Monitoring Report for Mexicali

April to September 2012

Data Collection in Mexicali, Baja California

Amanda Sinnige
Energy Efficient Exporters Alliance

2/15/2013

This project was undertaken with the financial support of / Ce projet a été réalisé avec l'appui financier de :

Environment Canada Environnement Canada

Contents

1 Introduction

This report is a modified version of the previous two reports prepared to summarize the monitoring results for five houses in Mexicali. This report only presents results from the months of May through September. In addition, the section on electrical energy consumption has been expanded to included more analysis.

2 House Location and Description

Five houses are being monitored in the new development in Jazmines, Manzana, or Block, 60, plots 29, 38, 40, 41 and 42. See Figure 1. These are brand new homes, approximately 38 square meters. They are constructed of concrete blocks with a concrete slab floor and roof. In an effort to improve comfort, insulation, in the form of an EIFS system, was placed on the south and north faces of the houses. An insulated stucco system was used for the east and west faces as well as the ceiling.

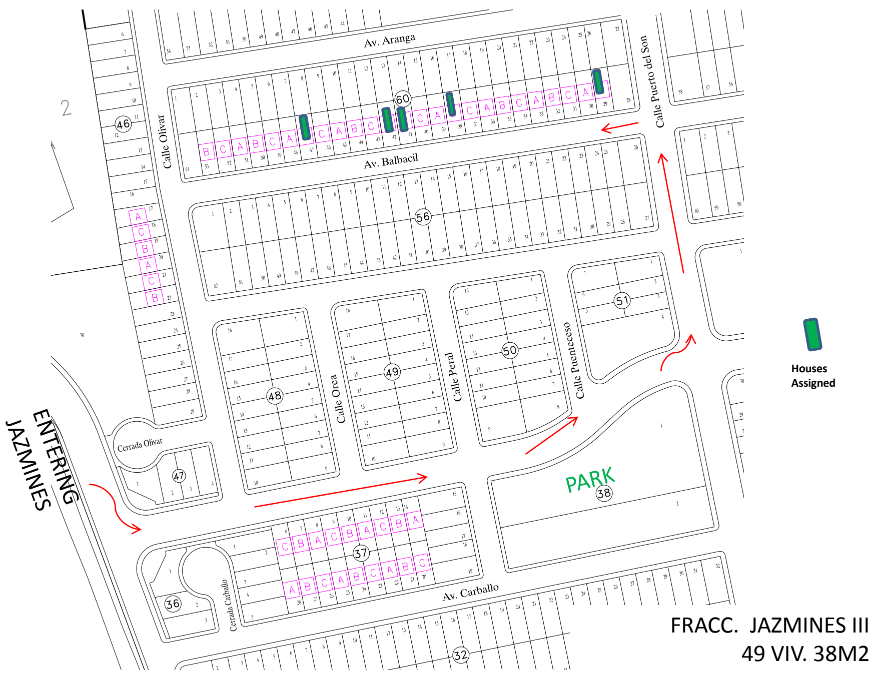


Figure 1 – Site Layout

3 Goals for Data Collection

The goals of data collection:

1. Develop a weather file for use in HOT2000.

   HOT2000 is a useful energy analysis tool that can b e used to evaluate energy efficiency upgrades and to predict the performance of houses. The weather data collected on site is to be used to develop a site-specific weather file for more accurate predictions and analysis of performance.

2. Monitor indoor air for air quality – temperature, relative humidity and carbon dioxide.

   The information collected on indoor air quality is useful for several different evaluations – the evaluation of indoor air quality as it relates to human comfort and health, and it is also used to predict the chances of surface condensation, in conjunction with the surface temperatures also being collected (see below). Surface condensation can lead to the growth of mould which is also bad for human health.

   Indoor temperature, combined with the HOT2000 analyses, will also be used to evaluate the effectiveness of the insulation used in these homes.

3. Monitor surface temperature to

   a. Check conditions for surface condensation, and
   b. Check effectiveness of insulation products used in the houses.

   The indoor temperature and relative humidity is used to determine the dew point temperature. If the surface temperature is lower than the dew point temperature, condensation will form, and with it the likely-hood of mould growth. These temperatures will also be used to verify the effectiveness of the insulation.

4. Monitor electricity consumption.

   Electricity consumption is being monitored by a company in California, USA called greenNet.com. They do a lot of work in Mexico. They installed the equipment to monitor the two air conditioners in each house as well as the overall electricity consumption. The data can be accessed on-line, in real time.

   In addition to the data on air conditioner electricity consumption, two “Kill-A-Watt” meters were installed. These meters plug into a wall outlet, and measure the cumulative energy consumption of the device that is plugged into it. In these houses, the refrigerator and the TV are being monitored.

4 Description of Monitoring Equipment

A weather station was installed that records outdoor temperature, relative humidity and solar radiation. Each of the five houses has been installed with an instrument to record room temperature, relative humidity and carbon dioxide. These were all installed in the living room. Surface temperatures are being recorded in bedrooms and living rooms at the top, middle and bottom of the wall as well as either the ceiling or floor.

Weather Station

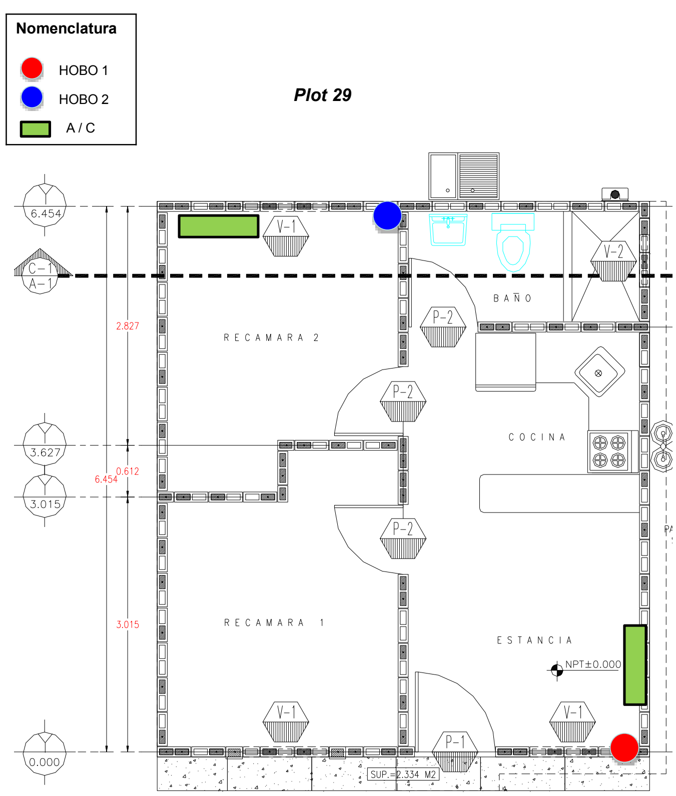
The weather station consists of a pyranometer to measure solar radiation, a temperature sensor and a relative humidity sensor along with a data logger (HOBO) to record the information on-site (HOBO). This equipment, along with the mounting mast and brackets, and the software, are from a company called Onset Computer Corporation.

Surface Temperature

Dataloggers are HOBO U12 4-channel external with fast response temperature sensors. As the name indicates, each datalogger can record information from 4 channels into which are plugged the surface temperature sensors. Sensors are located at three heights on the wall and either the floor or ceiling. Wall sensors are placed approximately 30 cm from the ceiling, and from the floor, and at approximately mid-height on the walls at locations indicated below.

The illustrations in this section have all been provided by Eric Mayagoitia.

<u>Plot 29</u>

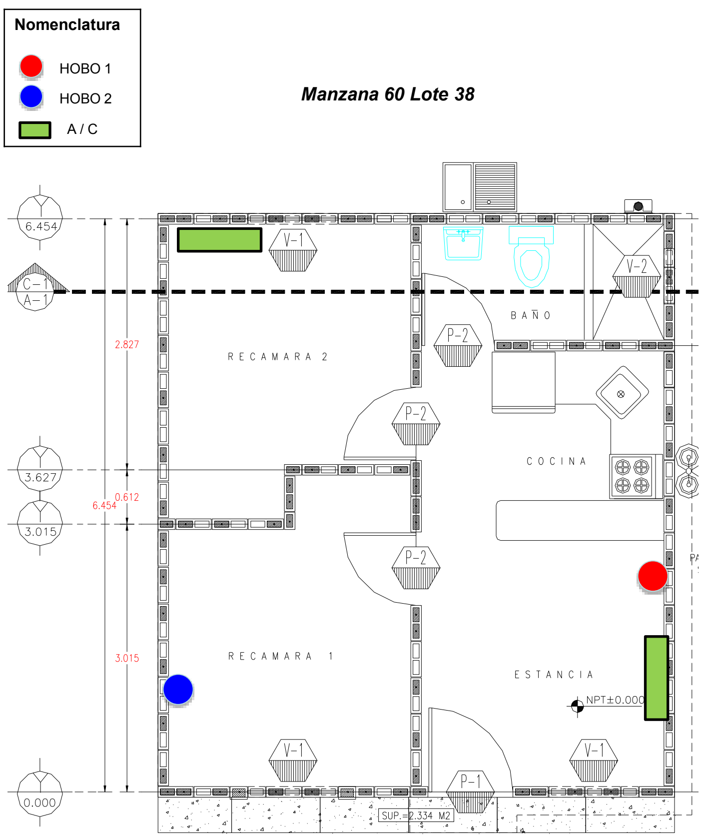


VIVIENDA DE 38 m2

Living Room, south wall – the fourth sensor is on the floor.

Bedroom, north wall – the fourth sensor is on the ceiling.

<u>Plot 38</u>

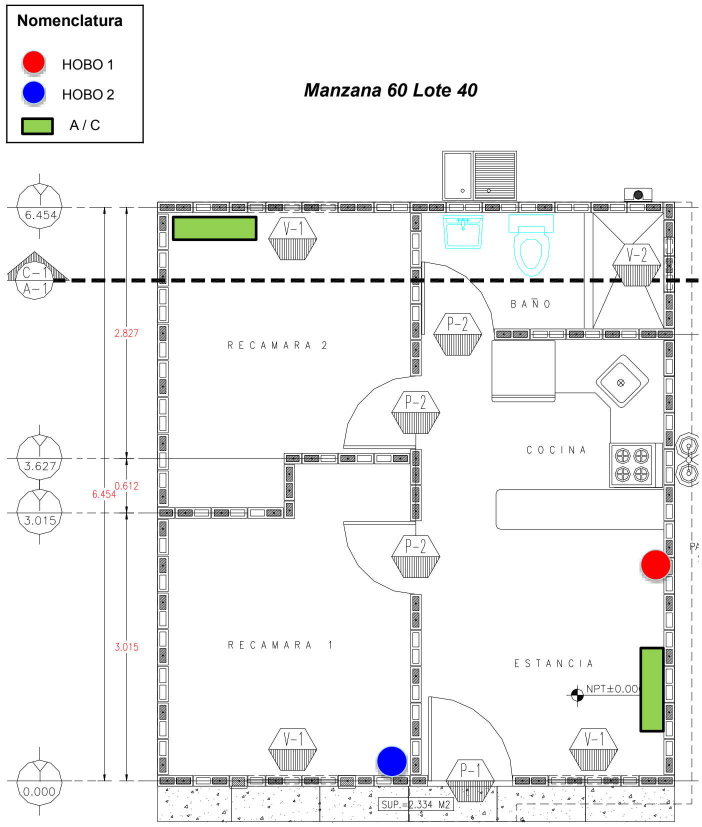


VIVIENDA DE 38 m2

Living Room, east wall – the fourth sensor is on the ceiling.

Bedroom, west wall – the fourth sensor is on the ceiling.

Plot 40



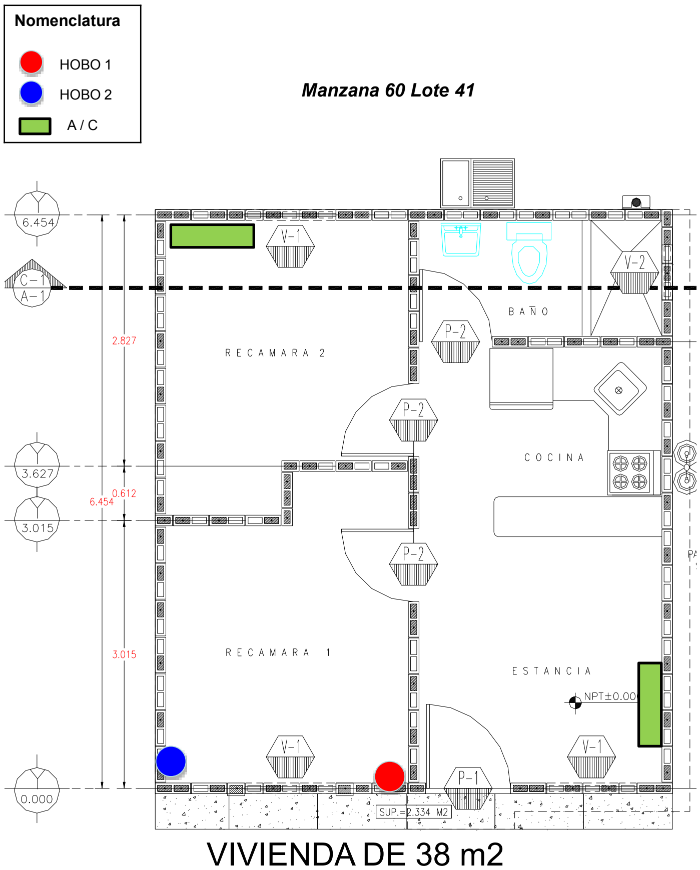
VIVIENDA DE 38 m2

Living Room, east wall – the fourth sensor is on the floor

Bedroom, south wall – the fourth sensor is on the ceiling.

.

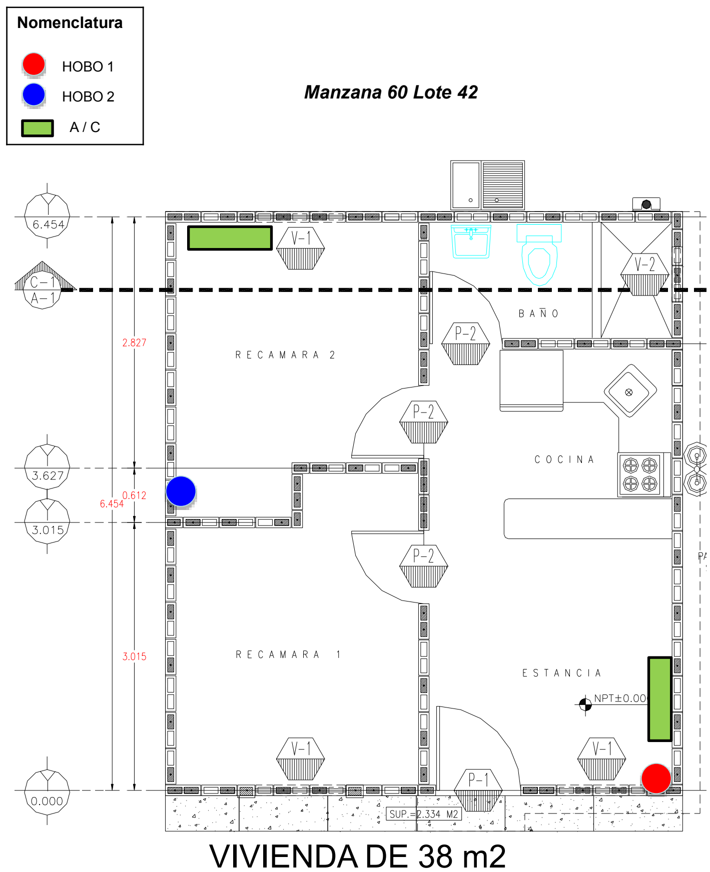
Plot 41



Bedroom, south wall – the fourth sensor is on the ceiling.

Bedroom, west wall – the fourth sensor is on the floor.

Plot 42



Living Room, south wall – the fourth sensor is on the floor.

