SUMMARY
First Monitoring Report for Mexicali

Data Collection in Mexicali, Baja California

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Contents

1 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.

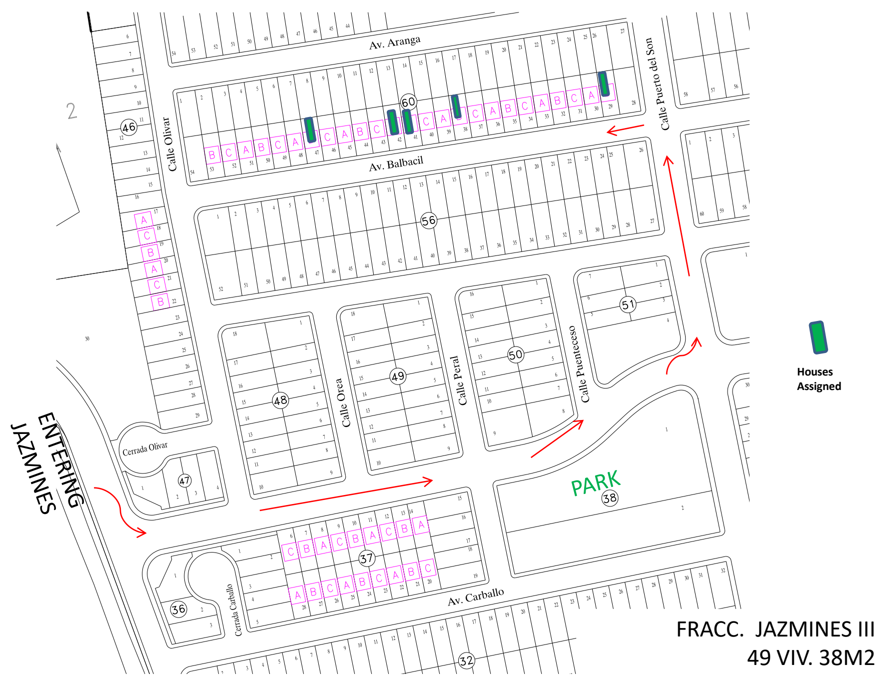


Figure 1 – Site Layout

2 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.

3 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

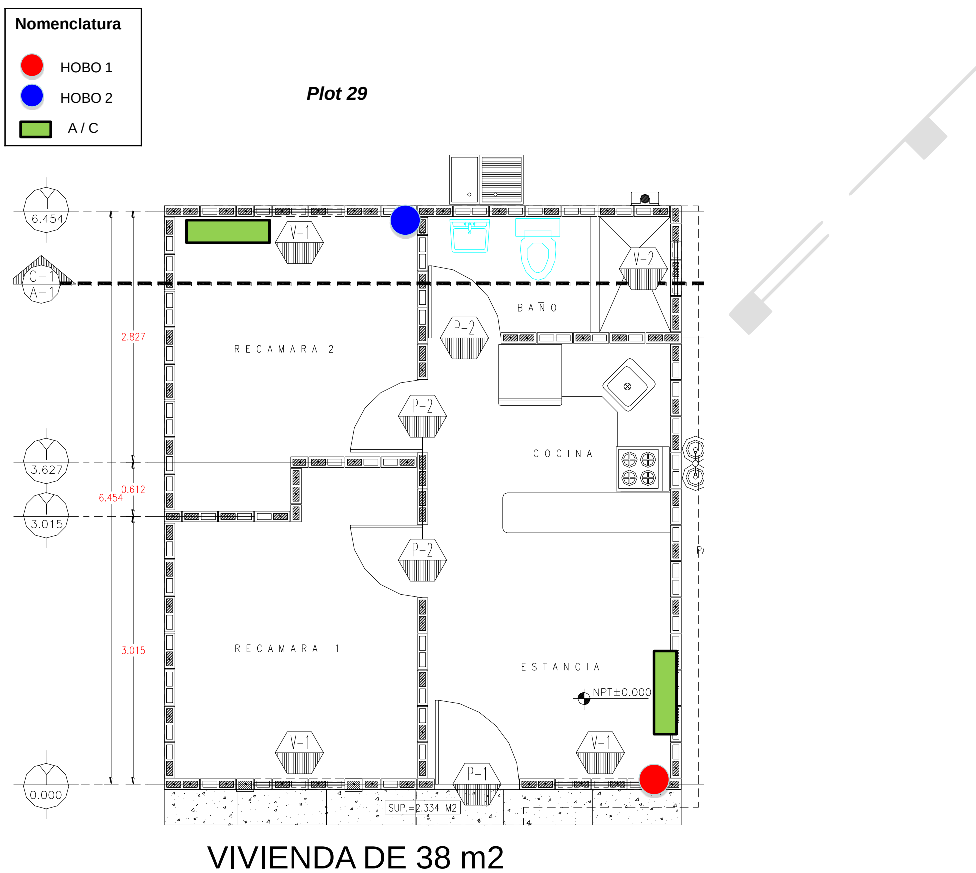
The weather station consists of a pyranometer to measure solar radiation, a temperature sensor and a relative humidity sensor along with a data logger (HOBO) to record the information on-site (HOBO). This equipment, along with the mounting mast and brackets, and the software, are from a company called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

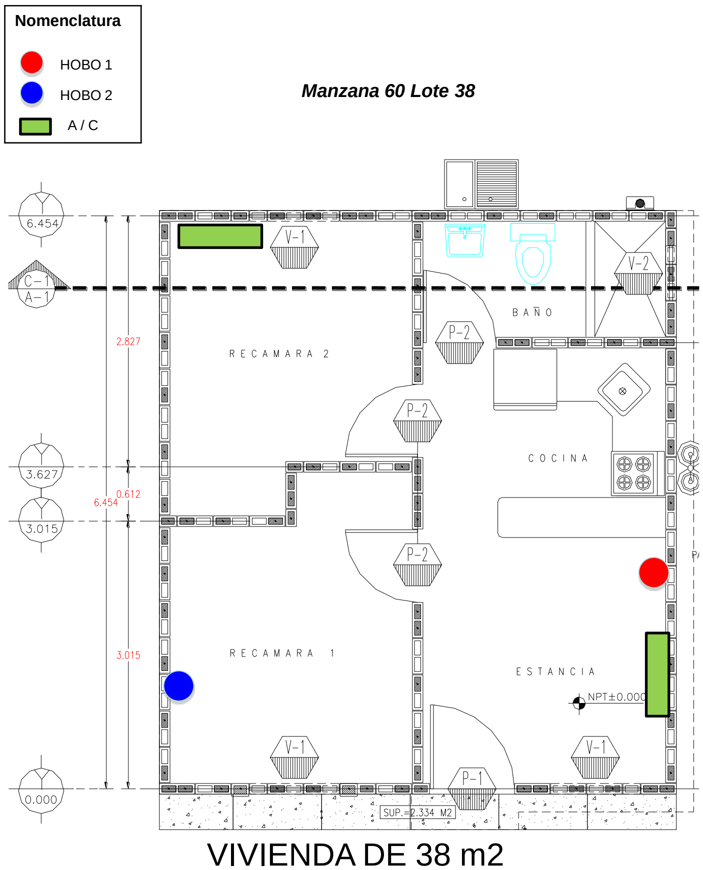
<u>Plot 29</u>



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

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

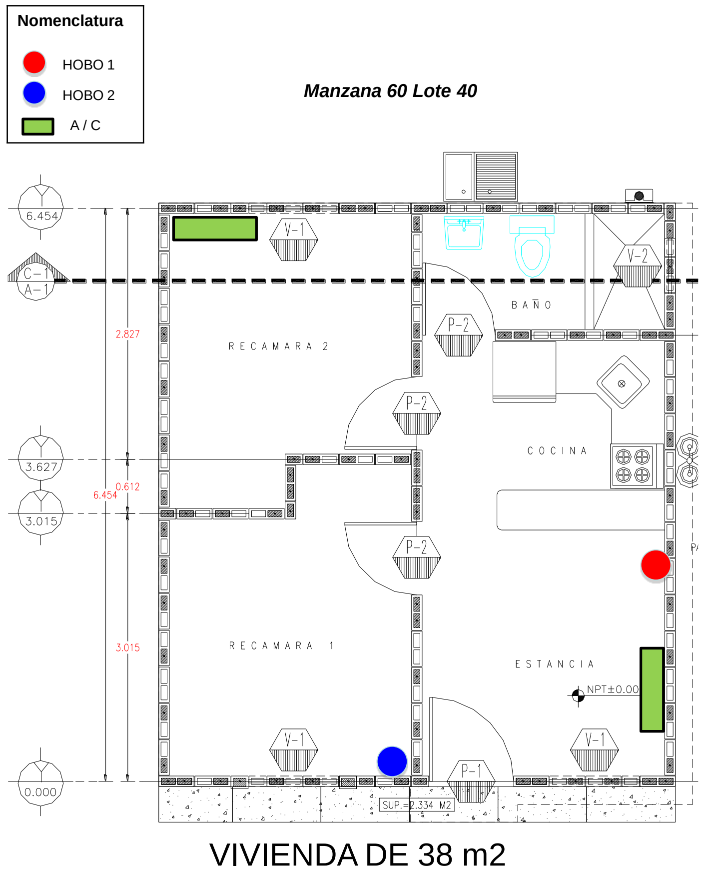
Plot 38



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

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

Plot 40



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

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

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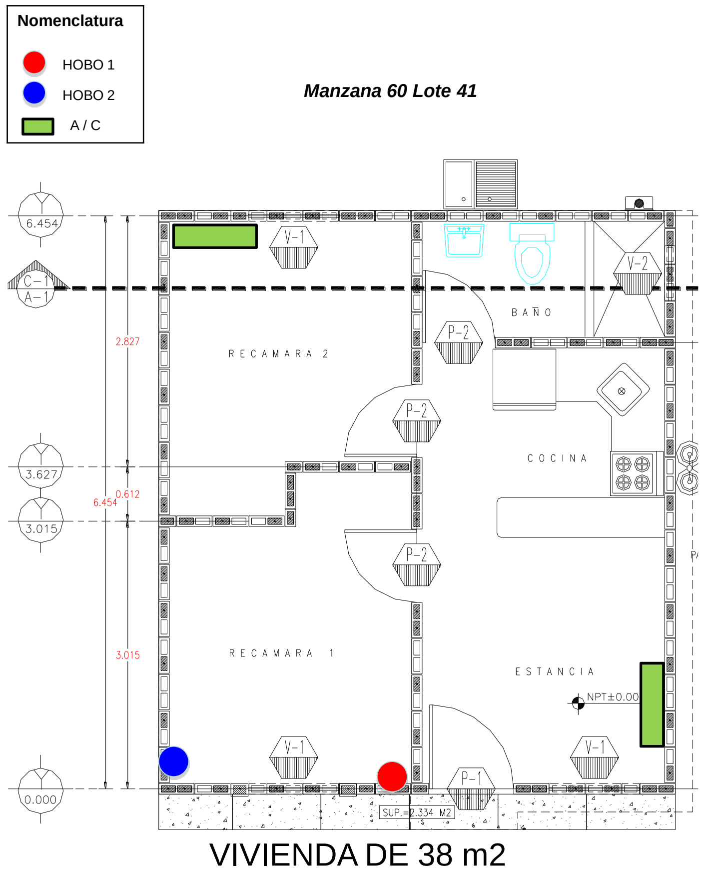
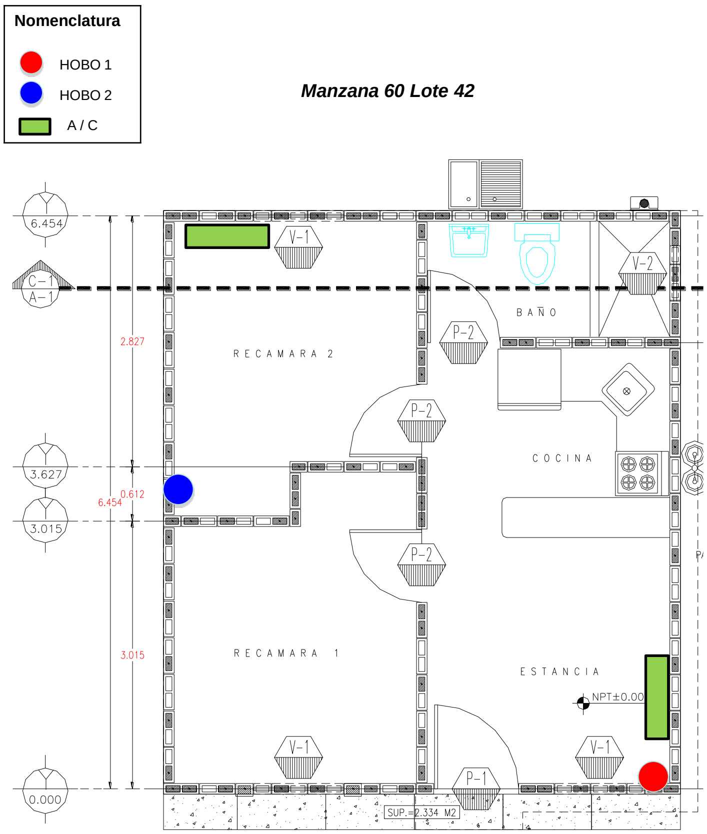
Plot 41



