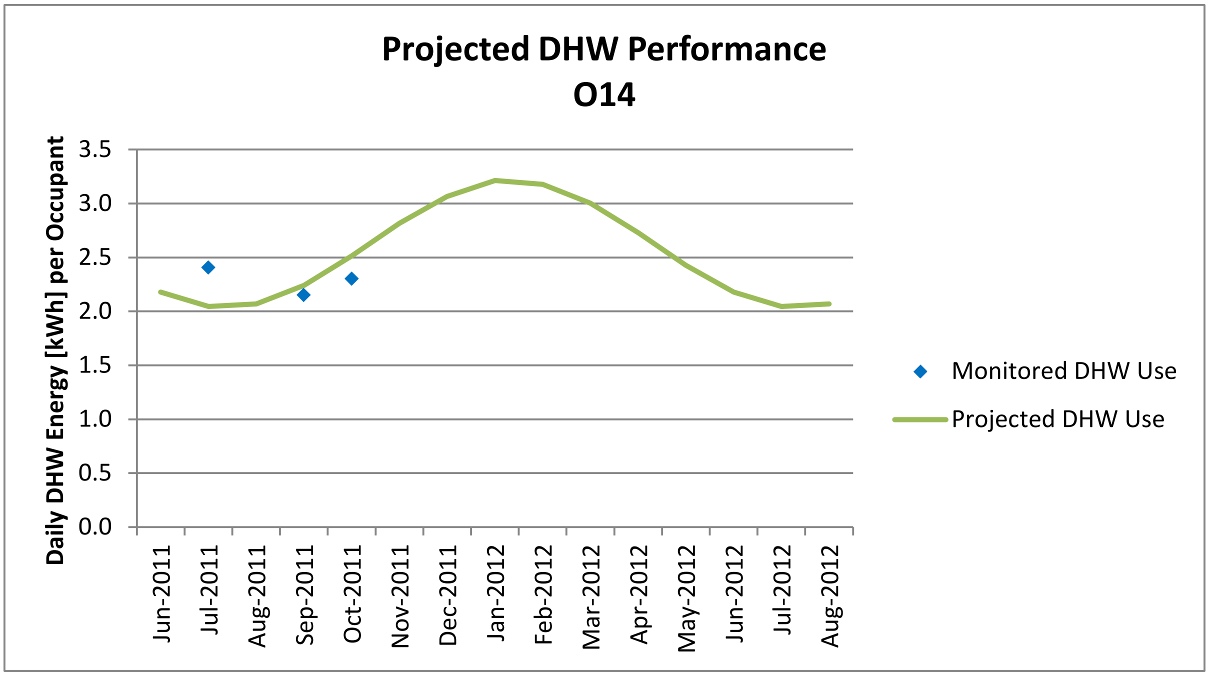

Figure A-117 Projected DHW Performance, O14

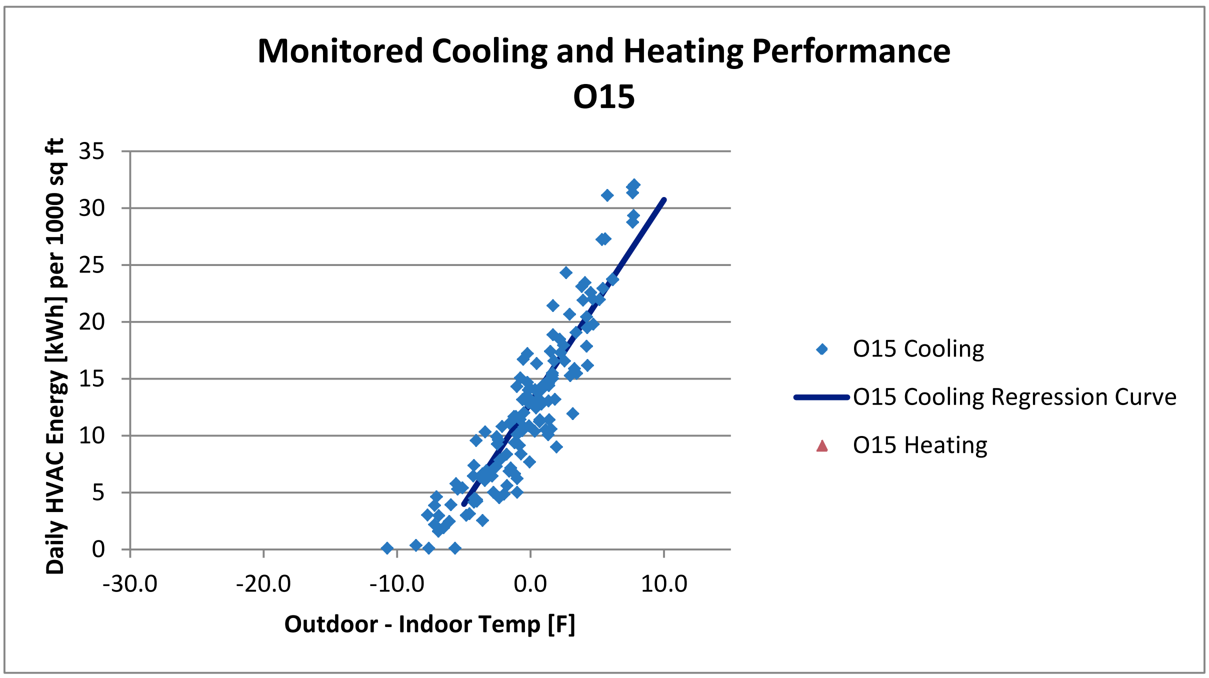

Figure A-118 Monitored Cooling and Heating Performance, O15

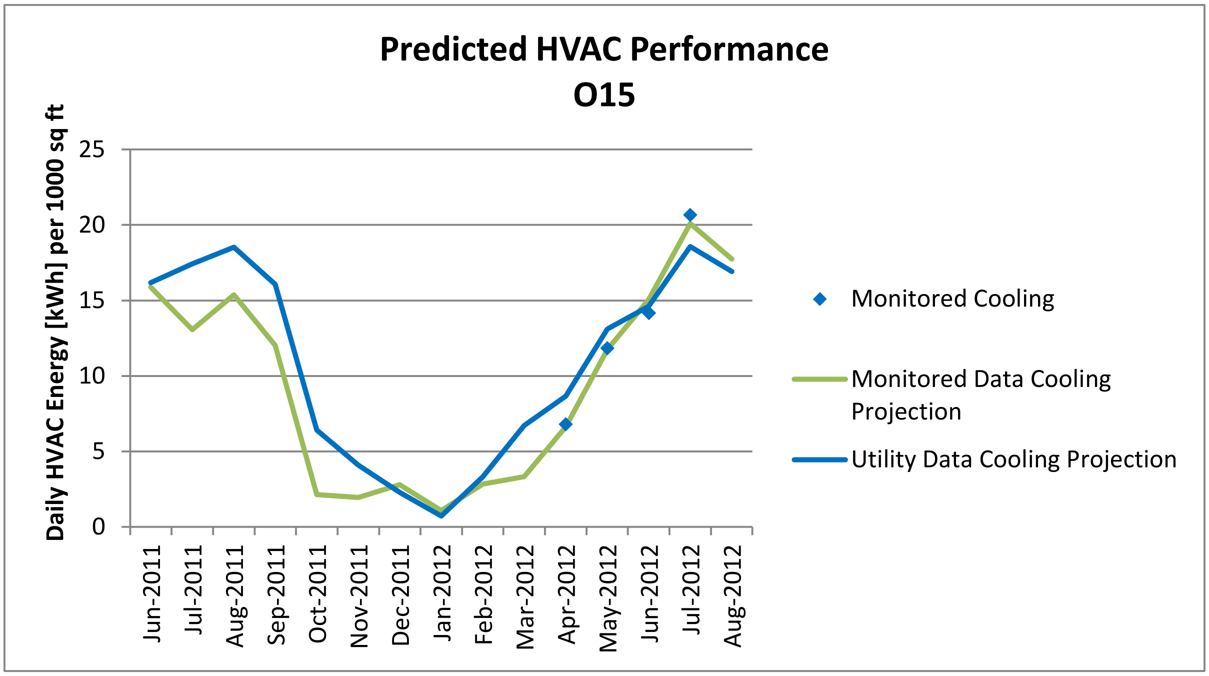

Figure A-119 Predicted HVAC Performance, O15

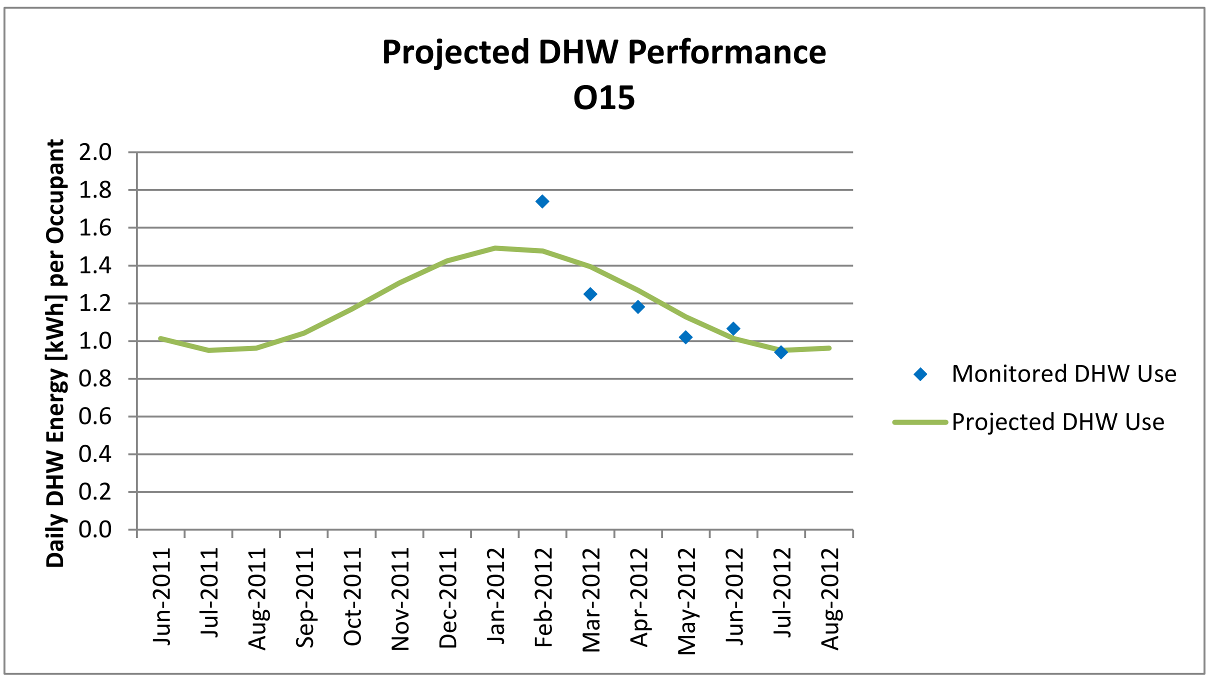

Figure A-120 Projected DHW Performance, O15

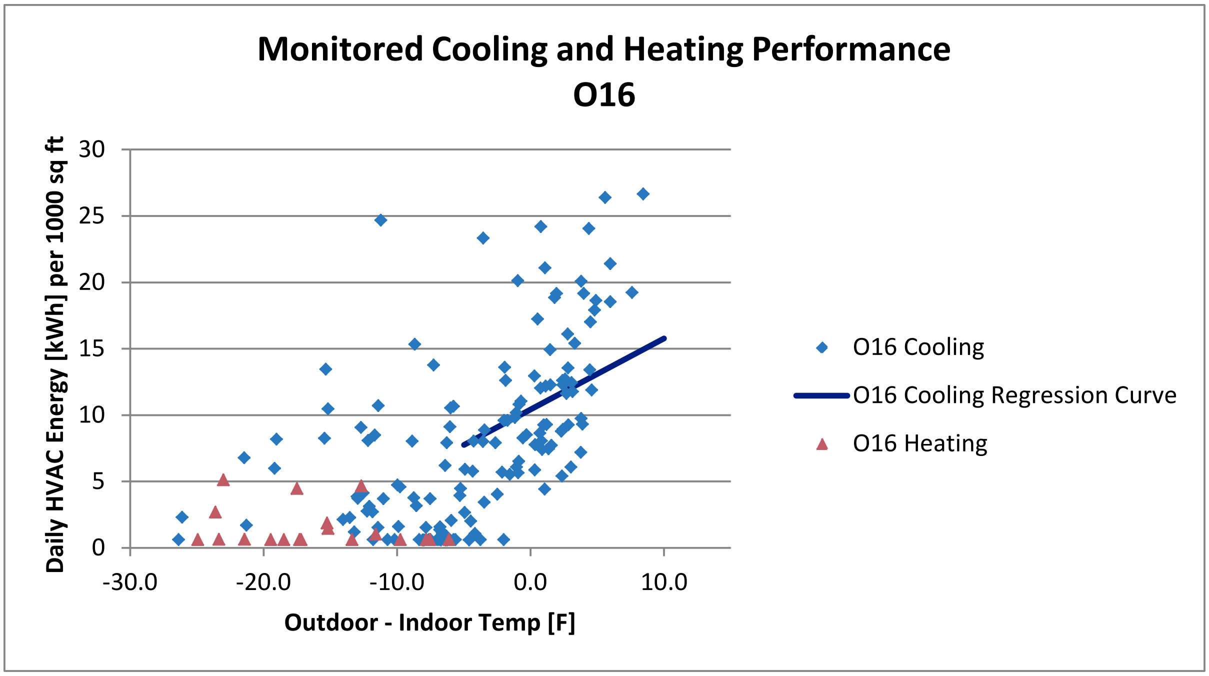

Figure A-121 Monitored Cooling and Heating Performance, O16

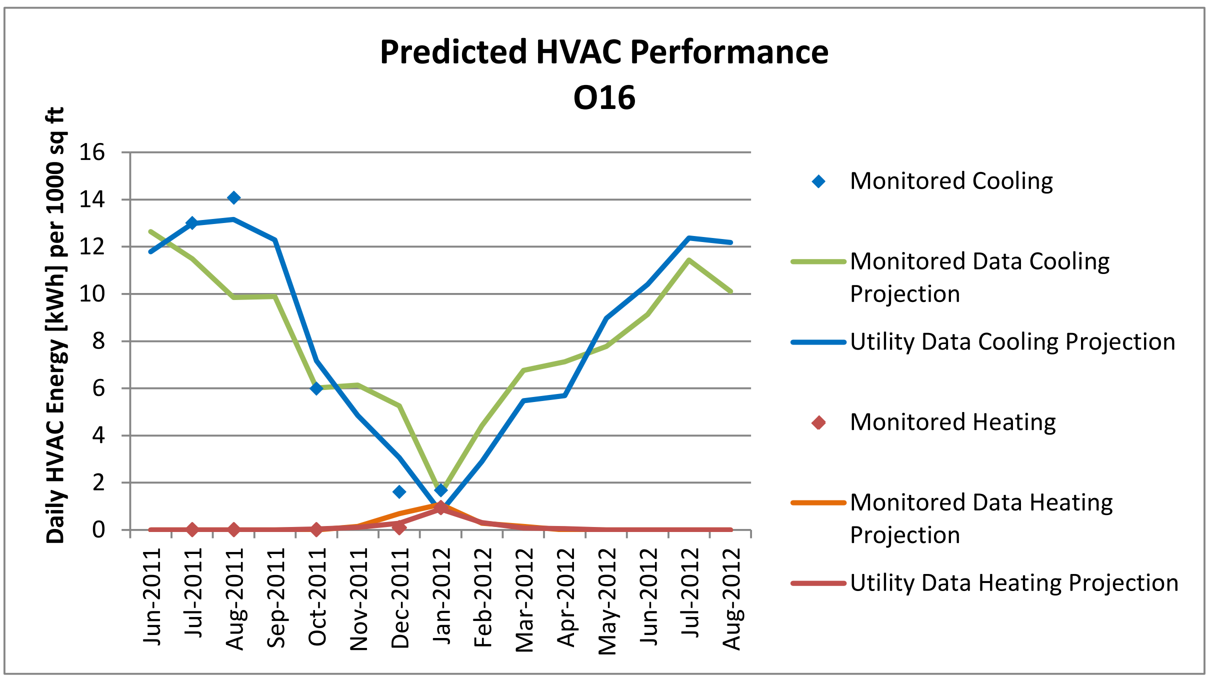

Figure A-122 Predicted HVAC Performance, O16

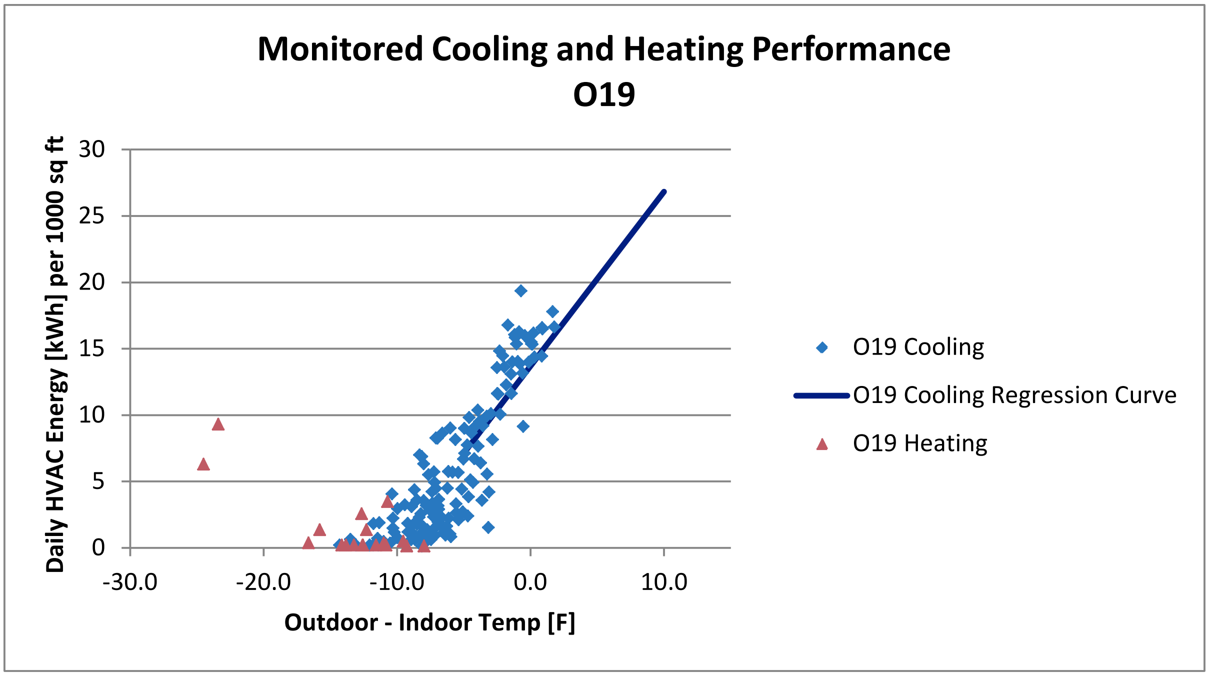

Figure A-123 Monitored Cooling and Heating Performance, O19

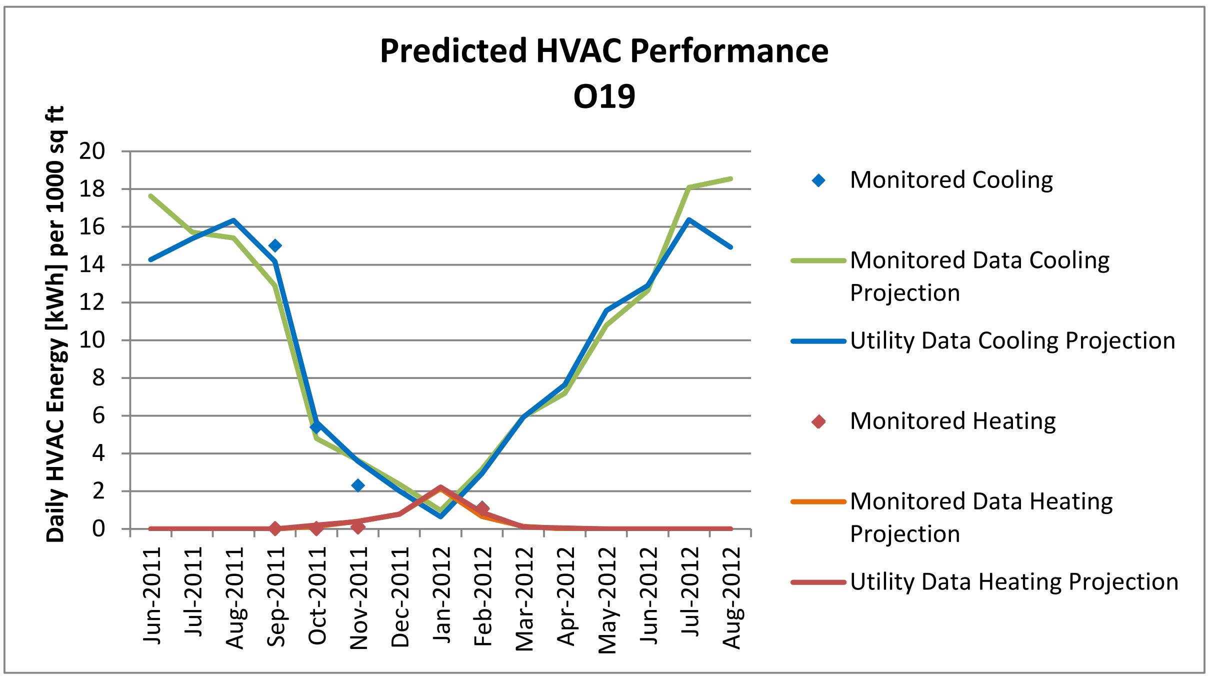

Figure A-124 Predicted HVAC Performance, O19

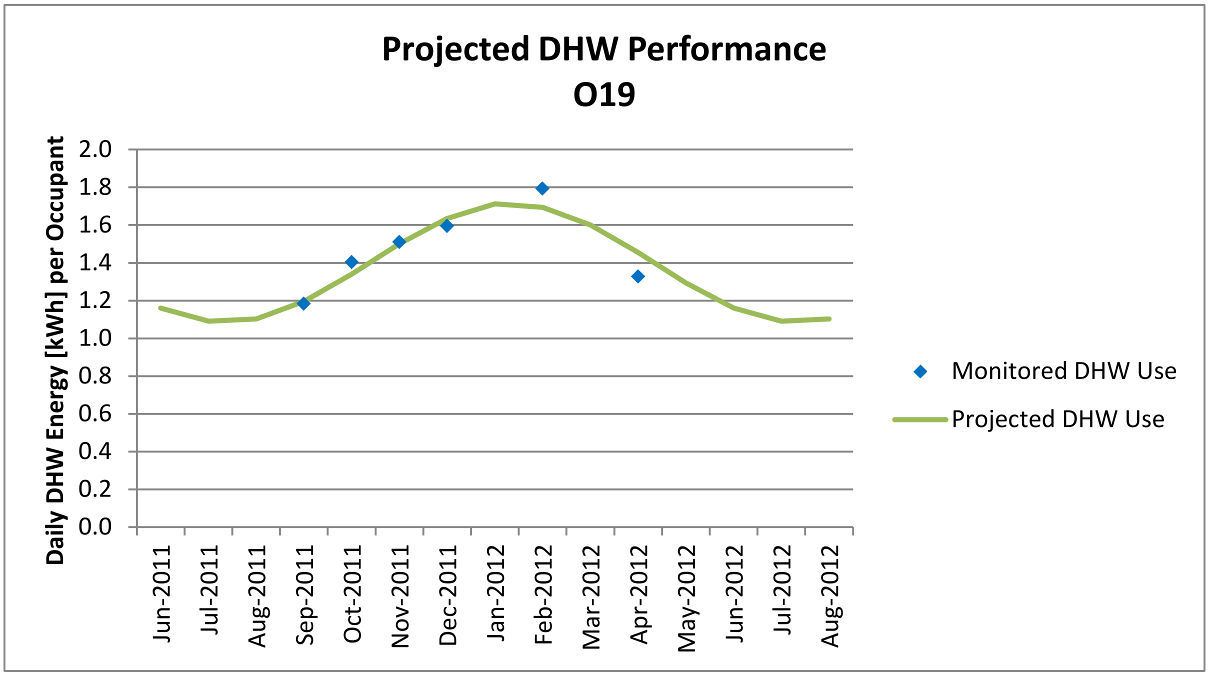

Figure A-125 Projected DHW Performance, O19

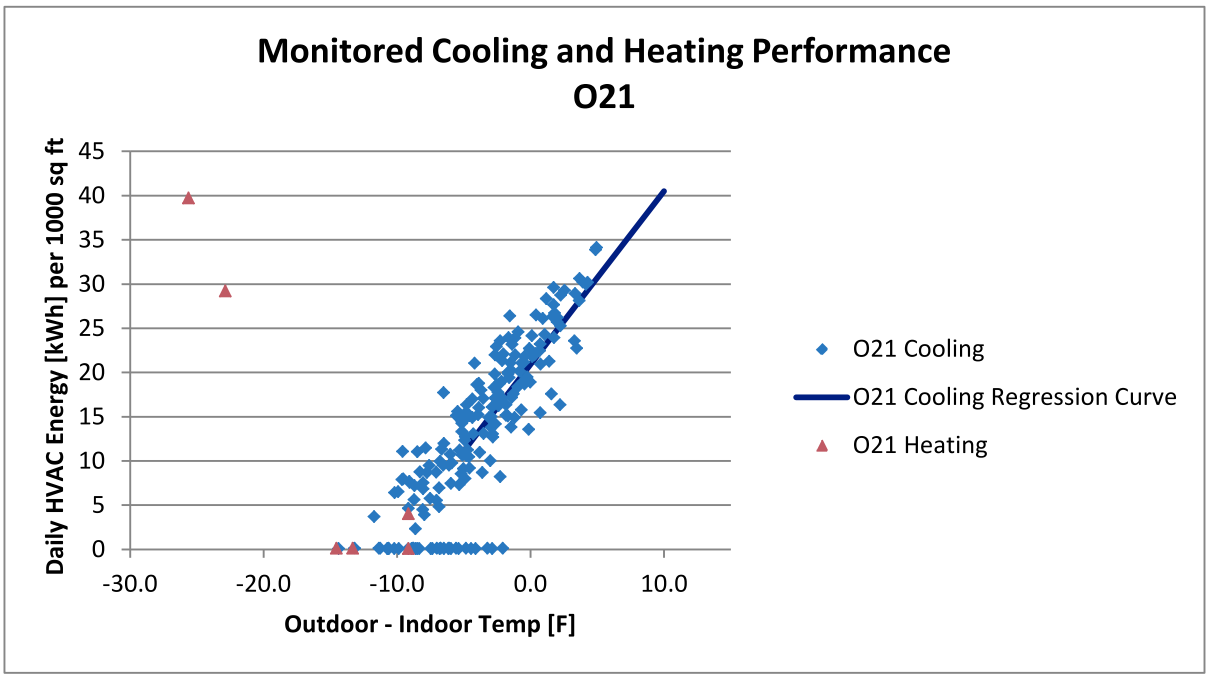

Figure A-126 Monitored Cooling and Heating Performance, O21

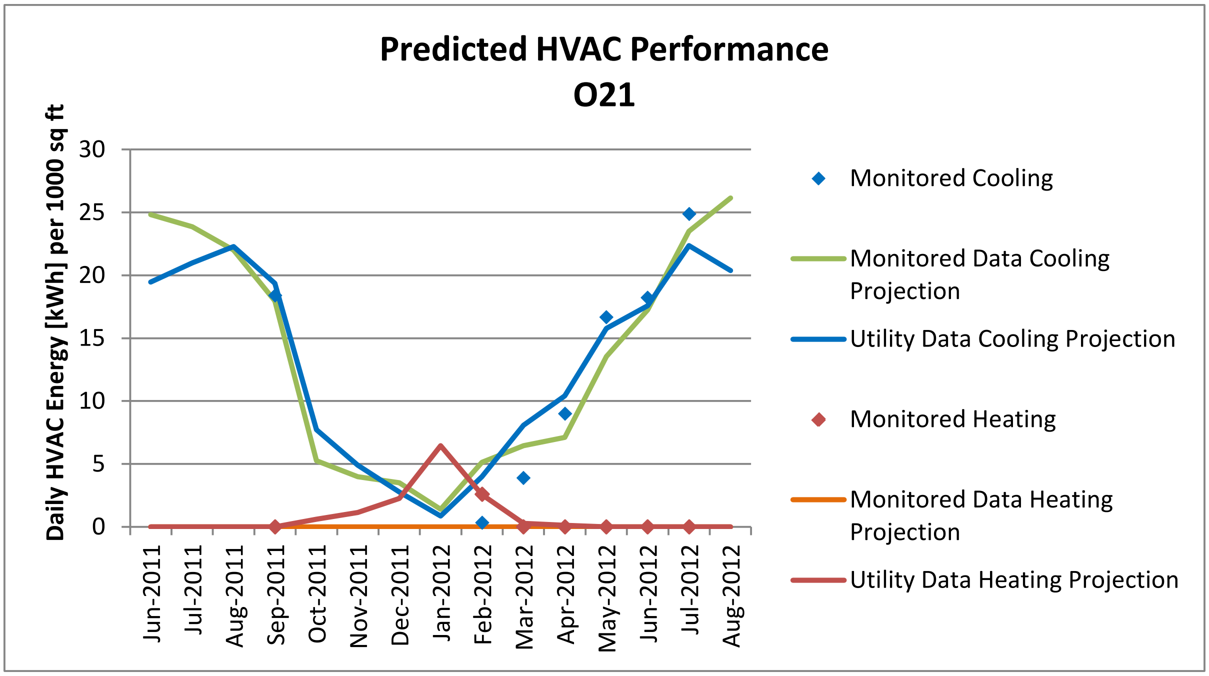

Figure A-127 Predicted HVAC Performance, O21

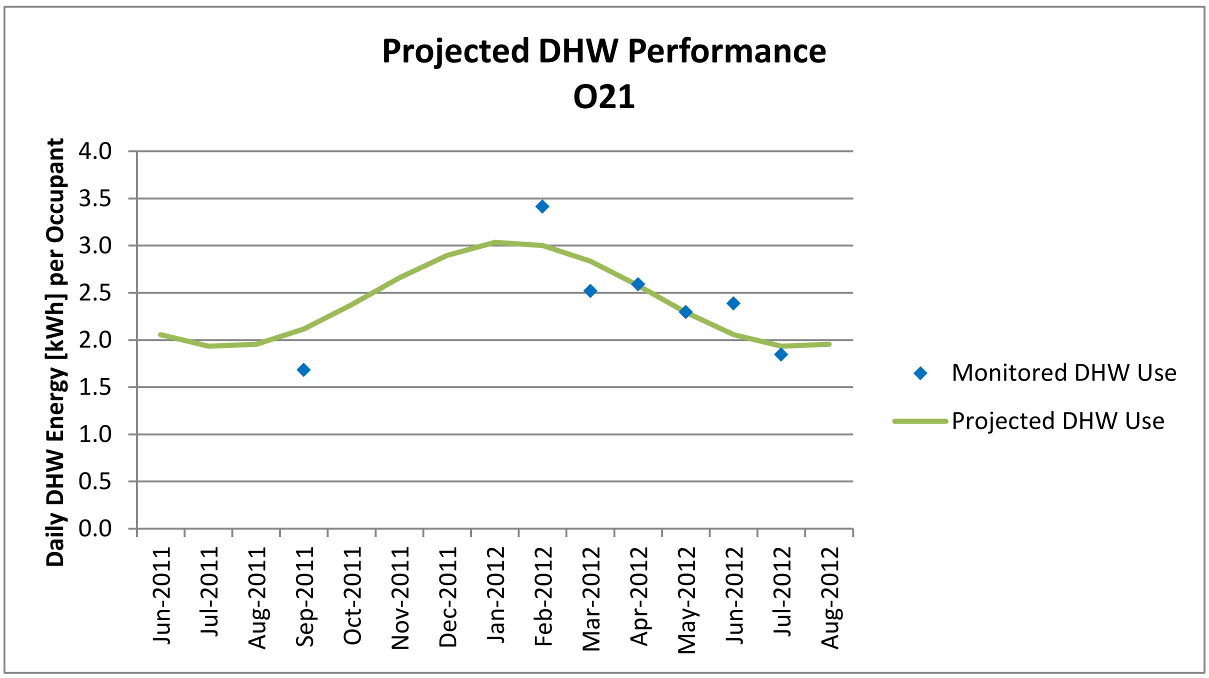

Figure A-128 Projected DHW Performance, O21

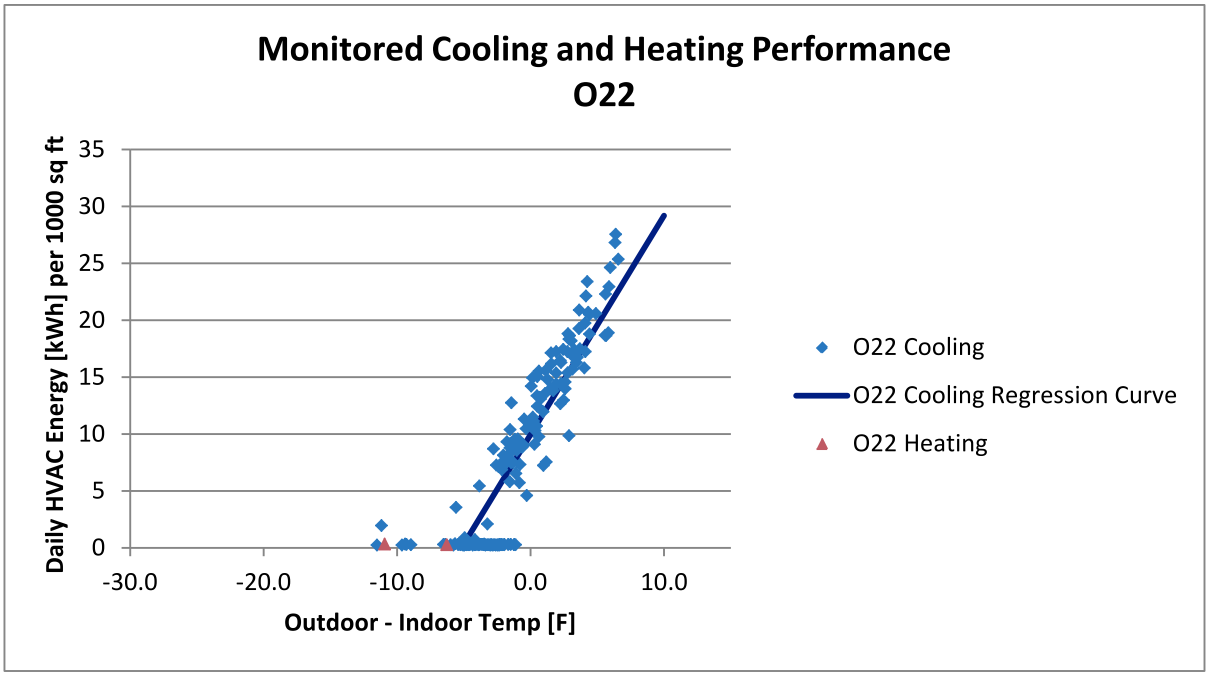

Figure A-129 Monitored Cooling and Heating Performance, O22

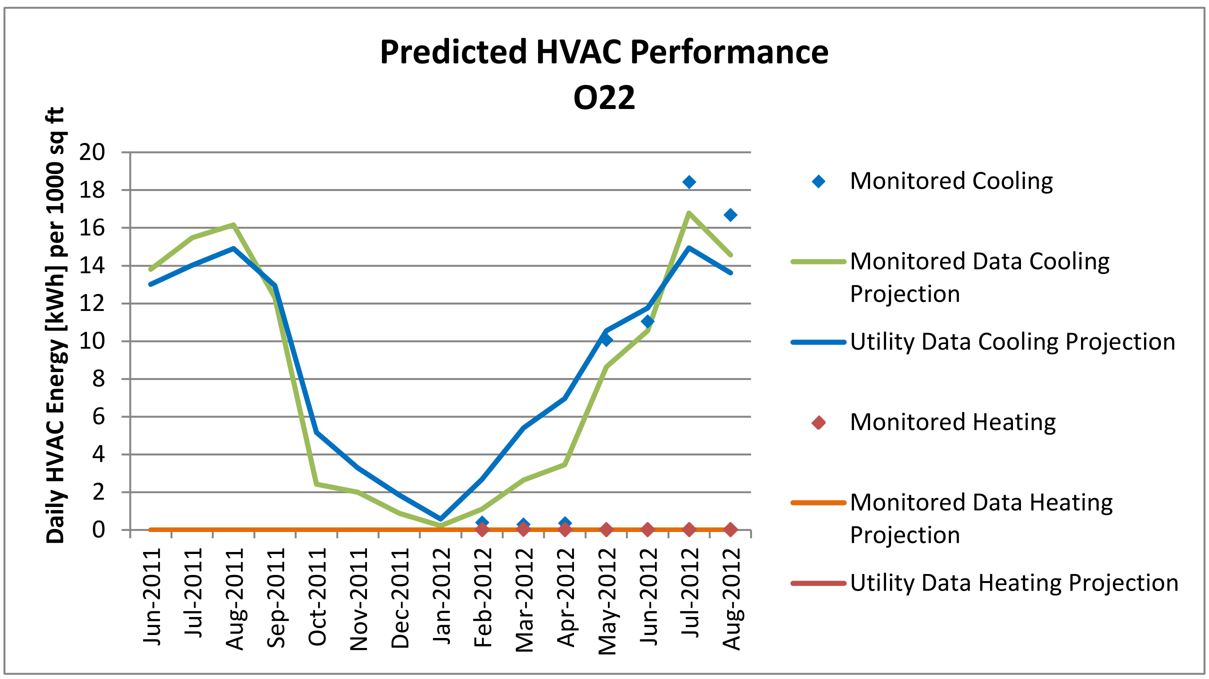

Figure A-130 Predicted HVAC Performance, O22

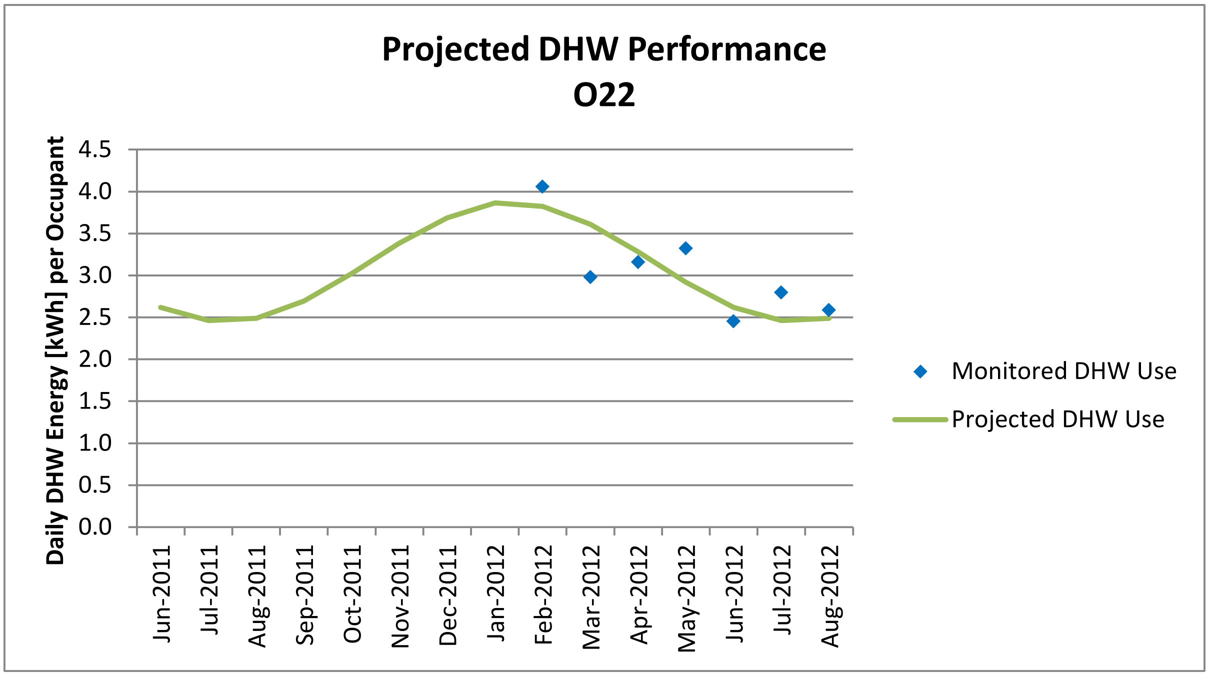

Figure A-131 Projected DHW Performance, O22

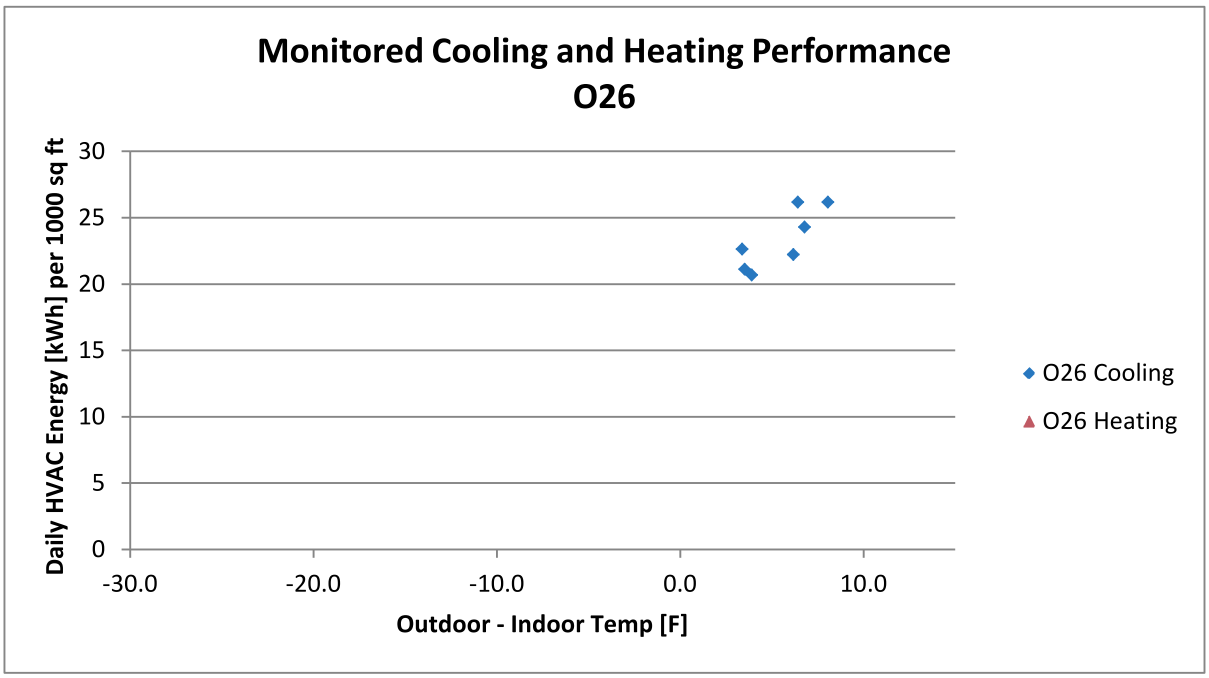

Figure A-132 Monitored Cooling and Heating Performance, O26

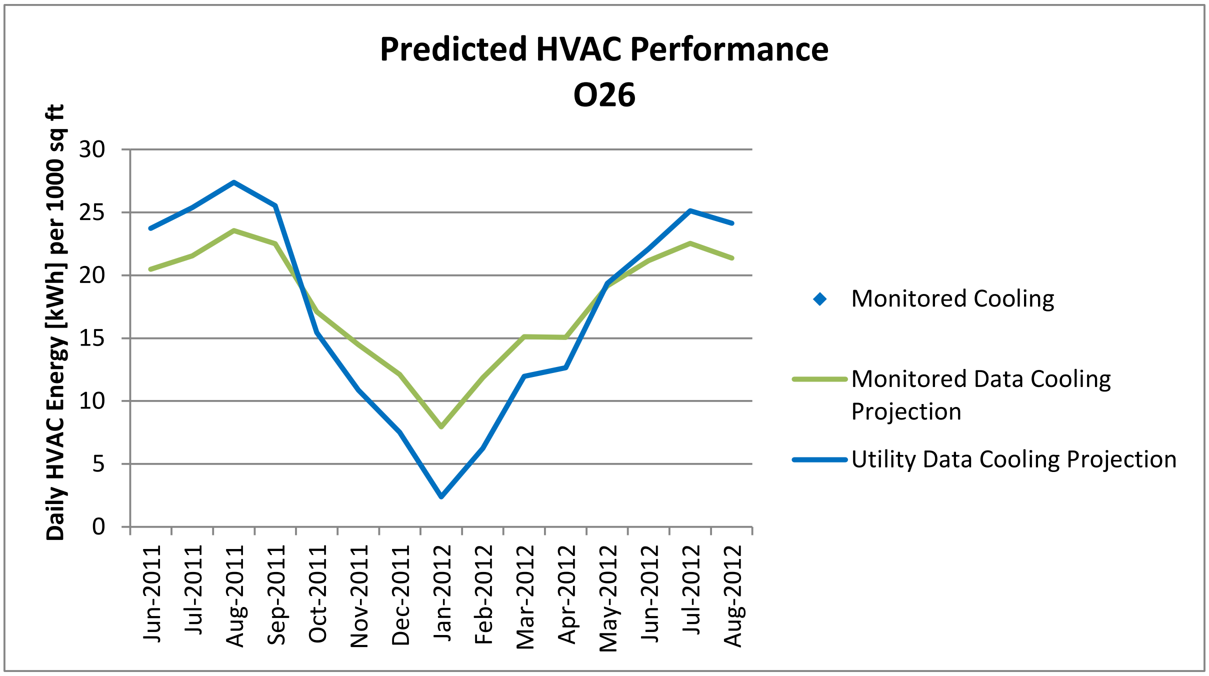

Figure A-133 Predicted HVAC Performance, O26

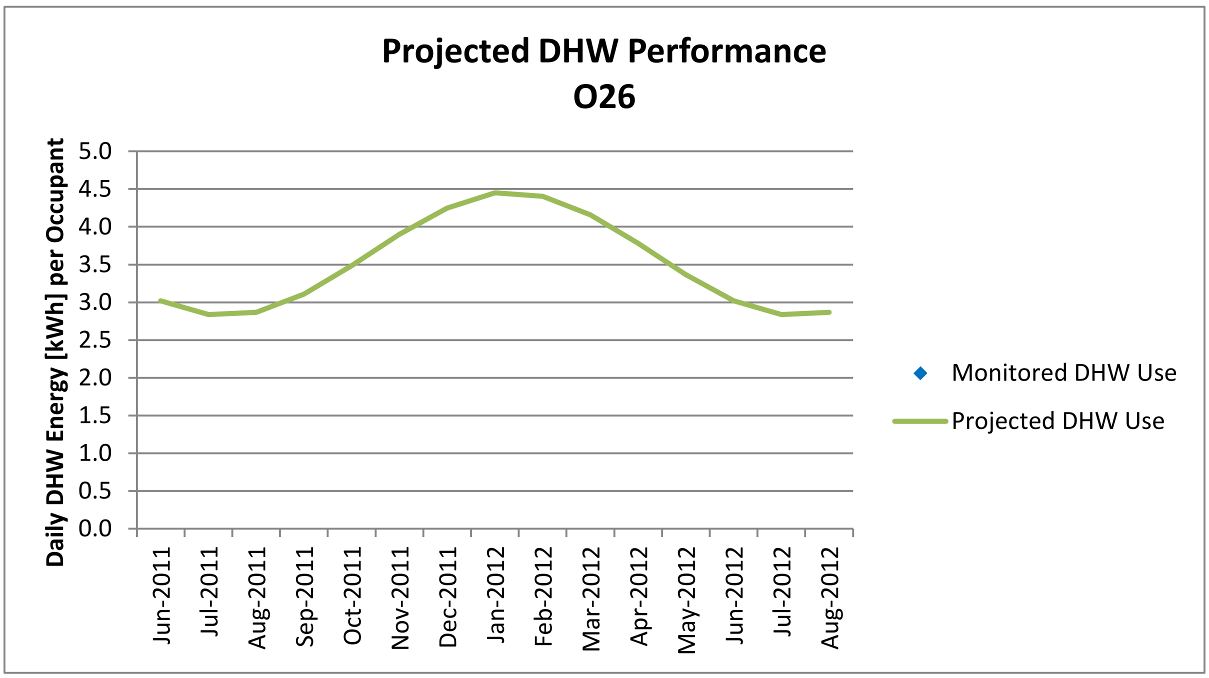

