# BEYOND PAYBACK: A COMPARISON OF FINANCIAL METHODS FOR INVESTMENTS IN GREEN BUILDING

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## ABSTRACT

*The green building movement is growing rapidly. Economic analysis of financial, other tangible, and intangible costs and benefits can help to sustain the movement over time. This purpose of this paper is to compare and contrast four methods of economic analysis to support green building decisions, and to identify the strengths, weaknesses, data requirements, and research needs associated with each. Five green features from a project in California are used to illustrate the methods and issues. The features are representative of the types of challenges building developers and designers face. The specific data used is illustrative, and the pattern of results across methods and examples is generally applicable. The more advanced financial calculations provide essential information for overcoming financial obstacles such as split incentives or excessively high hurdle rates for green investments.*

## INTRODUCTION

Green building is taking off around the world, as demonstrated by the creation of this journal and the explosive growth of the US Green Building Council (USGBC) and similar entities internationally. As of 2004, nearly 2000 commercial buildings in the US had either received or expressed intent to apply for certification under the Leadership in Energy and Environmental Design (LEED) rating system created by the Council (USGBC, 2004). Variations of LEED for remodeling of commercial buildings, for new core and shell[2] commercial projects, and for residential projects, are planned for release in 2005 and 2006. The National Association of Homebuilders (NAHB, 2004) reports that 13,000 homes were built in 2002 that complied with local green building guidelines, as compared with about 19,000 between 1990 and 2000.

This is a hopeful sign as human populations and economies continue to grow, and the associated environmental stresses they create are amplified by that growth. As Ehrlich et al. (1977) pointed out long ago, technological advance has been the primary factor in human history that offsets the environmental impacts of growth by making possible cleaner production and consumption. Such advances in the building sector have potentially significant environmental benefits since over 65% of total US electricity consumption and over 36% of total primary energy use takes place in buildings (EIA, 2001a). Over 47 billion gallons of water are used each day in the US for non-industrial building related activities (Hutson et al., 2004), and about 40% of global raw material use is building-related (Lenssen and Roodman, 1995).

Of course reduced consumption, created voluntarily through the choice of simpler lifestyles and smaller homes (see Gauer and Tighe, 2004; Susanka, 1998 and subsequent books), is another powerful beneficial trend that may reduce impacts. Average home sizes have increased from 1500 square feet in 1950 to 2272 square feet in 2003 (NAHB, 2004), and home improvement has evolved from a niche market for small contractors and a few hobbyists into an industry that single handedly supports numerous chains of “big box” home improvement centers. But this trend might not continue. A NAHB survey, “What 21st Century Home Buyers Want,” (summarized in NAHB, 2004) found that respondents were almost evenly divided between those who would prefer a larger home with fewer amenities or a smaller home with higher quality and amenities. Fifty-one percent opted for size; 49% for quality.

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[2] LEED certification historically has been available only for commercial projects that are ready to occupy. But much of the commercial market is core and shell construction, with internal walls and finishes installed as tenants agree to lease space.

Green building techniques cannot fully offset the environmental impacts of relentless upsizing and consumption-at-home. But these techniques are critically important nonetheless. If widely adopted, they could significantly reduce pressure on the environment and buy time for change in social attitudes toward consumption. There are, however, some significant obstacles to the adoption of green building techniques. This paper addresses one of the largest of those obstacles: a poor understanding of the economics of green building decisions. This obstacle is not just a misperception that green building is more expensive. There is also confusion about the economic methods that are most appropriate to use and a lack of transparency in the economic claims made by some supporters of green building. Architects, engineers, economists, and developers use different economic language and methods. This paper helps to create a common language and understanding of the economics of green buildings by comparing and contrasting four methods.

## POINT OF DEPARTURE

### *Literature*

The economic literature relevant to green building decisions is extensive. There are numerous finance or engineering economic textbooks (e.g., Riggs et al., 1996) that explain how to make decisions based on financial methods involving time value of money, incremental cost, sunk costs, return on investment, hurdle rates, and so forth. There is a related but more mathematically demanding economic literature that addresses more subtle benefits like the value of a view or good air quality, either in the neighborhood or in the building itself (e.g., Freeman 2003).

There are also a number of papers that specifically address some of the financial issues associated with green building, including factors such as productivity, health, and other quality of life benefits (e.g., Matthiessen 2004, Steven Winter Associates 2004, Kats 2003, Xenergy 2000, Fisk 2000, Heerwagen 2000, Heschong Mahone Group 1999, Nicklas and Baily, undated; Wilson et al., 1998). Each of these papers, however, has a different question in mind and uses a different method to address that question. For example, Matthiessen surveyed LEED certified commercial buildings and determined they have per square foot costs of construction that are difficult to distinguish from similar commercial buildings without green features. Steven Winter Associates estimated construction costs for two categories of US Federal buildings and found they would be only slightly higher (0–8%) for LEED certified designs as compared with current General Services Administration construction requirements. Both of these studies look only at capital costs.