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

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

Plot 42



VIVIENDA DE 38 m2

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.

4 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:

- carbon dioxide levels in the homes
- Potential for condensation on the walls
- Effectiveness of insulation
- Electrical energy consumption

4.1 Carbon Dioxide

Carbon dioxide 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. This is evident with the monitoring of CO_2 in these houses, as shown in the graphs below.

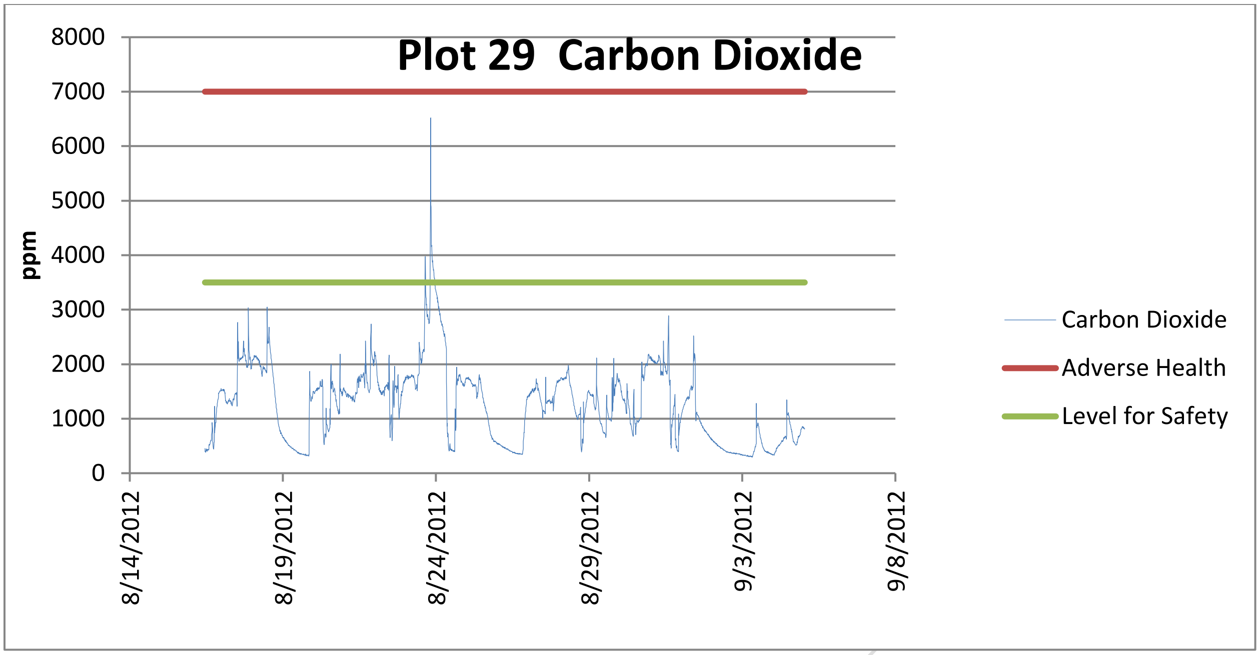


Figure 2: CO_2 in Plot 29

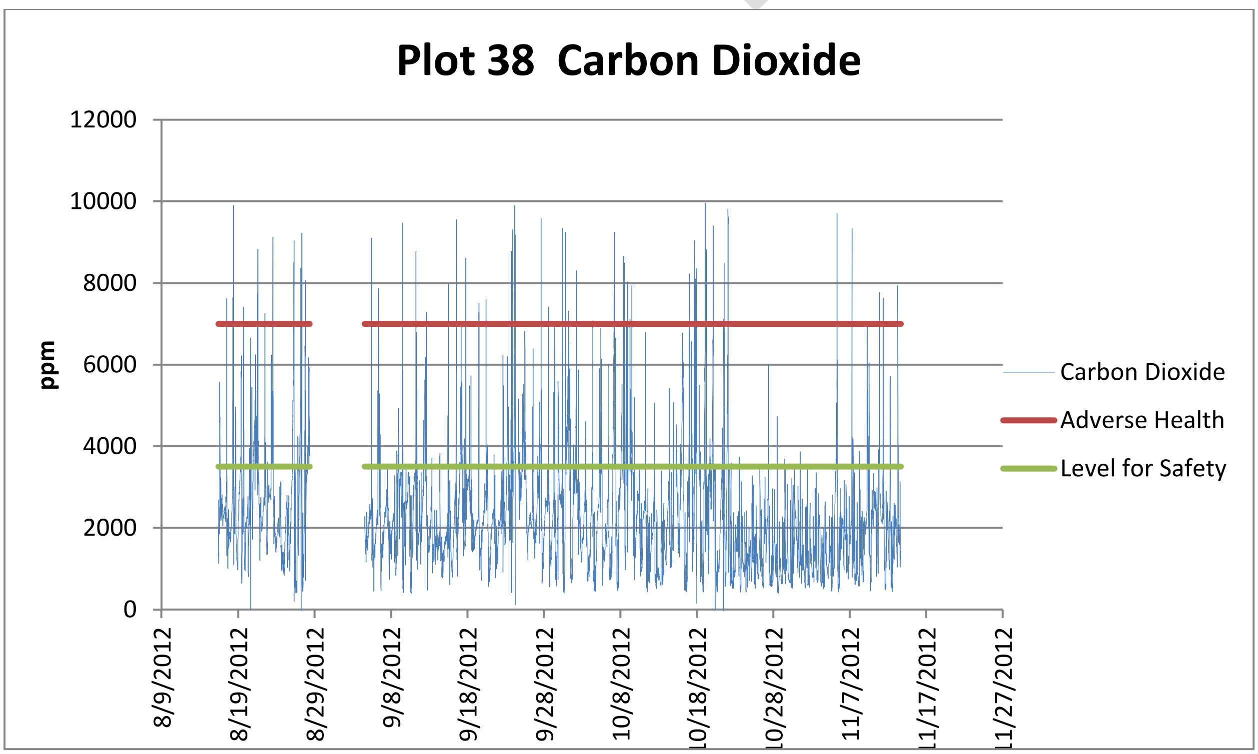


Figure 3: CO_2 in Plot 38

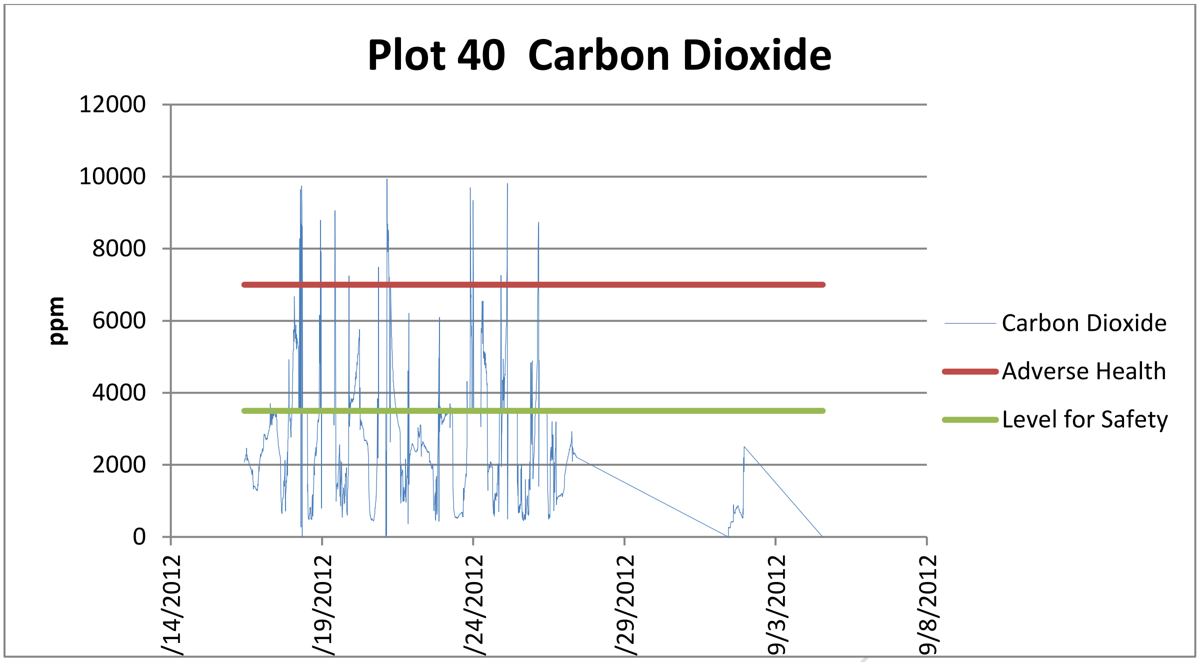


Figure 4: CO2 in Plot 41

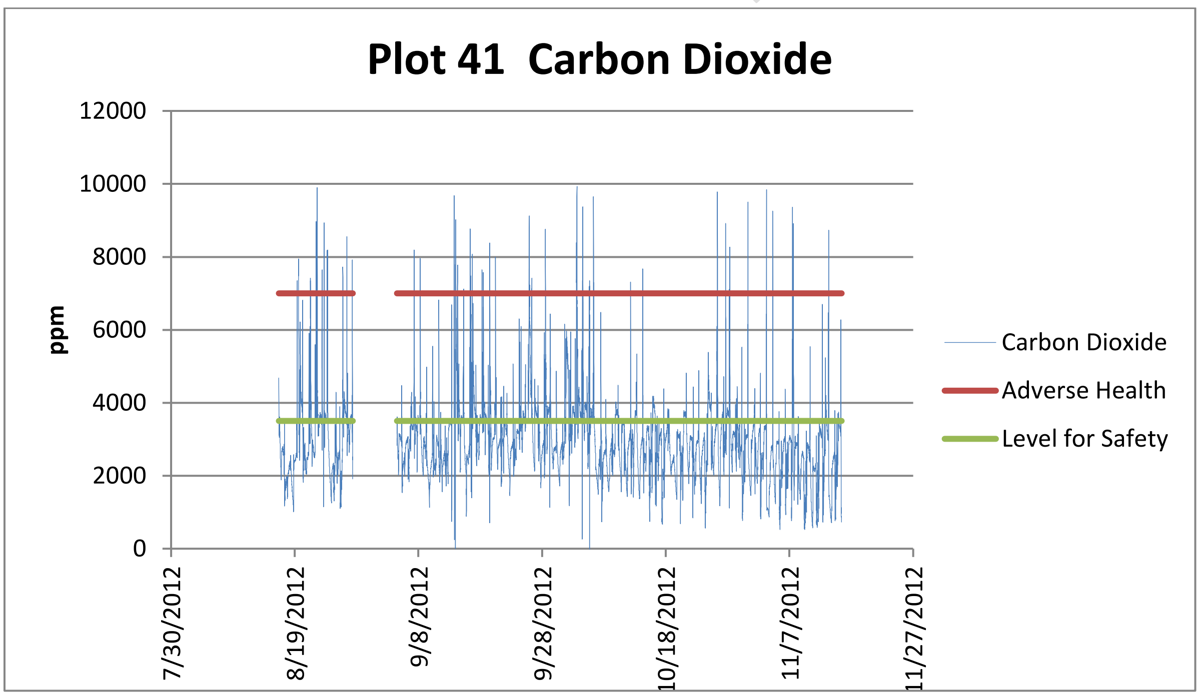


Figure 5: CO2 in Plot 41

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."

As can be seen in Figures 2 to 5, 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.**

4.2 Dew Point Temperature

The dew point temperature is the temperature at which condensation can form. Based on the indoor tempearutre 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 Figures 6 to 18. Problems with the data loggers in plots 29 and 40 prohibited the evaluation of dew point temperatures in October/November as well. These problems are being resolved.

