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First Year Energy Characteristics of Equinox House

January 2012

Introduction

This summary provides detailed descriptions of Equinox House energy usage from December 2010 through November 2011. Actual data from four conventional homes show the significantly lower energy requirements of Equinox House. Comparisons between actual house energy usage and Newell Instruments' simulation model predictions are in good agreement. Finally, characteristics of energy usage of Equinox House appliances and other electrical circuit demands are presented.

A significant finding from our Equinox House project is that proper engineering design will result in 100% solar energy powered high performance homes that are lower in cost than their conventionally constructed counterparts. Equinox House has also demonstrated that the energy savings of new heat pump water heater and heat pump clothes dryer technologies is sufficient for providing the electric energy needed for a family's electric vehicle transportation needs. That is, implementation of these technologies, whether or not a home achieves overall high performance, provides the electric energy capacity for shifting the bulk of our transportation needs from petroleum to solar energy at a cost that is competitive now. Finally, Equinox House has demonstrated that high performance homes with a low infiltration shell and a properly engineered ventilation system will have excellent indoor air quality, maintaining carbon dioxide, volatile organic compounds, and radon within desired levels.

Energy Usage and House Energy Characteristics

Equinox House required approximately 12,000kWh to operate during the December 2010 through November 2011 period. On average, the house will require 10,000kWh per year. During the 2010/2011 winter season, we used electric resistance heating in order to validate our residence simulation models. A high efficiency mini-split heat pump was installed in October 2011, and initial results for the 2011/2012 winter indicate a 50% reduction in winter heating, in agreement with our simulation model predictions. More detailed discussions of the energy usage are provided below.

Figure 1 shows the average daily energy for Equinox House for each month since December 2010. Also included in the plot is the energy data from four actual homes in the area of Urbana Illinois. These four homes have been built with modern construction methods. One home (Conventional #1) has a ground source heat pump. Equinox House, even with inefficient electric resistance heating, outperforms all of the conventional homes. The energy usage for the 2011/2012 data with mini-spilt heat pump operation shows another significant reduction in energy. November and December are months in which significant holiday periods occur in the United States (Thanksgiving in November and Christmas/New Years in December). Families often have increased energy demand if they have visitors for the holidays or lower energy demand if they travel during the holidays. In our case, we had visitors for both holiday periods with 9 people staying in Equinox House for the last week of November, and 6 people staying in Equinox House for the December holidays. Two data points are included in Figure 1 that show the daily energy usage for that portion of November (Nov 1-20) and December (Dec 1-15) 2011 prior to holiday visitors and activities.

Figure 2 shows Equinox House actual performance versus our energy simulation model's predicted performance for Equinox House with electric resistance heating (COP=1), mini-split air source heat pump (COP=2), and ground source heat pump (COP=4). The 2010/2011 data with electric resistance heating correspondence with our predicted results is excellent, and indications (through January 17, 2012) are that our air source heat pump predictions are also in excellent agreement with the actual performance. Some items of interest to note from Figure 2 are:

1) The minimum or baseload energy consumption of Equinox House is approximately 12-13 kWh per day, approximately 3-4kWh per higher than our model prediction. Data acquisition equipment and instrumentation in the house use ~ 150 W, which is responsible for 3-4kWh per day above the 9kWh per day baseload estimate. The baseload causes an upward shift of the data from the predicted.
2) Simulation model results used long term average weather data. Two data points for December 2010 and January 2011 are shown with actual weather data for comparison to the actual house performance data for those two months, displaying very good agreement.
3) November 2011 and December 2011 have higher energy usage per day due to the holiday seasons in those months in which week long periods with 8-9 people lived in the house and up to 18 people per day came for meals and visits. Two additional data points are included in which the holiday periods are excluded for November (Nov 1-20) and December (Dec 1-15) 2011. The data trend shows that the simulation model predictions are in agreement with the non-holiday winter trends, and that the holiday activities resulted in 3kWh per day additional energy usage for November and December, for a total of 180kWh extra.

