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Setting Priorities for Weatherization: Beyond Simple Payback

by Mary Beth Zimmerman

With oil overcharge monies being mopped up and federal dollars almost pumped dry, weatherization programs have to look at the efficiency of their own operations to get the most out of their limited resources.

Which energy efficiency measures belong in which houses? The two most challenging decisions in weatherizing a home are how to select the best set of measures for a particular house and when to stop installing more. Would an extra three hours of caulking be worth the effort? Do you need both a new furnace and wall insulation? Weatherization program managers also have to worry about whether an extra $600 of work in one home will leave too little money for another. Because the costs and energy savings of efficiency investments vary from area to area, both contractors and weatherization programs must be able to make their own estimates of the cost-effectiveness of efficiency investments. To help make these decisions, the Alliance to Save Energy has worked closely with weatherization programs around the country to modify basic investment principles to reflect the peculiarities of buying energy efficiency and to make the principles themselves more useful in day-to-day weatherization decisions.

Field research in Wisconsin and New York suggests that using guidelines like those laid out here can double the energy savings without increasing program costs. The savings increase because the guidelines help tailor the package of efficiency measures to each home and pick the most cost-effective measures across all the homes being weatherized by the program.

Measuring Savings

Determining whether an investment in energy efficiency is cost-effective means making certain that the benefits from the investment are greater than its cost. It is problematic, at best, to predict energy savings. But however imprecise engineering estimates of energy savings (or benefits) may be, it is better to work with the estimates systematically than to select weatherization measures blindly.

Both contractors and programs have the same difficulties predicting house-by-house differences in performance based on engineer estimates. In the audit, then, benefits should be measured for individual houses to the extent possible. Measurement includes testing the actual efficiency of the furnace and calculating air leakage rate. Use of a blower door for measuring the benefits of air sealing is especially important since this is the area in which weatherization benefits vary the most from house to house.

Programs or contractors who cannot use diagnostic equipment will have to rely on the experience of others. Look around and see what changes programs with blower doors have made in their methods. Over time, the use of blower doors by a large number of programs will result in a generalized sense of where to find the most cost-effective weatherization opportunities, and how much effort tends to pay off.

Harry Nelson

Even if you only save a half percent of your heating bill, it'll be worth it.

Mary Beth Zimmerman is Program Manager of the Alliance to Save Energy.

Tools for Comparing Costs and Benefits

The costs and benefits of energy efficiency measures are commonly compared in one of three ways:

- Simple Payback = $\frac{\text{Total Cost}}{\text{Annual Benefits}}$
- Net Present Value (NPV) = Total Benefits – Total Cost
- Benefit-to-Cost Ratio (BCR) = $\frac{\text{Total Benefits}}{\text{Total Cost}}$

All three methods rely on the same basic information: cost, lifespan, and annual benefits. (Only benefit-to-cost ratios and net present value, however, account for the difference in the current value of cash and its changing value over time. See the box below.)

What's the Difference?

Each of these tools tells you something different about the measures you must select from:

- Simple payback provides some cash-flow information by letting you know when the initial outlay will be repaid.
- Net present value tells you how much more benefits will be received than the investment costs.
- Benefit-to-cost ratio tells you how much benefit will be received for each dollar spent.

Discounting Future Benefits

To help weigh benefits and costs fairly, both NPV and BCR account for the fact that energy savings, like the returns from most investments, are received over a period of time, rather than all at once. Both NPV and BCR use the standard procedure of subtracting from the benefits any return that could have been received from an alternative investment. This is called "discounting."

Discounting indicates whether the homeowner benefits more from "buying" a stream of energy savings than from other uses of his money, such as earning interest at a bank. Even weatherization programs that cannot make alternative investments for their clients can still use discounting to ensure that the benefits they provide are *at least as good* as what the client could have received from the interest on a deposit.

Discounted benefits can be calculated easily with the aid of a $35 financial calculator. The most difficult decision is selecting a discount rate, the rate at which each successive year's benefits are lowered to reflect the delay in earnings (i.e., savings). Typically, commercial interest rates are used. For homeowner-purchased measures, we suggest discounting future energy savings by how much the homeowner pays to borrow money (the rate of interest for a home improvement loan), *less inflation.* Public or private non-profit agencies typically use a real discount rate of 5 or 7% (without inflation), although other rates could be used.

If investment funds are borrowed, the savings would have to be at least enough to cover interest charges. Either way, there is a "cost" to spending money now to receive benefits in the future.