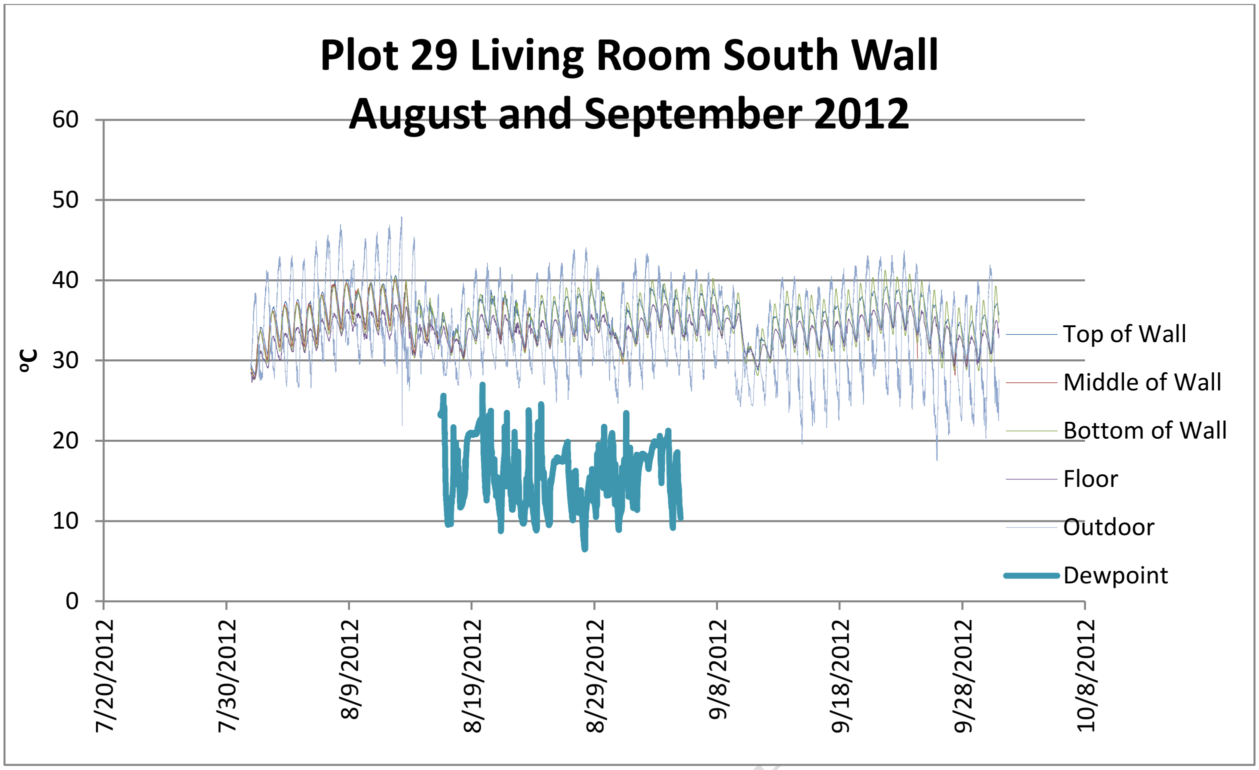


Figure 6: Plot 29 Living Room South Wall Temperatures

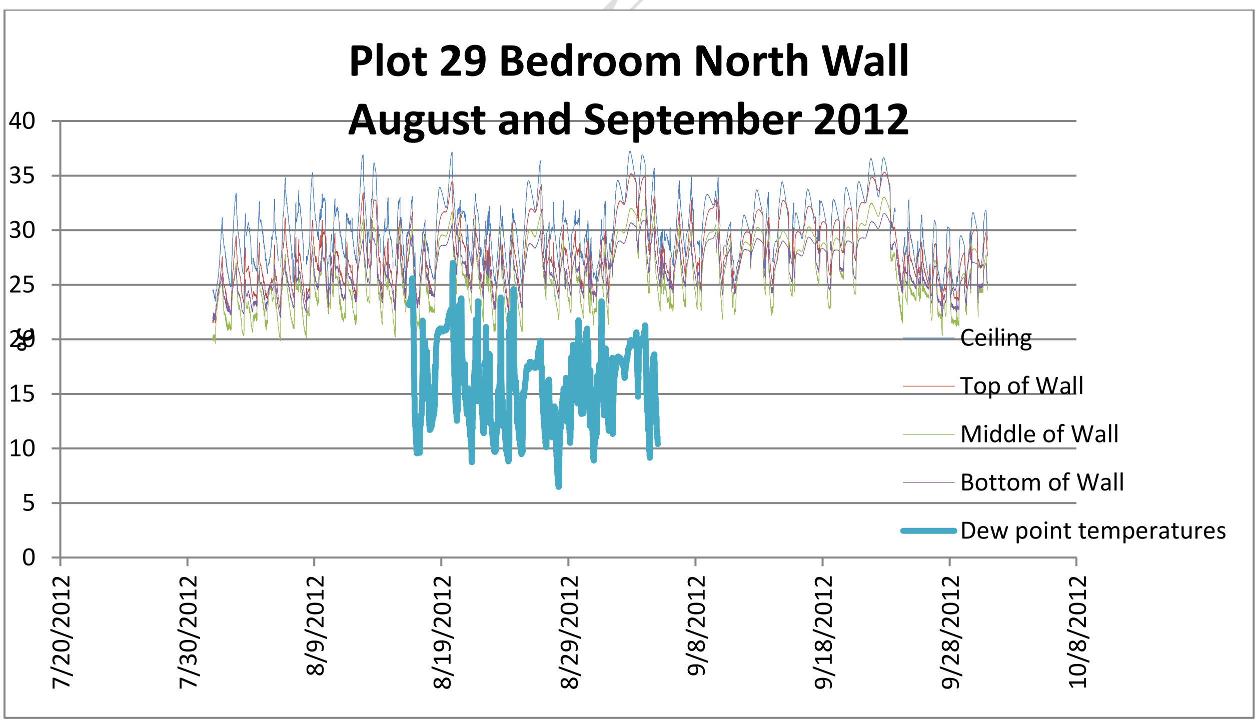


Figure 7: Plot 29 Bedroom North Wall Temperatures

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

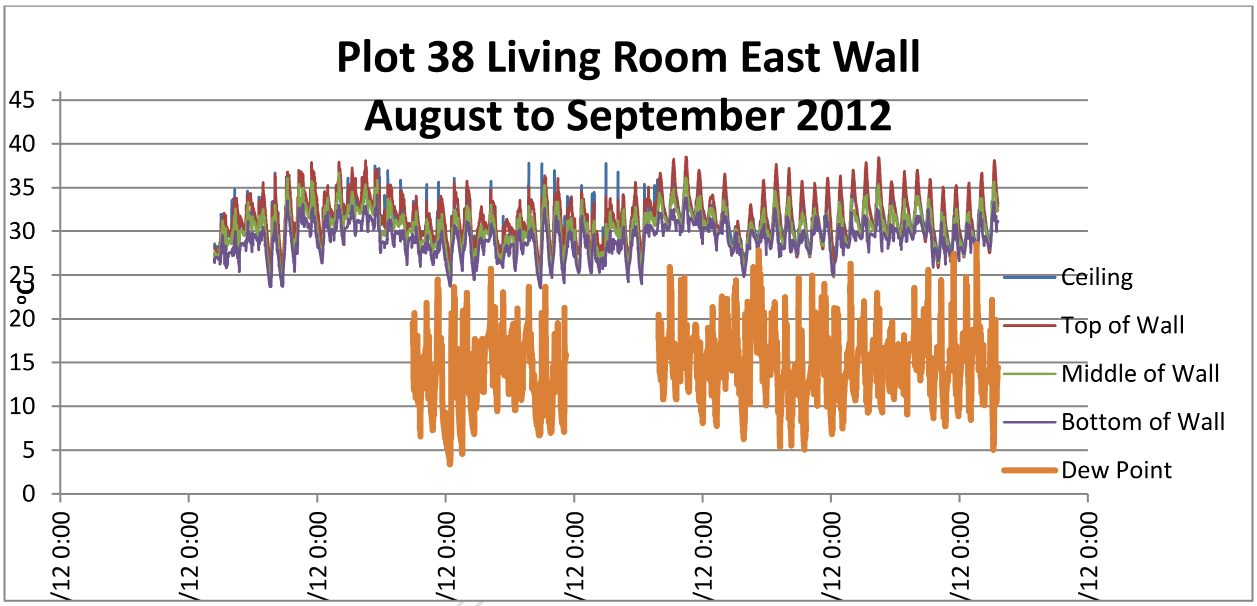


Figure 8: Plot 38 Living Room East Wall Temperatures

