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Computer-Based Tool for the Economic Analysis of Building Energy Retrofits

Gary P. Moynihan[1], Heather M. Estes[1], Daniel J. Fonseca[2]

[1]Department of Civil, Construction and Environmental Engineering, The University of Alabama, Tuscaloosa, AL, United States

[2]Department of Mechanical Engineering, The University of Alabama, Tuscaloosa, AL, United States

Abstract: *Research was conducted regarding improving the primary method the Alabama Industrial Assessment Center (AIAC) uses to make recommendations to companies regarding the economic sustainability of implementing energy saving retrofits. Consistent with U.S. Department of Energy guidelines, the current decision-making criterion utilizes the payback period method. As noted in the literature, payback is an insufficient method for analyzing economic feasibility since it is a measure of liquidity rather than profitability. An Excel-based tool was developed that is able to use the information obtained by the AIAC in their facility assessment reports to make a more informed decision regarding the economic sustainability of the retrofit by using the time value of money technique. Analysis was conducted to provide default values for the interest rate and life of the recommended asset. A comparison to recommendations based on the payback method was conducted.*

Keywords: *Energy management, energy conservation, engineering economics, building retrofit*.

1. Introduction

Proper use of energy in a building provides lower operating costs. This can be achieved by evaluating energy end-uses (lighting, electrical equipment, process equipment, and HVAC systems), and by implementing measures to reduce the amount of energy consumption for one or more of the end-uses. The manufacturing industry “consumes almost one-half of all the commercial energy used and is responsible for roughly similar shares of greenhouse gases” [1]. Replacing existing products with energy efficient ones can cut down energy costs tremendously especially in older facilities. Many such retrofits involve lighting, electrical equipment, and HVAC (heating, ventilation and air conditioning) systems.

The Industrial Assessment Centers (IACs) are funded under the United States Department of Energy’s Efficiency and Renewable Energy division. Their goal is to increase energy efficiency for small-to-medium-sized manufacturing companies throughout the United States. Many of their recommendations are for building energy retrofits that help lower the amount of energy used in the facility. IAC teams, consisting of students and faculty from universities participating in the effort, make these energy assessments [2]. One of the 24 universities that participate in the IAC program is the University of Alabama. Consistent with the procedure described by Thurmann and Younger [3], the IAC’s energy audit of a manufacturing facility is conducted in three phases. The first phase involves analyzing the data from the facility energy bills to determine what energy is used and how energy use is varied over time. The second phase consists of a plant walk-through inspection, looking carefully at each physical system within the facility and recording information for later use [3] the last phase is where specific energy-savings are identified for later implementation by the facility. The IAC team performs a detailed analysis supporting specific recommendations with related estimates of costs, performance and energy savings. Once the technical feasibility and expected energy-savings for each recommendation are reviewed, associated payback periods are then determined.

2. Quantification of Energy Savings

Consistent with Department of Energy procedures [2], the simple payback period method is the primary method the Industrial Assessment Centers utilize for determining whether implementing an energy saving retrofit is economically feasible for the client companies. The payback is an estimate of the time (in years) it will take to breakeven on the money invested. As noted by Newnan et al [4] and shown in Equation 1, the payback period only considers the cost of implementation and the annual savings. The payback period method is used by the IAC because of its simplicity. Payback is easy to calculate and easy to understand by facility managers reading the reports.

Payback Period = Cost of Implementation / Annual Savings (1)

Academic scholars have long accepted the payback method to be flawed [e.g. 5]. "The payback method screens projects on the basis of how long it takes for net receipts to equal investment outlays without including any time value analysis" [6]. For example, Park [6] also notes that "the principal objection to the payback method is that it fails to measure profitability", and that "simply measuring how long it will take to recover the initial investment outlay contributes little to gauging the earning power of the project". Canada et al. [7] echo the observation that payback is a measure of liquidity, rather than profitability, and may lead to erroneous project selection. Russell [8] states payback "is a risk assessment tool… [Not] a profitability metric." ASHRAE [9] affirms these deficiencies: "This method only works if an alternative has a short or long payback period compared to some baseline. It does not account for inflation; the cost of borrowing money; variations in periodic costs and savings; salvage value; future one-time costs to maintain or repair equipment; nor opportunity costs. Most importantly, simple payback omits an important benefit; it does not account for savings that occur after the initial equipment cost is recouped."

