

# Minimizing Electrical Output Utilized for Heating

By  
Burke Day  
Jeremiah K. Jones  
Rob Olsen

Prepared for Kara Bleazard  
Statistics 361  
Section 4  
12/04/01

TO: Kara Bleazard  
DATE: December 4, 2001

SUBJECT: Term Project on Minimizing Electrical Output Utilized for Heating.

Project Objective:

To determine what factors have a large affect on temperature in a small size apartment. Thus finding a direct relationship of how to minimize the cost of heating.

Project Explanation:

The response variable will be the electrical usage measured in kilowatt-hours. This will be found by taking a consistent daily meter reading.

The two controlled factors will be the use of the oven, and the setting of the thermostat. Oven use will be varied by whether or not the oven is used that day. When used, it will be used for exactly one hour each time, and at the same temperature. The thermostat will be varied by whether or not it is left at a constant temperature, or turned off each time there is nobody home.

While these remain the only two controlled factors, there are a few other factors that must be taken into consideration in finding an accurate analysis. They are: time away from home, time awake at home, outside temperature, and the number of times an outside door is opened.

The study will consist of randomized runs of the two controlled factors with six replications each; thus resulting in a total of 24 runs.

Project Justification:

Most people are consistent in trying to find ways to minimize the cost of heating a home. This experiment will provide an accurate analysis of what factors should be taken into consideration when trying to minimize the cost of heating. This will, in turn, provide very useful information in balancing between physical comfort, and economic efficiency.

Experimental Process:

The greatest hindrance to determining the amount of electricity used for heating is the uncontrolled environment. Because this experiment could not be run in a virtual or controlled environment, there were many aspects of the design that needed to be carefully observed. In order to prevent unexplained variation in our final model, we recorded data for all variables that could possibly show significant affect on heating. These factors and the process of recording their data

are explained in the following paragraphs. The two main factors, of which we could control, were set at two different levels. These are shown in the table below.

**Table 1 Table of Factor Levels**

	Thermostat	Oven (Gas)
Low Level (Indicated in the model as '-1')	Thermostat turned off when not home	Oven not used
High Level (Indicated in the model as '1')	Thermostat left at 75 degrees all day	Oven used for 1 hour

For consistency in time, each experimental day began at 8:45am. At this time, the current meter reading would be recorded on the data sheet. This number would then be used, along with the reading from the previous day to find the total amount of electricity (in kilowatt hours) used. The data sheet was used to indicate the status of the thermostat and oven. On constant thermostat days, the thermostat would be left at a constant temperature of 75 degrees Fahrenheit. On non-constant thermostat days, every time that there would be nobody in the apartment, the thermostat would be turned off, thus preventing the heating from turning on.

To keep track of the number of times each door was opened, a chart was placed on both sides of the front door (the front door was the only door used during the experimental trial period). Each time a person would enter or leave, a mark would be made on the chart. The total number of marks would be counted and recorded on the data sheet the next morning at 8:45am.

The data sheet was also referred to each day in order to determine the use of the oven. Because the oven is a gas oven, it will contribute only to the temperature level in the apartment, and not directly to electrical usage. On days for which the chart indicated oven usage, the oven would be turned on for precisely one hour in the evening. The oven would then be turned off, and not used again until the next "oven day." On days during which the oven was not to be used, the oven was simply left off.

The data for temperature was collected as a whole by courtesy of the Geography department of BYU. Each day, data is gathered from various sources around campus, and averaged in to determine the temperature throughout the day. At the end of each day, this data is analyzed to find the minimum and maximum temperature for each day. With permission from the Geography department, this data was used in the final analysis of our experiment.

In order to account for the effect of normal electrical usage due to activity in the home, the amount of time people were active and home was recorded. Each day before turning off the light to sleep, the time was noted. The time was then noted again upon waking up. Each time the apartment was to be left empty, or a person was returning to an empty apartment, the time would again be noted. This data

was used to calculate the total time spend away from home, as well as the total time spent home and active.

Data:

In order to obtain randomization in the experimental process, we used the MINITAB default generator to randomize the run order. Please refer to page iii of the appendix to see the resulting data.

