2-9-2010

Decision process for energy efficient building retrofits : the owner's perspective

Christian Birk Jones

Christian Birk Jones
Candidate

Civil Engineering
Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

Dr. Susan Bogus-Halter Susan Bogus Halter, Chairperson

Dr. Jerald L. Rounds Jerald L. Rounds

Dr. Giovanni C. Migliaccio Giovanni Migliaccio

DECISION PROCESS FOR ENERGY EFFICIENT BUILDING RETROFITS: THE OWNER'S PERSPECTIVE

BY

CHRISTIAN BIRK JONES

B.S. - CIVIL & ENVIRONMENTAL ENGINEERING
UNIVERSITY OF CALIFORNIA - DAVIS

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Science

Civil Engineering

The University of New Mexico
Albuquerque, New Mexico

December, 2009

DEDICATION

This thesis is dedicated to all advocates of building energy efficiency and sustainability.

ACKNOWLEDGMENTS

I heartily acknowledge Dr. Susan Bogus-Halter, my advisor, for her encouragement and input. I also thank my committee members, Dr. Rounds, and Dr. Migliaccio, for their contributions pertaining to this study and also assistance in my professional development. Gratitude is extended to the David Robertson, Ron Rioux, Hans Barsun, Glen Kilcup, Jim Romero, Shawn Katz, Darin Sand, Kent Beierle, Al Waldron, Bill Damon, Vincent Martinez, Tony Gurule, Nick Schiavo, Cary Weiner, John O'Connell, Calvin Steckler, Andre Larroque, Johnny Rehders, Bill Miller, and Brian Cassutt for their time in support in this research effort.

I acknowledge my family Larry, Tina, Henry, and Grammy who have given me immeasurable support over the years. Your encouragement is greatly appreciated.

DECISION PROCESS FOR ENERGY EFFICIENT BUILDING RETROFITS: THE OWNER'S PERSPECTIVE

BY

CHRISTIAN BIRK JONES

ABSTRACT OF THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

Civil Engineering

The University of New Mexico
Albuquerque, New Mexico

December, 2009

DECISION PROCESS FOR ENERGY EFFICIENT BUILDING RETROFITS: THE OWNER'S PERSPECTIVE

by

Christian Birk Jones

M.S., Civil Engineering, University of New Mexico, 2009

Energy consumption and conservation is an important consideration for commercial building owners. The commercial building sector consumes a great deal of energy. Energy reduction for commercial buildings can result in operations cost savings and reduction in environmentally harmful emissions. The decision process employed by owners to determine the energy conservation measures for an existing building retrofit requires a repeatable standard. This research investigates decision steps that are currently used. Then it determines what decision steps should be followed, and important aspects and considerations that will improve the process.

The research used literature review and case study interviews to collect and analyze qualitative data. The literature review examined published articles, books, and manuals that focused on all aspects of energy conservation of existing buildings. The interviews were conducted with twelve owner organizations involved in building retrofits that include energy conservation measures (ECM). The research used a collective case study design approach where the organizations answered open ended questions. Additionally, the research made observations of the process in action and acquired documents that helped describe criteria for the specific step in the process.

The research developed an integrated decision process for building retrofits that include ECMs. The integrated process is as follows: 1) Building Energy Data, 2) ECM Identification and analysis, 3) Assessment, 4) Design and Plan, and 6) Approval. The process must be conducted in an integrated manner. The building energy data stage must review the current energy consumption status and determine a set goal that the retrofit must achieve. The analysis must review the implementation of ECMs by using integrated design techniques. The assessment of the analyzed ECMs must review a set of

alternatives to determine the most financial feasible option that meets the energy conservation goals. The design and plan step uses the information determined in the assessment to prepare the project for approval and implementation. The final step of approval entails finalizing funding and procuring construction operations.

Organizations can improve their decision process by adopting the integrated process and also by establishing and following a set of goals. The goals must factor in financial and environmental indicators to appropriately prioritize and plan projects. Organizations should have strategies for dealing with issues such as upfront cost, lack of knowledge, low returns on investment, time to implement, and non-energy requirements. The research synthesized literature review and organizational practices to establish a best practice approach for decision makers. It also evaluates how organization can establish ECM goals and overcome common barriers.

