Financial Analysis Techniques for Passive House

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Author's Note

Economic analysis is almost always dependent on assumptions about the future, and the results of such analysis are extremely sensitive to these assumptions. It is important, in the opinion of the author, for these assumptions to be “credible” as they cannot be proven accurate until after the fact. Credibility is found through published evidence, historical precedent and established rules of thumb, and conservative estimates are generally best, lest an overly optimistic prediction lead to disappointment.

This article is intended to be a primer on economic analysis techniques in the context of Passive House. The values used in the calculations herein represent typical values, but are not necessarily accurate for any specific project or projects. Likewise, the conclusions drawn are for illustrative purposes only and are not representative of any specific project or projects. The paper is, by design, narrowly focused on comparing additional construction costs to anticipated utility savings and mortgage tax deductions in the context of a single family residence in the United States. The paper does not consider, nor attempt to valuate, additional benefits of Passive House including improved indoor air quality, better comfort, lower maintenance costs, environmental benefits, etc. That said, many of these benefits could be analyzed with the techniques presented if reasonable assumptions can be produced.

Introduction

The financial analysis of Passive House is, ultimately, a matter of comparing money spent in the present (additional construction costs for Passive House performance) to money saved, or “earned,” in the future (via reduced utility costs, reduced maintenance, higher resale value, etc.) as a result of this additional investment.

The analysis in this paper ignores the maintenance costs and resale value of the building. The focus is purely on comparing operational and ownership savings with construction costs, but maintenance savings and higher resale value could be analyzed in a similar manner if they were predicted reliably and accurately. Furthermore, additional considerations for commercial property valuation, such as impacts on operating income, employee productivity, etc. will not be addressed. This paper is focused on the relatively simpler analysis of single-family homes, but the principles and techniques described are valid for more complex analysis.
The crux of the issue is that one must decide whether to spend additional money now (during construction to create a Passive House) to save money later (over time) in the form of reduced operating and ownership expenses. A proper evaluation, therefore, requires directly comparing the relative value of money spent (or saved) now to money saved/earned later. Another way to look at this is that investing additional money in a Passive House is like buying a stock or bond that produces a regular payment, in the form of reduced future operating and ownership costs. An investment that generates a series of predetermined future payments for a fixed period of time is called an “annuity.” If the future payments are identical, it is known as a “fixed annuity.” If the payments increase over time, it is known as a “growing annuity.”

For the purposes of this paper, a construction cost of $250,000 will be assumed for a code-compliant home. An additional initial investment of 15% will be assumed to reach the Passive House standard, or $37,500 in this example. The Passive House energy savings are assumed to be 80% of the $3000 annual utility expenses assumed for the code-compliant building, or $2400 per year.

Analysis Methods

This paper explores three ways to reconcile a current expenditure with a future income stream:

I. By converting the future savings to an equivalent sum in today's dollars and comparing that sum to the initial investment required to realize those savings. This technique determines the total current or “net present value” of the project. This is referred to as a “discounted cash flow analysis,” a “whole-life” or “life-cycle” cost analysis, or the “capital value method.”

II. By converting the entire set of expenses and savings into an effective “yield,” or rate of return, aka “interest rate.” These techniques include calculation of the simple payback period (SPP); return on investment (ROI); internal rate of return (IRR); modified internal rate of return (MIRR); and savings to investment ratio (SIR.)

III. By converting the initial investment into a series of regular future payments and comparing those payments to the future operational savings. This is sometimes referred to as an “equivalent annual cost (EAC) analysis” or “the annuity method.”

In other words, the first method compares the construction cost with operational savings in the present; the second methods convert the expenses and savings into an equivalent interest rate for the life of the investment, and the third method compares the construction cost with operational savings in the future. The results of each method can be used to verify the others, which can be a useful form of error checking, or reconciliation.
As formulas are discussed and presented, the commands required to perform these calculations in Microsoft Excel® will be suggested.

I. Discounted Cash Flow Analysis (DCF), aka “Capital Value Method”

To perform a discounted cash flow analysis, it is necessary to convert future earnings and/or expenses to an equivalent “present value.”