Kats found that green buildings constructed by the State of California more than justify their average incremental capital costs through energy and other readily quantifiable operational cost savings (e.g., reduced water bills). In addition, the productivity benefits of green commercial buildings are relatively very large; on the order of ten dollars of net present value benefit for each dollar of additional capital cost spent to green the work space. The Xenergy analysis for the City of Portland used a similar net present value lifecycle method and found that readily quantifiable operational savings (e.g., energy and water use) can more than offset incremental capital costs. That analysis, however, was a retrospective, conceptual learning exercise to assist the City in the future by examining three facilities that had already been constructed without green building features.

These studies offer little guidance to architects, engineers, builders, or owners as to which green features are economically desirable. They do not describe the financial methods available and explain when each is best to use. Sometimes they do not clearly explain who benefits and who pays for each green feature, a critical issue for green building finance. All too often, government or wealthy individuals have built demonstration buildings that fail to catch on widely because these types of details have not been addressed fully and transparently. This paper fills these gaps in the green building economics literature, with specific examples to illustrate the methodological issues.

### *Focus of this Paper*

One paper cannot address the full range of economic topics relevant to green building. Discussing a few economic definitions will put this paper and its contribution in context. First, costs and benefits can be either *tangible* or *intangible*. By definition, tangible costs and benefits have been quantified; intangible ones have not (Tietenberg 2000). For example, the reduced maintenance costs associated with rubber versus vinyl resilient flooring in commercial applications is a tangible benefit, while the environmental benefit of less water pollution from less production of vinyl-based flooring is usually not quantified and is therefore usually an intangible benefit. Most economists believe that all costs and benefits can be quantified in principle but not in practice. One can think of intangible costs and benefits as qualitative factors that may be very relevant to a decision process, but that have not been quantified yet.

Second, quantified costs and benefit can be *financial* or *other tangible* values. Extra insulation in a home is a financial cost that will create a financial benefit (lower utility bills). In contrast, the financial cost of a recycled content material might not create financial benefits. For example, there may be tangible benefits for society such as less environmental damage from less resource extraction and less waste disposal, but unless these benefits can be described as specific cash flows to or from specific agents (individuals, businesses, or government agencies), they are not financial costs or benefits. But if their dollar value has been estimated, some *other tangible* benefits exist.

In *full cost accounting*, economists attempt to account for all costs and benefits: financial, other tangible, and intangible. The intangibles are often listed and acknowledged although numbers aren't assigned to them. Imperfect estimates of other tangible and financial costs and benefits are made, and tallied. To the extent possible, those who bear these costs and benefits are identified, because every cost or benefit accrues to someone, eventually (to as yet unborn persons in some cases). But as a practical matter, full cost accounting is rarely if ever possible.

An example is useful because it shows that the financial methods this paper will focus on are only part of the economic picture. Many green building projects specify concrete containing flyash, a waste product. Portland cement manufacture is very energy intensive (Worrell et al., 2001), which in turn creates air pollution and greenhouse gas emissions. Replacing some cement with flyash reduces these harms, creating a tangible benefit to someone, somewhere. Similarly, mixing flyash with Portland cement chemically stabilizes it, reducing the risk of water quality problems if the flyash were landfilled. Flyash concrete mixes are typically stronger than 100% Portland cement concrete, a potential benefit in earthquake country.

A project in the San Francisco Bay Area would have involved \$6,510 of conventional concrete in a pier and grade beam foundation. Specifying 50% fly ash content reduced cement purchase by \$3,255, although total spending for concrete work including labor increased by \$1,080. According to the Carnegie Mellon University Green Design Institute 2005 online economic input-output life cycle assessment model (www.eiolca.net), spending \$3,255 less on cement creates an air pollution and greenhouse gas benefit of \$842 to people somewhere. The model is not capable of estimating the potential water quality or strength benefits. The project owner faced a financial cost of \$1,080 in order to create an *other tangible* benefit of \$842 that the owner shares in negligibly,[3] and three *intangible* benefits: water quality protection, strength, and a good feeling or reputation benefit for the owner.[4]

Many non-financial benefits and costs exist. They can be decisive in green building decisions. Nonetheless, this paper focuses on financial methods because discussions of *other tangible* and *intangible* economic values are more productive when the *financial* values have been clarified first.

## METHODS AND EXAMPLES OF FINANCIAL ANALYSIS

There are four commonly used methods for analysis of financial costs and benefits. The payback method is very simple but is often misleading. More complicated methods such as levelized cost, relative net present value, and rate of return provide better answers but require more information and are often misunderstood. The more complicated methods also offer important practical guidance from which most analysts will benefit. This section briefly describes the methods and applies them to five features in an ac-

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[3] Unless the owner were directly downwind of a cement manufacturing plant, which is not the case here.

