A New Class of Retrofits: "Repair Indefinitely"

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ABSTRACT

This paper discusses an old issue: how to set the baseline efficiency and remaining measure life for retrofit energy efficiency measures. We focus on the special case of "Repair Indefinitely" measures, for which the remaining measure life may be extended indefinitely through repairs. We also discuss how and when the energy code is appropriately applied as the baseline. The paper describes a method for setting the baseline for retrofit measures that more closely represents the likely savings than does the code baseline assumption. It distinguishes between "Replace on Burnout" retrofits, Early Retirement" retrofits, and the important third type of "Repair Indefinitely" retrofits for long-lived measures that may never be replaced (or may only be replaced many years out).. This paper then shows that clear evaluation guidelines for the different kinds of retrofit measures can control the risk of unearned savings claims, and can increase both customer and program administrator incentives for pursuing deeper retrofit savings opportunities.

Background

Definition of "Retrofit"

For the present purpose, we refer to retrofits as actions that involve the replacement of existing building features or equipment (measures) with similar measures that provide the same or better service, along with improved energy efficiency. A simple example of a retrofit would be the replacement of an old, inefficient water heater with a new, efficient water heater. A more complex example would be the replacement of an opaque roof system, involving a waterproof membrane and a modest amount of insulation, with a new roof system that includes a new, cool roof waterproof membrane, increased insulation, skylights and daylight harvesting controls for the interior lighting system. In the former case, equivalent service (provision of heated water), is still provided, but at higher energy efficiency. In the latter, the water repellent function is retained, but the thermal performance is enhanced and the additional amenity and energy savings of daylight harvesting is provided. Clearly, the latter retrofit can afford deeper energy savings, but at higher cost and complexity. Calculating the total energy savings is also more complex, as we shall discuss further.

Size of Potential Retrofit Market

In the United States approximately 1.6 Billion sf of new commercial floorspace is added each year to the 72 Billion sf of existing floor space. [EIA 2003] The situation is only more dramatic in the housing sector with approximately 1.5 Million units being added each year to an existing housing stock of 111 Million dwelling units. [EIA 2005] With only 2.2% of the commercial building stock and 1.4% of the housing stock being added each year, deep societal reductions in energy consumption or greenhouse gas emissions in the building sector must rely heavily on retrofit programs.

General Program Evaluation Principles

Most energy efficiency programs are subject to independent evaluation to verify that the claimed energy savings are "real", and that the resources invested in the programs are well spent. The chief task of the program evaluator is to quantify the changes brought about by the energy efficiency program. This is the difference between what did happen due to program actions, versus what would have occurred without the program. Savings are differentiated between gross energy savings and net energy savings. Gross savings are calculated as the sum of the savings of all program participant actions relative to some assumed baseline. Net saving reduces this gross savings amount based on a number of factors with the key factor being free-ridership. Some fraction of the population would have installed energy measures even without program influence; if they also receive program incentives, they are free-riders and their savings are subtracted from the gross savings to arrive at the net savings. As we've just noted, the motivation of the party carrying out the retrofit is important in determining what would have happened absent the efficiency program. We can identify three primary motivations as they pertain to retrofits: forced retrofits, which are done of necessity such as equipment failure; self-directed retrofits, which are done without program encouragement and out of self-interest; and program-induced retrofits, which would not have happened without program support. It is the program-induced retrofits that are the target, and indeed the raison d'etre, of most retrofit programs. The other two types of retrofits would be deemed free-riders.

In any calculation of energy savings from a retrofit measure, the efficiency and energy use of the newly installed measure is compared to the efficiency and energy use of a baseline condition. It would be natural to assume that the baseline condition was the condition of the measure as it was found before the retrofit; a classic before/after comparison. Depending on the retrofit, however, it is often not so simple.

The Energy Code as Baseline

In many retrofit situations, especially in places where there are energy codes and standards, there is a different assumption: that the baseline is the level of efficiency and energy use required for the measure by the governing energy code. There are several reasons for this assumption.