More recently, Lewellen et al. [10] describe the business rationale for using the simple payback method. They note, "Businessmen seem to feel (1) that the requisite calculations are overly complex, (2) that they imply a degree of precision which is in fact uncharacteristic of many investment opportunities, and (3) that they are difficult to communicate effectively to the lower levels of the organization…" [10]. Similarly, Russell [8] explains "we rely on payback [because] our operating goals, budgets, bonuses, and rewards are fixed in an annual (time) format, [and that] simple payback seems to fit naturally in our calendar-driven world." While Lewellen et al. [10] "sympathize" with the businessmen, they also point out the importance of taking into consideration the time value of money. They argue that time value of money techniques have been studied and ascertained as a well-developed tool for calculating the viability of an investment.

Vanek and Albright [11] define time value of money by explaining, "Money returned in the future is not worth as much as money invested today. The change in value of money over time due to these two trends is given the name time value of money." The idea of time value of money is "the earlier a sum of money is received, the more it is worth, because over time money can earn more money, or interest" (Park, 2013). Time value of money methods of analysis include: present worth, annual cash flow, future worth, and benefit-cost ratio. These time value of money techniques have proved to be a very good for evaluating investments.

3. Scope and Methodology

One of the major concerns with using the payback method is that the technique does not consider important factors such as time value of money or the effect of inflation. The purpose of this study is to provide the Alabama Industrial Assessment Center with an improved tool for evaluating energy saving retrofits for the manufacturing industry. The challenge will be developing a tool that balances simplicity of use with accurate profitability analysis.

Time value of money has been accepted in the academic and professional world as a very useful technique for assessing profit on investments, but there are reasons why industry professionals chose not to use time value of money techniques for performing assessments. One of the principal challenges for professionals attempting to use these approaches is determining values for some of the variables included in the formulas when evaluating real life retrofits. Two values that cause concern are “n”, “the expected life of the asset,” and “i”, “the interest rate per interest period” [4]. The value for “n” causes concern because many managers do not know how long the retrofit will last. Similarly, the interest rate per interest period, “i” is where companies can apply their required rate of return or minimum attractive rate of return (MARR) value that can be computed. Many small companies like the ones assessed by the IAC, do not know what their MARR value is, and do not know how to compute the value. This research determined values acceptable for companies to utilize for their variables with guidelines for the companies to follow when using these values.

Consideration of inflation is extremely important in the evaluation of energy savings. With energy prices steadily increasing, considering inflation is necessary to correctly assess these eco-friendly retrofits. Different dynamics can affect the cost of energy though. Those dynamics include: energy type, location, industry, and demand. According to Newnan et al. [4], inflation can be factored into the time value of money analysis as long as “*f*”, the inflation rate is defined. In this study, the inflation rate will be directly related to fluctuating energy costs.

Russell [8] establishes the foundation for this research effort by noting that payback is “the wrong tool for energy project analysis [because] payback poses a two-step question in reaching one conclusion: (1) How long until I get my money back? ... (2) Is this an investment I should make?” These two questions can be combined into one question answered with yes or no: Will implementing the product be worthwhile? This is ultimately the question that investors want answered. Further, Russell [8] asks whether managers want to “continue to buy energy at-risk from the market, [or] save energy by reducing the volume at-risk? If they want to continue buying energy they are exposed to price fluctuations, but if they want to invest in energy saving alternatives they need to understand the economics of the investment”. The first step in this approach is determining the “annualized project cost” using time value of money techniques. Using this number he compares the cost to save energy to the cost to buy energy in a “cost-benefit ratio.” If the ratio is less than one, then the investment is worthwhile. Russell [8] then calculates the “break-even point” setting the “annualized project cost” equal to the “total value of annual energy savings.” If the “maximum acceptable up-front project cost” is less than the “actual cost” of investing in the project than the choice to invest can be affirmed. Russell [8] ends by comparing “payback vs. annualized cost analysis.” He asserts that “annualized cost analysis” performs all of the following functions where payback does not: “accounts for cash flows over the life of the improvement, incorporates time-value of money, provides basis for break-even cost evaluation, compares values of projects with different economic lives, permits real-time evaluations of the cost of waste, and measures the penalty for not taking action.” The “annualized cost analysis” is much more effective than the payback period method when evaluating energy saving retrofits, but the analysis stills has one substantial limitation. The analysis does not factor in inflation. Russell [8] agrees that the market exposes the consumer “to constant price volatility”, but neglects accounting for inflation in the assessment. Further, and consistent with other time value of money techniques, there is no guidance on determining some of the necessary variables (e.g. expected life of the asset).