[4] An anonymous reviewer pointed out that producing flyash has social costs such as air emissions from coal burning. But since using flyash in green buildings does not affect the amount of flyash that is produced, this cost is not attributable to the green building feature.

tual residential project in California. Tables 1, 2, 3a, 3b, 4a, and 4b, which appear after the discussion of examples below, summarize the numerical application of the four methods to the five features. The analysis assumes that all costs and benefits over the various planning horizons (10–40 years) are borne by one agent, a common assumption. The world is often different, however, and this important point is discussed in the concluding remarks.

The examples have been chosen to address some of the most common problems and issues that arise in financial analysis of green features, regardless of whether the structure is residential or commercial or the context is new construction or remodeling. These include fixtures or appliances that will save money on one or more utility bill; passive quasi-structural features like more insulation in sidewalls; features that many are interested in but that are difficult to justify financially (solar electric in this case, but rainwater cisterns in Australia and other examples abound); features that improve health or productivity; and features that are more durable but do not save on utility bills or improve health or productivity. Even if different data and assumptions were used, the pattern of results illustrated by the tables would not change.

The discussion of each example at the end of this section draws out the advantages and disadvantages of the methods and some of the design techniques that can be used to improve financial performance. The more complicated methods have the disadvantage that they require additional data, including best estimates of cost or price trends. Their advantages, however, are significant and well worth the additional effort. First, they better account for the time value of money. Second, the relative net present value and internal rate of return methods provide information that is essential if one wants to evaluate green features as financial investments.

## Methods

***Simple Payback.*** The simple payback method divides the *incremental capital cost* of the green feature by the first year financial benefit of the feature (Table 1). The incremental cost of "green" should be separated from the *total capital cost* of a feature, if a non-green feature would be built anyway. Also, the first year financial benefit is not always obvious. A device that saves hot water, for example, will reduce water and energy bills. A device that saves pressurized water might also reduce pump maintenance expenses. A solar electric system with time of use metering will have very different first year benefits than with standard metering.

***Levelized Cost.*** The levelized cost method compares the cost of conserving physical units of something (e.g., units of natural gas) with the cost of purchasing those units from a utility (Table 2). Unlike the payback method, it accounts for both the useful life of the green feature and the rate of interest an investor must pay (or forego) if they choose to invest. This means that durable features will be seen as more economic than short-lived features even if they have the same capital costs and first year benefits, a significant advantage over the payback method. Equation (1) is used to calculate levelized cost:

$$(1)\quad LC = \frac{ICC \times AF + \nabla O\,\&\,M}{ES}$$

$$(2)\quad AF = \frac{r \times (1+r)^n}{(1+r)^n - 1}$$

where LC is levelized cost; ICC is incremental capital cost; AF is the amortization factor; r is the interest rate; n is the useful life of the green feature; $\nabla O\&\,M$ is the first year change in operating costs[5]; and ES is the equivalent service provided, for example, units of natural gas conserved.

The levelized cost method also has a drawback: it does not account for future changes in utility prices or other costs. This can be seriously misleading over longer time frames because inflation alone will cause prices to rise while payments on a fixed rate loan will not rise.[6] Even if prices rise less than inflation, any positive increase will make the green feature more desirable over time. The levelized cost method will sug-

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[5] Excluding financial savings from equivalent services provided. For example, if the denominator in the equation is therms of natural gas, delta O&M will exclude changes in spending for natural gas. It will include other changes in O&M for a gas appliance, and changes in spending for other commodities like electricity or water if the green feature has an impact on those as well. See Gleick, et.al., Chapter 5, for a complete discussion and more examples.

[6] If a variable loan rate is involved, one should assume an average rate over the life of the loan.

gest that a feature is undesirable which conserves natural gas in the first year at higher cost than one could purchase gas from a utility, even if it would conserve so much gas in later years when utility prices are higher that it is well worth investing in today.

Furthermore, some green feature decisions do not involve utility prices. Composite decking and roofing materials made from scrap plastic and wood, for example, cost more than redwood decks (the material of choice in California) or asphalt roofing shingles (used in 80% of new residential construction in the US), but have longer lives and lower maintenance expenses. The levelized cost method can be applied to these situations, but doing so either omits future maintenance and replacement expenses (as in the roofing example in Table 2), or would be more complicated than using the relative NPV method.

***Relative Net Present Value.*** The relative net present value (NPV) method (Table 3a) explicitly accounts for future price changes and other costs by listing expenditures and revenues in each year over a planning horizon for each alternative (Table 3b). All figures should be in nominal dollars—the dollars of the year in which they occur. One can list either total costs for each alternative—which is sometimes more transparent—or omit costs that are the same for both alternatives. The results will be the same either way. The NPV of the alternatives is calculated and compared. The lower cost alternative is desirable. Spreadsheets calculate NPV and textbooks provide formulas, so they are omitted here.[7]

***Internal Rate of Return.*** Finally, the data used in the relative NPV method can be manipulated to calculate an internal rate of return (IRR) (Table 4a). Again, spreadsheet programs perform this calculation and many textbooks describe it, so the math is omitted here. The relative method shows the annual cost of each alternative in separate columns (Table 3b). The IRR method combines the two alternatives to obtain the net spending or revenue impact of the green feature in each year of the planning period (Table 4b). This typically involves spending more at first but less later.

