PHSC 104

Energy: Synthesis and Analysis

Energy Use in the Home

Introduction

The average household spends over $1,300 a year for energy to run the many devices found in the home[1]. The vast majority of this cost is for heating and cooling the air in our homes. However, these are not the only places that use a lot of energy. We also have some large appliances, such as the stove, water heater, and washer/dryers, which use a considerable amount of energy. In this week's lab, we are going to investigate ways to save both energy and money by modifying the largest of the energy uses in our homes (we will not be concerned with small changes, such as lightbulbs). In order to do this analysis, we are going to have to use the measurements of our dwellings that we made in the last two labs, as well as the online calculator used in last week’s lab.

Losses and Gains

Conduction and convection heat losses and gains are the two largest sources of energy changes in our home. Having walls and ceilings with minimal insulation can result in large heat movement either into or out of our home. Cracks around windows and doors, or even cracks in the walls themselves, can also be a severe drain on our energy budgets. There are many simple changes that one can make to improve both of these. Caulking and weatherstripping can seal cracks. Adding layers of insulation in the attic can drastically reduce the amount of heat transported through the ceiling.

Energy is also lost in our homes because of all of the energy transformations that are taking place there. The First Law of Thermodynamics tells us that the energy involved in any transfer must be conserved. This would seem to mean that we should never run out of energy and should pay no heed to anybody talking about energy being lost. The problem is that this is not the only law that governs energy transfers. While the total amount of energy does not change, the **Second Law of Thermodynamics** puts limits on the amount of **usable energy** that can be transferred. One of the consequences of this law is that the total amount of usable energy that comes out of any process will be less than the total amount of energy that went into the process. The difference between the total amount of energy input and the usable energy output is expended as waste heat.

This brings us to the issue of efficiency, which is a measure of the amount of usable energy that is generated during any type of transfer. If a transfer is very efficient, then the amount of usable energy that is generated is almost equal to the total amount of energy that went into the transfer. This means that very little waste energy will be produced. An inefficient transfer, conversely, is one in which most of the energy going into the process is converted to waste heat. For example, a natural gas heating system converts about 70% of the chemical energy of the gas into thermal energy. While this may sound pretty efficient, it is not as good as an electric resistive heater which converts almost 100% of the electricity into heat.

When discussing the efficiency of a process, we have to make sure and not forget all of the transfers that might need to take place in order to get to the one under investigation. While the efficiency of the electric heater above is almost 100%, the efficiency of creating the electricity and transferring it to your home is only about 35% efficient. This fact greatly reduces the overall efficiency of an electric heater. When we consider the total efficiency, from getting the energy from its natural source to the heater in the home, we find that the natural gas heater is better than an electric resistive heater.

Appliances

The efficiency of all of the appliances in our homes affects how much money we spend and energy we use. While heating/cooling does consume the largest single amount of the energy budget of the average household, it does not consume the majority. Other appliances in the home consume over 50% of all of the energy. Almost every American home has some type of stove or range, while about 75% of them have a washer and dryer, 50% have a dishwasher, and 33% have a separate freezer from their refrigerator. All of these appliances, plus the heating/cooling systems, amounted to over 101 million Btu's of energy being consumed in the homes of America in the last year. Considering the inefficiencies of transporting energy to homes, the total amount of energy that had to be consumed in order to power our houses was over 170 million Btu's.

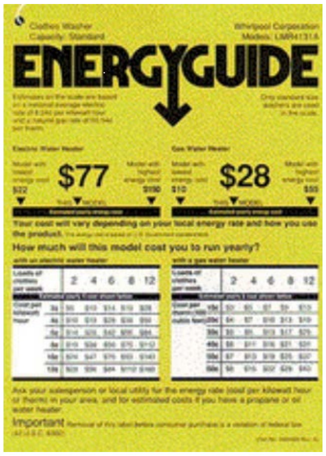

Fig. 1: Energy efficiency guide

The amount of money consumed by an appliance depends on the type of fuel used by the appliance, the power of the appliance, and the length of time that the appliance is allowed to run. For instance, the average electric oven uses an average of about 2,000 watts of power to heat itself to a temperature of 350 ^{o}F. If it is run for 1 hour, then it will use an amount of energy equal to

Energy = Power x Time = 2,000 watts x 1 hour = 2,000 watt-hour = 2 kilowatt-hour

At the current rate of about $.08 per kWhr, this corresponds to a cost of about 16 cents. The average natural gas stove uses about 11,000 Btu/hr to maintain the same temperature. If you ran it for the same amount of time as the electric stove, it would consume an amount of energy equal to

Energy = Power x Time = 11,000 Btu/hr x 1 hour = 11,000 Btu

The current cost of natural gas is about $.70 per therm. One therm is equivalent to 100,000 Btu. Thus, the natural gas costs about $.000007 per Btu. This means that the cost of running the natural gas stove for 1 hour is about 7 cents.