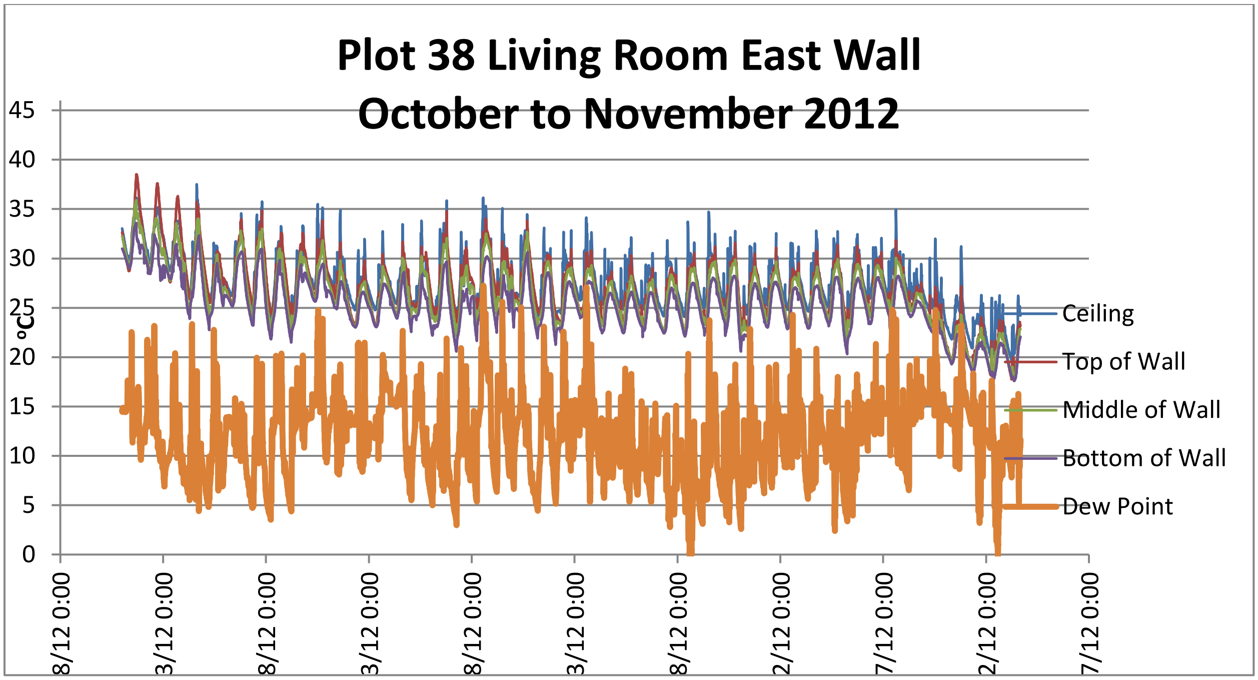


Figure 9: Plot 38 Living Room East Wall Temperatures

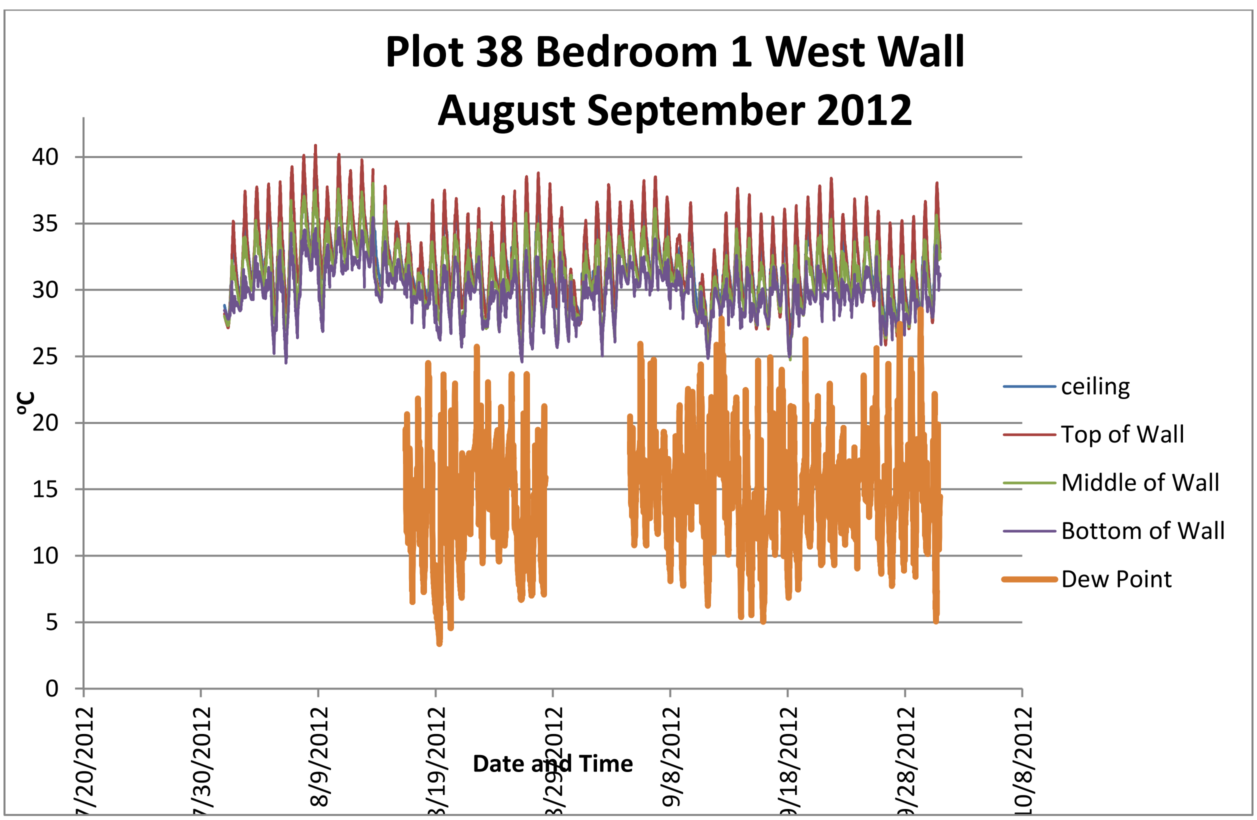


Figure 10: Plot 38 Bedroom West Wall Temperatures

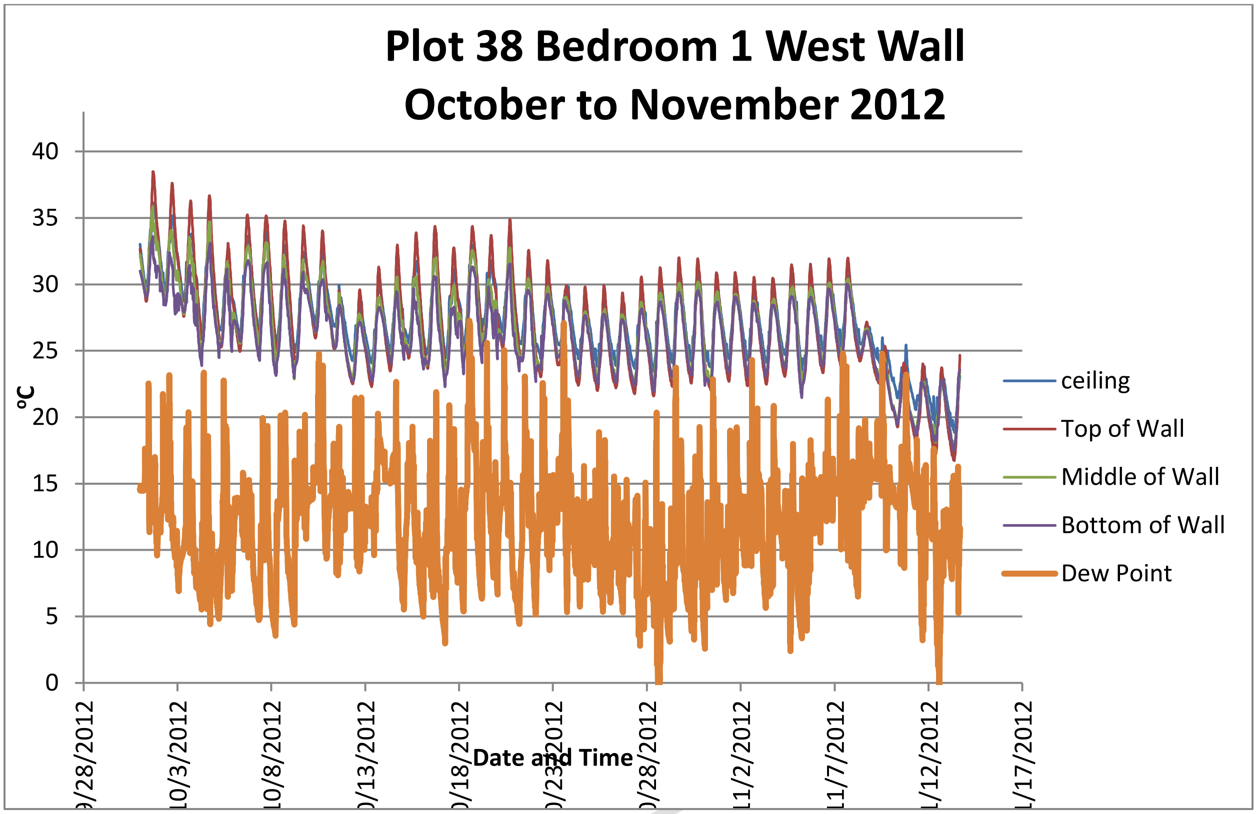


Figure 11: Plot 38 Bedroom West Wall Temperatures

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.