Figure A-134 Projected DHW Performance, O26

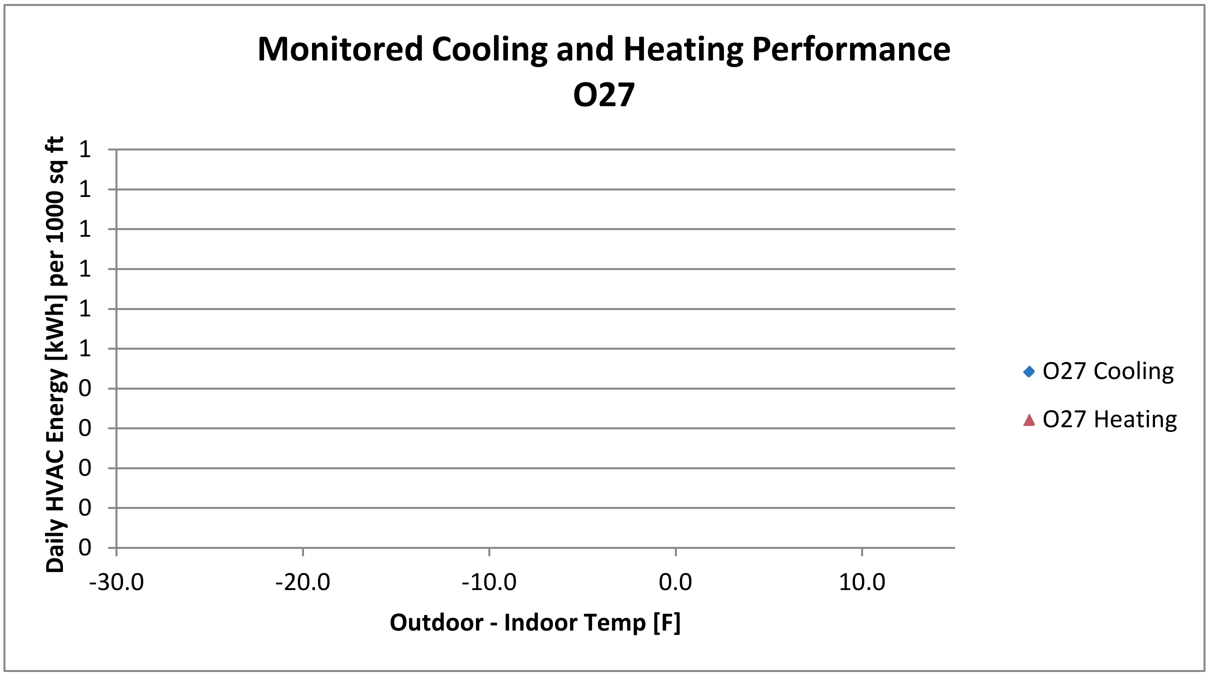

Figure A-135 Monitored Cooling and Heating Performance, O27

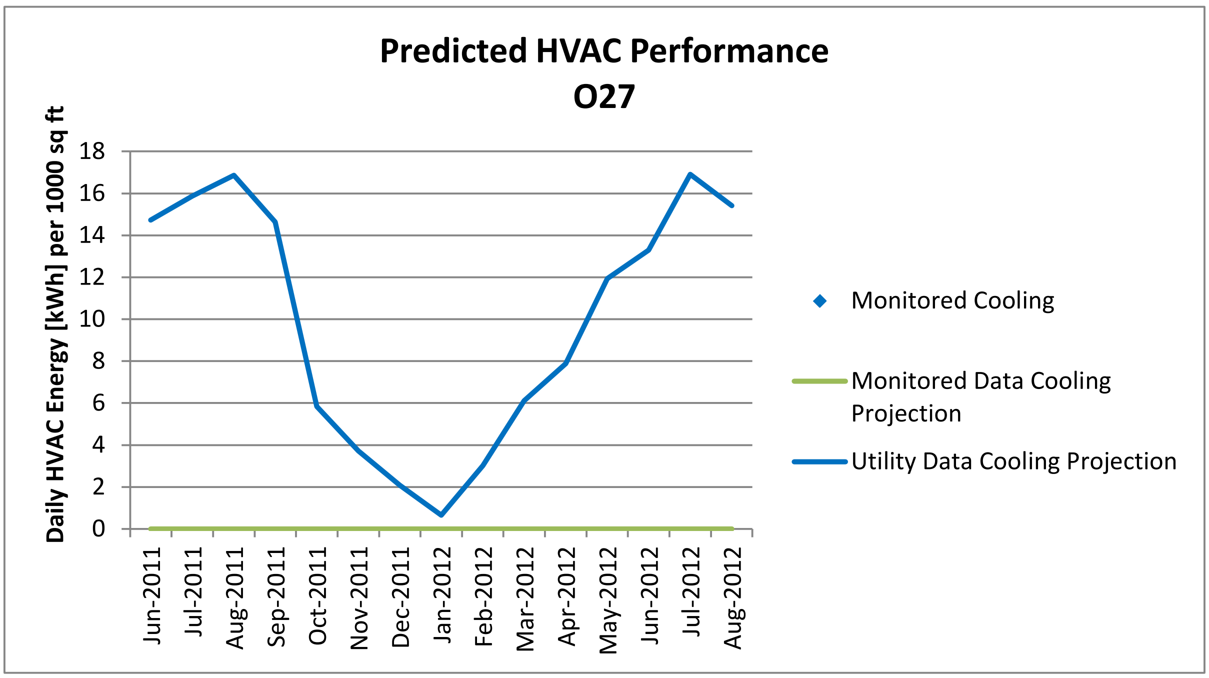

Figure A-136 Predicted HVAC Performance, O27

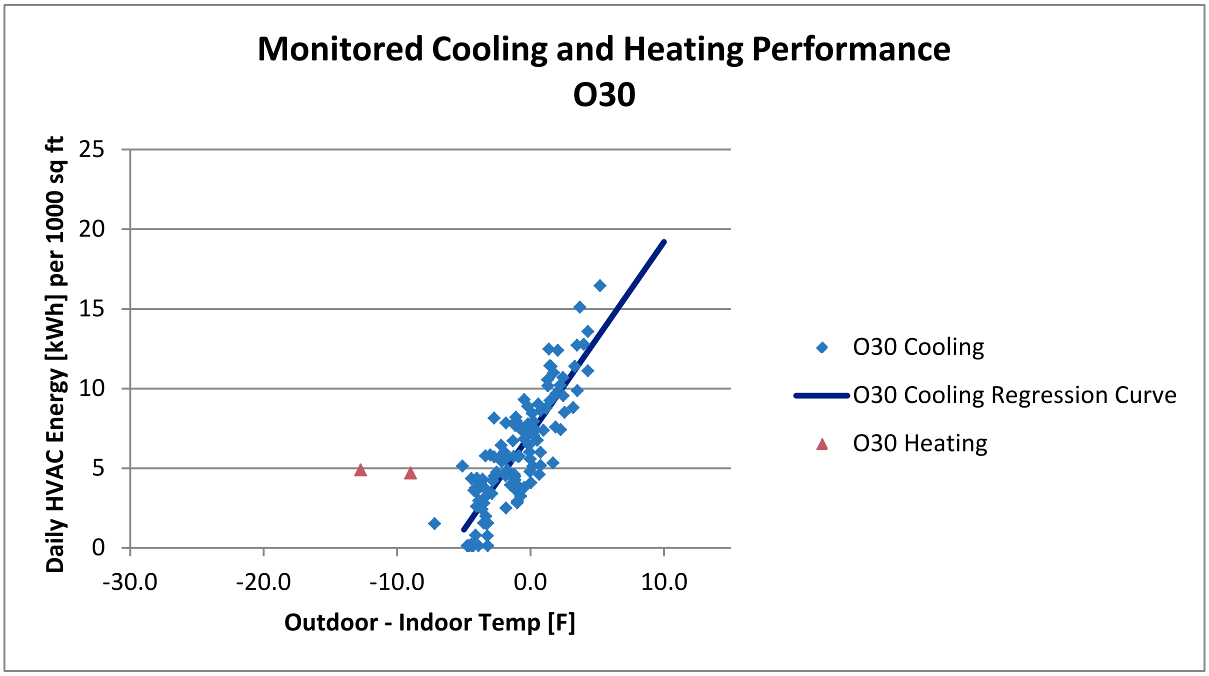

Figure A-137 Monitored Cooling and Heating Performance, O30

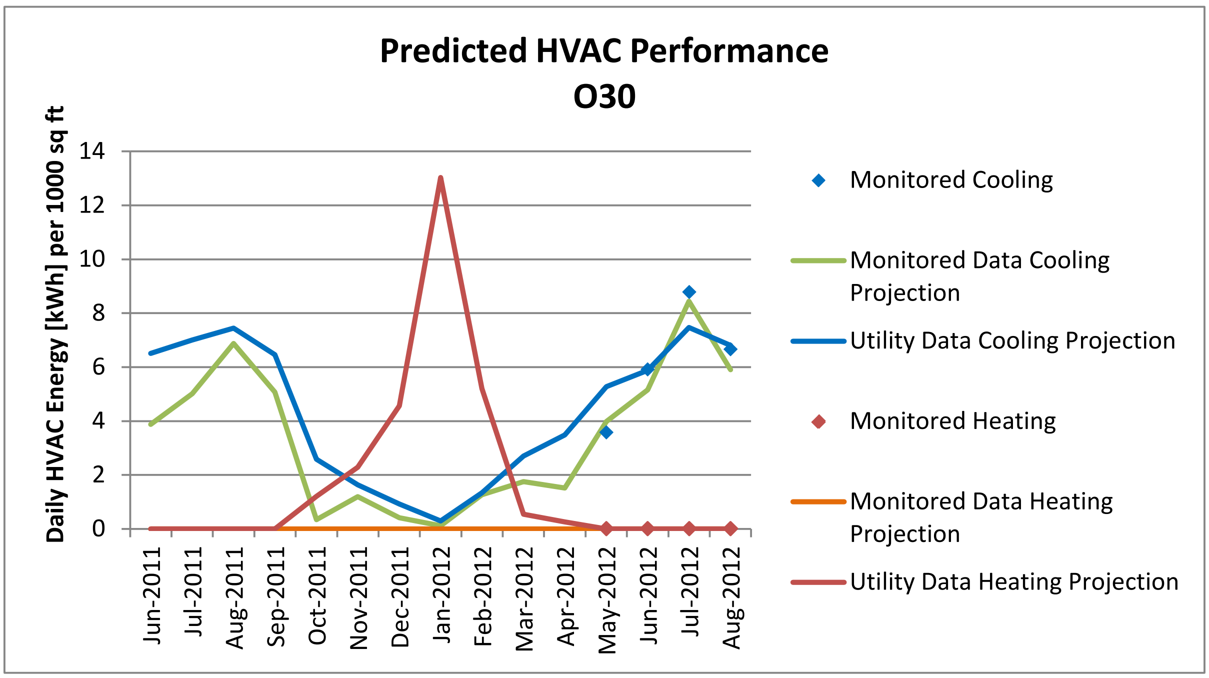

Figure A-138 Predicted HVAC Performance, O30

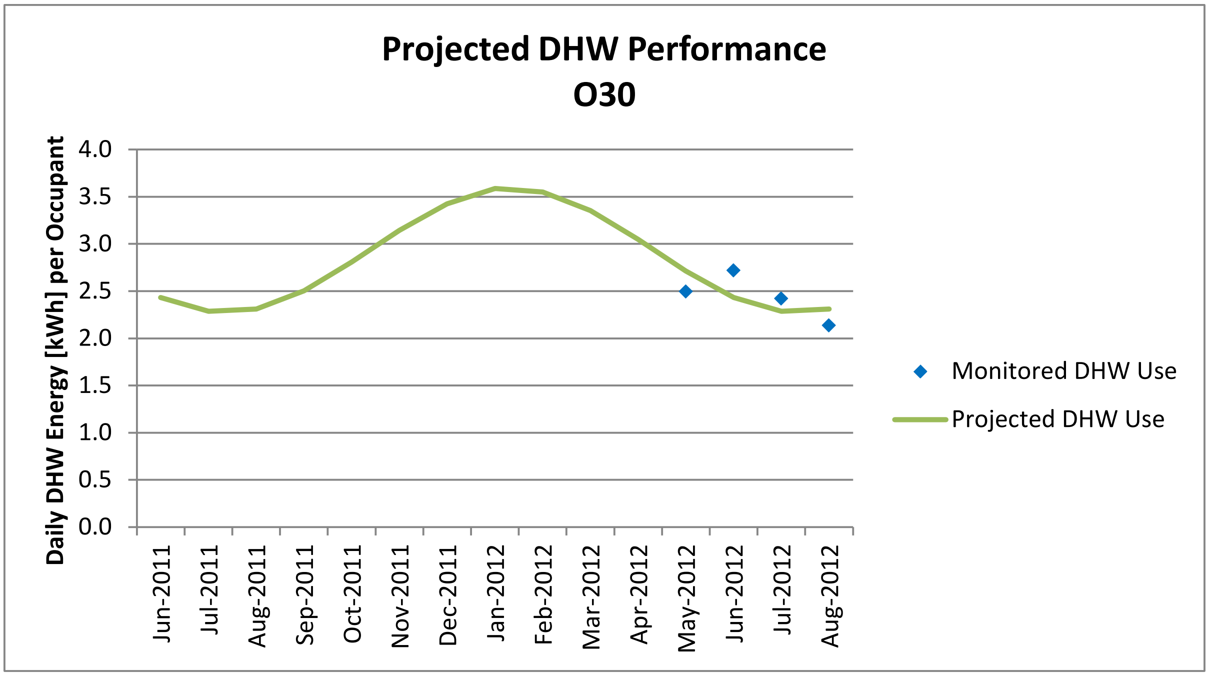

Figure A-139 Projected DHW Performance, O30

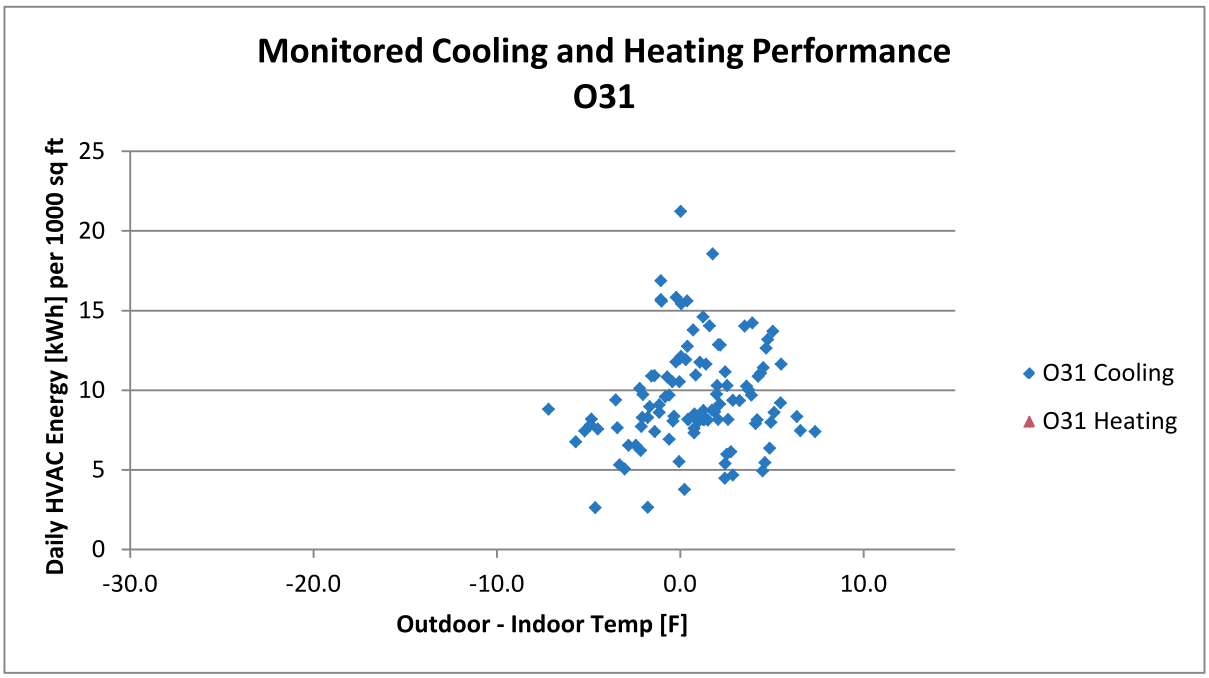

Figure A-140 Monitored Cooling and Heating Performance, O31

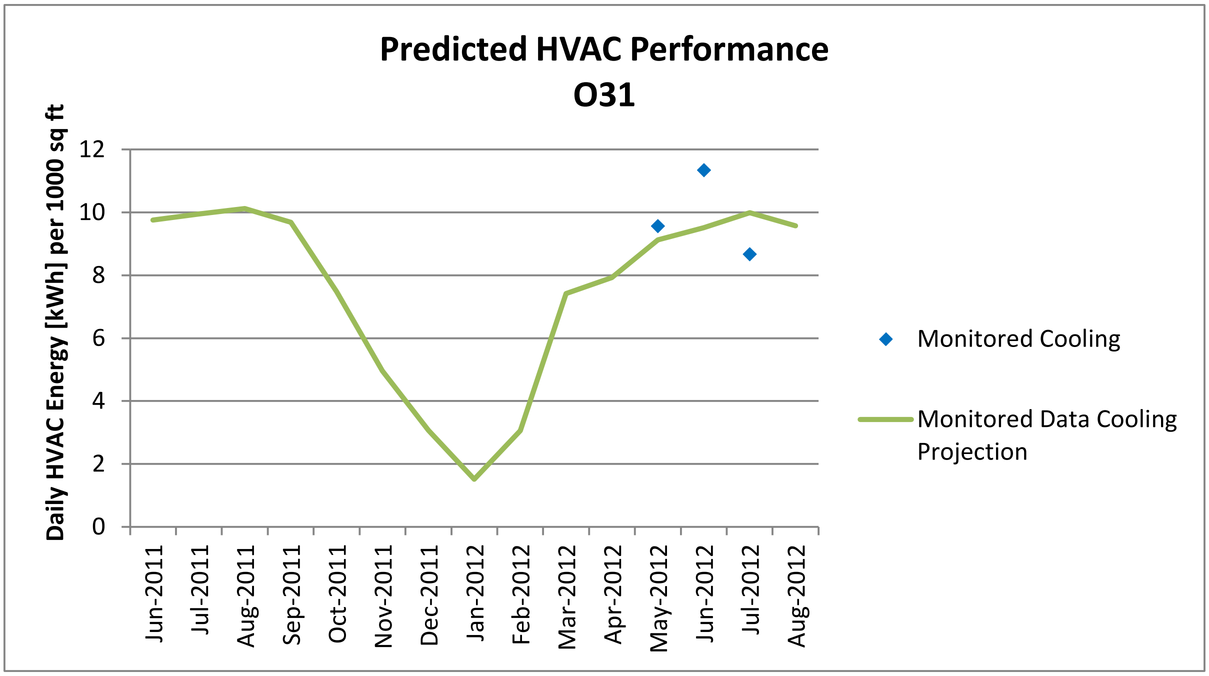

Figure A-141 Predicted HVAC Performance, O31

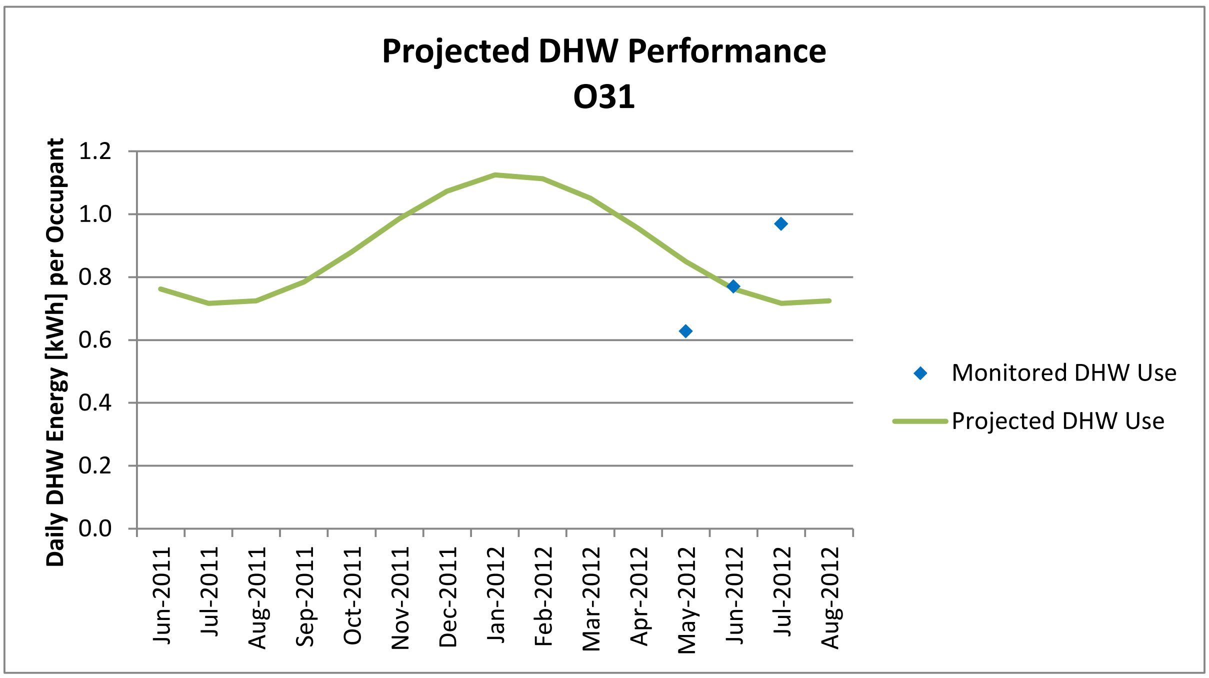

Figure A-142 Projected DHW Performance, O31

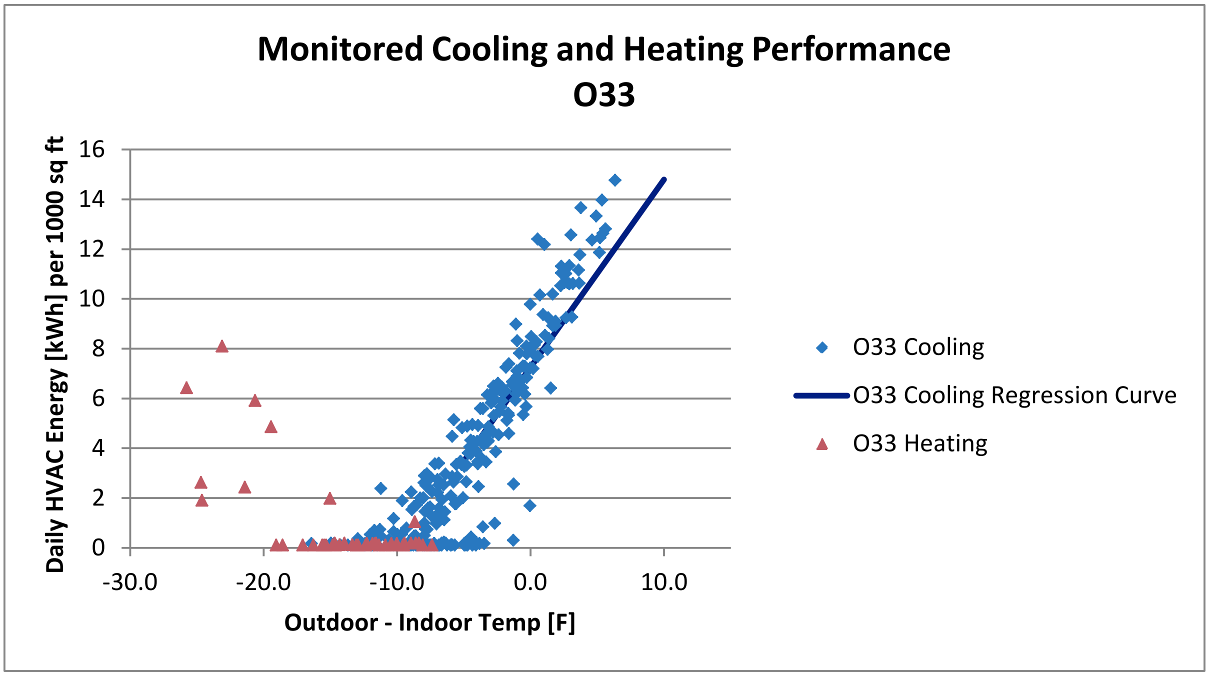

Figure A-143 Monitored Cooling and Heating Performance, O33

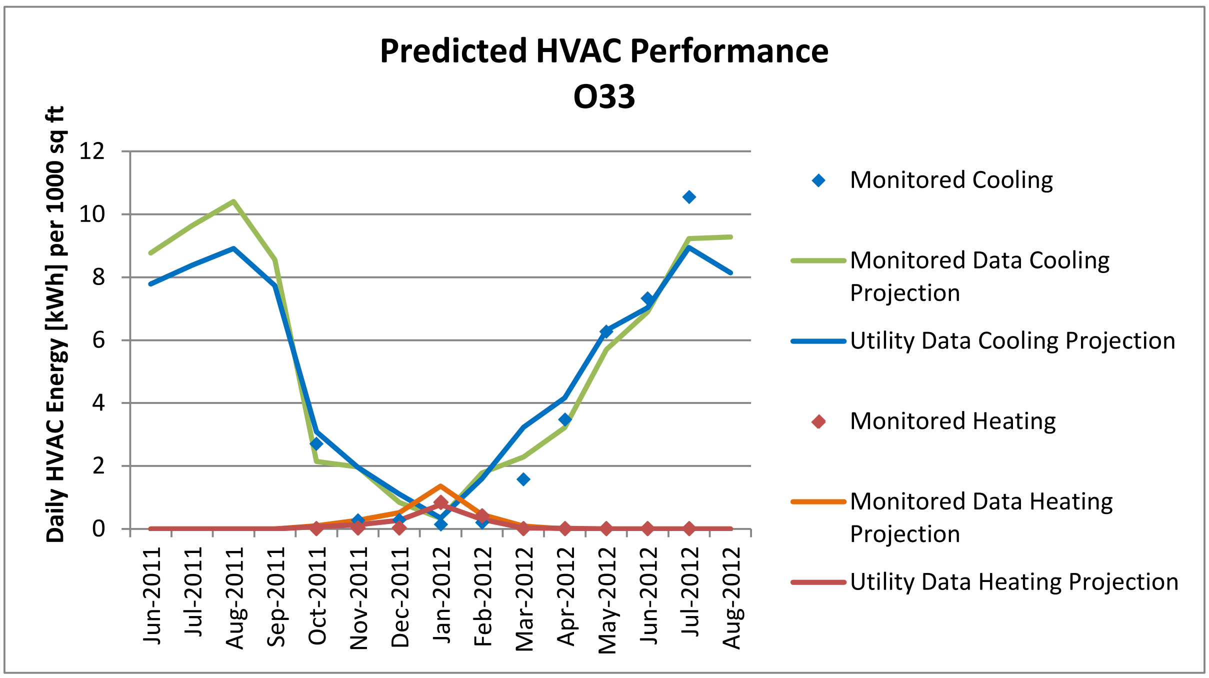

Figure A-144 Predicted HVAC Performance, O33

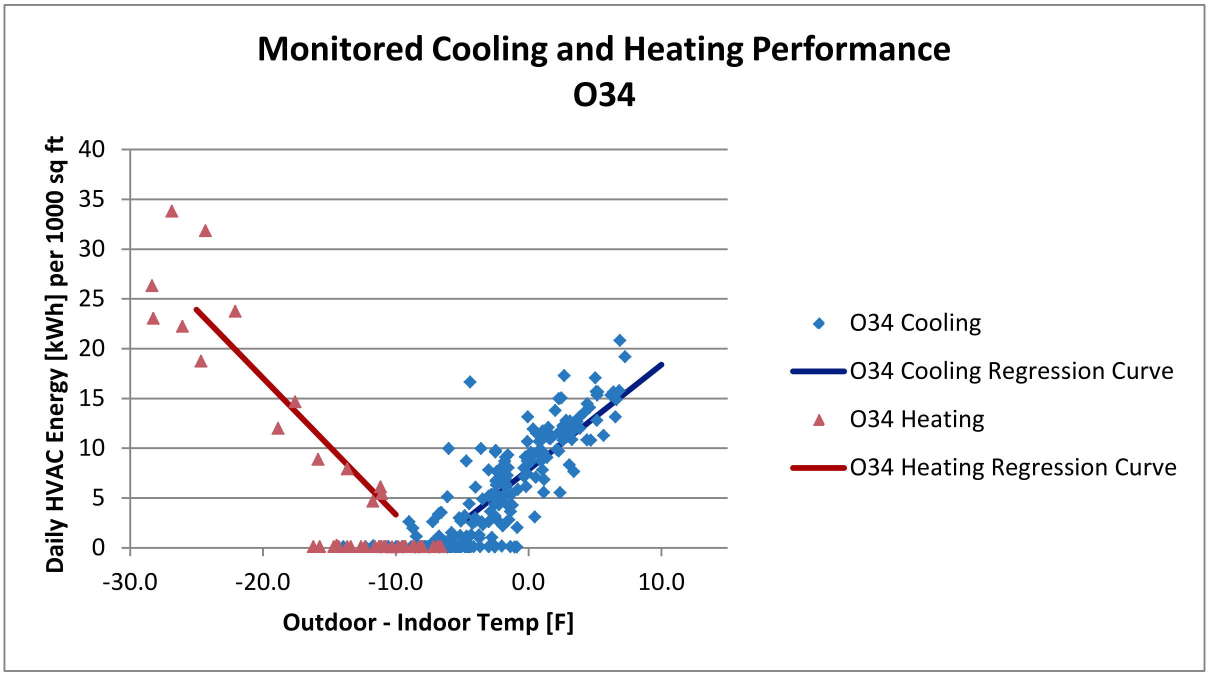

Figure A-145 Monitored Cooling and Heating Performance, O34

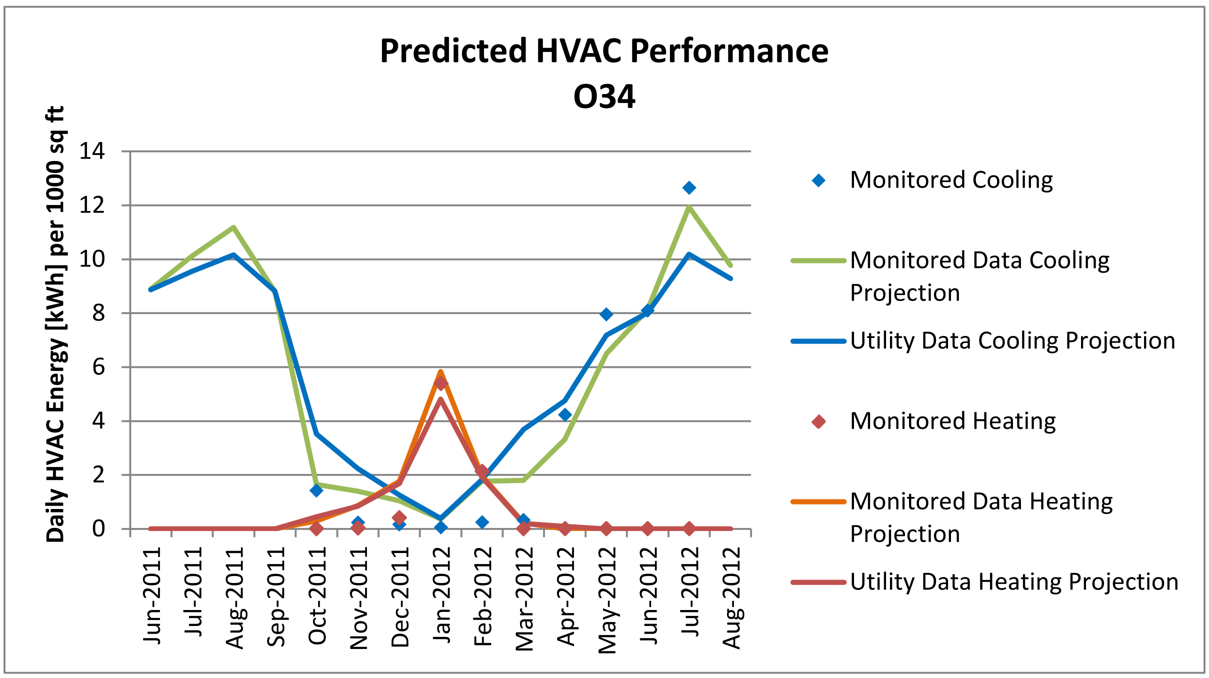

Figure A-146 Predicted HVAC Performance, O34

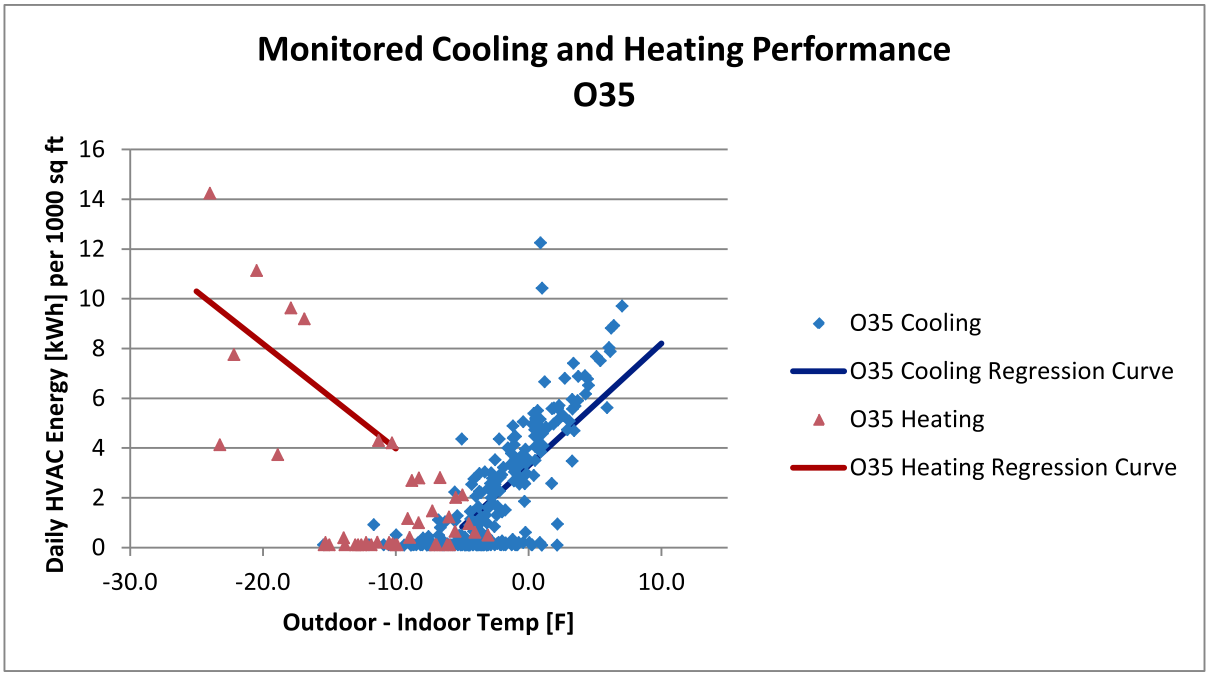

Figure A-147 Monitored Cooling and Heating Performance, O35

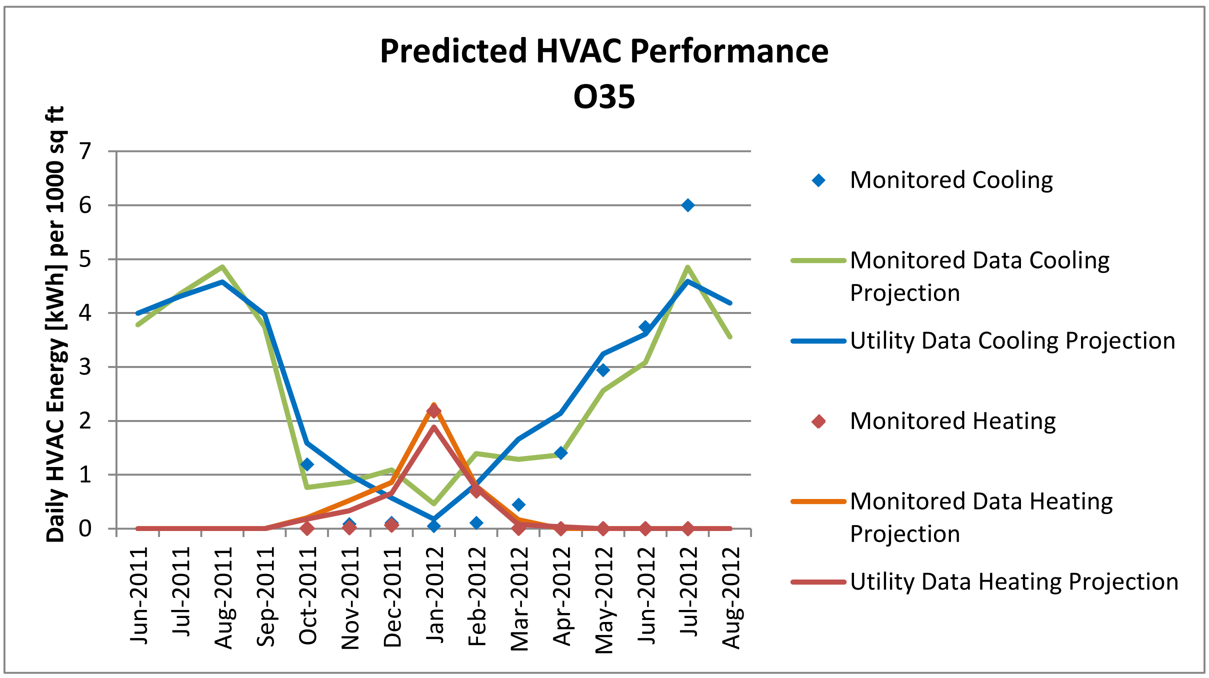

Figure A-148 Predicted HVAC Performance, O35

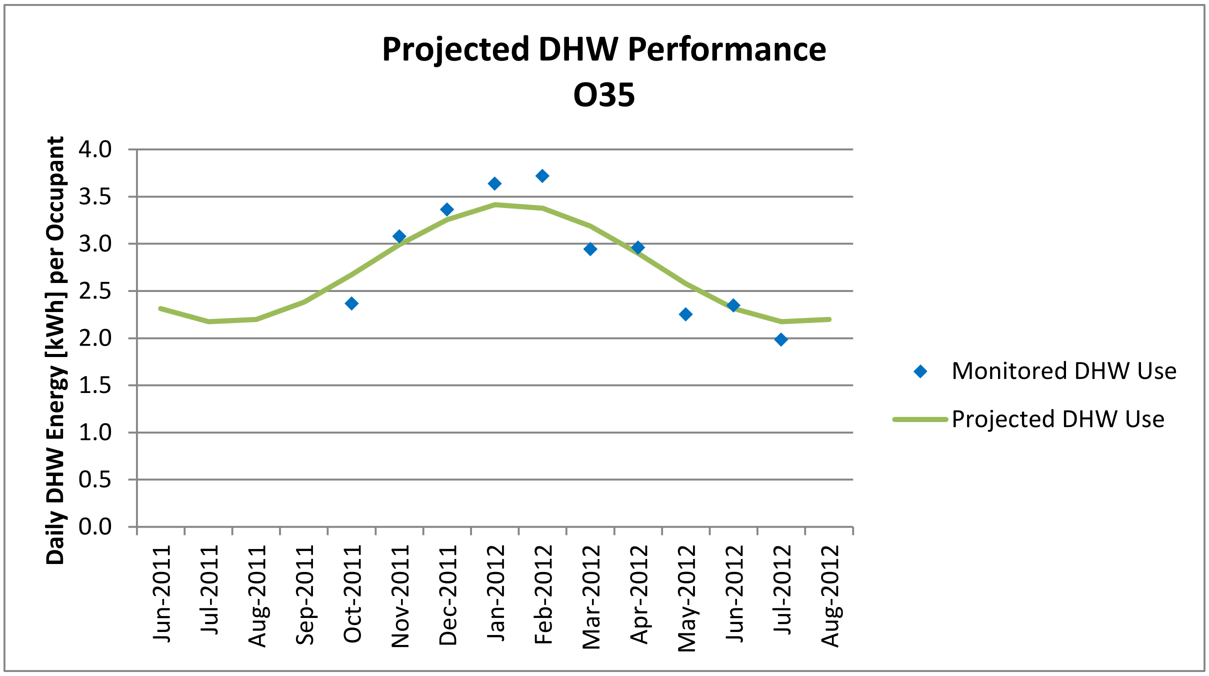

Figure A-149 Projected DHW Performance, O35

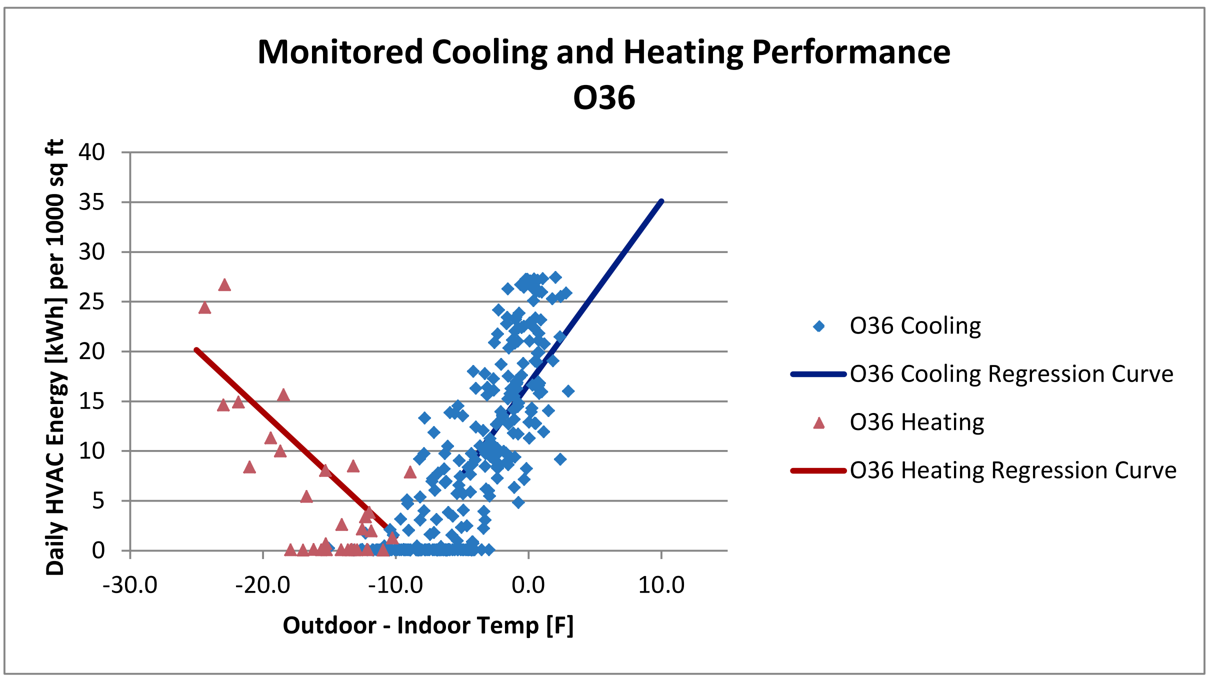

Figure A-150 Monitored Cooling and Heating Performance, O36

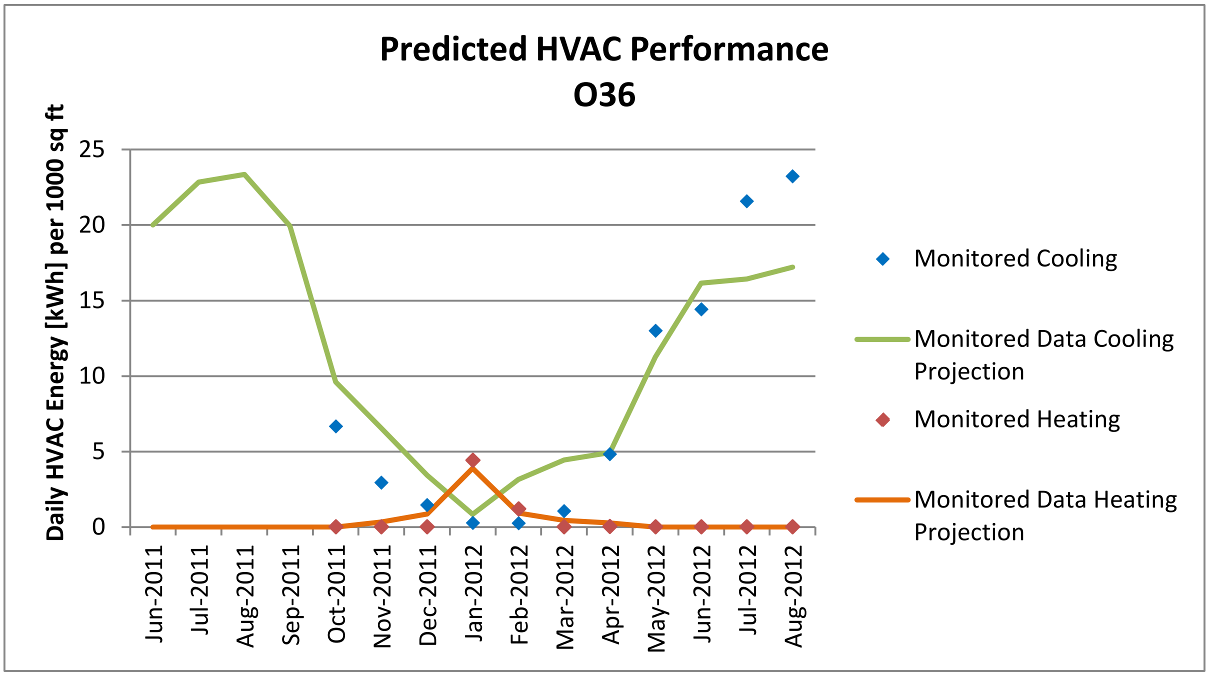