Bedroom, west wall – the fourth sensor is on the floor.

Room Indoor Environment

Room temperature, relative humidity and carbon dioxide is measured in the living in each house. The device that is installed is an "SD800" by a company called Extech Instruments. The unit includes a datalogger.

5 Data Analysis

The following data was collected:

- the surface temperature data loggers (2 dataloggers per house, four temperature locations each) measure surface temperatures at two locations per house, and four sensors per location,
- the room data loggers collects temperature, relative humidity and carbon dioxide and are located in the living room,
- the weather station collects global solar radiation, outdoor temperature and outdoor relative humidity, and
- electricity consumption for the whole house, as well as each of the two air conditioners per house, and
- cumulative electricity consumption for the TV and the refrigerator in each house.

This report presents the following information:

- indoor comfort and health conditions based on temperature and relative humidity,
- carbon dioxide levels in the homes,
- potential for condensation on the walls,
- effectiveness of insulation , and
- electrical energy consumption .

5.1 Indoor Relative Humidity

According to Health Canada, relative humidity (RH) should be between 30 and 55 for comfort and to avoid various molds and toxins as illustrated in the chart below.

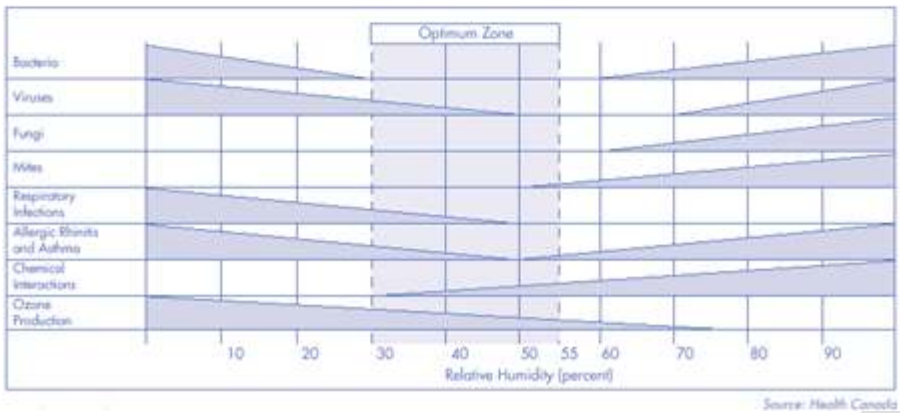


Figure 2 Relative humidity and health effects
Decrease in bar width indicates decrease in effect.[1]

Relative humidity has been monitored in these houses. The maximum and minimum monthly values are presented in the table below. It must be noted, as with the dew point calculations presented in Section 5.4, there were some problems with the data loggers and therefore some data is missing. However, the results are still note-worthy.

	Plot 29		Plot 38		Plot 40		Plot 41		Plot 42	
	max	min	max	min	max	min	max	min	max	min
August	61	19	66.2	19.7	58.2	22.6	55.5	20.7		
September	45.7	22.8	83.4	14.9	53.4	17.4	72	25.9	71.6	20.9

Table 1: Indoor Relative Humidity

All the minimum measured relative humidities are too low. The maximums are generally too high, especially in Plot 38.

As a next step, the relative humidity will be plotted to determine the length of time that the limits are exceeded. The length of time is equally important as the amount by which the limit is exceeded.

5.2 Indoor Temperature

Comfortable indoor air temperature will depend on the individual as well as the humidity. It is generally accepted to be between 73 ^{o}F and 79^{o}F, or 23 ^{o}C and 26^{o}C[2].

	Plot 29		Plot 38		Plot 40		Plot 41		Plot 42	
	max	min	max	min	max	min	max	min	max	min
August	38.5	30.1	37.9	25.2	41.8	24.9	33.9	23.1		
September	37.7	31.7	37.7	25.4	37	32.5	33.8	20.2	36.3	19.9

Table 2: Indoor Temperature

[1] http://oee.nrcan.gc.ca/residential/personal/15161
[2] http://en.wikipedia.org/wiki/Room_temperature

Averaging the results from the two months:

Temperature August/September 2012			
	Max	min	average
29	38.5	30.1	34.05
38	37.9	25.2	30.74
40	41.8	24.9	30.93
41	33.9	20.2	26.25
42	36.3	19.9	29.51

Table 3: Average Maximum and Minimum Indoor Temperature

In these houses, it can be seen that all the maximum temperatures far exceed the generally accepted values based on comfort. In most cases, the minimum values are within the limits described above.

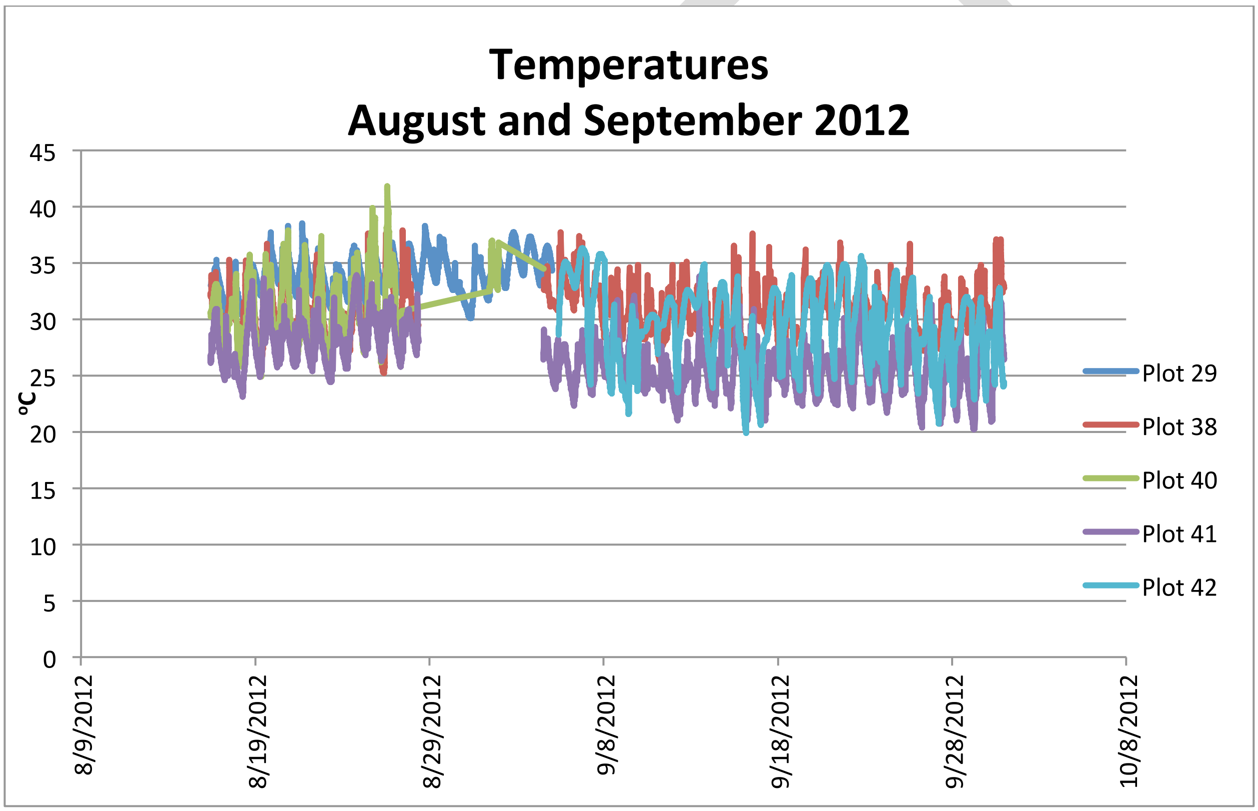


Figure 3: Indoor Temperatures August and September 2012

In general, the temperatures are lower in September than in August, as might be expected. For the purposes of energy simulation using HOT2000, the months of April to September will use the average temperature, 30.3 °C, as the set-point temperature.

5.3 Carbon Dioxide

Carbon dioxide (CO_2)was measured by data loggers in the living room and does not represent the actual state of conditions in the bedroom, which may or may not be worse depending on the number of occupants in each room.

There is a huge concern with regard to the carbon dioxide in these residences. During the initial installation of the monitoring equipment, one house was tested to determine the air tightness of the house. The house was found to be approximately 2.0 air changes per hour at 50 Pa. There is great concern that this is too tight given that no ventilation has been provided in these houses. When houses are built tight, then mechanical ventilation **must** be provided. Ventilation will provide fresh outside air, and remove contaminants from inside the house. CO_2 is a by-product of combustion as well as human respiration. It can be used as an indicator of the quality of the air. If the levels are too, not only is the elevated carbon dioxide a problem, it is an indicator that other contaminants may also be too high.