In the calculator that we will be using to estimate energy usage in our homes, the power usage for gas appliances will be assumed to be the national average, while the power usage for electrical appliances will need to be entered. This is because some gas appliances do not list a power rating or have the information in a non-reachable place on the appliance. If you cannot find the information for your electrical appliances, use the average values that we have provided in the calculator.

Assignment

You ran the calculator last month on the current state of your home to estimate what your costs currently are. Your assignment for this week’s exercise is to consider three changes to your dwelling that would save money and to analyze them for economic feasibility. You will do this by comparing the cost of performing a change to the savings that this change will provide. For example, if you were to replace the single pane windows in your home with double pane, you would need to change that factor in the calculator and run it again. Then, you would need to find out how much it would cost to install double pain windows, and divide this cost by the savings that you calculated. The number that you get would be the number of years that it would take to recoup the cost of your change. After analyzing three changes, complete the questions listed on the activity sheet, and attach printouts of your runs of the energy calculator. If you rent, pretend that you own the property in order to answer these questions. Describe the changes in detail on the Activity Sheet.

You will need to provide supporting evidence to show that the estimated cost of making each improvement is reasonable. If you propose to do the work yourself (and do so only if you possess such skills), then you will need to provide the prices of the required materials from a local home-improvement store, listing the specific items and the store location (feel free to attach clippings from store circulars showing the items and prices). If the proposed work is to be done by a professional, you must provide an estimate from an independent, home improvement store-affiliated, or online contractor. You can obtain an estimate for select home improvements with the ImproveNet web site's Estimators function.

Once you know what it will cost, determine the amount of money that would be saved with each home improvement. Do this by running the Home Energy Analysis calculator **with** the improvement, and then compare the sum of your annual energy costs before (using your initial run of the calculator) and after the improvement. Based on the cost of the improvement and annual energy savings, calculate the number of years required to recoup the costs of the improvement in reduced energy use. Attach printouts of the calculator for each of the three proposed changes to provide evidence of the cost savings through greater energy efficiency.

Calculator Instructions

While we did use the calculator last month, it would not hurt to repost the instructions for using it again. We also must reiterate that the calculator will not include the cost of running all of the smaller appliances in the home. The reason for this is that the list of appliances that we would have to include would make the calculator very unwieldy to use, as you would either have to scroll down a very lengthy list of items or to click through many different web pages. Because their portion of the energy diet is small, we are not going to include them here.

Below are the instructions for using the calculator found at **this link**.

1. The calculator comes in two parts, both of which are on the same page. You will need to finish the first section before proceeding to the second section. The first section concerns the measurements of your home that you took several weeks ago. You will notice that this section is laid out similar to the form that you filled out for each room of your home. There are two ways for you to enter the data for this section. One way would be to enter the data for each room of your home as it is listed on your worksheet(s). After typing this in, press the Calculate button that is on the left side of the screen. After the program makes the calculation, click the Next Set of Surfaces button to clear the room data. Enter the data for the next room, and proceed as above until all rooms are finished. The second way to fill in the data can only be used if the surfaces in your home are all the same (ex. all windows are double pane, all walls are R-factor 19 wall, all ceilings are R-factor 30, etc.). If this is the case, then you can add up all of the area for each component and enter it as if there were only one room.
2. After you finish entering the Conduction data, scroll down the page to the section entitled "Other Household Data".
3. From your drawings, you should be able to calculate the total area of all south-facing windows in your home that are not shaded from the outside. The reason why you need to know this data is that your south-facing windows are a source of solar energy. During the summer, each square foot of south-facing window will allow about 37 Btu/hr of solar energy into the house, unless it is blocked from entering the house outside of the window (curtains or shades on the inside of the window do not count as shade since they allow the energy into the home before blocking it). In the winter, this value is about 27 Btu/hr. Enter the area in the topmost text area of the section.
4. In the second slot, enter the total area of all east- and west-facing windows. While these windows do not allow sunshine into the house the entire day, they do allow solar energy in for half of the day. During the summer, this can be significant since the Sun will be further north in the sky throughout the day.
5. The next slot asks you for the square footage of the cooled and heated floor space in your home. You should be able to calculate this from your drawing.
6. The next slot asks for the average height of the ceilings in your home. In conjunction with the square footage of the floors of your home, these two numbers give us an estimate of the volume

of air space in the home. This is the amount of air that must be heated and cooled as air is being exchanged with the outside environment.