Figure A-151 Predicted HVAC Performance, O36

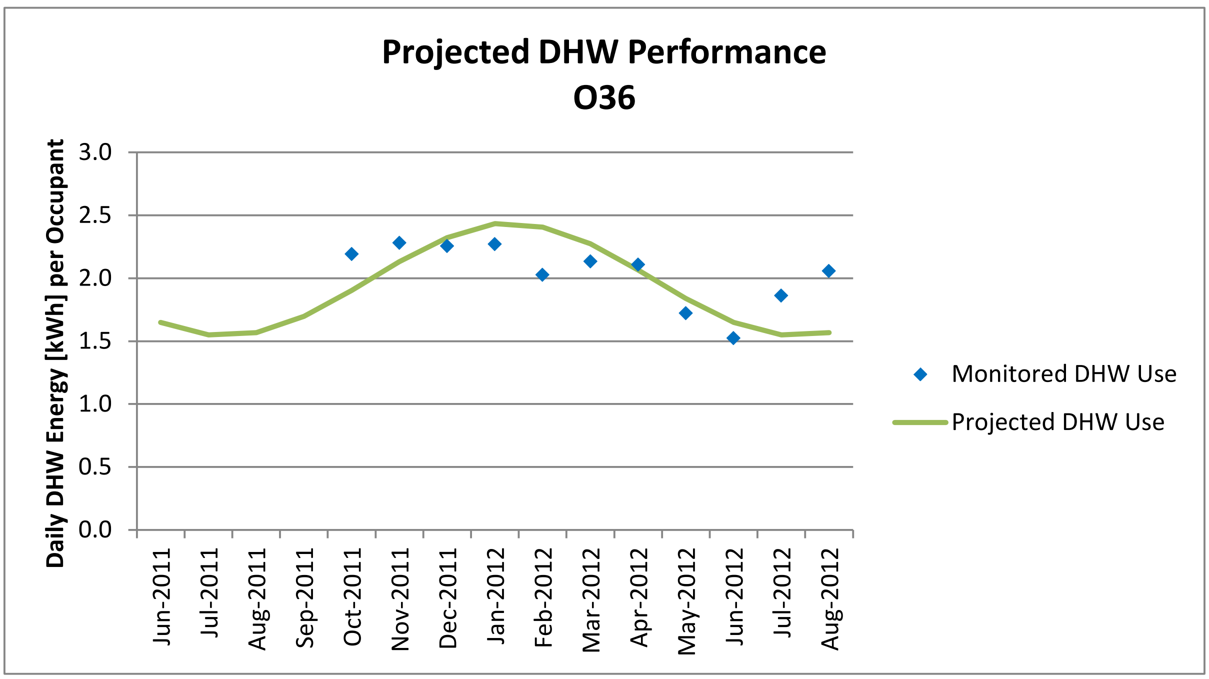

Figure A-152 Projected DHW Performance, O36

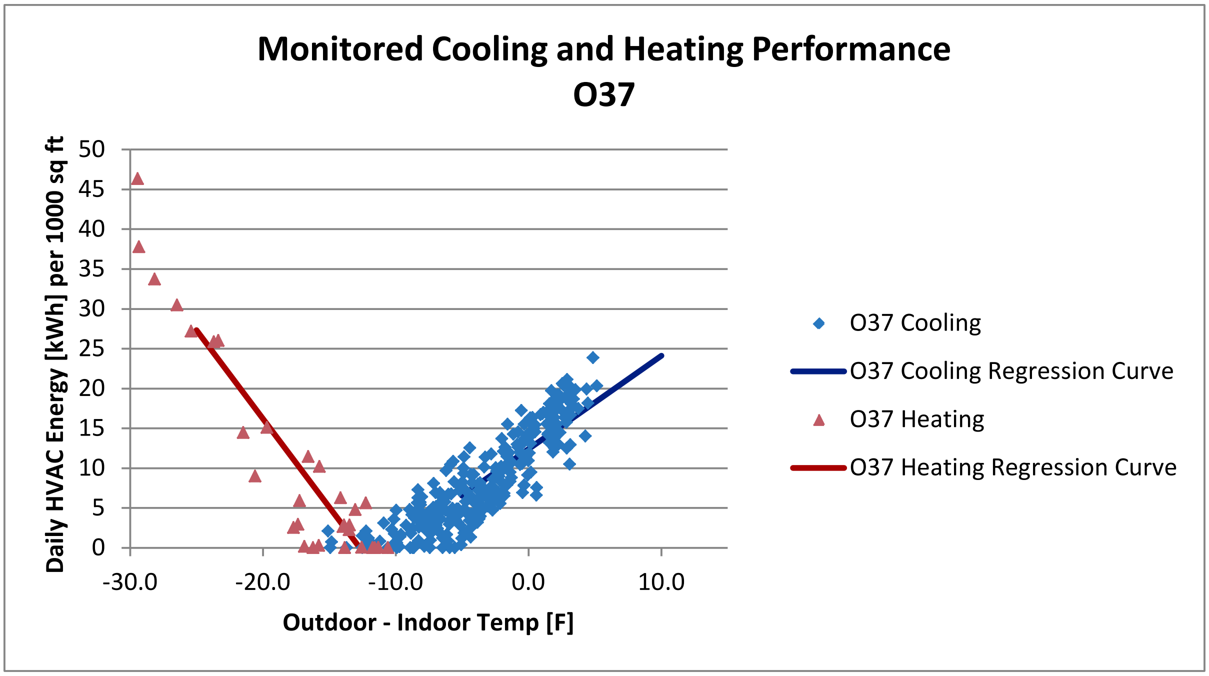

Figure A-153 Monitored Cooling and Heating Performance, O37

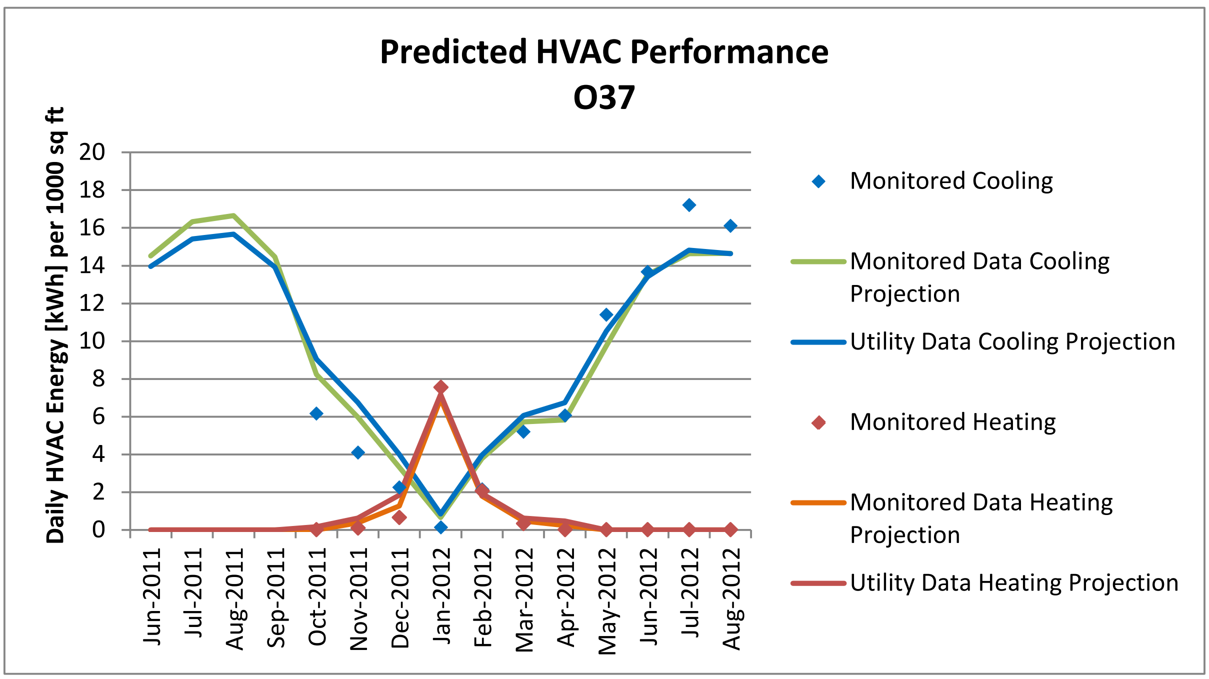

Figure A-154 Predicted HVAC Performance, O37

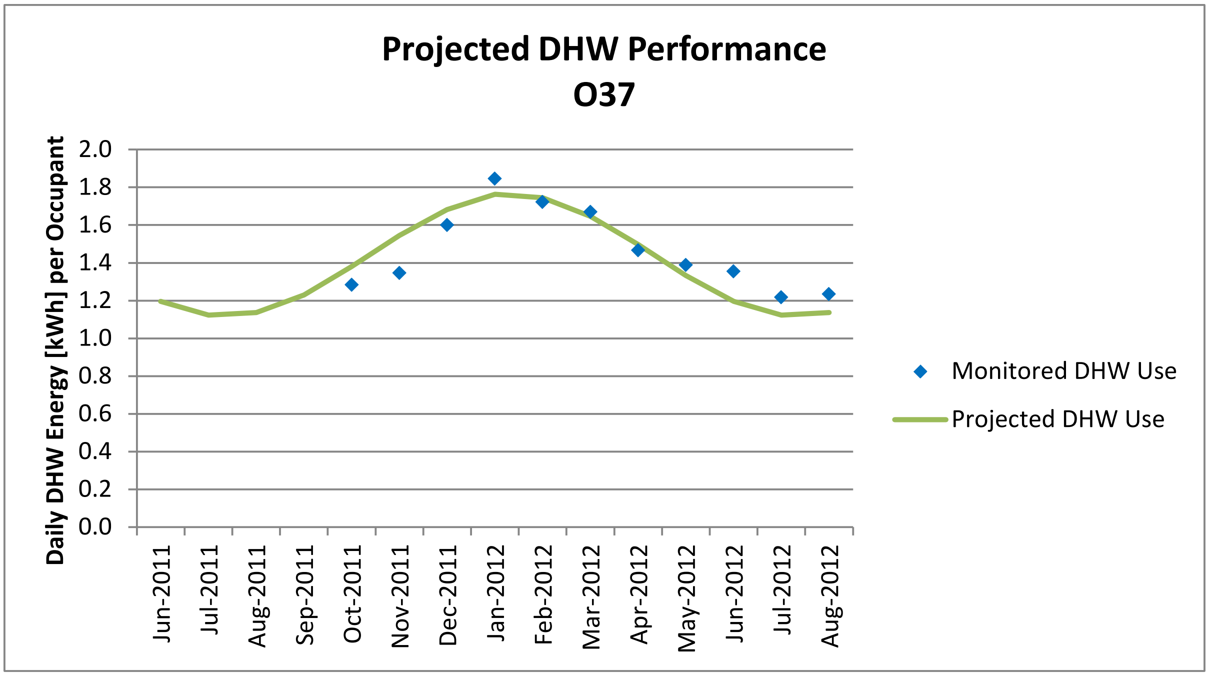

Figure A-155 Projected DHW Performance, O37

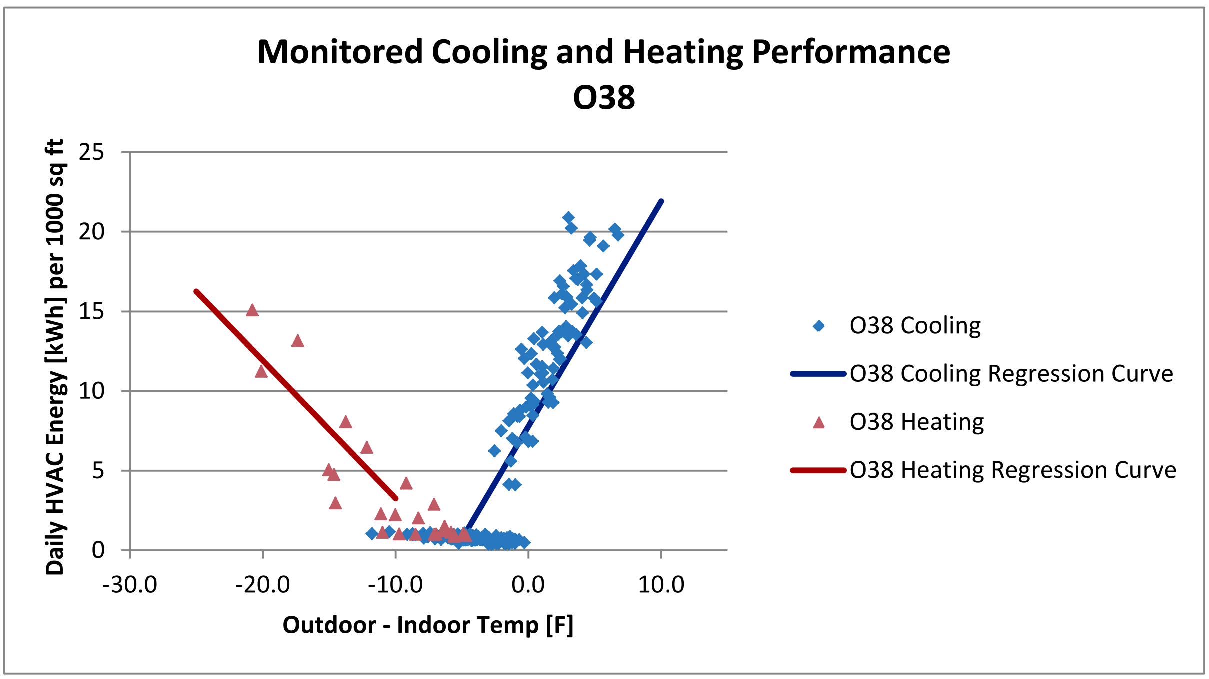

Figure A-156 Monitored Cooling and Heating Performance, O38

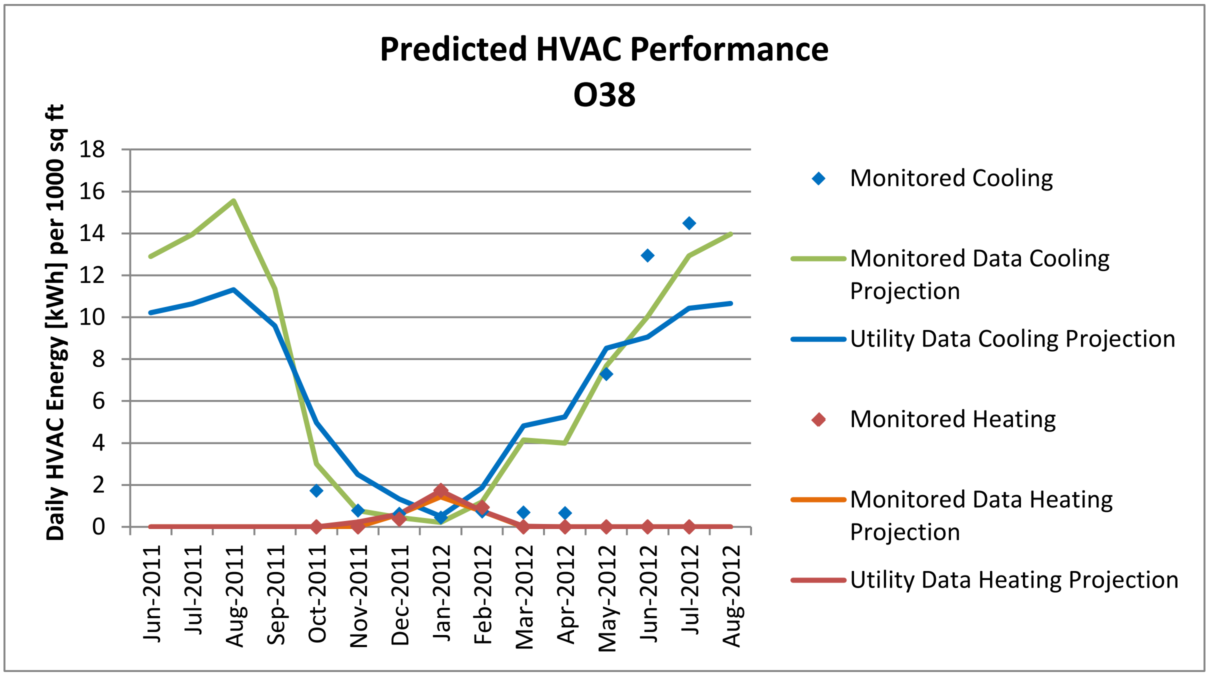

Figure A-157 Predicted HVAC Performance, O38

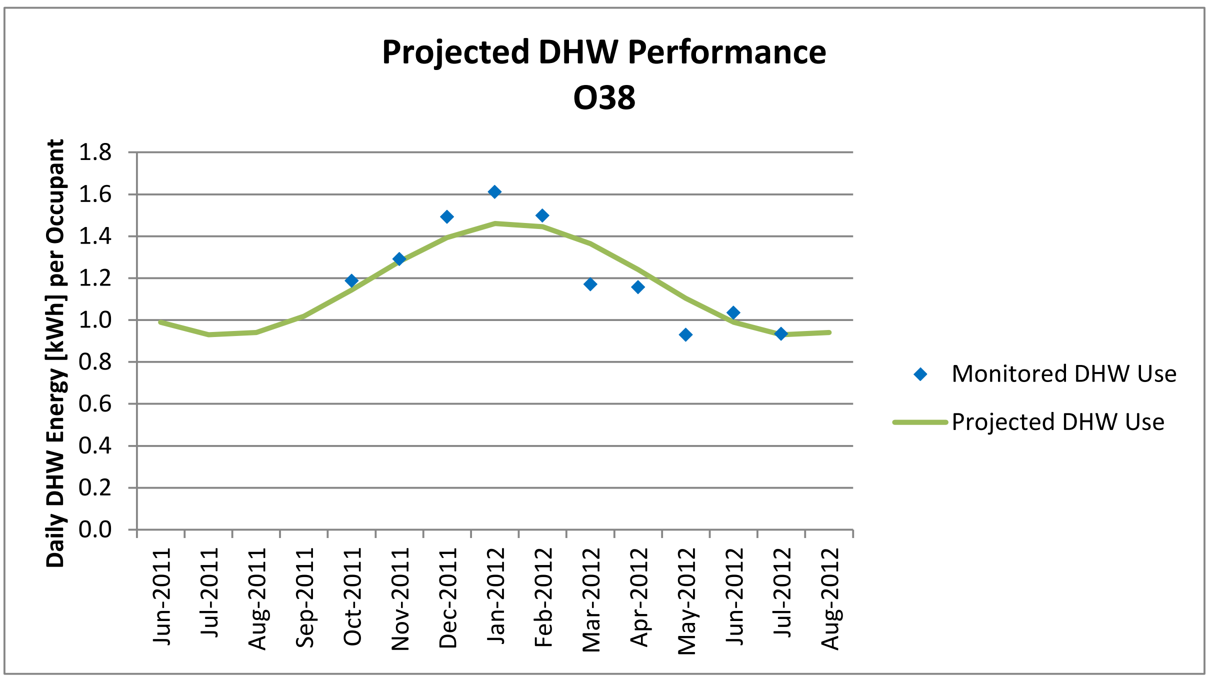

Figure A-158 Projected DHW Performance, O38

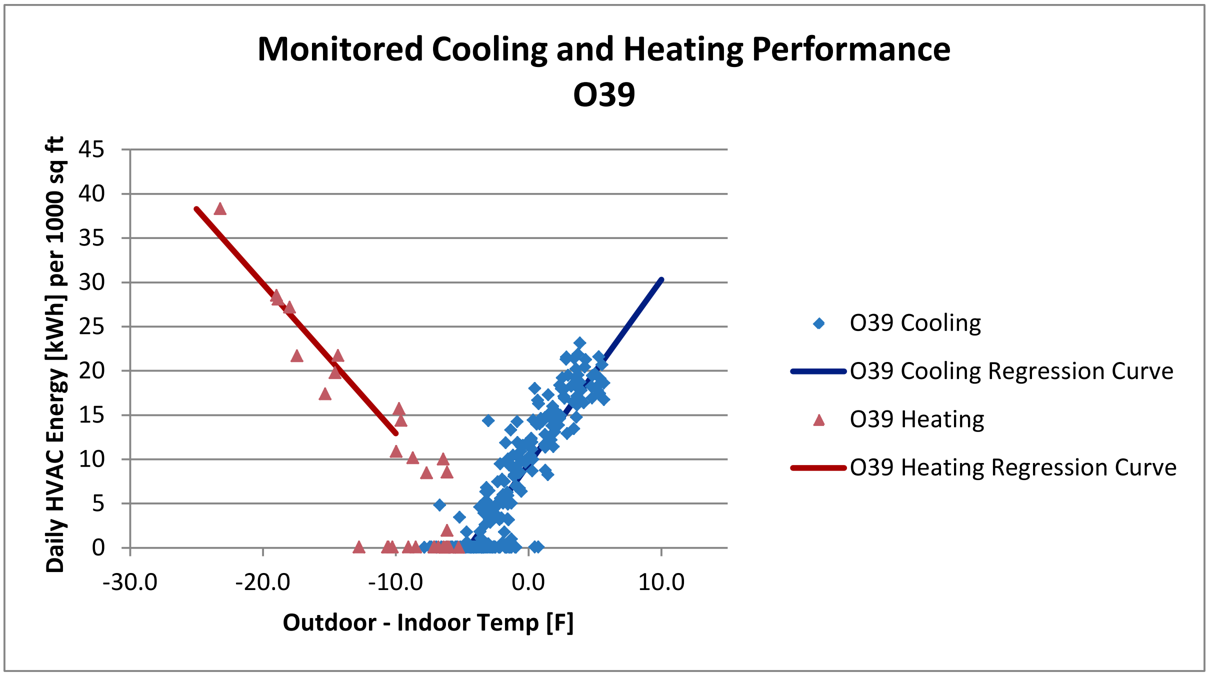

Figure A-159 Monitored Cooling and Heating Performance, O39

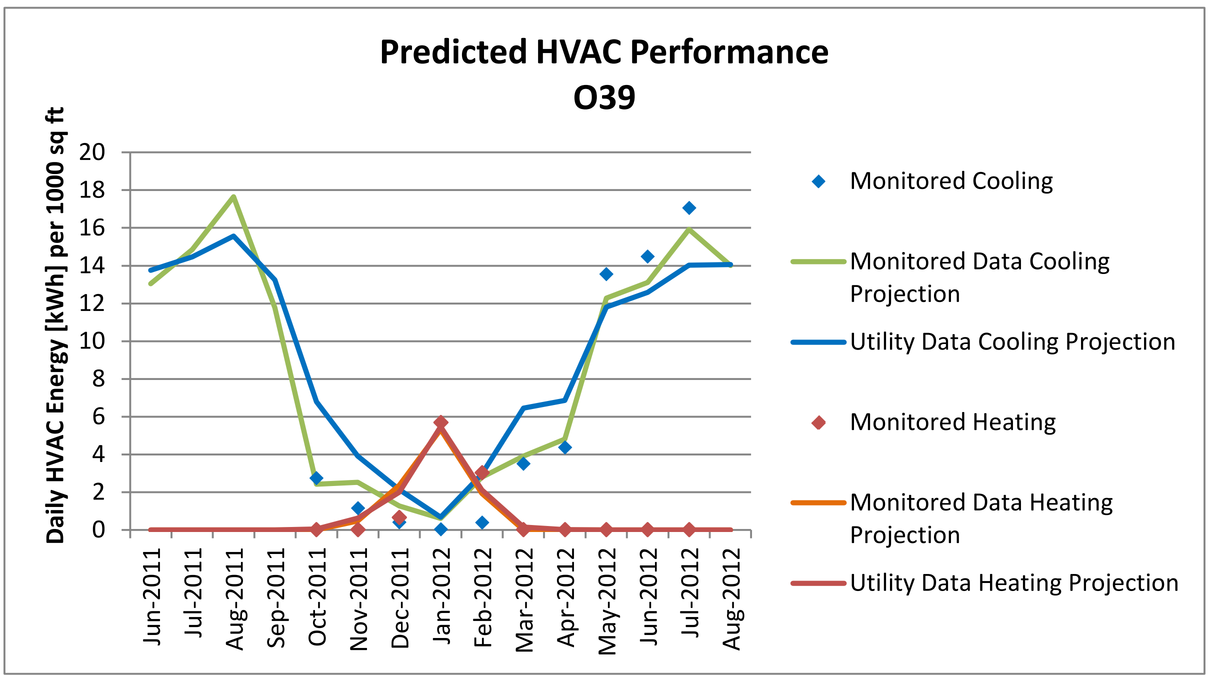

Figure A-160 Predicted HVAC Performance, O39

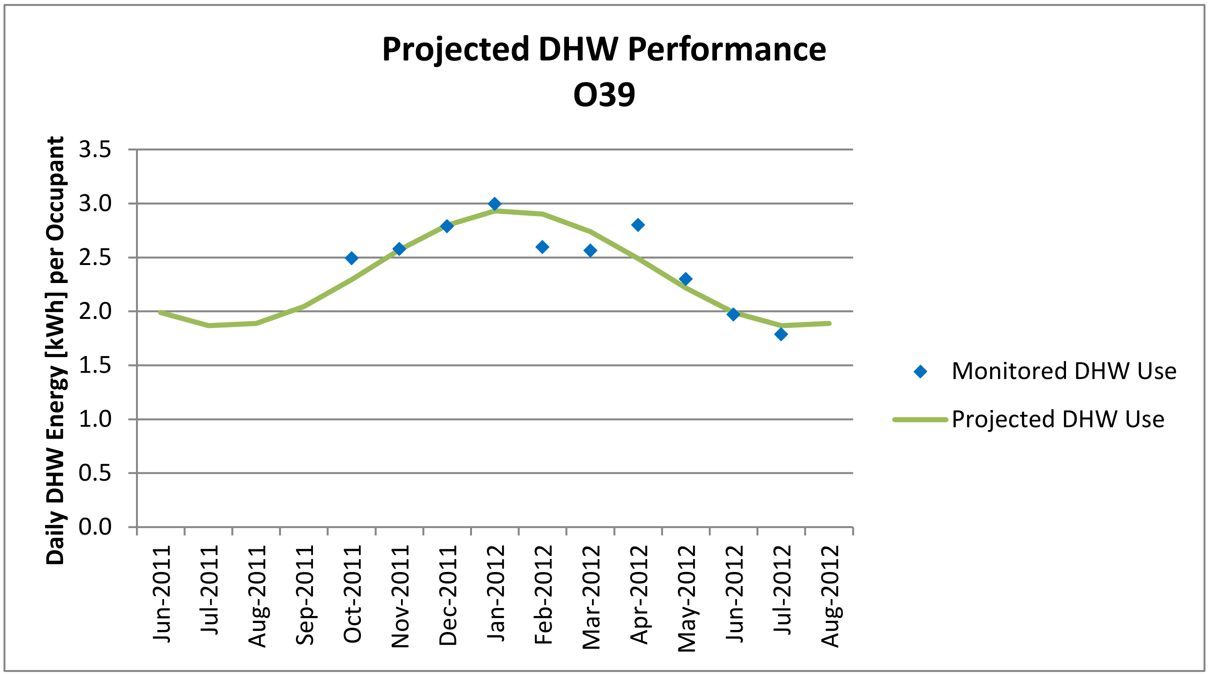

Figure A-161 Projected DHW Performance, O39

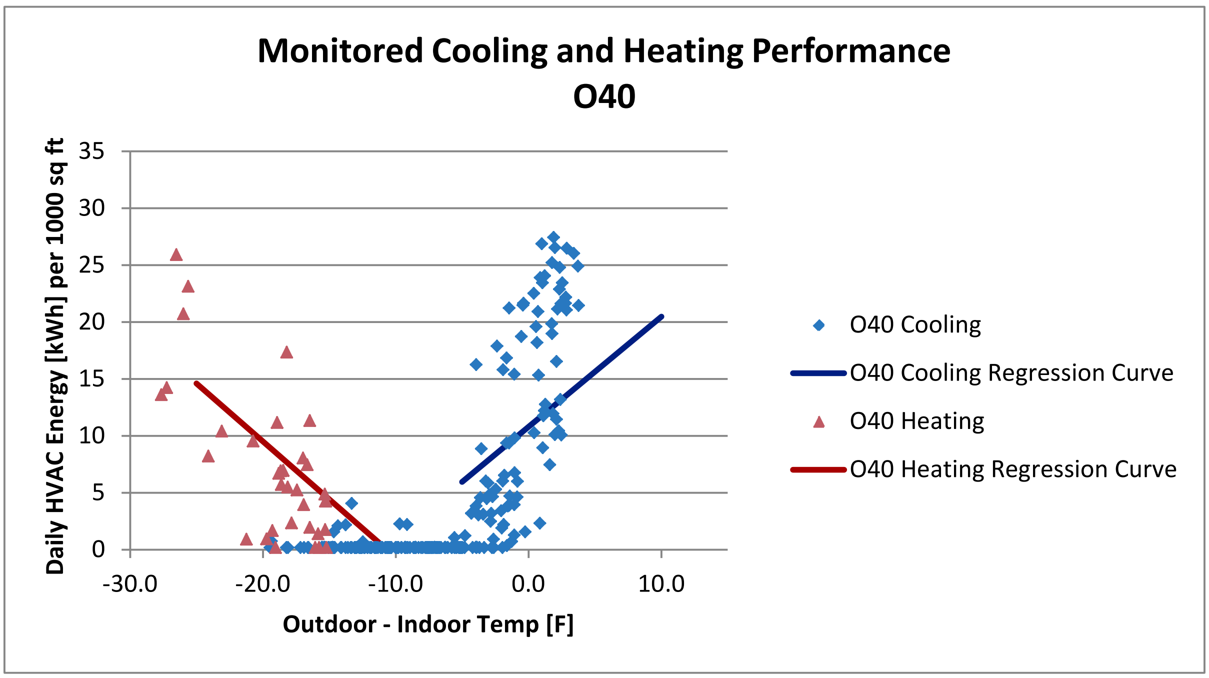

Figure A-162 Monitored Cooling and Heating Performance, O40

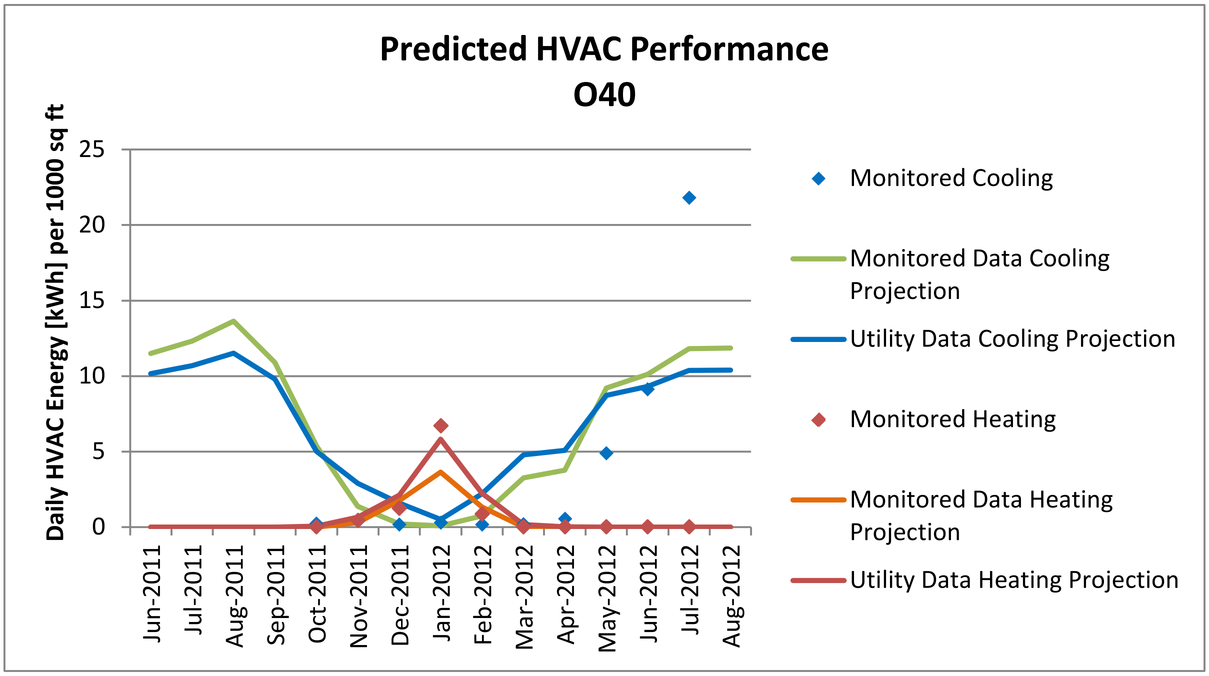

Figure A-163 Predicted HVAC Performance, O40

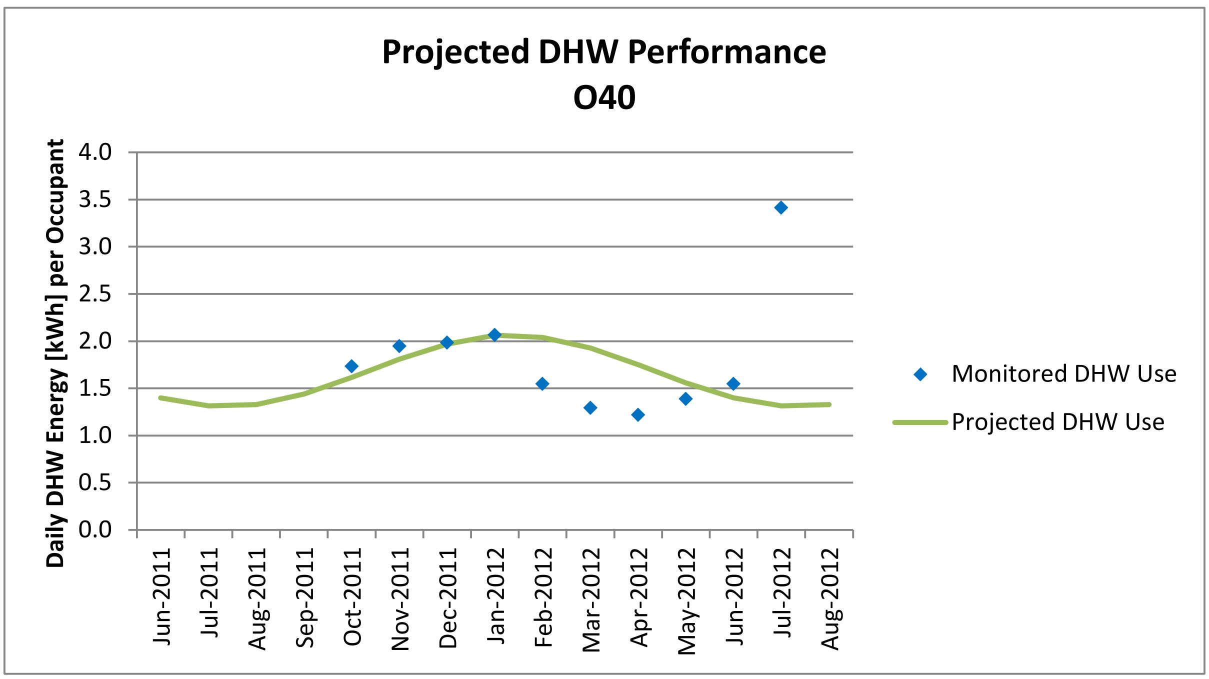

Figure A-164 Projected DHW Performance, O40

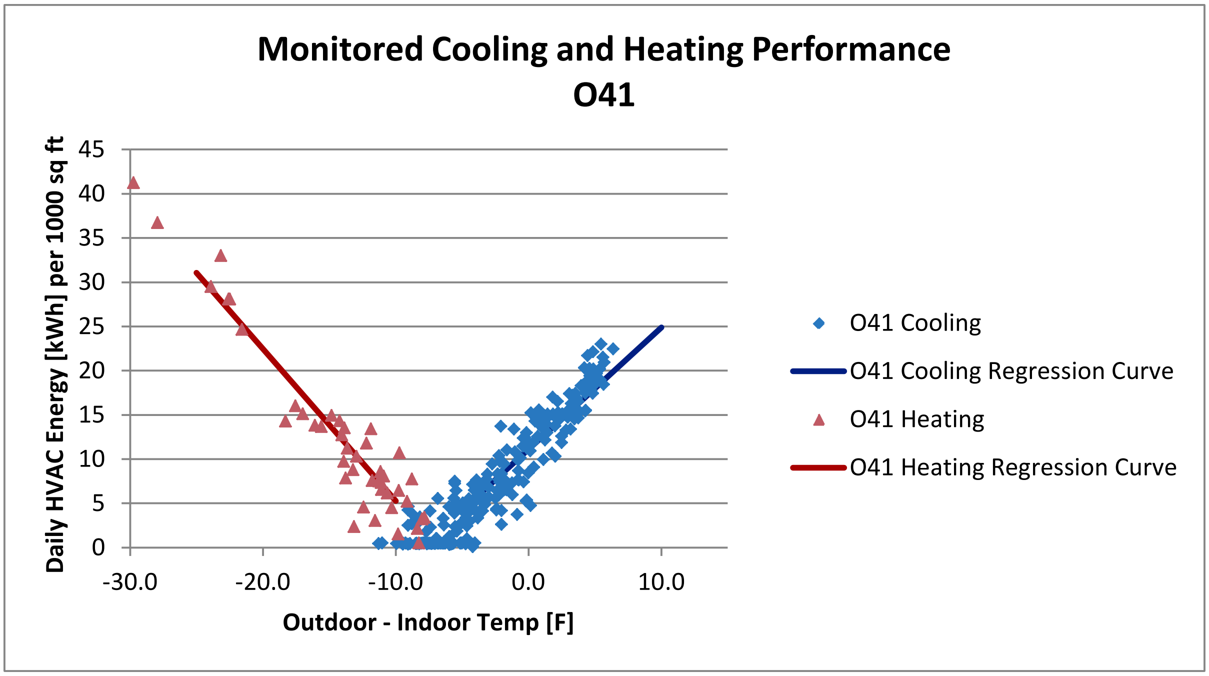

Figure A-165 Monitored Cooling and Heating Performance, O41

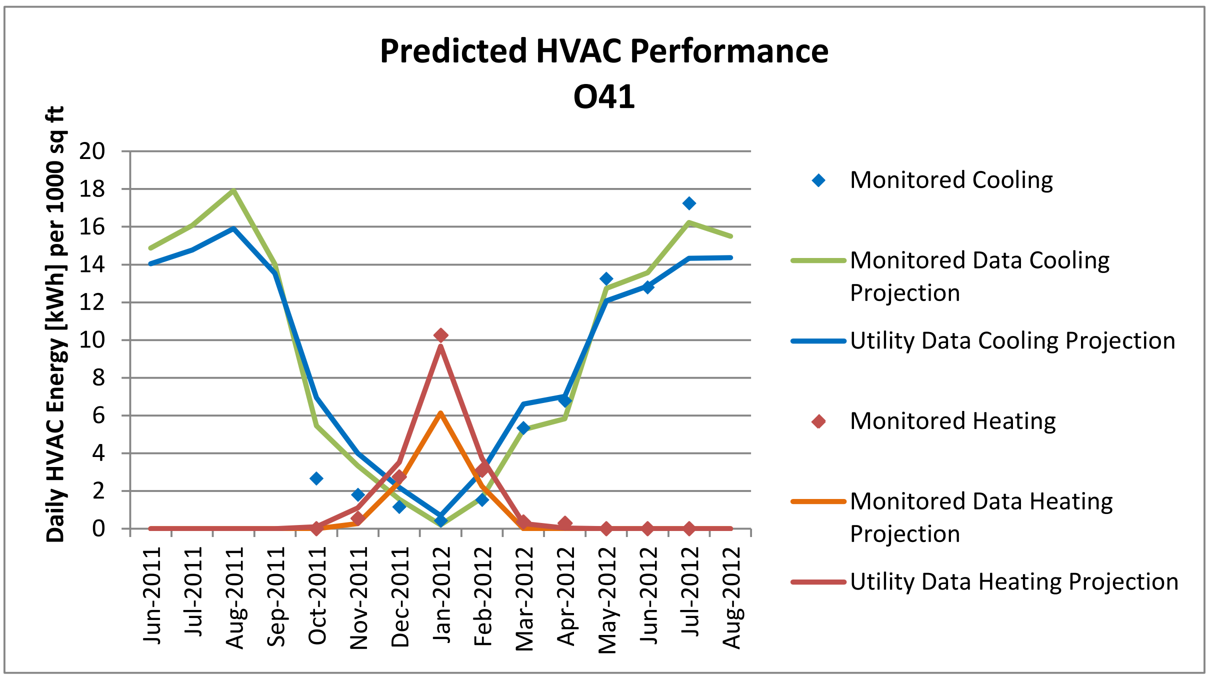

Figure A-166 Predicted HVAC Performance, O41

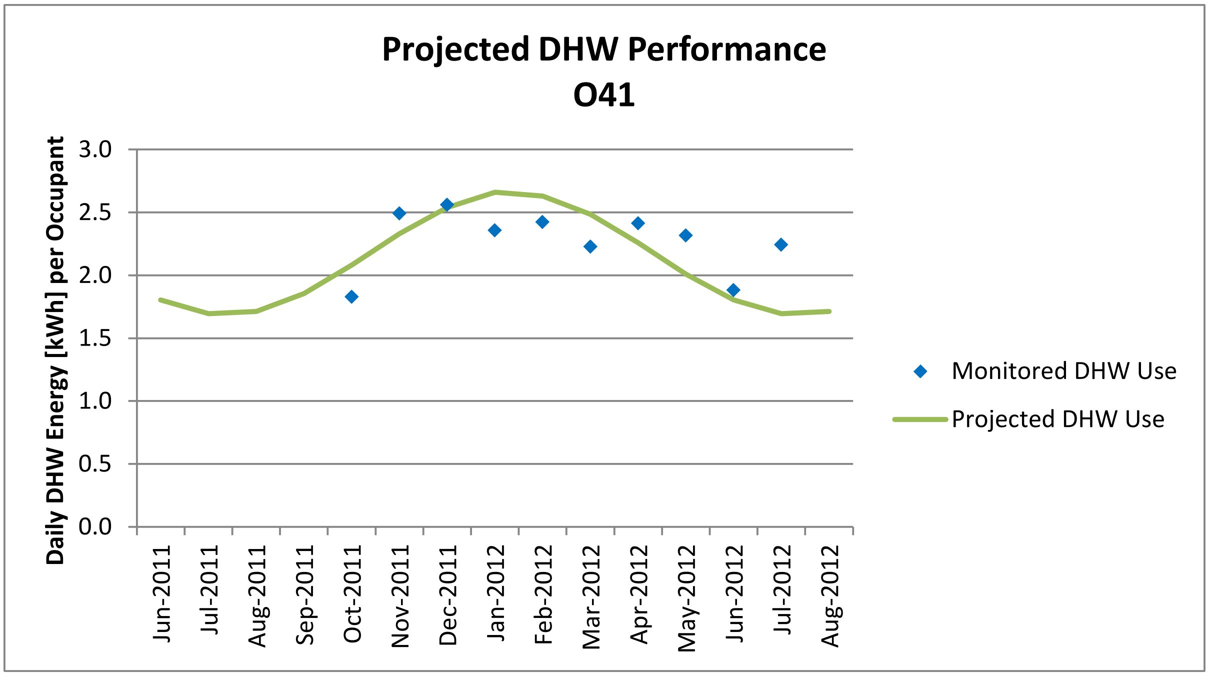

Figure A-167 Projected DHW Performance, O41

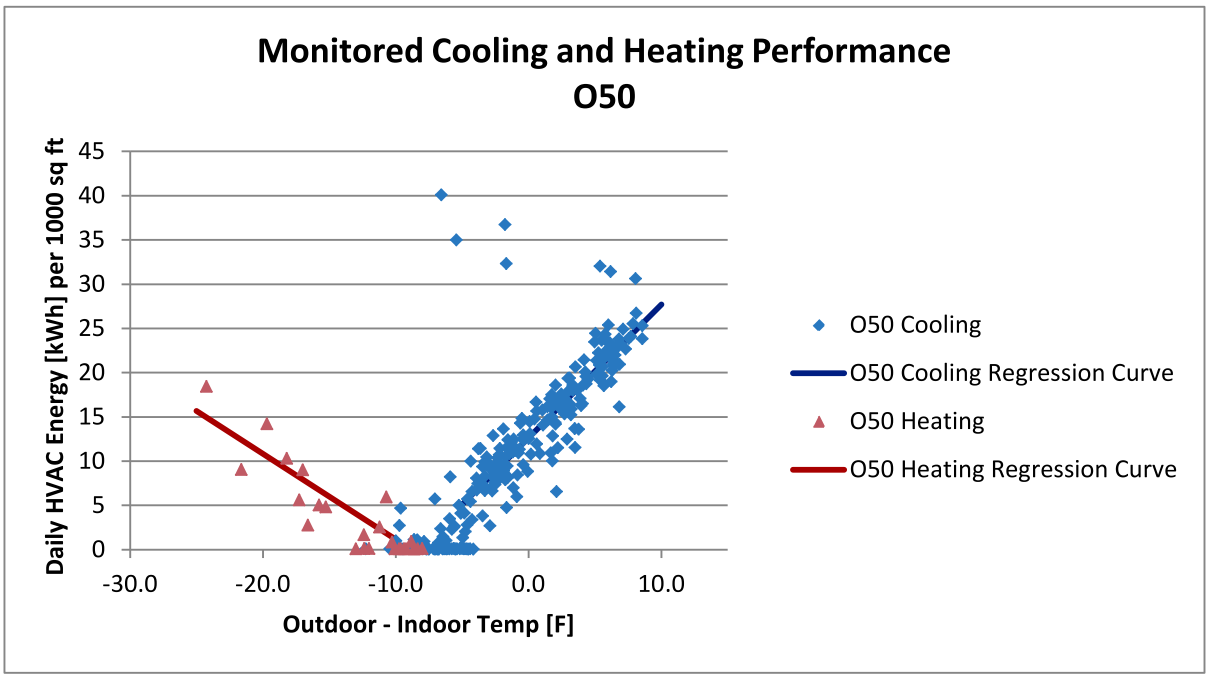