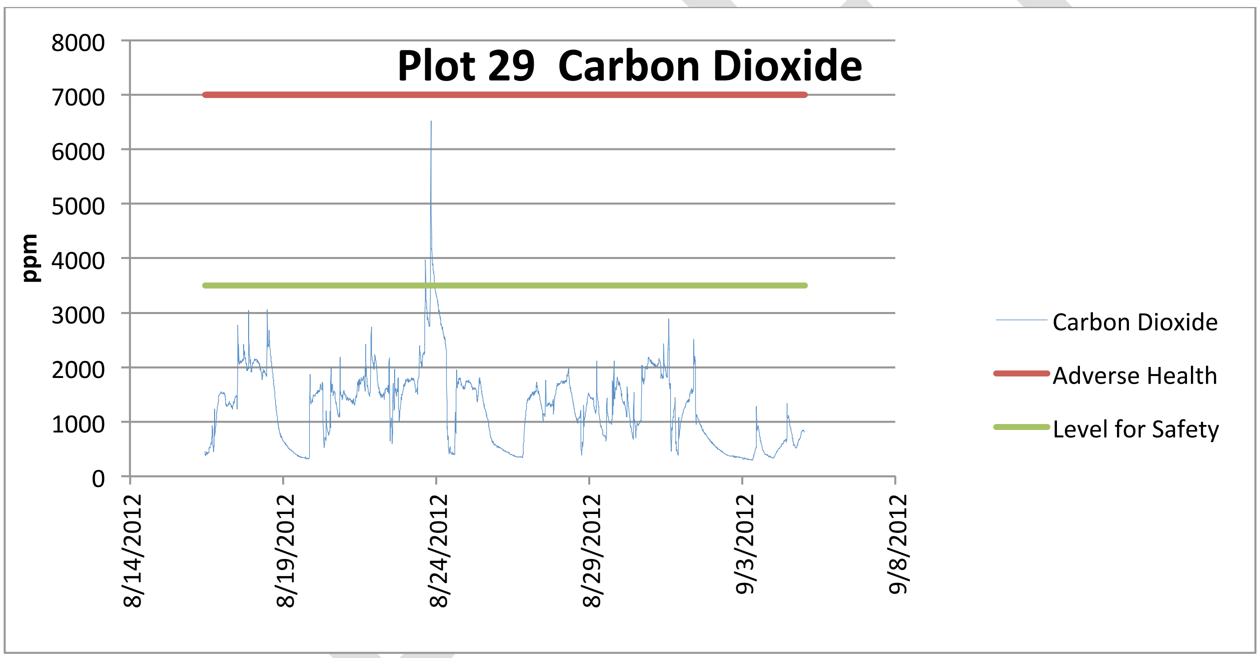


Figure 4: CO2 in Plot 29

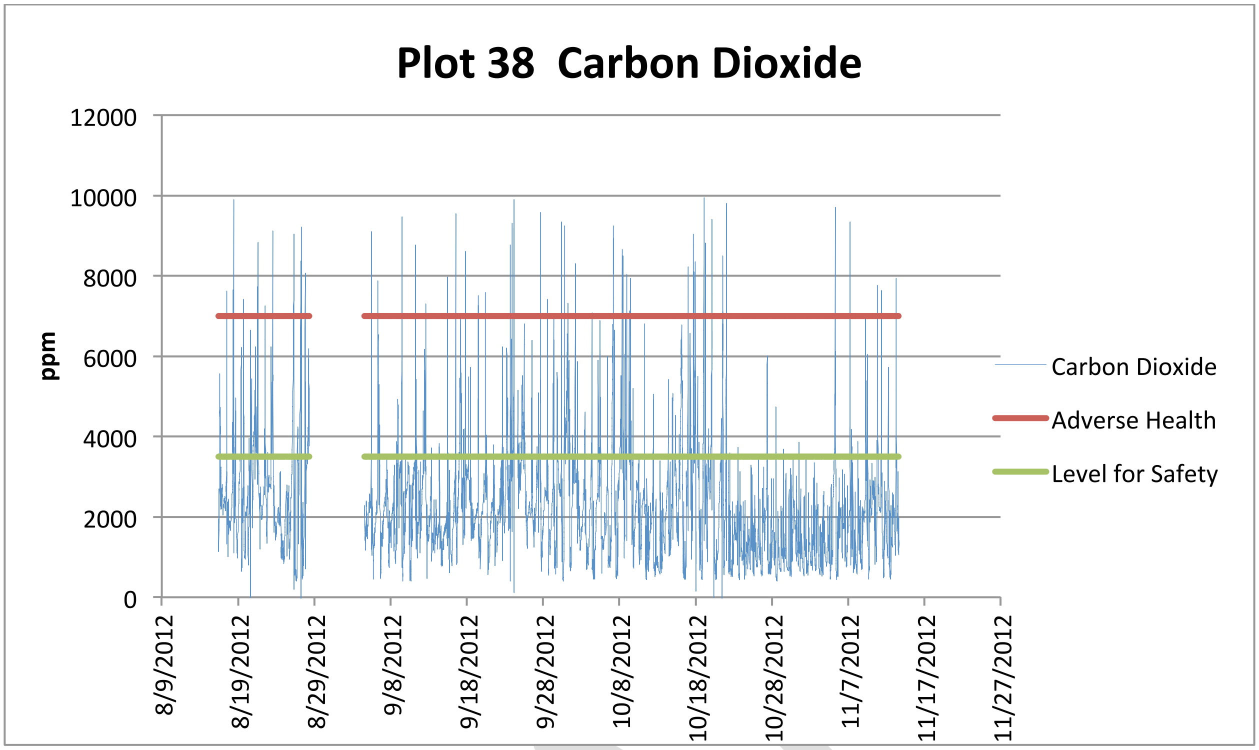


Figure 5: CO2 in Plot 38

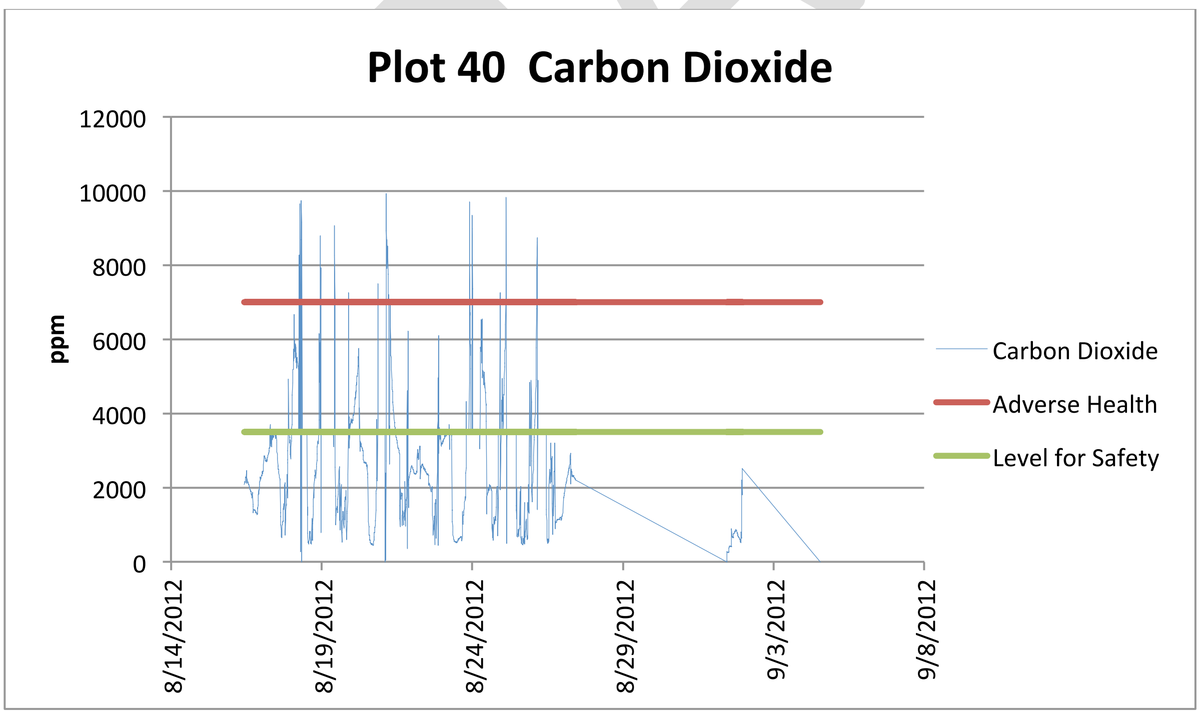


Figure 6: CO2 in Plot 40

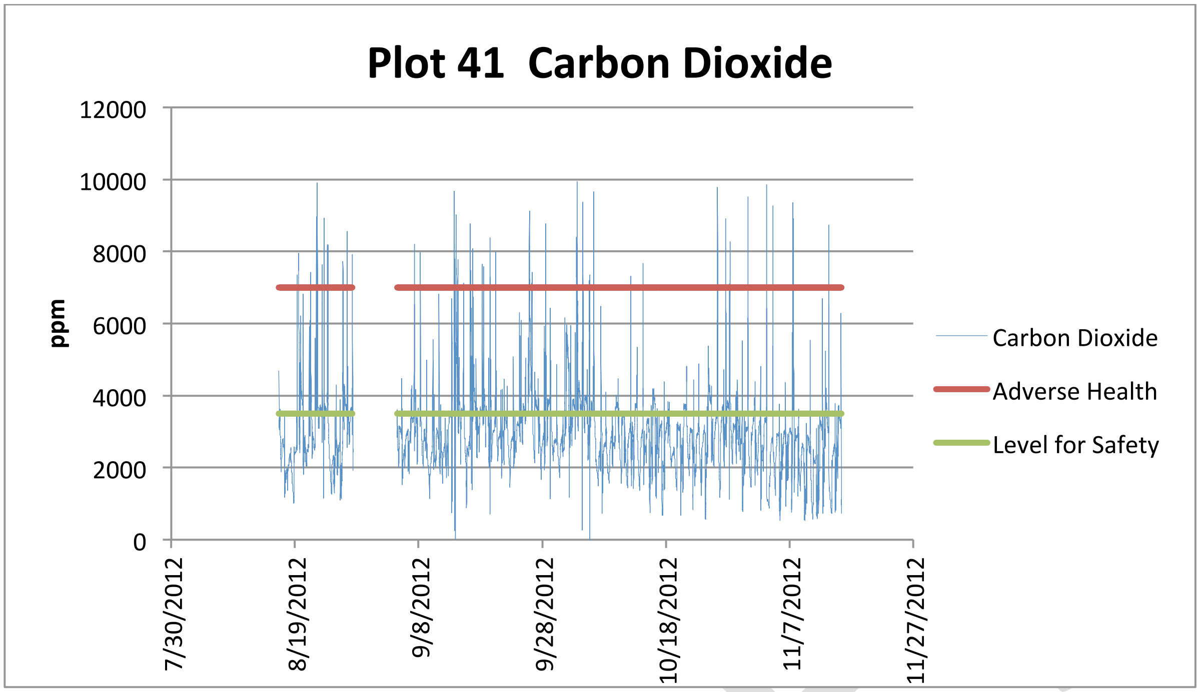


Figure 7: CO2 in Plot 41

Notes:

1. Plot 42 does not have data that is representative.; either the house is empty, or there is a problem with the CO_2 sensor in the unit.
2. Plot 40 developed a problem with the CO_2 sensor.

According to Health Canada: **"Based on health considerations, the acceptable long-term exposure range (ALTER) for carbon dioxide in residential indoor air is ≤ 6300 mg/m^3** (**≤ 3500 ppm).**

The lowest concentration at which adverse health effects have been observed in humans is 12 600 mg/m^3 (7000 ppm), at which level increased blood acidity has been observed after several weeks of continuous exposure. A maximum exposure level of 6300 mg/m^3 (3500 ppm) should provide a sufficient margin to protect against undesirable changes in the acid-base balance and subsequent adaptive changes such as the release of calcium from the bones."

CO_2 is affected by the number of occupants in the home and the amount of time they use the living room and the bedroom. In a house this size, it is common for the bedroom to be used during the day as much as the living room.

As can be seen in Figure 4 to Figure 7, the levels of CO_2 in some of these houses are of great concern. These will be affected by the number of people living in the home as well as the fuel used for cooking. Regardless of the reason, **IT IS CLEAR THAT VENTILATION IS NECESSARY.**

5.4 Dew Point Temperature

The dew point temperature is the temperature at which condensation can form. Based on the indoor temperature and relative humidity, as recorded by the data logger in the living room, a dew point temperature was determined. The data loggers were not working properly until mid-August, therefore there is not a lot of data to evaluate. The available results, along with the surface wall temperatures, are presented in Figure 8 to Figure 32.

5.4.1 Plot 29

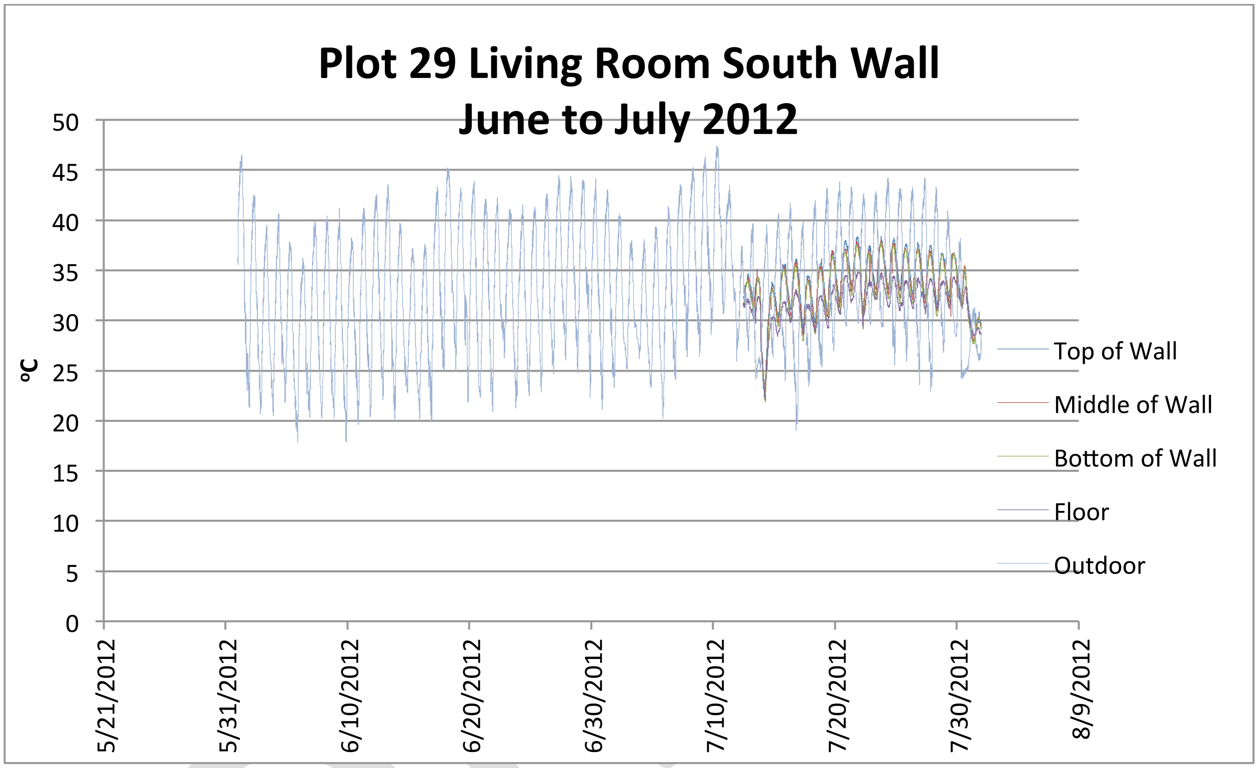


Figure 8: Plot 29 Living Room South Wall Temperatures - June and July 2012

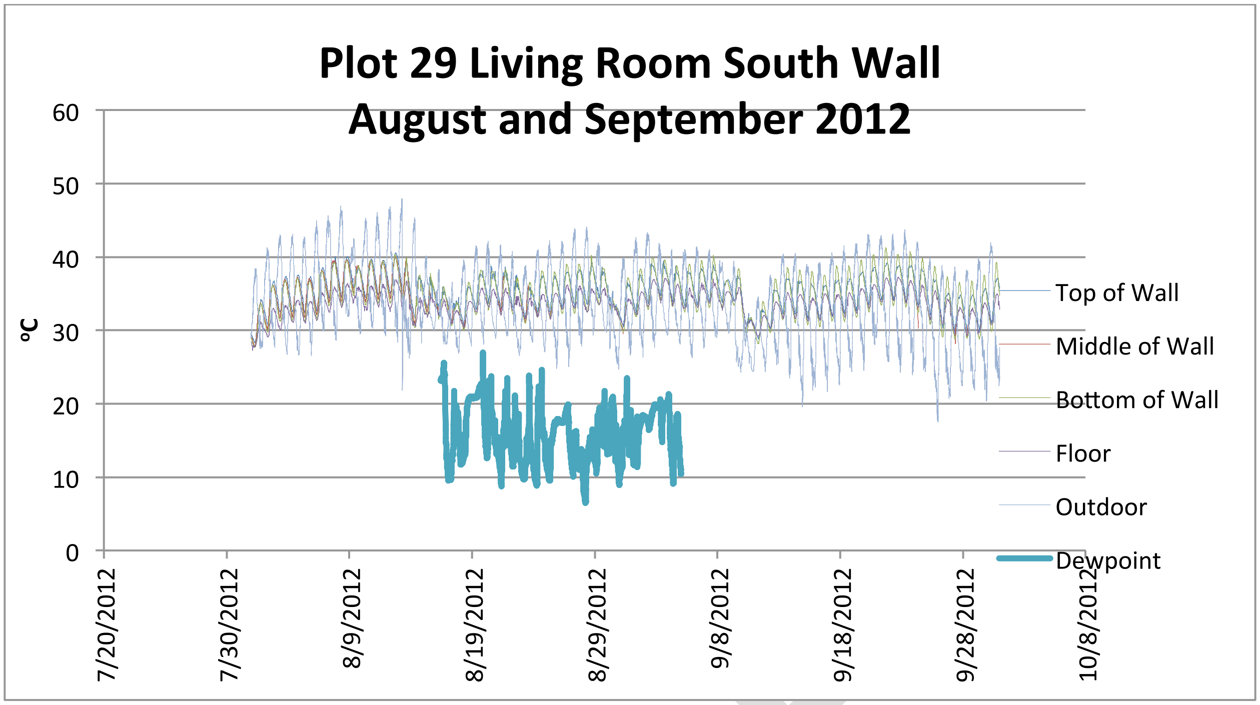


Figure 9: Plot 29 Living Room South Wall Temperatures – August and September 2012

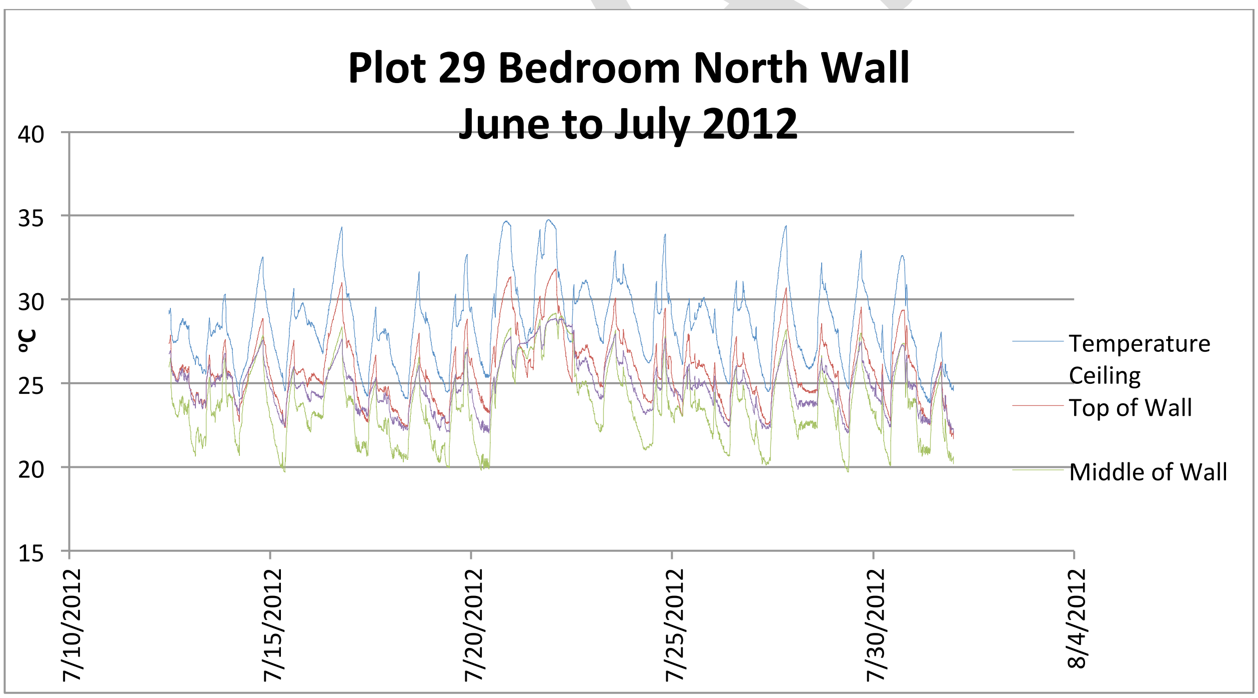


Figure 10: Plot 29 Bedroom North Wall Temperatures - June and July 2012

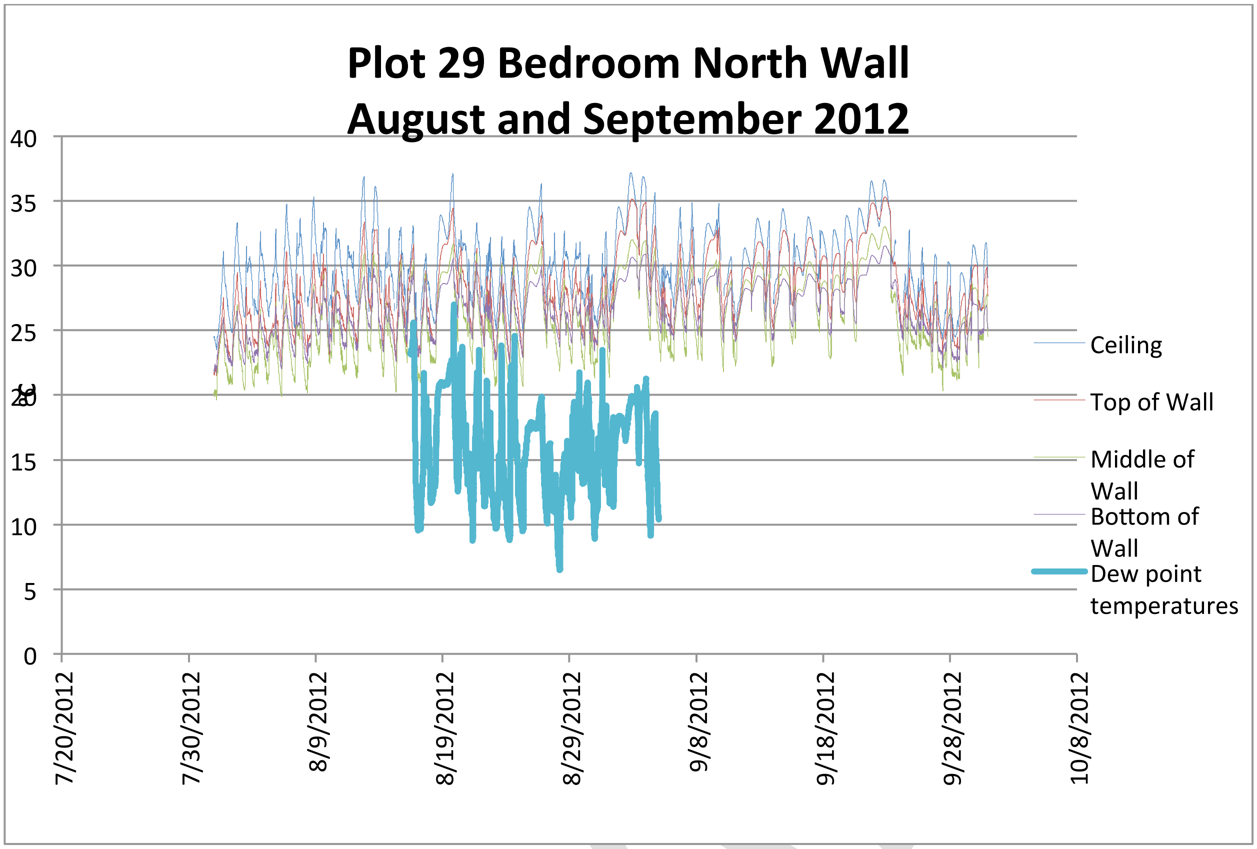


Figure 11: Plot 29 Bedroom North Wall Temperatures – August and September 2012

It is interesting to note that the wall with more potential for condensation is the north wall as compared to the south wall.

