# ECONOMIC ANALYSIS OF
# ENERGY RETROFIT
# OF BUILDINGS

by

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A THESIS

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# ABSTRACT

Research was conducted regarding improving the primary method the Alabama Industrial Assessment Center (AIAC) uses to make recommendations to companies regarding whether implementing an energy saving retrofit is economically sustainable. Their current decision-making criterion is based around the payback period method. 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 using the time value of money technique of annual cost and inflation. While the majority of the time the research confirmed the recommendation made using the payback period method, some of the time there was disagreement between the two methods.

Further testing is warranted in order to validate any direct correlation between the payback period method and the cost-benefit ratio values obtained using this tool for economic analysis of energy retrofits for buildings. Because payback is a measure of liquidity and not profitability, the assumption can be made that the new tool is more accurate for companies to make a more informed decision regarding implementing the retrofit, but only more research could confirm this hypothesis.

# DEDICATION

This thesis is dedicated to everyone who helped keep me motivated during the time it took me to complete this thesis. In particular, my family and friends who stood by my side. For those that pushed me to completion after the tragic storm that struck our town April 27, 2011, I will forever be thankful. With that being said, I would also like to dedicate this work to the families that lost loved ones during the storm and the volunteers that came together to rebuild our town. To the University of Alabama students that were taken from us that gruesome day, you will never be forgotten, and this is dedicated to you most of all.

LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| ADS | Alternate Depreciation System |
| AIAC | Alabama Industrial Assessment Center |
| ASHRAE | American Society of Heating, Refrigeration, and Air-Conditioning Engineers |
| CMM | Capability Maturity Model |
| CRF | Capital Recovery Factor |
| DPB | Discounted Payback Method |
| EMS | Energy Management System |
| EUAB | Equivalent Uniform Annual Benefit |
| EUAC | Equivalent Uniform Annual Cost |
| $F$ | Future Worth |
| $f$ | Inflation Rate |
| GDS | General Depreciation System |
| HVAC | Heating, Ventilation, and Air-Conditioning |
| $i$ | Interest Rate per Interest Period |
| IAC | Industrial Assessment Center |
| IRS | Internal Revenue Service |
| ITIL | Information Technology Infrastructure Library |
| kWh | Kilowatt Hour |
| LEED | Leadership in Energy and Environmental Design |
| MACRS | Modified Accelerated Cost Recovery System |
| MARR | Minimum Attractive Rate of Return |

| | |
|---|---|
| $n$ | Number of Interest Periods |
| NIST | National Institute of Standards Technology |
| $P$ | Present Sum |
| PW | Present Worth |
| SQA | Software Quality Assurance |

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

The importance of saving energy is more crucial now than ever, and will be even more important tomorrow as energy sources continue to be exhausted by the worlds' dependence on resources of energy suppliers. Alternative energy sources will eventually be required, but how soon "is directly related to future world energy demand, which is difficult to predict precisely" (Montgomery, 2006). Until then reducing the amount of energy used is very important for our planet, as well as our pocket books, as energy prices continuously fluctuate. Fortunately, new technologies are helping companies reduce the amount of energy consumed. This can come as a risk for the companies upfront, but in the long run may help everyone involved.

The use of fossil fuels as our primary source of energy is the largest reason decreasing consumption is so important. For centuries, humans have used fossil fuels as energy sources. Using fossil fuels was not a problem when the demand was small and "wood-fueled fires produced energy for cooking, heat, light, and protection from predators" (Montgomery, 2006). Machines and new technology sparked a demand for the resources, and now society relies on fossil fuels for more needs than were necessary during primitive living.

Although there are many drawbacks from using fossil fuels as a source of energy, people have not been able to develop alternative energy sources capable of completely taking the place of fossil fuels. Fossil fuels "pose certain environmental problems. All contribute to the carbon-dioxide pollution in the atmosphere, and several can present other significant hazards such as toxic spills and land subsidence (oil), or sulfur pollution, acid runoff, and mine collapse (coal)"

(Montgomery, 2006). While hydropower, geothermal power, nuclear power, and other sources of energy help factor into the world energy demand, the contribution is substantially lower than the total demand. Figure 1 illustrates the United States' primary energy consumption by source from 1949 to 2009 (U.S. Department of Energy, 2009c). Note that while the use of nuclear power and renewable energy has increased, together the two sources cannot account for a fraction of the demanded energy.

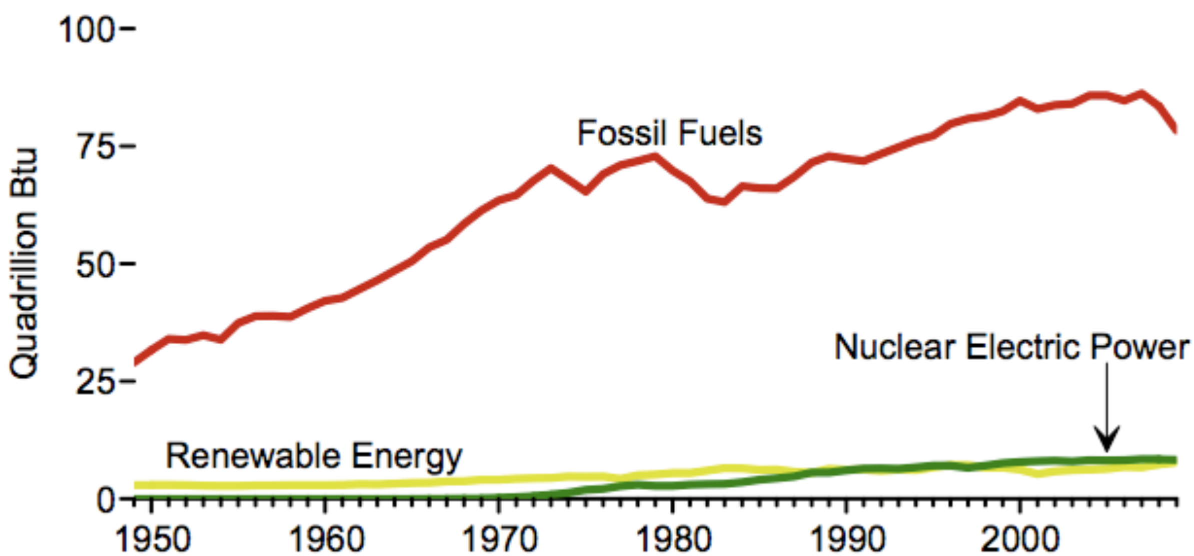


Figure 1. Primary Energy Consumption by Source

As previously stated, the natural reserves of the resources are being exhausted by this demand, and depletion of fossil fuels is not the only reason people are conscious of the amount of energy used. The ability for us to reach some of the reserves is gradually becoming more difficult. In previous decades, people have been able to tap into reserves below land for fuels such as oil and natural gas. While these are still in existence, many are exhausted and people have had to look elsewhere for oil and gas deposits. This required people to drill offshore. Just like the oil and natural gas industry, other industries have found that as accessibility to resource deposits decrease, the environmental factors become increasingly treacherous. Extracting the fossil fuels becomes more and more dangerous because of the location, and new technology is developed to keep up with the changing environmental factors. The equipment required to optimize well production at these sites is much more advanced than what is used at locations with easier accessibility, and extracting the resource takes energy. All of the factors combined force the cost of energy up. People do not want to continue to pay for the increased cost of energy, so people everywhere are developing ways to cut energy consumption.

## 1.1 RELEVANCE TO THE CONSTRUCTION INDUSTRY

Why is this important for the construction industry? After construction is complete, there is still a large demand for energy in the building sector for performance. A large portion of the life-cycle cost of a building goes into maintaining a comfortable environment for the tenants (Kreider, 2001). This may include lighting and ventilation systems. According to the Buildings Data Book (U.S. Department of Energy, 2009a), "the Buildings Sector consumed 39% of U.S. primary energy in 2006." Programs and technology are developing to help decrease the amount of energy consumed by buildings as well as energy consumed during construction of these facilities.

### 1.1.1 ENERGY AWARENESS PROGRAMS

One program that is popular within the construction industry is *Leadership in Energy and Environmental Design* (LEED). "LEED is an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, $CO_2$ emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts" (U.S. Green Building Council, 2010b). With programs such as LEED taking steps to maximize building energy performance, companies are able to establish a building energy rating. LEED has developed a checklist to evaluate the energy efficiency of new and existing buildings. This program has not been perfected, but is still developing. LEED is a step toward environmental awareness, and many companies are buying into the program. For many, this is merely a marketing tool, but for others, it is a money saving approach for the future. There are simple steps companies can take after building erection that can cut down on energy use. Many ideas are highlighted in the *LEED 2009 for Existing Buildings: Operations and Maintenance Rating System* handbook (U.S. Green Building Council, 2010a). Points can be obtained in seven different categories. Under each of the categories prerequisites and credits exist where each category's "intent" and "requirements" are explained as well as "potential technologies and strategies" to achieve points in the category (U.S. Green Building Council, 2010).

Out of 100 possible points in the *LEED 2009 for Existing Buildings* handbook at least 34 of the points have been established in regard to saving energy for existing buildings. The Department of Energy states that 75% of all electricity produced in the U.S. goes into building performance (Department of Energy, 2009b). Considering how much energy is required for building performance, it is important that programs such as LEED help reduce energy consumption of buildings by implementing incentives for saving energy such as weighting points heavily in this case. In the Energy and Atmosphere category of the *LEED 2009 for Existing*

*Buildings* handbook, Credit 1 Optimize Energy Efficiency Performance, allows 18 possible points to be acquired. The potential technologies and strategies section for this credit states:

> Existing building commissioning and energy audits will help identify areas of building operations that are not efficient. Implement energy-efficient retrofits and energy-saving techniques to reduce the building's energy use. Energy-efficient equipment such as office equipment, maintenance equipment and appliances will aid in the reduction of energy waste. Employ the use of meters on major mechanical systems to effectively monitor the energy consumption of each. In addition to efficiency improvements, consider renewable energy options as a way to minimize the building's environmental impact (U.S. Green Building Council, 2010).

Other programs taking steps to improve building efficiency include the Building Efficiency and Retrofit Program created by the Texas State Energy Conservation Office, the Energy Efficiency Building Retrofit Program, and programs set up through the Association of Energy Engineers among many others. These programs recognize the importance of saving energy within the building sector, and are providing incentives for improving efficiency.

### 1.1.2 ENERGY SAVING RETROFITS FOR BUILDINGS

Programs to improve building efficiency are only effective if energy saving retrofits exist to help the program succeed. In recent years, building/home owners have taken an interest in some of the products to reduce costs, specifically electric and gas bills. The demand for energy efficient heating and cooling systems has increased significantly as well as lighting.

Understanding the benefits these retrofits can bestow on the owner is important and may give one construction company an edge over another. Turpin (2010) agrees:

> Manufacturers have been on a roll lately, introducing numerous smart, sophisticated products that are aimed at improving control, comfort, and convenience in homes and businesses. Contractors may be wise to learn more about these intelligent solutions […] as customers are becoming increasingly smarter when it comes to controlling their indoor environments (Turpin, 2010).