Figure A-168 Monitored Cooling and Heating Performance, O50

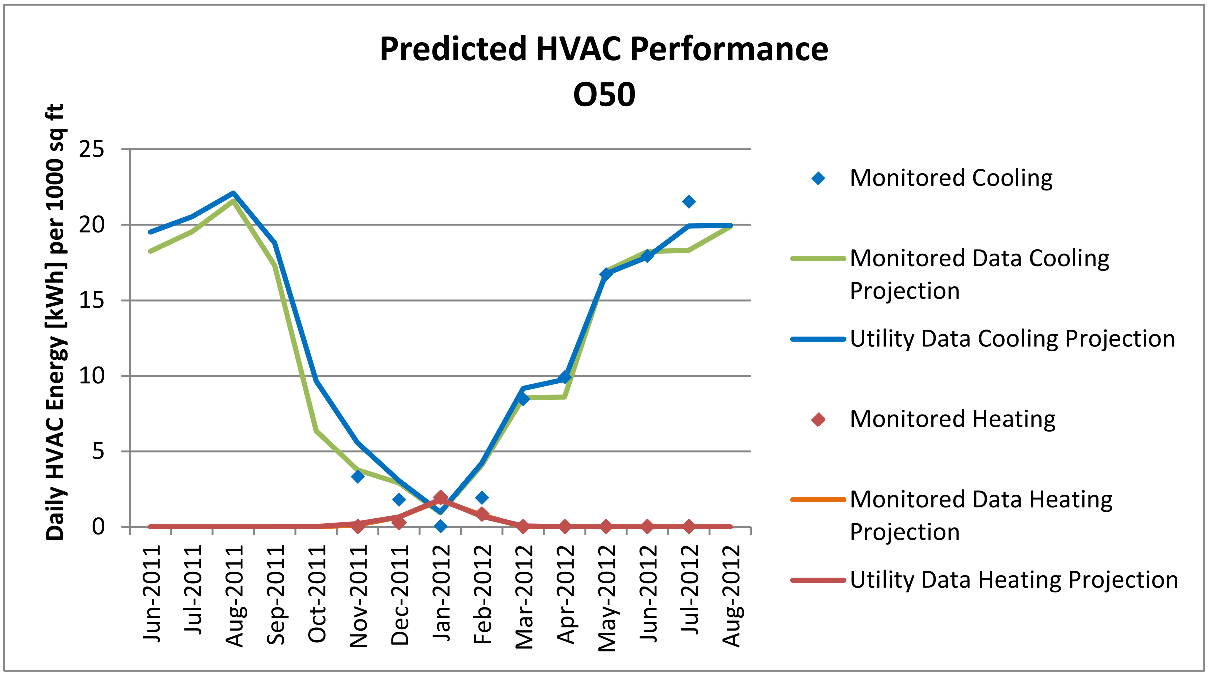

Figure A-169 Predicted HVAC Performance, O50

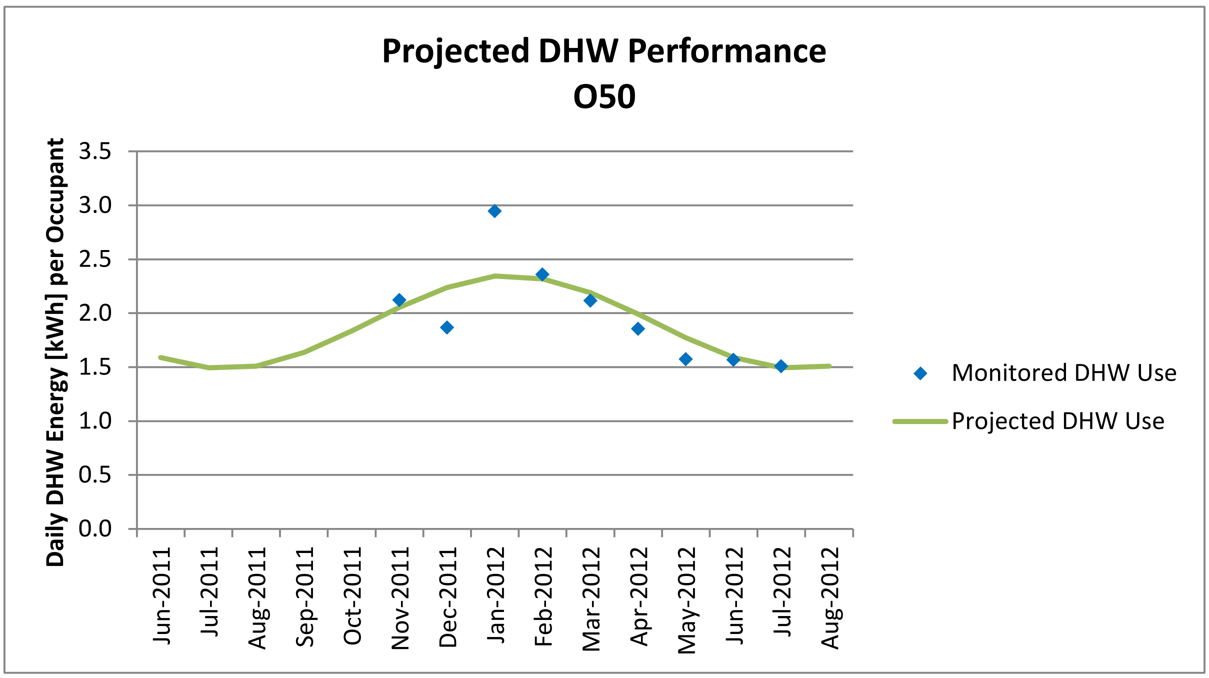

Figure A-170 Projected DHW Performance, O50

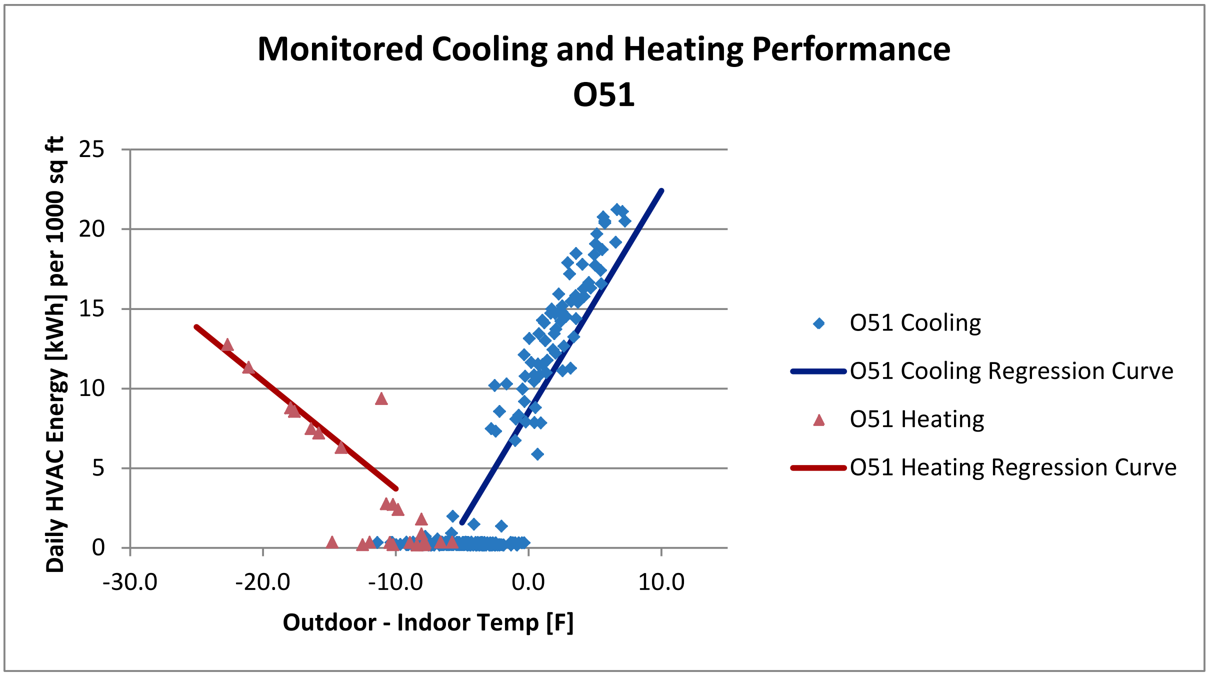

Figure A-171 Monitored Cooling and Heating Performance, O51

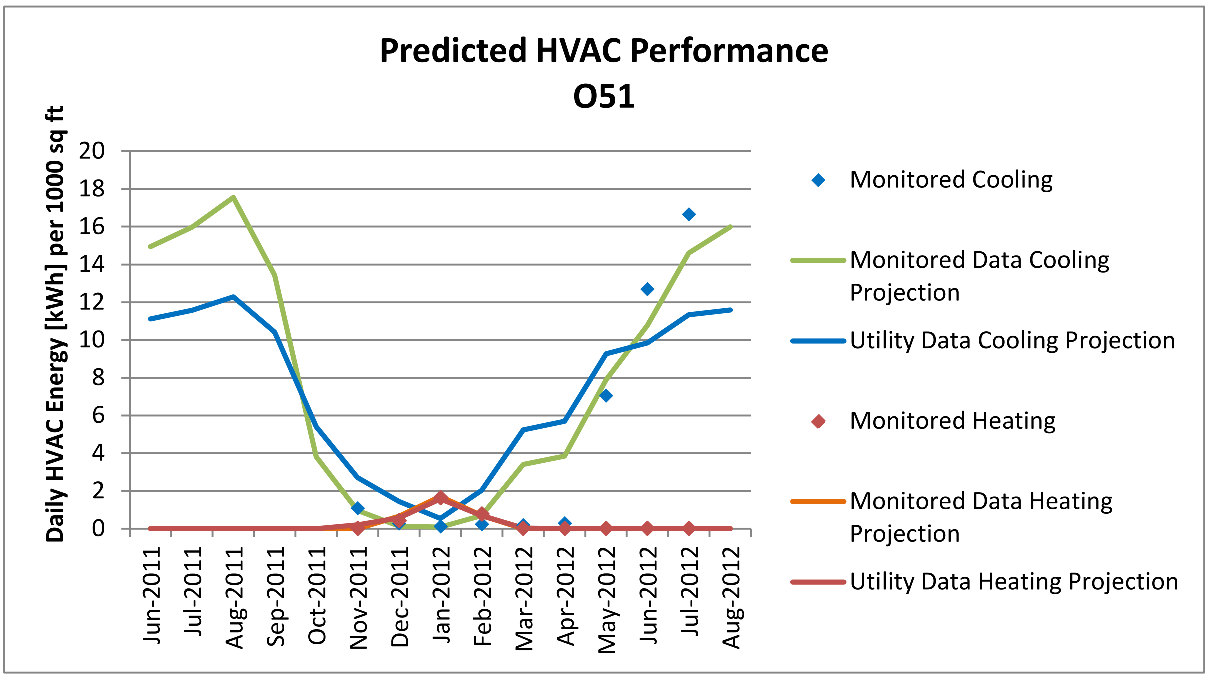

Figure A-172 Predicted HVAC Performance, O51

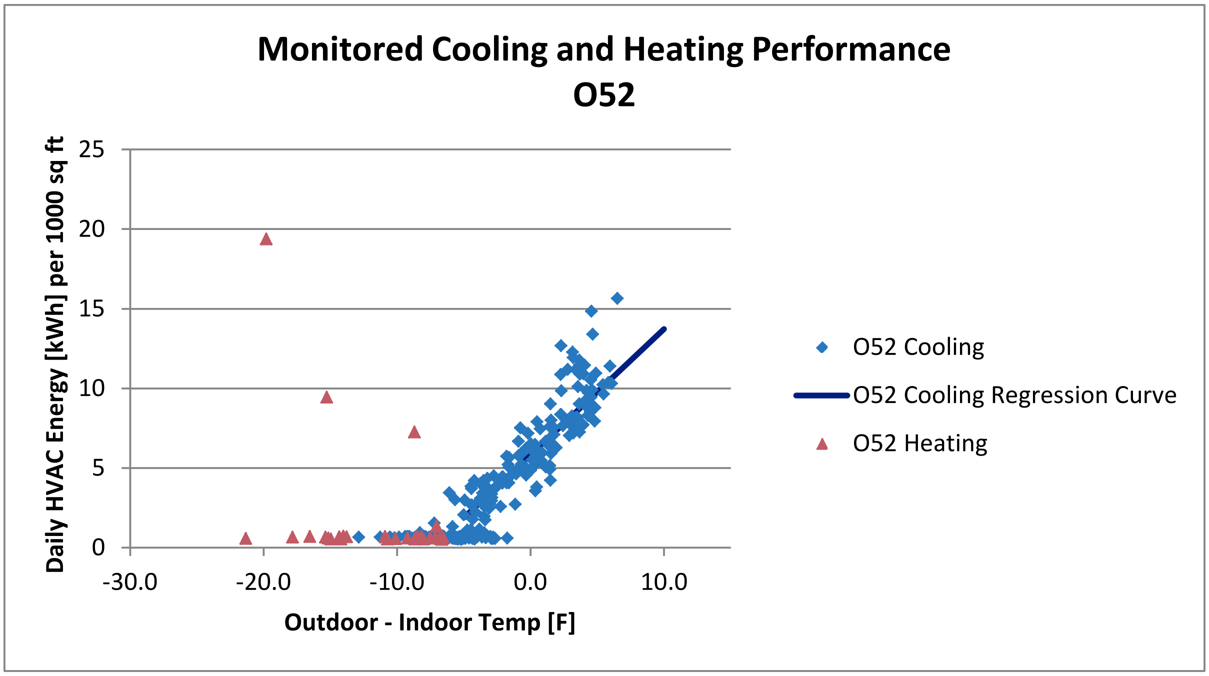

Figure A-173 Monitored Cooling and Heating Performance, O52

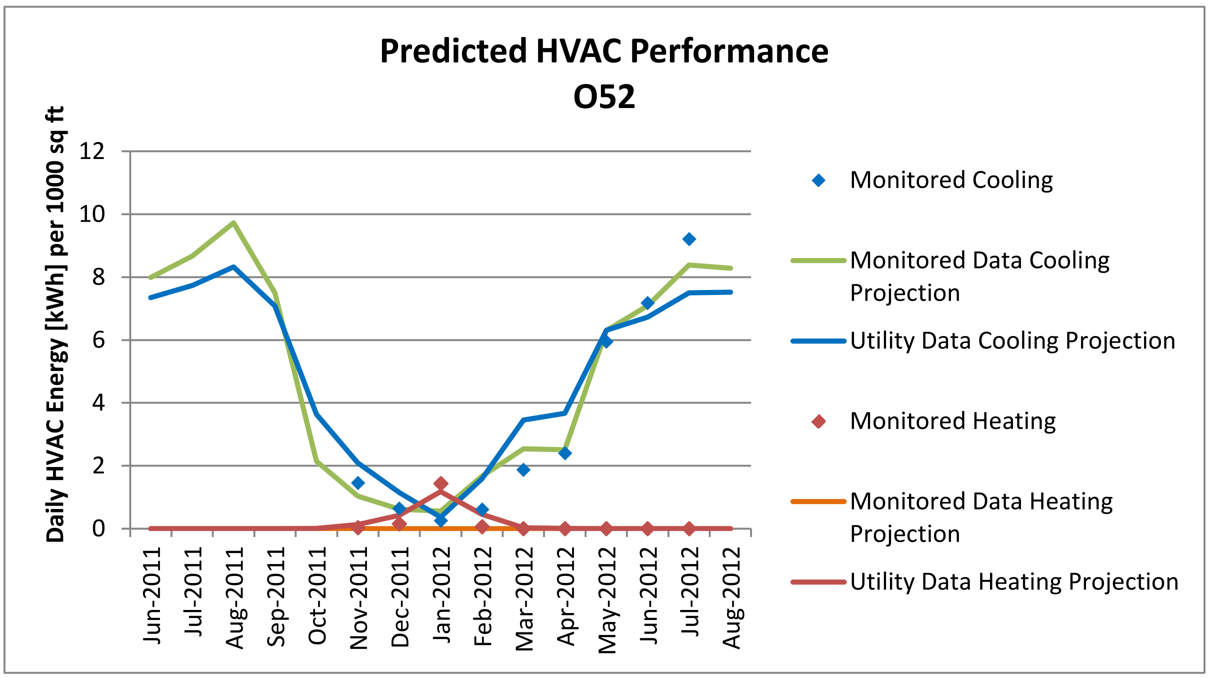

Figure A-174 Predicted HVAC Performance, O52

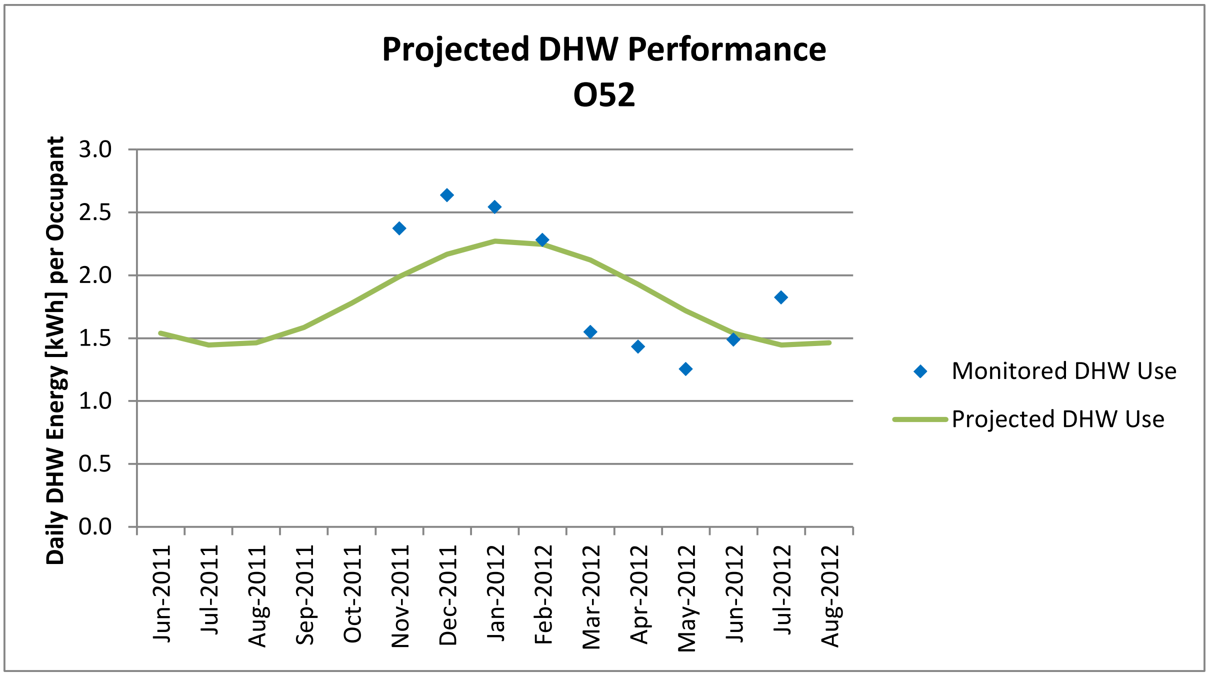

Figure A-175 Projected DHW Performance, O52

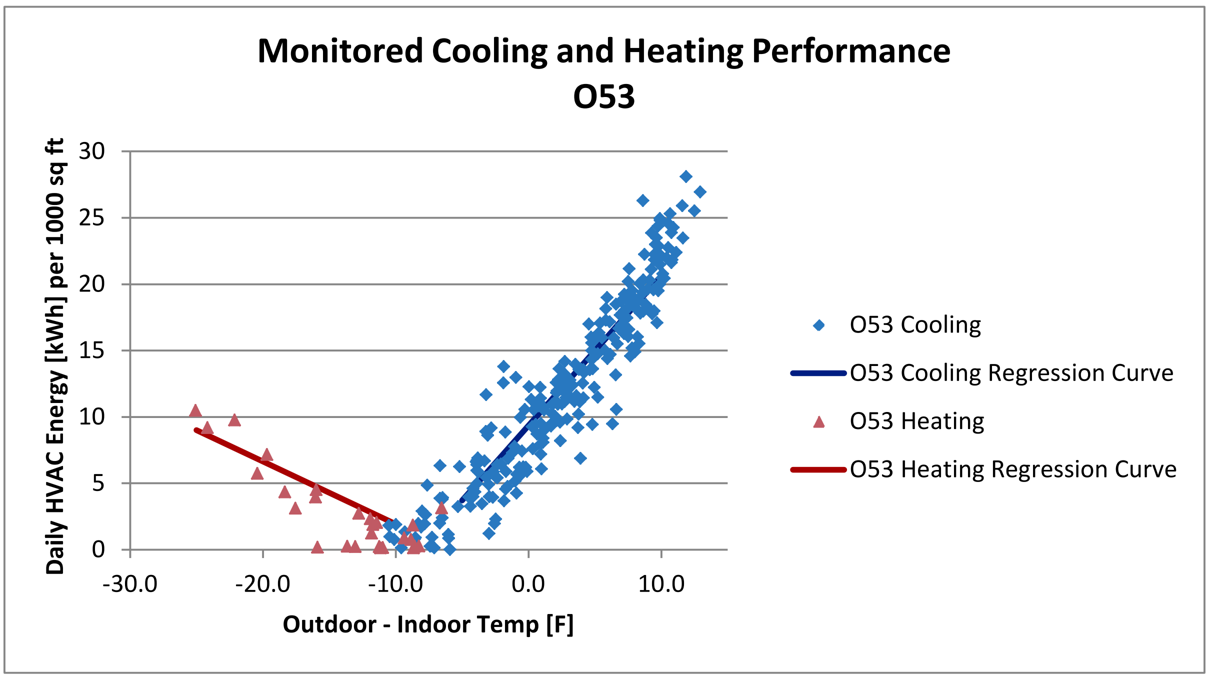

Figure A-176 Monitored Cooling and Heating Performance, O53

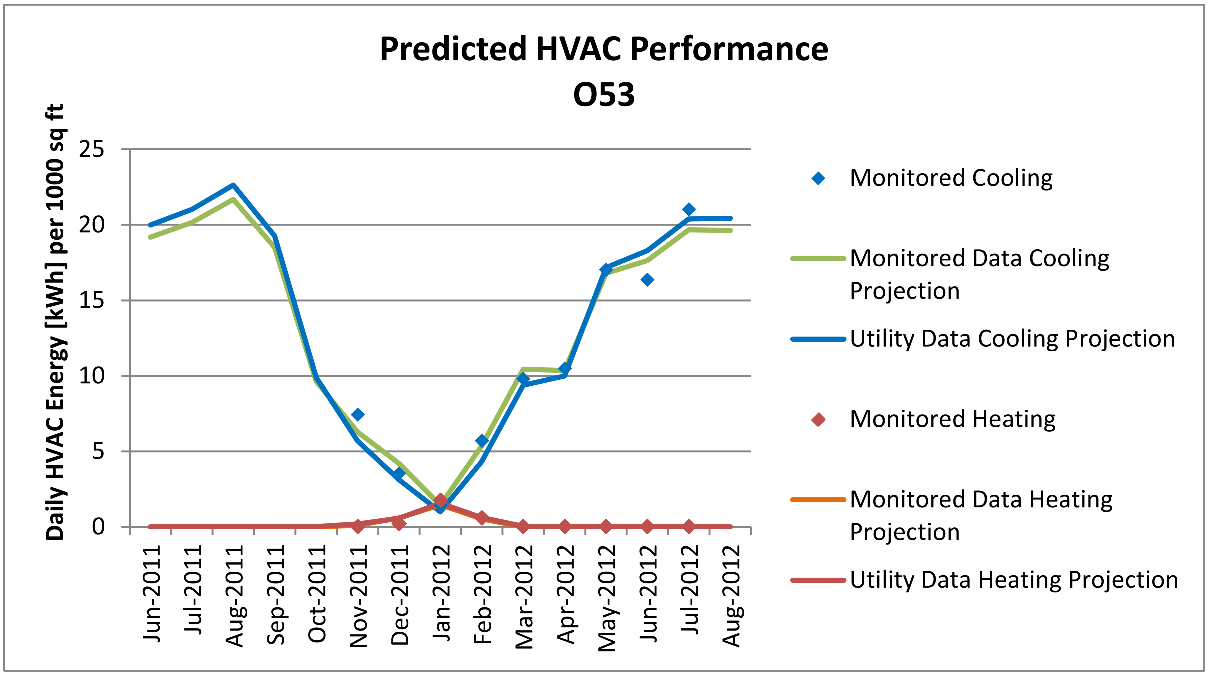

Figure A-177 Predicted HVAC Performance, O53

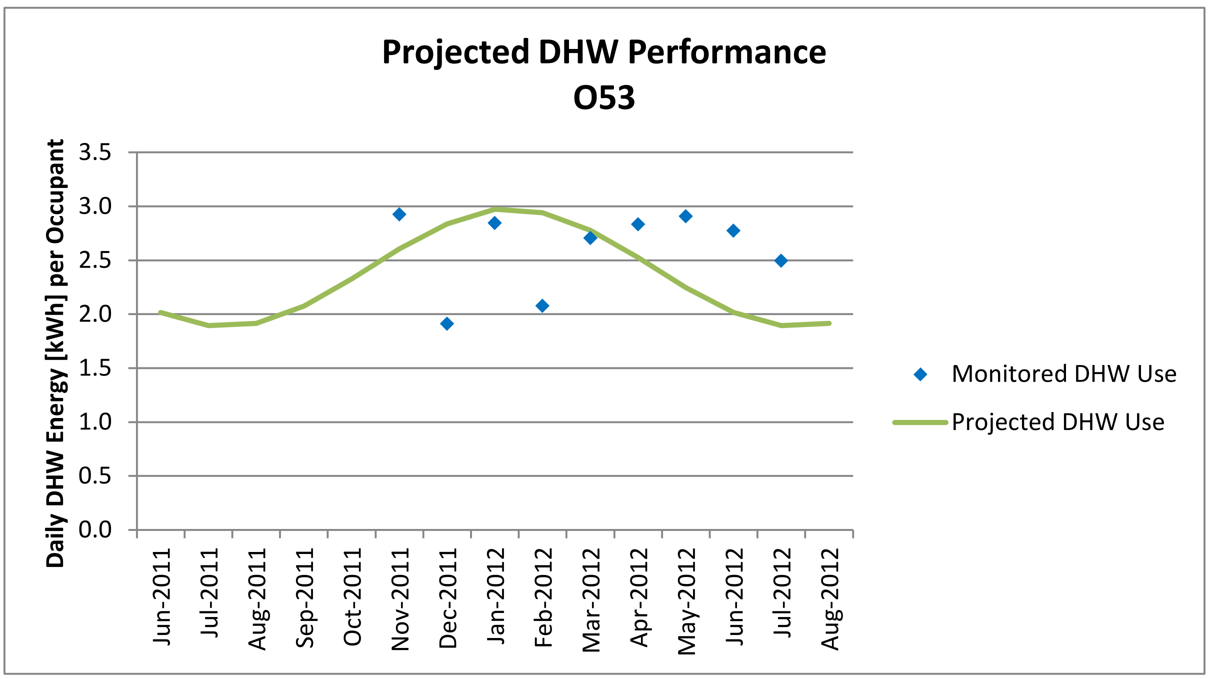

Figure A-178 Projected DHW Performance, O53

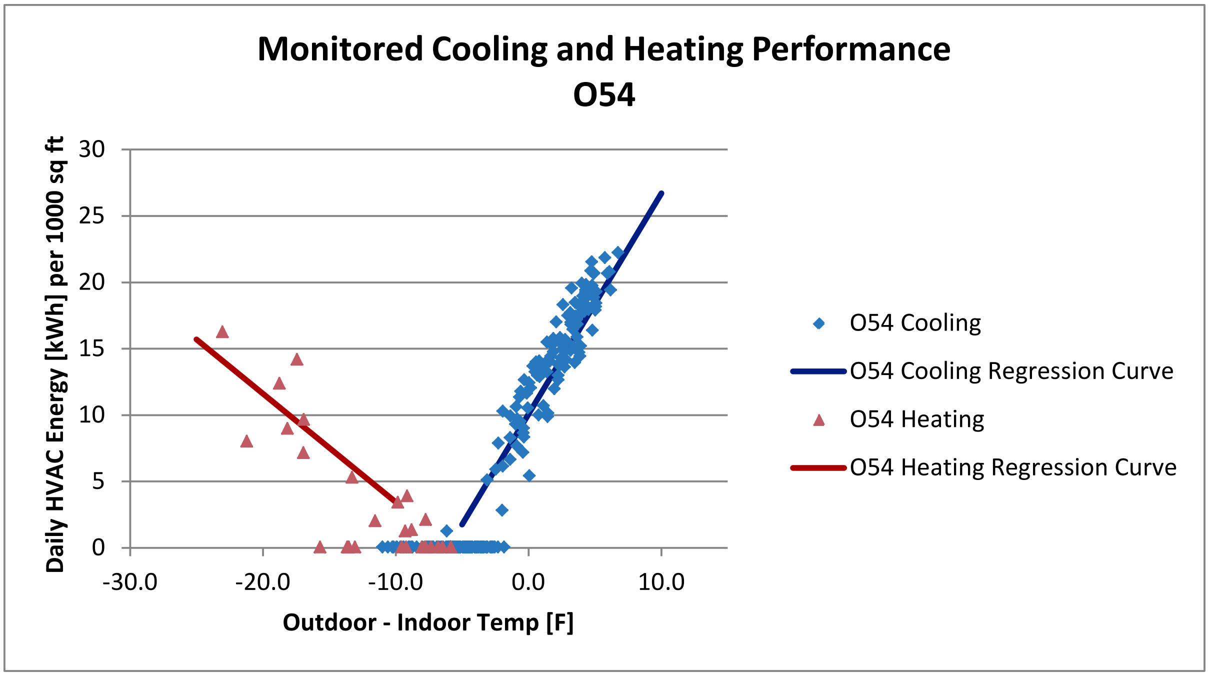

Figure A-179 Monitored Cooling and Heating Performance, O54

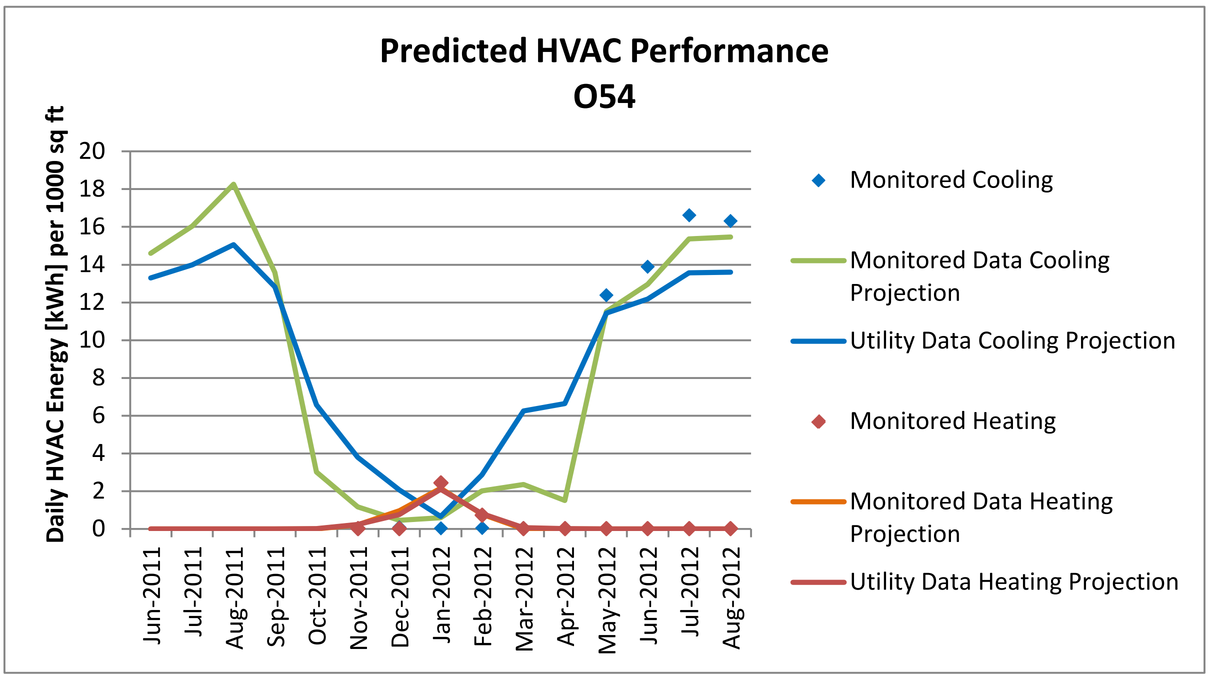

Figure A-180 Predicted HVAC Performance, O54

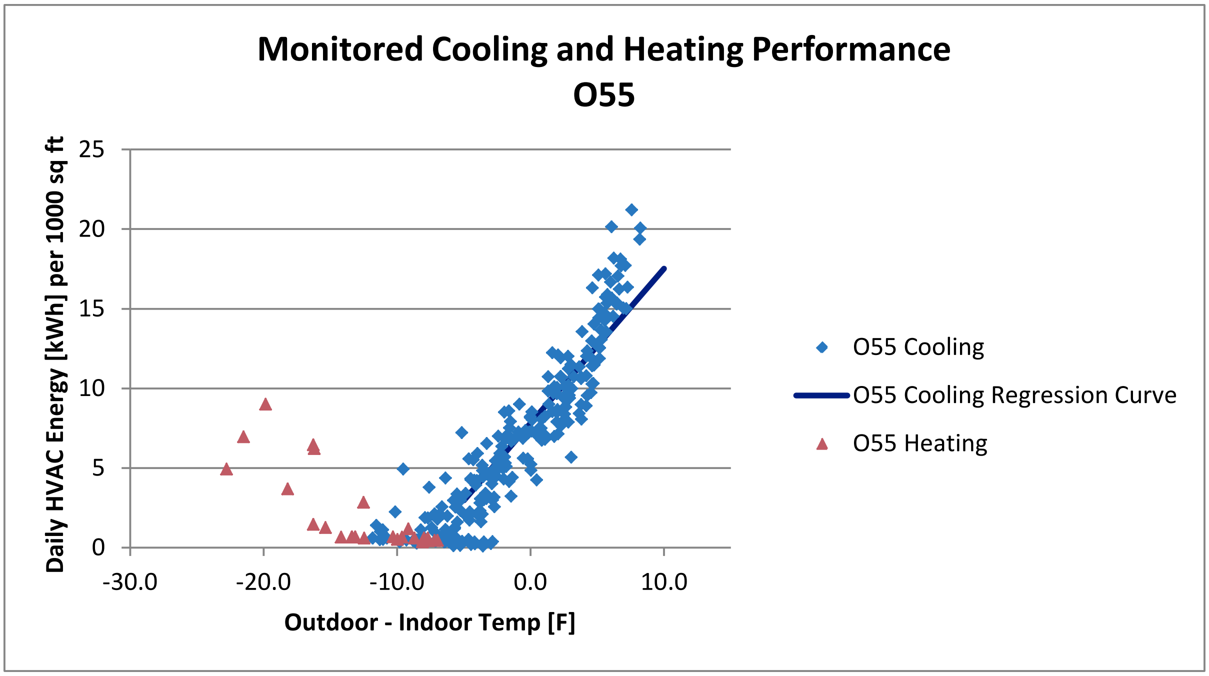

Figure A-181 Monitored Cooling and Heating Performance, O55

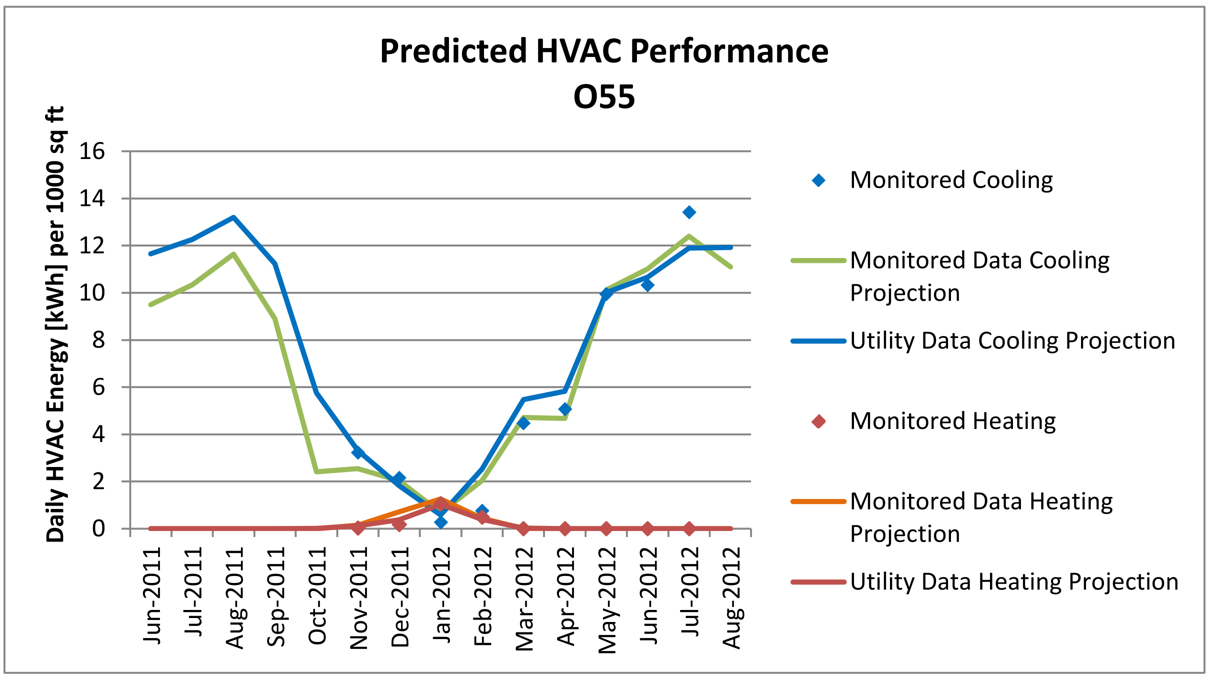

Figure A-182 Predicted HVAC Performance, O55

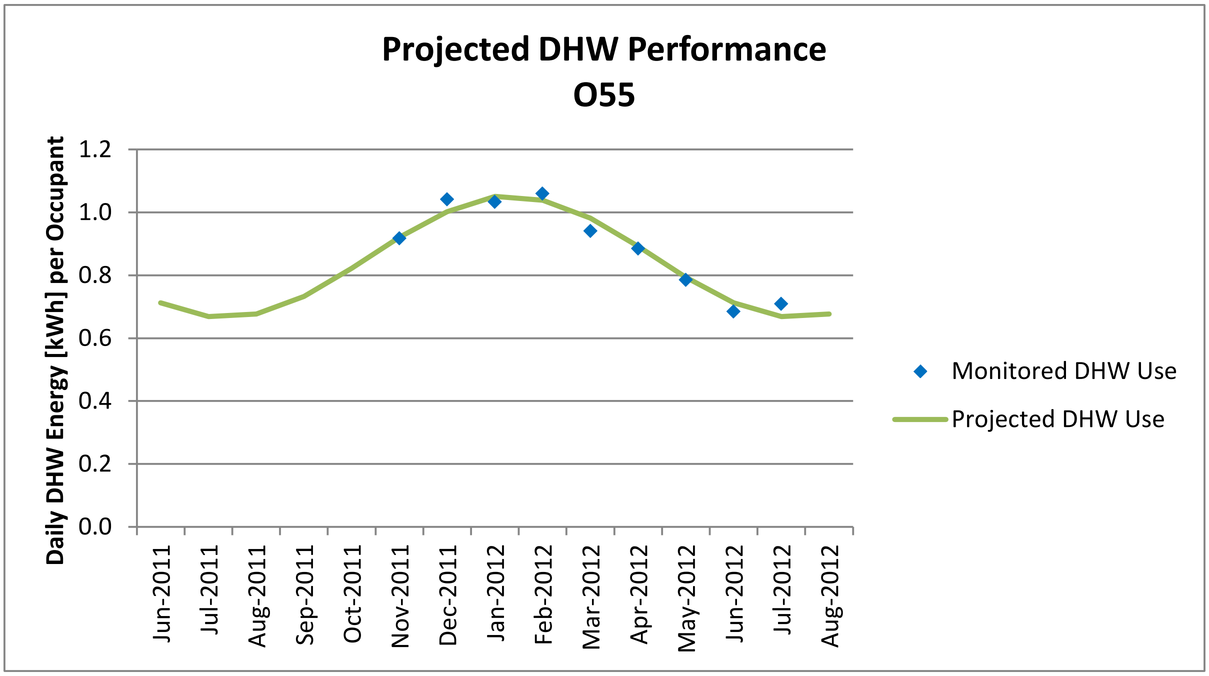

Figure A-183 Projected DHW Performance, O55

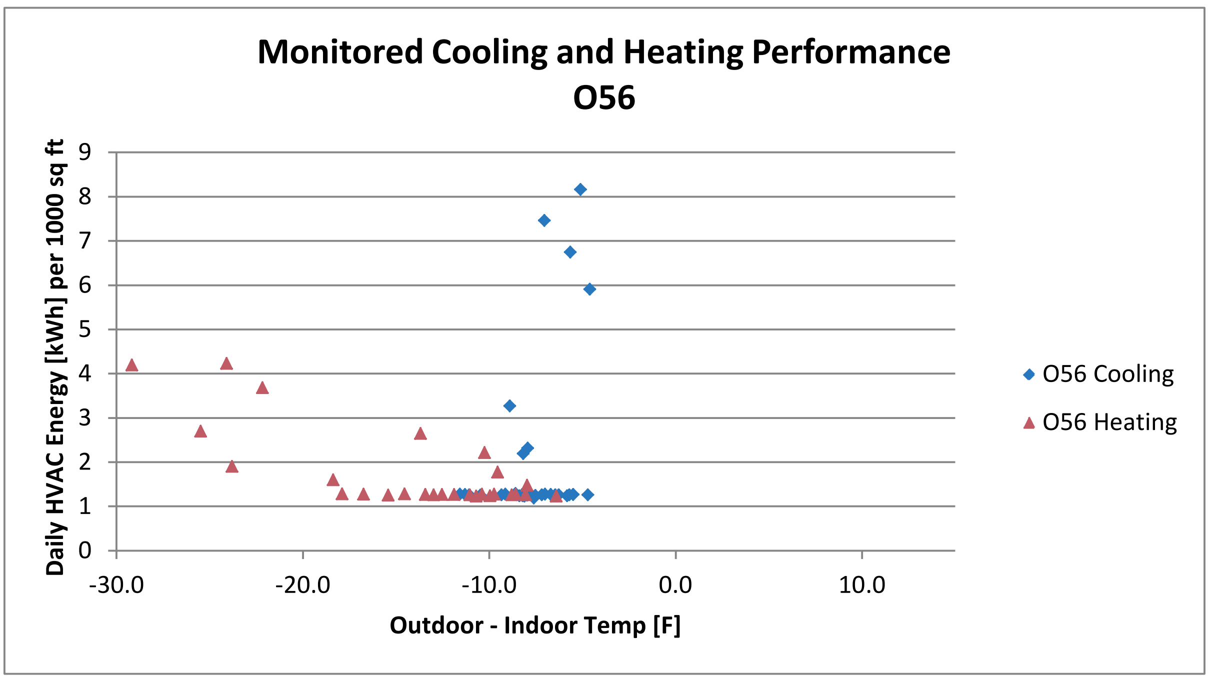

Figure A-184 Monitored Cooling and Heating Performance, O56

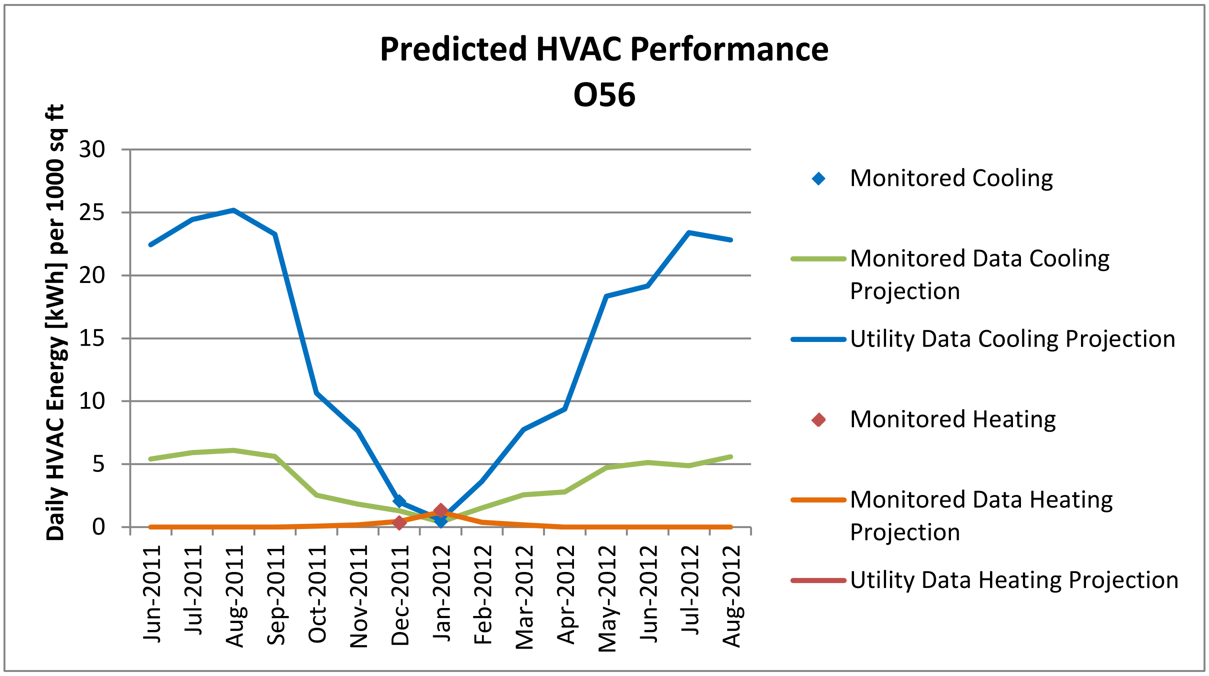

Figure A-185 Predicted HVAC Performance, O56