Present Value (PV)

To address the time-dependent value of money, one can calculate the “present value (PV)” of a savings or payment received at some point in the future, as follows:

\[
PV = \text{Payment}/(1+i)^t
\]

Where:
\[i\] = the “discount rate,” also referred to as the “hurdle rate,” or “cost of capital,” which is the minimum rate of return required by the investor. This could be as simple as the rate of inflation, but it typically includes factors related to the risk of the investment and “opportunity cost” of committing the money to the investment. An accepted “rule of thumb” value for the discount rate in commercial real estate investing is 10%\(^1\), but for this analysis, the assumption is that the financing is provided through a conventional 30-year home mortgage, at 5% annual interest.

\[t\] = the “date” that the payment is received. This date is “number” of the time period (typically in years) at the end of which the payment is received, i.e., for a payment received after one year, \(t=1\), after two years, \(t=2\), etc. For any payments received at the beginning of the project (rebates, etc.), \(t=0\).

In the example above, assuming a discount rate of 5% and no change in utility costs over time, the present value of the savings would be:

End of year 1: \(PV = \$2400/(1+5\%)^1 = \$2,285.71\)
End of year 2: \(PV = \$2400/(1+5\%)^2 = \$2,176.87\)
... 
End of year 30: \(PV = \$2400/(1+5\%)^{30} = \$555.31\)

The sum of the present values of these savings for the entire thirty-year period is $36,893.88.

Note that the length (or “life”) of the investment must be considered to determine the time period to analyze. In this example, the length of a typical residential mortgage (30 years) was used.

Note also that the further in the future a payment is received, the lower its present value. This stands to reason, as a smaller amount of today’s dollars (ie $555.31) invested at a compound annual interest rate of 5% would achieve a greater future value (ie $2400) at the end of thirty years than at the end of one year, for example.

Net Present Value (NPV)

The net present value (NPV) is the sum of the present values of all the cash inflows and outflows. Cash inflows are represented with positive numbers and outflows with negative numbers, generally displayed in parenthesis, ‘()’. For the example above, the net present value is:

\[
PV \text{ Cash Outflows} + PV \text{ Cash Inflows} = (\$37,500) + \$36,893.88 = (\$606.12)
\]

A project with a negative NPV is typically regarded as a bad investment from a strictly financial standpoint, since it loses money, according to the investor’s criteria. In this example, this simplified analysis may have too high a discount rate (5%), too
low a utility savings estimate, and/or ignore other factors that tend to be critical in this analysis, such as rising utility costs and income tax advantages, which will be explored later.

II. Yield Analysis

Methods used to effective “yield” of an investment are:

i. Simple Payback Period (SPP)  
ii. Return on Investment (ROI)  
iii. Internal Rate of Return (IRR)  
iv. Modified Internal Rate of Return (MIRR)  
v. Savings to Investment Ratio (SIR)

i. Simple Payback Period (SPP)

Calculation of the Simple Payback Period (SPP) is a matter of dividing the total investment (in dollars) by the recurring savings (in dollars per year) which results in the number of years it takes to “pay back” the investment. In the case of the Passive House project described above, the SPP, in years, is:

\[
SPP = \frac{\text{Additional Investment}}{\text{Recurring Savings}} = \frac{$37,500}{$2400/yr} = 15.625 \text{ years}
\]

The SPP is, mathematically, the inverse of the “equivalent interest rate,” ie:

\[
1/15.625 \text{ years} = 6.40\%/\text{year}
\]

This interest rate is referred to as the “return on investment (ROI).” (See below.)