—Mary Beth Zimmerman

Table 1 provides a sample calculation of simple payback, net present value, and benefit-to-cost ratio for six energy efficiency measures. The numbers shown are made up, but the calculations show that all three methods give different pictures of the individual measures. (Benefit and cost numbers, as well as discount rates, vary from area to area and no one set of numbers can be considered "correct.") Interestingly—and importantly—the different methods disagree about which measure is the most cost effective. For example, the furnace tune-up in Table 1 has a higher benefit-to-cost ratio than the wall insulation, but a lower net present value.

Table 1. Net present value and benefit-to-cost ratio for six weatherization measures.

	Storm Doors (2)	Insulate Attic	Replace Furnace	Insulate Floor	Insulate Walls	Tune-up Furnace
Initial Cost	$220	325	1,500	350	800	45
Lifespan (yrs)	10	20	18	15	20	3
Annual Savings	$25	60	160	45	100	43
Discounted Life Cycle Benefits	$ 188	680	1,722	439	1,134	121
Net Present Value	$ –32	355	222	89	284	76
Benefit-to-Cost Ratio	0.85	2.09	1.15	1.25	1.33	2.68
Simple Payback (yrs)	8.8	5.4	9.4	7.8	8.0	1.0

Using These Tools

Since the three ways of assessing costs and benefits give contradictory results, how can the most effective measures be determined? In general, use the benefit-to-cost ratio, except when indicated by the rules below.

Simple payback is the most widely used method of assessing costs because it is perceived to be the simplest. Unfortunately, simple payback is not a fair comparison of the cost-effectiveness of different measures since it does not give full credit for measures that continue to generate savings after the payback period. In an era of increasing concerns about energy use, these additional savings are too important to ignore.

Fortunately, both net present value (NPV) and benefit-to-cost ratio (BCR) do take all energy savings into account and in practice are just as easy to use as simple payback. Both methods also provide certainty about whether a measure is cost-effective or not.

- If BCR > 1, the measure is cost-effective.
- If NPV > 0, the measure is cost-effective.

Whenever BCR is greater than 1, NPV will be greater than zero, and vice versa.

Cost-effective measures may have different NPVs and BCRs, because each tool tells something different about the measure's performance. NPV gives an indication of the magnitude of overall savings, BCR an indication of the return on each dollar invested. NPV and BCR should be used together to help select the best package of investments for a home.

Selecting Measures

Used together, NPV and BCR provide the tools for selecting the package of efficiency investments best suited to any particular house. If you are a contractor, you can use these tools to illustrate why a recommended

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investment is sound. If you manage a public or non-profit weatherization program, you can ensure that your program is getting the most savings possible from its investments.

"Profit" for energy efficiency investments is total energy savings less total costs. The package of measures selected for any given home should generate as much profit or net energy savings as possible. Consider three factors—selecting individual measures, creating a package, and allocating resources among homes—when assessing your program's investment. In applying these tools, though, bear in mind that estimates of the net present value and benefit-to-cost ratio of weatherization measures are imprecise at best and that it will not always be possible to exactly meet each of the guidelines suggested below.

Selecting Individual Measures

Before the best package of weatherization measures can be put together, the cost-effectiveness of individual measures must be established. Two principles govern here:

Rule 1. Select those measures whose benefits are greater than their costs.

A measure is cost-effective if its NPV is greater than zero or if its BCR is greater than one.

Rule 2. Install only cost-effective measures.

While this statement may seem obvious, adhering to it is not always easy. Even non-cost-effective measures save *some* energy and therefore add to the total energy saved in the house. Consider, for example, the storm doors listed for the house in Table 1. They would cost $220 and save $125 a year in energy costs for the next 10 years. The discounted value of the storm door is about $188. The additional $188 in energy savings sounds good, but the net effect is a loss of $32.

It is also not wise to include a non-cost-effective measure like the storm doors in an otherwise cost-effective package. All of the weatherization measures for this house, including the storm doors, would cost $3,240 and have benefits of $4,243. The NPV of the total package, or the net return on the investment, is $1,003. (That is, $1,003 more than any other investment would have generated.) If we exclude the storm doors from the package, energy savings would fall to $4,055. But costs would fall to $3,020. The net return on the investment would *increase* to $1,035, $32 more than with the storm doors.

In short, the value of an investment rises by dropping any non-cost-effective components; this holds true for homeowners as well as program purchases.

Creating a Package

Once all cost-effective weatherization measures are identified, four more guidelines can be used to determine which measures work best together.