The IRR of the net spending column can be compared with the interest rate on borrowed funds or the rate of return that is possible from other investments. If the IRR is higher than the interest rate, one can make money by borrowing and investing in that green feature. But suppose the property owner can earn more on incremental capital investments than the rate of interest they will pay on borrowed funds for this project? In that case, one should compare the IRR with the rate of return on the investor's best possible alternative investment. If the IRR for a green feature is higher than that rate of return, the green feature is an even better investment.

## Discussion of Examples

***1.75 Gallon Per Minute (gpm) Showerhead.*** The example project included 1.75 rather than standard 2.5 gpm showerheads. The actual incremental cost was \$10, but \$30 is used in this paper to reflect the higher price of some models. First year water savings were estimated at 1,971 gallons based on a national average of 7.2 minutes of use per showerhead per day (Aquacraft 1999). At \$1.75 per hundred cubic feet of water (ccf), this amounts to a first year benefit of \$4.60. If only water were saved, this yields a payback of 6.5 years, which appears undesirable based on a five year or less payback criterion found by NAHB (2004) in a survey of homebuyers. However, shower water is nearly always hot, so energy is also saved. At an average temperature rise of 50 degrees Fahrenheit, a 60% efficient water heater and distribution system, and natural gas at \$0.98 per therm, first year energy savings would amount to about \$13.60. The combined first year savings of \$18 yields a payback of 1.7 years, well under the desirability threshold.

The example shows that even the simplest method can be used incorrectly, leading to a misleading result. Failure to account for all of the financial benefits of an appliance is an elementary mistake. But it applies to many features, not just appliances. Water based acrylic and urethane sealers, for example, have health benefits that may be accounted for, but what of the potential labor savings from being able to work in adjacent spaces sooner? Some resilient floorings in commercial applications reduce maintenance costs and improve indoor air quality. Even if only one benefit can be quantified today, research to quantify the other is important to pursue.

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[7] In fact, the help discussion of the NPV function in the Excel program provides the relevant formula.

The levelized cost of the ultra-low flow showerhead is negative because the energy benefit is so large. A negative levelized cost means that even if water were free, the energy benefits justify the green feature. This is not a surprising result. It is precisely why the National Energy Policy Act of 1992 (rather than a water policy act) mandated that all showerheads manufactured in the US could use no more than 2.5 gpm. The example here shows that it may be time to tighten that standard.

The relative net present value method shows that although the showerhead costs only $30 or less it is estimated to be worth more than twelve times as much ($153). A person who will pay the utility bills for that showerhead for its ten year life should be willing to pay up to that amount for the showerhead. If the person pays only $30, they will earn 63% per year on the investment for 10 years in a row. These figures are affected somewhat by the 3% and 5% rates of inflation in natural gas and water, respectively, that were used based on credible studies and surveys (CEC 2003b; Raftelis 2004). Of course these assumptions are subject to dispute; but changing them will not affect the conclusion that a very simple green feature with a high rate of return is not being implemented in many cases because its readily quantifiable financial benefits are not fully recognized.

***Additional Wall Insulation.*** The example project included 6-1/4 (six and one-quarter) inch structural insulated panel (SIP) walls rather than 4-1/2 (four and one-half) inch SIP walls. This cost $1,500 more, but increased the R-value of the wall by about R-8, which creates a $93 first year benefit based on natural gas heating with a 92% efficient furnace and air conditioning at a coefficient of performance of 3.5, 3500 square feet of wall surface, 3163 heating degree days and 500 cooling degree days per year, 500 watts required to run the furnace fan for each of 135 hours of estimated run time (calculated from the heating and cooling loads and rated capacities of the furnace and air conditioner), and natural gas and electricity purchase prices of $0.98 per therm and 0.12 per kWh (CEC 2003a).

A useful life of 30 years was assumed to be consistent with typical residential loan terms, but the walls will almost certainly last longer. Using a 30 year horizon, and even after accounting for natural gas heating, electric cooling, and the avoided cost of running the furnace fan, the payback period is 16.1 years and the levelized cost per unit of gas saved is more than 20% higher than one can purchase gas from the utility. The additional wall insulation looks financially undesirable. But the relative net present value method shows that it is not, because natural gas and electricity prices will rise in the future. The real price of gas is projected to remain constant (CEC 2003b) while the real price of electricity is projected to fall by 2% per year (Coito and Russo, 2003). But any real price change that is greater than the negative of the general rate of inflation (e.g., –3%), means that spending will increase each year in nominal dollars. Table 3b shows what this looks like for both wall thicknesses.