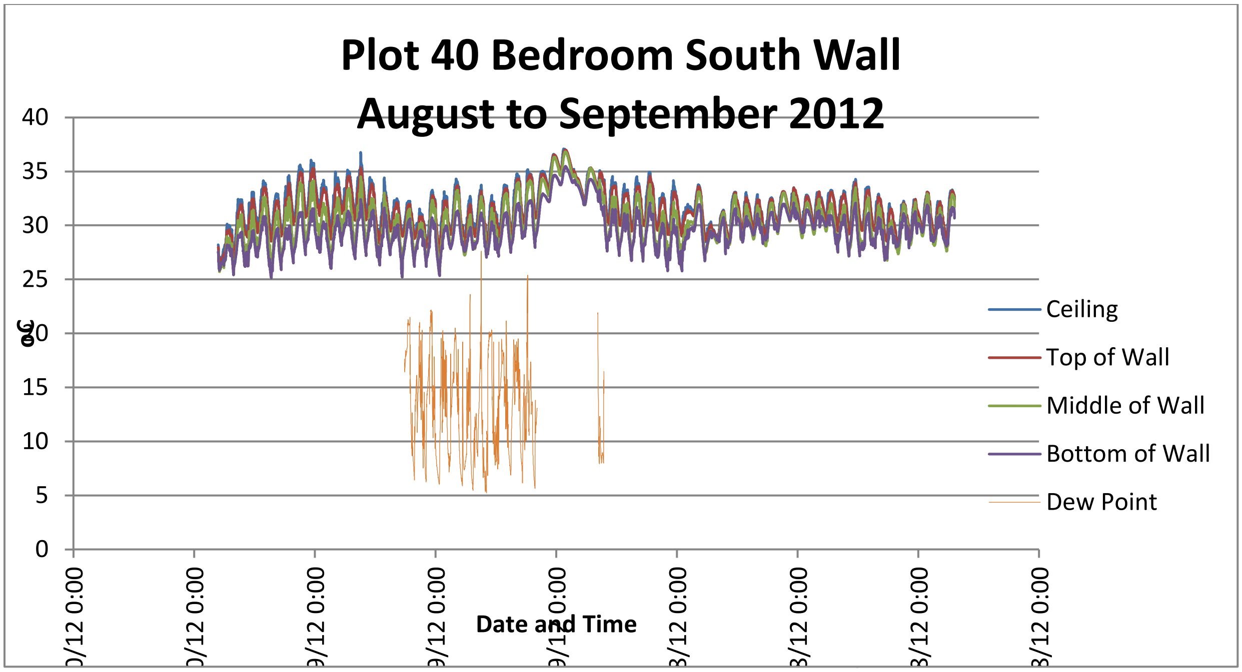


Figure 12: Plot 40 Bedroom South Wall Temperatures

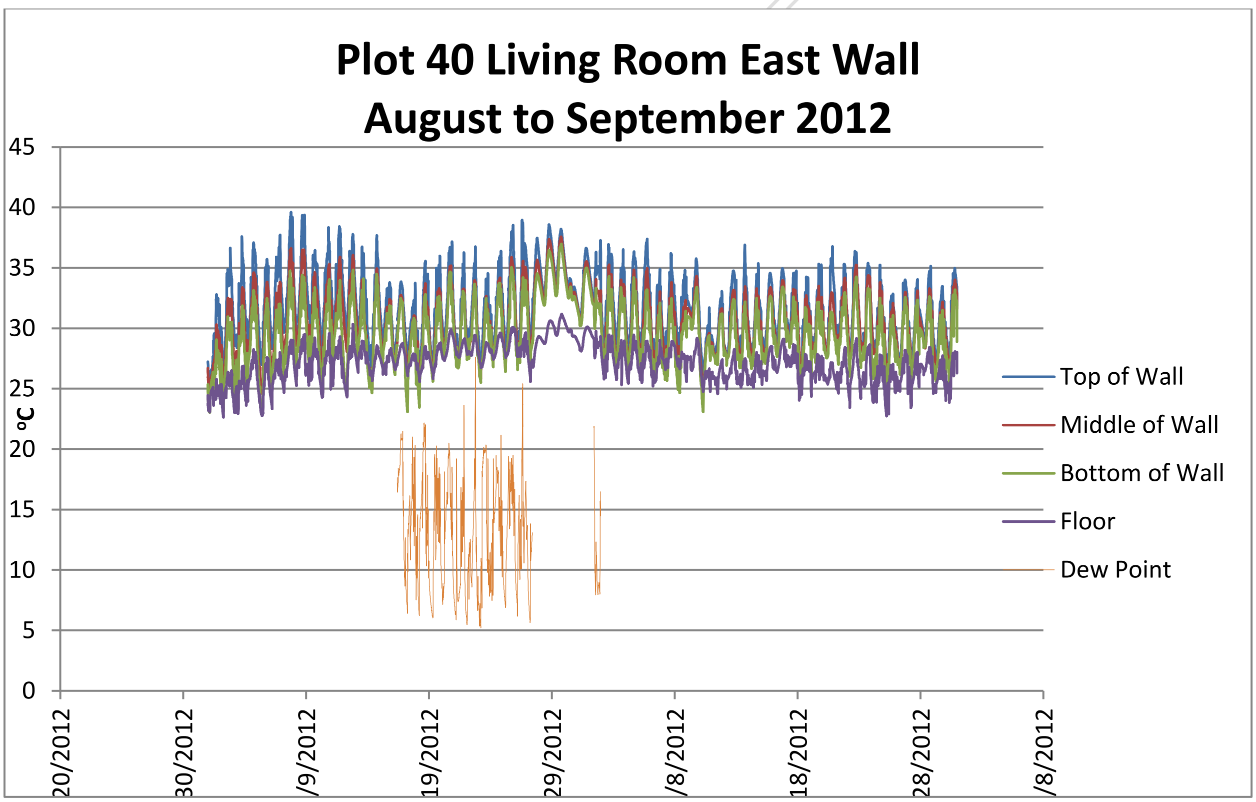


Figure 13: Plot 40 Living Room East Wall Temperatures

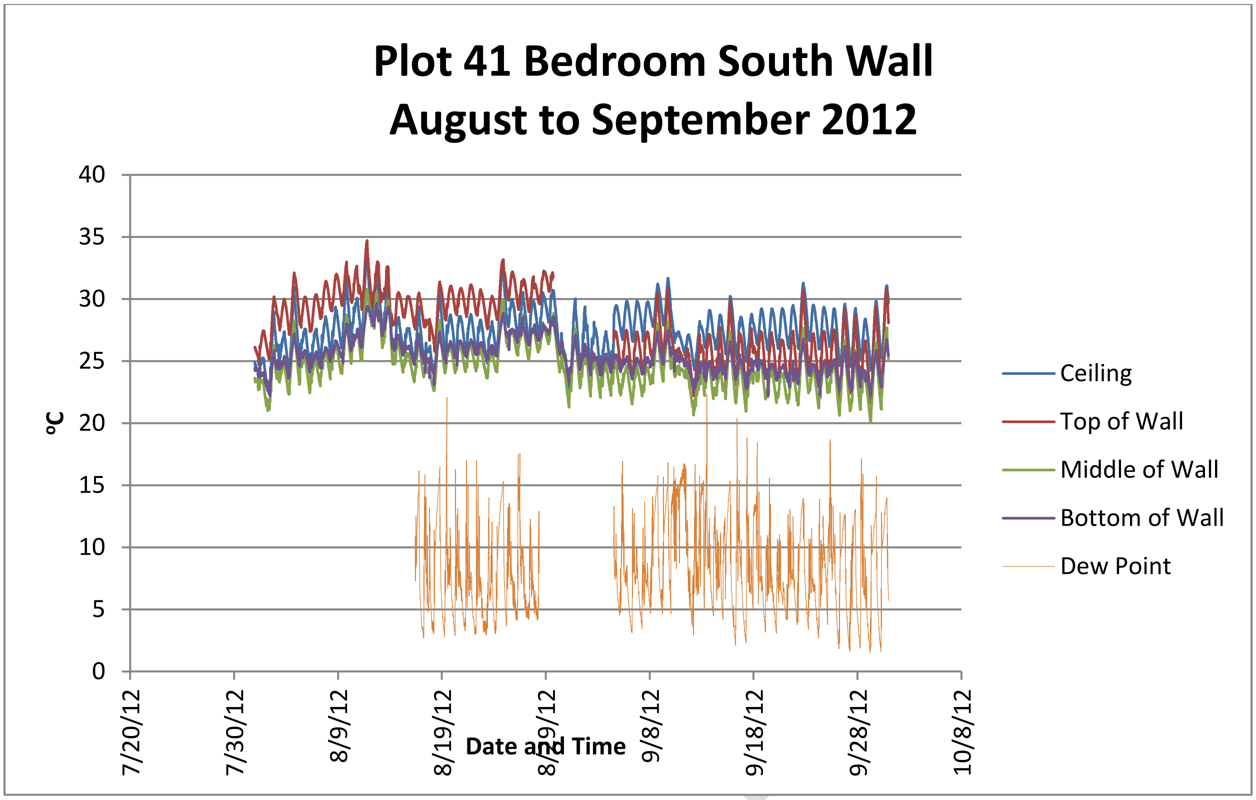


Figure 14: Plot 41 Bedroom South Wall Temperatures

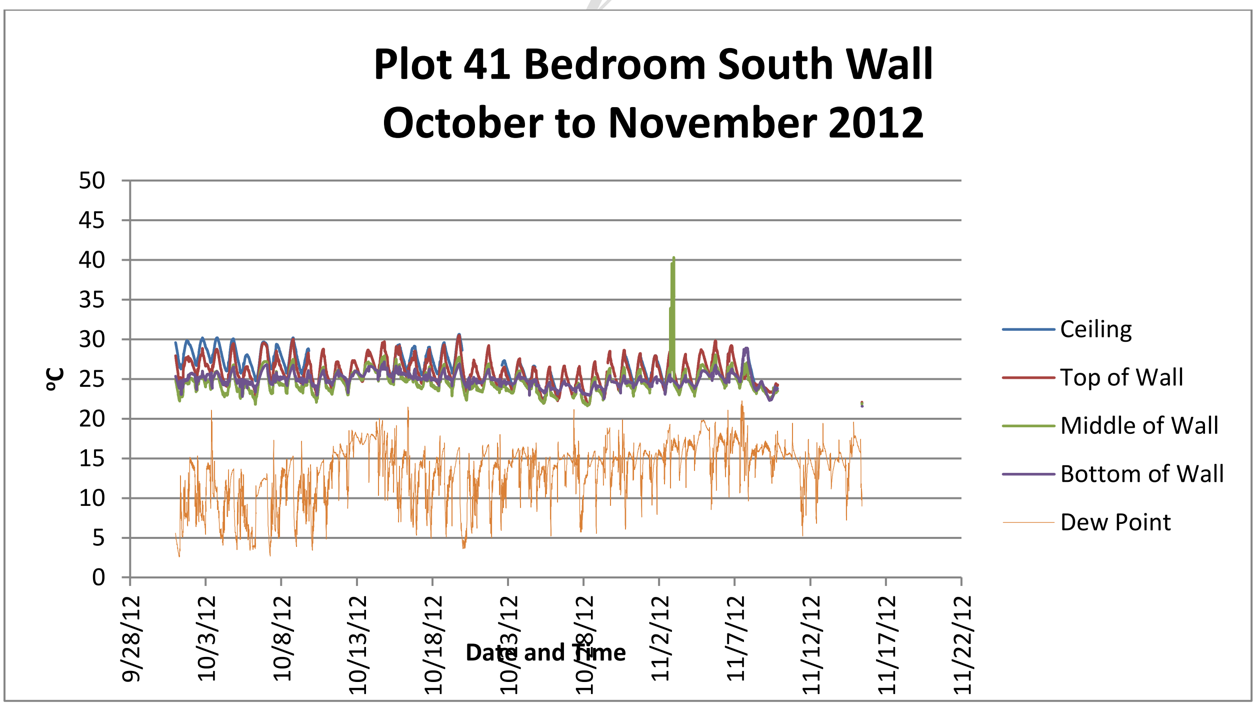


Figure 15: Plot 41 Bedroom South Wall Temperatures

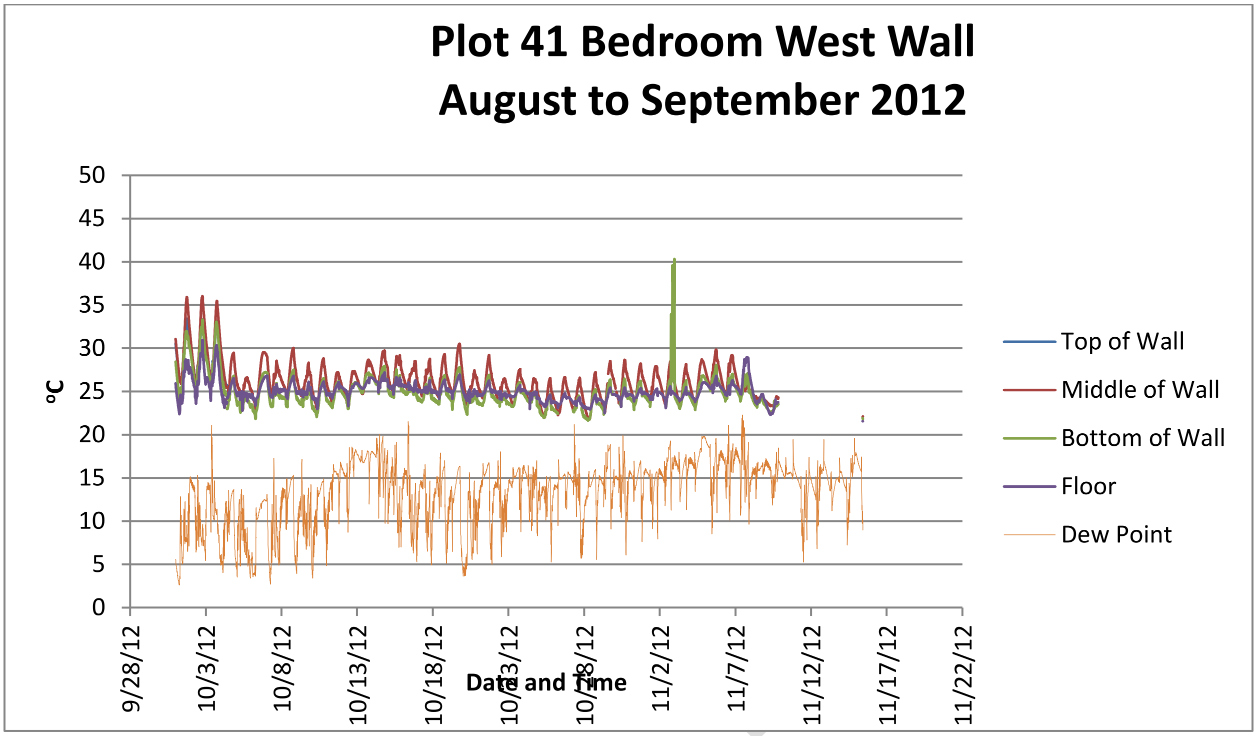