1. When two cost-effective measures cannot be physically installed at the same time, select the measure with the higher NPV.

In this situation, two (or more) measures, such as a furnace tune-up and replacement of the furnace are mutually exclusive. Often one measure will have both a higher NPV and BCR than the other measure and the choice is obvious. But if one measure has a higher NPV and the other a higher BCR, as illustrated below, the solution is not immediately clear.

	Furnace tune-up	Furnace replacement
NPV	$75	$222
BCR	2.68-to-1	1.15-to-1

Situations like this usually occur when low-cost, immediate-return items are compared to high-cost, long-lived measures. In the example, the furnace replacement would be selected because the $222 in net savings it generates will add more to the overall net energy savings (or profit) for the home than will the $75 from the tune-up (to the clear advantage of the homeowner's pocketbook).

2. If the savings from one measure affects the savings from another, select the measure with the higher NPV and then recalculate the savings of the other measure.

The savings from furnace improvements will depend on how well-insulated the home is; likewise, the savings from new wall insulation will depend upon how efficient the furnace is. Use a two-step process to avoid overestimating the cost-effectiveness of interactive measures.

If, in our example house, the furnace replacement had the higher NPV, it would be selected for installation first. The NPV of the wall insulation would then be recalculated using the new (higher) furnace efficiency, even though the furnace has not yet been physically installed. The wall insulation would only be chosen if its NPV remains greater than zero when calculated with the new figure.

3. Air infiltration should be reduced until further efforts are no longer cost-effective.

Infiltration reduction is often considered a priority weatherization measure, but in many houses there is virtually no limit to the number of cracks that can be filled or sealed. As a result, the funds available for other measures may be limited by the dollars used to pursue infiltration reduction.

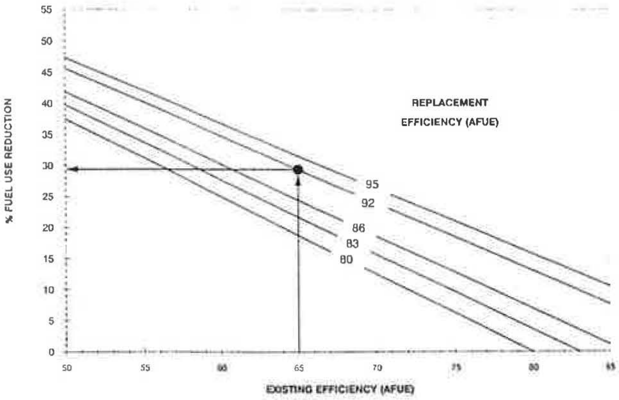
Whether physically implemented before or after other weatherization measures, the amount of infiltration reduction achieved should be determined by both the opportunities for energy savings and the costs (including labor costs) of additional work. This is the only way to ensure a balance between infiltration work and other measures. One way to approach the problem—most workable with a blower door—is to begin work on the areas of the home with the greatest expected reduction in air exchanges. Proceed on an hour-by-hour basis only as long as the new reductions in air exchanges are worth the additional hour's cost. It is important to be flexible, maybe spending an hour or two in one house and five hours in the next. Some blower doors can be programmed to calculate directly the cost effectiveness of each hour's additional work. For more on this technique, see *HE*, "Blower Door Guidelines for Cost-Effective Air Sealing," Mar/Apr '90, p. 34.

How to Determine the Benefit-to-Cost Ratio for Heating System Replacements

by Jeff Schlegel

Here's one way to determine when a natural gas heating system replacement is cost-effective. This procedure is designed to account for different conditions or circumstances and accurately predict the benefit-to-cost ratio. You can either follow the five steps using the figures where necessary or use the formulas to perform the calculations yourself. (This system is designed for programs bearing the entire cost of the heating system only; a homeowner replacing a defunct heating system can use the difference between a less efficient and more efficient furnace as the total cost.)