The NPV of the cost of the thicker wall is slightly lower, indicating it is worth building. The IRR of the investment in a thicker wall is 7%, which means that borrowing at 6% over 30 years to pay for the thicker wall is a worthwhile investment because the saved utility payments will just repay principal plus interest on the additional amount borrowed. Of course the differences are small, so being wrong about future energy prices might mean the thicker wall is not worth[8] the extra expense. On the other hand, repeating the analysis over a 40-year time horizon increases the IRR to over 8%. In general, the example shows that the useful life of durable features is an important research topic, and that failing to account for future real price changes, even if flat or falling, can lead one astray.

***Solar Electric.*** The example project included a 2.8 kilowatt (KW) pole mounted solar electric system that cost $9,500 to install after rebates from the California Energy Commission and State and Federal tax credits. The first year benefit for analytical purposes was $752 based on actual production of 4,062 kilowatt-hours (kWh) during its first year of operation, and a utility price of $0.185 per kWh under a standard residential schedule with marginal electric

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[8] Of course thicker walls have the intangible benefits of greater strength in earthquake territory and a quieter interior. They also have an other tangible benefit: less air pollution from power plants.

use between 131% and 200% of baseline.[9] The example project actually has a time of use rate schedule under which the produced kWh were worth about $898. The appropriate comparison, however, is between the solar electric system and the utility under the least cost, available rate schedule.

The payback of 12.6 years suggests the feature is highly undesirable while in contrast the levelized cost of $0.17 per kWh shows that the feature produces electricity for less than one could currently purchase it from the utility. The example also shows that the desirability of solar electric in an "add-on" installation depends on high marginal electric rates even after significant state and federal subsidies. What if these high rates decline in real terms over time? The relative net present value and internal rate of return methods show that the feature is still probably desirable. The alternative to solar electric in Table 3a is utility purchases at $0.185 per kWh initially, increasing at 1% per year thereafter (Coito and Russo 2003). If inflation averages 3% over that time frame, this is equivalent to a 2% decline in the real price of electricity each year. Even under this scenario, the solar electric system has an NPV of costs about $2,000 less than the no solar electric alternative. The IRR on the $9,500 investment is 8%, comfortably above the assumed 6% cost of capital.

The design path to financially desirable installations when marginal electric rates are so low that the rate of return is below the borrowing cost is to integrate solar electric with the building shell so that its incremental cost is much smaller than when it is added to a structure without integration. Commercial designers experienced with solar electric know this and have used solar panels as roof finish materials, exterior sheathing in steel and glass designs, or as covers over outdoor functions that required a cover anyway (e.g., parking canopies or shading devices over roof mounted cooling equipment). The incremental cost in these installations is greatly reduced, sometimes enough to justify reduced generation from panel locations that are not oriented south (in the northern hemisphere). This is a general point—developers and designers should minimize the incremental cost of green features as well as account for their multiple financial benefits, as noted above.

***Mechanical Ventilation and Filtration.*** One of the strongest drivers of green building is increased awareness of the health issues associated with poor indoor air quality. Numerous researchers have studied sick building syndrome (SBS). Fisk (2000) summarizes the literature and conservatively estimates that improved ventilation increases work time or productivity by about 2% in office buildings.[10] There is no comparable literature on the health benefits of ventilation in homes, so we used a 2% estimate for illustration. Median family income in the US is about $50,000, so 2% more work time or greater productivity amounts to a first year benefit of about $1,000 before taxes and perhaps $750 after taxes. This estimate is very crude for many reasons, not the least of which is that many employees enjoy paid sick leave. Nonetheless, the illustration serves as a proxy analysis for the many green building features that improve indoor air quality or health in general.

In the case study facility, a heat recovery ventilator was installed for about $2,000. It costs about $180 per year to operate, including electricity to run the ventilator and furnace fan in tandem and electricity and natural gas to cool or heat the outside air that is brought in. These figures depend strongly on peculiarities of the example used and should not be generalized to other situations. A $750 gross benefit less $180 of additional operational cost yields a first year benefit estimate of $570 and a payback of 3.5 years. The levelized cost of amortizing the ventilator over 15 years at 6% ($206) plus operating cost is $386 per year. The ventilator is much less expensive than missing 2% of work time or producing 2% less at work and thereby losing $750 of income.

The relative NPV and IRR methods indicate that the ventilator is worth nearly $5,000 more than it costs ($8,748 – $3,856 = $4,892), and earns a 31% IRR on the initial investment of $2,000. This is more than double the total NPV benefit of solar electric (about $2,000), and a much higher IRR since

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[9] The standard residential rate for purchases in excess of 200% of baseline levels is $0.227 per kWh, and peak summer power (12-6 p.m., M–F, May–September) on a time of use schedule is over $0.31 per kWh.