Figures 3 and 4 show an annual breakdown of energy consumption in terms of "major" and "minor" energy users. In Figure 3, the solar energy system's energy harvest is shown for the two halves of the 8.2kW solar PV array. Nearly 11,000kWh were collected during the year. December 2010 and January 2011 were very cloudy and snowy (December 2010 set a record for 17 days of snowfall), resulting in solar energy collection that was half of that of a typical year. Because of the energy "credit" built up from previous months, Equinox House has always been "net-zero" with no utility usage. During the spring 2011, net-positive solar energy harvesting increased our solar credit, and the gap between solar energy harvested and Equinox House energy usage is increasing. This "excess" solar energy harvest, estimated to reach 2000kWh per year, is for providing 8000 miles (13,000km) of electric vehicle transportation per year.

Other major circuits consist of the CERV fresh air conditioner system, sub-panel electrical circuits "A" and "B", and the mini-split heat pump circuit. The CERV ensures fresh air ventilation throughout the year, with energy exchange between the fresh air and indoor exhaust air when energy exchange is favorable. In addition, the CERV augments the cooling, heating and dehumidification of the house. Sub-panel "A" energy is small, but is included with the major circuits because its primary electrical load for the year was electric water heating during the initial December 2010 occupation period. Building inspectors required delayed installation of Newell Instruments' heat pump water heater in order to verify the use of "listed" components. Approval for installation of the heat pump water heater was granted in December 2010, and the heat pump water heater was operational in early January. Sub-panel "B" includes electric resistance heating for Equinox House during the 2010/2011 winter, and is the dominant (over 90%) energy usage of that circuit. Sub-panel B energy consumption will be much smaller with electric resistance heating removed. The mini-split heat pump was installed in early October 2011 followed by unseasonably mild October and November weather, resulting in minor house comfort conditioning requirements.

Figure 4 shows an annual breakdown of the "minor" electric circuit usages. The minor circuits totaled 1600kWh of energy usage for the December 2010 through November 2011 time period. Figure 5 breaks the appliance energy and general house circuit energy into percentages. Refrigerator, cooking, water heater, and clothes dryer are the primary energy requirements. Notable items from the circuits are:

1) The Blomberg dishwasher required approximately 1kWh per load, indicating that 75 dish loads were washed though the year. On average, with two person occupancy, one dish load per week is operated with additional dish loads during various holiday and visitor periods.
2) The Blomberg heat pump clothes dryer and clothes washer required 300kWh and 25kWh, respectively. Cold water clothes washing settings were primarily used throughout the year, which resulted in low hot water requirements as discussed below. Tide "cold water" detergent was used. The power converter used for the Blomberg clothes dryer required 200W of additional power. The clothes drying energy should be reduced by 33% for estimates of actual heat pump clothes drying energy. The heat pump clothes dryer performed well throughout the year, however power constraints of the power converter (maximum power output of 2000W) caused some problems during activation of the dryer's compressor. Overall, clothes drying characteristics of the dryer were excellent, and the energy savings advantage of the clothes dryer were proven. As of October 2011, the clothes washer circuit and clothes dryer circuits were combined in order to add the mini-split heat pump.
3) The Kitchen Aid French door, Architect Series refrigerator performed well through the year with a total energy consumption of 325kWh.
4) Due to the water conservation features of Equinox House coupled with efficient water heating using the heat pump water heater, water heating required only 275kWh compared to an estimated 2000kWh per year of water heating energy requirement for two occupants using traditional electric water heaters.
5) The "east" and "west" sink water heaters are small electric water heaters (2 gallon tank capacity, 1500W elements) that were installed for heating sink water. The intent was to keep sink water on "city" water when toilet, laundry and shower water switches to rainwater harvested water. We determined that the small water heaters were very inefficient with very high standby losses. The sinks were connected to the main heat pump water heater, which substantially reduced water heating energy usage. When rainwater usage is expanded to laundry and showers, the sink hot water will be connected to a second heat pump water heater.
6) Sub-panel "B" winter energy usage shows electric resistance heating is the primary energy usage. As of October, the mini-split heat pump system was installed, reducing winter heating energy by 50%.

Figures 6 and 7 display the major and minor electrical circuit energy usage on a monthly basis. Various annual trends are observed such as lighting which correlates with daylength. In typical homes designed without regard to window placement for effective daylighting, electrical demand for lighting would be similar to Equinox House lighting needs during the winter months. The high water heating energy usage in November 2011 shown in Figure 7 reflects the holiday activity with 9 people living in Equinox House over a 5 day period. Clothes dryer, cooking energy, room lighting, dishwasher and water pump energy requirements for November 2011 are similarly increased due to the occupancy and activity level.