Schneider Electric is one company offering products to help their clients save energy. According to Schneider Electric's studies, their Cassia Energy Management System (EMS) saves 25 to 44% on energy cost using monitoring software to detect vacancies in hotel units or in multi-unit residencies (Schneider, 2011). Other companies offering products to increase building efficiency include Bryant, Honeywell, Can2Go, Venstar, Aircuity, Johnson Controls', Illumra, and many others. Some of the products offered by these companies are recognized by LEED. OptiNet by Aircuity and Illumra's light sensor both qualify for LEED credits (Turpin, 2010).

Energy efficient products can lower energy use in many industries. One industry many researchers are concentrating on is the manufacturing industry because it "consumes almost one-half of all the commercial energy used and is responsible for roughly similar shares of greenhouse gases" (Ross, 1992). Replacing existing products with energy efficient ones can cut down energy costs tremendously especially in older facilities. Many of the retrofits involve new energy efficient products that can be used in manufacturing facilities, such as light fixtures, insulation, HVAC systems, and heating systems.

## 1.2 QUANTIFICATION OF ENERGY SAVINGS

Calculating the return on energy saving retrofits is important. For a company to be profitable, they must understand each investment, so they are able to make an educated decision on whether or not to invest. The industry has struggled with how to quantify the return on energy saving retrofits for some time now. There are techniques to calculate values such as the breakeven point and dollars accrued. The more factors considered when measuring the return, the more complicated and time consuming the system becomes, but increasing the number of items considered, decreases the amount of error in the quantification. The complicating, time demanding calculations potentially lead managers to make uninformed decisions regarding investment opportunities.

## 1.3 INDUSTRIAL ASSESSMENT CENTERS

The Industrial Assessment Centers (IAC) are funded under the United States Department of Energy's Efficiency and Renewable Energy division. The group helps manufacturing companies become more energy efficient. Using 26 universities across the nation and a broad database to house the information gathered, they assist small-to-medium sized companies throughout the United States.

"The Industrial Assessment Centers program has been in existence for over twenty-one years and is nationally recognized for its economic assistance to small and medium-sized industrial manufacturers" (Center for Energy Efficiency & Renewable Energy, 2010). The program began in 1984, and in 2009 the IAC saved each company an average of $162,000 for the year due to recommendations the group made (Center for Energy Efficiency & Renewable Energy, 2010). Students and faculty make the assessments from universities participating in the effort. “The assessment begins with a university-based IAC team conducting a survey of the eligible plant, followed by a one or two day site visit, taking engineering measurements as a basis for assessment recommendations. The team then performs a detailed analysis for specific recommendations with related estimates of costs, performance and payback times” (United States Department of Energy, 2011c).

One of the 26 universities that participate in the IAC program is the University of Alabama. The Alabama Industrial Assessment Center’s (AIAC) mission is “assist small-to-medium sized manufacturing industry in Alabama with energy conservation, waste reduction, and productivity increases” (United States Department of Energy, 2011b). The AIAC received a supplement from the Department of Energy that allows them to also assess “large” manufacturing companies. This has broadened their work since receiving the award in 2009.

Their goal is to increase energy efficiency, and many of their recommendations are for building energy retrofits that help lower the amount of energy used in the facility. They take the information gathered, and for each manufacturer, a report is written. Within the report they explicitly define the problem in the “observation” section. Then they provide a solution in the “recommendation” section. “A summary of the savings” is then outlined. This includes “energy savings,” “cost savings,” and other factors to be considered before employing the retrofit. Also included in the output for each recommendation is the payback of the investment.

## 1.4 PAYBACK PERIOD METHOD

The payback period method is the method the Industrial Assessment Center chose for determining whether implementing an energy saving retrofit is feasible for small to medium-sized 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 (2004) and shown in Equation 1, the payback period only considers the cost of implementation and the annual savings. Canada et al (1996) state that the payback "method is often considered a screening technique, permitting the reduction of the number of candidate alternatives to a manageable size, rather than a final selection method." The payback period method is used by the IAC because of its simplicity. Payback is easy to calculate and easy to understand by managers reading the reports.

$$\text{Payback Period} = \text{Cost of Implementation} / \text{Annual Savings} \tag{1}$$

The simple payback period method is the primary method companies assessed by the IAC use to determine whether to subsidize ideas. According to the literature, the simple payback period method lacks the capability to consider several important economic factors. Problems with the payback period method include: the method does not assess risk, does not measure profit, does not reflect the effects of interest, does not consider government payback incentives, does not consider inflation or fluctuation in energy prices, and does not account for budget verses actual performance (Russell, 2009).

## 1.5 STATEMENT OF THE PROBLEM

There is a problem with the popular method the IAC and therefore companies use to calculate the economic return on energy saving investments. The purpose of this thesis is to examine the methods used, particularly simple payback, and develop an improved approach for evaluating the economic aspects of building energy retrofits.

# CHAPTER 2

# LITERATURE REVIEW

Academic scholars have basically accepted the payback method to be flawed for many years now (Weingartner, 1969). Alternative methods have surfaced that take into account other factors, but still some of the same problems persist. Time value of money is not considered in most of the methods, and academia has proven the importance of considering this aspect when investing in products. This review highlights some of the methods used by companies as well as how some of the proposed components of the alternative economic analysis have been used in the past.

## 2.1 ECONOMIC EVALUATION METHODS

The following methods are a few alternatives that can be used to evaluate the return and feasibility of an investment. They include but are not limited to the payback period method, internal rate of return, and discounted payback period method. These methods are among the most common used and are reviewed in this section. Other alternate methods include life-cycle cost, overall rate-of-return, levelized cost of energy, benefit-to-cost ratio, and others. Not every method is reviewed in this research due to the number of methods that exist.

### 2.1.1 PAYBACK PERIOD METHOD

"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" (Park, 1997). The payback period is frequently used due to its simplicity. Payback is easy to calculate and very easy for users to understand. For this reason many companies use the payback period method including the Department of Energy's Industrial Assessment Centers program.

Russell (2009) states payback "is a risk assessment tool… [not] a profitability metric." Many misapply the technique as a measure of profitability when in fact the method measures liquidity by determining how long the investment will take to pay for itself. This is assuming the asset doesn't depreciate. In actuality, the asset will depreciate over the time the investment takes to pay for itself, and interest on the money spent on the investment is not considered.

For many years now, people have argued that the payback period has flaws. In 1969, an article in Management Science suggested, "The Payback Period has been dismissed as misleading and worthless by most writers on capital budgeting at the same time that businessmen continue to utilize this concept" (Weingartner, 1969). The problem still exists. ASHRAE (2007) affirms the deficiencies regarding the payback method:

> 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.

All of these statements are true regarding the payback method. There are also other components that can be included in this argument in regards to energy savings. There are many economic incentives for people to save energy today in the United States, and those also need to be taken into account. Weingartner (1969) questions, "… why is the payback period so ubiquitously used, despite its universal critics? It may be the case that the problem which managers are seeking to solve by use of payback is not, in fact, handled by the tools many text-book writers espouse." In this article, Weingartner uses a different form of payback that incorporates upfront investment, revenue assumed to be uniform over a period of time, payback, and revenue variance. The expression is more complicated than the simple payback method that includes initial expenditures and annual savings, but time value of money and other components such as interest are still not taken into consideration. The payback period Weingartner considers here can be directly related to other payback methods including the simple payback method discussed above. He describes the method in the context of gambling and discusses how certainty is the most important component of the technique. Each value inputted has a level of uncertainty, yet managers are basing their decisions around a "world of certainty." Because this is not the case in any situation, the technique could be deemed useless. If the technique is inherently useless what is it good for ensuring, and why is it still being utilized? The method does give managers a sense of when the company will receive a return on their investment with probabilistic conditions. He argues that the technique is only useful in the sense that managers can feel confident about their decision, and that the company will break-even at some point. This is undoubtedly not enough information to base impacting decisions around.

In July 1985, the Journal of Business also published an article expressing concerns of using the payback method. Narayanan (1985) suggests, "Managers who use the payback method apparently prefer projects with quick returns." He questions why techniques suggested by academic professionals are not used, and then accounts for a circumstantial scenario. Narayanan (1985) proposes there are some instances where only the quickest payback is important to managers. This may not in fact be best for the manager or the company, but if a new manager is seeking approval by the stockholders, he may need to establish trust by returning economic investment as quick as possible. The circumstances in this case is one of only a few times the payback method could be the most useful technique for managers, and this is only true if the investment payback time is relatively short (within one or maybe two years maximum).

More recently, Lewellen (2010) takes the side of businessmen when he describes their reasons for using the simple payback method. He points out, "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…" (Lewellen, 2010). While Lewellen "sympathizes" with the businessmen, he also points out the importance of taking into consideration time value of money. He argues that time value of money techniques have been studied and ascertained as a well-developed notion for calculating the payback on an investment. As he sets up a scenario, and proceeds with the calculations, he begins to develop an understanding for why the payback method is still entertained. Lewellen (2010) finishes the analysis on the project but agrees that the particular methodology, time value of money analysis, has to be reassessed for changing scenarios. No one formulation will work consistently for each project.

This review proves that, although the payback period has been used for years, scholars have deemed the method flawed. If the payback method is only good for short amounts of time (less than two years), then why does anyone need to use the method? Maybe managers just want to reassure themselves a retrofit will in fact pay for itself quickly. Russell (2009) 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." Other authors, that agree the payback period method has too many flaws to rely on include: Canada et al (1996), Park (1997), Zandin (2001), and Newnan et al (2004) who asserts the payback period method "should never be used as the sole measure of quality."

### 2.1.2 TIME VALUE OF MONEY

Vanek and Albright (2008) 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, 1997). One widely used time value of money analysis technique is the internal rate of return method. According to Newnan et al (2004), "… rate of return is the interest rate earned on the unrecovered investment such that the payment schedule makes the unrecovered investment equal to zero at the end of the life of the investment." Time value of money methods of analysis include: present worth, annual cash flow, future worth, and benefit-cost ratio. Methods of calculating these values include: single payment compound amount and present worth, uniform series compound amount, sinking fund, capital recovery, and series present worth, arithmetic gradient uniform series, arithmetic gradient present worth, geometric series present worth, and other factors and equations.

Time value of money techniques have proved to be a very good estimate for analyzing return on investments. Traditionally applied techniques alone are insufficient for this analysis. One reason is the economic analysis needs to also take into consideration energy inflation costs from one year to the next. People in the past have not used time value of money because they have had trouble defining a few of the terms like interest rate and the number of interest periods.

### 2.1.3 DISCOUNTED PAYBACK METHOD

The discounted payback method (DPB) is a more accurate prediction of the time an investment takes for the owner to break even. This method does take into account time value of money. The only difference between the simple payback period method and the discounted payback method is the cost and savings of an investment are discounted. This method is like the simple payback method in that the only real conclusion to be formed is whether the company should accept the investment in relation to the time taken to break even. Kreith and Yogi (2007) conclude, "DPB is often (correctly) used as a supplementary measure when project life is uncertain" (Kreith and Yogi, 2007). Section 2.1 points out the same is true for the simple payback method. Kreith and Yogi (2007) go on to say, "It [the discounted payback method] is also over used and misused. Because it indicates the time at which the investment just breaks even, it is not a reliable guide for choosing the most profitable investment alternative, as savings or benefits after the payback time could be significant." The discounted payback method also neglects any profit the asset will bring to the company after the breakeven point is reached. While this method may be helpful in comparing possible investments, it should not stand alone when making a decision regarding implementing a product.