[10] Estimates by others average 4% according to Fisk, but he conservatively discounts by a factor of two.

the initial investment is less. The ventilator or other features that prevent SBS are very desirable investments if the estimate of benefits is even remotely accurate. The example shows that research to better quantify health benefits from green building features could have very high financial rewards, especially given that health care and housing costs are two of the most rapidly rising expense categories for US families and employers.

***Composite Recycled Content Roof.*** Some green products are durable but do not save energy or water or improve human health within the structure. Many recycled content products fit this category. Most of their benefits are intangible or other tangibles. But durability can create financial benefits by reducing future maintenance costs. This last example shows how the four methods evaluate a product of this type: a recycled content plastic/wood composite shake. The particular material involved cost $3,200 more to install than asphalt shingles. It has a 50-year warranty, but a life of 40 years is assumed for analysis. It has an infinite payback period since it creates no financial benefit in the first year, or indeed for decades.

The levelized cost method can be used to estimate the annual cost of producing a unit of service: in this case, a dry house. But the usual way of doing that comparison—amortizing the capital expense over a time frame and adding or subtracting other annual costs as shown in equation (1)—is misleading when the alternatives have unequal lives. The composite roof amortized over 40 years ($618) looks more expensive per year than the asphalt roof amortized over 20 years ($532).

The relative net present value method can account for the difference in useful life by including a replacement asphalt roof in the 21st year. The initial cost of installing that roof ($6,100) is inflated by 3% per year in Table 3b to reflect a constant real cost of asphalt roofing. Since labor comprises most of the cost of roofing and a second layer can usually be nailed over a first without tearing off the old, this is a reasonable assumption. Table 3a shows that the roofs have about the same costs once durability has been accounted for. Table 4a shows that the green feature is (marginally) desirable if capital is borrowed at 6%. The NPV and IRR method results are strikingly different than the payback and levelized cost results. If the composite roof has other tangible or intangible benefits (e.g., the indirect resource and environmental benefits of recycled content materials rather than virgin content materials), the more advanced financial methods help to see that a decision to proceed is primarily based on those benefits, not financial ones. In this particular case, the more advanced methods show that financial considerations are at least not strongly against the composite roof.

## CONCLUDING REMARKS

Financial analysis of green features via more than one method is worth the effort because it often changes the conclusions one would reach with simplified methods. Even if conclusions are not changed, different methods provide different insights. The relative

**TABLE 1.** Payback Examples

| Green Feature | Incremental Capital Cost (1) ($) | First Year (1) Financial Benefit ($/Yr) | Simple Payback (Years) | Appears Desirable? (2) (Yes/No) |
|---|---|---|---|---|
| 1.75 gpm Showerheads | $ 30 | $4.60 (water only) | 6.5 | No (3) |
| 1.75 gpm Showerheads | $ 30 | $18.00 (water and energy) | 1.7 | Yes |
| Additional Wall Insulation | $1,500 | $ 93 | 16.1 | No |
| Solar Electric | $9,500 | $752 | 12.6 | No |
| Mechanical Ventilation and Air Filtration | $2,000 | $570 | 3.5 | Yes |
| Composite Roof | $3,200 | $0 | Infinite (never) | No |

Notes: (1) Incremental and first year financial benefit calculations described in text. (2) Using a 5-year criterion per NAHB (2004). (3) Omitting the second (energy) benefit provides an incorrect answer; shown because it is a common user (not method) error.

**TABLE 2.** Levelized Cost Examples (1) (2) (3)

| Green Feature | Equivalent Annual Units of Service | Levelized Cost ($/Unit) | Utility or Other Cost ($/Unit) | Appears Desirable? (Yes/No) |
|---|---|---|---|---|
| 1.75 gpm Showerhead (4) | 2.64 ccf Water | –$ 3.53 | $ 1.75 | Yes |
| Additional Wall Insulation | 75.00 Therms | $ 1.20 | $ 0.98 | No |
| Solar Electric | 4,062 kWh | $ 0.17 | $ 0.185 (5) | Yes |
| Mechanical Ventilation and Filtration | 2% More Work Time or Productivity (5) | $386 | $750 | Yes |
| Composite Roof | One Dry House (5) | $618 (6) | $532 (6) | No |

Notes: (1) Incremental capital cost and first year financial benefits as in Table 1. (2) Interest rate of 6%. (3) Assumed useful lives of green features are: additional wall insulation, solar electric, 30 years; showerhead, 10 years; ventilator, 15 years; composite roof, 40 years, asphalt roof, 20 years. (4) Includes the energy co-benefit, as one should. Negative levelized cost means that even if water were free the feature would be cost-effective. (5) See discussion in text. (6) $9,300 and $6,100 capital costs, respectively.