Figure 16: Plot 41 Bedroom West Wall Temperatures

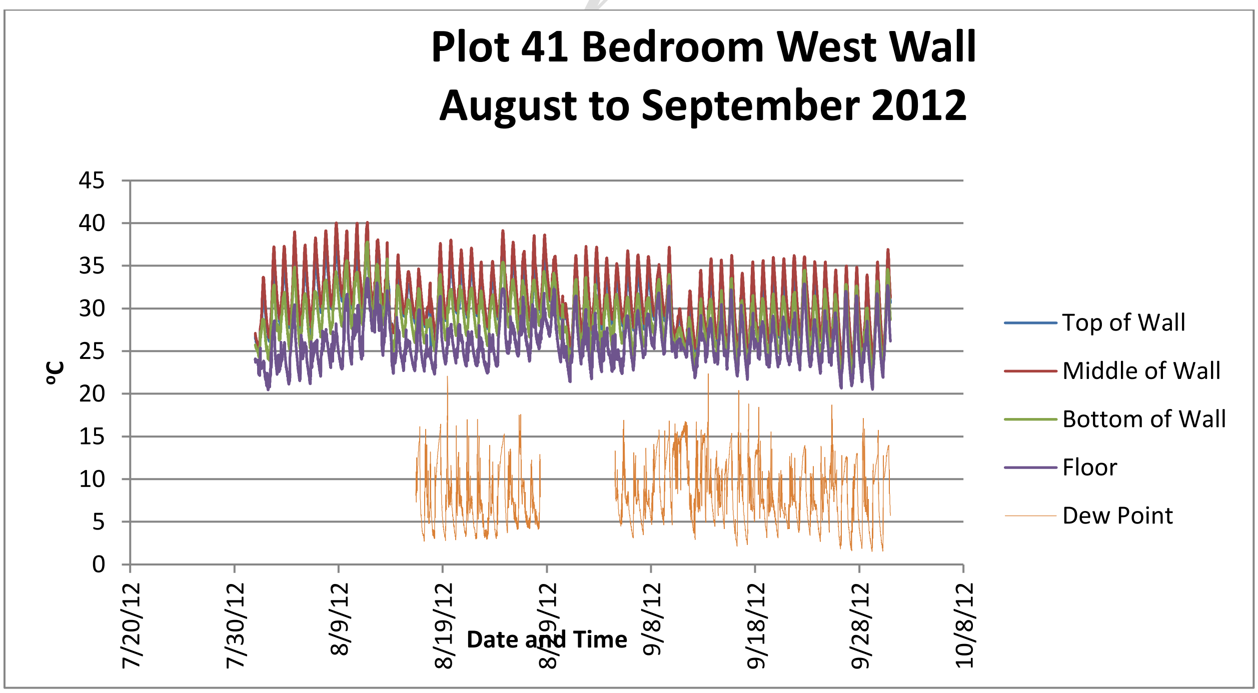


Figure 17: Plot 41 Bedroom West Wall Temperatures

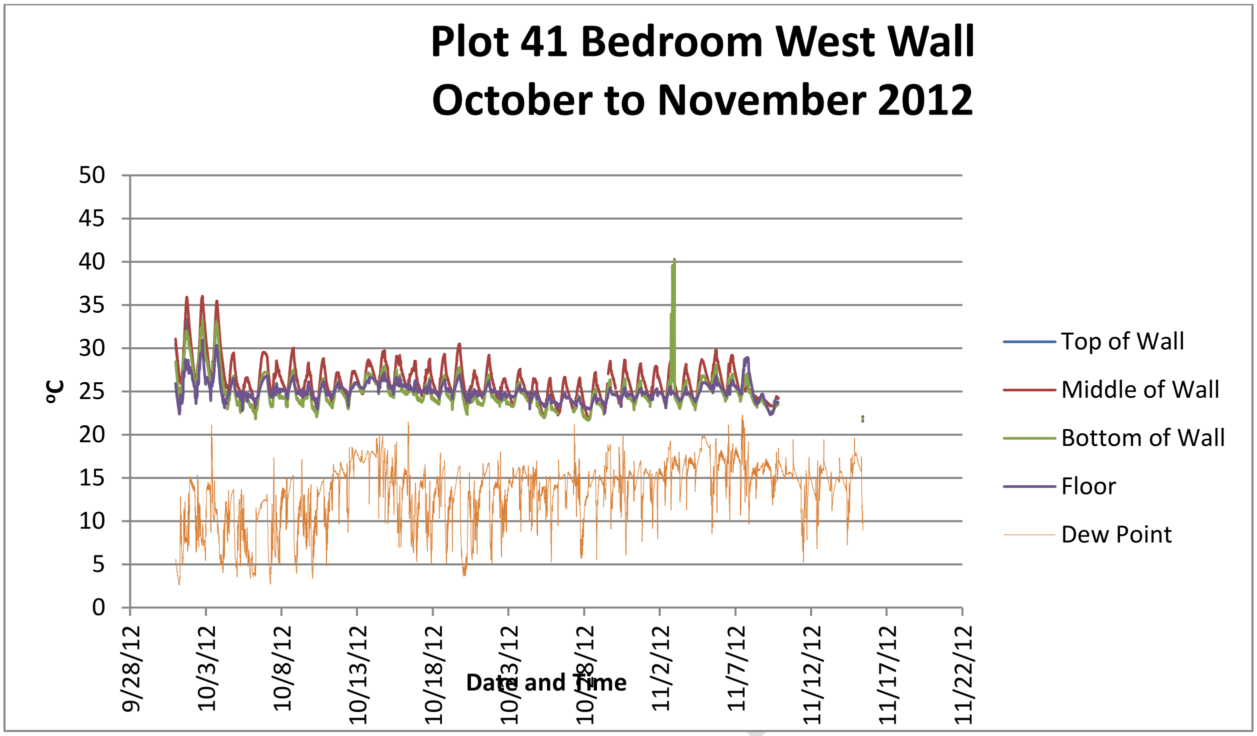


Figure 18: Plot 41 Bedroom West Wall Temperatures

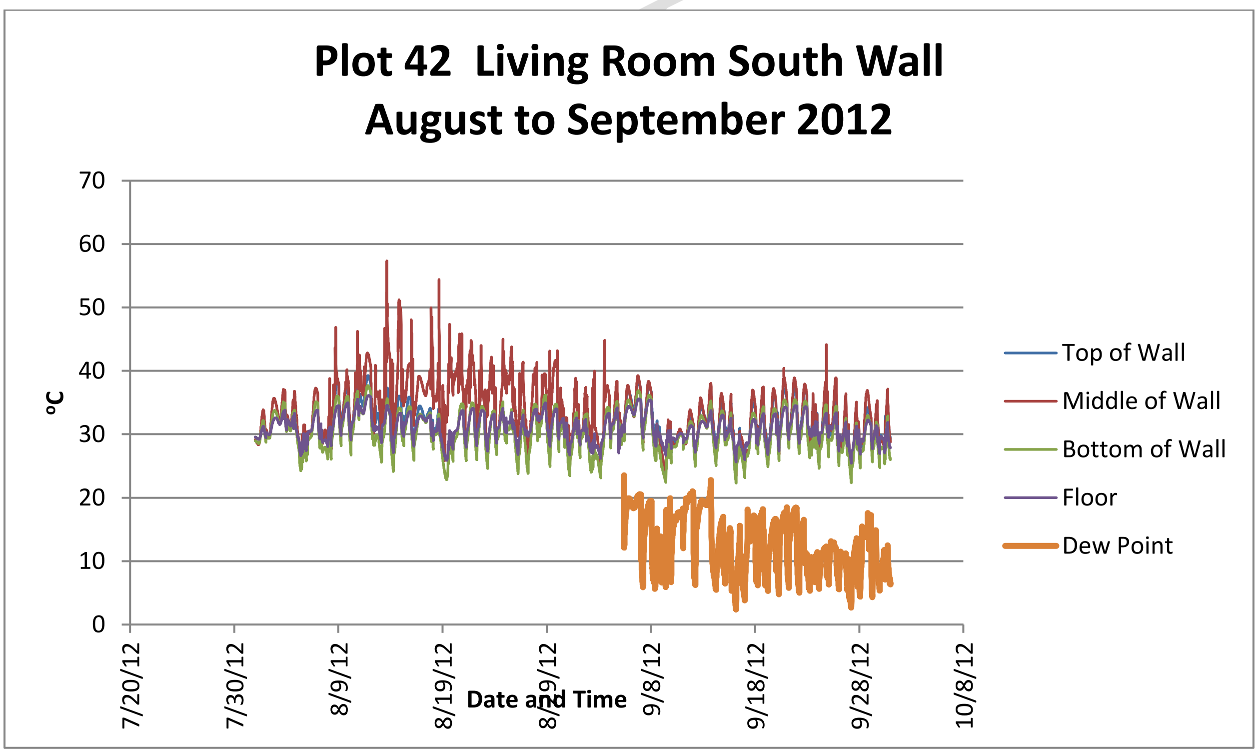


Figure 19: Plot 42 Living Room South Wall Temperatures

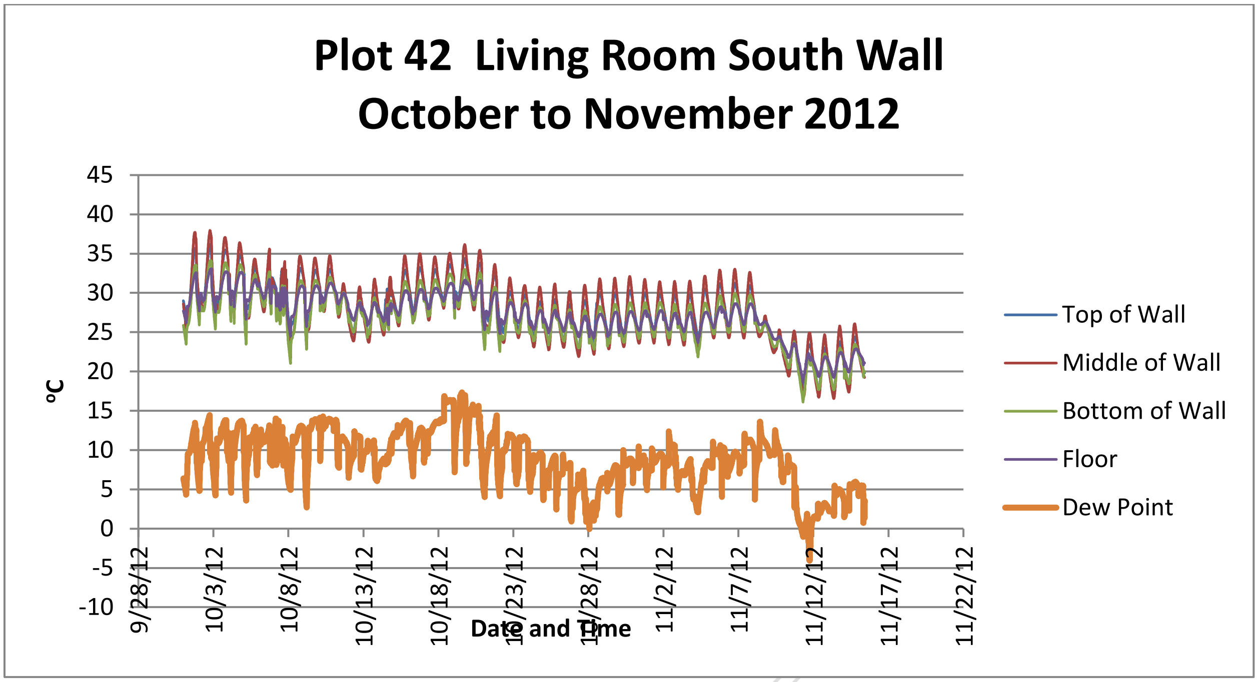


Figure 20: Plot 42 Living Room South Wall Temperatures