## 2.2 METHODOLOGY PROBLEMS

Other methods have been created to evaluate building retrofits, but deficiencies remain in all of them. The problem that is most consistent between all of the methods with the exception of simple payback is that as they become more complex, more time has to be taken to determine the payback on the investment, and not everyone understands these methods. Managers would have to understand the complex methods well enough to be able to manipulate the functions to obtain a correct analysis of the investment. Information that is pertinent in some cases has to be differentiated from irrelevant information, and the process can become increasingly intricate with each variation.

## 2.3 ENERGY PROJECT ANALYSIS

Christopher Russell (2009) lays the foundation for this research effort. In his "How the Money Works" lecture, he points out deficiencies in methods such as payback, and then provides an alternative approach. Russell (2009) explains 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. Russell (2009) 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.

Russell's first step in his 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 the investment is worthwhile. Russell (2009) 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 (2009) 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 (2009) 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).

## 2.4 SOLUTION

This thesis will investigate developing an alternative economic analysis technique using computer-based software expanded from Russell's (2009) approach. The method will be convenient to use and understandable for the user, with a user manual provided to accompany the analysis. 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 economics to make an informed decision regarding investing in energy saving retrofits.

# CHAPTER 3

# SCOPE AND METHODOLOGY

One of the major concerns with using the payback method is the technique does not consider important factors such as time value of money or 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. The system must take into consideration time value of money and inflation without presenting complicated results, and the tool must be easy for the assessors to utilize and understand. If the tool cannot meet these criteria, then assessors will continue employing the payback method.

## 3.1 CONSIDERATION OF TIME VALUE OF MONEY

Time value of money has been accepted in the academic and professional factions 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. Two common time value of money methods are present worth and uniform series annual cash flow. Both of these methods would be beneficial when assessing proposed energy saving ideas. They both can help evaluate the proposals including profitability analysis. 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" (Newnan et al, 2004). The value for "n" causes concern because many managers do not know how long the retrofit will last. Therefore, the value for "n" is hard to determine exactly. The interest rate per interest period, "i", is where companies can use their required rate of return or minimum attractive rate of return (MARR) value that can be computed. Park (1997) defines MARR as the determined "interest rate that the firm wishes to earn on its investments. The [MARR] … represents the rate at which the firm can always invest the money in its investment pool." Newnan et al (2004) goes on to say the "minimum attractive rate of return should be equal to the largest one of the following: cost of borrowed money, cost of capital, or opportunity cost." Many small companies like the ones assessed by the AIAC do not know what their MARR value is, and do not know how to compute the value. This research conclude values acceptable for companies to utilize for their variables with guidelines for the companies to follow when using these values.

## 3.2 CONSIDERATION OF INFLATION

Considering inflation is extremely important, especially in this case because we are evaluating 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. For the economic assessment tool to be accurate inflation must be considered. According to Newnan et al (2004) "the inflation rate captures the effect of goods and services costing more. … The inflation rate is measured as the annual rate of increase in the number of dollars needed to pay for the same amount of goods and services." A problem with considering inflation is where it fits within the assessments. According to Newnan et al (2004) 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.

## 3.3 EASE OF USE

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. The tool must be convenient, quick, uncomplicated, easy to understand, simple to employ, and present a more accurate evaluation of the investment.

Development of this tool was based upon information available from a standard AIAC assessment. This includes assessment recommendations along with facility utility bills. No other information will be necessary to obtain, which will contribute to the tool's simplicity. From this available information, other variables were determined. Guidelines and rationale for the determined variables are included in an accompanying user manual that is easy for the user to understand. Instructions for interpreting calculated values are provided. The manual allows the user to employ the tool quickly and without confusion. Execution of the tool provides a clear answer to whether or not implementing the product is worthwhile.

## 3.4 USER CONVENIENCE

The evaluation must be convenient for the users or the tool will not be utilized. After considering alternative ways to form a conclusion that incorporates the time value of money and other important factors, 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. The chance of the program already being contained on the existing computers at the company is probable. Also, the Excel user base is wide. It is a relatively simple program to use. Therefore, people who do not have a substantial amount of computer experience could still use the program. Young people are very familiar with the functions of Excel, and because Microsoft parallels their programs with one another, it is easy for anyone who has used another Microsoft program (e.g. Microsoft Word) to employ Excel. Microsoft Excel also possesses the ability to perform the calculations necessary in the spreadsheet. According to Cahill et al (2000), Excel is a good choice for economic functions for many reasons. He argues that while "writing spreadsheet applications does take considerable time and effort," (Cahill et al, 2000) the program is still a good choice. He goes on to say, "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" (Cahill, 2000). Students from any discipline can expect to use Microsoft Excel after college now. Excel's ease of use and other feasible properties made the program the most logical choice for performing the calculations. Many textbooks incorporate descriptions for how to use a spreadsheet when making calculations. Newnan et al (2004) includes the section "Using Spreadsheets for Inflation Calculations" which provides an example for calculating annual cost including inflation using a spreadsheet.

The spreadsheet will help managers decide whether or not to invest in an energy saving idea. As a solution is drawn, documentation of the attempts was organized. Trials, errors, and successes were recorded, and conclusions were drawn as the project proceeded. These were incorporated into the deliverable. A verification of the spreadsheet was conducted to ensure that the tool worked properly, and that it was easy for managers to use. After the final spreadsheet was created, 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. A conclusion regarding the output of that data was included in the spreadsheet in the form of questions and answers. The questions, "is the proposed retrofit worth the investment," and "is the cost of implementing the project within budget," will be answered in the spreadsheet. Using Excel, a prediction concerning the future benefit using the information gathered is included. The deliverable is considered sufficient for companies to make an improved decision regarding the energy saving investments, as well as understand the basis for the costs involved.

## 3.5 CONCLUSION

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.

## CHAPTER 4

## DESIGN AND DEVELOPMENT OF THE SYSTEM

The design of the Excel-based tool that incorporates the time value of money, inflation, and other relevant factors is included within this chapter. This tool provides a better evaluation of the economic factors associated with energy saving retrofits. The design of the evaluation technique along with the basis behind the calculations for the cost benefit analysis and break-even point analysis are contained within the following sections. An approach by Christopher Russell (2009) was used as a foundation for the development of this tool. However, his approach neglects considering inflation. This approach incorporates inflation with his recommended method.

### 4.1 COST-BENEFIT ANALYSIS

The cost-benefit analysis was designed first for managers to determine whether implementing the product is worthwhile. "Cost-benefit analysis refers to changes in the allocations of resources brought about by a project" (Jha, 1997). The advantage of using cost-benefit analysis is that a manager can compare "the allocation of resources before and after the installation of a project" (Jha, 1997). In this case the goal of the cost-benefit analysis is to consider the factors of time value of money and inflation to compare the cost of investing versus the cost of not investing in an energy saving retrofit.

Newnan (2004) uses the term benefit-cost when referring to the analysis. Two formulas can be used when calculating the cost-benefit analysis (Equation 2 and 3). Equation 3 represents a cost-benefit ratio. This is an important technique because the output is easy to interpret. While the formula for cost-benefit analysis is simple, the calculation can actually be complex. Determining the present worth (PW) for costs of implementing a product and the present worth for not implementing a product presents multiple problems discussed later in the chapter.

PW of benefits – PW of costs Eqn (2)

PW of benefits / PW of costs Eqn (3)

"At a given minimum attractive rate of return, [a manager] would consider an alternative acceptable" if equation 2 is greater than or equal to 0 or if equation 3 is greater than or equal to 1 (Newnan et al, 2004). For this research the variables are modified in the cost-benefit analysis to correspond to annualized values collected from the IAC. The equivalent uniform annual cost (EUAC) and the equivalent uniform annual benefit (EUAB) are calculated to determine their difference (EUAB-EUAC).

### 4.1.1 ALABAMA INDUSTRIAL ASSESSMENT CENTER DATA

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 (IAC). The output from these assessments will be utilized as part of the input for the tool to reach a more accurate presumption regarding the economic return on the investment.

### 4.1.2 APPLICATION OF TIME VALUE OF MONEY

As noted in Chapter 3, time value of money is important to consider in the economic analysis because the money allocated for investing in the energy saving retrofit will be tied up for a period of time. Because our money is worth more now than in the future, time value of money has to be considered for an accurate evaluation. Multiple time value of money techniques exist.

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" (Russell, 2009). Therefore uniform series capital recovery is used to calculate annual cost. Uniform series capital recovery "convert[s] a present sum *P* to a series of equivalent uniform end-of-period cash flows" (Newnan et al, 2004). Because we can calculate the cost to implement the retrofit *P* and need to find the estimated annual cost, the uniform series capital recovery technique is selected for the analysis.

Problems reside with using the time value of money technique for these types of analyses. These problems have kept many from using the technique for analyzing economic return. The problems occur with the determination and selection of the variables interest rate per interest period *i* and number of interest periods *n* included in the capital recovery factor (Equation 4).

$$\frac{i(1+i)^n}{(1+i)^n - 1} \qquad \text{Eqn (4)}$$

Many company managers do not know what values to use for some of these variables. To deal with this problem values are suggested for the interest rate and number of interest periods from this research.

4.1.2.1 SERVICE LIFE

For 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. This system is known as the Modified Accelerated Cost Recovery System used for calculating the depreciation of an investment (Newnan et al, 2004).

When determining the life cycle of the product, choosing a system that corresponded to the government's accepted values was important. "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" (Canada et al, 1996). For the alternative calculation proposed, the life cycle of the product must be determined. MACRS depreciates assets using two alternative methods: General Depreciation System (GDS) and Alternate Depreciation System (ADS). For the economic analysis proposed, GDS will be used because the property being used does not fall under any of the categories required for ADS. Newnan et al (2004) explains 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." If the depreciated life is underestimated versus the "actual useful life" then the end value is conservative. This is an additional safety factor within the calculation. The salvage value is also understood to be zero. While this may be true, some products may be able to be salvaged which only increases the value of the product. MACRS was chosen for all of the prior reasons, and the user-friendly table makes using MACRS easy for the assessor.

Therefore the value for *n* will come from the Modified Accelerated Cost Recovery System (MACRS) to determine the life cycle of the item. "MACRS is used to recover the basis of most business and investment property placed in service after 1986" (U.S. Department of the Treasury, 2009). Because the investments being considered are new technologies to better energy performance in present day, there will not be a problem with the property being placed in service prior to 1987. In the MACRS GDS Property Classes Table personal property descriptions are outlined along with a property class (Newnan et al, 2004). 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.

#### 4.1.2.2 INTEREST RATE

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.

The default value comes from an assessment of the values companies prefer to use. An interview conducted with Scott Perkins, C.P.A. (2010), confirmed that 7% was a suitable interest value for the energy saving implementations being employed. Mr. Perkins explained that each company's interest rate would vary slightly depending on their industry and revenue but stated there was not a suitable table or book to get the value from to use for the analysis. He went on to say this was a delicate process, and for many managers calculating this number would be difficult. From Mr. Perkins' experience he stated an interest between 6% and 8% would be suitable for the calculation at hand.

### 4.1.3 INFLATION

The third component incorporated into this tool is inflation. Inflation separates Russell's (2009) work from the work in this thesis. Because the demand and supply for energy is moving in opposite directions, energy prices continue to rise. This gives companies the incentive to turn to these energy saving retrofits. Considering the rising cost of energy into the analysis is pertinent to performing an accurate economic evaluation of the retrofit.