Summary

Overall, Equinox House has performed at an excellent level and its performance is in agreement with our performance modeling and design tools. In addition to the energy data discussed in this report, water and indoor air quality (carbon dioxide, volatile organic compounds, and radon) data have been collected and compared to Newell Instruments simulation models with very good agreement.

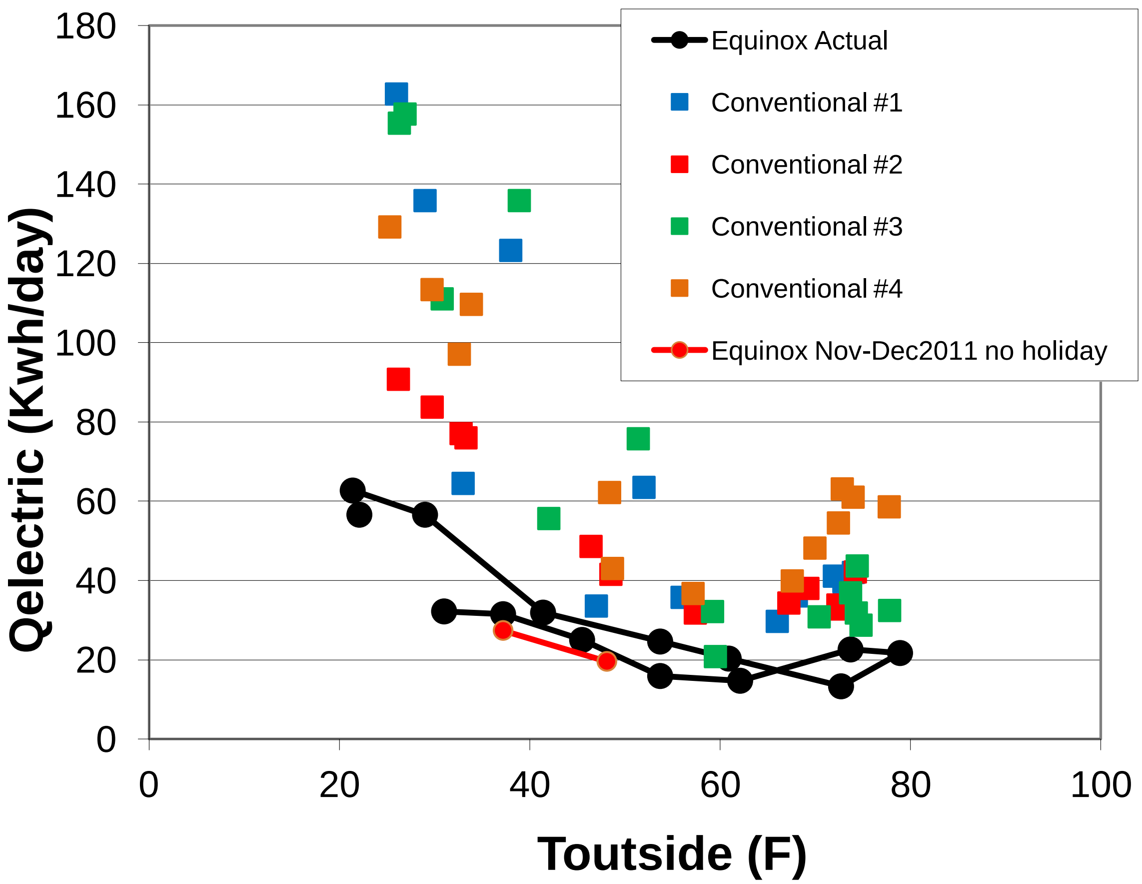

Figure 1 Comparison of Equinox House energy performance versus 4 modern homes in Urbana.