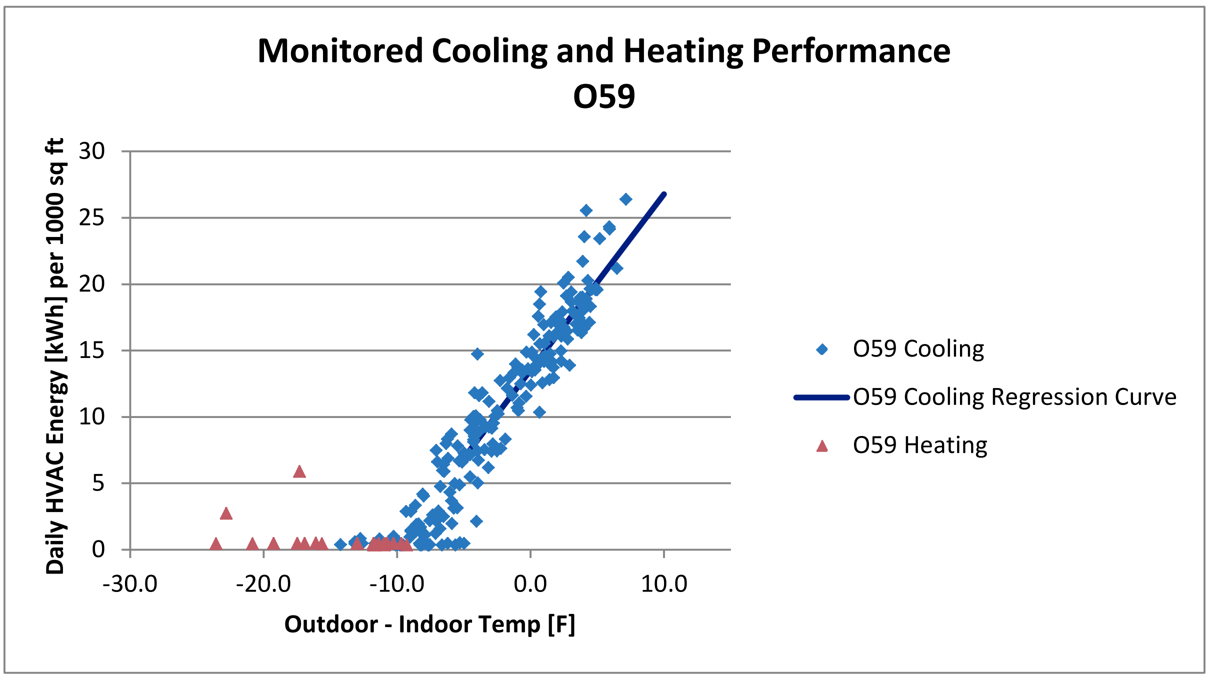

Figure A-186 Monitored Cooling and Heating Performance, O59

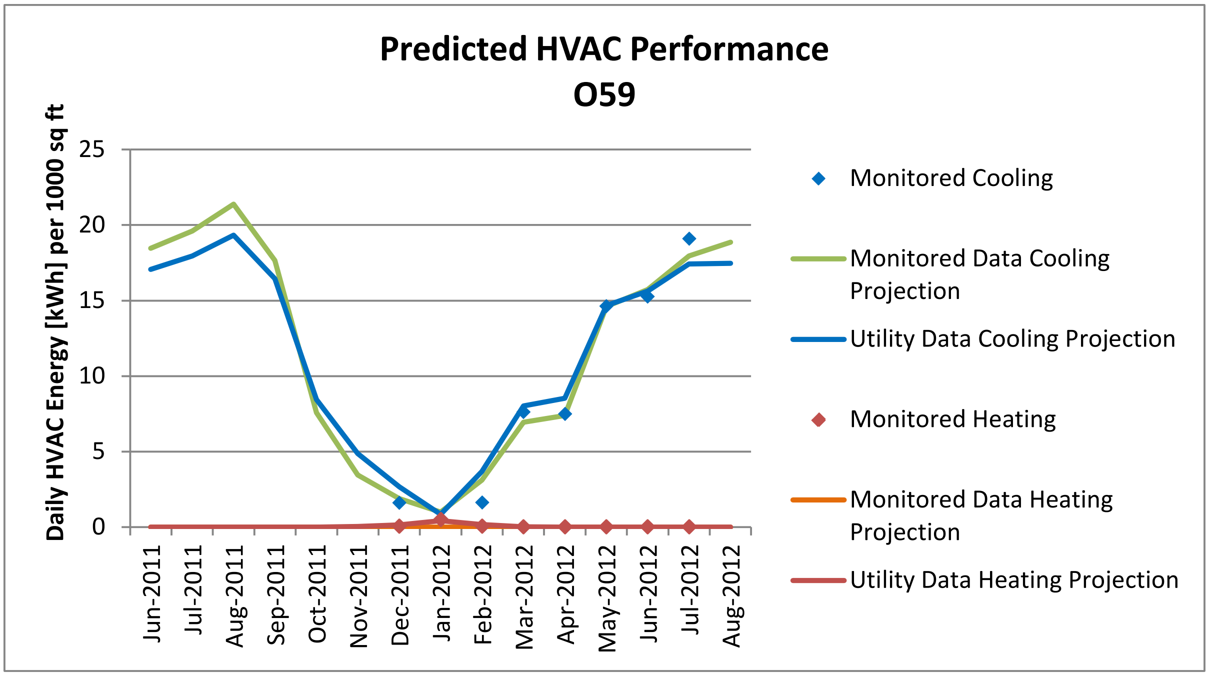

Figure A-187 Predicted HVAC Performance, O59

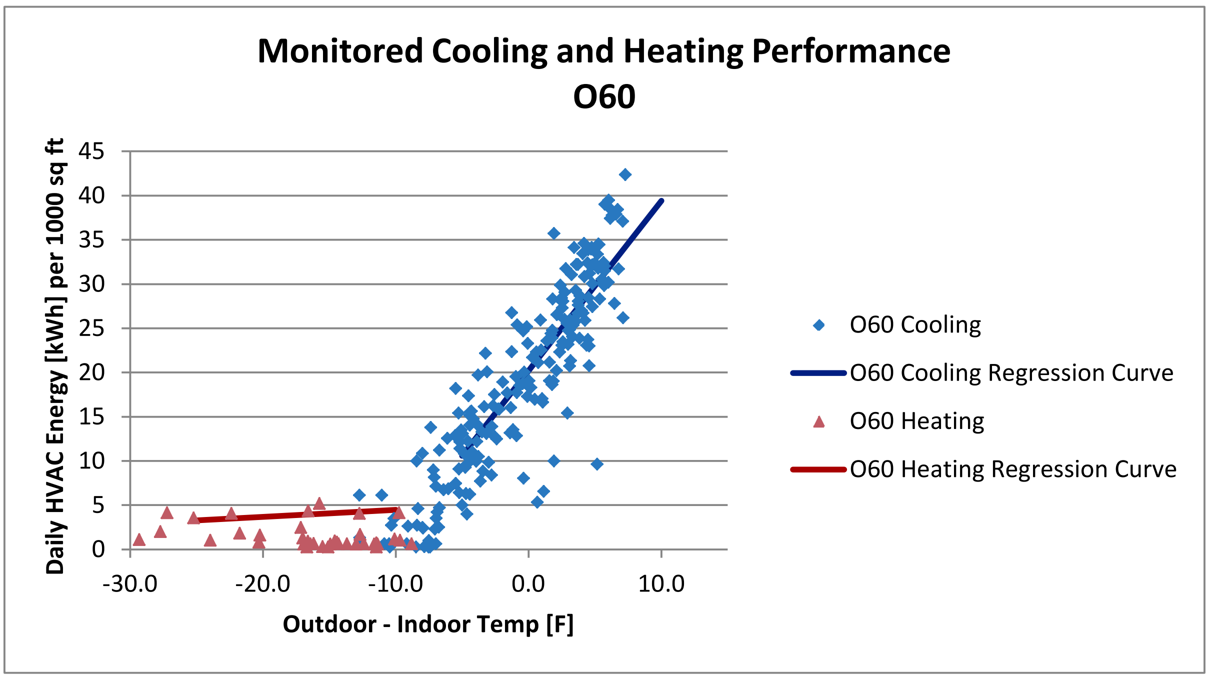

Figure A-188 Monitored Cooling and Heating Performance, O60

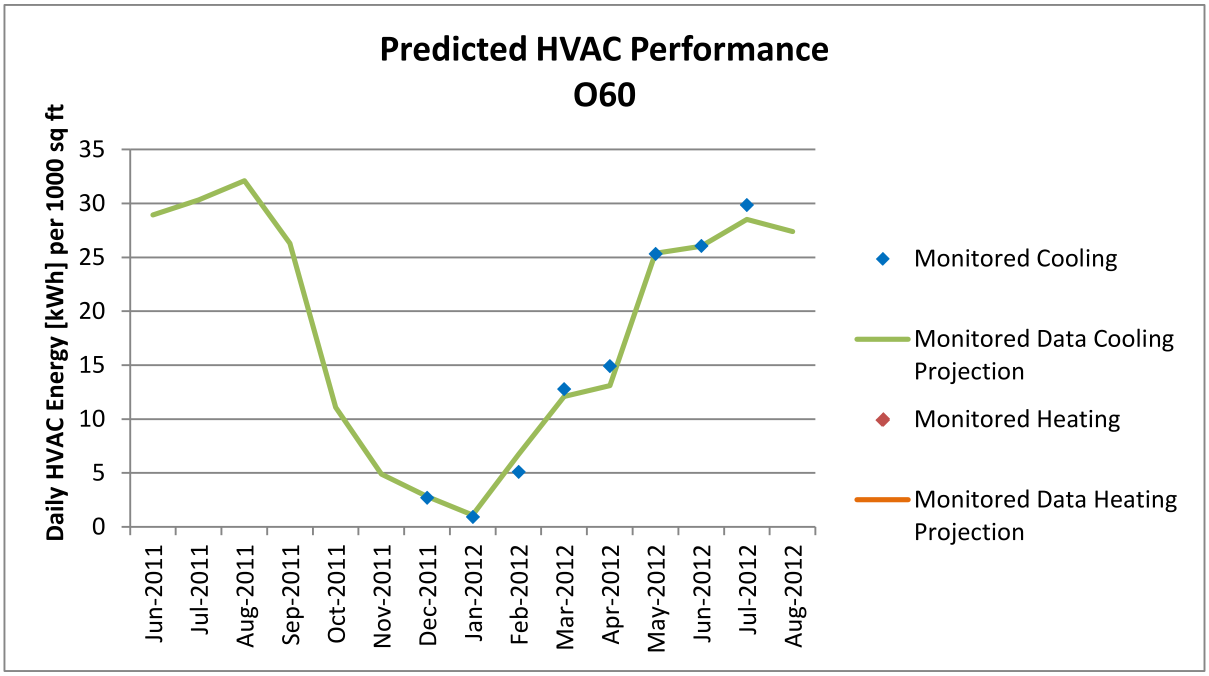

Figure A-189 Predicted HVAC Performance, O60

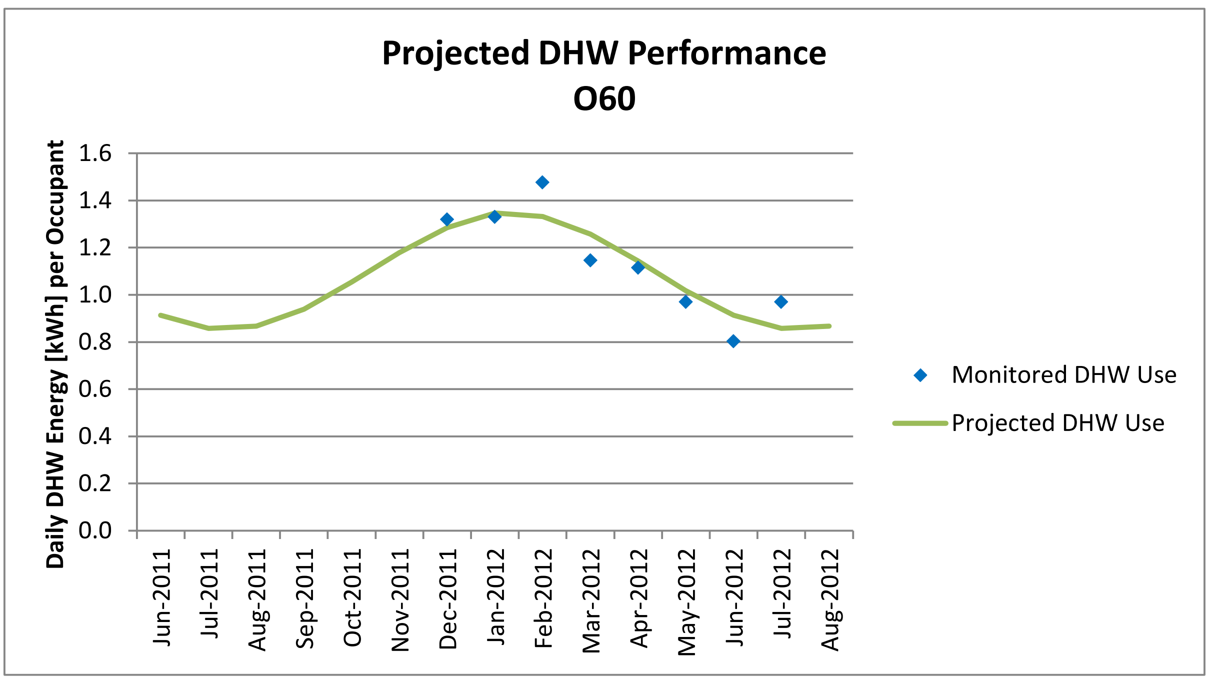

Figure A-190 Projected DHW Performance, O60

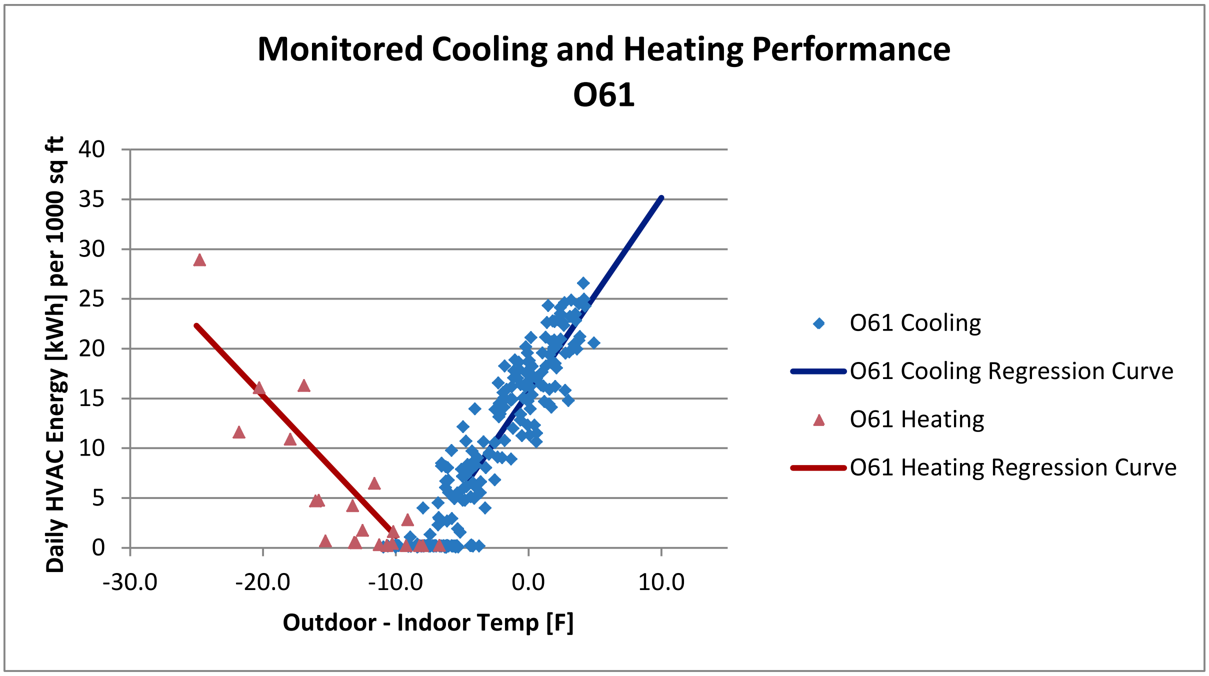

Figure A-191 Monitored Cooling and Heating Performance, O61

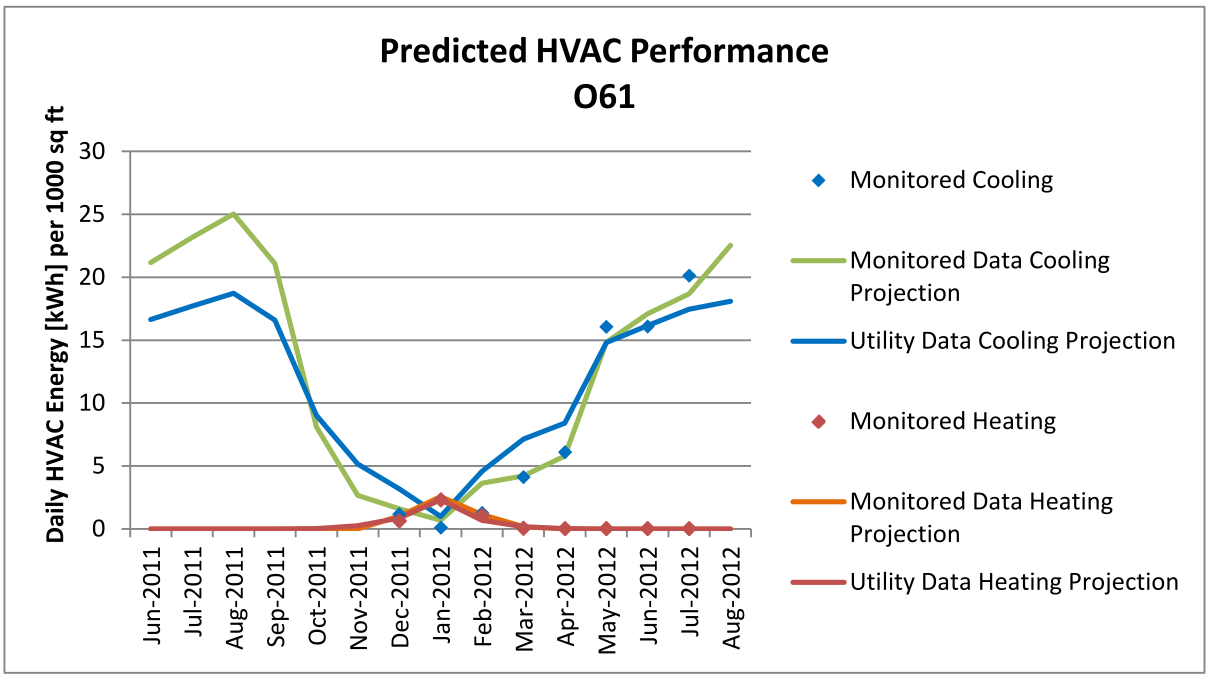

Figure A-192 Predicted HVAC Performance, O61

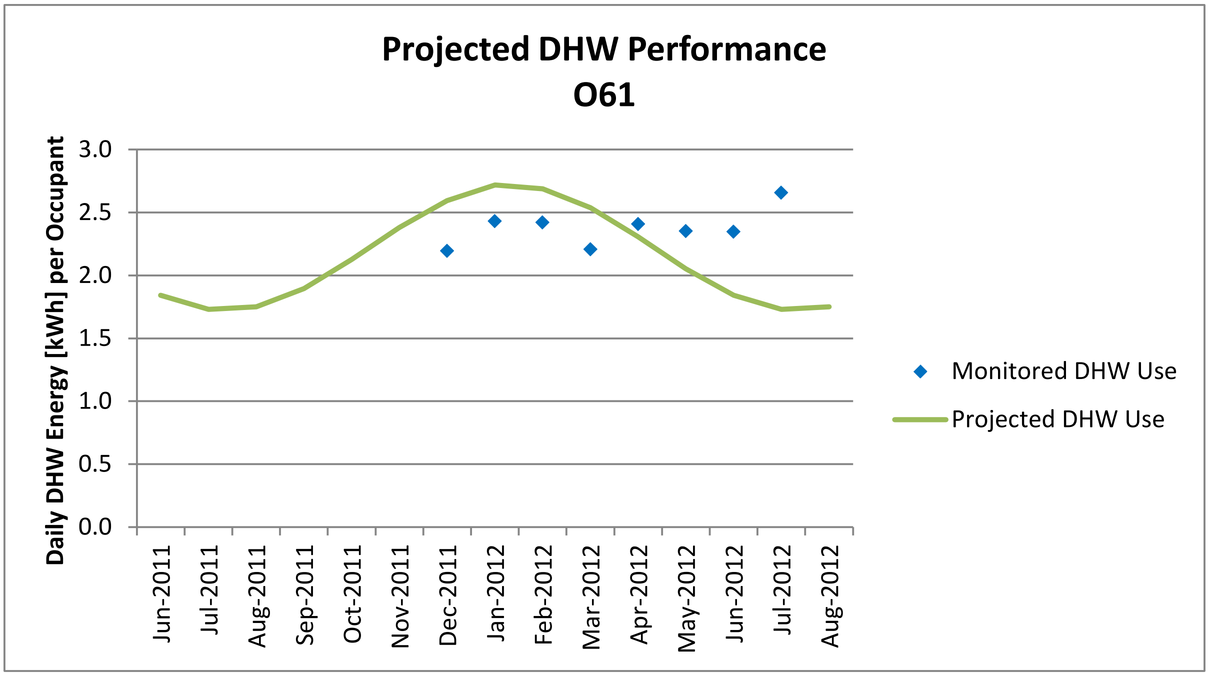

Figure A-193 Projected DHW Performance, O61

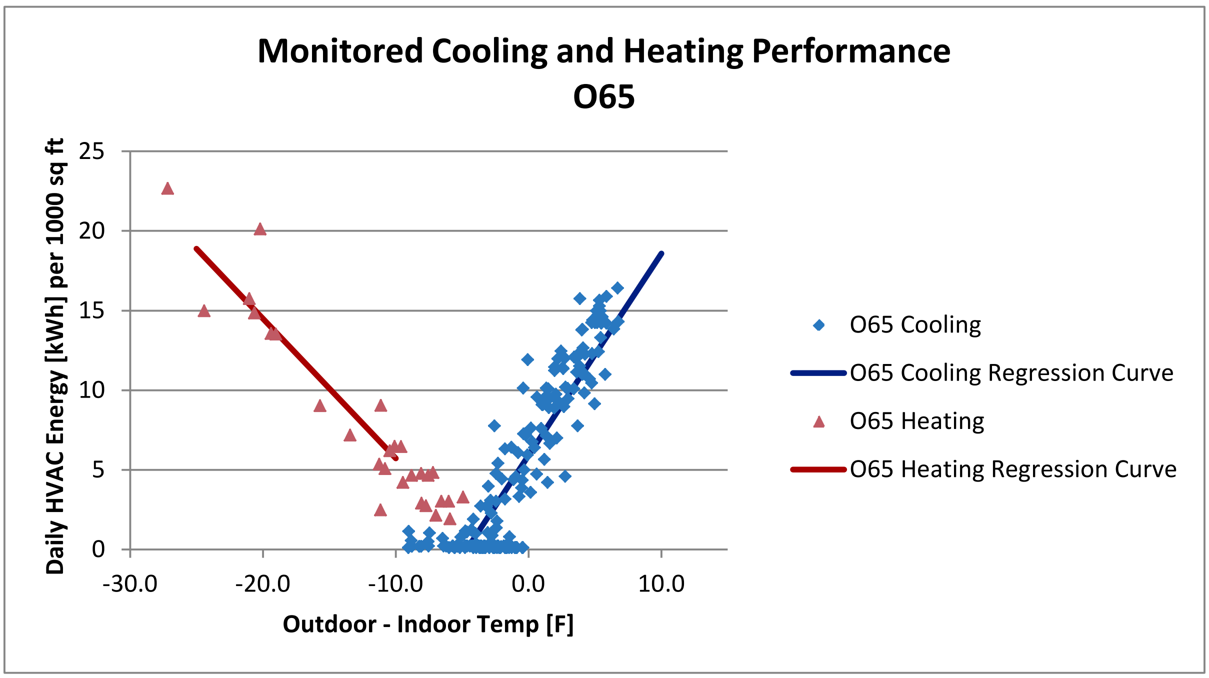

Figure A-194 Monitored Cooling and Heating Performance, O65

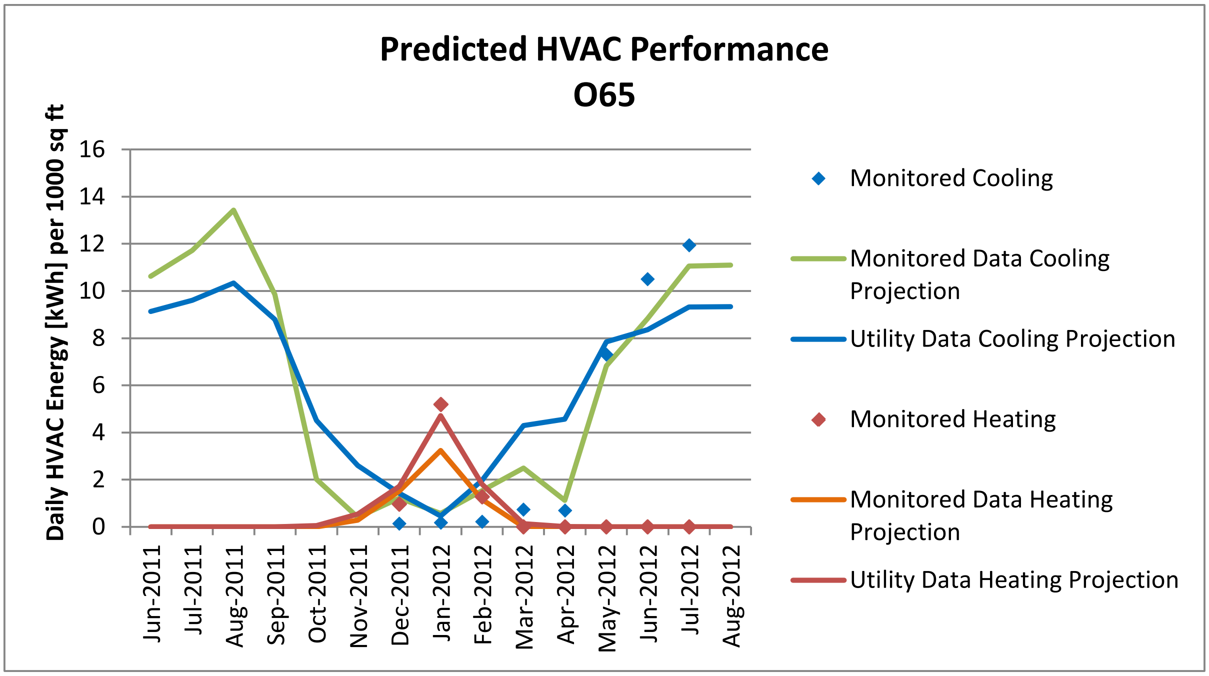

Figure A-195 Predicted HVAC Performance, O65

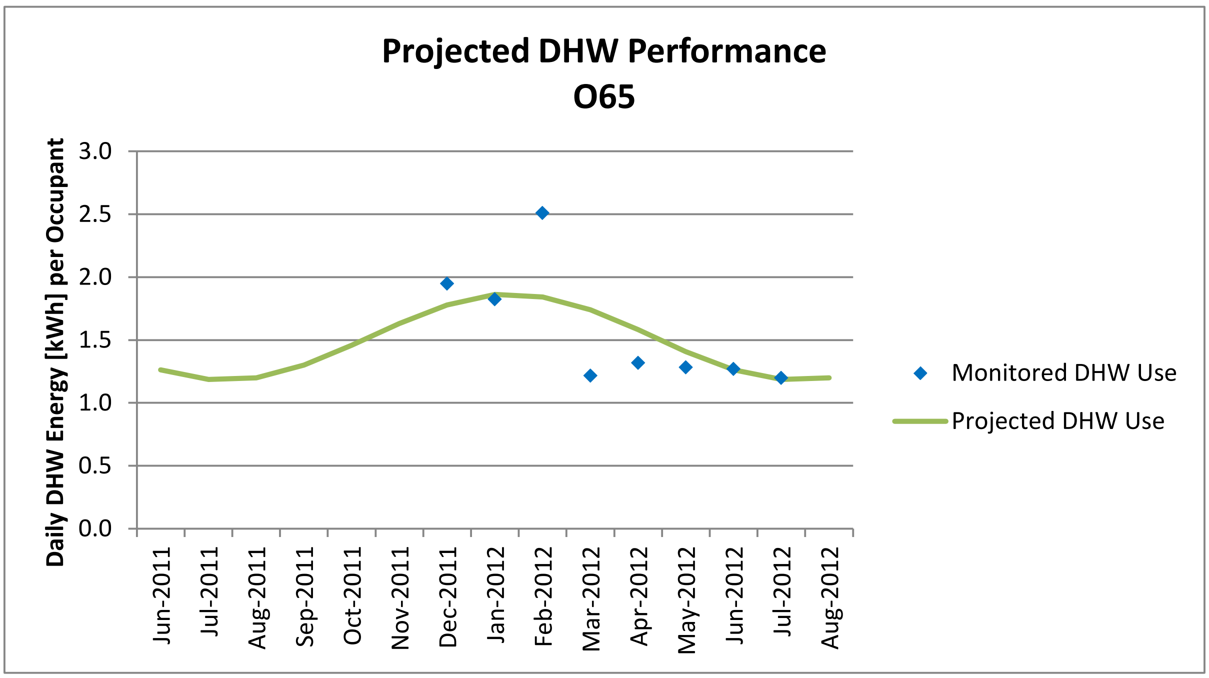

Figure A-196 Projected DHW Performance, O65

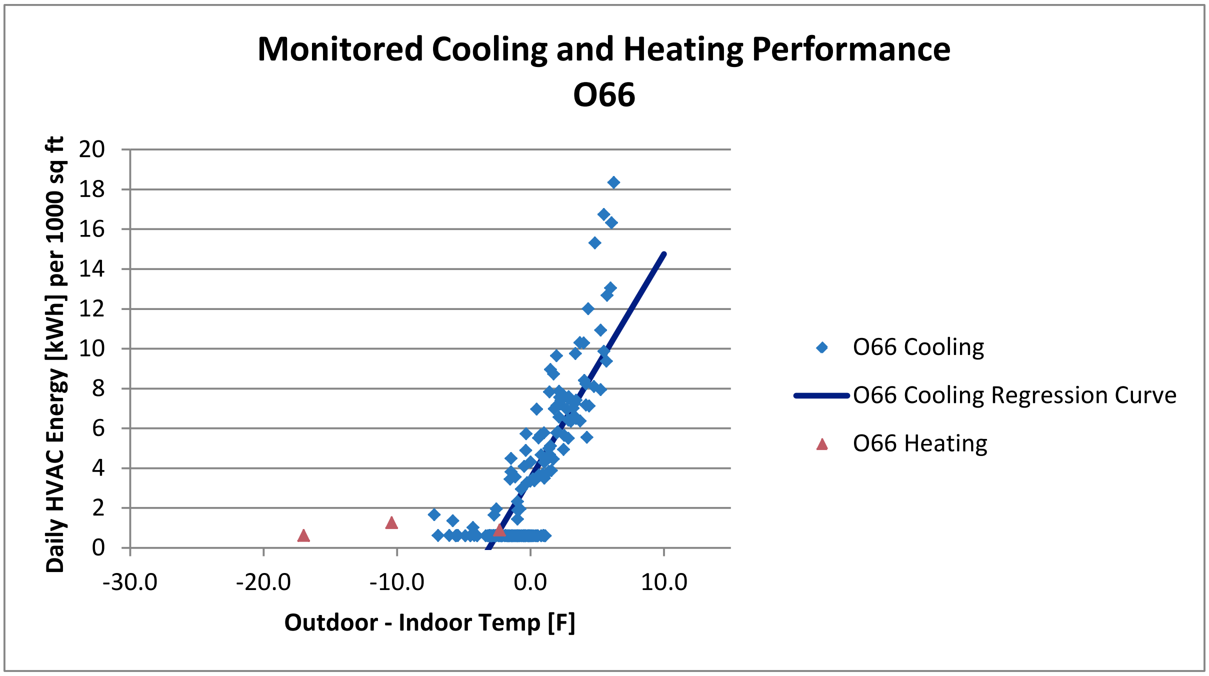

Figure A-197 Monitored Cooling and Heating Performance, O66

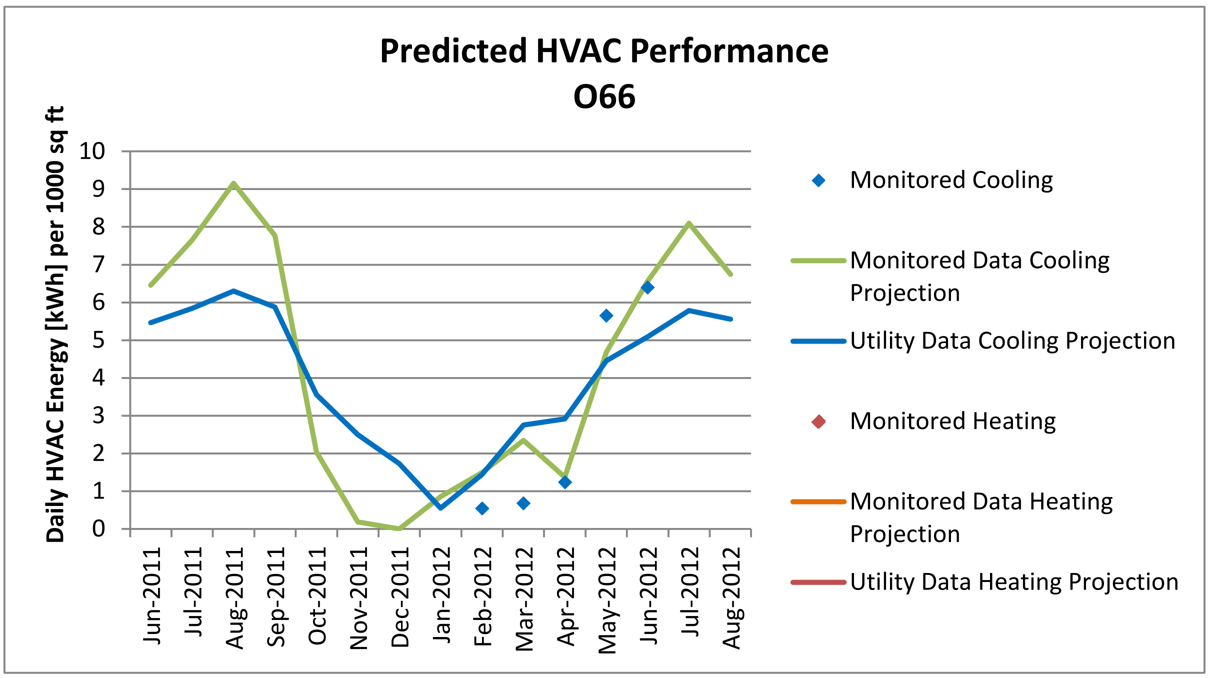

Figure A-198 Predicted HVAC Performance, O66

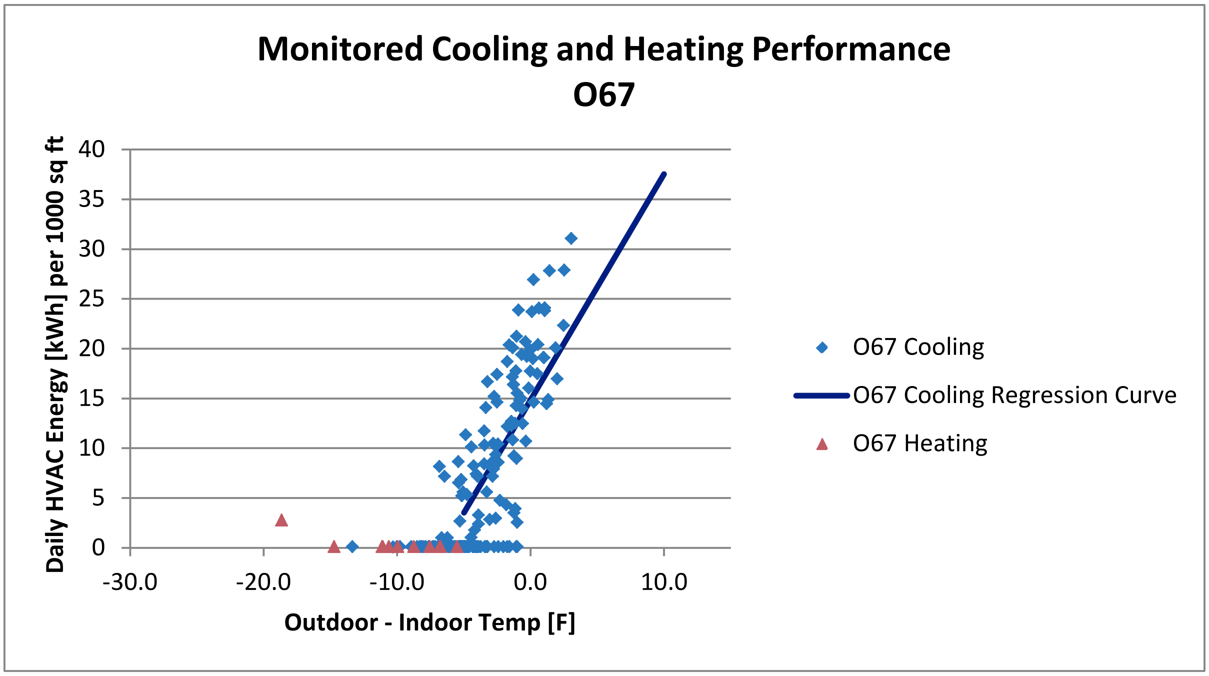

Figure A-199 Monitored Cooling and Heating Performance, O67

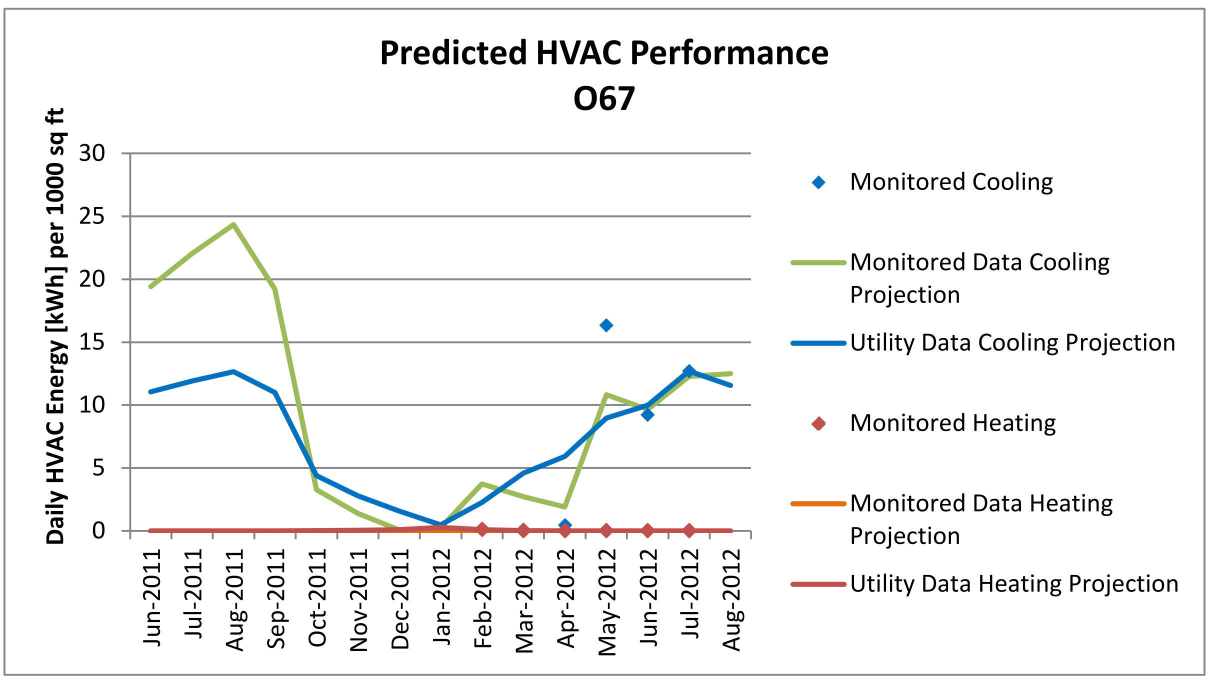

Figure A-200 Predicted HVAC Performance, O67

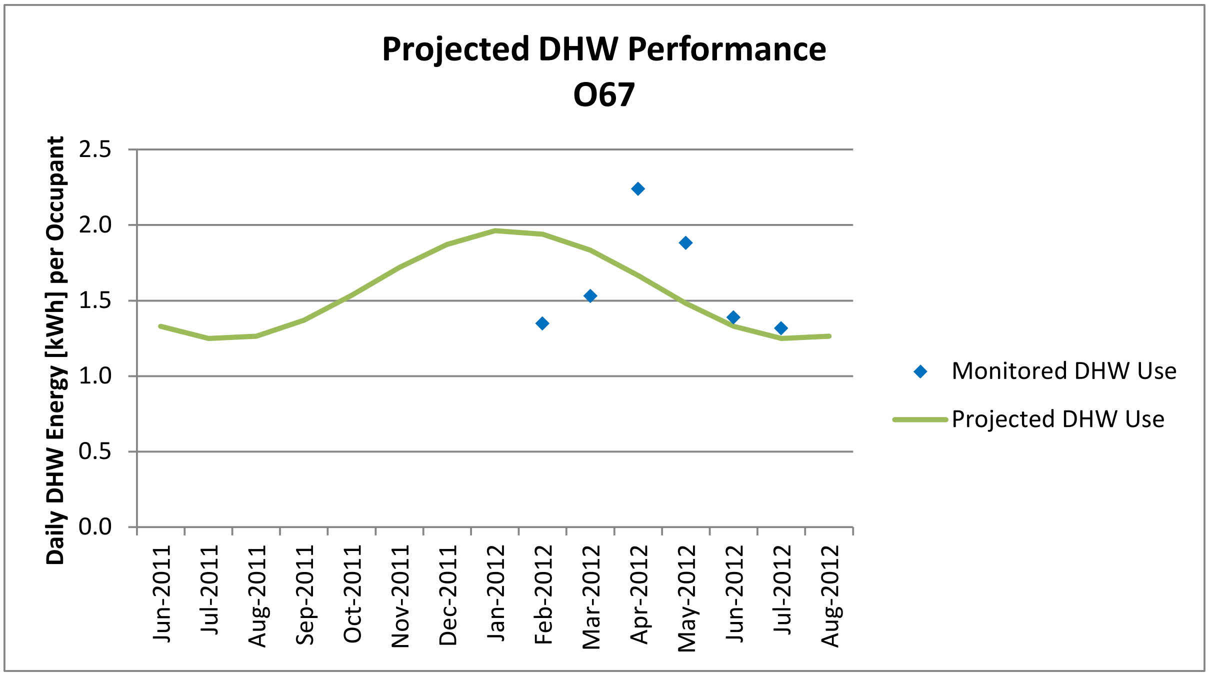

Figure A-201 Projected DHW Performance, O67

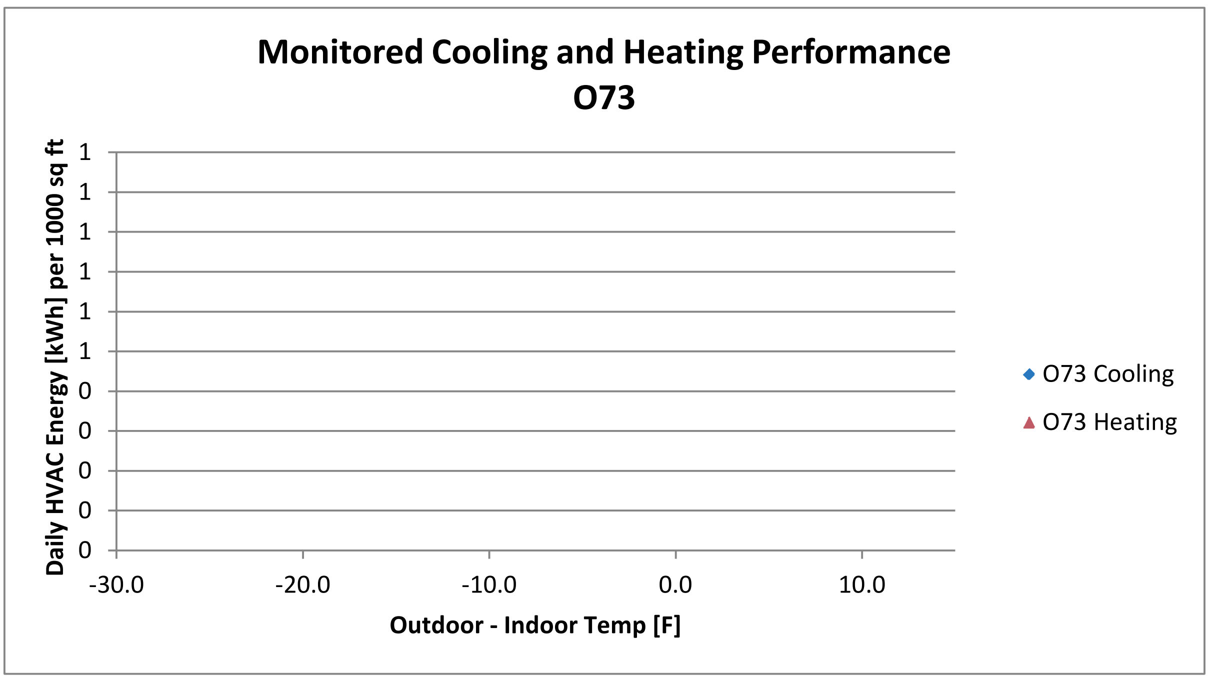

Figure A-202 Monitored Cooling and Heating Performance, O73