Newnan et al (2009) describes how inflation can be incorporated into time value of money analysis by adding an additional variable $f$ to represent inflation. Newnan et al (2009) state, "next year's labor costs are likely to be estimated as equal to this year's costs times $(1 + f)$, where $f$ is the inflation rate." When $(1 + f)$ is raised to the $n$ power, one can see the inflation at the end of year $n$. This approach is consistent with the time value of money equations. While this is useful information, this analysis will not take into consideration inflation after the first year. To take multiple years into consideration, a more accurate inflation rate would need to be measured. The inflation rate for this analysis will come from comparing the cost of energy this year to the cost of energy last year from a company's bills. To forecast an accurate number for several years into the future, a company would need to have more information from a span of several years from the past to determine a trend. Due to the volatility in energy pricing, such trend analysis might not be useful even if available. Since most companies do not keep that information on file, gathering those values would be difficult. 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 (U.S. EIA, 2010). 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" (U.S. EIA, 2010). The values used were from the industrial sectors in Alabama. The average cost for July 2010 was $.0624 and the average for July 2009 was $.06.

### 4.1.4 CONSTRUCTION OF THE SPREADSHEET

The spreadsheet was constructed using Christopher Russell's (2009) approach. Russell first suggests calculating the annualized project cost (Equation 5) using the "up-front project cost" and the capital recovery factor (Russell, 2009). As discussed in Section 4.1.2, the capital recovery factor is calculated first using the expected life of the asset $n$ and the applicable interest rate $i$ (Figure 2). From these, the annualized project cost is calculated (Figure 3). For this thesis, the up-front project cost will be referred to as the "cost of investment" or implementation cost.

*Annualized project cost = Cost of investment x Capital recovery factor* Eqn (5)

| *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 | =(E10*(1+E10)^E9)/((1+E10)^E9-1) |
| *Cost of Investment x Capital Recovery Factor =* | |
| Annualized Project Cost ($/yr) | $16,332.64 |
| *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*** |

Figure 2. Capital Recovery Factor

| *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*** |

Figure 3. Annualized Project Cost

"Energy savings are accounted annually" (Russell, 2009). Therefore, the cost to save must also be annualized. Using the annualized project cost and "annual savings" the "annualized project cost per annual savings" is calculated per Russell's (2009) suggestion (Equation 6). The cost to save spreadsheet calculation is presented in Figure 4. 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 thesis.

*Cost to save = Annualized project cost / Energy savings* Eqn (6)

Russell (2009) ends his analysis by comparing the cost to save to the unit price of energy for the present year. This thesis takes the analysis one step further by incorporating an inflation factor into the time value of money approach (Newnan et al, 2004). 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.

| *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) | $16,332.64 |
| *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) | =E21/E7 |
| *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*** |

Figure 4. Cost to Save

To calculate inflation $f$, the cost of energy in the present year and the cost of energy from the previous year will be needed (Equation 7). This information will be 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" in this thesis (Figure 5). From inflation, the energy inflation factor is computed according to Newnan et al (2004) (Equation 8). The planning horizon for this thesis is only one year resulting in $1 + f$ being used for the energy inflation factor (Figure 6).

$$\textit{Inflation } (f) = \textit{This year} / \textit{Last year} - 1 \qquad \text{Eqn (7)}$$

$$\textit{Energy Inflation Factor } (F/P, f, n) = (1 + f)^n \qquad \text{Eqn (8)}$$

Using the energy inflation factor, the cost to buy energy can now be calculated using Newnan's et al (2004) idea of combining the inflation factor and the time value of money (Equation 9). The calculation is shown in Figure 7. Now the cost to buy energy can be compared to the cost to save as in Russell's (2009) approach (Equation 10) to acquire the cost-benefit ratio discussed previously in Section 4.1. In this thesis as the cost-benefit ratio will also be referred to as the cost-benefit analysis (Figure 8).

$$\textit{Cost to buy} = \textit{This year x Energy inflation factor} \qquad \text{Eqn (9)}$$

$$\textit{Cost-benefit analysis} = \textit{Cost to save} / \textit{Cost to buy} \qquad \text{Eqn (10)}$$

| *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) | $16,332.64 |
| *This Year / Last Year - 1 =* | |
| Inflation (*f*) | =E14/E13-1 |
| $1+f=$ | |
| 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*** |

Figure 5. Inflation

| *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) | $16,332.64 |
| *This Year / Last Year - 1 =* | |
| Inflation (*f*) | 4.67% |
| $1 + f =$ | |
| Energy Inflation Factor | =1+E24 |
| *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*** |

Figure 6. Energy Inflation Factor

| *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) | $16,332.64 |
| *This Year / Last Year - 1 =* | |
| Inflation ($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 ($/kWh) | =E14*E27 |
| *Cost to Save ($/kWh) / Cost to Buy ($/kWh) =* | |
| Cost-Benefit Analysis | 0.798 |
| ***Will implementing the product be worthwhile?*** | ***Yes*** |

Figure 7. Cost to Buy

| *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) | $16,332.64 |
| *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 | =E30/E33 |
| ***Will implementing the product be worthwhile?*** | ***Yes*** |

Figure 8. Cost-Benefit Analysis

Using an "IF" statement in Microsoft Excel, the result of the cost-benefit analysis answers the question "will implementing the product be worthwhile?" According to Russell (2009), this analysis indicates that the company will pay $.798 to avoid buying $1.00 worth of energy. Thus the proposed retrofit is economically worthwhile, and any cost-benefit analysis result less than one would deem the retrofit worthwhile. The spreadsheet answers the question with "yes" or "no" using this information (Figure 9).

## 4.2 BREAKEVEN ANALYSIS

From the cost-benefit analysis the breakeven point can be determined. Russell (2009) 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" (Newnan et al, 2004). For this analysis Russell (2009) 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. This analysis is provides more information for the manager to use. 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 (2009) uses the "price per unit of energy" and "units of avoided energy consumption" to determine the "maximum acceptable annualized project cost" (Equation 11) as shown in Figure 11. 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 thesis.

| *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) | $16,332.64 |
| *This Year / Last Year - 1 =* | |
| Inflation ($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?*** | ***=IF(E36<1,"Yes","No")*** |

Figure 9. Will Implementing The Product Be Worthwhile?

The cost to buy energy and energy savings are taken from the energy analysis of energy retrofit of buildings tool as shown in Figure 10. Using the maximum acceptable annualized project cost and the capital recovery factor (CRF), Russell (2009) calculates the maximum acceptable up-front project cost (Equation 12) shown in Figure 12. In this thesis, 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. The capital recovery factor is consistent with the CRF value used in 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 (Figure 13). If the maximum acceptable cost of investment is greater than of equal to the implementation cost, the project is considered to fall within budget. Detailed instructions for the utilization and interpretation of the spreadsheets, for both modified cost-benefit and breakeven analysis, are provided in the user guide in Appendix A.

*Maximum annualized project cost = Energy savings x Cost to buy* Eqn (11)

*Maximum implementation cost = Maximum annualized project cost / CRF* Eqn (12)

| *Break-even Analysis of Energy Retrofit of Buildings* | |
|---|---|
| | |
| Energy Savings (kWh/yr) | =E7 |
| Cost to Buy Energy ($/kWh) | =E33 |
| | |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost | $20,476.48 |
| | |
| *Maximum Acceptible Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | $53,736.76 |
| | |
| ***Is the project within budget?*** | ***Within Budget*** |

Figure 10. Energy Savings and Cost to Buy Energy

| *Break-even Analysis of Energy Retrofit of Buildings* | |
|---|---|
| | |
| Energy Savings (kWh/yr) | 311,521 |
| Cost to Buy Energy ($/kWh) | $0.07 |
| | |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost | =E42*E43 |
| | |
| *Maximum Acceptible Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | $53,736.76 |
| | |
| ***Is the project within budget?*** | ***Within Budget*** |

Figure 11. Maximum Acceptable Annualized Project Cost

| Break-even Analysis of Energy Retrofit of Buildings | |
|---|---|
| | |
| Energy Savings (kWh/yr) | 311,521 |
| Cost to Buy Energy ($/kWh) | $0.07 |
| | |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost | $20,476.48 |
| | |
| *Maximum Acceptible Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | =E46/E18 |
| | |
| ***Is the project within budget?*** | ***Within Budget*** |

Figure 12. Maximum Acceptable Cost of Investment

| Break-even Analysis of Energy Retrofit of Buildings | |
|---|---|
| | |
| Energy Savings (kWh/yr) | 311,521 |
| Cost to Buy Energy ($/kWh) | $0.07 |
| | |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost | $20,476.48 |
| | |
| *Maximum Acceptible Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | $53,736.76 |
| | |
| ***Is the project within budget?*** | ***=IF(E49>=E8,"Within Budget","Over Budget")*** |

Figure 13. Is the Project Within Budget?

## 4.3 VERIFICATION OF SOFTWARE

Ensuring that the software works properly is important. "A 2002 study by the National Institute of Standards Technology (NIST) estimated that software errors cost the U.S. economy $59.5 billion each year. The report noted that software testing could have reduced those costs to about $22.5 billion" (Laplante, 2007). Guidelines for the software creator have been compiled to decrease the amount of software errors. These standards fall under Software Quality Assurance. "Software Quality Assurance (SQA) is responsible for verifying that the project activities and work products conform to the project's designated processed, procedures, standards, and requirements" (Kan, 2003). SQA frequently includes a checklist based on the capability maturity model (CMM) and its five maturity levels. Other quality standards include ISO-9000, Six Sigma, as well as the information technology infrastructure library (ITIL) (Laplante, 2007). All of these quality assurance models parallel, and some can be used in conjunction with others due to respective shortfalls and strengths.

Quality assurance software testing is required to find defects as well as to verify and validate the process. Laplante (2007) 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 (Appendix B). In A comparative analysis of the two methods will be conducted in Chapter 5.

# CHAPTER 5

# COMPARISON WITH PREVIOUS METHOD

As previously discussed, the Alabama Industrial Assessment Center uses the payback method in their assessment of energy efficient retrofits for companies. Time value of money and inflation are not included in the analysis. The hypothesis is if the time value of money and inflation are considered, the results of the assessment could vary. The results obtained from the previous method will be compared to the results acquired from the economic analysis of energy retrofits of buildings tool.

## 5.1 APPLICATION OF THE SPREADSHEET

To test the spreadsheet, data from a specific IAC assessment report was used. Included in the recommendations section, a table provides the company with information regarding the item(s) that could be replaced. The table includes: energy savings, energy cost savings, implementation cost, and simple payback period (Table 1). For the following example, the recommendation is to "replace metal halide lamps with T-8 fluorescent fixtures" (Alabama Industrial Assessment Center, 2010b).

| *AR No.* | *Description* | *Electricity Savings (kWh/yr)* | *Energy Cost Savings ($/yr)* | *Imp Cost ($)* | *Simple Payback* |
|---|---|---|---|---|---|
| 1 | Replace Metal Halide Lamps with T-8 Flourescent Fixtures | 20,639 | 2,330 | 5,324 | 2.3 |

Table 1. Assessment Recommendation Cost Table

The spreadsheet was then populated with relevant data for this IAC recommendation in order to provide an initial verification. Using this information to calculate the economic analysis of energy retrofit and performing the cost benefit analysis, replacing the lamps with a more efficient product would indeed be worthwhile economically (Figure 14). Russell (2009) explains the results by suggesting the retrofit allows the investor to pay \$0.260 to avoid buying \$1.00's worth of energy.