**TABLE 3A**. Relative Net Present Value (NPV) Examples (1) (2)

| Green Feature | Baseline Features | NPV of the Cost of Green Features | NPV of the Cost of Baseline Features | Appears Desirable? (Yes/No) |
|---|---|---|---|---|
| 1.75 gpm Showerhead (3) | 2.5 gpm Showerhead | $ 30 | $ 153 | Yes |
| Additional Wall Insulation | 4-1/2 inch SIP Wall (4) | $25,100 | $25,314 | Yes |
| Solar Electric | No Solar Electric | $ 9,500 | $11,510 | Yes |
| Mechanical Ventilation and Filtration | No Mechanical Ventilation or Filtration | $ 3,856 | $ 8,748 | Yes |
| Composite Roof | Asphalt Shingle Roof | $ 9,300 | $ 9,340 | Yes |

Notes: (1) Table 3b illustrates the full calculation for two green features: additional wall insulation and the choice of roofing. (2) Incremental capital costs, first year financial benefits, assumed useful lives, and interest rate, as in Tables 1 and 2. Overall and natural gas inflation rates at 3% (CEC 2003b); water price inflation at 5% (Raftelis, 2004); electricity inflation at 1% (Coito and Russo, 2003) [that is, real electricity rates declining at 2% per year]. (3) Includes water and energy spending, as it should. (4) This comparison is between a 6-1/4 inch and 4-1/2 inch structural insulated panel (SIP) wall. SIPS contain a continuous foam core, so thicker walls have more insulation.

NPV and IRR methods in particular can help to overcome a major obstacle to green building features: the *split incentive problem*.

The tabular analysis assumes that all financial costs and benefits are certain and paid or received by one agent. Clearly this is often not the case. Buildings not only change owners but rental buildings often separate capital costs into shell and core improvements and split operating costs between owners and tenants. These realities mean that owners have inadequate incentives to invest in green features unless future owners or tenants agree to pay at least something for them. The split incentive problem between owners helps to explain the popularity of the payback method, which implicitly asks how long one needs to own a structure before one can sell it without loss to a subsequent owner who does not value the feature. An investor's *hurdle rate*, which an invest-

**TABLE 3B.** The Relative NPV Method Illustrated

| Year | 6-1/4 Inch SIP Wall Related Cashflow | 4-1/2 Inch SIP Wall Related Cashflow | Composite Roofing Expenses | Asphalt Roofing Expenses |
|---|---|---|---|---|
| 0 | $22,100 (1) | $20,600 (1) | $9,300 | $6,100 |
| 1 | $163 (2) | $256 (3) | $0 | $0 |
| 2 | $167 (4) | $263 (4) | $0 | $0 |
| 3 | $171 | $269 | $0 | $0 |
| 4 | $176 | $276 | $0 | $0 |
| 5 | $180 | $284 | $0 | $0 |
| 6 | $185 | $291 | $0 | $0 |
| 7 | $190 | $299 | $0 | $0 |
| 8 | $195 | $306 | $0 | $0 |
| 9 | $200 | $314 | $0 | $0 |
| 10 | $205 | $323 | $0 | $0 |
| 11 | $211 | $331 | $0 | $0 |
| 12 | $216 | $340 | $0 | $0 |
| 13 | $222 | $349 | $0 | $0 |
| 1 | $228 | $358 | $0 | $0 |
| 15 | $234 | $368 | $0 | $0 |
| 16 | $240 | $377 | $0 | $0 |
| 17 | $246 | $387 | $0 | $0 |
| 18 | $253 | $398 | $0 | $0 |
| 19 | $260 | $408 | $0 | $0 |
| 20 | $267 | $419 | $0 | $0 |
| 21 | $274 | $431 | $0 | $11,017 (5) |
| 22 | $281 | $442 | $0 | $0 |
| 23 | $289 | $454 | $0 | $0 |
| 24 | $297 | $467 | $0 | $0 |
| 25 | $305 | $479 | $0 | $0 |
| 26 | $313 | $492 | $0 | $0 |
| 27 | $321 | $506 | $0 | $0 |
| 28 | $330 | $519 | $0 | $0 |
| 29 | $339 | $534 | $0 | $0 |
| 30 | $348 | $548 | $0 | $0 |
| 31–40 | Not Evaluated | Not Evaluated | $0 | $0 |
| **NPV of cost (6)** | **$25,100** | **$25,314** | **$9,300** | **$9,340** |

Notes: (1) Material cost only; labor for wall installation was not affected by thickness. (2) $128 of natural gas for heating and $35 of electricity for air conditioning, furnace fan, and ventilator operation. (3) $202 of natural gas and $54 of electricity as in note 2. (4) In this row and all below, gas prices inflated at 3% per year and electricity price at 1% per year. (5) Assumes the real cost of roofing does not increase, but inflation is 3% per year. (6) 30 year time horizon for the walls, 40 year time horizon for the roof

ment must exceed, that is higher than the rate at which the investor can borrow, may also be a response to uncertainty about who will receive the future benefits of an investment.