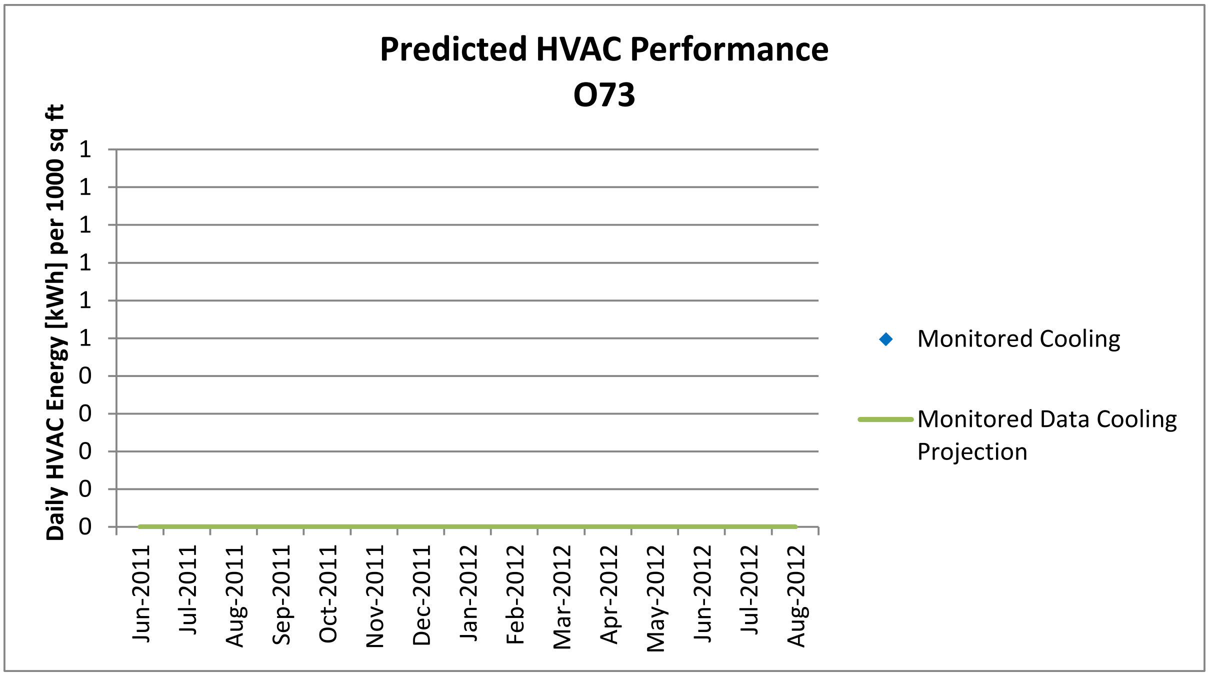

Figure A-203 Predicted HVAC Performance, O73

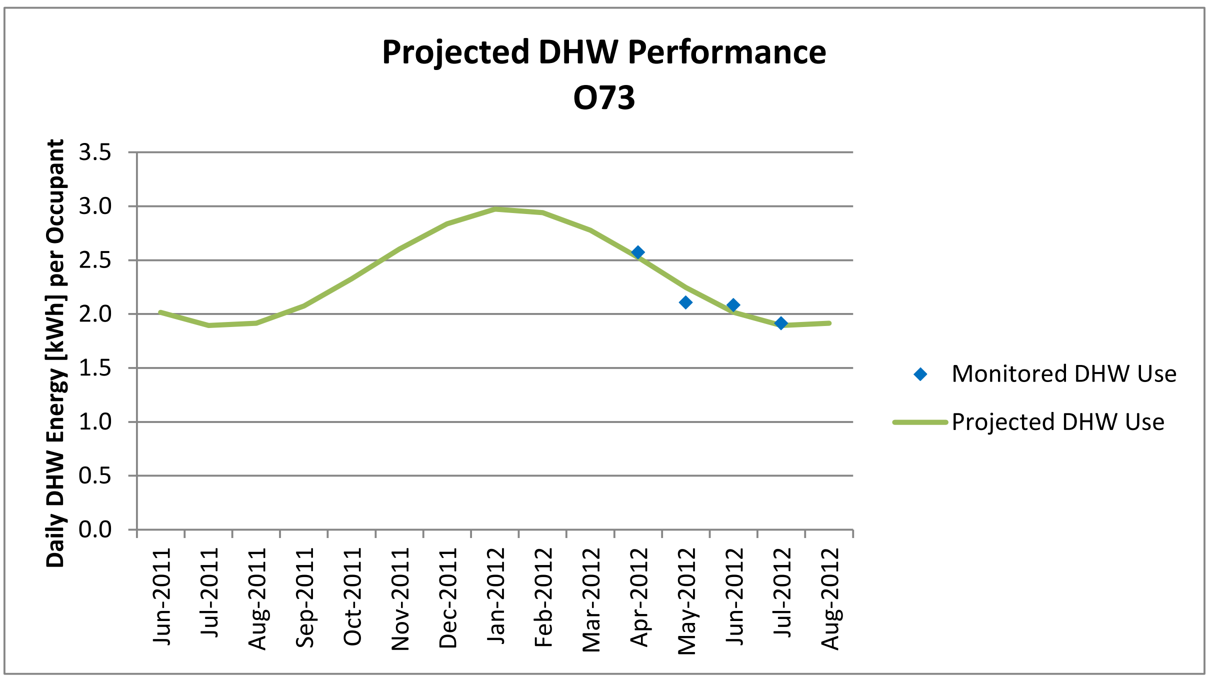

Figure A-204 Projected DHW Performance, O73

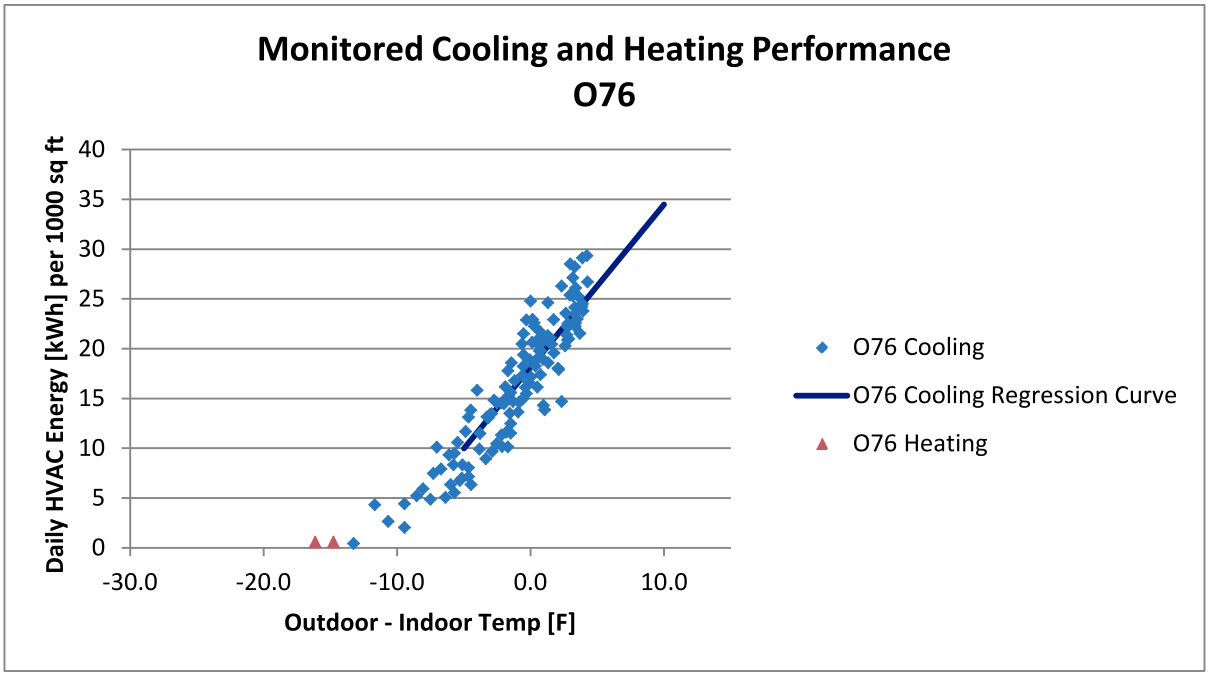

Figure A-205 Monitored Cooling and Heating Performance, O76

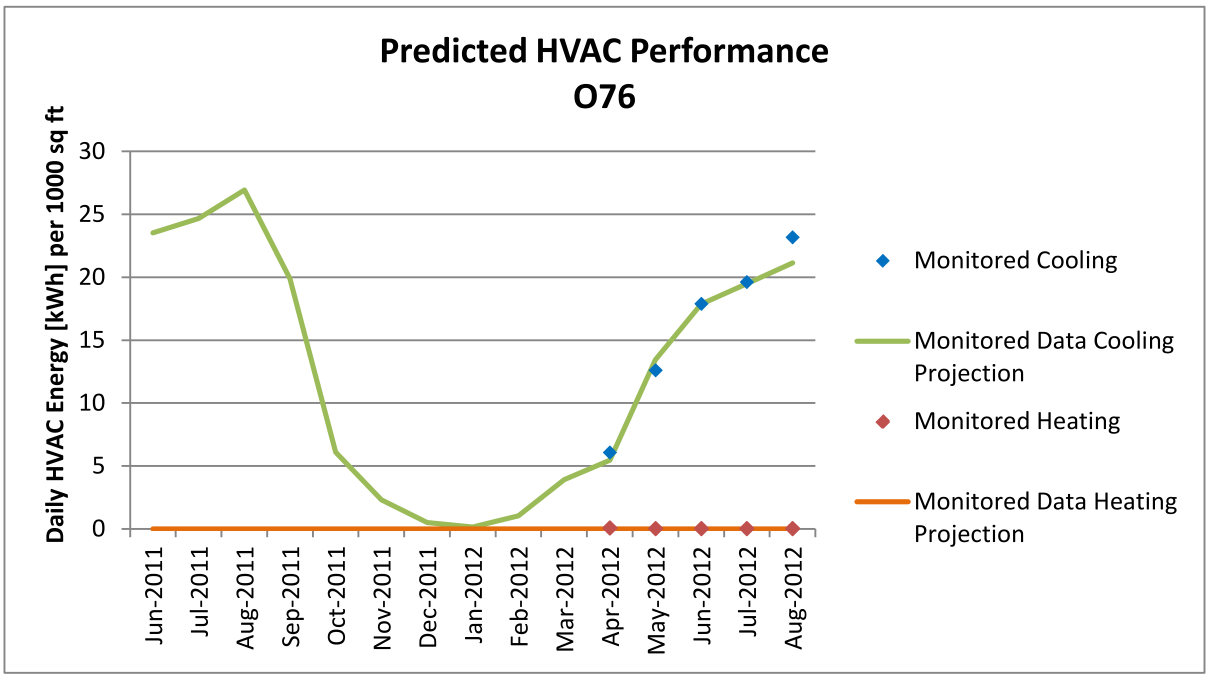

Figure A-206 Predicted HVAC Performance, O76

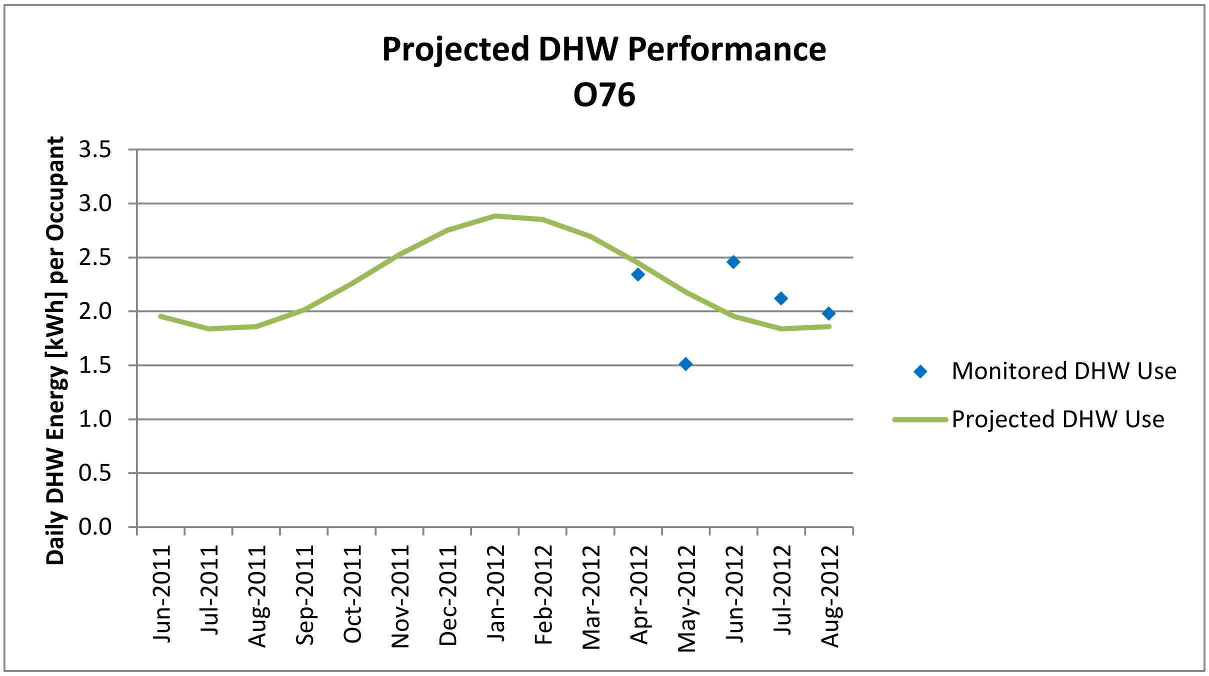

Figure A-207 Projected DHW Performance, O76

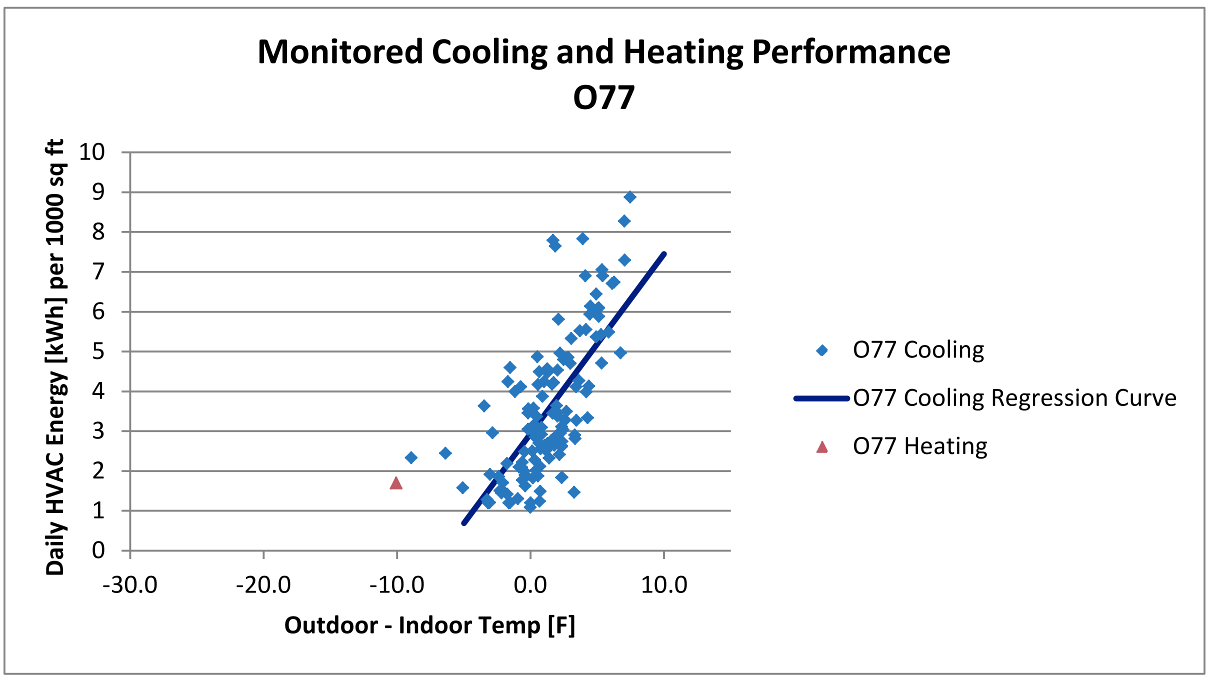

Figure A-208 Monitored Cooling and Heating Performance, O77

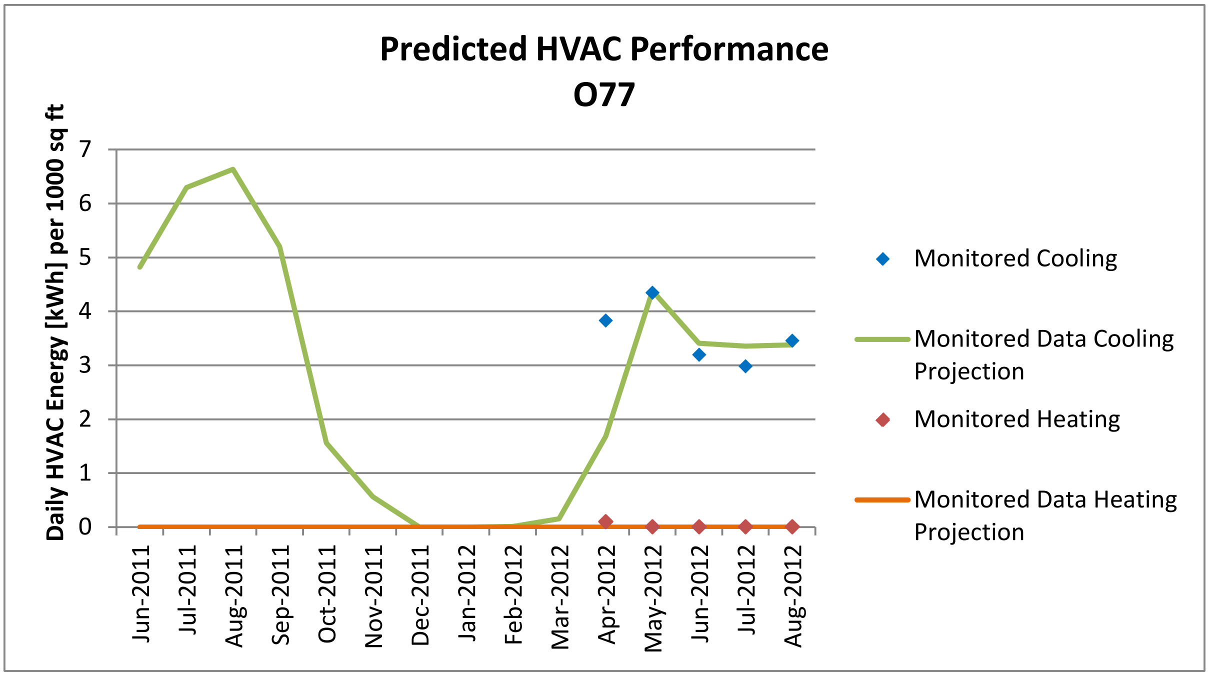

Figure A-209 Predicted HVAC Performance, O77

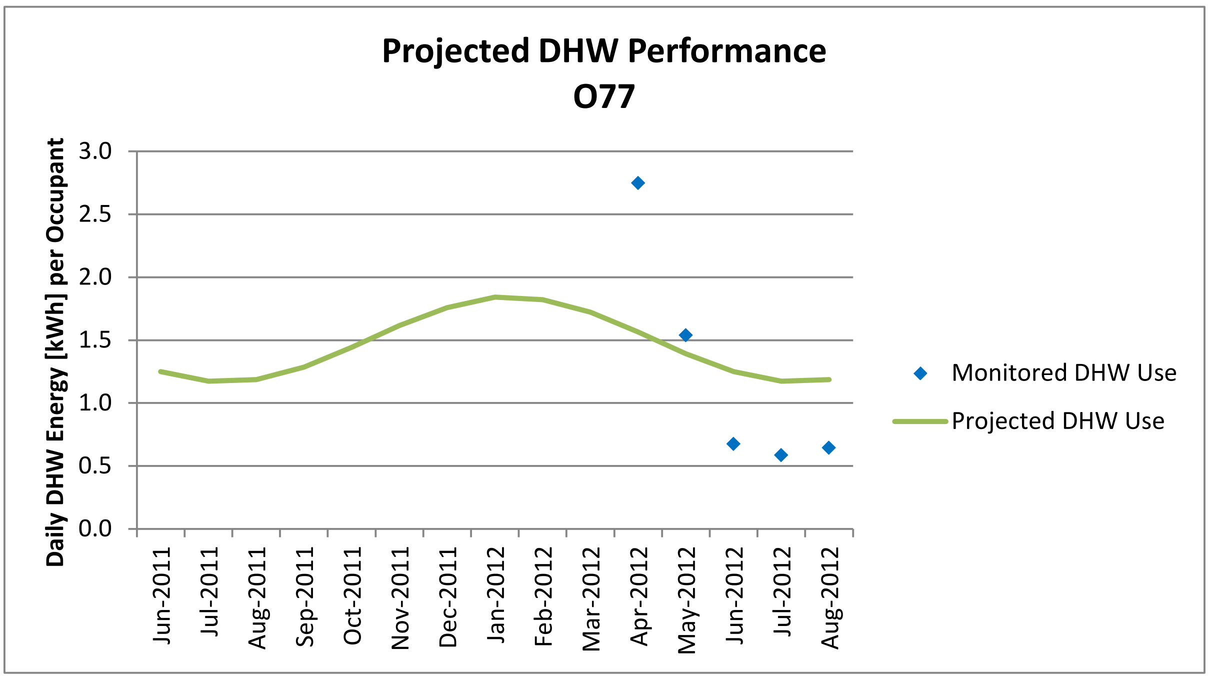

Figure A-210 Projected DHW Performance, O77

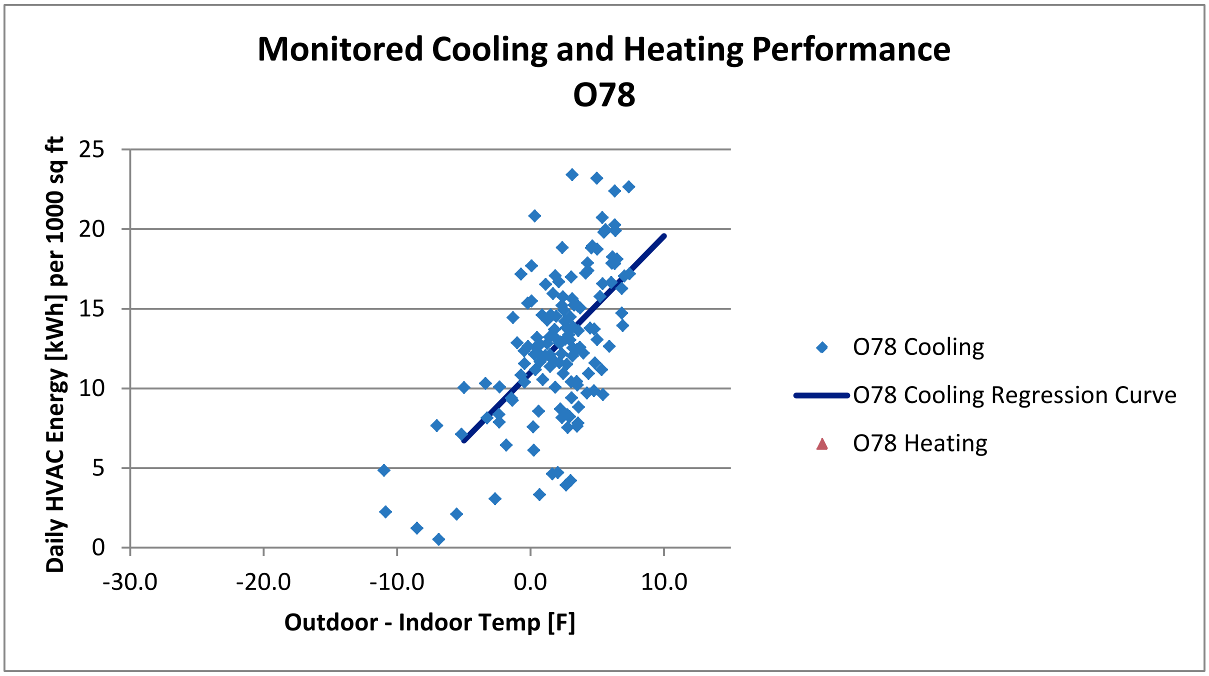

Figure A-211 Monitored Cooling and Heating Performance, O78

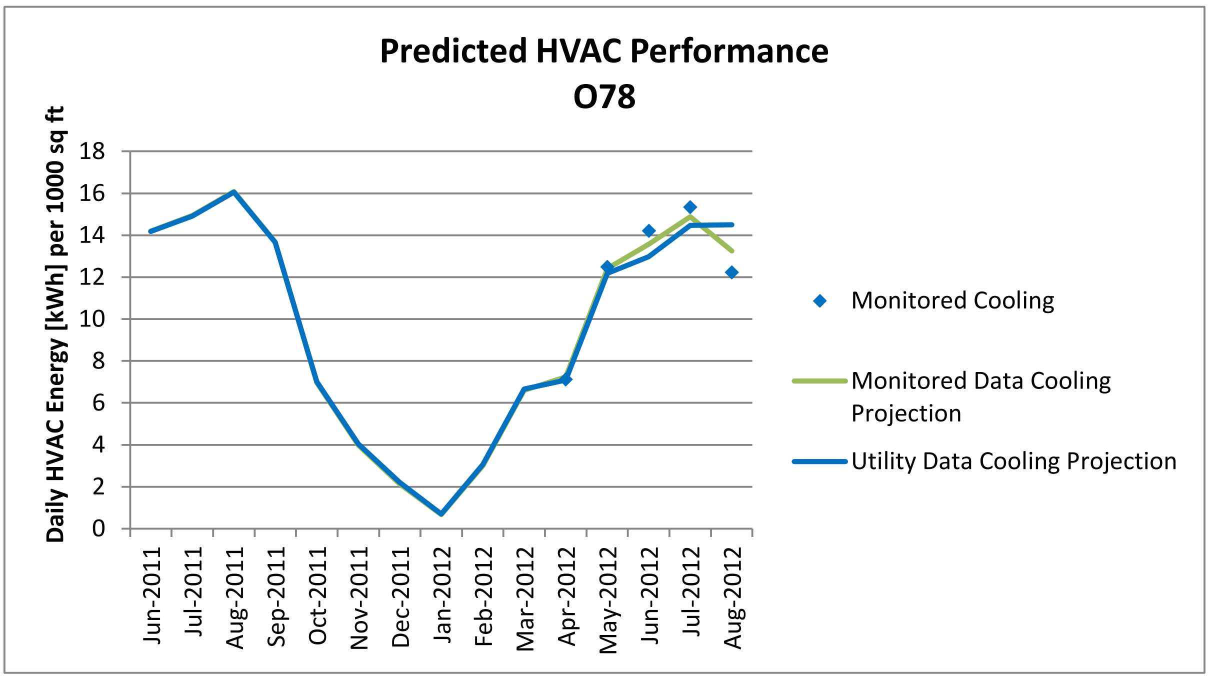

Figure A-212 Predicted HVAC Performance, O78

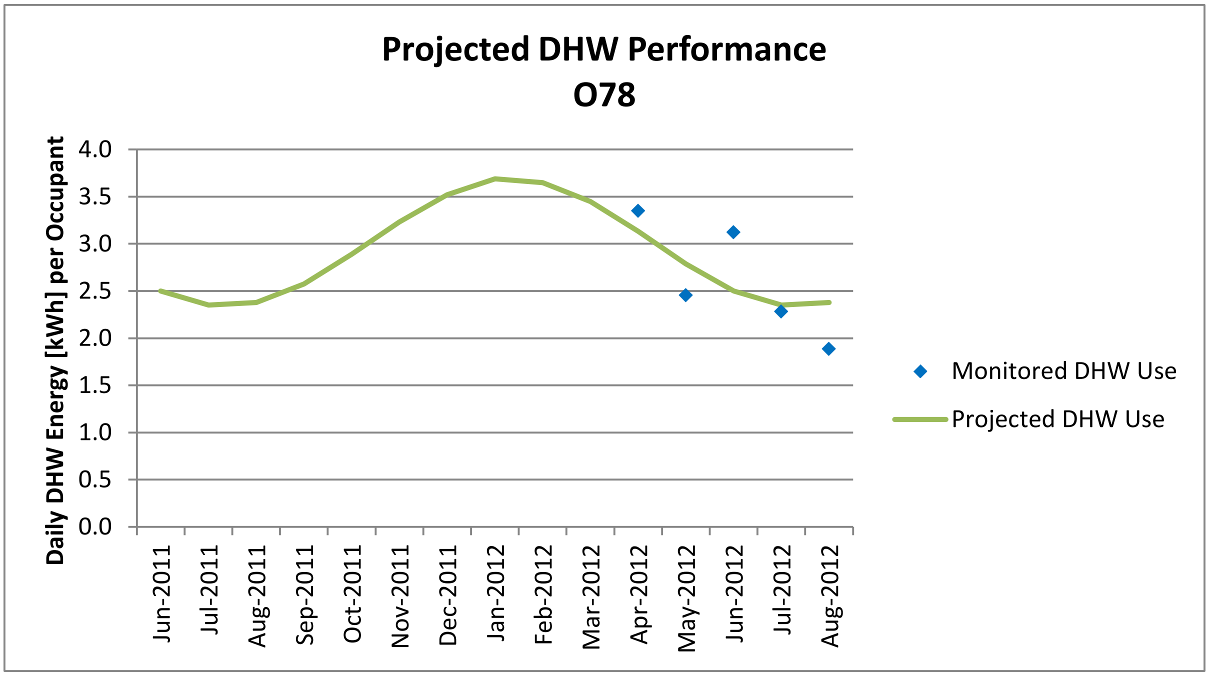

Figure A-213 Projected DHW Performance, O78

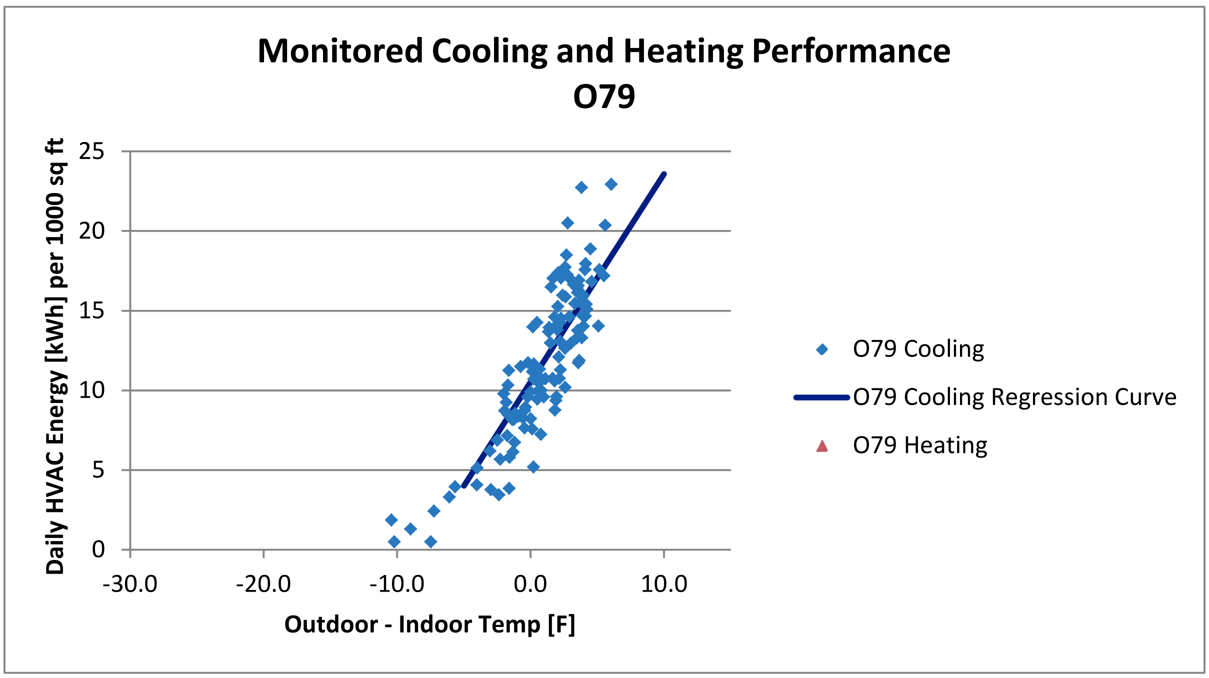

Figure A-214 Monitored Cooling and Heating Performance, O79

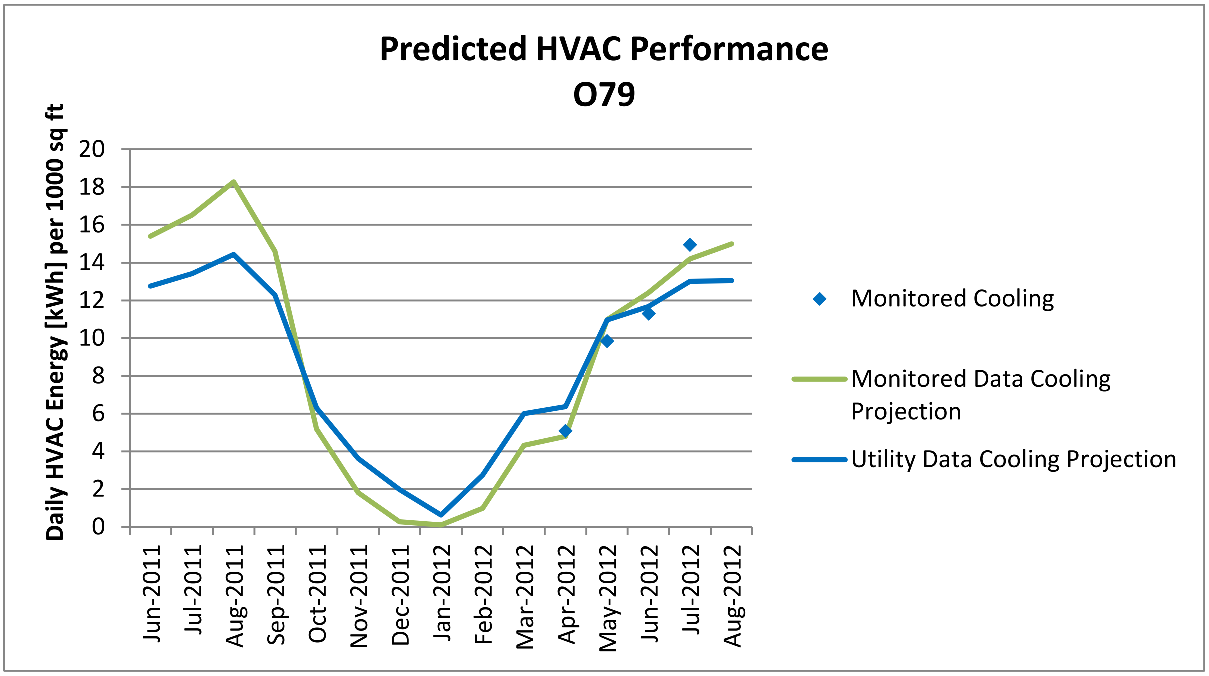

Figure A-215 Predicted HVAC Performance, O79

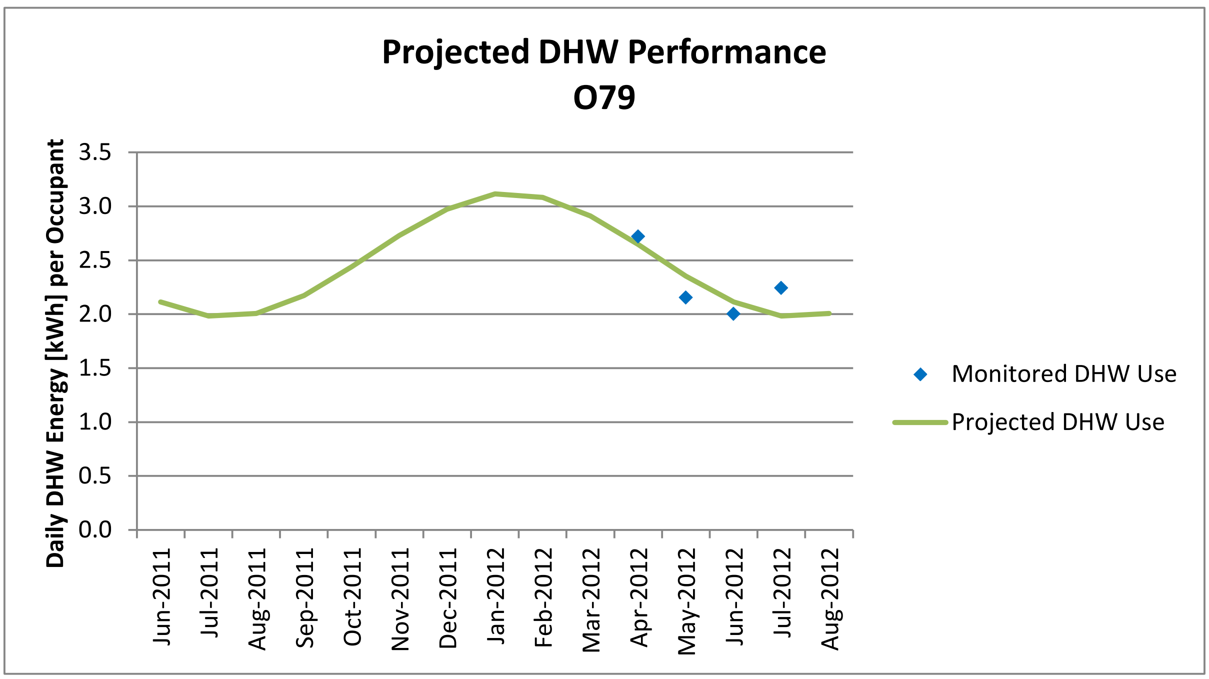

Figure A-216 Projected DHW Performance, O79

Appendix B- Home Interior Temperature and Relative Humidity Charts

The following graphs show a composite day for twelve months with the mean, minimum and maximum of measured indoor temperature and relative humidity for each code group. Each hour shown is the composite of hourly data collected from each group.