First, many energy code requirements state that, upon retrofitting, a measure must be installed at the code level of efficiency. The rationale is that, if a building owner is going to the trouble to replace an energy measure, the replacement should meet a minimum standard. Further, there's a lost opportunity argument: if the replacement is not done with efficient equipment or materials, it is unlikely to be improved again for a very long time. The efficiency level of the code sets the baseline. This assumption makes sense for retrofits that the owner is undertaking because the measure has failed and must be replaced. It also makes sense when the owner is being proactive, recognizing that replacing an existing measure that has outlived its useful life, but is still functional, is worthwhile based on the savings to be realized. The minimum standard and lost opportunity rationales make sense, and that is why codes require retrofit measures to meet the standard.

The rationale breaks down, however, for some measures, when the owner chooses to repair the equipment indefinitely rather than undertaking the retrofit before failure. Then the inefficient equipment remains in place long past its useful life, wasting energy until it fails beyond repair and replacement is no longer optional. For a large fraction of the nonresidential building population, the owners make it standard practice to keep equipment and materials in place until they fail catastrophically. This can also be true of residential measures. Those owners should be the targets of most retrofit programs, because they represent the greatest opportunity to eliminate inefficient systems and to save energy.

Second, using the energy code as the baseline is convenient. The efficiency levels are well defined, making it relatively easy to establish the base energy use. The alternative would be to determine the efficiency of the old equipment or materials, as found prior to retrofit. This efficiency depends on the condition of the existing measure, which may not be something one can read from a label or look up in a database. Again, when the owner is doing a self-directed retrofit of a measure that has reached the end of its effective useful life, or when the measure has failed, it makes sense to use the energy code baseline. In these cases, retrofit efficiency programs encourage the choice of better-than-code efficiencies through technical assistance, upstream incentives and/or rebates. The code still provides the baseline, and the savings derive from the higher installed efficiencies.

Third, program evaluators often prefer the energy code baseline for retrofits, because of the first and second reasons. The energy code baseline minimizes the likelihood that savings will be claimed that would have happened anyway. The presumption is that, if the baseline is set lower than would have been required by code, then some of those savings would be free-rider savings and "don't count" as program accomplishments.

For all of these reasons, the energy code baseline is the "convenience baseline." It is not necessarily the true baseline, however. The true energy savings attributable to a retrofit are the savings that occurred because of the change in efficiency that <u>would not have happened otherwise</u>. The differences are illustrated by the following scenarios:

- **Retrofit: replace upon burnout.** If the equipment was replaced because it failed, and equipment replacement triggered a code-required minimum efficiency, then the savings attributable to the retrofit would be relative to the code baseline.
- **Early replacement.** If the program induces an upgrade of equipment that ordinarily would have remained in place because it still had some useful life left, then the savings associated with the program induced upgrade should be relative to the actual estimated efficiency of the older equipment being replaced, for the remainder of its useful life.
- **Retrofit: replacement beyond useful life.** Equipment that is still operating beyond its deemed useful life, is considered to be close to failure and would be treated like the replacement upon failure scenario (i.e. evaluated relative to the code baseline) [IPMVP 2009].

Thus the evaluation baseline for the replacement of an operational piece of equipment is different depending upon the age of the equipment. Equipment replaced before the end of its useful life is considered early replacement and older but operating equipment replaced after what is deemed its useful life is treated as a retrofit.

We have two major categories so far: retrofits, including replace on burnout or at the end of its effective useful life, and early replacements. These two are relatively straightforward and discrete.

Regardless of the scenario considered, there is a separate set of program savings attribution considerations associated with "free-ridership." A free-rider is one who would have done essentially the same upgrade without the program. These free-riders are more aware of the benefits of energy efficiency opportunities and may purchase higher efficiency products under retrofit conditions or may even undertake a self-directed early retirement without needing retrofit program support, usually based on economic or amenity motivations. Those retrofits, if the savings are claimed by a retrofit program, represent true free-riders, and their savings are not credited to the program. For purposes of this paper, we will set the free-rider considerations aside as a different topic, and focus on assessing program savings for program participants whose actions were impacted by the program..

