Case 35
Northern Windows

Harvey Newby recently graduated in mechanical engineering, and was hired by an oil company working in the arctic. He moved north, and like many other newcomers, he was impressed with the number of windows many homes had. Harvey's studies had concentrated on pump and turbine design and operation, but he had taken a course in heat-flow analysis. His main memory was of how incensed his "heat flow" professor had been over the repeal of the federal tax credit for energy conservation improvements. However, he also vaguely remembered the professor's statement that windows transmitted nearly ten times more energy than did walls.

These memories were vague, and he did not worry about following up on them, until recently when he bought a home. He discovered that virtually all homes had the same or more windows than did homes in Southern California. When the real estate agent was pressed for an explanation, she replied somewhat untactfully, "You obviously have not spent a winter inside yet. After the first three months, and for the next four, cabin fever is a big problem. Being able to look outside, and feeling open rather than closed in, both help a lot." His coworkers all agreed with the salesperson, so he swallowed his misgivings and purchased a typical home. It has lots of windows.

However, his misgivings came back when he got a $125 electric bill for October. At this point he called the old owner and asked what the electric bills had been last winter. His summary of the answer is in Table 35-1.

Table 35-1 Last Winter's Electric Bills

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
$115	$158	$245	$360	$310	$242	$170	$138

Last week he got two shocks. First, he heard on the radio that electric rates might double because of the expiration of long-term natural gas contracts. Second, he read in the newspaper that the Public Utilities Commission was planning on discouraging electric heating by eliminating the old declining rate schedule for a new flat rate (see Table 35-2).

Table 35-2 Electric Rates

Old Schedule		Proposed
KWh	$/KWh	New Schedule
0–500	0.115	
501–1000	0.09	$.08/KWh
1001–3000	0.07	
3001–6000	0.055	
6001 & over	0.05	

Harvey cannot afford to sell the home and buy another one, so his only options are to turn down his thermostat, install energy conservation improvements, or switch to a new fuel supply. Luckily, his area of town is scheduled to receive natural gas within the next four years, so he can look forward to replacing his electric furnace. And it is worth looking forward to, since at current prices natural gas costs about 20% as much as electricity for equivalent heating values. But it certainly won't pay to switch to fuel oil for the short-run, and both coal and wood are far too inconvenient.

Harvey paid for a state-sponsored energy evaluation of his home, but there were relatively few suggestions. Harvey has bought a well-built home, so caulking and other minor improvements are of little value. Two improvements seem more substantial. He can add an "arctic entry" to his main entrance and/or he can provide insulation for his windows. Because these two improvements were recommended in the energy evaluation, Harvey can receive a state-subsidized loan to complete them. These 5% loans are available for a 20-year term.

For esthetic reasons, Harvey does not wish to add an arctic entry. This would involve extending his roof and entry, and adding another door to provide an air lock. For esthetic reasons he does not want to replace his current miniblinds with insulated drapes. Thus the option he wishes to consider is adding additional panes of glass to his existing windows.

The payoff of adding panes comes through lowering heat losses due to conduction and radiation. Both of these phenomena can be modeled on a square foot basis, so he believes he can simply choose a single window size to analyze in detail. Later he expects to modify this analysis for window direction (south vs. north), type (opening vs. fixed), and size.

His home has 19 clerestory windows, each of which is 16" ×32" in size. With so many of this size, he has decided to analyze these first. These windows do not open, and they will also be easy to modify. They face south and it is a cold climate, so the net impact of radiation is positive. As a result, Harvey does not plan to consider the various coatings that are designed to reduce radiant heat flow. Since clear window glass has an insignificant impact on radiant heat flow, he is left with a simple problem in conductive heat flow.

He calls the glass company and asks for quotes on 16" × 32" windows. Their response is \$8.54 for a single pane and \$16.91 for a thermopane unit. He also estimates \$5 of wood, paint, glue, etc., would be required for each window. More importantly, he estimates 2 hours of labor for each window. Since this kind of project is a nice break from working and playing at a computer, he values his time at \$5 per hour. His windows are already double-pane. Thus if he adds the glass, he will end up with either triple- or quadruple-pane windows.

He has completed the heat-flow analysis and simplified the equations (as shown in Table 35-3) to ease the economic analysis. To keep his home at 70° requires 10,911 degree days per year of heating. *The average yearly outside temperature of 40°F implies that he must supply 30F° for 365 days.* As long as he wants to keep his home at 65°F or warmer, he must heat year-round (in this northern climate), so adjusting for lower temperatures simply requires multiplying the temperature change by 365 days per year.

Table 35-3 Formulas for Calculation of Heat Requirements

Annual Heat = (degree days) × area × conversion factor × (24 hr/day)

His conversion factor is stated in terms of BTUs per hour-ft^{2}-F°.

Note that 1 kWh = 3413 BTUs

Number of Panes	2	3	4
Conversion factor	.48	.33	.24

So energy cost savings from increasing the number of panes are based on the difference between the conversion factors.

Since he set the problem up for the economic analysis, Harvey has realized that he wants some help. And you are the lucky person he's asked (you teach engineering economy at the local college). There is quite a bit of uncertainty, and he believes either complicated equations or a very large number of spreadsheets will be required to analyze the problem. Thus he has asked you to determine which variables are the most critical to his decision making and to summarize the relative sensitivity of your recommendations to changes in the variables. He also has asked that this option be compared with the possibility of lowering his thermostat.

In summarizing his economic position, Harvey states that he expects about a 10% return on his investments. As a result he believes the state loan is a good deal, but he is also wondering if the improvements could be justified without it. Harvey also believes the improvement will last as long as the home—probably 50 years, but he does not expect to own it that long. His best guess is that he will sell the home in 10 years.

Options

1. Rather than assuming no inflation, analyze the impacts of inflation in the money supply on the value of the load repayments and energy bills, and varying inflation rates for electricity and for natural gas.

2. Consider the impact of income taxes on the decision. Harvey's marginal tax rate for federal and state income taxes combined is 30%. Assume that commercial financing

would be tied to his mortgage, so that the interest payments would still be tax deductible. (The subsidized loan is not tax deductible.)

Suggestions to the Student

1. The power bills on Harvey's house and the old power schedule can be combined to calculate his average cost of power and his power usage. Then the new schedule provides a base case for his future power costs.

2. A second case is to double these costs, due to the expiration of natural gas contracts. This change is less certain, and its timing even less so.

3. If a horizon shorter than 50 years is used, then there is likely to be some salvage value for the window improvements—the home is likely to sell for a higher price.

4. When natural gas becomes available, the amount of energy lost through the windows will not change. Only its price will. By what factor?

5. The uncertainty of when the natural gas will become available can be limited by two extreme cases—immediately and never.