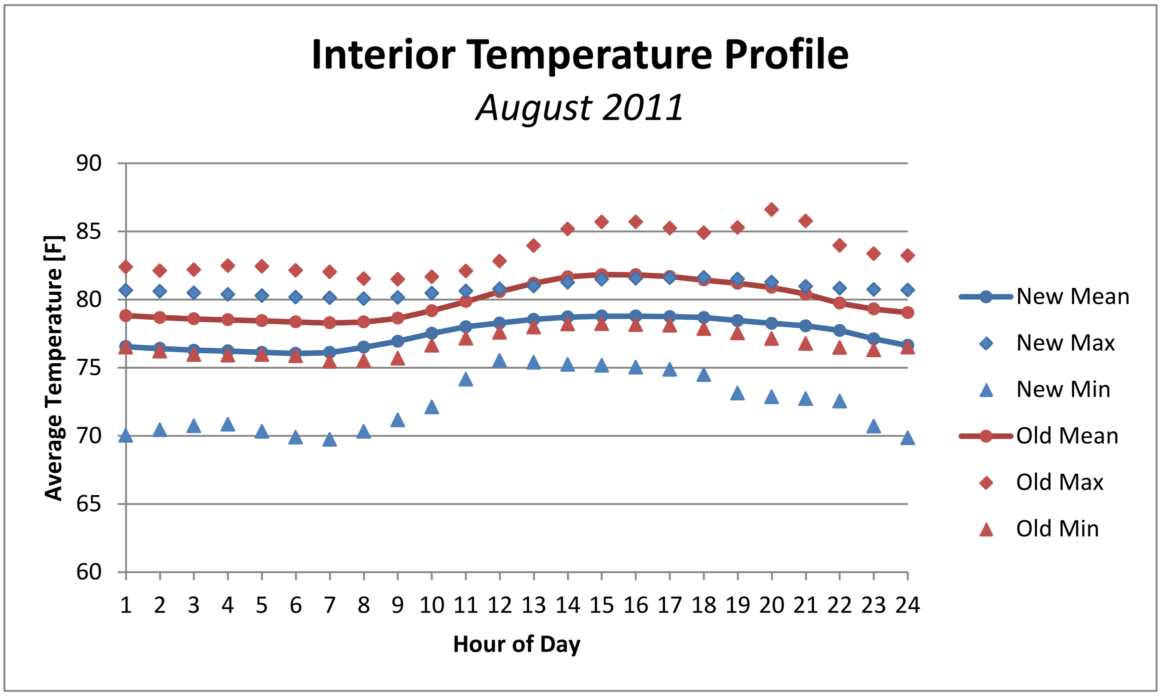

Figure B-1 Interior Temperature Profile, August 2011

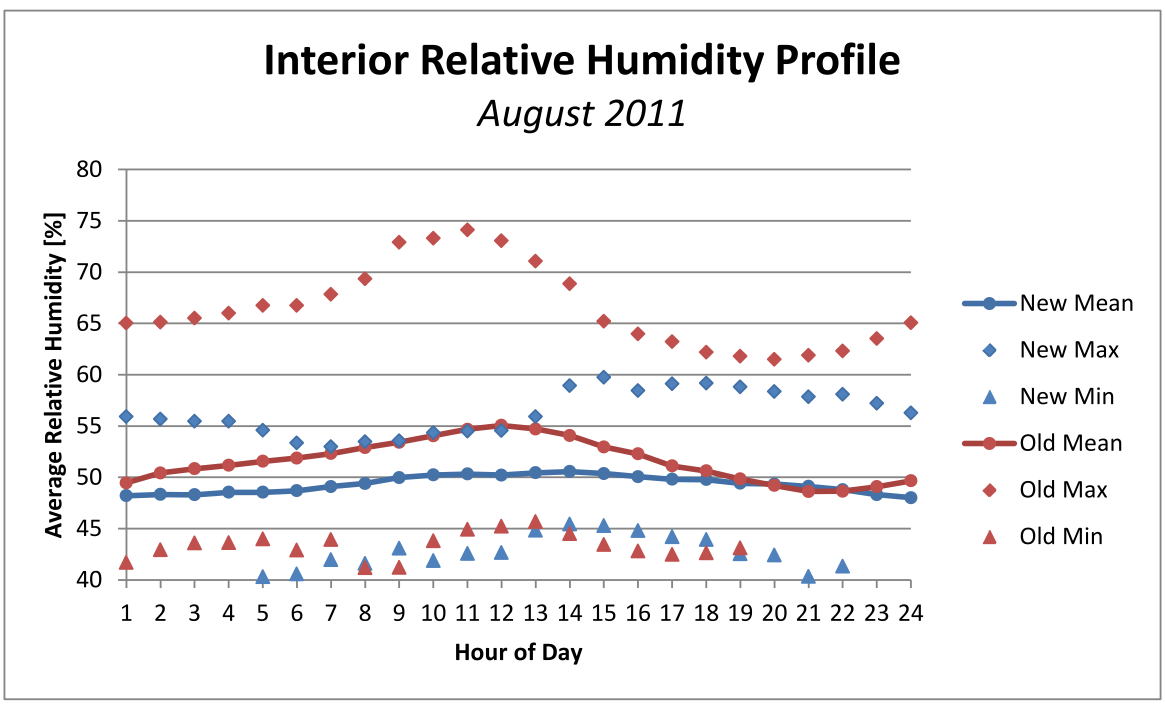

Figure B-2 Interior Relative Humidity Profile, August 2011

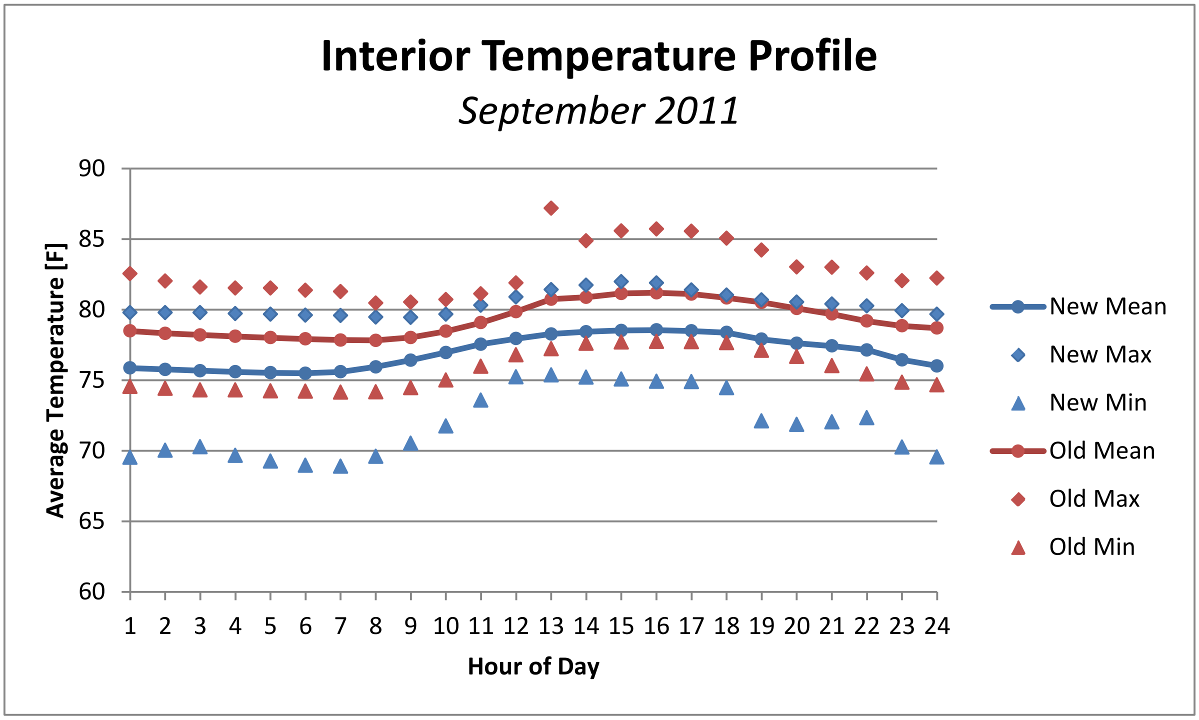

Figure B-3 Interior Temperature Profile, September 2011

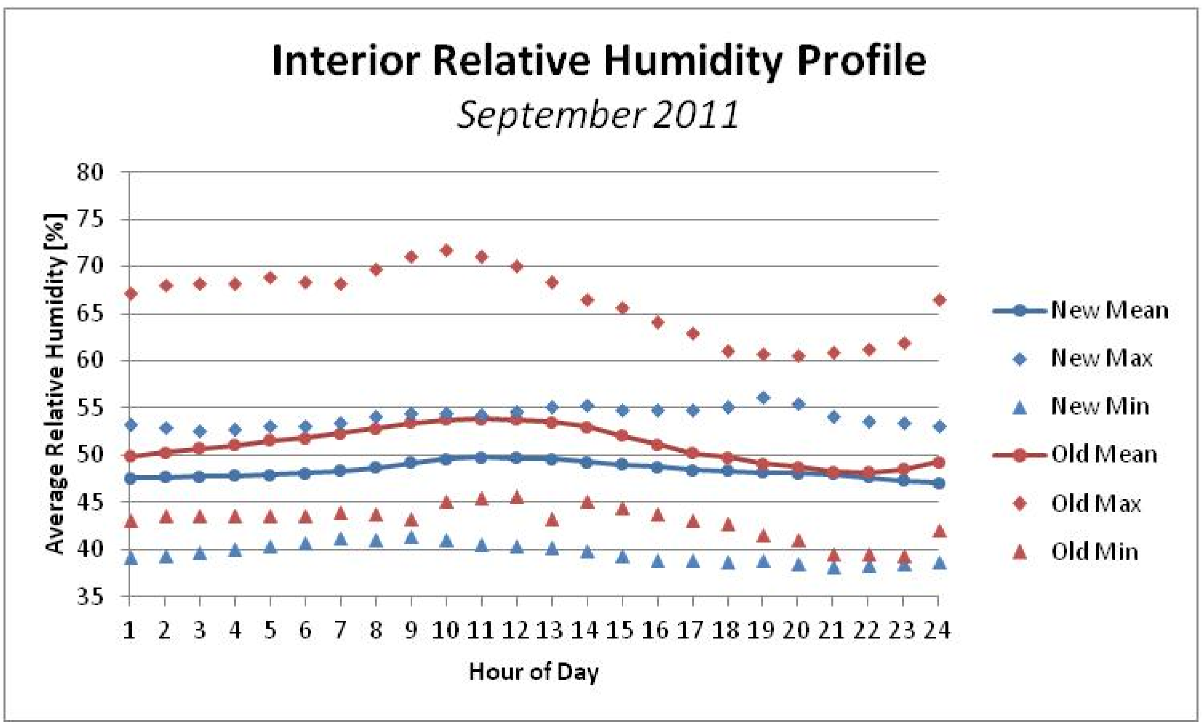

Figure B-4 Interior Relative Humidity Profile, September 2011

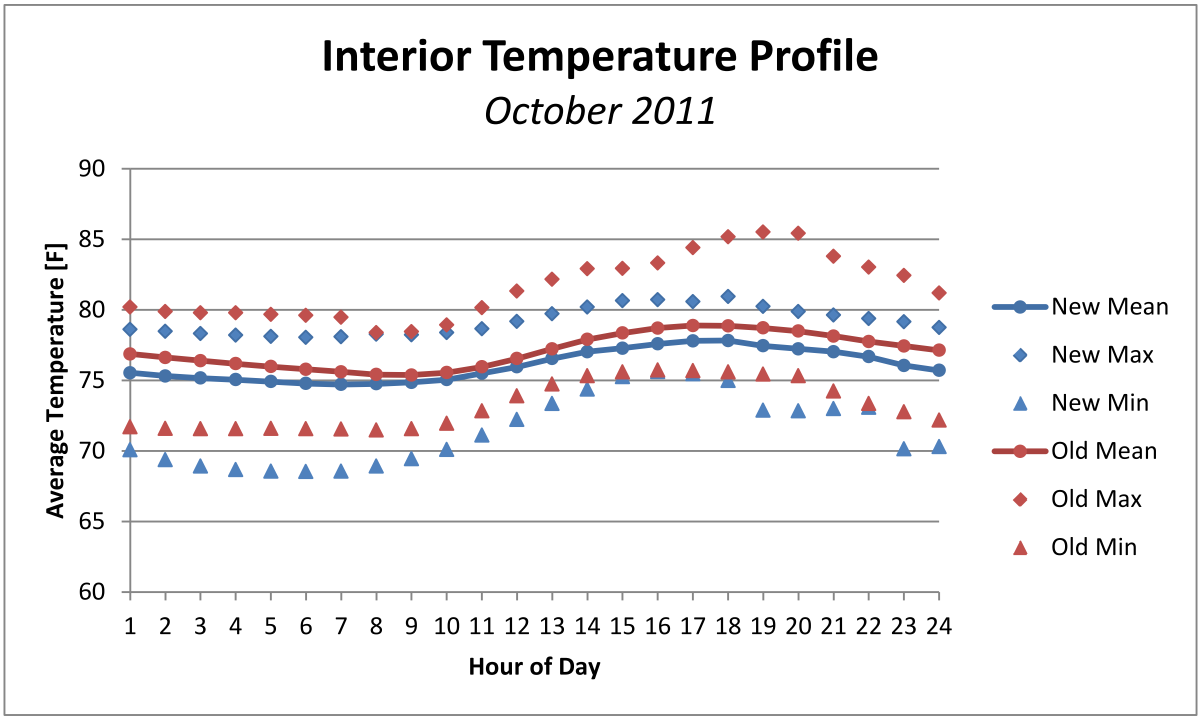

Figure B-5 Interior Temperature Profile, October 2011

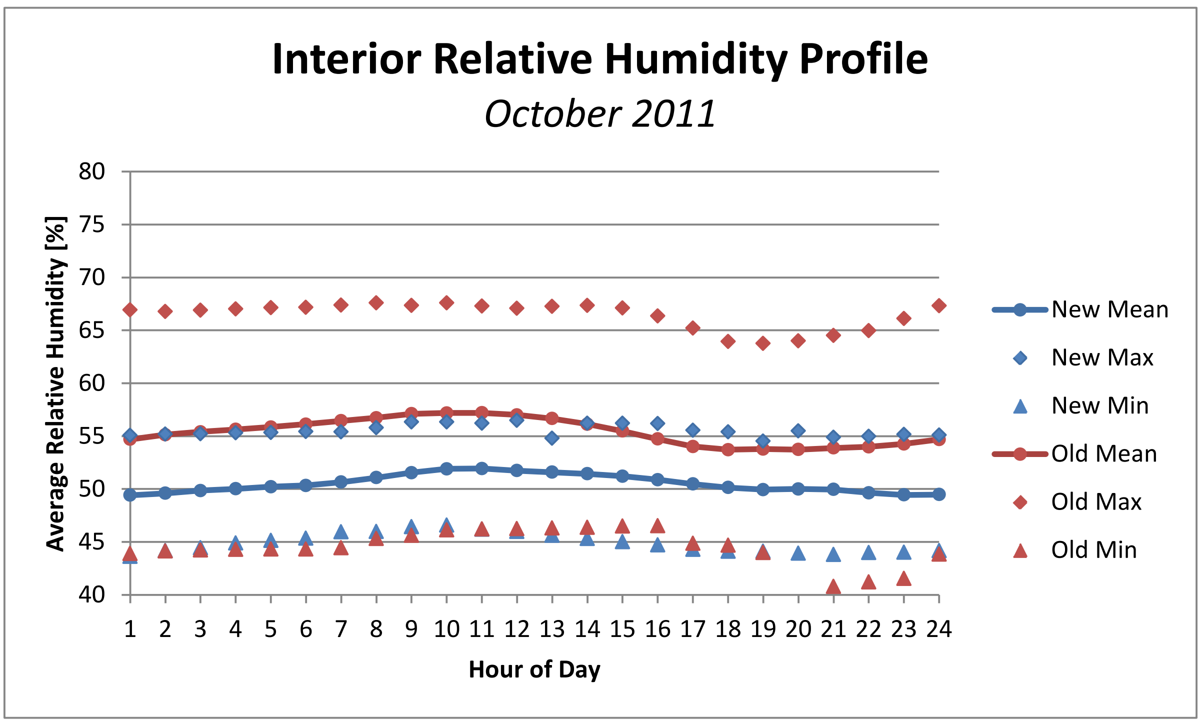

Figure B-6 Interior Relative Humidity Profile, October 2011

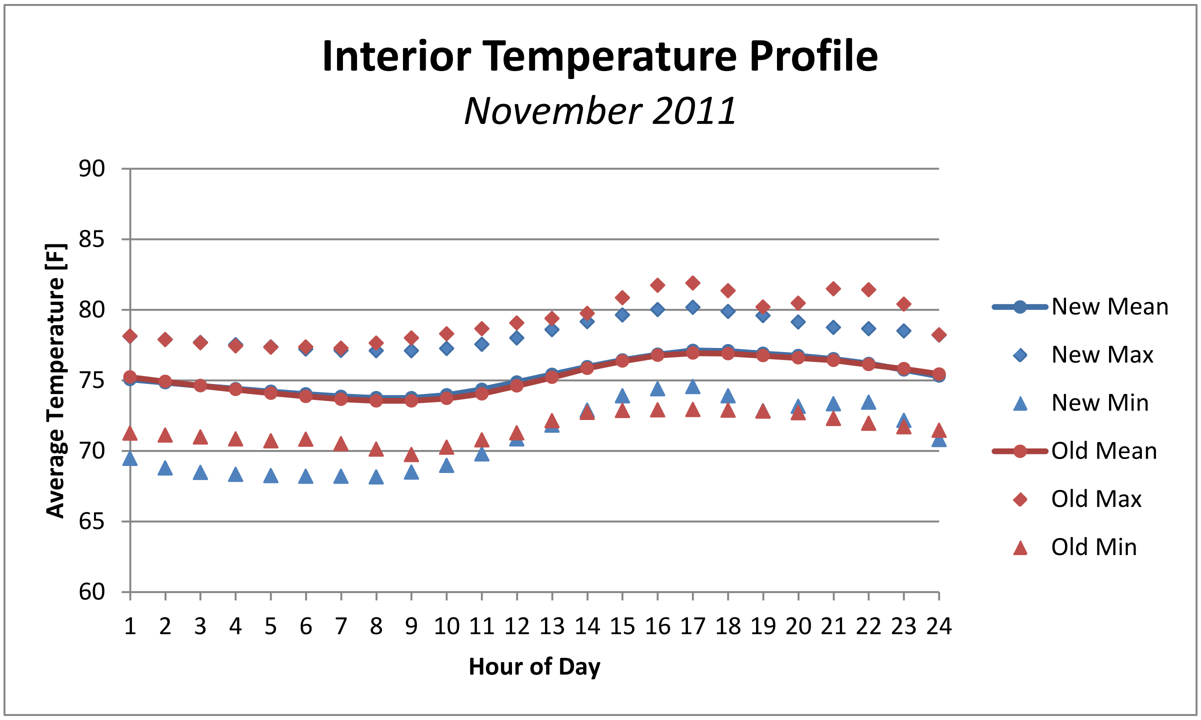

Figure B-7 Interior Temperature Profile, November 2011

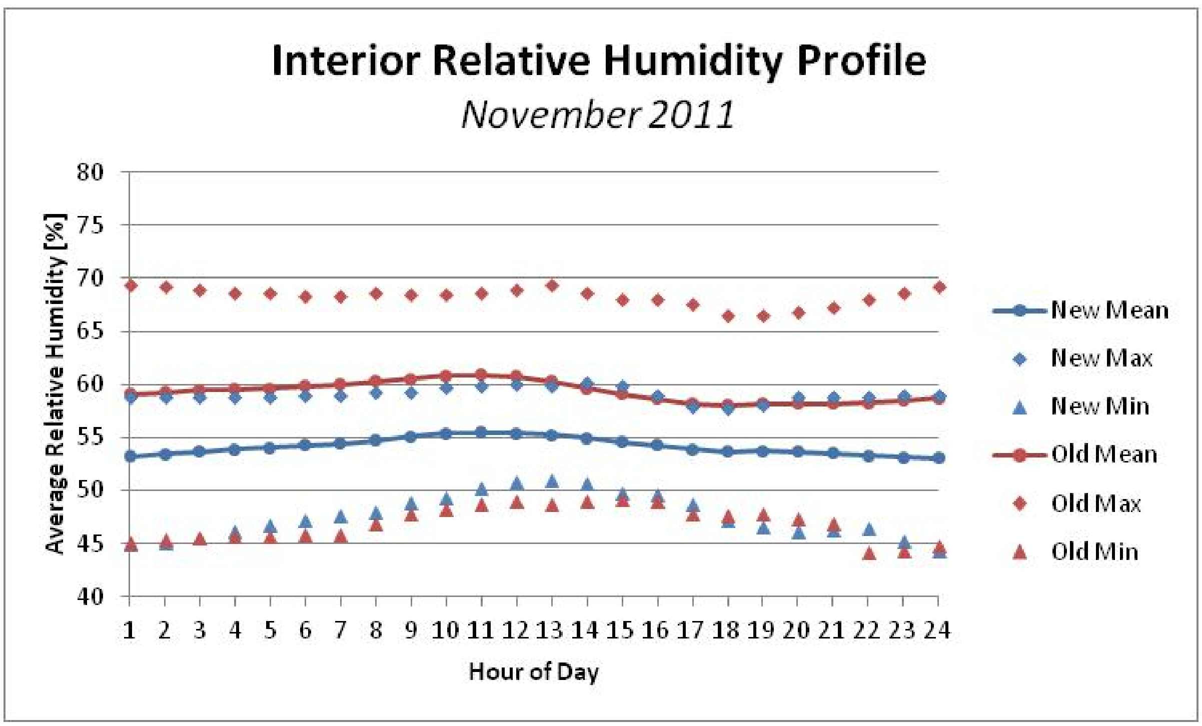

Figure B-8 Interior Relative Humidity Profile, November 2011

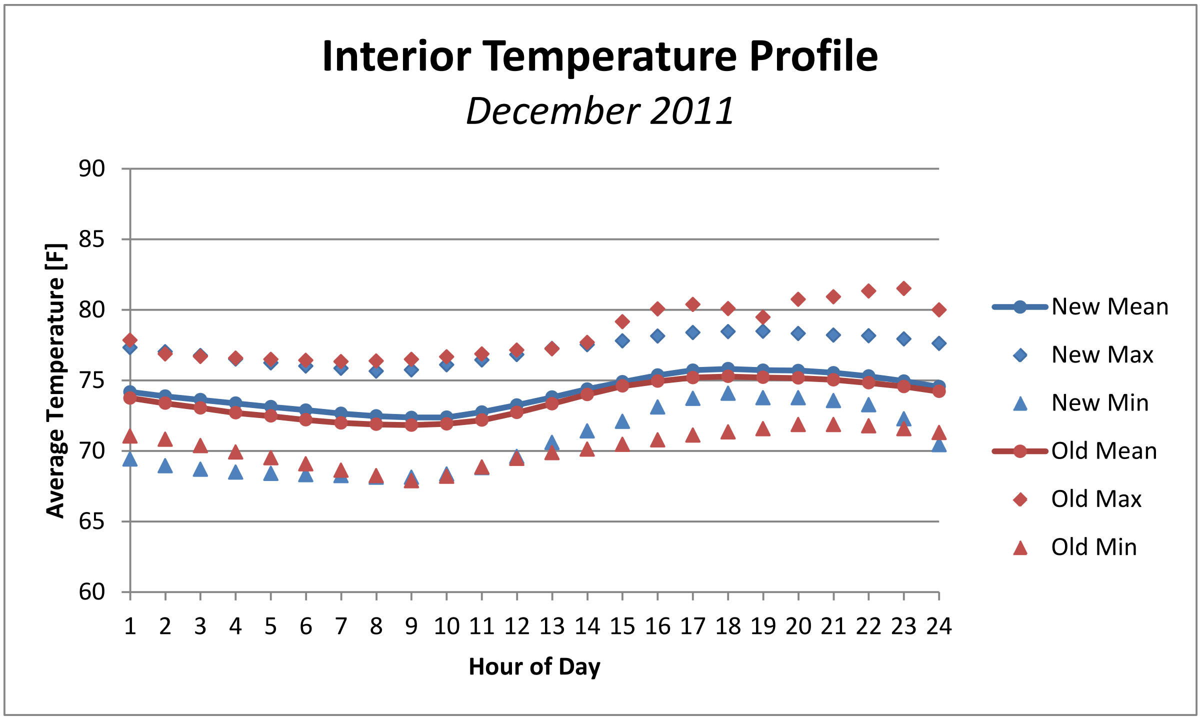

Figure B-9 Interior Temperature Profile, December 2011

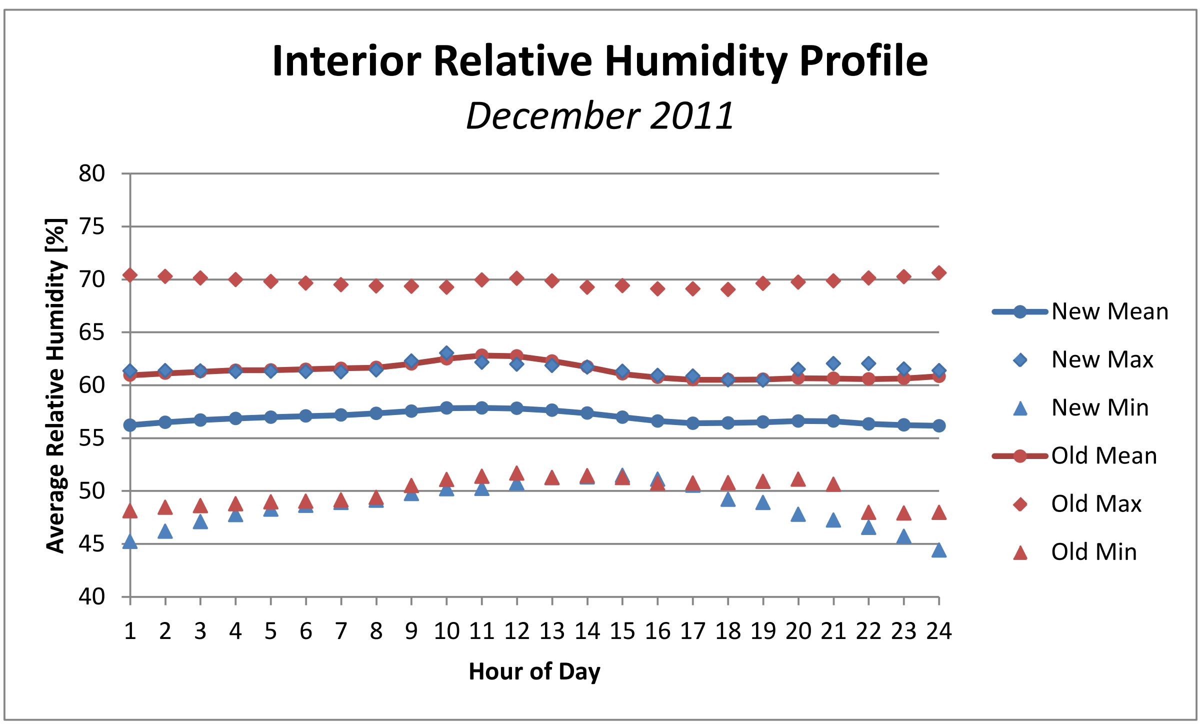

Figure B-10 Interior Relative Humidity Profile, December 2011

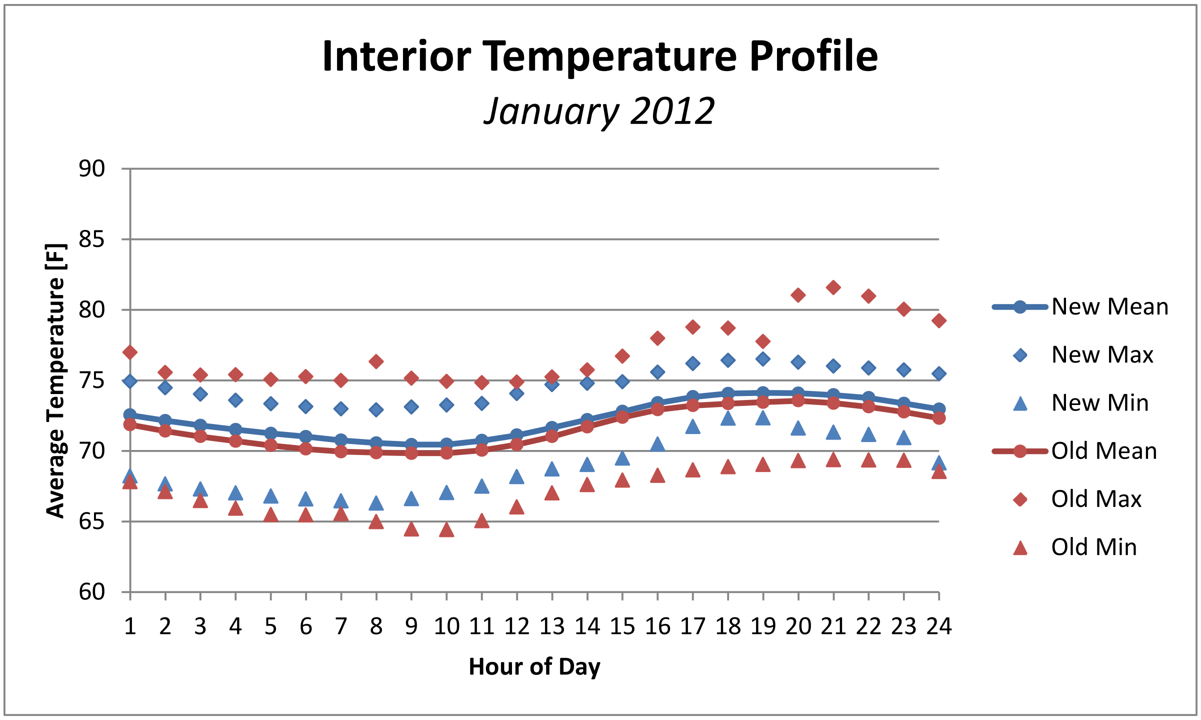

Figure B-11 Interior Temperature Profile, January 2012

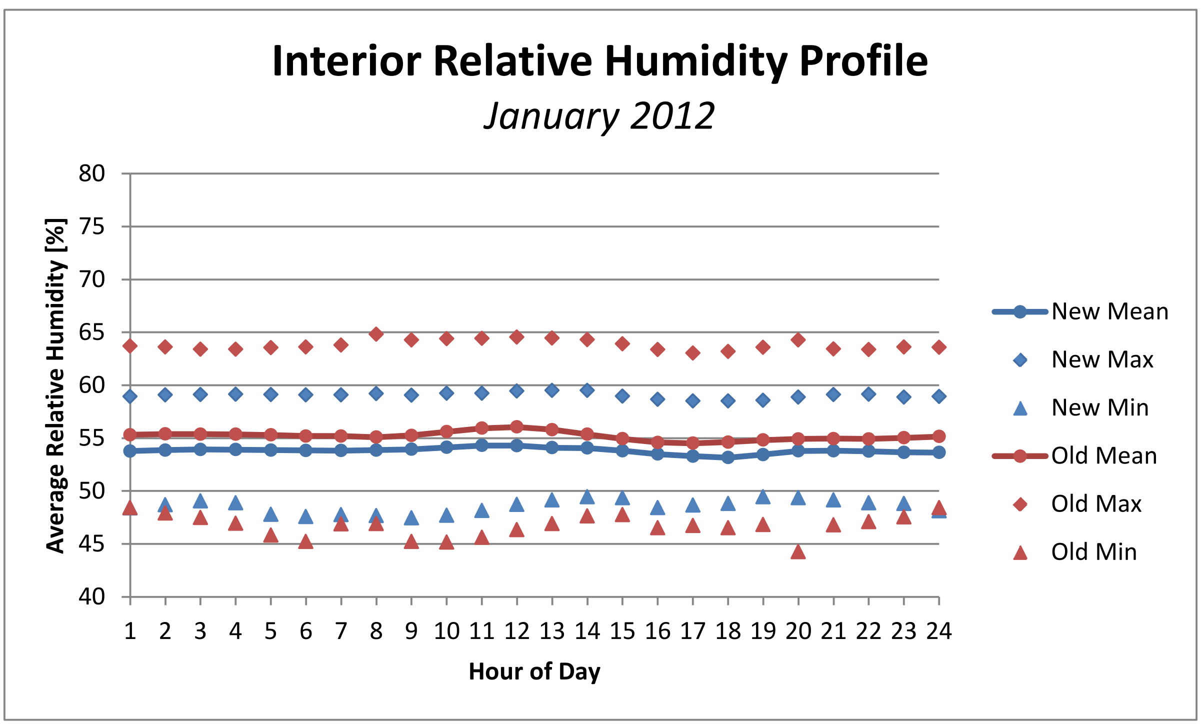

Figure B-12 Interior Relative Humidity Profile, January 2012