Code Baseline as Barrier to Retrofits

The simplest kind of retrofit program rule is to treat all program-induced retrofits as high efficiency Replace on Burnout (ROB) retrofits. The savings are based on the energy code baseline efficiency, for the reasons discussed above. The problem with this approach is that many such measures will not prove to be cost effective from a retrofit program perspective. This becomes more true as energy codes become increasingly stringent. The beyond-code measures may be economically advantageous to the building owner, but the savings may not be substantial enough to justify program expenses and rebates. In that case, most owners will simply wait until the measure fails. It is likely that the only such beyond-code retrofits that will happen will be when there is an economically enlightened owner who seeks out the additional savings on his own. All of the other potential savings opportunities will be lost, because owners will simply do what the code requires of them when they replace on burnout, and there will be no program support for them to do better (it's not cost effective to do so).

If, on the other hand, energy efficiency programs aggressively seek to encourage building owners to retrofit inefficient older systems, then they need to pursue early retirement retrofits. To do that, efficiency programs must provide support and incentives to encourage this unnatural behavior among nonresidential building owners, and they must be able to cost justify those efforts. To be cost effective, programs must be able to claim all savings that would not have occurred without their help, and this means using the existing equipment efficiency (or inefficiency) as the baseline to calculate at least some of the savings.

We say "some of the savings," because there are some subtleties in this approach. Remember, there is a distinction between replace on burnout retrofits and early retirement retrofits. If a given piece of old, inefficient equipment has five years remaining on its effective useful life, then using the existing efficiency baseline for the first five years of energy savings is the right way to calculate savings; beyond that date of expected failure, the code baseline is appropriate. This is consistent with current evaluation approaches, so it will not be discussed further.

A New Class of Retrofits - "Repair Indefinitely"

The preceding discussion leaves out an important class of real-world retrofits, which we propose to name "Repair Indefinitely" retrofits. These are measures that would likely be kept in service long past their effective useful life, nor are they likely to be retrofitted without the inducements of an energy efficiency program.

In Repair Indefinitely situations, the owner has no intention of replacing the measure, and is likely to keep repairing and patching it up indefinitely. Typically, the measure becomes less and less efficient, compared to current practice, as it gets older and in poorer condition. A simple example is windows, which can last an incredibly long time as the glass is very stable – there are windows over 100 years old. These are the "never replace" measures, and they should be prime targets for retrofit programs (if we can get the baseline right).

Not all long-lived measures are "repair indefinitely" measures. For most, there will ultimately come a time when they fail and must be replaced (e.g. for water heaters or furnaces), which puts them in the "Replace on Burnout" (ROB) category, with a long effective useful life.

Identifying Repair Indefinitely measures, and distinguishing them from measures that will ultimately fail and become ROB measures, would entail three criteria:

1. The failure mode is not catastrophic - it can be kept in service indefinitely through repairs and part replacements;
2. There is a history of rebuild/repair rather than replace; and
3. It is far cheaper to rebuild/repair than to replace

There are many examples of measures that meet these criteria:

- Large electric motors - these can be rewound and refurbished, and typically are;
- Large pumps and fans - these can be difficult to replace with more efficient units;
- Chillers - these can be rebuilt and repaired, typically extending the life of the equipment by 10 years or more, and due to the complexity and cost of replacement, they typically are;
- Lighting fixtures - for spaces that are seldom renovated, such as classrooms or churches, the fixtures can be kept in service indefinitely, even if lamps and ballasts are updated; and
- Windows - typically last the lifetime of the building and are seldom replaced, even though broken panes or occasional broken sash may be repaired

Program Design to Minimize Free-Ridership

For all of these types of Repair Indefinitely measures, the default baseline assumption is the current energy code, which specifies minimum efficiency levels for these when they are replaced. The problem is that the "would have happened" case is NOT to replace the equipment. Calculating savings on the assumption that they would have been replaced, and so using the code as the baseline, seriously undervalues the retrofit. This means that program support and assistance can only be justified at a very low level, and dramatically reduces the likelihood the retrofits would be done.