This thesis-based research investigated developing an alternative economic analysis technique expanded from Russell’s [8] approach. The purpose of this research is to examine the methods currently used, particularly simple payback, and develop an improved approach for evaluating the economic aspects of building energy retrofits. The enhanced method will incorporate time value of money and inflation to give managers a more accurate value for the return on investment. The alternative economic analysis technique will be implemented on a computer-based program to improve the technique's ease of use. This will allow managers who have little to no prior knowledge in engineering economics to make an informed decision regarding investing in energy saving retrofits.

4. Design and Development of the Computer-Based Tool

The most significant reason managers use the payback period method is because the method is simple to use, and easy to understand. For the economic analysis tool to be utilized, the tool must possess these same qualities. Utilization of a spreadsheet approach appeared reasonable. An integration of the observed methods and common input regarding energy analysis allowed us to create a spreadsheet that evaluates the profitability of the recommended retrofit. Excel was chosen as the software platform for many reasons. Excel is a widely-available program that is also inexpensive. Microsoft Excel also possesses the ability to perform the calculations necessary in the spreadsheet. According to Cahill and Kosicki [12], "spreadsheet software is relatively easy to use, and its flexibility makes it useful in many different courses at all levels of the traditional economics curriculum. Most economics students almost certainly will use it after graduation in both career and personal settings".

For the analysis to be made comparing the cost of the retrofit to the economic benefit of implementing the retrofit, the user must first know the cost associated with not implementing the product or doing nothing. Before the suggested tool can be utilized, certain numbers must be gathered from company data. These numbers include the cost to buy energy this year and last year, cost of investment (implementation cost), and energy savings. Many of these values are gathered from assessment data compiled by the Industrial Assessment Centers. For this analysis the annualized project cost is needed because "operating budgets are annual, energy savings are accounted annually, [the analysis will] compare annual cost to annual benefit, [and the analysis will] compare 3-year project(s) to 10-or 5-year projects" [8]. Therefore uniform series capital recovery is used to calculate annual cost.

In this analysis, the number of interest periods correlates to the expected service life of the retrofit. While the service life of a retrofit can be hard to determine, there is a system adopted by the United States Internal Revenue Service as a helpful guideline when determining the expected life of an investment [13]. "The Modified Accelerated Cost Recovery System (MACRS) method was created by the Tax Reform Act of 1986 (TRA 86) and is now the principal means for computing depreciation expenses" [7]. Newnan et al [4] explain the "three major advantages of MACRS are that (1) the 'property class lives' are less than the 'actual useful lives,' (2) salvage values are assumed to be zero, and (3) tables of annual percentages simplify computations." The value from the property class will stand as the value for n in the spreadsheet. Most of the values for this assessment will fall between the 3-and 7-year margins. The spreadsheet will default "n" as 3, but the value can be changed.

Another problem encountered by company managers when using the capital recovery factor is determining what value to use for the interest rate. This is especially true for small companies. Some companies know the minimum attractive rate of return (MARR) value they will use, but for companies who do not know what their expected MARR value is, this is a problem. From research of applicable interest rates for this analysis, a value of 7% will be the default value. This value can be overridden. If the manager performing the analysis wishes to replace the value with the company's MARR value, they may do so. However, from information gathered 7% seems to be accepted as the average. This default value comes from an assessment of the values companies prefer to use. A limited series of interviews were conducted with Central Alabama accountants, and indicated that 7% was a suitable interest value for the energy saving implementations being employed.