Step 1: Fuel Use Reduction (%)

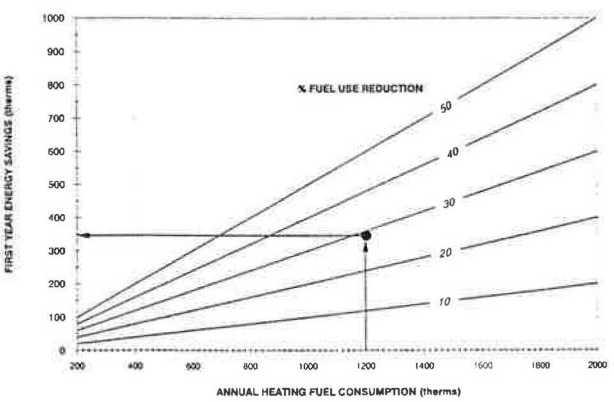


- Determine the existing efficiency (Annual Fuel Utilization Efficiency or AFUE) of the heating system. Select the AFUE of the heating system replacement. Find the fuel use reduction percentage.

$$\text{Fuel Use Reduction (\%)} = \frac{1 - \text{Existing efficiency (AFUE)}}{\text{Replacement efficiency (AFUE)}}$$

Note: Using steady-state efficiency rather than AFUE in Figure 1 gives a more conservative savings prediction, which is more accurate when compared to measured results.

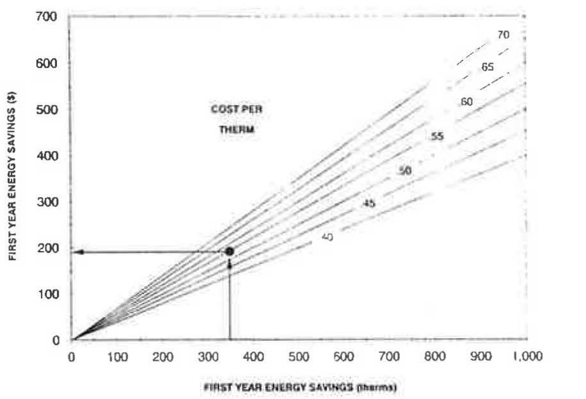
Step 2: First Year Energy Savings (therms)



- Determine the annual heating fuel consumption (therms). Baseload consumption must be subtracted. Heating consumption should be weather-normalized for greater accuracy. In addition, savings from more cost-effective shell measures being installed at the same time should be subtracted from the heating consumption before determining the savings from the replacement. Select the applicable fuel use reduction percentage (from Step 1). Find the first year energy savings in therms.

First year savings (therms) = Annual heating fuel consumption (therms) x Fuel use reduction (%)

Step 3: First Year Energy Savings ($)



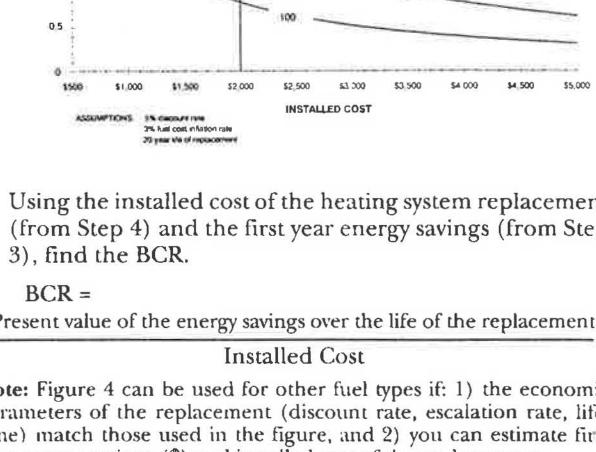
- Find the first year energy savings in therms (from Step 2). Select the cost per therm. Find the first year energy savings ($).

First year energy savings ($) = First year energy savings (therms) x Cost per therm ($)

Step 4: Installed Costs ($)

- Determine the installed cost of the replacement. Use a specific quote or estimate if you have one.

Step 5: BCR For Heating System Replacement



- Using the installed cost of the heating system replacement (from Step 4) and the first year energy savings (from Step 3), find the BCR.

$$\text{BCR} = \frac{\text{Present value of the energy savings over the life of the replacement}}{\text{Installed Cost}}$$

Note: Figure 4 can be used for other fuel types if: 1) the economic parameters of the replacement (discount rate, escalation rate, lifetime) match those used in the figure, and 2) you can estimate first year energy savings ($) and installed cost of the replacement.

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4. Do not weatherize a home at all if the net energy savings are not great enough to cover all of the extra costs of weatherization.

Weatherizing a house usually incurs costs in addition to the cost of installing the individual measures. We call these "walk-in costs." Contractors often reflect the costs of getting their crews on site and organized in a "set-up" charge or an additional fee for the first hour's work. Public or non-profit programs do not have fixed charges, but can still incur substantial costs in arranging for and following up on the weatherization of each individual house. In either case, the net savings from the efficiency investment could be wiped out by set-up and other additional costs. This situation will typically occur only when a house is already very well-insulated or when the need for repairs is so great that substantial extra costs are added.