7. The next two slots ask for the thermostat settings for both winter and summer. These temperatures will determine the rate at which heat is exchanged with the outside, and thus, how much cooling and heating are necessary. Two assumptions go into this calculation. The first one is that the thermostat is not being switched from this temperature setting, i.e. the thermostat is not a programmable thermostat. If you have such a thermostat, you will need to enter an average setting of your thermostat that will take into account the variability of the temperature in your home. For instance, if you set your thermostat in summer at 78 during the day and 72 at night, then you will probably want to enter 74 as your average temperature (while 75 might be the actual average, this does not take into account that the variation in temperature during the day actually lowers the average temperature difference between inside and outside). The second assumption in this calculation is that we are experiencing a normal year in outside temperatures.
8. The next slot asks you to enter the number of air exchanges per hour in your home. Refer to the first page of this module for help in estimating this number.
9. The next slot asks you to enter the number of people in the home. This number is needed, since human bodies produce heat. In the winter, this decreases the amount of heating that you will need; in the summer, it will increase the amount of cooling that you need.
10. The next slot asks you what type of ductwork you have for your heating system. If you have central heat, then you will have some type of ductwork to bring the heated air to each room. If this ductwork is insulated, then you need to enter 1 in the slot; if it is not insulated, then you need to enter 2. If you use a wood stove or a portable kerosene heater in your home, you have no ductwork, and should enter 0 in the slot.
11. The next slot asks you what type of heater that you have. This is important, since it will determine what type of fuel that you use and how efficient each type of heater is. We are assuming that a natural gas and propane heaters are 80% efficient, a resistive electric heater is 100% efficient, a heat pump is 250% efficient (remember our discussion about heat pumps in week three of this module), and a wood stove is 60% efficient. If your true efficiencies differ from this, it will cause some error in the estimates. In order to select the appropriate stove, please enter the corresponding number in the slot
12. The next slot asks for the type of air conditioner that you have. We have assumed that all air conditioners have a seasonal performance factor of 2.5. If you have no air conditioner, enter a 0 in the slot; for window units, enter 1; for a central air conditioning system, enter 2.
13. The next several slots deal with some of the major appliances in your home. Enter the appropriate data in each slot, including the number of hours each appliance is used in a typical week. We have assumed that all refrigerators and hot water heaters are always operating.
14. The last bit of data that you need to enter is the price of each fuel that you use. This data should be available from the energy supplier that you use. If it is not, we have provided an estimated average of current costs.
15. After completing all of this data, press the **Calculate Summary** button at the bottom of the page. The program should return the cost of energy in your home for the year. If you find that you wish to change any of the Other Household data (the second section), you may do so without having to go back and enter the Conduction data again. Merely change the data that you want, and then press the **Calculate Summary** button again. It will recalculate your costs with the new changes. If you wish to change something about the Conduction data, you will need to press the **New Energy Analysis** button, which will clear the entire calculator and allow you to begin over again.

References

1 "A Look At Residential Energy Consumption in 1997", U.S. Department of Energy, November 1999.

PHSC 1014 Activity Sheet
Name: Synthesis & Analysis

Describe in detail the three proposed changes below, list the cost of each and the annual savings, and calculate the payback time in years. Attach all supporting documentation (prices, estimates, calculator runs) to this sheet.

Scenario 1:

Savings/year = $_________ Cost = $________Payback time = ____ years
Description of change:

Scenario 2:

Savings/year = $_________ Cost = $________Payback time = ____ years
Description of change:

Scenario 3:

Savings/year = $_________ Cost = $________Payback time = ____ years
Description of change:

Analysis:
Compare/contrast the three scenarios that you have listed. Do any of them make economic sense to perform? Why or why not? Which of them would be the most feasible, and why?

The previous question examines the feasibility of home improvements solely from an economic standpoint. There is, of course, another perspective. Whenever you heat or cool your home, you are likely using energy derived from the combustion of a fossil fuel, which produces pollutants and contributes greenhouse gases to the atmosphere. The lower your home's energy efficiency, the more energy you will consume, and the more pollution you will generate. With this in mind, would you consider making improvements in your home's efficiency to reduce your energy usage (and therefore release of pollution) even if you did not recoup all of the costs associated with the improvement? Fully explain why or why not.