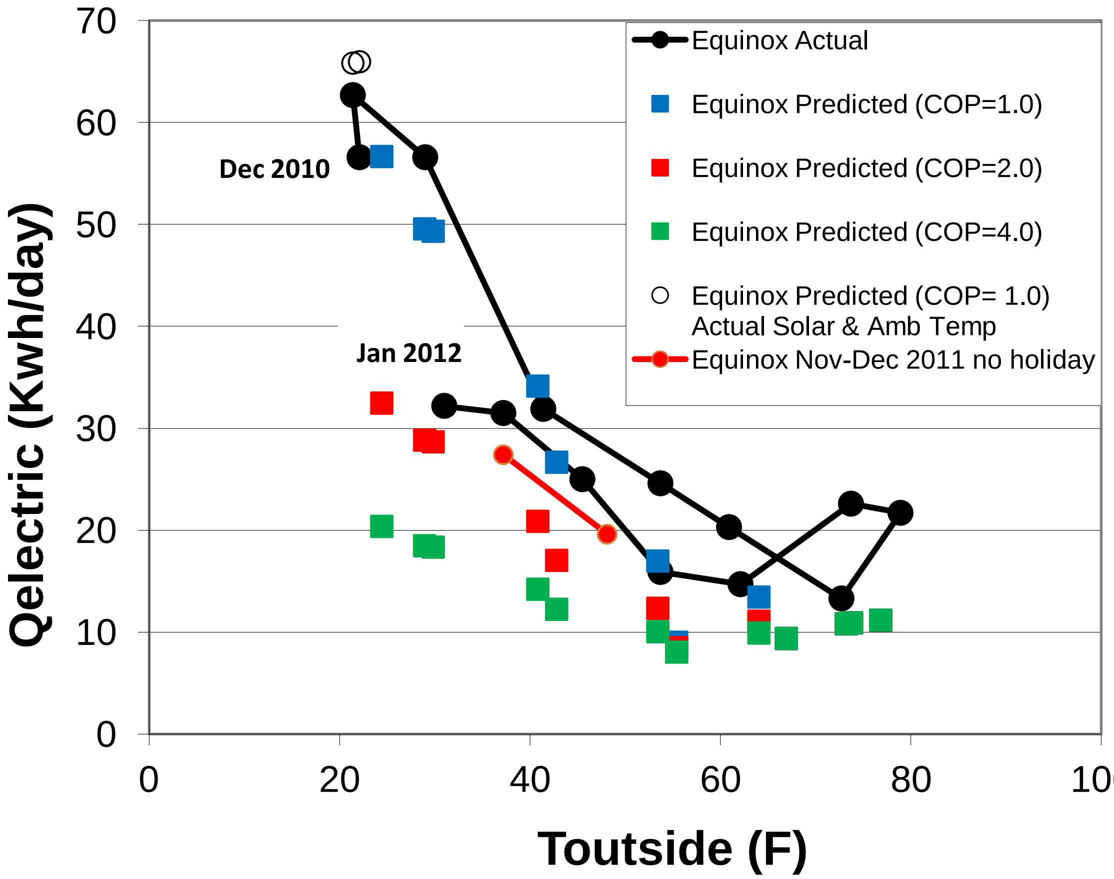

Figure 2 Actual Equinox House energy performance versus simulation model predicted energy performance for electric resistance heating (COP=1), mini-split air source heat pump (COP=2) and ground source heat pump (COP=4).