Simple Payback Period Limitations

While “simple payback” is an easy calculation that is seemingly easy to understand, the approach has a number of significant shortcomings:

1) It assumes that money has a constant value (ie there is no currency devaluation due to inflation)  
2) It assumes that there is no “cost” for the money invested (no interest charged, no other investment opportunities forsaken)  
3) It assumes that utility costs are constant (no change in utility rates)  
4) It ignores the relative risks of investment alternatives  
5) It ignores any savings after the payback period (ie, after 15.625 years, don’t the utility savings in the example above continue?)
6) The SPP is not a widely used economic indicator with few ready comparisons, so the results sought are often quite unrealistic. As an example, the current prime rate (the interest rate banks charge each other for loans, which is the basis for much commercial and consumer lending) is 3.25% per year\(^2\). As a simple payback period, an investment with a rate of return of 3.25% annually equates to \(1/3.25\%/yr = 30.77\) years, yet common expectations for an “acceptable” SPP range from roughly 2 years (50%/yr return) to 5 years (20%/yr return.) Investments with such returns are generally quite risky, if available at all.

As such, the apparent simplicity of the SPP approach actually obscures the more complex reality behind such a decision. For these reasons, SPP is not an approach favored by economists or investment professionals.

ii. Return on Investment (ROI)

To calculate return on investment (ROI), the yearly savings is divided by the total investment. For the example above:

\[
\text{ROI} = \frac{\text{Annual Savings}}{\text{Investment}} = \frac{$2400/\text{year}}{$37,500} = 6.40\%/\text{year}
\]

Note that this is also the inverse of the SPP from above, ie:

\[
\text{ROI} = \frac{1}{\text{SPP}} = \frac{1}{15.625 \text{ years}} = 6.40\%/\text{year}
\]

Unlike the simple payback period, the ROI is easy to compare directly with the prime rate and other common economic measures.

This calculation is fairly simple, and easy to compare to an investor’s cost of money, but shares limitations with simple payback period calculations:

1) The annual savings are assumed to be constant throughout the life of the investment. Any savings variations are unaccounted for.
2) The time-value of money is not addressed, nor inflation, nor relative investment risk.
3) The length of the investment is unaccounted for. ROI assumes that the savings continue at the same level in perpetuity.

iii. Internal Rate of Return (IRR)

The internal rate of return (IRR) is a means of converting a net present value analysis to an equivalent rate of return. Basically, the IRR is the discount rate at which the net present value of the investment is zero. If a project has an IRR greater than the investor’s discount or “hurdle” rate, it is deemed worthwhile. In other words, the internal rate of return is the compound interest rate that would generate the specified savings for the given investment.

There are a number of numerical and iterative techniques for finding the IRR, but for the purposes of this discussion, it can be calculated using the Microsoft Excel® formula Irr():

\[
\text{IRR} = \text{Irr( range, estimated_irr )}
\]

where:
“range” = the range of cells containing the NON-ADJUSTED cash inflows and outflows, NOT the PV cash flows
“estimated_irr” = an optional parameter, a guess at the correct answer

For the example above, the IRR is 4.86%. This stands to reason, as a 5% discount rate resulted in a negative net present value, suggesting that a discount rate at which the NPV is zero would be lower than 5%.

**Internal Rate of Return Limitations**

IRR results tend to vary unpredictably between projects with different cash flows. For example, the IRR of a project with a higher initial investment may be lower than the IRR of another project requiring a lower initial investment, even though the net present value (NPV) of the first project is higher than the second. In this case, the first project (with lower IRR, but higher NPV) would be the better choice. As such, IRR should not be used to compare mutually exclusive projects, only to analyze whether a specific project is worthwhile. If a choice needs to be made between projects, the project with the higher NPV should be selected.

Furthermore, IRR contains the inherent assumption that the positive cash flows of the project are reinvested at a rate of return equal to the IRR. For projects where the rate of return available for re-invested cash flows is lower than the IRR, the IRR is an overstatement of the return of the project.

Lastly, projects with alternating positive and negative cash flows can have more than one IRR, which can be confusing.

The Modified Internal Rate of Return (MIRR) is an alternative to IRR that overcomes many of its shortcomings.
iv. Modified Internal Rate of Return (MIRR)

The Modified Internal Rate of Return (MIRR) improves upon IRR in two ways:

1) MIRR allows for the “reinvestment rate” to be specified, which indicates the rate of return for reinvested positive cash flows from the project. MIRR also allows for a “finance rate,” which accounts for the cost of borrowing during negative cash flow periods. Typically, MIRR more accurately states the actually rate of return of the project than does IRR.