The break-even analysis (Figure 15) concluded that the retrofit should be implemented as well by stating the project is within budget since the maximum acceptable cost of investment (\$20,477.25) is greater than the actual cost of implementing the retrofit (\$5,324.00). The spreadsheet confirms the AIAC recommendation of this retrofit.

## 5.2 ASSESSMENT COMPARISON

Once the spreadsheet was verified using the assessment data, the tool could be used to compare further results gathered by the IAC to conclusions made by the tool incorporating time value of money and inflation. To perform the calculations, data from a selected Industrial Assessment report was used (Alabama Industrial Assessment Center, 2010b). This data was drawn from an assessment of a manufacturing facility for finished sewage pipe.

### 5.2.1 ANALYSIS ASSUMPTIONS

To perform the economic evaluation using the assessment tool assumptions had to be made regarding the expected life of the asset *n*, applicable interest rate *i*, and the cost to buy energy last year and this year.

| *Economic Analysis of Energy Retrofit of Buildings* | |
|---|---|
| | Input |
| | Output |
| Energy Savings (kWh/yr) | 20,639 |
| Cost of Investment (Implementation Cost) | $5,324.00 |
| Expected Life of Asset (n) | 7 |
| Applicable Interest Rate (i) | 7.00% |
| Cost to Buy Energy | |
| Last Year ($/kWh) | $0.1495 |
| This Year ($/kWh) | $0.1659 |
| $\frac{i(1+i)^n}{(1+i)^n-1}$ = | |
| Capital Recovery Factor | 0.186 |
| *Cost of Investment x Capital Recovery Factor =* | |
| Annualized Project Cost ($/yr) | $987.89 |
| *This Year / Last Year - 1 =* | |
| Inflation (*f*) | 10.97% |
| $1+f$ = | |
| Energy Inflation Factor | 1.110 |
| *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) | $0.18 |
| *Cost to Save ($/kWh) / Cost to Buy ($/kWh) =* | |
| Cost-Benefit Analysis | 0.260 |
| ***Will implementing the product be worthwhile?*** | ***Yes*** |

Figure 14. Cost-benefit Analysis Test

| *Break-even Analysis of Energy Retrofit of Buildings* | |
|---|---|
| | |
| Energy Savings (kWh/yr) | 20,639 |
| Cost to Buy Energy ($/kWh) | $0.18 |
| | |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost ($/yr) | $3,799.62 |
| | |
| *Maximum Acceptable Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | $20,477.25 |
| | |
| ***Is the project within budget?*** | ***Within Budget*** |

Figure 15. Break-even Analysis Test

Included in the AIAC (2010b) report appendices is information regarding "energy consumption and price" for the particular facility over the past year. To determine the inflation factor the price of electricity per kWh was calculated using July 2009 and June 2010 data. In AIAC (2010b) report the usage rate is calculated to be $0.1129 per kWh. This number is acquired by dividing the total electrical cost over the course of the year by the total electrical usage (kWh) over the year. For the cost to buy energy, the same principle needs to be applied. To determine the inflation factor, the cost of energy per kWh for the months of July 2009 and June 2010 need to be calculated and compared. For each month the total electrical cost is divided by the total electrical usage (kWh). For this specific analysis the inflation factor was calculated to be almost 11%.

| | *Electrical Cost ($)* | *Electrical Usage (kWh)* | *Cost to Buy Energy ($/kWh)* |
|---|---|---|---|
| *Jul-09* | 5770.84 | 38,600 | 0.1495 |
| *Jun-10* | 7613.52 | 45,880 | 0.1659 |

Table 2. Cost to Buy Energy

For the expected life of the asset, the U.S. Department of the Treasury (2009) Table of Class Lives and Recovery Periods is used to obtain the MACRS value for each retrofit. For the lighting system retrofits, a 7-year cost recovery period will be used. According to the asset class 00.11, “office furniture, fixtures, and equipment” have a 7-year recovery period (U.S. Dept. of Treasury, 2009). The lighting system retrofits fall under this category because many light fixtures will have to be replaced and they are “not a structural component of [the] building” (U.S. Dept. of Treasury, 2009).

For the HVAC systems the same 7-year recovery period will apply. This is for a different reason. The MACRS table does not explicitly describe a property class where HVAC units are mentioned. MACRS does however suggest a 7-year property value be designated to “any property that does not have a class life and has not been designated by law as being in any other class” (U.S. Dept. of Treasury, 2009). Because the retrofits considered by the IAC were assumed to fall within the 3- and 7-year life cycle spans, the 7-year assumption is acceptable.

The interest rate that will be used in comparing the existing method to the suggested tool will be the default interest rate of 7% for this tool. This is because the MARR for the company assessed by the AIAC (2010b) is unknown. The IAC provides the company with a brief questionnaire before making the assessment with questions requiring information including what the company’s maximum payback for the retrofits is. As of now the IAC does not request the company’s MARR value, but if the tool is accepted for determining whether the retrofit is economical, the value could be requested for the assessment.

### 5.2.2 ASSESSMENT RECOMMENDATIONS

In the Alabama Industrial Assessment Center’s (2010) report, seven assessment recommendations were made involving the lighting and HVAC systems. For the lighting system they also suggested the company "install photosensor controls to utilize daylight" (Alabama Industrial Assessment Center, 2010b). For the space conditioning assessment, two recommendations were made. They were to "install programmable thermostats in the office [and] adjust the year round thermostat set points in the offices" (Alabama Industrial Assessment Center, 2010b). The last three recommendations that were made by the AIAC (2010b) were to "reduce overall pressure in compressed air system, reduce leaks in compressed air system, [and] eliminate use of air motors on pipe turners."

All seven of these recommendations were based on the assessment of electricity savings, cost savings, implementation cost, and payback. The payback method is the method they use to support whether the retrofit is economically sustainable for the company and the deciding factor before making the recommendation. The requirement for the AIAC to determine if the retrofit is economically sustainable is if the payback lies under the maximum payback set by the company. This is typically three years. Each of the seven recommendations made in this assessment fall under the 3-year requirement as seen in Table 3.

### 5.2.3 ECONOMIC ANALYSIS OF RECOMMENDATIONS

Using energy savings, the cost of investment, and the cost to buy energy obtained from the AIAC (2010b) report as well as the MACRS table, a more thorough evaluation of the retrofits is performed using time value of money and inflation. The results from the tool are included in Table 4. With the assumptions and data from the report, the tool confirms every recommendation made by the AIAC from the assessment is in fact economically sustainable for the company.

| | AR No. | Description | Payback (yrs) |
|---|---|---|---|
| Lighting | 1 | Replace Metal Halide Lamps with T-8 Flourescent Fixtures | 2.3 |
| | 2 | Install Photosensor Controls to Utilize Daylight | 0.6 |
| Space Conditioning | 3 | Install Programable Thermostat in the Office | 0.2 |
| | 4 | Adjust the Year Round Thermostat Set Points in the Office | 0.2 |
| Compressed Air | 5 | Reduce Overall Pressure in Compressed Air System | 0.2 |
| | 6 | Reduce Leaks in Compressed Air System | 1.1 |
| | 7 | Eliminate use of Air Motors on Pipe Turners | 1.0 |

Table 3. Assessment Recommendation Payback

| | AR No. | Description | Electricity Savings (kWh/yr) | Imp. Cost ($) | Annualized Project Cost ($/yr) | Cost-Benefit Analysis Results | Is the retrofit worthwhile? | Max Acceptable Annualized Proj. Cost ($/yr) | Max Acceptable Imp. Cost ($/yr) | Break-Even Analysis Results (Is the retrofit within budget?) |
|---|---|---|---|---|---|---|---|---|---|---|
| Lighting | 1 | Replace Metal Halide Lamps with T-8 Flourescent Fixtures | 20,639 | 5,324 | 987.89 | 0.259 | Yes | 3,813.37 | 20,551.38 | Yes |
| | 2 | Install Photosensor Controls to Utilize Daylight | 1,742 | 112 | 20.78 | 0.065 | Yes | 321.86 | 1,734.60 | Yes |
| Space Conditioning | 3 | Install Programable Thermostat in the Office | 6,845 | 170 | 31.54 | 0.025 | Yes | 1,264.72 | 6,815.94 | Yes |
| | 4 | Adjust the Year Round Thermostat Set Points in the Office | 2,797 | 50 | 9.28 | 0.018 | Yes | 516.79 | 2,785.13 | Yes |
| Compressed Air | 5 | Reduce Overall Pressure in Compressed Air System | 46,728 | 800 | 148.44 | 0.017 | Yes | 8,633.72 | 46,529.62 | Yes |
| | 6 | Reduce Leaks in Compressed Air System | 39,615 | 5,000 | 927.77 | 0.127 | Yes | 7,319.48 | 39,446.82 | Yes |
| | 7 | Eliminate use of Air Motors on Pipe Turners | 14,118 | 1,550 | 287.61 | 0.110 | Yes | 2,608.52 | 14,058.06 | Yes |

Table 4. Analysis Results for Recommendations

For the first recommendation, "replace metal halide lamps with T-8 fluorescent fixtures" (AIAC, 2010b), the cost-benefit analysis verified the retrofit would indeed be worthwhile. The company has the opportunity to pay $0.259 for implementing the product to save $1.00 in energy costs. Therefore, for every $1.00 the company would have spent on energy they could be saving $0.741. As a result, the cost-benefit analysis concludes the first recommendation is in fact worthwhile consistent with the result from the simple payback analysis. From the other perspective the break-even analysis also concludes the retrofit is within budget, and consequently can be implemented, which is consistent with the expected result of the analysis. This result stems from the maximum acceptable annualized project cost being greater than the annualized project cost and the maximum acceptable implementation cost being greater than the implementation cost.

For recommendations two through seven, the same confirmation is obtained. Recommendation two proves the company could spend less than $0.07 to save $1.00 worth of energy, which is even more economically sustainable than recommendation one. The lower the value for the cost-benefit analysis ratio, the less risk occurs with the investment. The break-even analysis for this recommendation is also to implement the retrofit, consistent with the cost-benefit analysis. For the other five recommendations in the table, the same concept is applied. Every retrofit in this specific report that has been recommended according to the payback period, would also have been recommended through the economic analysis.

### 5.2.4 OTHER RECOMMENDATIONS

There were two other alternatives considered to increase energy efficiency in the building. The considerations assessed by the AIAC (2010b) were to "replace T-12 fixtures with energy efficient T-8 fixtures [and to] increase compressed air storage capacity." These alternatives were not recommended by the AIAC. The recommendation to replace T-12 fixtures with energy efficient T-8 fixtures was not made because the simple payback for the retrofit totaled 15.4 years, which is much greater than the 3-year requirement. The recommendation to increase compressed air storage capacity was not suggested because there was insufficient data to perform a thorough assessment.