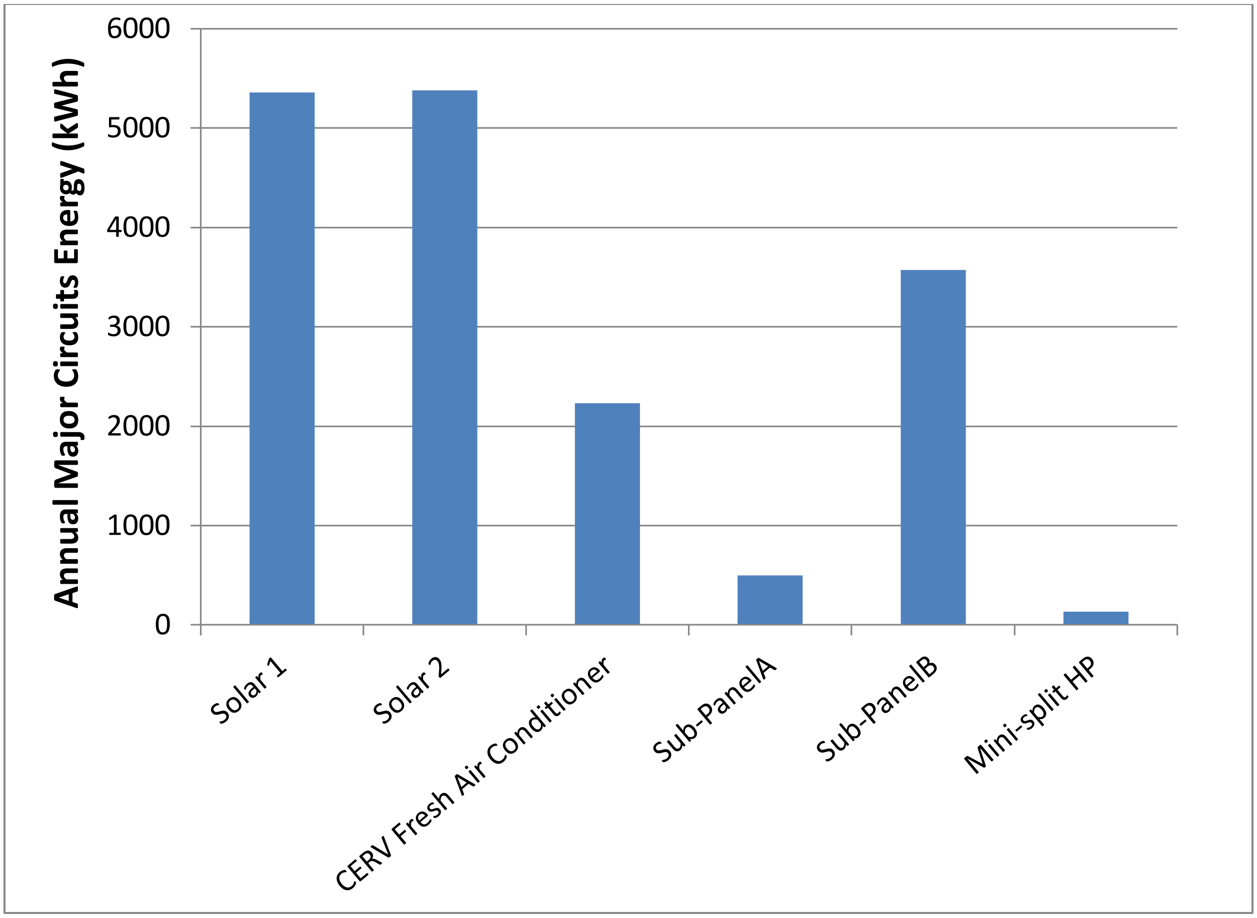

Figure 3 Major electrical circuit energy users in Equinox House.