2) MIRR only has one value, even when cash flows alternate between negative and positive.

MIRR can be calculated with a formula, but for the purpose of this paper, the Microsoft Excel® formula Mirr() is used:

\[
\text{MIRR} = \text{Mirr}(\text{range}, \text{finance\_rate}, \text{reinvestment\_rate})
\]

where:
“range” is the range of cells containing the NON-ADJUSTED cash inflows and outflows, NOT the PV cash flows.
“finance\_rate” is the rate the investor pays on borrowed money.
“reinvestment\_rate” is the rate of return the investor sees when investing money.

The assumption here is that the funding is from a 30 year mortgage at an interest rate of 5% and that the future savings are used to pay down the mortgage, so the finance rate and reinvestment rate are both 5%. In this case, the MIRR is 4.94%.

The discrepancy between the MIRR and the IRR is due to the higher return on positive cash flows for MIRR (reinvestment rate = 5%) than the inherently assumed reinvestment rate of IRR (equal to the IRR, or 4.86%). Verifying this, if the reinvestment rate for the MIRR is set to 4.86% with a finance rate equal to the IRR discount rate (5%), the MIRR equals the IRR at 4.86%.

v. Savings to Investment Ratio (SIR)

The Savings to Investment Ratio (SIR) is defined as the present value of the future savings divided by the initial additional investment. In this case:

\[
\text{SIR} = \frac{\text{PV}(\text{savings})}{\text{Additional Investment}} = \frac{\$36,893.88}{\$37,500.00} = 0.98
\]

An SIR of 1 or greater indicates that the project has a positive net present value (NPV.) The SIR, like the NPV, is dependent on the discount rate used.
III. Equivalent Annual Cost (EAC), aka “Annuity Method”

In the “annuity method,” rather than converting future cash flows to current value as in method I, above, the initial investment is converted to a series of equivalent future payments and compared to the future annual savings and costs on a year-by-year basis. This method is often more accessible for homeowners who do not have a financial background and can be quite compelling, as the homeowner can see how he/she will make more and more money in the future. If the investment can be shown to break even from the first year, it can be a highly effective sales tool.

Converting the initial investment into a series of equivalent future payments is somewhat the reverse of the present value calculations above. It is commonly done using a value called the “annuity factor”:

\[ P = \frac{PV}{a} \]

where:

- **P** = the value of each repeated future payment
- **PV** = the present value of the investment
- **a** = the annuity factor

This calculation may also be performed with the Excel PMT function:

\[ \text{PMT} \left( \text{rate, nper, pv, fv, type } \right) \]

where:

- **rate** = the annual interest rate for the loan
- **nper** = the total number of payments for the loan
- **pv** = the present value or the amount borrowed or the "principal of the loan"
- **fv** = future value (for a loan this will be $0.00, it can be omitted)
- **type** - indicates when payments are due:
  - "0" (or omitted) = at the end of the period ie: end of the month
  - "1" = at the beginning of the period ie: beginning of the month

In this case:

\[ \text{PMT}(5\%,30,37500) = (2439.43) \]

**Annuity Factor Calculation**

The annuity factor is dependent on the interest rate and the number of payments in the life of the annuity. The annuity factor can be calculated as follows:

\[ a = \frac{(1-(1+r)^{-n})}{r} \]
where:
\[ a = \text{the annuity factor} \]
\[ r = \text{the interest rate} \]
\[ n = \text{the number of payments (the operating life of the investment)} \]

For the current example, the annuity factor is:

\[ a = \frac{(1-(1+r)^{-n})}{r} = \frac{(1-(1+5\%)^{-30})}{5\%} = 15.37 \]

The equivalent yearly future payment for the initial investment above is:

\[ P = \frac{PV}{a} = \frac{\$37,500}{15.37} = \$2,439.43 \]

To find the equivalent annual cost (EAC), the yearly costs and savings can be summed:

\[ (\$2,439.43) + \$2,400 = (\$39.43) \]

The same equivalent annual cost, $39.43, is experienced each year, and if these yearly costs are converted to present value, the sum represents the net present value, which is -$606.12. This value is identical to that derived in the NPV section above, which serves to verify both calculations. If ancillary benefits such as
improved indoor air quality and comfort are not considered, and the decision is made purely on a financial basis, this example may not be “compelling” for a homeowner, since it is a consistent, if minor, cost year by year. Additional factors can be considered which change the situation significantly, as will be seen below.