Before the energy audit, there is no way to determine whether a home will be "worth" weatherizing, so audit costs will be incurred whether or not weatherization proceeds. Because audit costs are not recovered if the house is not weatherized, they are called "sunk costs" and should not be considered when deciding whether a full weatherization job is worthwhile. After the audit, the information gathered (however simple) can be used to decide whether the total benefits of cost-effective weatherization measures will be greater than the costs of proceeding further—the costs of the measures plus walk-in costs.

Allocating Resources Among Homes

The problem of allocating resources among homes is unique to weatherization programs that 1) are responsible for investments in more than one unit and 2) operate under a fixed budget. The fixed budget means that a dollar invested in one house is a dollar not available for another house, and deciding which house gets which investments is difficult. Some programs have a limit on the average amount spent per home. (For example, U.S. DOE regulations still require that Low-Income Weatherization Assistance Program subgrantees not average more than $1,600 per home, and that at least 40% is spent on materials, not labor.)

1. Invest to roughly the same level of cost-effectiveness in each home.

This approach will ensure different levels of expenditure for each home, meaning that more energy-efficiency dollars will be directed to the homes where energy improvements will have the biggest impact. This approach contrasts dramatically with approaches that fix the total amount spent on each house in advance or that select the same number of measures for each house.

The easiest way to ensure that investments are made to the same level of cost-effectiveness in each home is to purchase all measures with a BCR greater than one, as provided for in Rule 1. You can think of the BCR of one as the "floor" below which measures are not purchased. In some homes, three measures will qualify; in others ten. The number of homes a program can afford to weatherize will, in turn, depend upon the average amount invested in each home.

A higher BCR floor would result in fewer measures, on average, being purchased for each home, and thus more dollars available to weatherize additional homes. For example, the BCR floor could be raised to 1.5, and all measures meeting the cutoff could be selected. This floor is called the "BCR cutoff." A program selecting a BCR cutoff greater than one will purposely forego some cost-effective measures in some homes in order to increase the number of homes weatherized.

2. Adjust the BCR cutoff so that, over time, the desired number of homes are reached or any spending restrictions are complied with.

There are some trade-offs in selecting different BCR-cutoffs. A ratio of one-to-one will ensure that no cost-effective energy savings opportunities will be left uncaptured. A higher ratio will let a program with a limited budget reach more households in a given year (Figure 1) but not without reducing the average energy savings in each home weatherized. (It is possible to calculate the BCR-cutoff that maximizes program-wide energy savings for a single year's budget, but we do not present that detail here.) It's unlikely that any program would know off-hand how much average expenditures per house would change if the BCR-cutoff were changed. All but the smallest programs can get a feel for the magnitude of change by trying out a new BCR-cutoff on a sample of 10 homes. Before experimenting with different BCR-cutoffs, though, it is important to be already investing to roughly the same BCR in each house. Also, remember there is considerable uncertainty in the benefits amounts, which limits the amount of precision possible in the calculations.

EFFECT OF CHANGING BCR CUTOFF

When BCR ↑	# of homes weatherized ↑	and	amount spent on each home ↓
When BCR ↓	# of homes weatherized ↓	and	amount spent on each home ↑

3. The split between materials and labor costs required by the federal weatherization program can also be met with the use of benefit-to-cost ratios.

Instead of working from a single list, the measures offered by a program can be divided into two columns, one with measures that typically have a higher portion of labor costs than required, and one with a higher portion of materials costs. In each case, some of the measures will have a BCR greater than the program's cutoff, and some will have a lower BCR. A program spending too much on labor could use these columns to drop off those measures just above the BCR cutoff from the high-labor cost column and add those measures just below the BCR cutoff from the high-materials cost column. This is done by gradually increasing the BCR cutoff for high labor cost measures until the materials-labor split is met.

Because this approach is based on the cost-effectiveness of individual measures, it allows the materials-labor split to be met without any unnecessary loss of program energy savings. Programs capable of determining the BCR of measures on a house-by-house basis will be able to determine which high-labor cost measures are dropped and which high-materials cost measures are added for each house, but should use the same two BCR cutoffs for all houses.

Conclusion

The investment guidelines presented here can be summed up in one idea: let the energy efficiency investment made in each home be driven by cost-effectiveness, not a pre-determined idea of how much money should be spent. The principle holds whether you are a contractor advising an individual homeowner, or the manager of a weatherization program juggling the demands of a hundred homes a year. ■

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