5.4.2 Plot 38

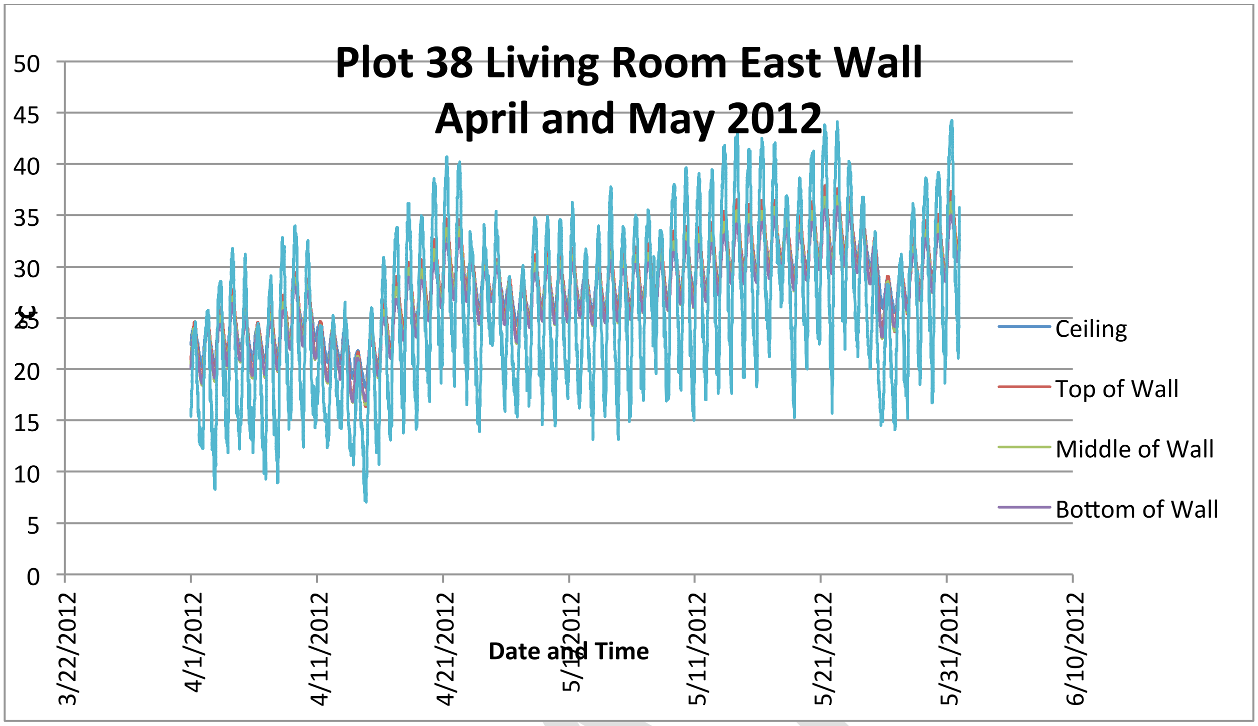


Figure 12: Plot 38 Living Room East Wall Temperatures – April and May 2012

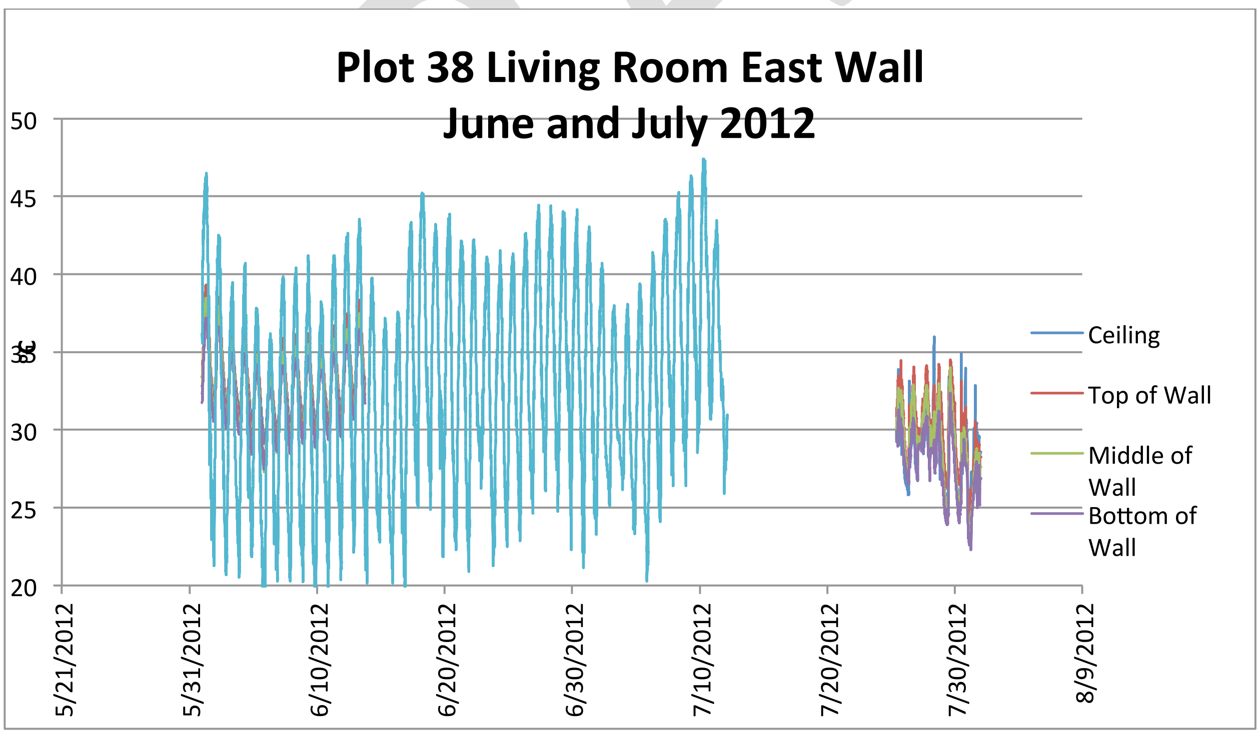


Figure 13: Plot 38 Living Room East Wall Temperatures – June and July 2012

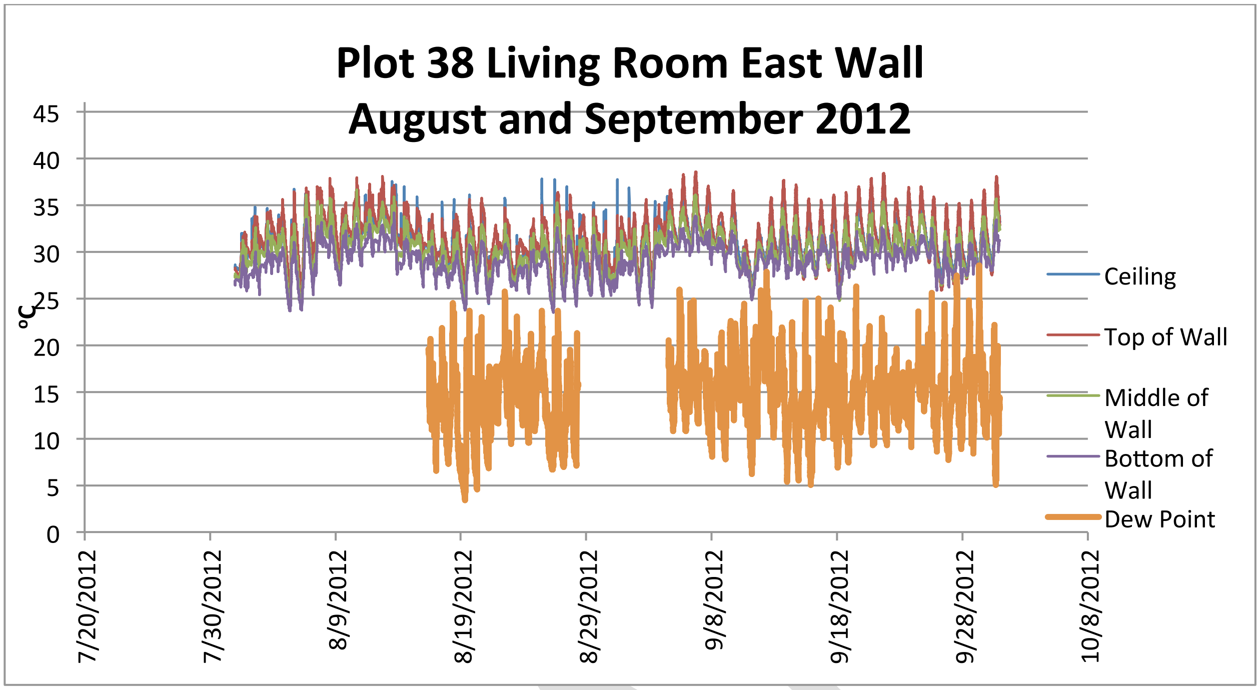


Figure 14: Plot 38 Living Room East Wall Temperatures – August and September 2012