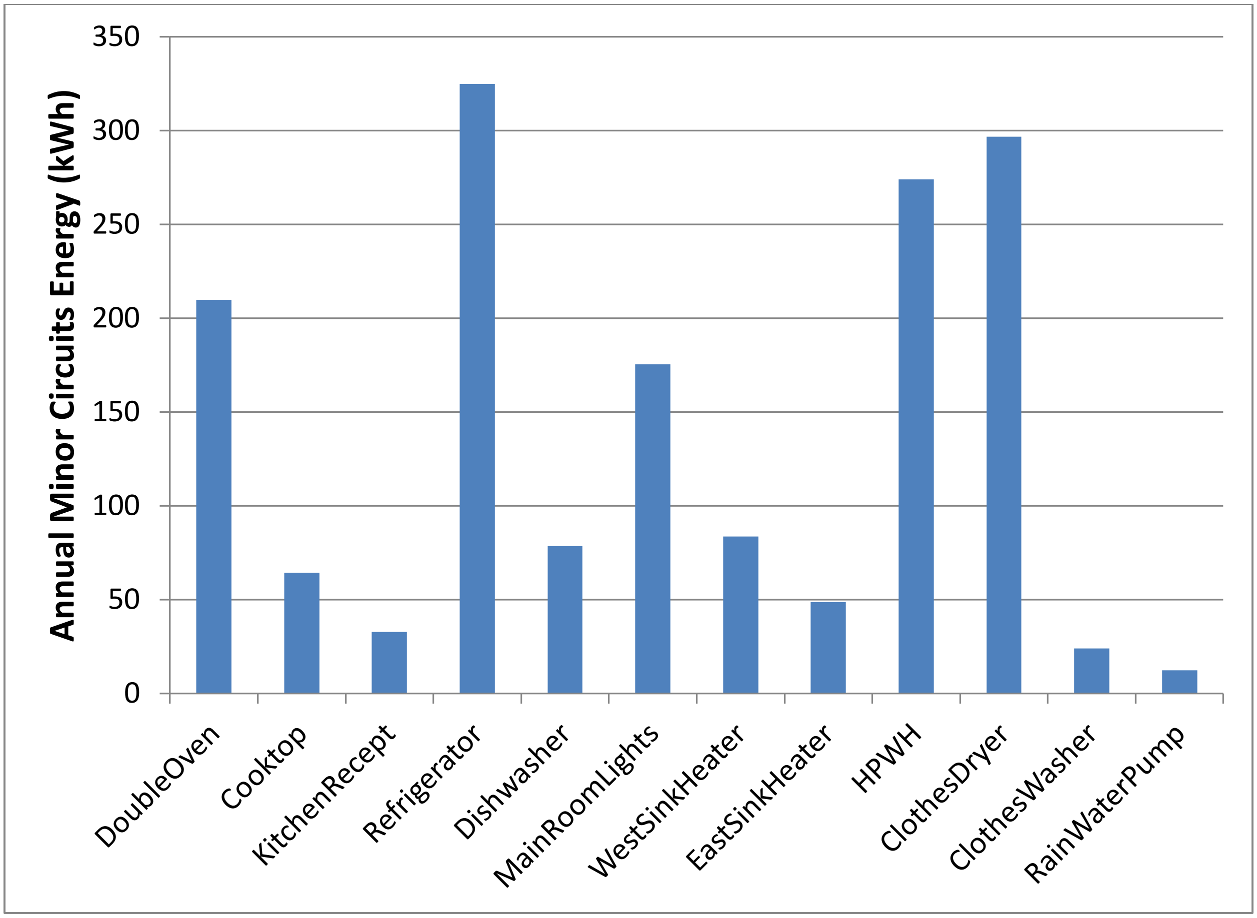

Figure 4 Minor energy users in Equinox House.