Of course, these kinds of retrofits do sometimes happen as self-directed retrofits by enlightened owners. In a retrofit program, these would be free-riders. It is a matter of program design and documentation to minimize the level of free-ridership, and to capture the true Repair Indefinitely retrofit opportunities. One possible program design strategy would be to simply anticipate a portion of free-riders, and to set incentive levels and services so that the program is still cost effective. Another program design strategy would be to offer lower level incentives to all customers (assuming an ROB code baseline), and to offer the higher Repair Indefinitely incentive levels to customers when it is clear that they are not going to act without greater support. Of course, this decision would need to be well documented in the program records to ensure that evaluators do not retrospectively decide the participant was a free-rider.

These are strategies for maximizing retrofit program savings, while minimizing evaluation risk for the program managers. This is important for portfolio managers and for policymakers, to ensure that programs are demonstrably cost-effective. It is also, therefore, necessary in order to achieve deep energy savings from retrofit programs, in accordance with aggressive energy savings targets and greenhouse gas reduction goals.

Complex Example - Skylighting Retrofit

A more complex example of the Repair Indefinitely retrofit measure involves adding a new building efficiency component as part of the retrofit, rather than simply replacing a measure. For example, a retrofit could replace an opaque roof system with a new roof system that includes skylights and daylight harvesting controls for the interior lighting system. Not only does this retrofit improve the performance of the existing roof system, it improves the overall building efficiency by bringing in daylight to replace a portion of the electric lighting energy through the use of daylight harvesting controls.

This brings up several issues for counting and crediting savings. Some of these are related to code requirements. There is no code requirement to add skylights to a building. However, if one does add skylights, then the building energy efficiency code requires that photocontrols be added for daylight harvesting. This is because skylights, by themselves, don’t save energy, but skylights plus photocontrols do. So, again, the code would require the photocontrols, but in this case the skylights and the photocontrols would never be installed. So the “would have happened” case is no skylights and no photocontrols.

Under current lines of reasoning, if skylights are added then the photocontrols are code required, thus the baseline for comparison would be skylights and minimally complying photocontrols. Our recommendation is that the baseline for this measure be the existing building without skylights and photocontrols, as that would represent the state of affairs without the efficiency program. The energy savings is the savings from skylights and photocontrols as compared to no skylights for the expected useful life of the skylights. This new evaluation approach would allow a type of energy efficiency measure that would significantly expand the economic potential of additional energy efficiency opportunities; measures that, under default evaluation rules, may not be not economic to promote as part of an energy efficiency program.

This example is timely, not just for California which has had daylighting requirements for skylit spaces since the 2005 Title 24 building efficiency standards, but also for states that make use of the ASHRAE 90.1 building efficiency standard. The soon to be published ASHRAE 90.1-2010 building standard also requires photocontrols for the daylit area under skylights.[1]

[1] Photocontrol requirements in skylit areas were adopted in ASHRAE 90.1-2007 addendum d

Potential Savings from Skylight Retrofit Program

An example skylight retrofit program not allowed by existing evaluation rules gives an insight into the magnitude of additional program opportunities that would be available given a careful revisiting of the issues associated with end of useful life and especially consideration of the Repair Indefinitely class of retrofits. The program savings are calculated based upon minimally meeting the code requirements. However the code requirements are fairly well optimized so that additional savings would be small compared to the savings of complying with the code.