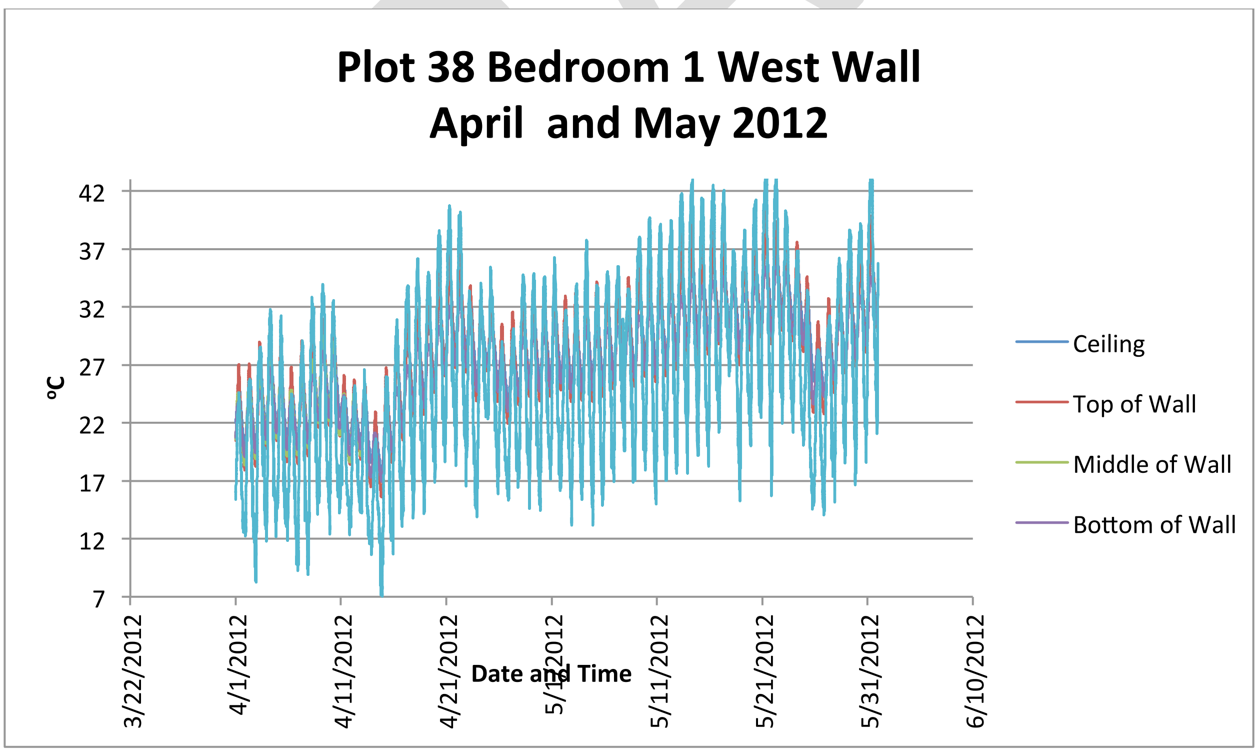


Figure 15: Plot 38 Bedroom West Wall Temperatures – April and May 2012

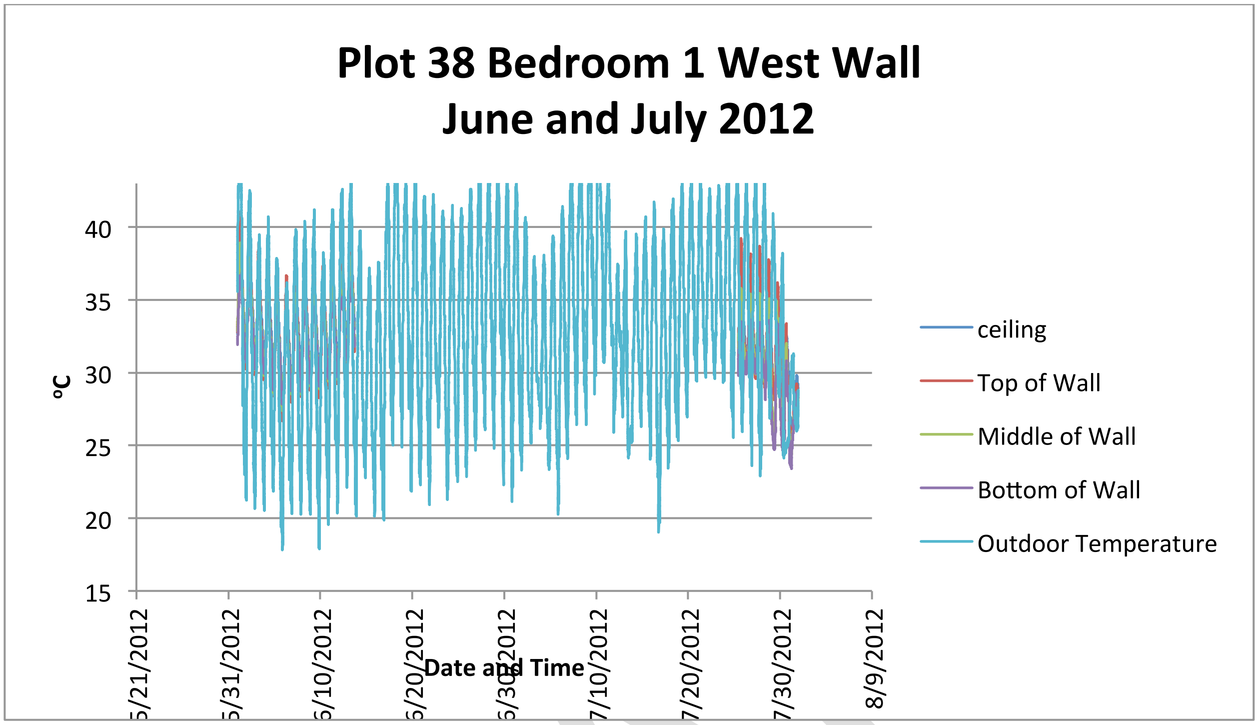


Figure 16: Plot 38 Bedroom West Wall Temperatures – June and July 2012

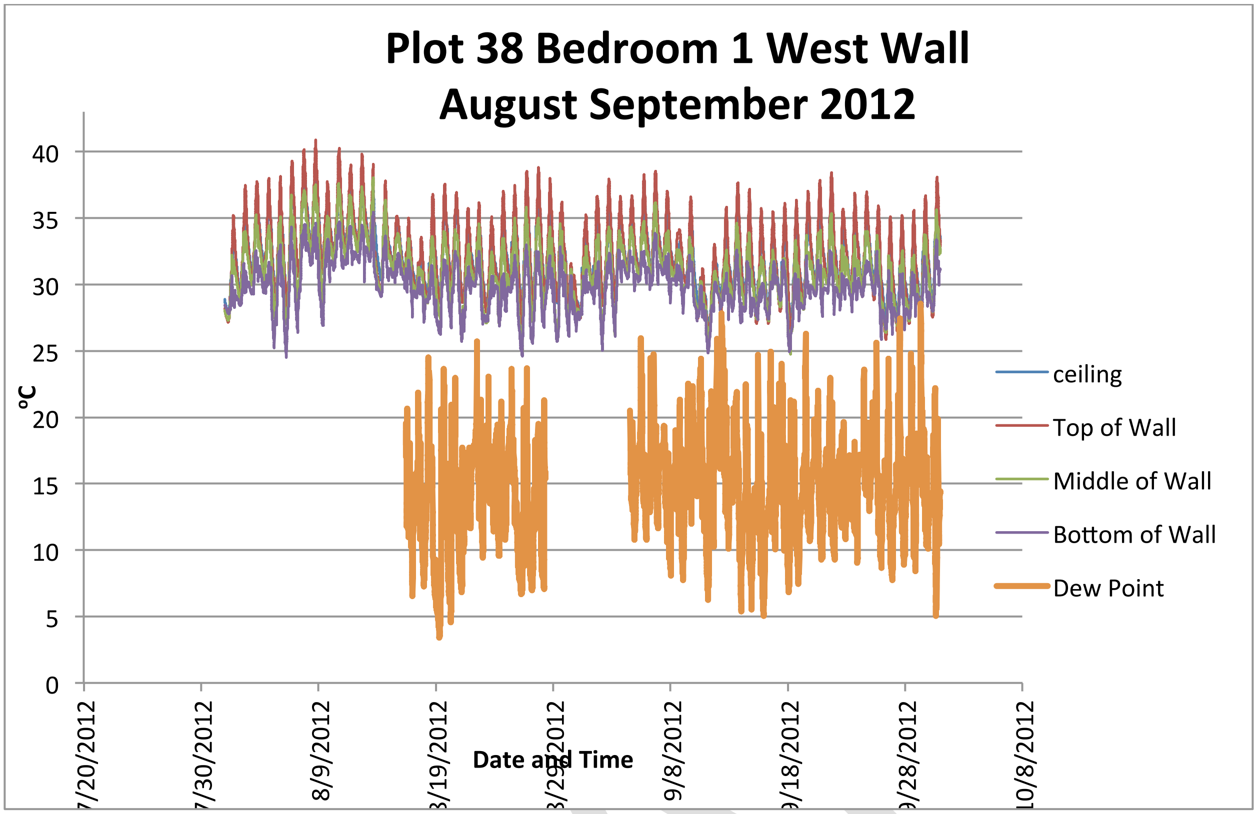


Figure 17: Plot 38 Bedroom West Wall Temperatures – August and September 2012

In this house, the potential for surface condensation appears to be about equal for both the east and west walls. However, the living room seems to have a slightly greater potential for condensation.