Analysis:

In order to establish the best model for the determination of power usage we analyzed the data that was collected. To begin the analysis of the data, we considered the following variables:

- Constant thermostat
- Oven Usage
- Outside temperature
- Time spent active indoors
- Number of times the door was opened

The method used to perform the analysis was regression. The results from this preliminary analysis are displayed below in table 2.

**Table 2 Table of Effects**

Predictor	Coef	SE Coef	T	P
Constant	7.7709	0.7824	9.93	0.000
Const T	0.2263	0.1098	2.06	0.054
Oven	-0.17460	0.09247	-1.89	0.075
Min T	-0.03110	0.01354	-2.30	0.034
Active	0.14311	0.04150	3.45	0.003
Door	-0.00080	0.01291	-0.06	0.951

These results are used to determine if the effect of each variable is significant. A t-test was used in the regression analysis. T-tests are often used to determine the significance of variables in a model. This test provides a p-value, which determines the level of significance with a given level of confidence. Our test used a level of confidence of 90%, which gives us a probability significance level of .10. If the p-value is less than this significance level, the effect is determined to be significant.

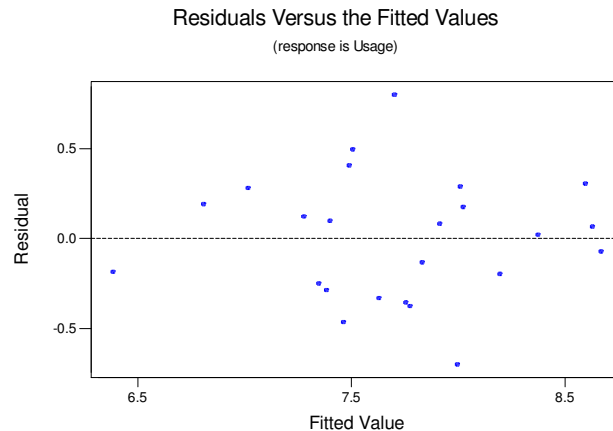
As you may notice, all of the effects are significant except for that of the Door variable. Knowing this, we dropped the Door variable out of the model and performed the regression analysis again. The results from this analysis are shown below in table 3.

**Table 3 Table of Significant Effects**

Predictor	Coef	SE Coef	T	P
Constant	7.7630	0.7514	10.33	0.000
Const T	0.2240	0.1007	2.22	0.039
Oven	-0.17406	0.08961	-1.94	0.067
Min T	-0.03125	0.01295	-2.41	0.026
Active	0.14303	0.04038	3.54	0.002

From the table above, we can see the effect of each variable in the model. The coefficient listed above can be interpreted as the change in usage from the one unit increase of the specific variable, in the presence of all other variables in the model.

The next phase is the analysis of the residuals. A residual is the distance the observed usage value lays from the expected value calculated in the regression analysis. The expected value is also referred to as the fitted value. Each observed value has a residual. These residuals can be plotted vs. the fitted values or each variable to determine if the variability of the observed values is constant. These plots can help us to determine if the variability in the process is random. In observing the plot of residuals vs. fitted values in figure 1, we see that the variability seems to be constant.



**Figure 1 Residuals Versus Fitted Values**

This helps to prove our assumption of random variability, which provides us with more confidence of the significance of the effects. Additional residual plots can be found on page iv of the appendix.

Conclusion:

The model used to predict the amount of kilowatt-hour usage per day is:

$$\text{Kilowatt-hour Usage} = 7.76 + (0.224 * \text{Const T}) - (0.174 * \text{Oven}) - (0.0313 * \text{Min T}) + (0.143 * \text{Active})$$

In this equation, the only variables that we had control over were the constant temperature of the thermostat, and whether or not the oven was used. Therefore, according to the data, and this model, the minimal usage of electricity will be on a luke-warm day with the residents spending most of the day away from the house. However, since we don't control the weather and don't stay away from home all day the best we can predict is that if we turn off the thermostat when nobody is home, and try to use the (gas) oven for at least an hour every day, we will pay less per month to Provo Utilities.

Using the data taken from this project, and projecting it into an average for a year, without minimization, the bill could amount to more than \$207 (using the current rate of \$0.0698 per kWh). However, by following the model to minimize electrical output, this bill could drop to below \$185. This is a difference of \$22 per year, which equates to more than one entire month of electrical use (according to the monthly average for the apartment used in the experiment). Thus we can see that it is more economic to follow the model outlined above.