The assumptions for recommendations will stay the same for other recommendations because the company's cost to buy energy is the same, the company's MARR is assumed to be 7%, and the observation is to update a portion of the lighting system. Using the assumptions and plugging in information obtained by the AIAC (2010b) report for "replacing T-12 fixtures with energy efficient T-8 fixtures" an evaluation is made which is shown in Figures 16 and 17. According to the results (Table 5) from the evaluation, the retrofit would not be economically sustainable for the company, which confirms the AIAC's (2010b) recommendation to not implement the retrofit according to the payback period.

## 5.3 SENSITIVITY ANALYSIS

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 usage rate from the AIAC (2010b) assessment is \$0.1129 per kWh. The results for the recommendations and other recommendation made in the AIAC (2010b) report using the usage rate and no inflation are summarized in Table 6.

| *Economic Analysis of Energy Retrofit of Buildings* | |
|---|---|
| | Input |
| | Output |
| Energy Savings (kWh/yr) | 1,267 |
| Cost of Investment (Implementation Cost) | $2,273.00 |
| Expected Life of Asset (n) | 7 |
| Applicable Interest Rate (i) | 7.00% |
| Cost to Buy Energy | |
| Last Year ($/kWh) | $0.1495 |
| This Year ($/kWh) | $0.1659 |
| $\frac{i(1+i)^n}{(1+i)^n - 1} =$ | |
| Capital Recovery Factor | 0.186 |
| *Cost of Investment x Capital Recovery Factor =* | |
| Annualized Project Cost ($/yr) | $421.76 |
| *This Year / Last Year - 1 =* | |
| Inflation (*f*) | 10.97% |
| $1 + f =$ | |
| Energy Inflation Factor | 1.110 |
| *Annualized Project Cost ($/yr) / Energy Savings (kWh/yr) =* | |
| Cost to Save ($/kWh) | $0.33 |
| *Cost to Buy Energy This Year ($/kWh) x Energy Inflation Factor =* | |
| Cost to Buy ($/kWh) | $0.18 |
| *Cost to Save ($/kWh) / Cost to Buy ($/kWh) =* | |
| Cost-Benefit Analysis | 1.808 |
| ***Will implementing the product be worthwhile?*** | ***No*** |

Figure 16. Economic Analysis of Other Recommendation

| *Break-even Analysis of Energy Retrofit of Buildings* | |
|---|---|
| Energy Savings (kWh/yr) | 1,267 |
| Cost to Buy Energy ($/kWh) | $0.18 |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost ($/yr) | $233.25 |
| *Maximum Acceptable Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | $1,257.07 |
| ***Is the project within budget?*** | ***Over Budget*** |

Figure 17. Break-Even Analysis of Other Recommendation

| *OR No.* | *Description* | *Electricity Savings (kWh/yr)* | *Imp. Cost ($)* | *Annualized Project Cost ($/yr)* | *Cost-Benefit Analysis Results* | *Is the retrofit worthwhile?* | *Max Acceptable Annualized Proj. Cost ($/yr)* | *Max Acceptable Imp. Cost ($/yr)* | *Break-Even Analysis Results (Is the retrofit within budget?)* |
|---|---|---|---|---|---|---|---|---|---|
| *Other Rec.* | Replace T-12 Fixtures with T-8 Fixtures | 1,267 | 2,273 | 421.76 | 1.808 | No | 233.25 | 1,257.07 | No |

Table 5. Analysis Results for Other Recommendation

When inflation is not considered, the cost-benefit ratio is much higher. Comparing Table 6 to Tables 4 and 5 shows the trend. 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.

| | AR No. | Description | Electricity Savings (kWh/yr) | Imp. Cost ($) | Annualized Project Cost ($/yr) | Cost-Benefit Analysis Results | Is the retrofit worthwhile? | Max Acceptable Annualized Proj. Cost ($/yr) | Max Acceptable Imp. Cost ($/yr) | Break-Even Analysis Results (Is the retrofit within budget?) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Lighting* | 1 | Replace Metal Halide Lamps with T-8 Flourescent Fixtures | 20,639 | 5,324 | 987.89 | 0.402 | Yes | 2,460.17 | 13,258.56 | Yes |
| | 2 | Install Photosensor Controls to Utilize Daylight | 1,742 | 112 | 20.78 | 0.100 | Yes | 207.65 | 1,119.07 | Yes |
| *Space Conditioning* | 3 | Install Programable Thermostat in the Office | 6,845 | 170 | 31.54 | 0.039 | Yes | 815.92 | 4,397.25 | Yes |
| | 4 | Adjust the Year Round Thermostat Set Points in the Office | 2,797 | 50 | 9.28 | 0.028 | Yes | 333.40 | 1,796.80 | Yes |
| *Compressed Air* | 5 | Reduce Overall Pressure in Compressed Air System | 46,728 | 800 | 148.44 | 0.027 | Yes | 5,569.98 | 30,018.22 | Yes |
| | 6 | Reduce Leaks in Compressed Air System | 39,615 | 5,000 | 927.77 | 0.196 | Yes | 4,722.11 | 25,448.81 | Yes |
| | 7 | Eliminate use of Air Motors on Pipe Turners | 14,118 | 1,550 | 287.61 | 0.171 | Yes | 1,682.87 | 9,069.45 | Yes |
| *Other Rec.* | | Replace T-12 Fixtures with T-8 Fixtures | 1,267 | 2,273 | 421.76 | 2.793 | No | 151.03 | 813.92 | No |

Table 6. Analysis Results Without Inflation

## 5.4 RESULT INTERPRETATION

The results from the analysis coincide with the results from the payback period in this specific case. The analysis assessment and the simple payback parallel each other quite well actually. Using the results provided in Table 7, a direct link to the simple payback and the cost-benefit analysis considering inflation can be made. Each of the recommendations, in this case, has a payback period that is less than three or greater than ten. The pattern in this specific case is the greater the simple payback the greater the economic risk of implementing the product is. This pattern is actually consistent with the expected findings. The payback and cost-benefit analysis for this report (AIAC, 2010b) has a high correlation.

<table>
<tr><th rowspan="2"></th><th rowspan="2">AR No.</th><th rowspan="2">Description</th><th rowspan="2">Cost-Benefit Analysis Results</th><th rowspan="2">Simple Payback (yrs)</th><th colspan="2">Should the Retrofit be Implemented?</th></tr>
<tr><th>According to Payback</th><th>According to Analysis</th></tr>
<tr><td rowspan="2">Lighting</td><td>1</td><td>Replace Metal Halide Lamps with T-8 Flourescent Fixtures</td><td>0.259</td><td>2.3</td><td>Yes</td><td>Yes</td></tr>
<tr><td>2</td><td>Install Photosensor Controls to Utilize Daylight</td><td>0.065</td><td>0.6</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="2">Space Conditioning</td><td>3</td><td>Install Programable Thermostat in the Office</td><td>0.025</td><td>0.2</td><td>Yes</td><td>Yes</td></tr>
<tr><td>4</td><td>Adjust the Year Round Thermostat Set Points in the Office</td><td>0.018</td><td>0.2</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="3">Compressed Air</td><td>5</td><td>Reduce Overall Pressure in Compressed Air System</td><td>0.017</td><td>0.2</td><td>Yes</td><td>Yes</td></tr>
<tr><td>6</td><td>Reduce Leaks in Compressed Air System</td><td>0.127</td><td>1.1</td><td>Yes</td><td>Yes</td></tr>
<tr><td>7</td><td>Eliminate use of Air Motors on Pipe Turners</td><td>0.110</td><td>1.0</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="2">Other Rec.</td><td>Replace T-12 Fixtures with T-8 Fixtures</td><td>1.808</td><td>15.4</td><td>No</td><td>No</td></tr>
</table>

Table 7. Overall Results from AIAC Report (2010b)

In this analysis, the payback is approximately within a factor of ten with the cost-benefit analysis. One would assume this would not always be the case due to differing inflation factors and other components. However, with this trend, the assumption could be made that when the AIAC suggests not implementing a retrofit whose simple payback approximately lies between three and ten, the economic analysis would more than likely suggest the retrofit actually be implemented.  This means companies could assume having a simple payback of greater than three is in fact acceptable in many cases.  More data was assessed to determine if the assumption could be made.

### 5.4.1 OTHER REPORT RESULTS

In AIAC (2010c) Report No. UA0056 and AIAC (2010d) Report No. UA0057 the same analyses were conducted. The inflation rates for both reports turned out to be negative which suggests the cost of energy actually decreased over the course of the year for both companies that were assessed. In the AIAC (2010c) analysis the inflation rate was -16.69%, and in the AIAC (2010d) analysis the inflation rate was -20.95%. The results from the reports are summarized in Table 8 and Table 9.

| | *AR No.* | *Description* | *Cost-Benefit Analysis Results* | *Simple Payback (yrs)* | *Should the Retrofit be Implemented?* | |
|---|---|---|---|---|---|---|
| | | | | | *According to Payback* | *According to Analysis* |
| *Lighting* | 1 | Replace 8' T-12 Bulbs with 8' T-8 Bulbs | 1.085 | 3.6 | Yes | No |
| *Lighting* | 2 | Install Photo Sensor Controls | 0.525 | 2.0 | Yes | Yes |
| *Comp Air* | 3 | Lower Air Compressor Discharge Pressure | 0.093 | 0.3 | Yes | Yes |
| *Space Conditioning* | 4 | Install Programmable Thermostats | 0.128 | 0.4 | Yes | Yes |
| *Space Conditioning* | 5 | Increase Air Conditioning Thermostat Set Points | 0.012 | 0.0 | Yes | Yes |
| *Other Rec.* | | Replace 4' T-12 Lamps with 4' T-8 Lamps | 1.881 | 4.9 | No | No |

Table 8. Overall Results from AIAC Report (2010c)

| | AR No. | Description | Cost-Benefit Analysis Results | Simple Payback (yrs) | Should the Retrofit be Implemented? | |
|---|---|---|---|---|---|---|
| | | | | | *According to Payback* | *According to Analysis* |
| *Compressed Air* | 1 | Reduce Air Leaks in Compressed Air System | 0.076 | 0.4 | Yes | Yes |
| | 2 | Utilize Existing Shutoff Controls | 0.003 | 0.0 | Yes | Yes |
| | 3 | Turn Off Air Compressors When Not In Use | 0.118 | 0.5 | Yes | Yes |
| *Lighting* | 4 | Replace Inefficient Top Mount Lighting with Flourescent Side Mount Lighting | 1.566 | 6.3 | Yes | No |
| | 5 | Install Photosensor Controls in Areas with Adequate Daylighting | 0.111 | 0.5 | Yes | Yes |
| | 6 | Turn Off Lights During Non-Operating Hours | 0.161 | 0.6 | Yes | Yes |
| *Space Cond* | 7 | Install Programmable Thermostats for the Offices | 0.053 | 0.2 | Yes | Yes |
| *Motors* | 8 | Replace Large Partially Loaded Motors with Smaller Fully Loaded Motors | 1.037 | 3.9 | Yes | No |
| *Other Rec.* | | Replace Electrical Resistane Heaters with Heat Pump Units or Natural Gas Furnaces | 1.575 | 6.3 | No | No |

Table 9. Overall Results from AIAC Report (2010d)

The first recommendation made in the AIAC (2010c) report showed a discrepancy in whether to implement the retrofit. According to the payback period, the retrofit should have been implemented, but the economic analysis determined implementing the product would not be economically sustainable for the company. This is not consistent with the prediction that the economic analysis would suggest the retrofit was economically feasible when the payback was less than approximately ten years. Because the difference in the cost of energy suggests deflation is occurring at the specific location, the increase in the cost-benefit ratios compared to the cost-benefit ratios from the AIAC (2010b) report is justified. From the data in the AIAC report (2010c), it seems any payback greater than approximately 3.5 years would in fact be deemed uneconomical for the company. This significant drop from approximately 10 years to 3.5 years in acceptable payback is probably due to the considerable deflation that is suggested to have occurred over the year. The rest of the recommendations made from the payback method are consistent with the results from the economic analysis.