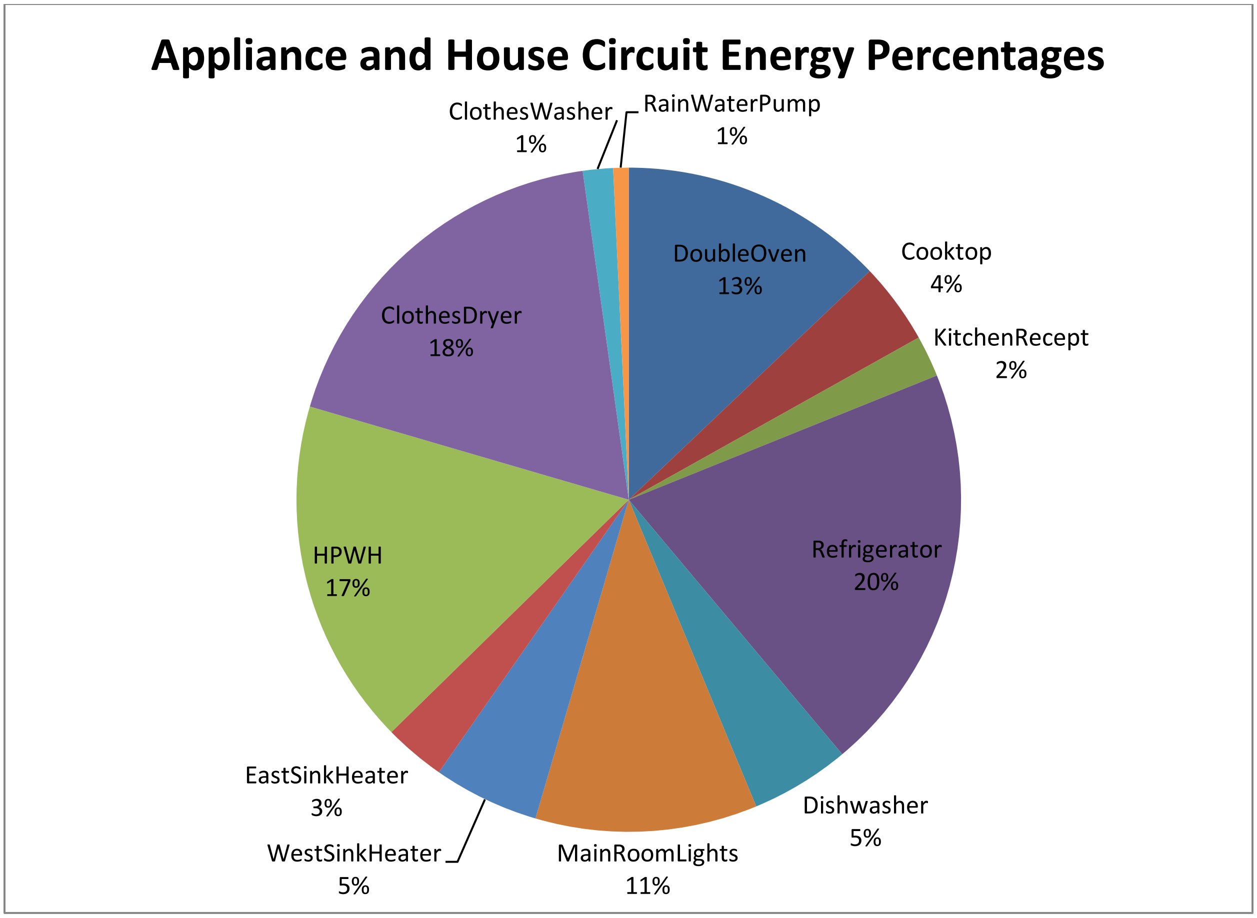

Figure 5 Annual energy percentages for appliances and general house electrical circuits.

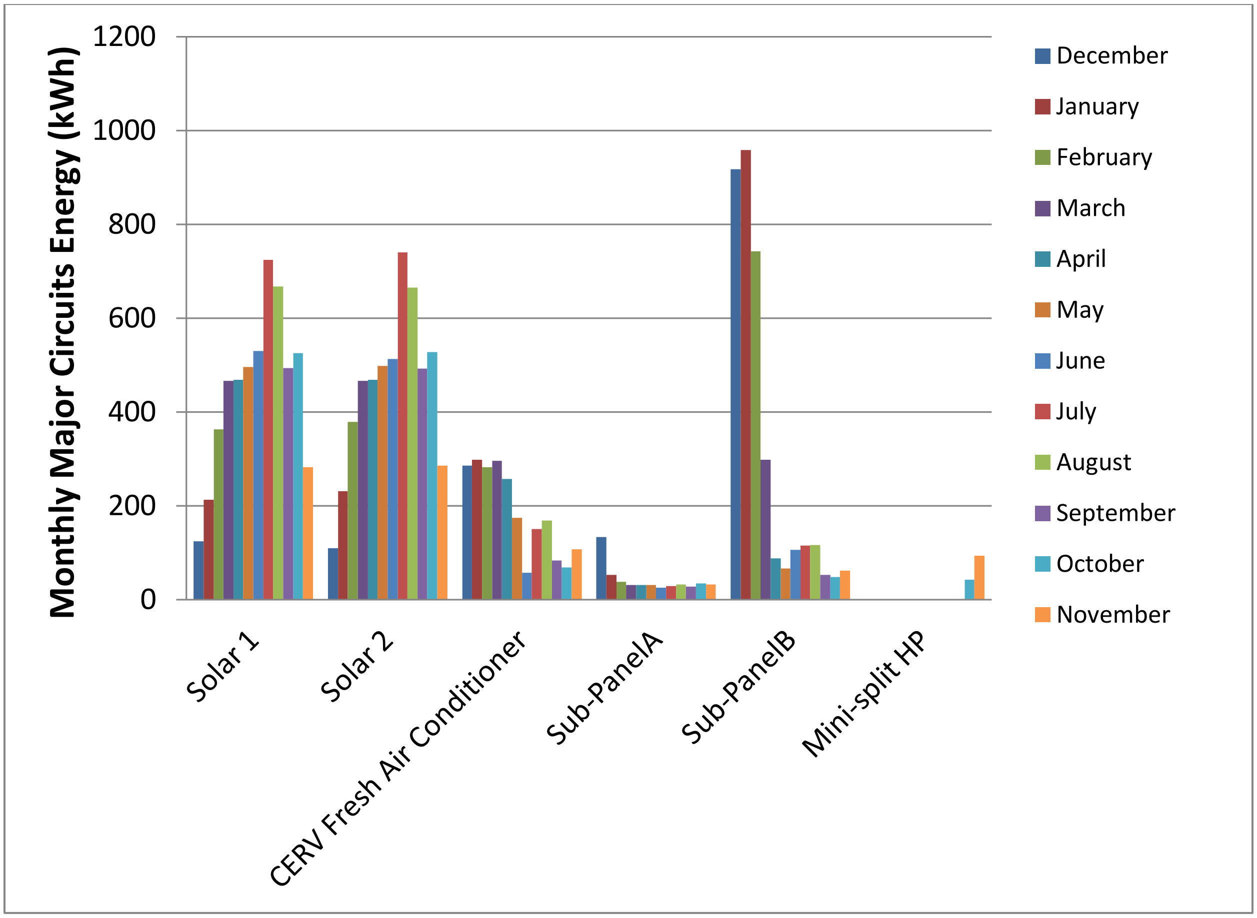

Figure 6 Monthly breakdown of major circuit energy.