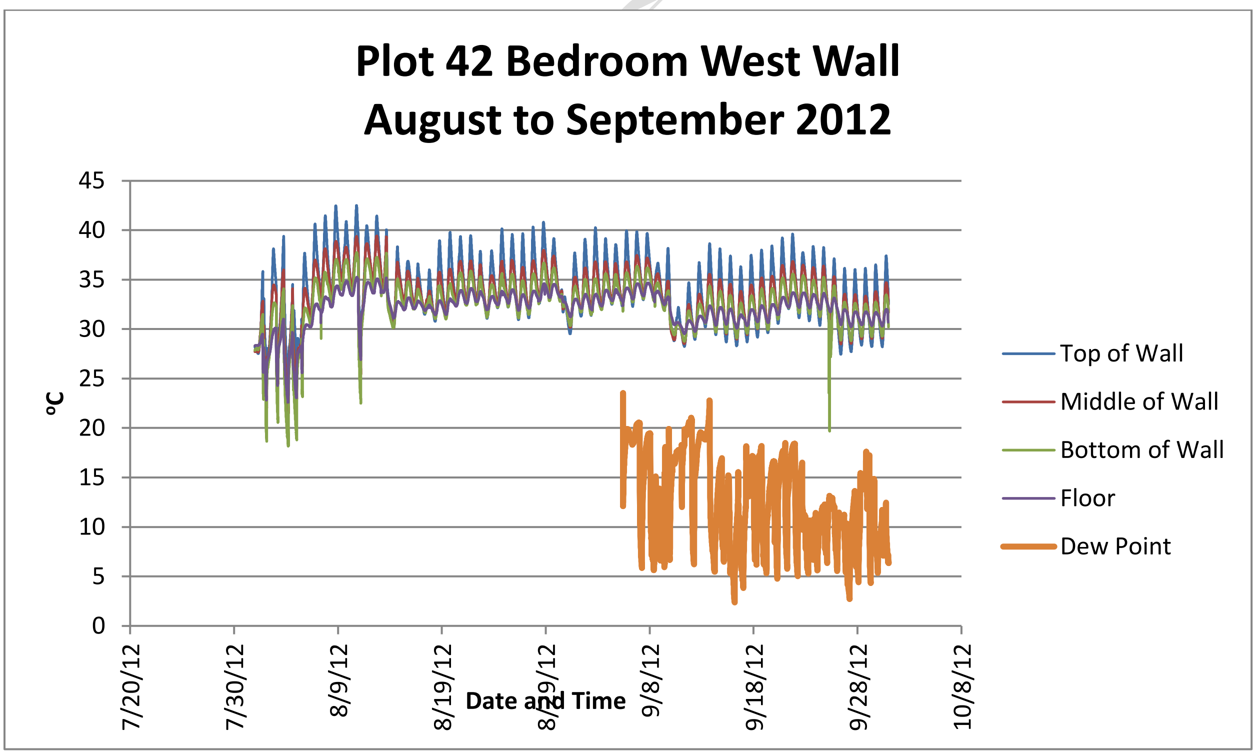


Figure 21: Plot 42 Bedroom West Wall Temperatures

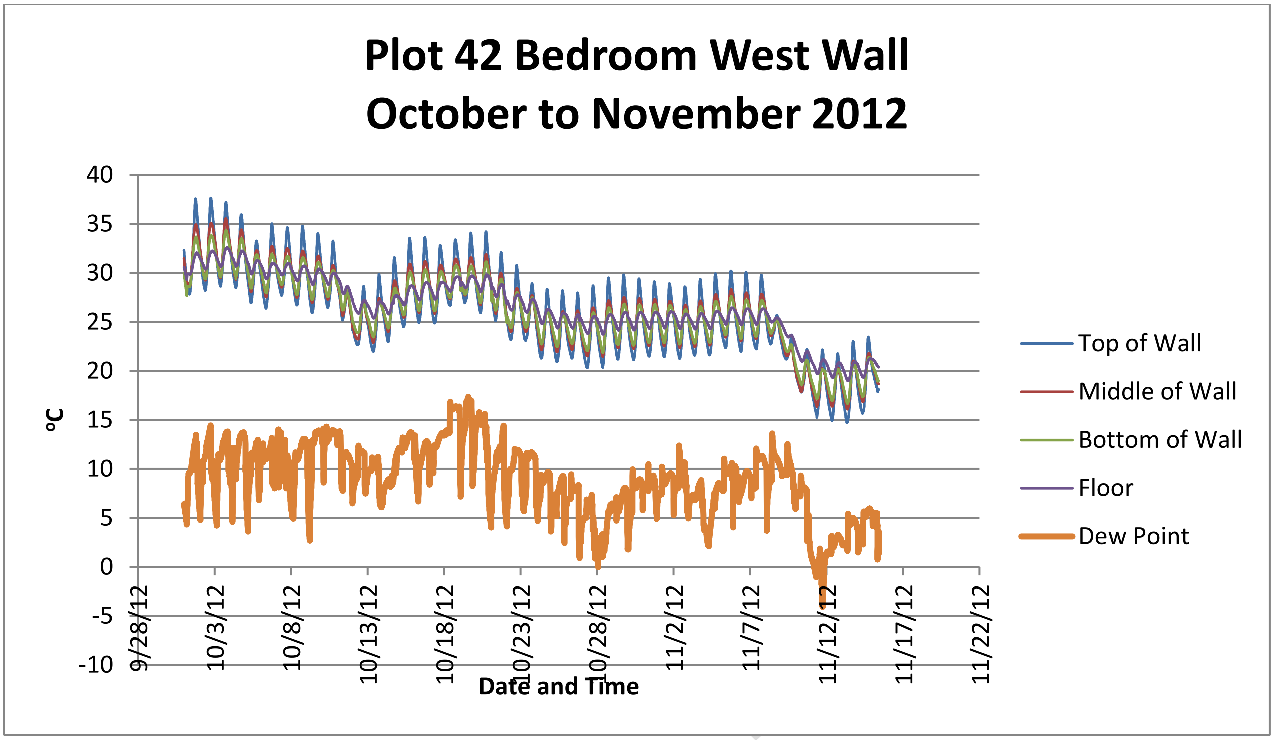


Figure 22: Plot 42 Bedroom West Wall Temperatures

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.). **More work needs to be done to correlate the energy consumption from air conditioners, occupant behavior, room conditions and surface temperatures as well as orientation of the walls.**