5.4.3 Plot 40

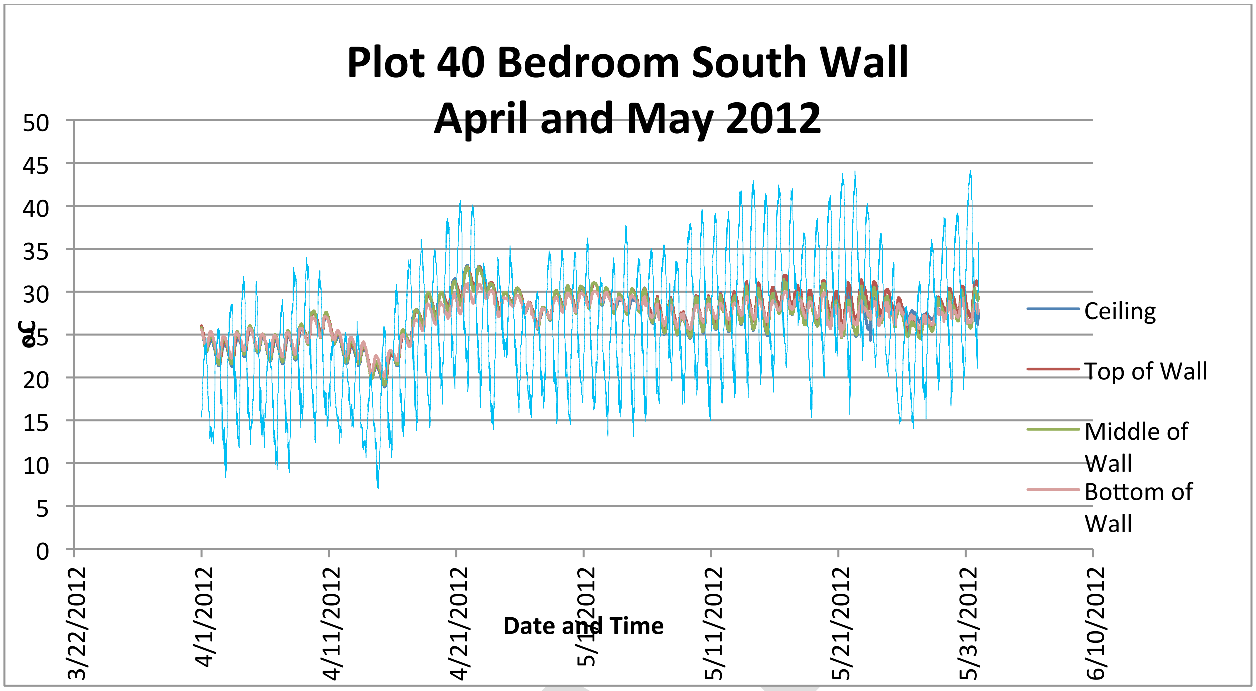


Figure 18: Plot 40 Bedroom South Wall Temperatures – April and May 2012

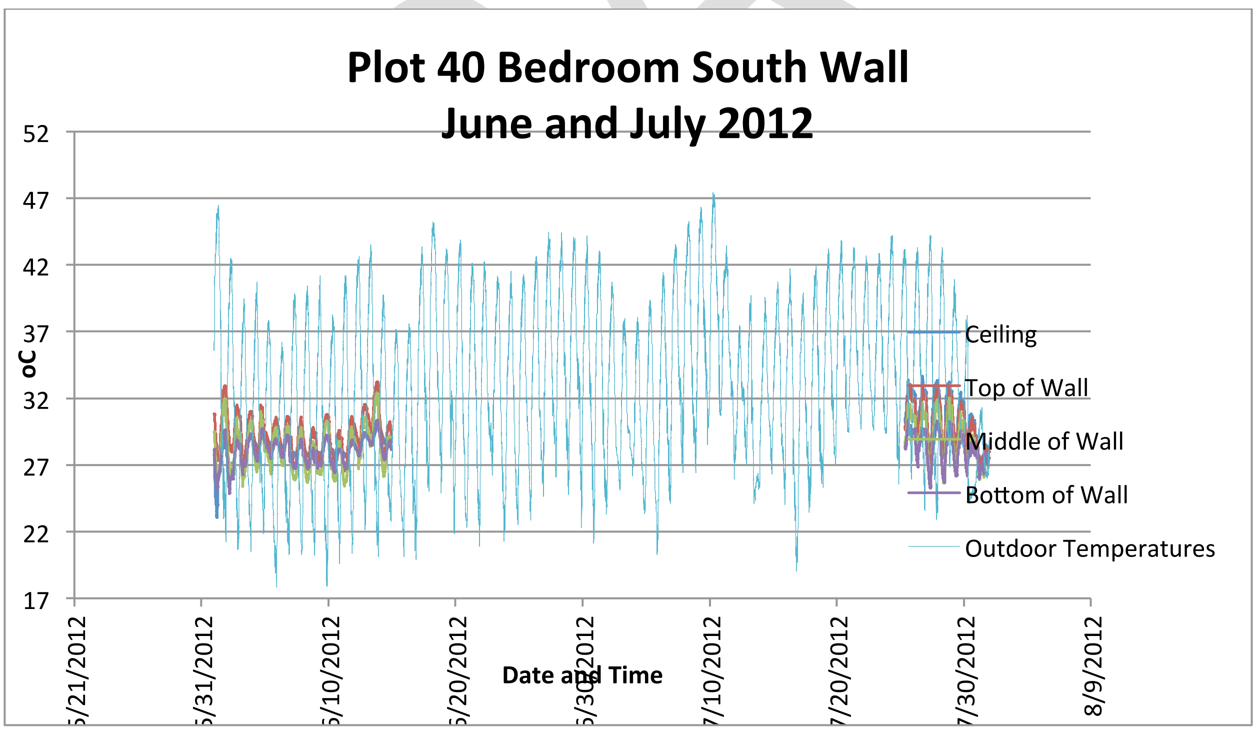


Figure 19: Plot 40 Bedroom South Wall Temperatures – June and July 2012

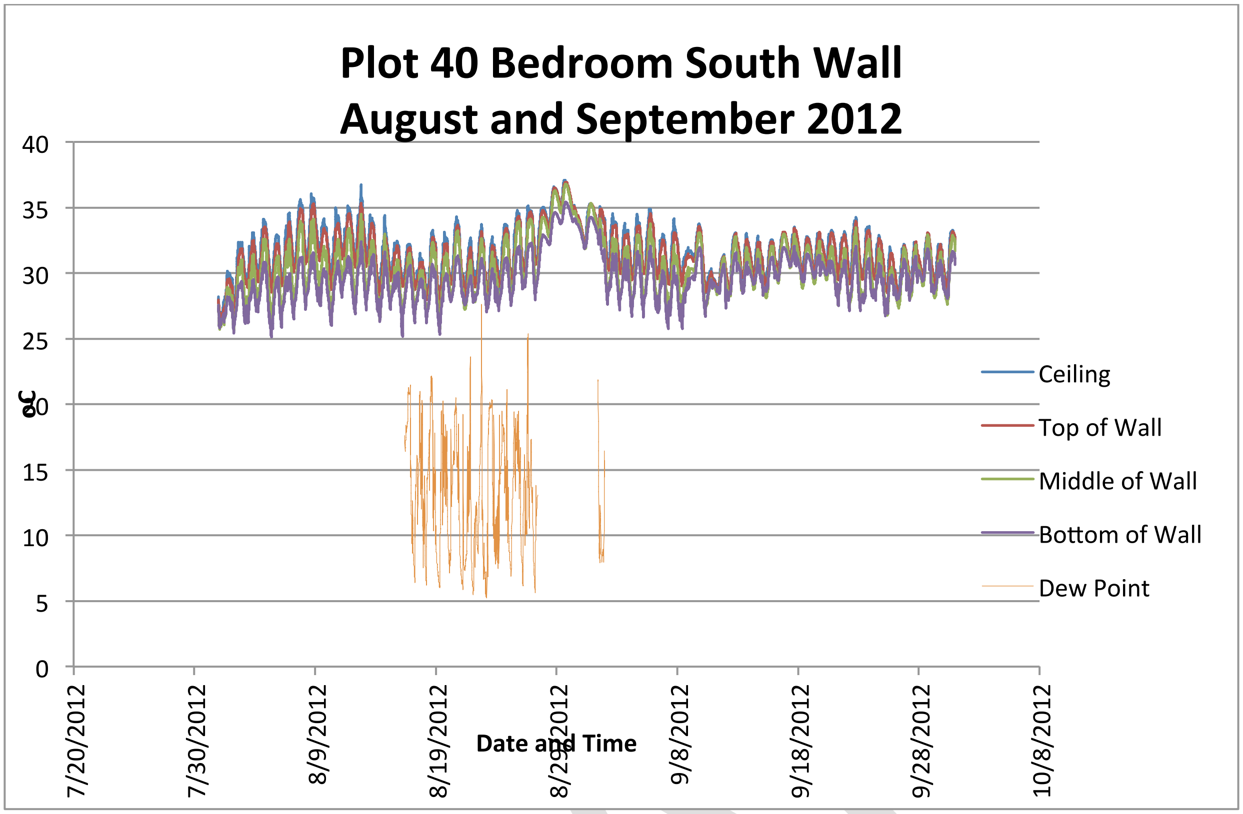


Figure 20: Plot 40 Bedroom South Wall Temperatures – August and September 2012

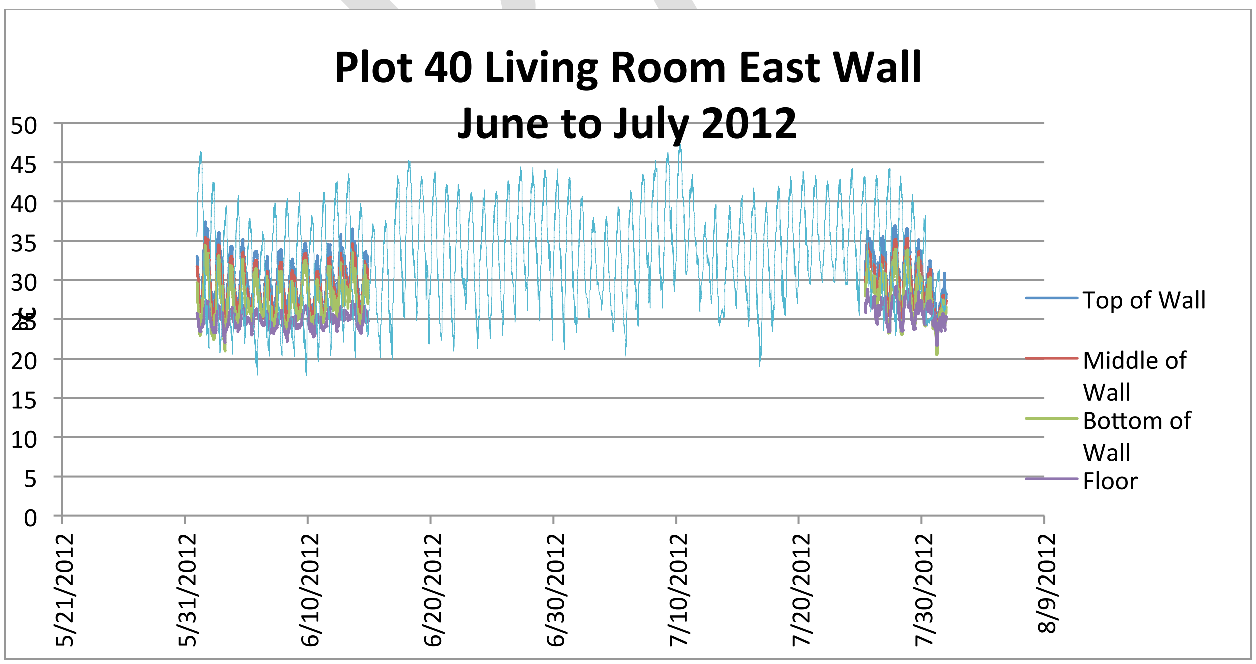


Figure 21: Plot 40 Living Room East Wall Temperatures

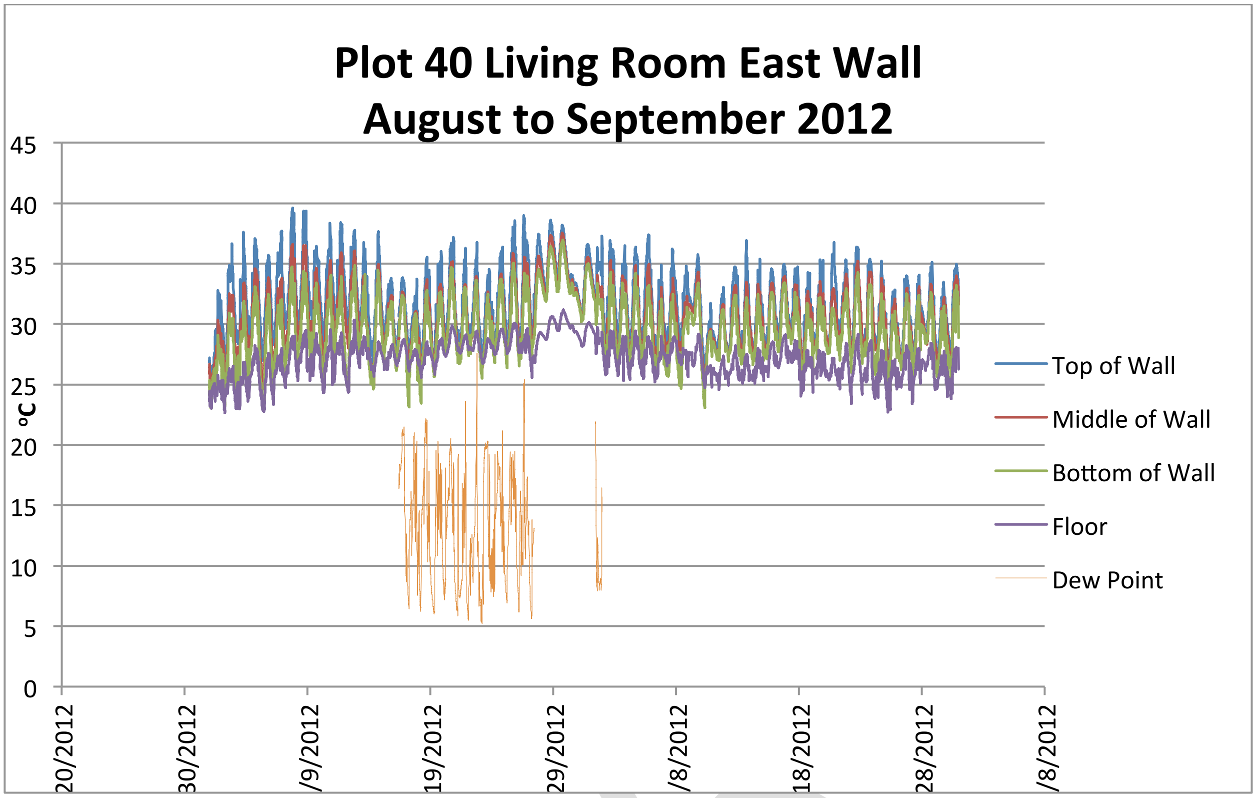


Figure 22: Plot 40 Living Room East Wall Temperatures

5.4.4 Plot 41

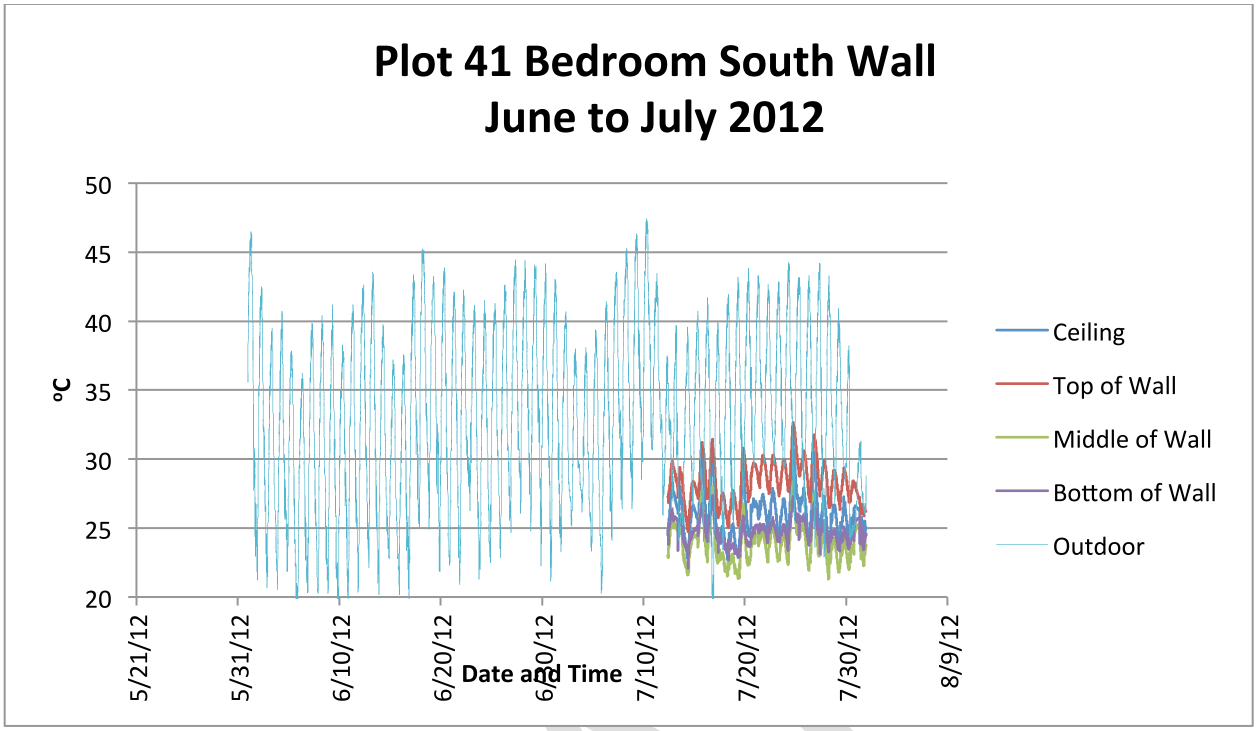


Figure 23: Plot 41 Bedroom South Wall Temperatures – June to July 2012

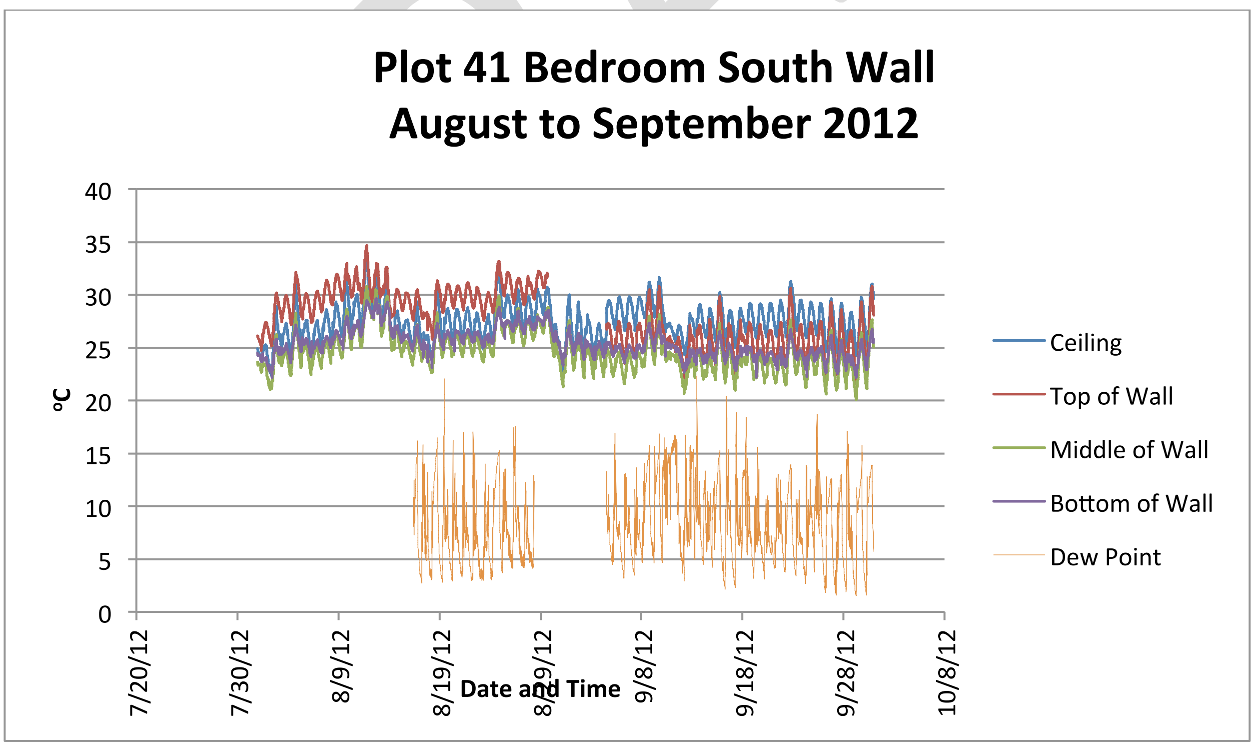


Figure 24: Plot 41 Bedroom South Wall Temperatures

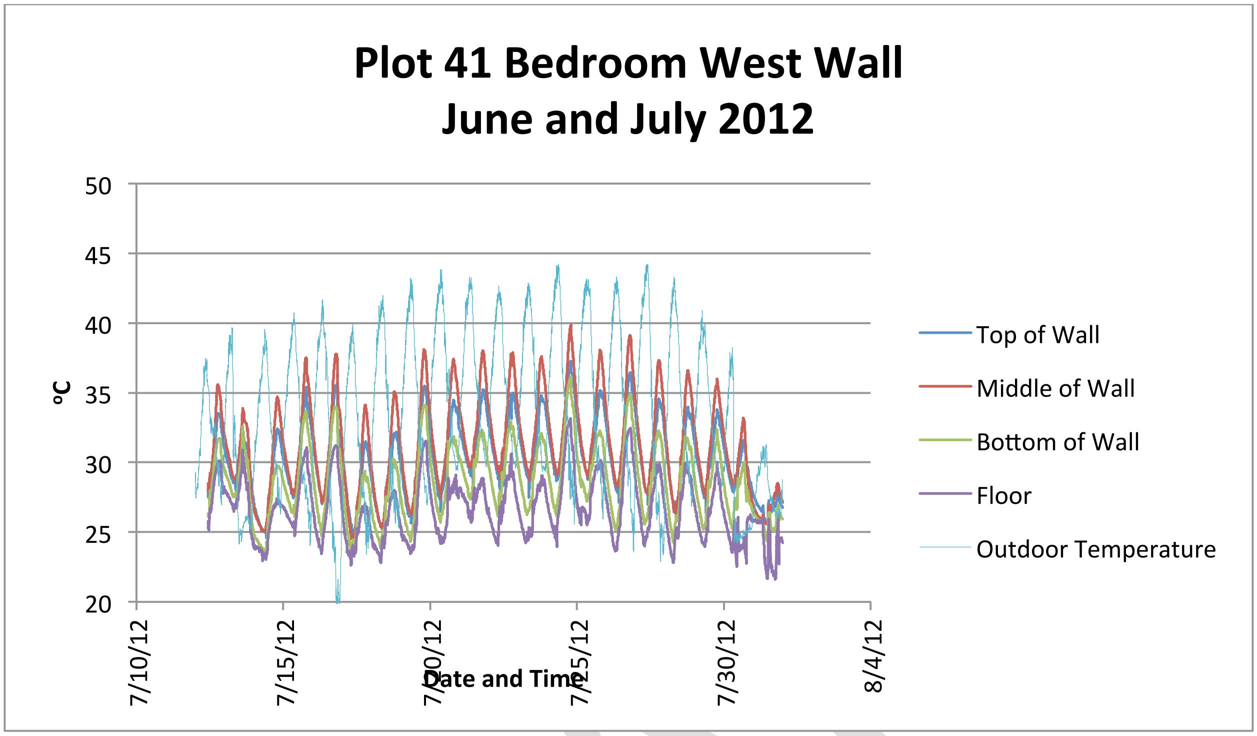


Figure 25: Plot 41 Bedroom West Wall Temperatures – June and July

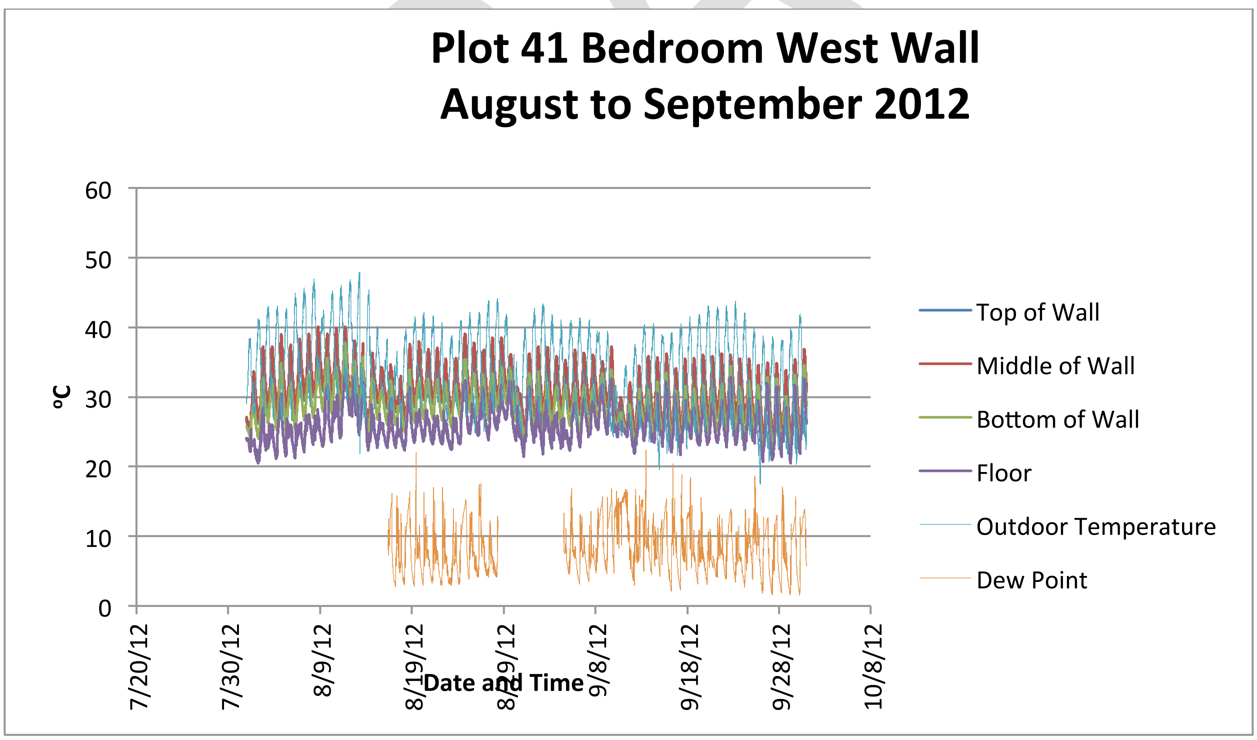