**Annuity Factor vs Annuitätsfaktor**

There is a difference between the American and the German (European?) definitions of “annuity factor” and “annuitätsfaktor,” respectively. The annuitätsfaktor is actually $1/a$, if ‘a’ is calculated according to US convention, above. It is also frequently written as a percentage, likely for clarity. As such, a German might offer an annuity factor (‘annuitätsfaktor’) for the above situation of:

\[
a' = \frac{1}{a} = \frac{1}{15.37} = 0.0651 = 6.51\%
\]

One would find the equivalent future payment by MULTIPLYING the initial investment by the annuitätsfaktor:

\[
P = PV \times a' = $37,500 \times 6.51\% = $2,439.43
\]

**Additional Financial Considerations**

The analysis above does not show a financial gain for the investor. There are, however, at least two plausible additional factors to be considered that have a significant impact on the outcome: 1) utility price increases and 2) income tax deductions for additional mortgage interest.

**Utility Price Increases**

It is likely that utility prices will increase over the course of a 30-year mortgage. Many utilities make historically average price increases available to the public, which allows for an easy definition of this value. 2% per year is a reasonable estimate for this analysis. A utility price increase can be applied as follows:

\[
S_{i+1} = S_i (1+r)
\]

where:

- $S_i$ = utility savings at the end of period $i$
- $S_{i+1}$ = utility savings at the end of period $i+1$ (the following period)
- $r$ = the rate of increase in utility prices (%/year, in this case)

For the current example:

\[
S_2 = S_1 (1+r) = $2400 \times (1+2\%) = $2448.00
\]
S_3 = S_2 (1+r) = $2448 (1+2\%) = $2496.96

S_{30} = S_{29} (1+r) = $4178.46 (1+2\%) = $4262.03

The present value of each can be calculated in turn:

End of year 1: PV = $2400.00/(1+5\%)^1 = $2,285.71
End of year 2: PV = $2448.00/(1+5\%)^2 = $2,220.41

End of year 30: PV = $4262.03/(1+5\%)^{30} = $986.14

A comparison with the previous analysis shows that, although the discount rate still erodes the present value over time, the annual price increase offsets the erosion significantly. As a result, the present value from the previous analysis without utility inflation, $36,893.88, is now $46,471.34, or $9,577.46 greater, when a 2% annual cost increase is included.

When the analysis above is repeated with the assumption that utility savings increase 2% annually, the results are as follows:
Simple Payback Period: 15.625 years (unchanged)
Return on Investment: 6.40% (unchanged)
Net Present Value: $8,971.34 (an increase of $9,577.46)
Internal Rate of Return: 6.78% (an increase of 1.92%)
Modified Internal Rate of Return: 5.75% (an increase of 0.81%)
Savings to Investment Ratio: 1.24 (an increase of 0.26)

It is easy to see the limitations of both simple payback and return on investment in this comparison, as they are both based on first year savings alone.

The annuity method now shows cost of $39.43 for the first year followed by an increasingly positive return from the end of year 2 on:

Income Tax Savings

Because mortgage interest is tax deductible in the United States, but residential utility costs are not, the decision to invest more construction dollars in a building with lower utility costs has tax advantages. To add this calculation, the additional mortgage payments must be divided into payment for interest and payment for principal, and an assumption must be made about the investor’s marginal income tax rate.
To calculate the interest and principal payments, one can take the first regular payment and subtract from it the interest charged that year on the loan. The remainder is the principal payment. The next year’s payment is the same total amount, but the interest is less, since the principal has declined, so the principal payment is larger. This chart is known as an “amortization schedule.” In this example:

Yearly payment: $2,439.43

End of year 1:
Interest payment = rate x principal = 5% x $37,500 = $1875
Principal payment = $2,439.43 - $1875 = $564.43
Remaining principal = $37,500 - $564.43 = $36,935.57

End of year 2:
Interest payment = rate x principal = 5% x $36,935.57 = $1,846.78
Principal payment = $2,439.43 - $1,846.78 = $592.65
Remaining principal = $36,935.57 - $592.65 = $36,342.92

End of year 30:
Interest payment = rate x principal = 5% x $2,323.27 = $116.16
Principal payment = $2,439.43 - $116.16 = $2,323.27
Remaining principal = $2,323.27 - $2,323.27 = 0

Excel has a pair of functions that make these calculations easier:

IPMT(rate, per, nper, pv, fv, type) = the interest payment
PPMT(rate, per, nper, pv, fv, type) = the principal payment

where:
rate = the annual interest rate for the loan
per = the period for which you want to find the interest/principal (from 1 to nper)
nper = the total number of payments for the loan
pv = the present value or the amount borrowed or the "principal" of the loan
fv = future value (for a loan this will be $0.00, it can be omitted)
type - indicates when payments are due:
"0" (or omitted) = at the end of the period ie: end of the month
"1" = at the beginning of the period ie: beginning of the month
To calculate the income tax savings, an assumption must be made about the marginal tax rate of the investor. Below is the 2012 tax rate table\(^3\) for a “head of household.” 25% will be used in the following analysis.

- 10% on taxable income from $0 to $12,400, plus
- 15% on taxable income over $12,400 to $47,350, plus
- 25% on taxable income over $47,350 to $122,300, plus
- 28% on taxable income over $122,300 to $198,050, plus
- 33% on taxable income over $198,050 to $388,350, plus
- 35% on taxable income over $388,350.

The previous cash flow analysis can be performed with income tax savings in addition to utility savings. As above, a 2% rate of increase in utility savings is assumed. The income tax savings is simply the assumed marginal income tax rate multiplied by the interest payment for the particular period, ie:

End of year 1: tax savings = tax rate x interest payment = 25% x $1875 = $468.75
End of year 2: tax savings = tax rate x interest payment = 25% x $1846.78 = $461.69

End of year 30: tax savings = tax rate x interest payment = 25% x $116.16 = $29.04

When the tax savings is added to the utility savings, the results are as follows:

**Simple Payback Period:** 15.625 years (unchanged)
**Return on Investment:** 6.40% (unchanged)
**Net Present Value:** $14,314.71 (an increase of $5,343.37)
**Internal Rate of Return:** 7.86% (an increase of 1.08%)
**Modified Internal Rate of Return:** 6.14% (an increase of 0.38%)
**Savings to Investment Ratio:** 1.38 (an increase of 0.14)

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The annuity method now shows a positive and increasing return from year 1:

**Consequences of an Early Sale**

A net present value analysis can be performed on a year-by-year basis. The analysis shows a positive return under the assumption that the additional investment is recouped upon resale and/or ownership of the building is retained for some time. If
the initial investment is entirely recouped at sale, the NPV of the investment rises steadily year-by-year to a maximum of $51,814.71 at the end of year 30.

Worst Case
If none of the initial investment is recouped, the NPV starts at a low of -$37,500 in year 0, and turns positive at the end of year 19:

If the upgrade to Passive House from conventional construction adds any value to the sale price, the results trend toward the previous example, and would actually
exceed it if the Passive House upgrade results in a increase in resale value beyond the initial cost. As mentioned in the introduction, analysis of Passive House resale value is beyond the scope of this paper.

Conclusions

The sample financial analysis in this article shows positive returns that are significantly affected by utility price increases and improved with a long-term outlook. The resale value of the upgraded home has a significant effect on the value of the investment as well. Recent studies\(^4\) show cause for optimism in this regard, and suggest that demonstrable operational savings have value in the real estate market.

As with much financial analysis, the values used for the factors involved both strongly influence the results and necessitate assumption. A convincing and responsible analysis should, therefore, involve careful and defensible evidence to support the suppositions involved.

References