The results from analyzing data from the AIAC (2010d) report were comparable to those from the AIAC (2010c) report. The economic analysis confirmed any simple payback greater than a three-year period would no be economically sustainable. While this is the usual requirement the AIAC uses in their assessments, these two cases do not confirm the assumption that any payback greater than approximately three years should not be implemented. In these two cases, that assumption might be able to be made. However, the significant deflation values in both cases must be noted.

This may suggest that when deflation is occurring any payback greater than approximately three years should not be implemented and when inflation is occurring any payback greater than approximately ten years should not be implemented. This assumption cannot be made unless more data is tested using the economic analysis tool. The two examples where deflation is occurring also have significantly high deflation values, which one would assume is not the case in most instances. It is probable that the deflation values in these cases are incorrect to some degree. This could be one source of error in the analysis.

## 5.5 CONCLUSION

Payback is not a measure of profitability, but it is a measure of liquidity. These results confirm that a company should not make economic decisions based only on the payback period.

# CHAPTER 6

# CONCLUSIONS AND FURTHER RESEARCH

A new economic analysis tool was created for assessing recommendations made by the AIAC after an investigation of the tool versus the payback period method. While most of the time the tool confirmed the payback period method recommendations, the payback period alone is unsuitable for companies to base their decisions on. After testing the spreadsheet using AIAC assessment reports, conclusions regarding the spreadsheet were made. While most of the assessment recommendations were confirmed, some of the recommendations made according to the payback method were not in agreement with the results from the proposed economic analysis tool. After interpreting the results, assumptions regarding the payback method were made. The spreadsheet analysis tool has room for improvement, but the research done through this thesis is significant.

## 6.1 CONCLUSION

For this thesis, an evaluation was made of the Alabama Industrial Assessment Center's method for determining whether energy saving retrofits should be implemented. The AIAC takes information gathered from the company they are assessing, and using that information along with a thorough evaluation of the facility, makes recommendations. 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. Payback is a measure of liquidity and not profitability, which deems the method by many accounts useless (Weingartner, 1969). Yet due to the method's simplicity of use and its understandability, people still frequently use simple payback. Other methods used to determine the economic feasibility of projects are much more reliable but are also more complicated. Of the other methods, time value of money is the best for analyzing whether or not to subsidize ideas.

Using time value of money and Russell's (2009) approach for calculating the cost-benefit analysis and break-even point by turning the costs into an annuity, a spreadsheet was created in Excel. However, Russell's (2009) approach ignores inflation. Inflation is a very important component in the economic evaluation for the AIAC assessments because the cost of energy continues to increase. This is due to the world's reliance on energy increasing and the supply for energy producing fossil fuels decreasing. According to Newnan et al (2004), inflation can be factored in with time value of money techniques. Using this information, inflation was included in the spreadsheet to determine a more accurate value for the cost to buy energy.

Similar to problems encountered by previous users of time value of money, the values for interest rate $i$ and the life of the asset $n$, were hard to determine. Through this research, the assumed value for $i$ will be 7%. This value can be changed to the company's MARR if the value is known. For the life of the asset $n$, MACRS is used. MACRS was a good choice because the IRS and other government agencies accept the depreciation life of an asset with life cycles obtained from the MACRS tables. This will be simple for the user to find and is widely accepted. While the value for $n$ can be determined from a table, the default life of the retrofit will be three years.

Once the default values were determined the only input needed for the analysis to be made was the cost of implementation, energy savings per year, and the cost of energy last year and this year for the inflation factor. All of this information is included in each AIAC assessment report. Every assessment recommendation is broken down and the information is easily accessible from a table. Included in the table is the simple payback, which is the current determining factor for whether the retrofit is implemented.

Once the spreadsheet was verified to work properly, actual AIAC report data (2010b) 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 confirmed the suggestions made by the AIAC (2010b) but provided a more reliable justification for the investment. While the recommendations made in the AIAC report (2010b) were confirmed, some results from other reports showed some disagreement.

The interpretations made from analyzing the data are if inflation is occurring an approximation of the accepted cut-off payback period could be greater than the informal threshold, but if deflation is occurring the approximate cut-off period might have to be reduced. Cut-off periods depend on many factors, but the inflation rate seems to make the most difference in the economic analysis.

## 6.2 FURTHER RESEARCH

Using this spreadsheet as a foundation, further research can be conducted and improvements to the spreadsheet can be made. While any consideration of inflation is better than discounting the inflation factor all together, the inflation factor for the spreadsheet could be improved. One suggestion would be to develop a trend using every month of the year's energy cost data. This may develop a more accurate inflation factor due to twelve periods being considered rather than only two. One way this may be done is to take the values straight from data located in Appendix A.3 of each AIAC report and input them into the spreadsheet. An imbedded formula could determine the slope of the line, which could be used to represent the inflation factor. If data from previous years were available, that would also be very helpful for determining an accurate trend. As mentioned in Section 4.1.3 the United States Energy Information Administration also keeps data on file broken down by state and sector. This may be a helpful source to incorporate into determining a more precise inflation factor.

If a method for determining a fairly accurate prediction of inflation is developed, the spreadsheet could be modified to consider inflation over the entire life of the asset rather than over the first year. This would give companies a more accurate value for what the future cost of energy would be, and therefore, a better analysis could be conducted.

### 6.2.1 EXPECTED LIFE OF THE ASSET

The expected life of the asset for this thesis comes from the Modified Accelerated Cost Recovery System (MACRS) table. While this table gives detailed explanations of many depreciable products, the description for the recommendations made by the AIAC are not explicitly stated. This may be because the change to using more energy efficient products is a fairly new movement, because the need for revamping existing building infrastructure is increasing, because technology is advancing, or due to a combination of those. Whatever the case may be, they are not directly referenced. The MACRS is constantly changing though, and if they do extend the table to include energy saving retrofits for specific buildings or industries, the expected life of the asset will need to be adjusted.

Another way the expected life of the asset could be improved is for someone to build an elaborate set of references. For example, 1000bulbs.com provides expected lifetimes for a variety of light bulb and ballasts. Using sources such as this one, the life of the asset would be more accurate.

### 6.2.2 OTHER FURTHER RESEARCH

This analysis has investigated the economics relating to electricity. Analogous spreadsheets could be established to consider the cost of natural gas, fuel oil, or any other energy source that is relevant to the retrofit.

Other products can be developed from this research as well. The spreadsheet could be shared online for companies that are not assessed by the AIAC but would like to compute a profitability analysis on energy efficient retrofits. Further research could provide sources for information needed to compute the analysis. Using that information Internet links could be imbedded into the system to navigate the user to pages where the data could be obtained.

If the tool is accepted by the AIAC as a basis to evaluate the economic feasibility of recommendations, analytical data accumulated from the assessments could be unlimited. That data could then be used to determine how accurate the predicted inflation factor and life of the asset was. If the AIAC follows up with the companies who decide to implement the retrofits, this data could be acquired and compared to increase the accuracy of the analysis. This tool could also be shared with the other twenty-five state IACs around the country.

One factor this spreadsheet does not consider is taxes. Since the push for a more environmentally sustainable world, the government has granted tax breaks to energy efficient products like some cars. These energy efficient products being implemented may actually present an opportunity for the company to see some tax deductions. This is another factor that needs to be considered in the analysis, and the spreadsheet could be improved by considering government taxes on the retrofits and taxes to do nothing.

While this project focused on the usefulness of the tool for businesses, the tool could also be used for analyzing retrofits in residential cases. The only problem would be a homeowner would not have a MARR to use in place of the interest rate. Another study could be done to determine a default interest value for homeowners. Otherwise the inputs would come from the homeowner's utility bills and information from the manufacturer of the retrofit regarding energy savings. A foreseeable problem with using a value the manufacturer's claimed energy savings is that their study may be biased. Many of these products have not had extensive research from outside parties to confirm the claims of the companies. This would be another opportunity for further research.

## 6.3 SIGNIFICANCE OF RESEARCH

This research concluded the method by which recommendations are presently made by the AIAC should be altered. A new economic tool is proposed, and 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. This also proved the payback period method is more useful than originally expected. The analyses from both tools were comparable although the payback period method did not take into consideration many factors. Payback proved to be a decent estimate of the results. Due to the few discrepancies that occurred though, we confirm the payback period method should not be used alone.

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 confirms considering time value of money and inflation is very important to make a more accurate decision regarding implementing the product.

## REFERENCES


Alabama Industrial Assessment Center, "Alabama Industrial Assessment Center - Home," *Alabama Industrial Assessment Center*, http://iac.ua.edu/, Jan 26, 2011b.

Alabama Industrial Assessment Center, "Can We Help?," *Alabama Industrial Assessment Center*, http://iac.ua.edu/canwehelp. html, Jan 26, 2011a.

Alabama Industrial Assessment Center, Final Report E3005, The University of Alabama, Tuscaloosa, AL, 2010a.

Alabama Industrial Assessment Center, Final Report E3006, The University of Alabama, Tuscaloosa, AL, 2010b.

Alabama Industrial Assessment Center, Final Report UA0056, The University of Alabama, Tuscaloosa, AL, 2010c.

Alabama Industrial Assessment Center, Final Report UA0057, The University of Alabama, Tuscaloosa, AL, 2010d.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Technical Committee 7.8, Owning and Operating Costs, "Life-Cycle Cost Analysis," Atlanta: ASHRAE, Nov 15, 2007, http://www.ashrae.org/lifecycle.

Burris, B. E., "Energy Conservation for Existing Wastewater Treatment Plants," *Journal (Water Pollution Control Federation)*, Vol. 53, No. 5 (May, 1981): p. 540, http://www.jstor.org/stable/25041140.

Cahill, M. and Kosicki, G., "Exploring Economic Models Using Excel," *Southern Economic Journal* Vol. 66, No. 3 (Jan, 2000): p. 770-792, http://www.jstor.org/stable/ 1061439.

Canada, J. R., Sullivan, W. G., and White, J. A., *Capital Investment Analysis for Engineering and Management,* 2nd ed. New Jersey: Prentice Hall, Inc., 1996.

Center for Energy Efficiency & Renewable Energy – University of Massachusetts Amherst, "About IAC," *Industrial Assessment Center,* Oct 14, 2010, http://www.ceere. org/iac/index.html.

Chaturvedi, S., "Energy Efficiency and Sustainability in Buildings," ASCE Conf. Proc. 328, 59 (2008), doi: 10.1061/41002(328)59.

D&R International, Ltd., prepared for the "Buildings Technologies Program, Energy Efficiency and Renewable Energy, United States Department of Energy," *2009 Buildings Energy Data Book*, Oct, 2009, http://buildingsdatabook.eren.doe.gov/ docs/DataBooks/2009BEDB_ Updated.pdf.

Jha, Raghbendra, *Modern Public Economics*, Routledge, 1997, doi: 10.4324/ 9780203023587.CH19.