4.3 Electrical Energy Consumption

4.3.1 Air conditioning

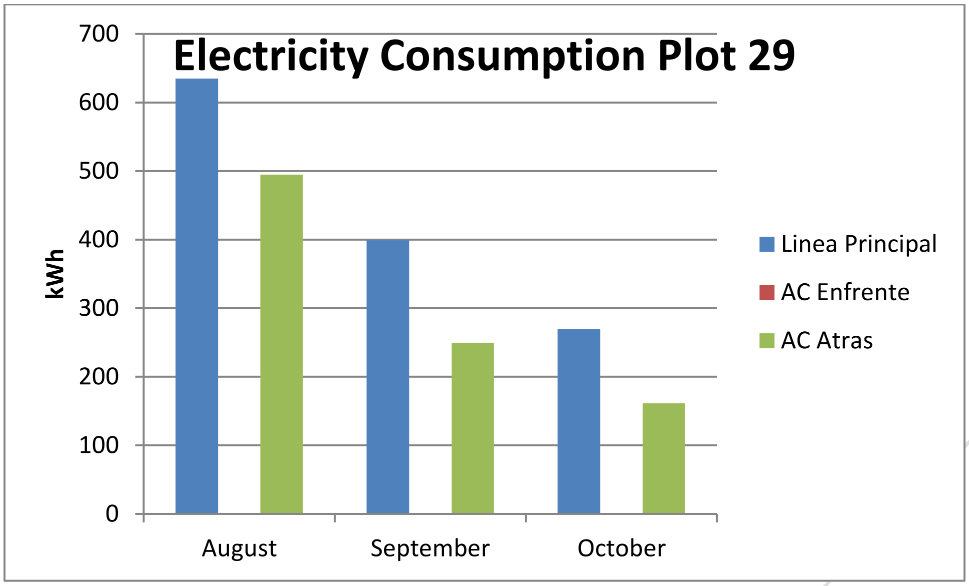


Figure 23: Plot 29 Electricity Consumption

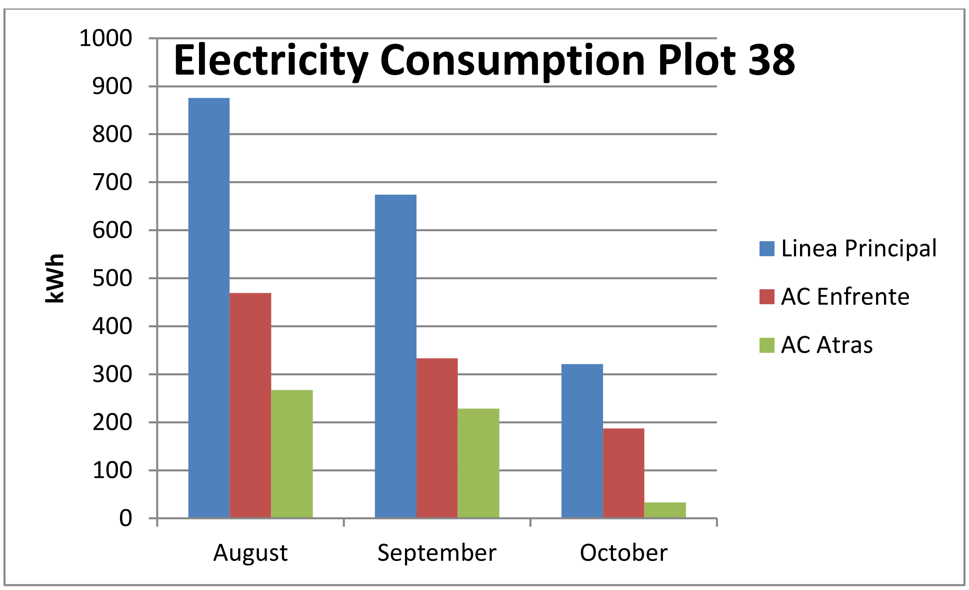


Figure 24: Plot 38 Electricity Consumption

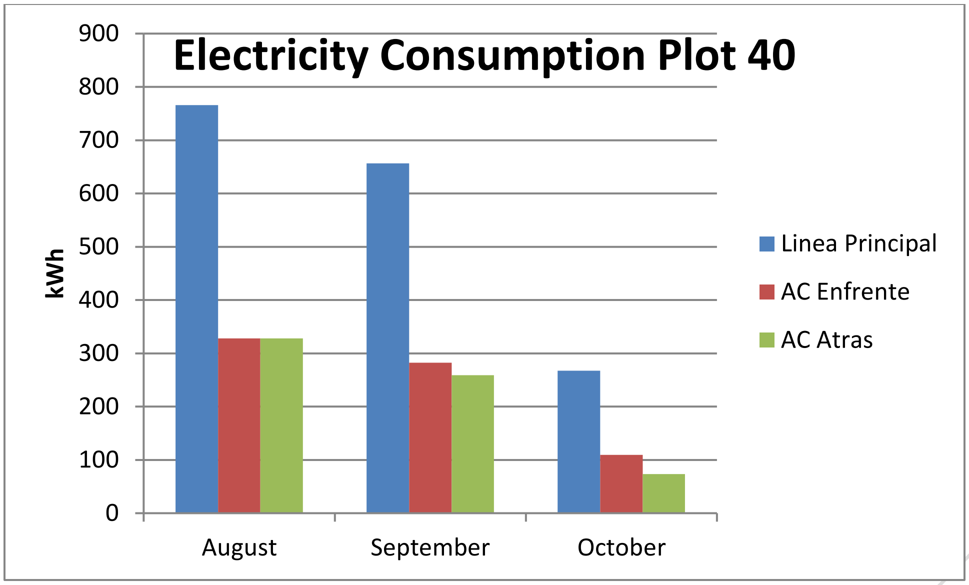


Figure 25: Plot 40 Electricity Consumption

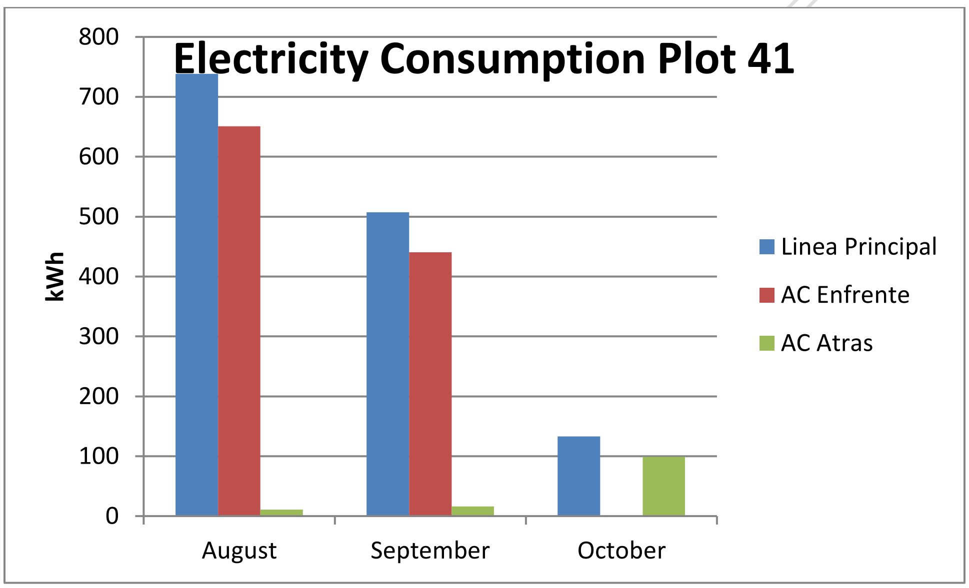


Figure 26: Plot 41 Electricity Consumption

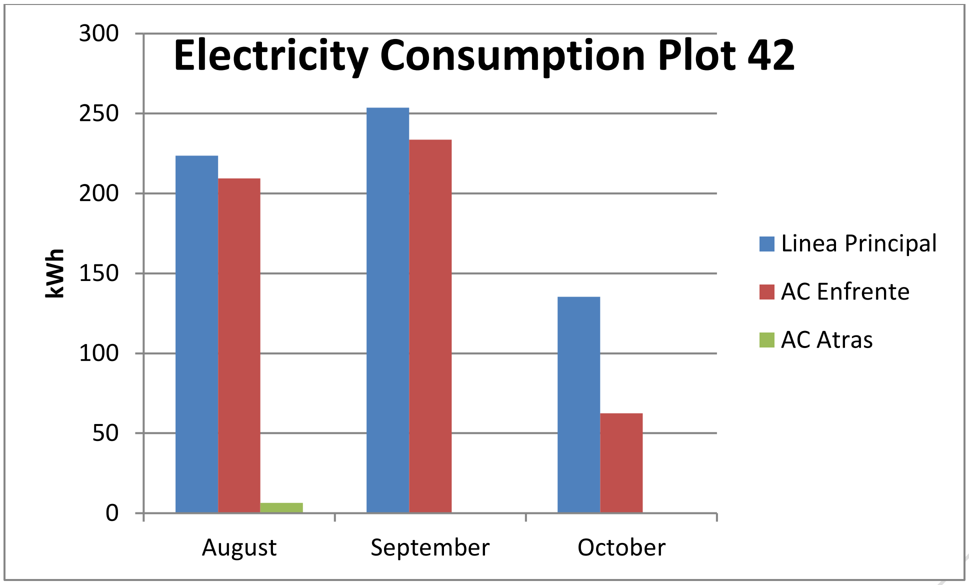


Figure 27: Plot 42 Electricity Consumption

4.3.2 HOT2000 Energy Analysis

Using a model of a typical house, an energy analysis was performed using the HOT2000 energy analysis software. Energy consumption appears as follows:

	Month			Savings due to energy-efficient A/C
	August	September	October	
HOT2000 with energy efficient A/C (installed)	1056.8 kWh	921.8	621.7	31 to 34%
HOT2000 with inefficient A/C	1598.4	1384.8	900.1	
Monitored (low)	215.9	233.7	62.4	
Monitored (high)	736.3	561.6	220	

The energy consumption that is predicted (HOT2000) depends greatly on occupant behavior. More work is needed to correlate energy consumption with number of occupants as well as set-point temperatures. Obviously, the actual energy consumption is far lower than that predicted. The predicted is based on a set-point temperature of 25°C.

It is obvious that, according to the simulations, the energy efficient air conditioners (COP of 3.2 versus COP of 2) can save 31 to 34% under standard conditions. These need to be confirmed according to occupant behavior.

The effectiveness of the insulation in improving the thermal comfort of the houses and reducing energy consumption needs to be further considered, taking into consideration the set-point temperatures of the homes.

4.3.3 Refrigerators

KILL A WATT (REFRIGERATOR)			
PLOT	**CONSUMPTION (KWH)**	**Hours**	**Hour Consumption**
29	69.45	999	0.06951952
38	14.1	189	0.074603175
40	98.44	1105	0.089085973
41	46.62	980	0.047571429
42	88.64	983	0.09017294

KILL A WATT (TELEVISION)			
PLOT	**CONSUMPTION (KWH)**	**Hours**	**Hour Consumption**
29	34.31	999	0.034344344
38	33.04	982	0.033645621
40	29.21	1105	0.026434389
41	53.46	980	0.05455102
42	17.72	1269	0.013963751

The energy consumption by the refrigerators is between 0.047 and 0.091 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 0.014 and 0.054 kWh/hour. It must be noted that this is the total time that the TV is on and is not based on the number of hours the TV is turned on. Factors that need to be considered include: type of television, number of hours per day that the TV is on. It is interesting to note that the TVs use between 25% and 50% of the amount of energy used by the refrigerators. When considering that the refrigerators run 24 hours a day and 7 days a week, the amount of energy consumed by the TVs is relatively high.

4.4 Indoor Relative Humidity

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

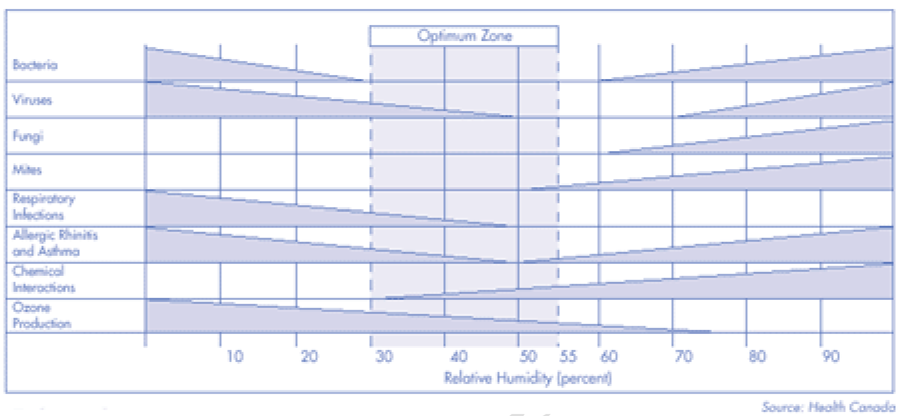


Figure 28 Relative humidity and health effects
Decrease in bar width indicates decrease in effect.[1]

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 4.2, 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
October			70	13.1			66.2	25.2	36.6	22.2

Table 1: Indoor Relative Humidity

[1] http://oee.nrcan.gc.ca/residential/personal/15161

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.

4.5 Indoor Temperature

Comfortable indoor air temperature will depend on the individual as well as the humidity. It is generally accepted to be between 73 °F and 79°F, or 23 °C and 26°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
October			38.4	23.5			30.6	20.8	33.6	22.2

Table 2: 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.

As a next step, the temperatures 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.

[2] http://en.wikipedia.org/wiki/Room_temperature

5 Next Steps

This report was the second interim report of the project and of the data collected. Data is continuing to be collected and the information will be updated accordingly. Winter months may provide an interesting change in the results as seen thus far. The following lists some of the tasks to be completed in the next two months and on to the end of March 2012.

- Continue to:
  - collect data from surface temperature dataloggers and the weather station;
  - evaluate surface temperature data and weather data with indoor T/RH/CO_2;
  - further modify weather file with additional data, to be used with HOT2000 analysis;
  - evaluate the potential for mould growth based on room RH and surface temperatures.
  - evaluate/validate the thermal properties of the insulations and assess the impact this has on overall energy consumption using HOT2000;
  - collect electricity data for the air conditioners and the refrigerators and TVs.

The next steps, which will be completed by March 31, 2013, include the following:

- Correlate the data more closely with human occupation, such as number of occupants and time at home, heating system installed if any, thermal set-points for temperature, etc.
- Plot 40 data logger inside the house has been having difficulty and this will be investigated.
- Correlate the dew point temperatures with surface orientation (N, S, W, E).
- 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.
- The temperatures 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.