The relative NPV method provides essential information with which to address these problems. It answers the question: "How large a premium is ideally reasonable?" For example, an ultra low flow showerhead will save $153, so the initial owner should ideally be willing to pay up to $153 more per showerhead. The premium that is reasonable is the number in the baseline column minus the number in the green feature column in Table 3a, plus the incremental capital cost of the green feature in Table 1. These

**TABLE 4A.** Internal Rate of Return (IRR) Examples (1)

| Green Features | Baseline Features | IRR of the Green Feature Investment | Appears Desirable? (2) (Yes/No) |
|---|---|---|---|
| 1.75 gpm Showerhead | 2.5 gpm Showerhead | 63% | Yes |
| Additional Insulation (3) | 4-1/2 inch | | |
| SIP Wall | 7% | Yes | |
| Solar Electric | No Solar Electric | 8% | Yes |
| Mechanical Ventilation & Filtration | No Mechanical Ventilation or Filtration | 31% | Yes |
| Composite Roof | Asphalt Shingle Roof | 6% | Yes |

Notes: (1) Uses data implicit in Table 3a or presented in Table 3b, manipulated as shown in Table 4b. (2) Determined by comparing each IRR with assumed borrowing cost and best possible rate of return for alternative investments of 6%. The composite roof is weakly desirable in the sense that it just matches the borrowing & opportunity cost rate of 6%. (3) Compares 6-1/4 inch and 4-1/2 inch structural insulated panel (SIP) walls. SIPS contain a continuous foam core, so thicker walls have more insulation.

premiums are not trivial, amounting to $23,509 for the five example features. Some common sense governs this calculation, although it is not obvious. Since all of the features are economically desirable (even if only weakly so), they must be worth at least as much as their incremental costs. Since some are worth more than their incremental cost, the total premium is more than the sum of incremental costs for desirable features.

Estimates of premiums, even when uncertain, provide a rational basis for conversation and negotiation. For example, a potential buyer can be shown the conditions under which each efficient showerhead is worth $153 less the water and energy savings already captured by the previous owner (e.g., subtract $18 after one year, subtract $36 plus inflation after two years, etc.). Tables like 3b can be divided at a point in time to show the NPVs for seller and buyer. Similarly, separate Tables like 3b (but which add up to the numbers in 3b) can be created for owners and tenants in order to see how costs and benefits are distributed under various lease arrangements.

In addition, the NPV and IRR methods help to identify those features that are worth an extra effort when split incentives or other obstacles exist. The estimated rate of return and premium on indoor air quality are large enough to justify negotiations between owners and tenants. Both can benefit from innovative solutions. In contrast, although the estimated rate of return on the showerheads (63%) is much larger than for the ventilator (31%), the number and dollars involved with showerheads in a residence is far too small to justify much time on the green-feature decision. That would not be the case, however, for a hotel or large rental apartment complex with dozens or hundreds of showerheads.

In summary, economic analysis of green building features should account for financial, other tangible, and intangible benefits and costs when possible. Full cost accounting that incorporates life-cycle analysis and the more advanced techniques of economics is a worthy goal. But there is much to be learned from financial analysis alone, so long as one uses a variety of methods other than simple payback and avoids the common mistakes illustrated in this paper.

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**TABLE 4B.** The IRR Method Illustrated

| Year | Thicker Sidewall Insulation | Longer Lived Recycled Content Roof |
|---|---|---|
| 0 | –$1,500 | –$3,200 |
| 1 | $93 | $0 |
| 2 | $95 | $0 |
| 3 | $98 | $0 |
| 4 | $100 | $0 |
| 5 | $103 | $0 |
| 6 | $106 | $0 |
| 7 | $109 | $0 |
| 8 | $111 | $0 |
| 9 | $114 | $0 |
| 10 | $117 | $0 |
| 11 | $120 | $0 |
| 12 | $124 | $0 |
| 13 | $127 | $0 |
| 14 | $130 | $0 |
| 15 | $134 | $0 |
| 16 | $137 | $0 |
| 17 | $141 | $0 |
| 18 | $145 | $0 |
| 19 | $149 | $0 |
| 20 | $153 | $0 |
| 21 | $157 | $11,017 |
| 22 | $161 | $0 |
| 23 | $165 | $0 |
| 24 | $170 | $0 |
| 25 | $175 | $0 |
| 26 | $179 | $0 |
| 27 | $184 | $0 |
| 28 | $189 | $0 |
| 29 | $194 | $0 |
| 30 | $200 | $0 |
| 31–40 | Not Evaluated | $0 |
| **IRR of Feature** | **7%** | **6%** |

Notes: (1) Combines data presented in Table 3b into net expenditure impacts by year. Negative numbers represent additional spending, positives are reduced spending.

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