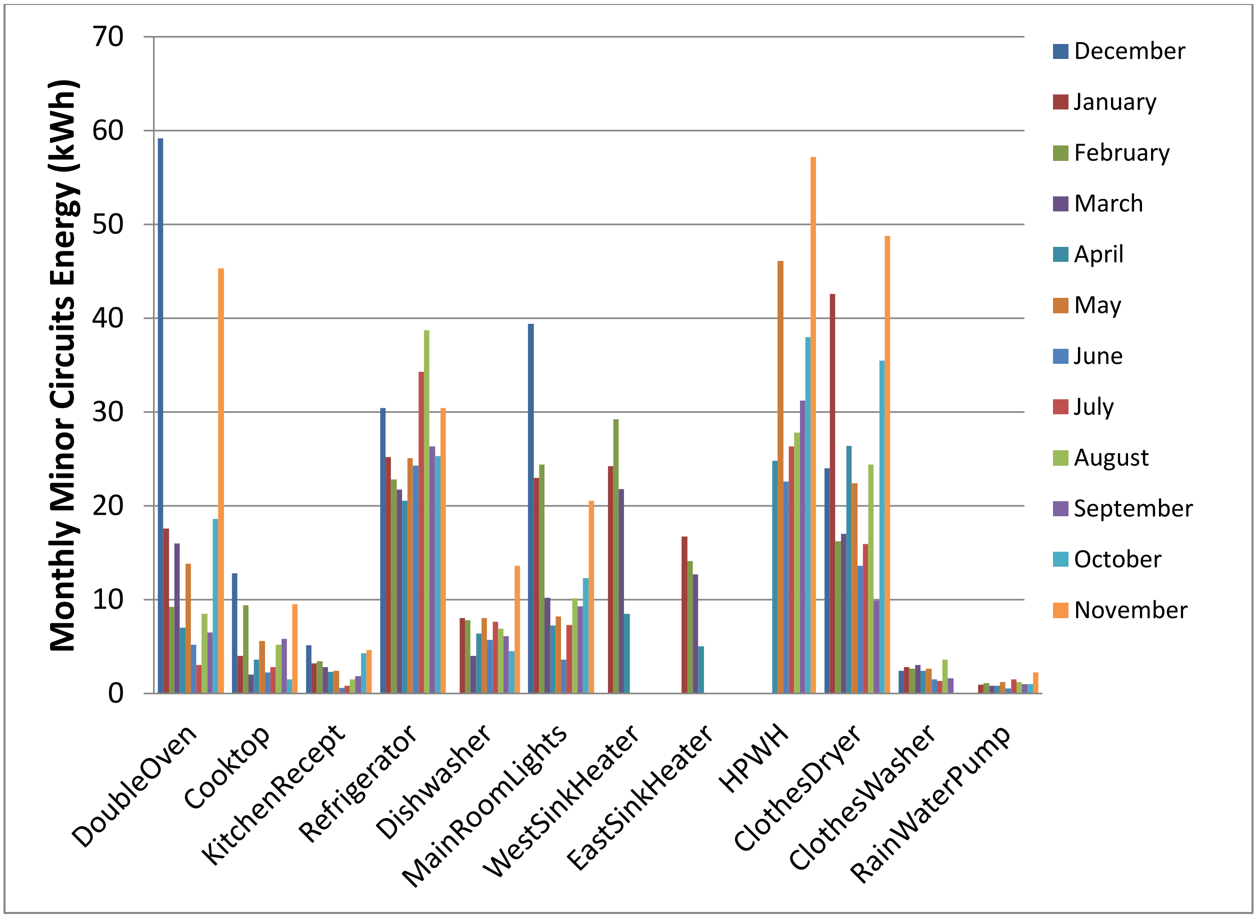

Figure 7 Monthly breakdown of minor circuit energy.