Figure 26: Plot 41 Bedroom West Wall Temperatures – August and September

5.4.5 Plot 42

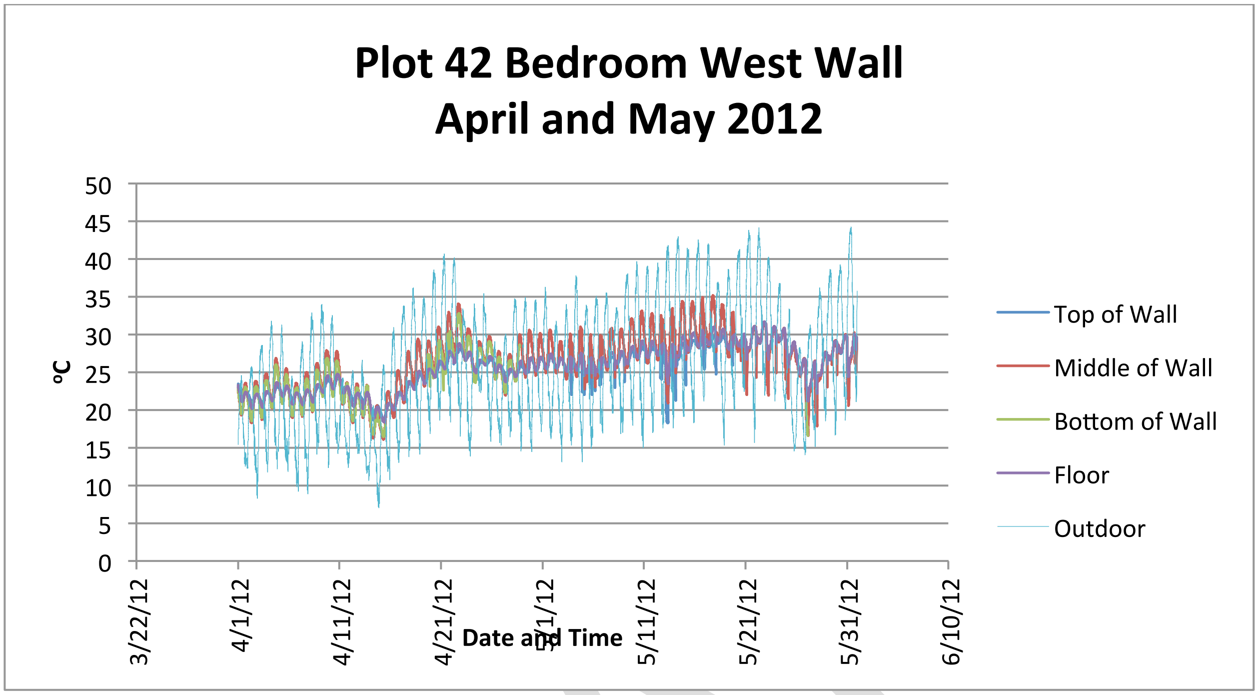


Figure 27: Plot 42 Living Room South Wall Temperatures – April and May 2012

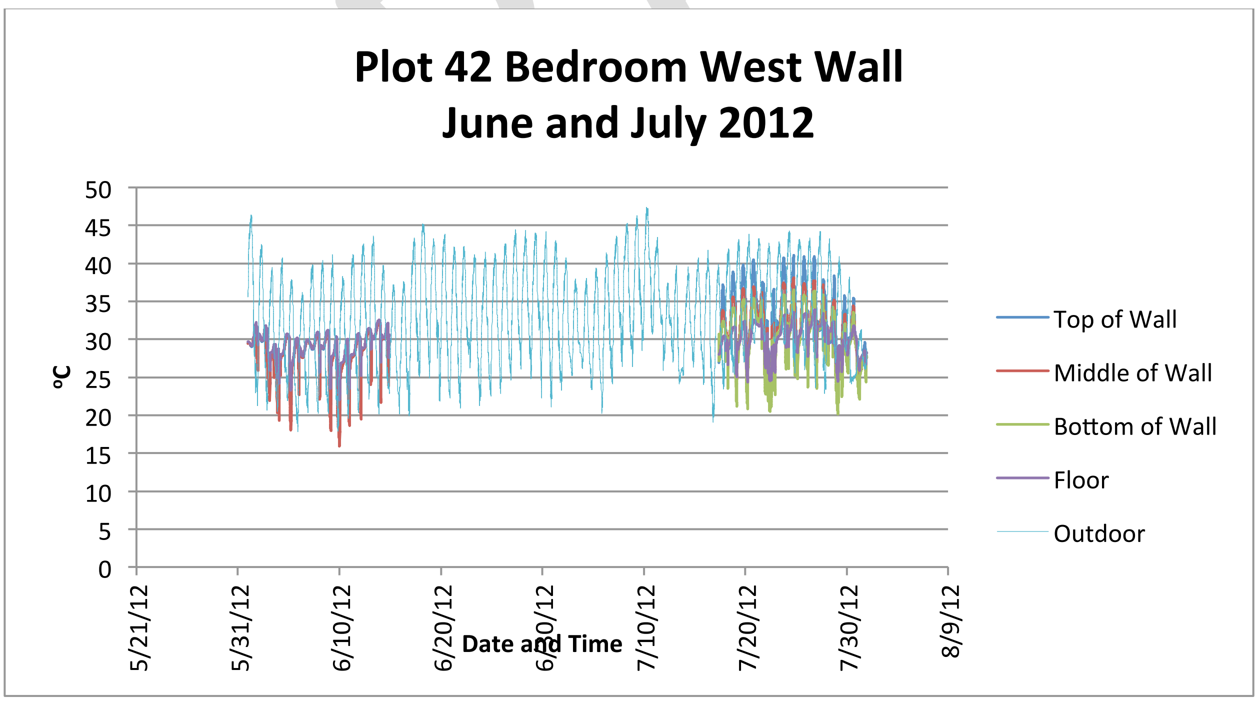


Figure 28: Plot 42 Living Room South Wall Temperatures – June and July 2012

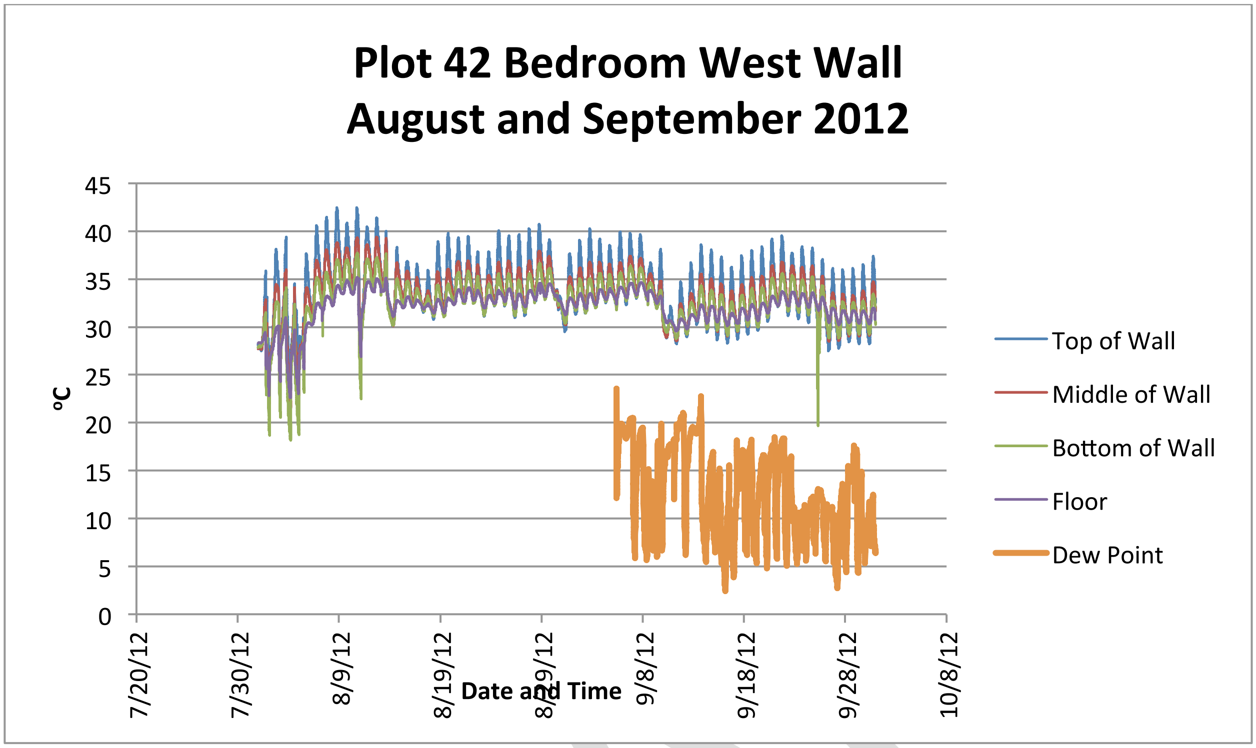


Figure 29: Plot 42 Bedroom West Wall Temperatures – August and September 2012

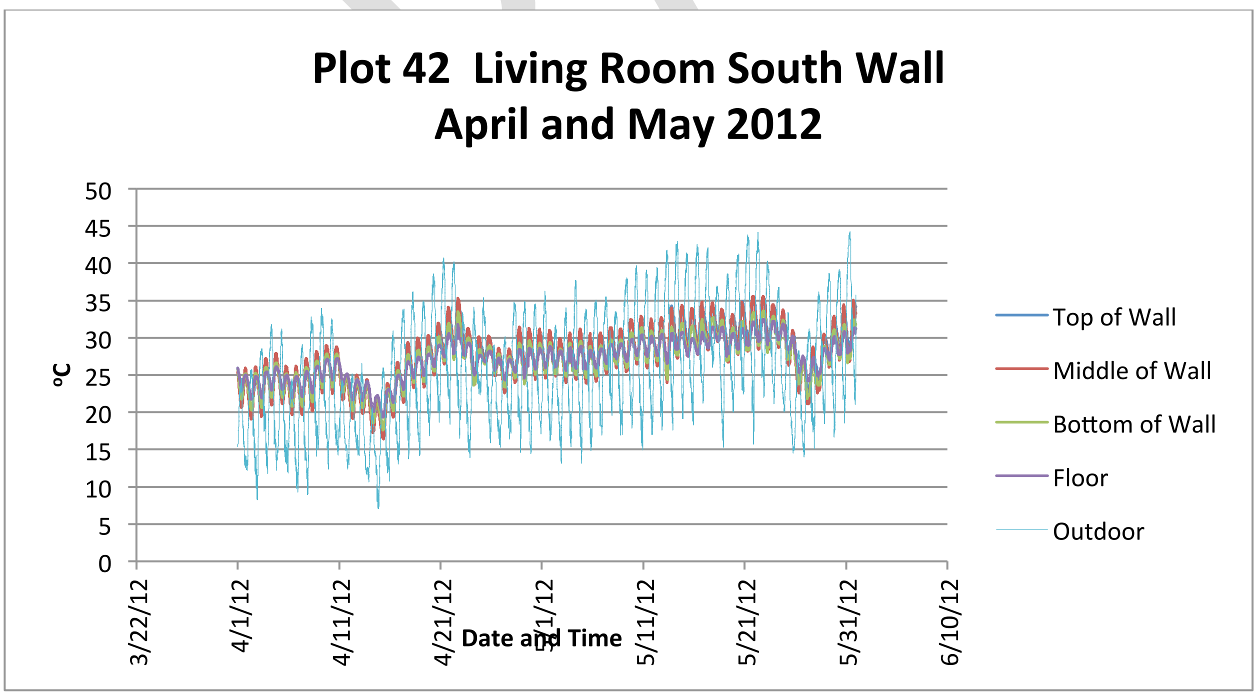


Figure 30: Plot 42 Living Room South Wall Temperatures – April and May 2012

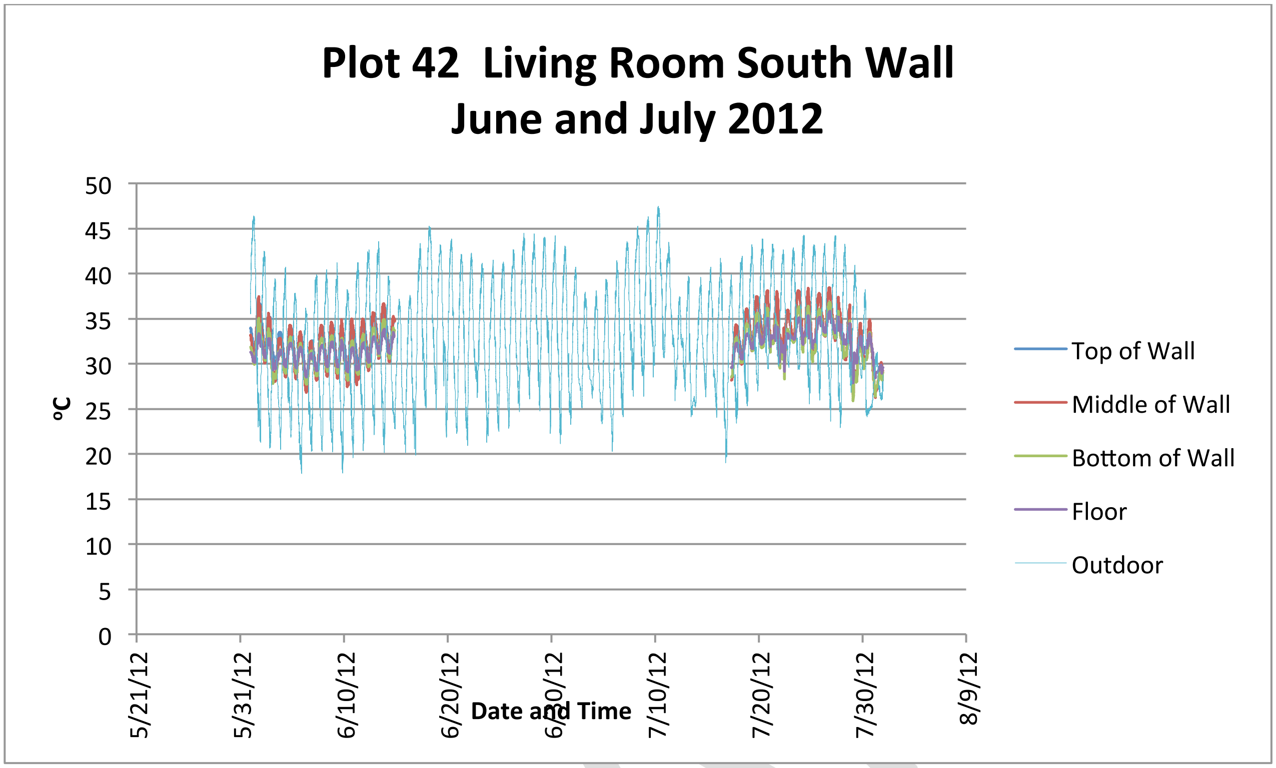


Figure 31: Plot 42 Living Room South Wall Temperatures – June and July 2012

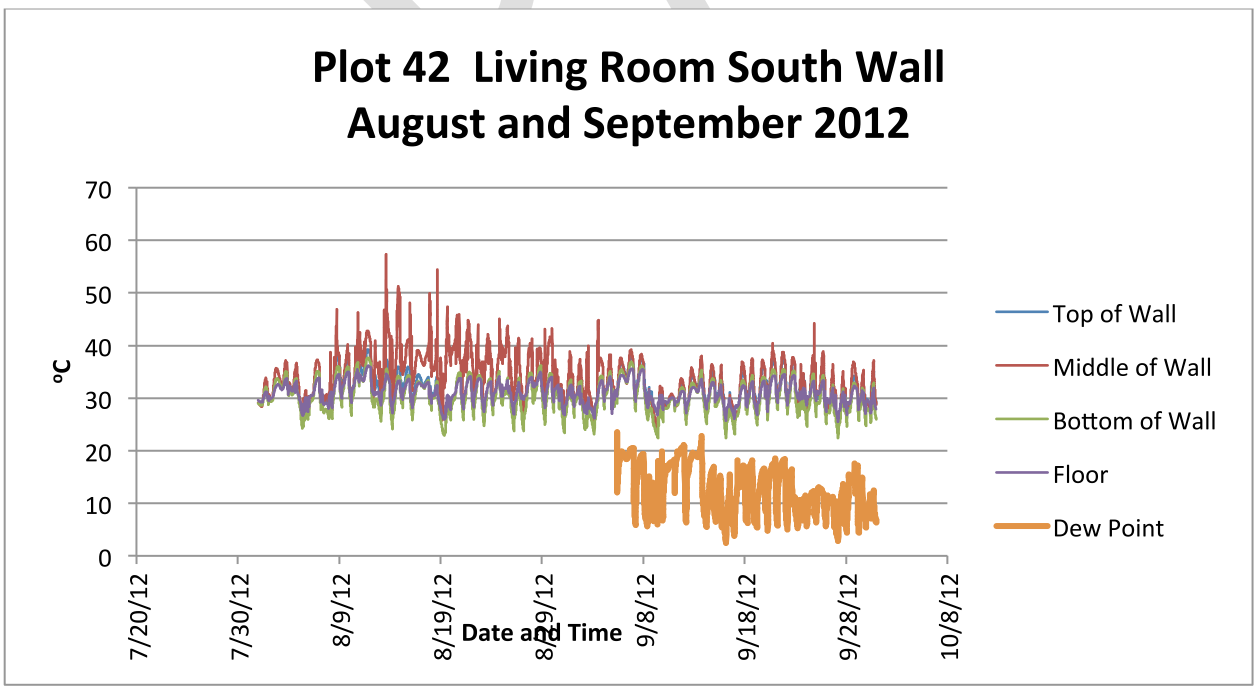


Figure 32: Plot 42 Living Room South Wall Temperatures – August and September 2012

Plot 29 and 38 have the potential for surface condensation several times during the monitoring period, whereas Plots 40, 41 and 42 do not have the risk of surface condensation.