The third component incorporated into this tool is inflation. Russell [8] ends his analysis by comparing the cost to save to the unit price of energy for the present year. This research takes the analysis one step further by incorporating an inflation factor into the time value of money approach [4]. To achieve an accurate value for inflation, the cost of energy from year to year has to be compared. The value could come from a total cost of energy last year compared to this year, or from the cost of energy per unit last year compared to this year. If last year's total energy expense is taken, a company would have to sum each month's bill from the previous year assuming they still had access to that information. If a building was renovated or additions had been made, that could also influence the cost of energy for the year. A more accurate ratio would use the cost of energy per unit from last year to this year. This way if there are changes to the building those will not affect the energy inflation factor. To calculate inflation *f*, the cost of energy in the present year and the cost of energy from the previous year will be needed. This information is obtained from the company's bills. The cost of energy in the present year will be referred to as the cost to buy energy "this year," and the cost of energy from the previous year will be referred to as the cost to buy energy "last year". From inflation, the energy inflation factor is computed according to Newnan et al [4]. Using an "IF" statement in Microsoft Excel, the result of the cost-benefit analysis answers the question "will implementing the product be worthwhile?" Because this analysis is simple, and the life of most of the retrofits being considered will be only a few years, the inflation rate over the total life expectancy of the product will be assumed equal to the rate over the first year. The input for obtaining the inflation rate will come from the company's bills. If however the information cannot be gathered, the United States Energy Information Administration contains prices per unit separated into different industrial sectors ranging over a period of time [14]. During construction of the spreadsheet, there was no access to the company bills. Therefore, the cost to buy energy last year and this year came from "Electric Power Monthly – Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State" [14]. The values used were from the industrial sectors in Alabama.

Russell [8] first suggests calculating the annualized project cost using the "up-front project cost" and the capital recovery factor. The capital recovery factor is calculated first using the expected life of the asset *n* and the applicable interest rate *i*. From these, the annualized project cost is calculated. For this research, the up-front project cost will be referred to as the "cost of investment" or implementation cost. Using the annualized project cost and "annual savings" the "annualized project cost per annual savings" is calculated per Russell [8] the annual savings will be referred to as energy savings and the annualized project cost per annual savings will be referred to as the cost to save in this research. From the cost-benefit analysis the breakeven point can be determined. Russell [8] describes the breakeven point as the "most that should be paid for the project, given certain investment criteria." The breakeven analysis "determines the conditions where two alternatives are equivalent" [6]. For this analysis Russell [8] suggests the annualized project cost must equal the total value of annual energy savings, and the "maximum acceptable annualized project cost should be no more than [the] annual value of avoided energy purchases." This is helpful for this specific research because the manager can see under specified criteria what the maximum acceptable implementation cost is. The analysis is not an additional analysis that must be used in order to determine if the retrofit must be implemented, but rather another way of looking at the data at hand. Russell [8] uses the "price per unit of energy" and "units of avoided energy consumption" to determine the "maximum acceptable annualized project cost". The "price per unit of energy" and "units of avoided energy consumption" are known as the cost to buy energy and energy savings in this research.

Using the maximum acceptable annualized project cost and the capital recovery factor (CRF), Russell [8] calculates the maximum acceptable up-front project cost. In this paper, the maximum acceptable up-front project cost will be referred to as the maximum implementation cost. The maximum acceptable annualized project cost will be referred to as the maximum annualized project cost. The values for energy savings and the cost to buy will be taken from the cost-benefit analysis spreadsheet. Once the maximum acceptable cost of investment is calculated the break-even analysis can be completed by using an "IF" statement in Excel to compare the maximum acceptable cost of investment to the actual implementation cost noted in the economic analysis of energy retrofit of buildings spreadsheet. If the maximum acceptable cost of investment is greater than or equal to the implementation cost, the project is considered to fall within budget. An example of the formatted spreadsheet is depicted in Figure 1. Detailed instructions for the utilization and interpretation of the spreadsheets, for both modified cost-benefit and breakeven analysis, are provided in the user guide that accompanies the developed software.

5. Verification and Validation

Quality assurance software testing is required to find defects as well as to verify and validate the process. Laplante [15] explains that verification "determines whether the products of a given phase of the software development cycle fulfill the requirements established during the previous phase… [While] validation determines the correctness of the final program or software with respect to the user's needs and requirements." To verify that the tool has been developed properly, hand calculations were made to ensure the values from the imbedded formulas are accurate, and the values obtained from the spreadsheet are correct.

To test the spreadsheet, data from specific IAC assessment reports were used, including energy savings, energy cost savings, implementation cost, and simple payback period. The spreadsheet was then populated with the relevant data for this IAC recommendation in order to provide an initial comparative validation. When conducting the analyses, the variation in the inflation rate seemed to cause the results of the analyses to change significantly. For this reason, a sensitivity analysis was conducted on the inflation rate. The ratio increases are expected because as energy costs rise, confidence in implementing the energy saving retrofits increase. While considering inflation did alter the numeric results for the cost-benefit analysis and the break-even analysis, the overall results of whether or not to implement the retrofit did not change.