If this program retrofitted only ¼ of the 550 Million sf [Itron 2006a] of existing warehouses in California to the code minimum levels of skylights this would save approximately 186 GWh/yr of electricity.[2] This program would also result in a slight increase natural gas energy consumption by 0.29 Million therms due to reduced internal gains associated with turning lights off and the higher thermal transmittance of skylights as compared to. the opaque roof area they replace.. Only ¼ of the current building stock is considered because some fraction of warehouses already have skylights and of the remaining warehouses only some of the building owners will agree to participate. Savings are likely larger since there are other building types that could also benefit from this type of skylighting program such as big box retail, gymnasiums, etc.

If one used a 3 times source energy multiplier for electricity relative to natural gas the calculated electricity savings is 66 times greater than the added natural gas consumption. The additional natural gas consumption would increase carbon dioxide emissions by 1,653 tons per year while the electricity savings would decrease carbon dioxide emissions by 111,720 tons per year for a net reduction on CO2 emission by 110,067 tons per year.[3] If this program were expanded to the entire United States, the savings would be approximately 10 times larger.

Determining Existing Measure Efficiency

One of the challenges of the Repair Indefinitely class of retrofits, and of calculating measure savings, is determining the existing measure efficiency, which we propose as the proper baseline. Typically older equipment has fouling factors on heat exchange surfaces, induction motors can lose their efficiency after a number of rewindings, lighting fixture efficacy is not labeled, etc. The nature of existing equipment efficiencies are not necessarily well known unless they are measured, which is expensive unless sampling is used to reduce measurement costs (i.e. sample a fraction of the equipment being replaced.) Despite these difficulties, the problem is not really different from the problem of measuring the existing equipment efficiency in the more common, early replacement retrofit scenario. When it is not possible to directly determine existing efficiencies, reasonable engineering estimates can be made.

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[2] Savings calculated extracted from SkyCalc (Heschong & McHugh 2000) energy simulations.

[3] Source: Table 1, Appendix B page 2, Initial Study/Proposed Negative Declaration for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings September 2003 P400-03-018 http://www.energy.ca.gov/reports/2003-09-12_400-03-018.PDF Values provided by the CEC System Assessment and Facilities Siting Division. Emission multipliers used were 115 lbs CO_2 per MMBtu of natural gas and 1,200 lbs of CO_2 for each MWh of electricity consumption.

Conclusions

A policy decision that removes program development barriers to deep efficiency improvements in existing buildings is critical for meeting Greenhouse Gas reduction and energy savings targets. With new construction adding only 1-2% per year to the area of building stock, it is clear that any realistic plan for major reductions in overall energy consumption in the building sector must include deep efficiency improvements in existing buildings. Energy codes are becoming increasingly more stringent, which has a positive impact on the energy savings from new buildings and from retrofits that are planned without utility intervention. However, for utility programs designed to motivate retrofits which ordinarily would not occur, the stringent code baselines result in substantially smaller deemed savings than the full energy savings impact of the program. This code baseline has hindered or prohibited the development of programs that could be impacting some of the least efficient buildings.

This paper has argued for broad acceptance of a new class of retrofits, the Repair Indefinitely retrofit. We have argued that these retrofits should use the existing measure efficiency as the baseline when calculating savings, rather than the energy code required efficiency (even when such requirements exist). We have proposed rules for deciding whether a given retrofit would qualify for this special treatment by identifying a method for determining that the measure would typically be kept in service indefinitely. We have argued that this special treatment is necessary if deep retrofit savings are to be achieved in existing buildings; else these measures would not be installed and programs would not be able to provide sufficient inducements to get them installed.

To make the Repair Indefinitely class of retrofits a permanent fixture in the energy efficiency portfolio, policymakers and evaluators must agree that the class exists, must accept the definitions, and must permit program designers to develop program strategies to pursue Repair Indefinitely measures with vigor and with rigor. If adopted, this new evaluation policy would expand program opportunities to areas that are effectively off limits. Skylighting is but one of these opportunities; however, if the skylighting retrofit opportunity were pursued for just ¼ of all warehouse space in the United States, the electricity savings could be in excess of 1 TWh/yr.

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