Kan, S., *Metrics and Models in Software Quality Engineering,* 2nd ed. Boston: Pearson Education, Inc., 2003.

Kreider, J. F., "Introduction to the Buildings Sector," *Handbook of Heating, Ventilation, and Air Conditioning*, Boca Raton: CRC Press, 2001, doi: 10.1201/ 9781420036466.CH01.

Kreith, F. and Goswami, D. Y., *Handbook of Energy Efficiency and Renewable Energy*, Boca Raton: CRC Press, 2007.

Laplante, P.A., *What Every Engineer Should Know about Software Engineering*, CRC Press, 2007.

Lewellen, W. G., Lanser, H. P., and McConnell, J. J., "Payback Substitutes for Discounted Cash Flow," *Financial Management* Vol. 2, No. 2 (Summer, 1973): p. 17-23, http://www.jstor.org/stable/3665478.

Montgomery, C. W., *Selected Chapters from Environmental Geology*, 7th ed. Boston: McGraw Hill, 2006.

Narayanan, M. P., "Observability and the Payback Criterion," *The Journal of Business* Vol. 58, No. 3 (Jul, 1985): p. 309-323, http://www.jstor.org/stable/2353000.

Newnan, D. G., Eschenbach, T., and Lavelle, J. P., *Engineering Economic Analysis*, 9th ed. New York: Oxford UP, 2004.

Park, C. S., *Contemporary Engineering Economics*, 2nd ed. Menlo Park: Addison-Wesley Longman, Inc., 1997.

Perkins, S., Telephone interview, 22 October 2010.

Ross, M., "Efficient Energy Use in Manufacturing," *Proceedings of the National Academy of Sciences of the United States of America* Vol. 89, No. 3 (Feb, 1992): p. 827, http://www.jstor.org/stable/2358388.

Russell, C., "Energy Cost Control: How the Money Works," Internet Presentation to the U.S. Department of Energy Industrial Technologies Program, April 9, 2009.

Schneider Electric, "Cassia In-Room Energy Management System - Schneider Electric Schneider Products," http://products.schneider-electric.us/products-services/products/lighting-control/in-room-energy-management-system/in-room-energy-management-system/cassia-in-room-energy-management-system/, Jan 19, 2011.

Turpin, J. R., "Plethora of Intelligent Products for HVAC," *Air Conditioning, Heating & Refrigeration News* (Dec 13, 2010), http://www.achrnews.com/Articles/Feature_Article/BNP_GUID_9-5-2006_A_10000000000000957274.

United States Department of Energy, "Department of Energy - Chu Announces Joint U.S.-China Building Efficiency MOU," *Department of Energy*, Jul 16, 2009a, http://www.energy.gov/news/7648.htm.

United States Department of Energy, Energy Efficiency and Renewable Energy, "What is the IAC? – IAC Database," *USDOE – Industrial Assessment Centers*, http://iac.rutgers.edu/about.php, Jan 26, 2011c.

United States Department of Energy, Energy Information Administration, *Annual Energy Review 2009*, Washington, D.C.: U.S. Department of Energy, 2009b, http://www.eia.doe.gov/aer/pdf/perspectives_2009.pdf.

United States Department of Energy, Energy Information Administration, "Electric Power Monthly – Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State," October 2010, http://www.eia.doe.gov/cneaf/electricity/epm/table5_ 6_a.html.

United States Department of the Treasury, Internal Revenue Service, "How to Depreciate Property," Publication 946 Cat. No. 13081F, Apr 9, 2009, http://www.irs.gov/publications/p946/ch04.html.

United States Green Building Council, *LEED 2009 for Existing Buildings Operations and Maintenance*, July 2010a, http://www.usgbc.org/ShowFile.aspx?DocumentID= 7245.

United States Green Building Council, "USGBC: Intro - What LEED Is," *USGBC: U.S. Green Building Council*, 2010b, http://www.usgbc.org/DisplayPage.aspx?CMSPageID =1988, Jan 18, 2011.

Vanek, F. M. and Albright, L. D., *Energy Systems Engineering Evaluation & Implementation*, New York: McGraw-Hill, 2008.

Weingartner, H. M., "Some New Views on the Payback Period and Capital Budgeting Decisions," *Management Science* Vol. 15, No. 12 (1969): p. B594-B607, http://www.jstor.org/stable/2628424.

Zandin, K. B., *Maynard's Industrial Engineering Handbook*, 5th ed. New York: McGraw-Hill, 2001.

# APPENDIX A:

# USER MANUAL

## Intent

The intention of this economic tool is to provide the Alabama Industrial Assessment Center (AIAC) with a more reliable estimate than the existing method provides of the profitability of energy saving retrofits installed in existing buildings. The Excel spreadsheet utilizes time value of money techniques and converts implementation costs into an annuity and uses inflation calculations to provide the AIAC with a better economic analysis of the retrofit. Using the information obtained in the AIAC assessment the cost-benefit and break-even analyses can be determined.

## Starting the Software

- Start Excel.
- From the "File" drop down menu select "Open."
- Retrieve the Economic Analysis of Energy Retrofits for Buildings file and select "Open."
- The economic analysis tool should be on your computer screen (Figure A-1). Please follow the subsequent steps.

| *Economic Analysis of Energy Retrofit of Buildings* | |
|---|---|
| | Input |
| | Output |
| Energy Savings (kWh/yr) | 0 |
| Cost of Investment (Implementation Cost) | $0.00 |
| Expected Life of Asset (n) | 3 |
| Applicable Interest Rate (i) | 7.00% |
| Cost to Buy Energy | |
| Last Year ($/kWh) | $0.0000 |
| This Year ($/kWh) | $0.0000 |
| $\frac{i(1+i)^n}{(1+i)^n-1} =$ | |
| Capital Recovery Factor | 0.381 |
| *Cost of Investment x Capital Recovery Factor =* | |
| Annualized Project Cost ($/yr) | $0.00 |
| *This Year / Last Year - 1 =* | |
| Inflation (*f*) | 0.00% |
| $1+f=$ | |
| Energy Inflation Factor | 1.000 |
| *Annualized Project Cost ($/yr) / Energy Savings (kWh/yr) =* | |
| Cost to Save ($/kWh) | $0.00 |
| *Cost to Buy Energy This Year ($/kWh) x Energy Inflation Factor =* | |
| Cost to Buy ($/kWh) | $0.00 |
| *Cost to Save ($/kWh) / Cost to Buy ($/kWh) =* | |
| Cost-Benefit Analysis | 0.000 |
| ***Will implementing the product be worthwhile?*** | ***Yes*** |

| *Break-even Analysis of Energy Retrofit of Buildings* | |
|---|---|
| Energy Savings (kWh/yr) | 0 |
| Cost to Buy Energy ($/kWh) | $0.00 |
| *Energy Savings x Cost to Buy Energy =* | |
| Maximum Acceptable Annualized Project Cost ($/yr) | $0.00 |
| *Maximum Acceptable Annualized Project Cost / Capital Recovery Factor* | |
| Maximum Acceptable Cost of Investment | $0.00 |
| ***Is the project within budget?*** | ***Within Budget*** |

Figure A-1. Economic Analysis of Energy Retrofits of Buildings

## Determining the Input

- Determine which recommendation made be the AIAC you would like to analyze.
- Using the table from Section 1.4 or a table within Chapter 4 Other Recommendations the input values for energy savings and implementation cost can be gathered for the recommendation.
- Enter the value of "energy savings" into cell E7 labeled energy savings (kWh/yr) into the spreadsheet.

- Enter the value of "implementation cost" into cell E8 labeled cost of investment (implementation cost) into the spreadsheet.

- The life of the asset can be found using the Modified Accelerated Cost Recovery System (MACRS) table.
- Using the MACRS table find the closest description of the product being recommended in the column labeled "Description of Assets."[1]
- Once the asset's description is located, follow the table across to the column labeled "GDS (MACRS)."
- Take the MACRS value for the recommended asset and input that value into cell E9 labeled life of asset (n).

- Determine the MARR of the company assessed.
- Input the company's MARR value into cell E10 labeled interest rate (i).[2]
- Reference the AIAC assessment report Appendix A.3 Energy Consumption and Cost for the cost to buy energy section.
- Using the Electrical Billing History table from Appendix A.3, divide the first month's "total cost" by the "energy usage" to determine the cost to buy energy last year.
- Input the cost to buy energy last year value into cell E13 in the spreadsheet.
- Using the Electrical Billing History table from Appendix A.3, divide the last month's "total cost" by the "energy usage" to determine the cost to buy energy this year.
- Input the cost to buy energy this year value into cell E14 in the spreadsheet.

**Interpreting Results**

- The cost-benefit analysis determines whether the project is economically worthwhile according to the result located in cell E38.
- The cost-benefit ratio value located in cell E36 represents the cost to save one dollar of energy (e.g. If the cost-benefit analysis determines the ratio is 0.550, the company can pay $.55 to save each dollar worth of energy.).
- The break-even analysis determines whether the project is within budget according to the result located in cell E51.
- Cell E46 expresses the maximum acceptable annualized project cost, which must be greater than the annualized project cost located in cell E21 for the project to be within budget.
- Cell E49 expresses the maximum acceptable cost of investment, which must be greater than the cost of investment located in cell E8 for the project to be within budget.

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[1] Note: According to the MACRS table under "Description of Assets for Certain Property for Which Recovery Periods Assigned Personal Property With No Class Life or Section 1245 Real Property With No Class Life" the recovery period or life of the asset is 7 years.

[2] The spreadsheet will default the interest rate as 7% if the company's MARR rate is unknown or unavailable.

## APPENDIX B:

## HAND CALCULATIONS

Capital Recovery Factor =

$$\frac{i(1+i)^n}{(1+i)^n-1} = \frac{.07(1+.07)^3}{(1+.07)^3-1} = 0.38105$$

Annualized Project Cost =

Cost of Investment x Capital Recovery Factor = \$42,862(0.38105) = \$16,332.64 per year

Inflation (*f*) =

$$(\text{Cost to Buy Energy This Year / Cost to Buy Energy Last Year}) - 1 = \frac{\$0.0628}{\$0.0600} - 1 \cong 4.67\%$$

Energy Inflation Factor =

$1 + f = 1 + 0.0467 \cong 1.047$

Cost to Save =

$$\text{Annualized Project Cost / Energy Savings} = \frac{\$16,332.64}{311,521 kWh} = \$0.05243 \text{ per kWh}$$

Cost to Buy =

Cost to Buy Energy This Year x Energy Inflation Factor = \$0.0628(1.047) = \$0.06575 per kWh

Cost-Benefit Analysis =

$$\text{Cost to Save / Cost to Buy} = \frac{\$0.05243}{\$0.06575} = 0.7974$$

0.7974 < 1.00 Therefore, implementing the product will be worthwhile.

Maximum Acceptable Annualized Project Cost =

Energy Savings x Cost to Buy Energy = 311,521 kWh/yr ($0.06575 per kWh) = $20,483.00

Maximum Acceptable Cost of Investment =

Maximum Acceptable Annualized Project Cost / Capital Recovery Factor =

$$\frac{\$20,483.00}{0.381} = \$53,753.88$$

$16,332.64 < $20,483.00 and $42,862.00 < $53,753.00 Therefore, the project is within budget.