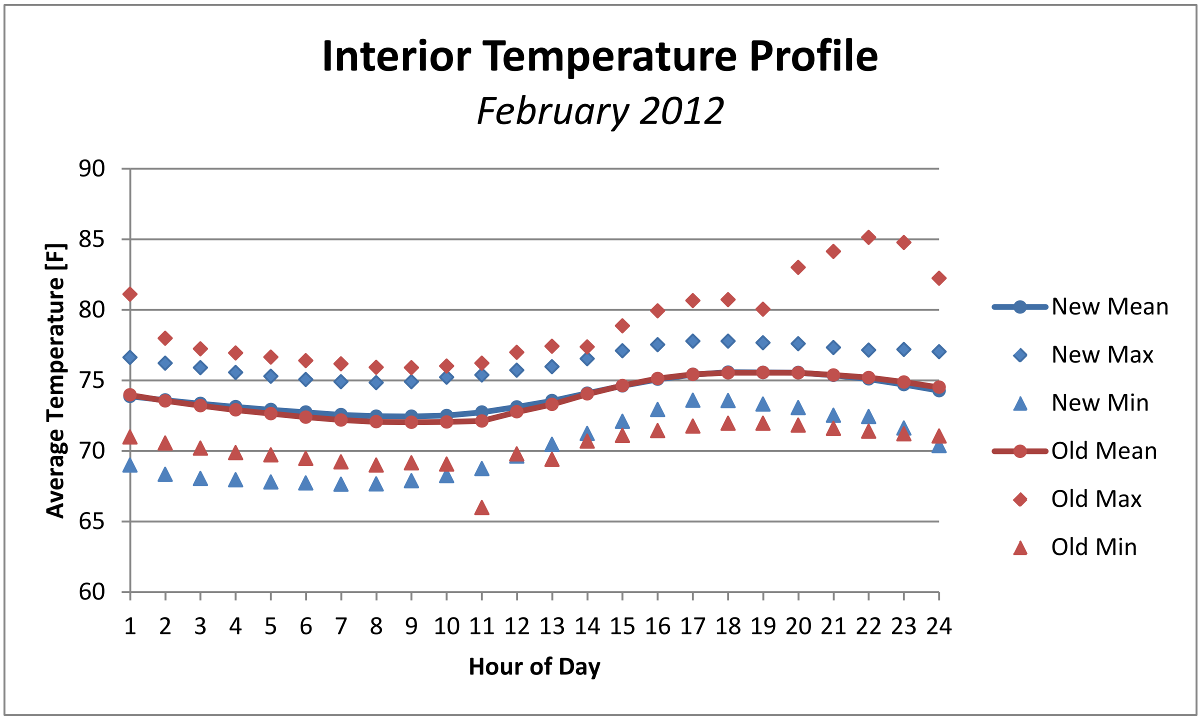

Figure B-13 Interior Temperature Profile, February 2012

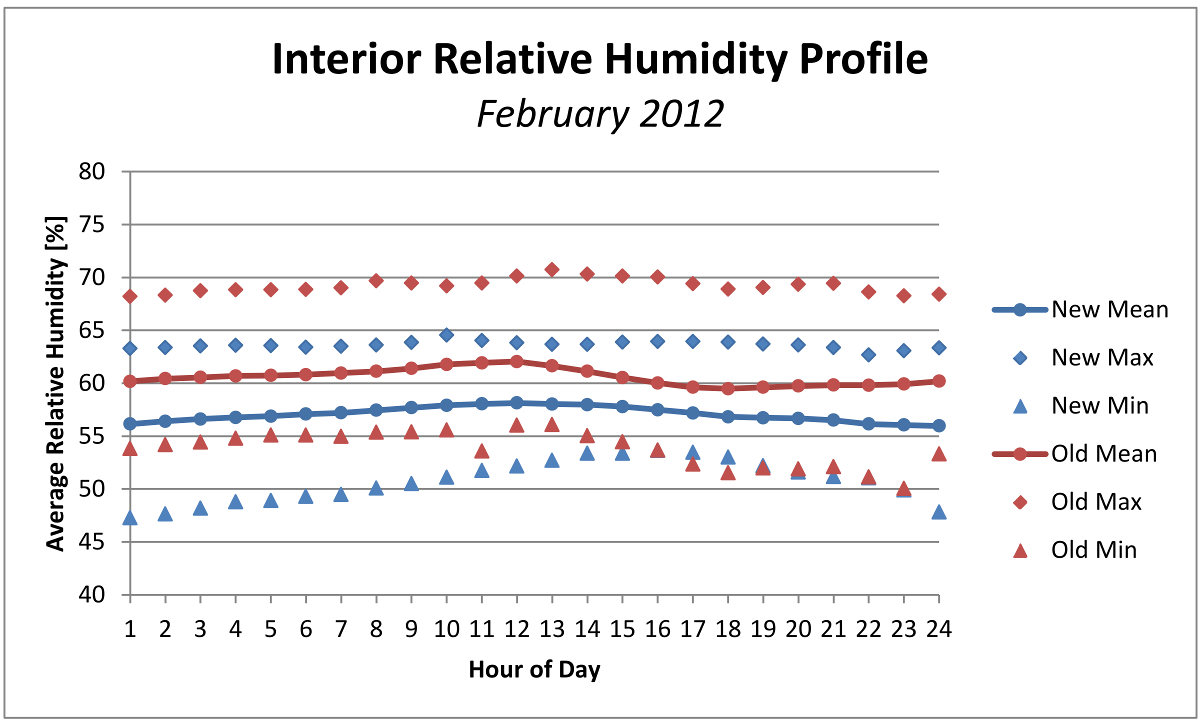

Figure B-14 Interior Relative Humidity Profile, February 2012

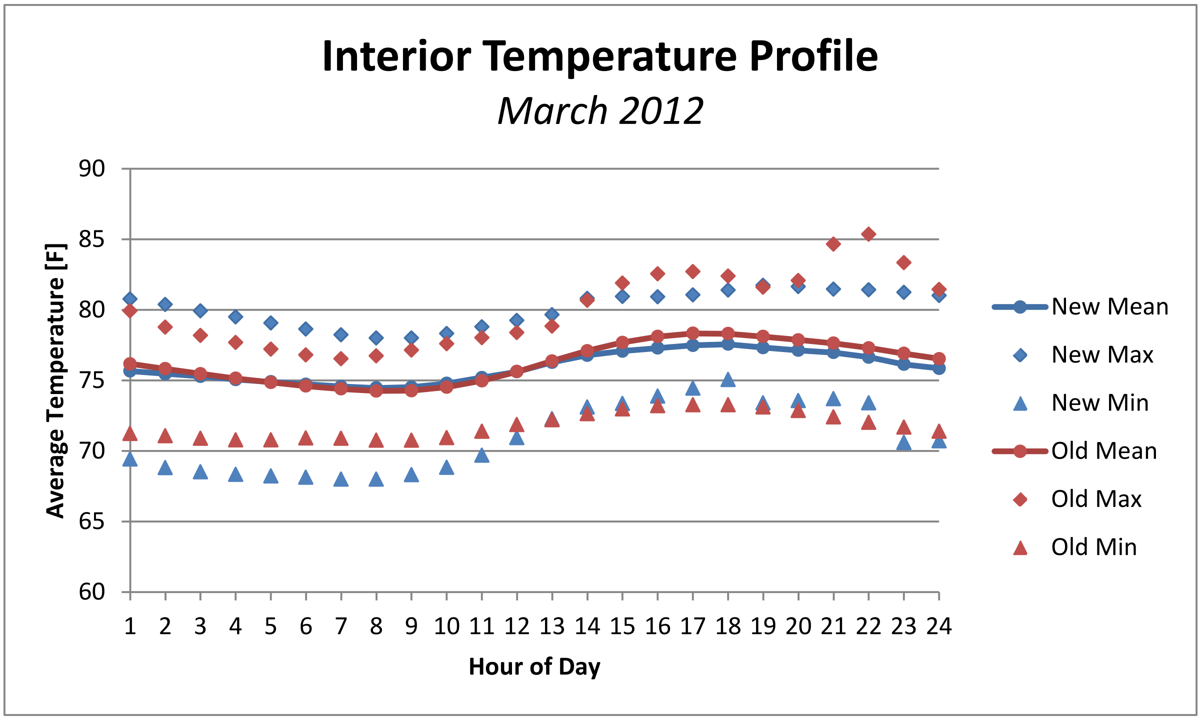

Figure B-15 Interior Temperature Profile, March 2012

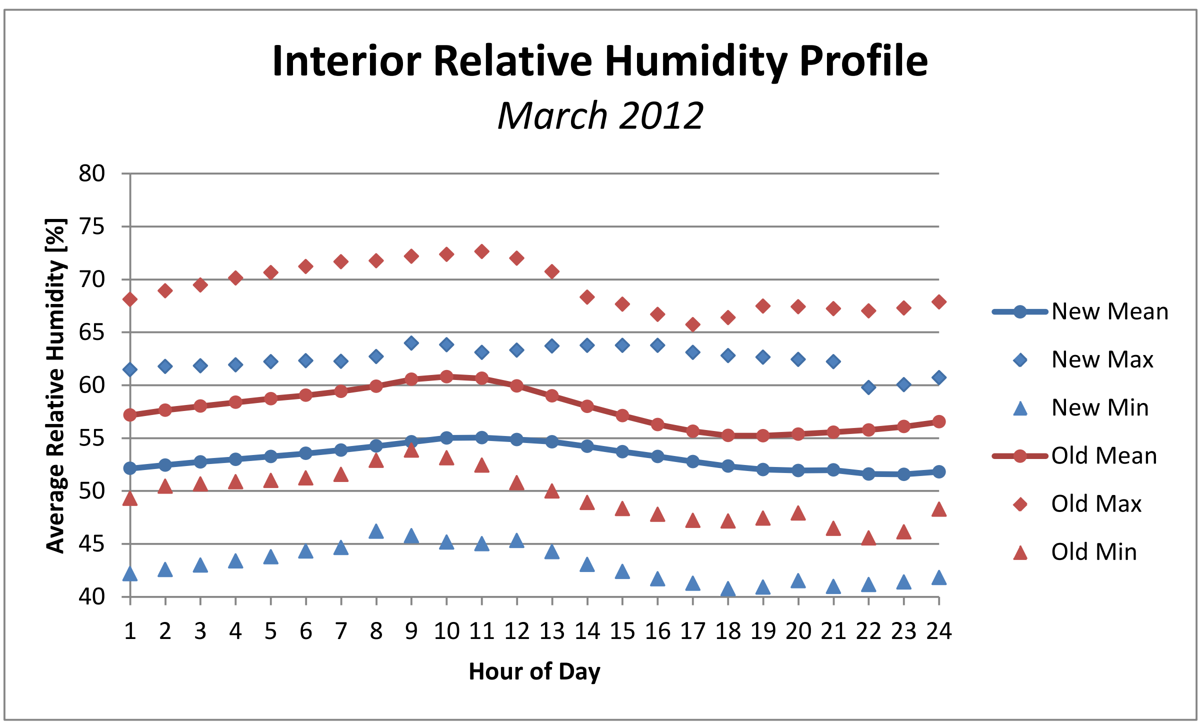

Figure B-16 Interior Relative Humidity Profile, March 2012

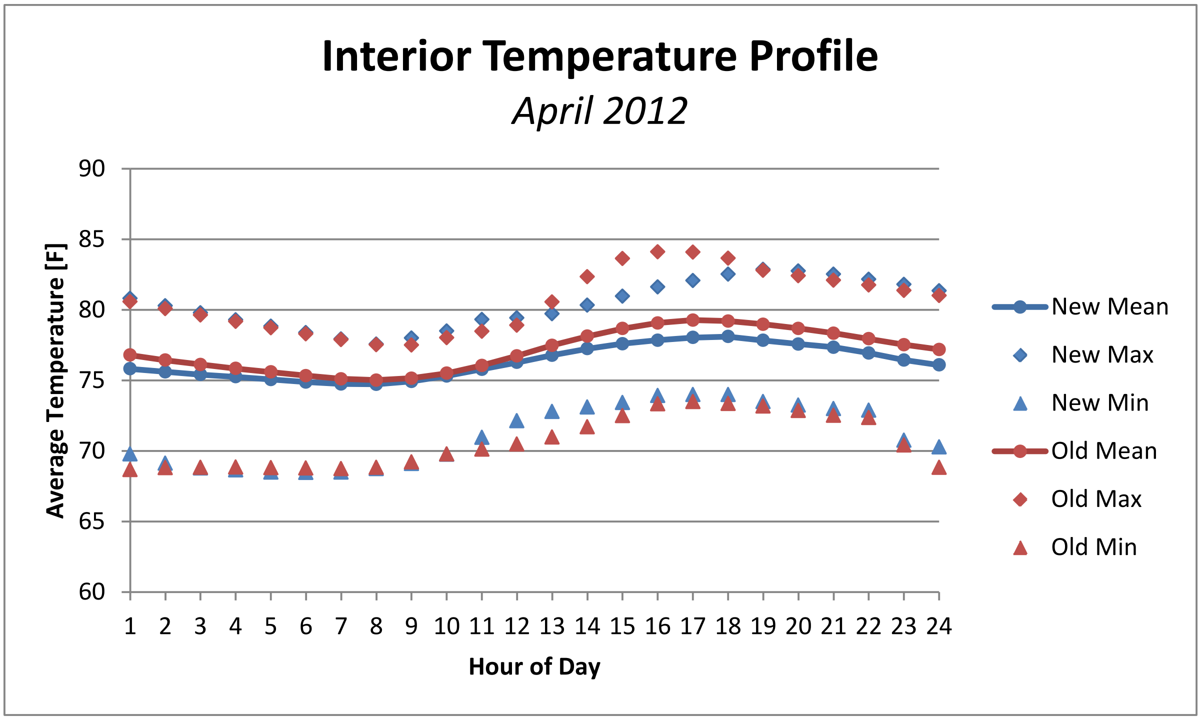

Figure B-17 Interior Temperature Profile, April 2012

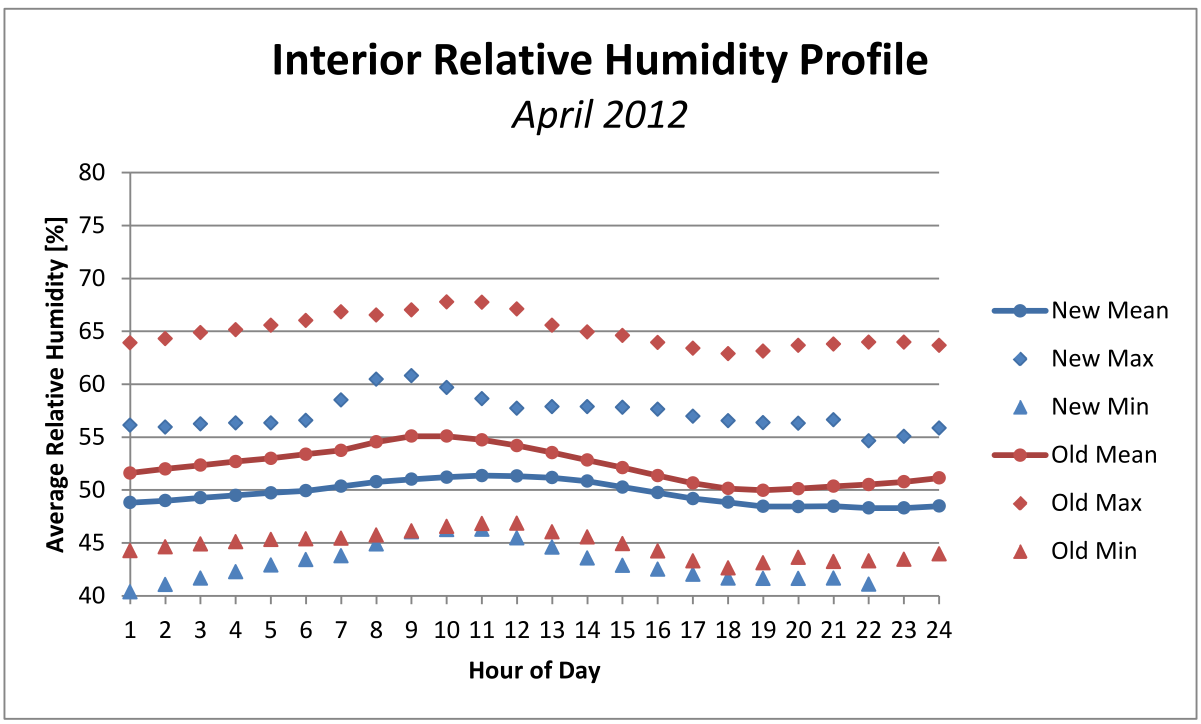

Figure B-18 Interior Relative Humidity Profile, April 2012

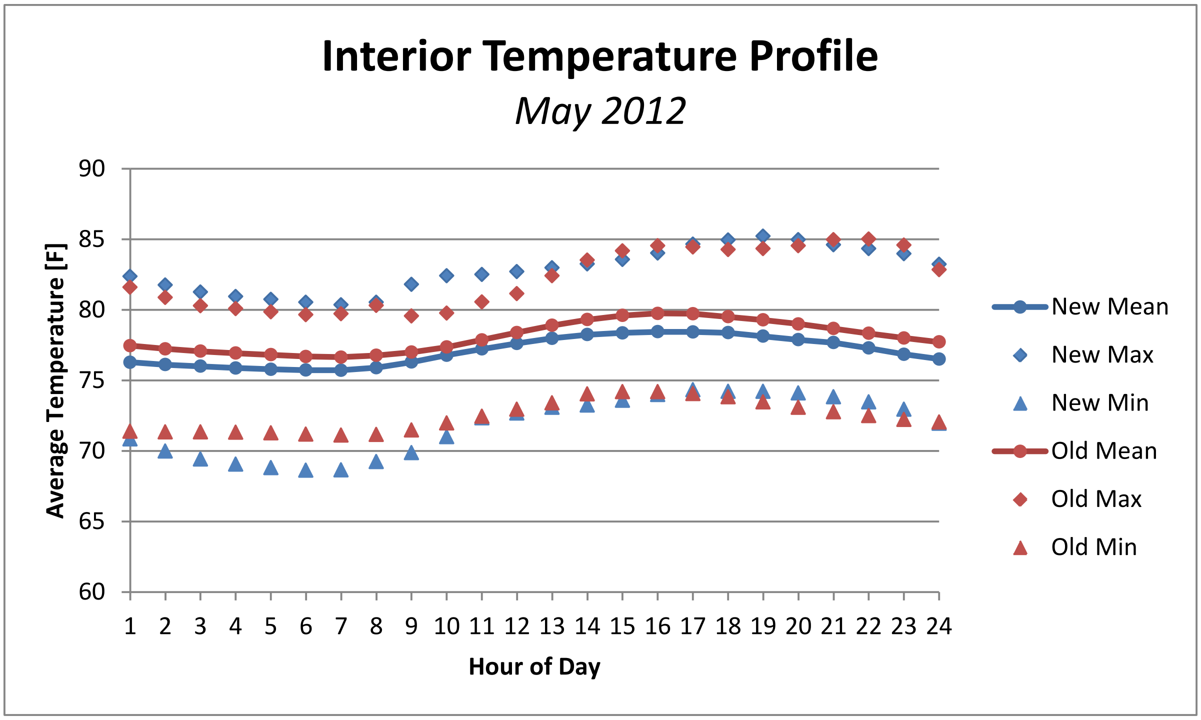

Figure B-19 Interior Temperature Profile, May 2012

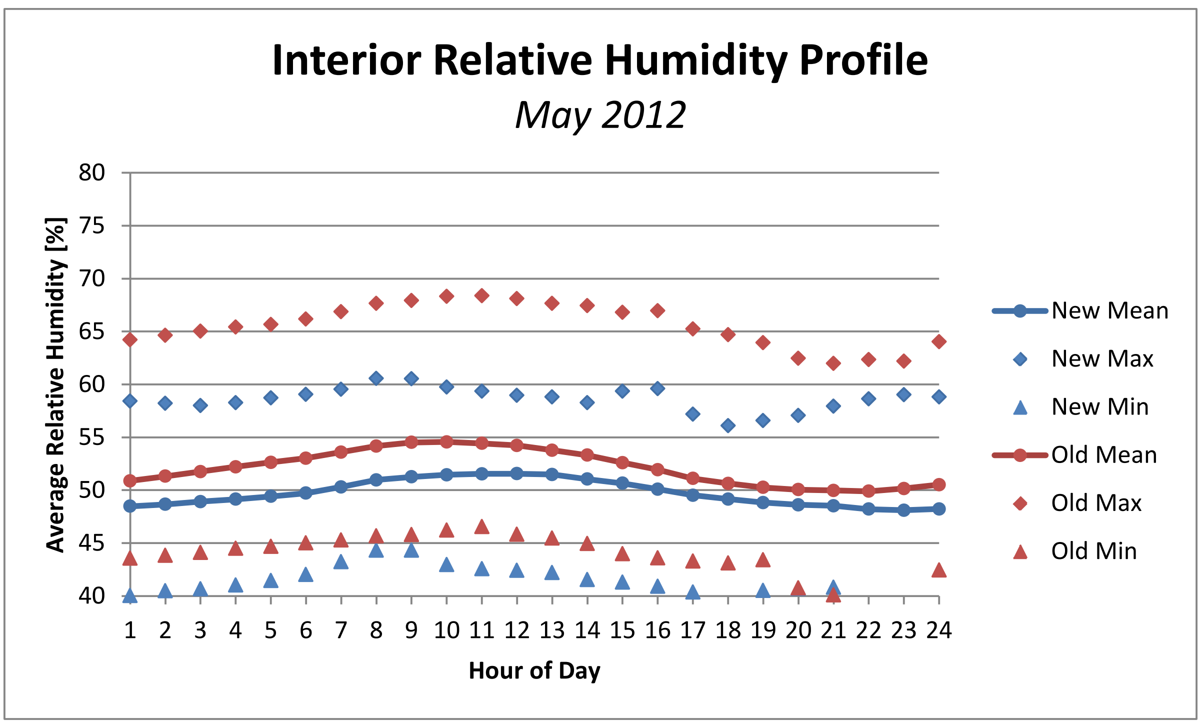

Figure B-20 Interior Relative Humidity Profile, May 2012

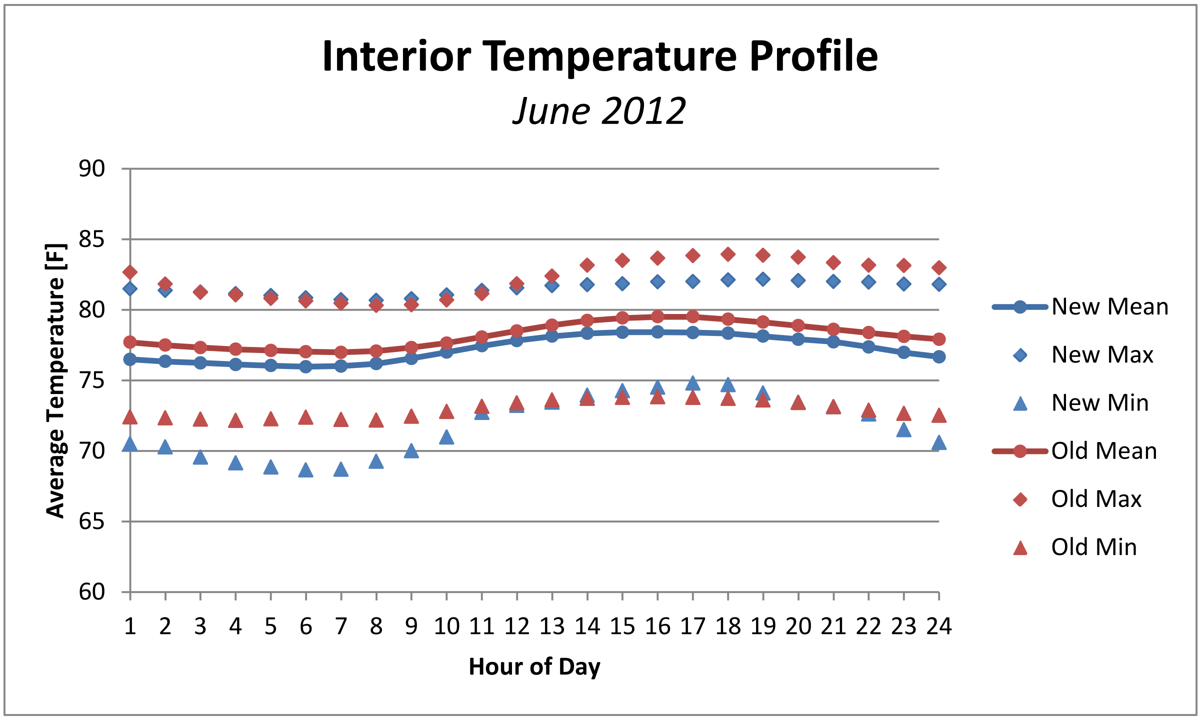

Figure B-21 Interior Temperature Profile, June 2012

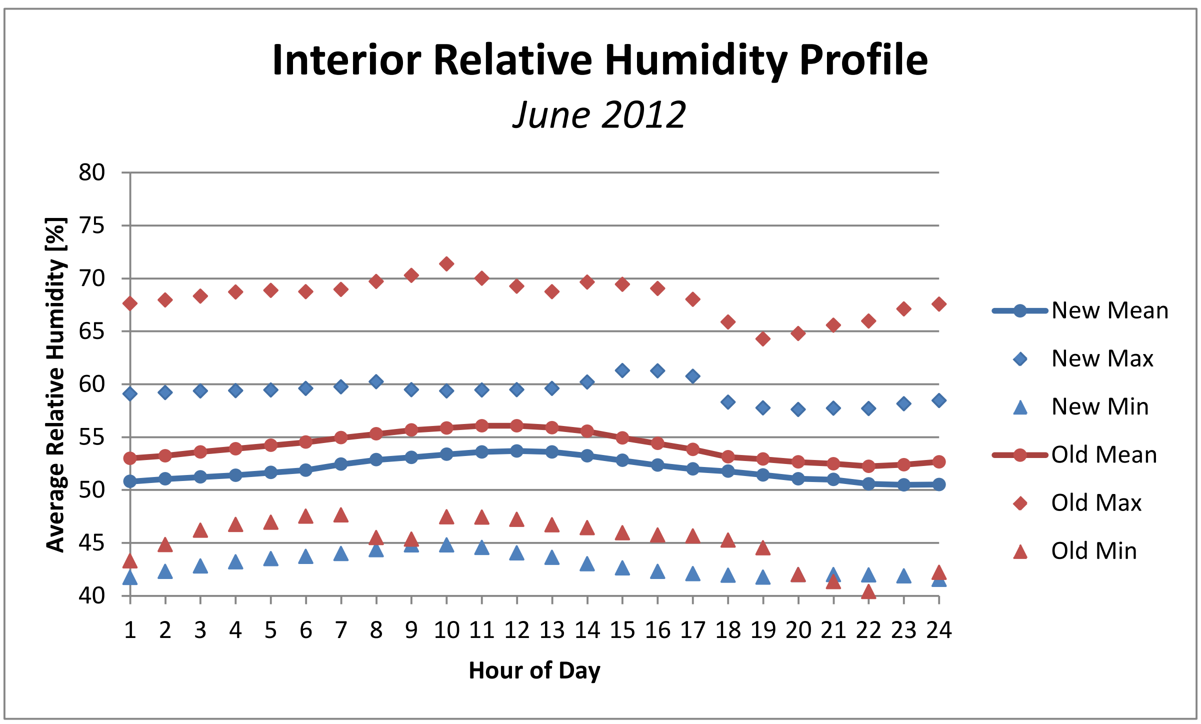

Figure B-22 Interior Relative Humidity Profile, June 2012

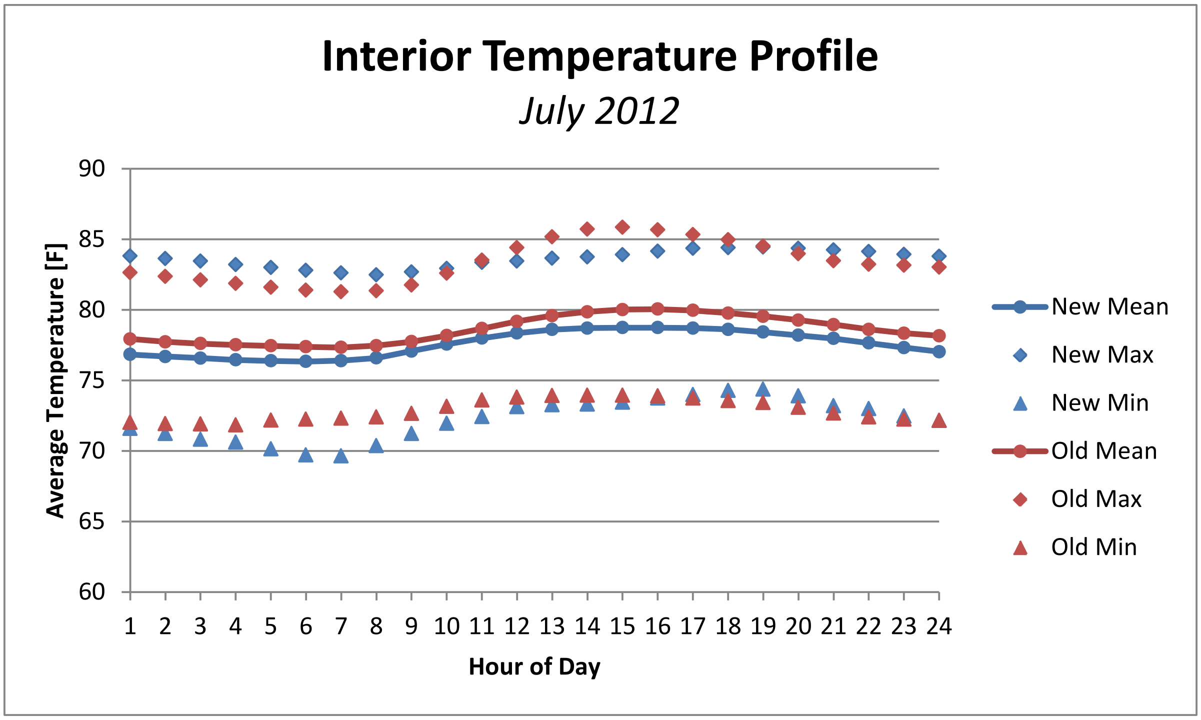

Figure B-23 Interior Temperature Profile, July 2012

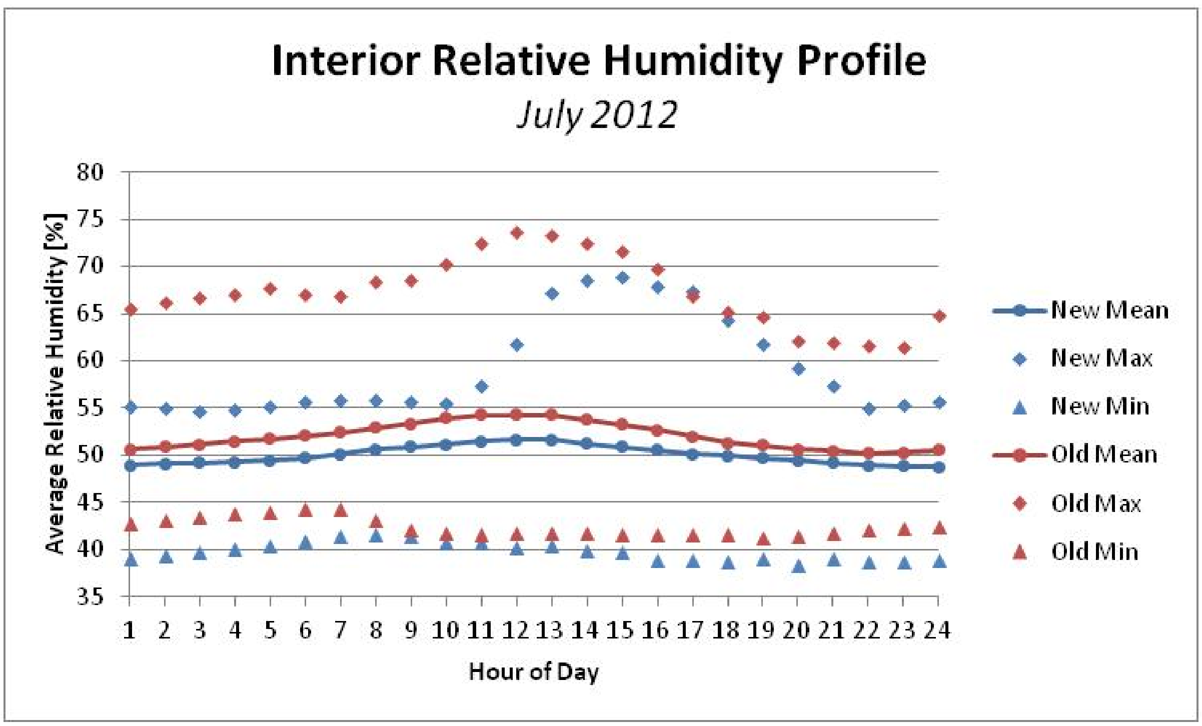

Figure B-24 Interior Relative Humidity Profile, July 2012