So far, there does not appear to be a correlation between electricity use in these units for air conditioning and the potential for surface condensation. It is true that air conditioning dehumidifies the air and it is likely that this contributes to the lack of surface condensation potential in these units. The more likely attributes that contribute to the potential for surface condensation are the number of occupants and the use of the space (number of showers, cooking habits, etc.).

5.5 Electrical Energy Consumption

5.5.1 Air Conditioning and Total

The following bar charts show the electricity consumption in each of the houses. It is interesting to note the differences between houses, given that the houses are the same size, with the same air conditioners. The differences are a result of occupant behavior, including number of occupants, use of air conditioners (temperature choice and number of hours in use), cooking, and other plug loads.

This information will be used in combination with the HOT2000 analysis to evaluate the performance of the house with and without the insulation, and the impact of energy-efficient air conditioners.

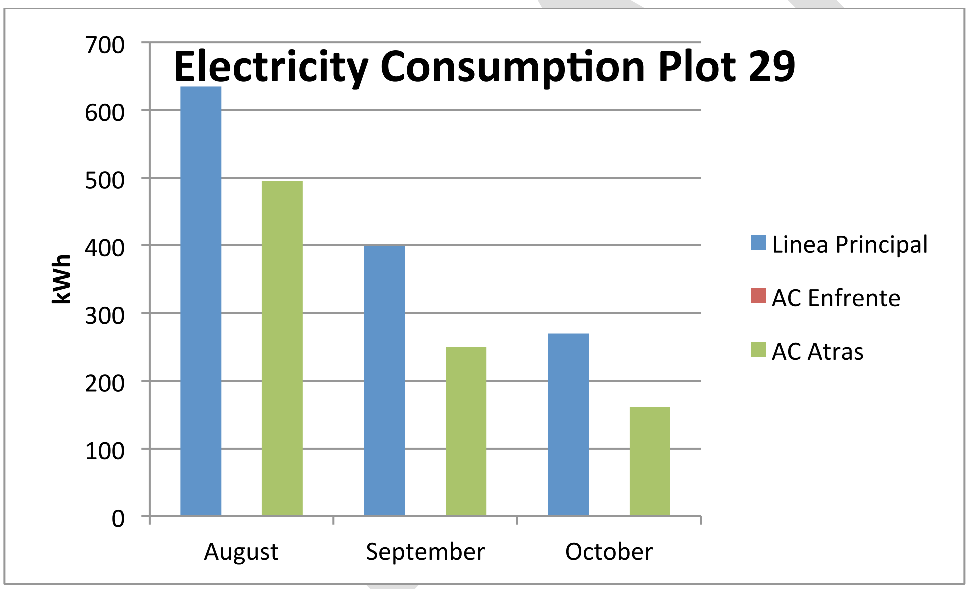


Figure 33: Plot 29 Electricity Consumption

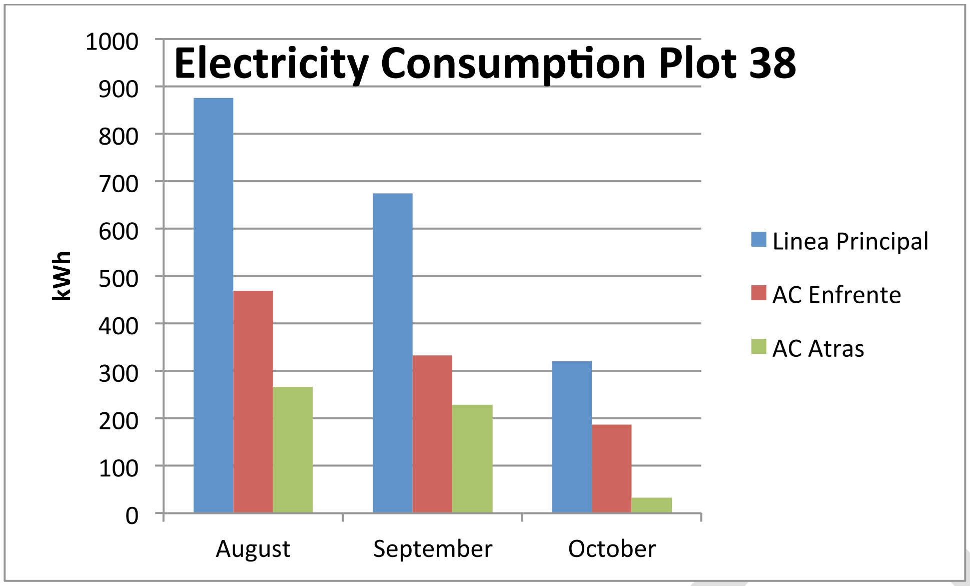


Figure 34: Plot 38 Electricity Consumption

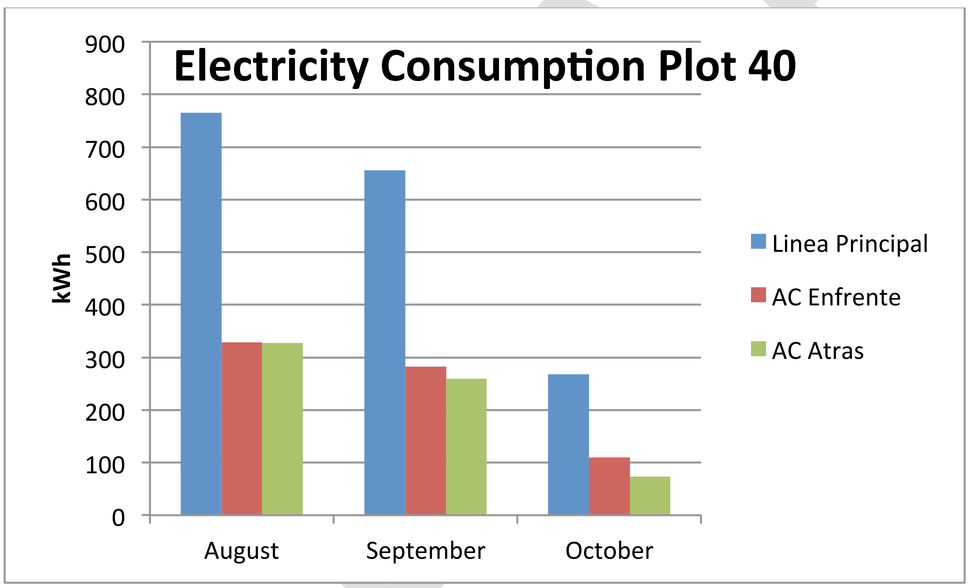


Figure 35: Plot 40 Electricity Consumption

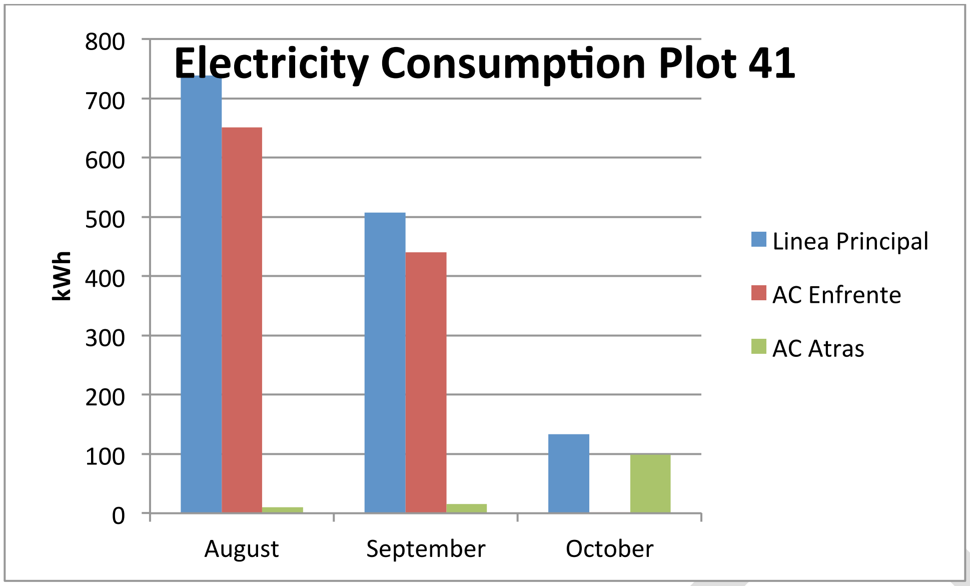


Figure 36: Plot 41 Electricity Consumption

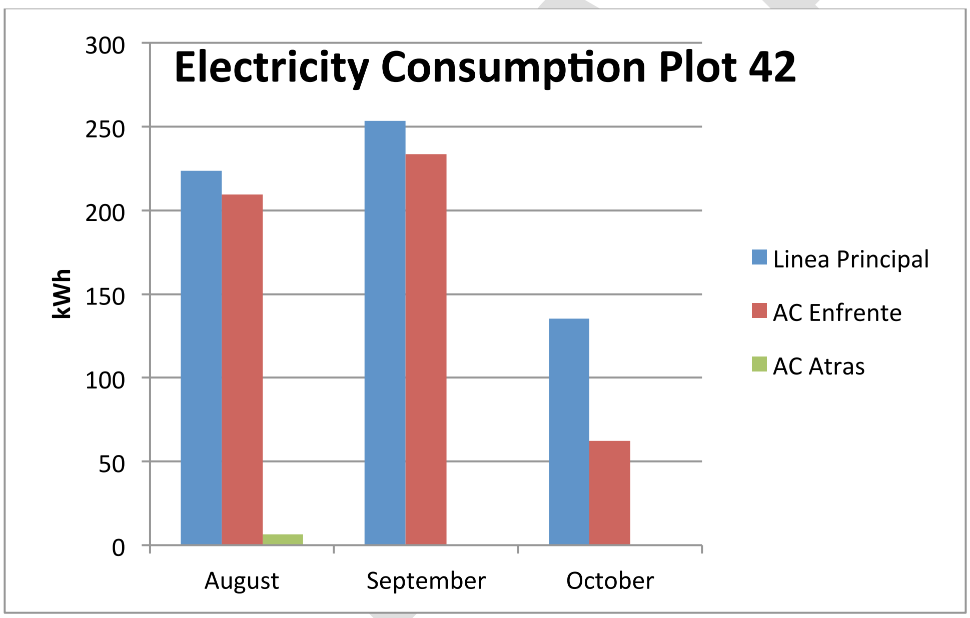


Figure 37: Plot 42 Electricity Consumption

Based on the average energy consumption for the air conditioning in each of the bedroom and the living room, and summing these, the total 'average' energy consumption can be represented by:

	Total (kWh)
August	552.9927
September	408.6635
October	145.1927

Table 4: Average Air Conditioning Energy Consumption

5.5.2 Refrigerators and Televisions

The following data is the energy consumption data for the refrigerators and televisions, collected using the Kill-A-Watt meters. The Kill-A-Watt meters are cumulative so that there is no hourly recordings, only the total for the time that the unit is plugged in. Data was collected on October 22 and again on December 13. The December 13th data is provided in the tables below. The longer period of time allows for a better calculated average energy consumption for base loads.

Please note that the Kill-A-Watt meters in Plot 29 were stolen so the data in the table below was that collected on October 22.

KILL A WATT (REFRIGERATOR)			
PLOT	**CONSUMPTION (KWH)**	**Hours**	**Hourly Consumption**
29	69.45	999	0.070
38	139	2253	0.062
40	262	3503	0.075
41	156	3233	0.048
42	259	2924	0.089

KILL A WATT (TELEVISION)			
PLOT	**CONSUMPTION (KWH)**	**Hours**	**Hourly Consumption**
29	34.31	999	0.034
38	116	3236	0.036
40	86.28	3067	0.028
41	163	3232	0.050
42	54.85	3211	0.017

The energy consumption by the refrigerators is between 0.048 and 0.089 kWh/hour. More work is needed to evaluate why the discrepancy is so large. Factors that must be considered include: set point temperatures of the refrigerators, volume of food in the refrigerators and amount of time the door is open.

The energy consumption by the televisions is between 0.017 and 0.050 kWh/hour. Factors that need to be considered include: type of television, number of hours per day that the TV is on.

In one household, the TV consumes twice as much electricity as the refrigerator. However, televisions consume, on average, 54% as much electricity as the refrigerators. When considering that the refrigerators run 24 hours a day and 7 days a week, the relative amount of energy consumed by the TVs is relatively high.

The average daily energy consumption due to televisions and refrigerators is 2.44 kWh/day. This number will be used in the base load estimates in HOT2000.

5.5.3 HOT2000 Energy Analysis

Using a model of a typical house, energy analyses were performed using the HOT2000 energy analysis software.

1. baseloads were determined using the refrigerator and television monitored energy (see Section 5.5),
2. a set-point temperature was based on the average temperature measured in the homes,
3. the air conditioner was modeled with the efficiency of those installed (COP 3) and then changed to a less efficient model (COP 2), and
4. houses were modeled with the existing insulation and then without any insulation.

The energy consumption due to the air conditioning was estimated to be (kWh):

	May	June	July	August	September
energy efficient A/C and insulation	329.9	491.1	561.8	599.3	481.8
energy efficient A/C and NO insulation	342.7	547.3	629.4	678.0	534.7
inefficient A/C and insulation	463.4	724.3	835.7	895.8	709.4
inefficient A/C and NO insulation	481.3	812.2	941.7	1019.8	791.9

Table 5: HOT2000 Predicted Energy Consumption of Air Conditioners

Using the monitored energy consumption for air conditioning as presented in Section 5.5.1 and comparing it to the predicted energy consumption, it can be see that the HOT2000 program predicts the energy consumption with a comfortable degree of accuracy. Therefore, it can be assumed that the predicted performance with less efficient air conditioners, and without insulation, as presented in the table above, can be assumed to be reliable. Therefore, the percent increases in energy consumption due to the less efficient air conditioner and the lack of insulation are presented in the table below:

	May (%)	June (%)	July (%)	August (%)	Sept (%)	Average Increase (%) for May to September	Average Increase (%) for June to September
energy efficient A/C and insulation							
energy efficient A/C and NO insulation	3.9	11.4	12.0	13.1	11.0	10.3	11.9
inefficient A/C and insulation	40.5	47.5	48.8	49.5	47.2	46.7	48.2
inefficient A/C and NO insulation	45.9	65.4	67.6	70.2	64.4	62.7	66.9

Table 6: Predicted Increase in Energy Consumption from As-Built using less Efficient A/C and Removing insulation