Economic Analysis of Energy Retrofit of Buildings	
	Input
	Output
Energy Savings (kWh/yr)	311,521
Cost of Investment (Implementation Cost)	$42,862.00
Expected Life of Asset (n)	3
Applicable Interest Rate (i)	7.00%
Cost to Buy Energy	
Last Year ($/kWh)*	$0.0600
This Year ($/kWh)*	$0.0628
$\frac{i(1+i)^n}{(1+i)^n-1}=$	
Capital Recovery Factor	0.381
Cost of Investment x Capital Recovery Factor =	
Annualized Project Cost ($/yr)	=E8*E18
This Year / Last Year - 1 =	
Inflation (f)	4.67%
$1+f=$	
Energy Inflation Factor	1.047
Annualized Project Cost ($/yr) / Energy Savings (kWh/yr) =	
Cost to Save ($/kWh)	$0.05
Cost to Buy Energy This Year ($/kWh) x Energy Inflation Factor =	
Cost to Buy ($/kWh)	$0.07
Cost to Save ($/kWh) / Cost to Buy ($/kWh) =	
Cost-Benefit Analysis	0.798
Will implementing the product be worthwhile?	***Yes***

Fig1. *Completed spreadsheet*

The results from the analysis coincide with the results from the payback period in most cases. The analysis assessment and the simple payback parallel each other quite well for retrofits with short payback periods (i.e. three years or less). While most of the assessment recommendations were confirmed, a few of the recommendations made according to the payback method were not in agreement with the results from the proposed economic analysis tool. These tended to have longer payback periods associated with the recommended retrofit. After the spreadsheet was validated, a user manual was developed to accompany it. The manual explains how the spreadsheet has been designed to work, what can be calculated, what information is necessary for implementation, how to insert data, and what interpretations can be drawn from the output.

6. Conclusion

The Alabama Industrial Assessment Center takes information gathered from the client company that they are assessing, and using that information along with a thorough evaluation of the facility, makes recommendations for esaving energy. To determine whether to subsidize the retrofits, the AIAC uses simple payback to establish the economic feasibility of the project. From a literature review, payback is deduced to be an insufficient method for analyzing economic feasibility, since payback is a measure of liquidity and not profitability.

This research concluded the method by which recommendations are presently made by the AIAC should be altered. A new economic tool is proposed expanding Russell's (2009) approach for calculating the cost-benefit analysis and break-even point by turning the costs into an equivalent annuity. The economic analysis tool utilizes time value of money, inflation, and other relevant factors into the evaluation without complicating the process. The tool will help assessors make more informed decisions by using Excel as the computer-based program to perform the analysis. Deliverables include a detailed description of how the solution was obtained, a spreadsheet, a user guide, and verification that the spreadsheet works using actual data for a proposed facility retrofit.

Actual AIAC report data was used to compare the recommendations made by the AIAC to the conclusions drawn from the economic analysis of buildings as well as the break-even analysis. The results from the study showed the new tool may in fact be a better analytical technique for determining whether recommendations made by the AIAC should be implemented. Comparing the results of the new tool, which takes into consideration time value of money and inflation, to the previous suggestions made in multiple AIAC reports, provided an initial validation of the spreadsheet approach.

Using this spreadsheet as a foundation, further research can be conducted and improvements to the spreadsheet can be made. This analysis has investigated the economics relating to electricity. Analogous linked spreadsheets could be established to consider the cost of natural gas, fuel oil, or any other energy source that is relevant to the facility's retrofits. Further, as noted by Bonilla and Merino [16], to be realistic in any formal economic evaluation, the effect of income taxes must also be considered.

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AUTHORS' BIOGRAPHY

Gary P. Moynihan is a professor in the Department of Civil, Construction and Environmental Engineering, the University of Alabama. He received his BS in chemistry, and MBA in operations management degrees from Rensselaer Polytechnic Institute, and a PhD in industrial engineering from the University of Central Florida. He currently serves as Assistant Director for the Alabama Industrial Assessment Center.

Heather Estes holds both BS and MS degrees in civil engineering from the University of Alabama. Upon graduation, she has accepted a position as assistant project manager with Brasfield & Gorrie in Birmingham, Alabama.

Daniel J. Fonseca is presently an Associate Professor with the Department of Mechanical Engineering at the University of Alabama. He previously taught at the Monterrey Institute of Technology campuses in Mexico City and Tampico. He received his BSIE and MSIE Degrees from the University of Alabama and both MS and PhD Degrees in Engineering Science from Louisiana State University.