TABLE OF CONTENTS

LIST OF FIGURES XI

LIST OF TABLES XIV

LIST OF ACRONYMS & KEY TERMS XV

CHAPTER 1 INTRODUCTION 1

1.1 Overview 1

1.2 Research Objective 2

1.3 Methodology Overview 2

1.4 Readers Guide to Thesis 3

CHAPTER 2 REVIEW OF RELATED LITERATURE 5

2.1 Building Energy Consumption Impacts 5

2.2 Commercial Building Energy Consumption 7

2.3 Building Energy Retrofits 16

2.4 Decision Process 21

CHAPTER 3 METHODOLOGY 35

3.1 Research Questions 35

3.2 Research Approach 36

3.3 Data Collection 37

3.4 Data Analysis 39

CHAPTER 4 CASE STUDIES OF ORGANIZATION DECISION PROCESSES ..42

4.1 Organization 1 42

4.2 Organization 2 47

4.3 Organization 3 49

4.4 Organization 4.....52
4.5 Organization 5.....56
4.6 Organization 6.....57
4.7 Organization 7.....59
4.8 Organization 8.....61
4. 9 Organization 9.....64
4.10 Organization 10.....65
4.11 Organization 11.....66
4.12 Organization 12.....66
4.13 Summary of Case Study Observations 69
4.14 Development of Integrated Decision Process.....70

CHAPTER 5 ENERGY RETROFIT INTEGATED DECISION PROCESS.....72

5.1 Retrofit Overview 73
5.2 Integrated Decision Process.....75
5.3 Organization Integration of Integrated Decision Process Steps 104

CHAPTER 6 DECISION IMPROVEMENTS.....108

6.1 Recognizing Retrofit Goals.....108
6.2 Development of Goal Indicators.....109
6.3 Energy Retrofit Barriers.....116

CHAPTER 7 CONCLUSION.....123

7.1 Conclusion 123
7.2 Future Study.....124

APPENDIX A - ENERGY RETROFIT LEVELS.....126

APPENDIX B - ENERGY RE-COMMISSION.....129

APPENDIX C - ENERGY UPGRADE.....131

APPENDIX D - RENOVATION.....133

REFERENCE.....137

LIST OF FIGURES

Figure 1 U.S Energy Consumption by Source 2008 (EIA, 2009) 7

Figure 2 Energy Consumed by Sector 2008 (EIA, 2009).....8

Figure 3 Commercial Building Energy Consumption Breakdown (EIA, 2003) 8

Figure 4 Commercial Building Energy Consuming Elements (EIA, 2003).....9

Figure 5 Production Source for Electricity (EIA, 2009).....10

Figure 6 Retail Sales of Electricity in the U.S (EIA, September 2009).....11

Figure 7 Electricity Consumption in the U.S. 2007 (EIA, September 2009) 11

Figure 8 Natural Gas Consumption 2007 in the US (EIA, September 24, 2009).....13

Figure 9 Electricity vs. Natural Gas Rates 2006 (EIA, September 2009) 13

Figure 10 U.S Carbon Dioxide Emissions by Fuel (EIA, October 2009).....14

Figure 11 U.S Carbon Dioxide Emissions by Sector in 2005 (EIA, October 2009) 15

Figure 12 U.S. CO_2 Emissions Total vs. Commercial Buildings (EIA, October 2009)....15

Figure 13 Owner Decision Process (based on Parker et al, 2000).....22

Figure 14 Research Approach.....37

Figure 15 Data Collection Process.....39

Figure 16 Qualitative Data Analysis Process (Seidel, 2008).....40

Figure 17 Evaluation of Categorized Information 41

Figure 18 Organization 1 Decision Process.....43

Figure 19 Sample Benchmarking Tool based on data from Organization 1.....44

Figure 20 Organization 1 Basic Analysis Information Produced 45

Figure 21 Organization 2 Decision Process.....48

Figure 22 Organization 3 Decision Process.....50

Figure 23 Organization 4 Decision Process for the HVAC Program 52
Figure 24 Decision Process Energy Conservation Program 53
Figure 25 Organization 6 Decision Process 58
Figure 26 Organization 7 Decision Process 60
Figure 27 Organization 8 Decision Process 62
Figure 28 Organization 10 Decision Process 65
Figure 29 Organization 12 Decision Process 67
Figure 30 Utilization of a Decision Process - Based on data from 12 Organizations 69
Figure 31 Retrofit Process Overview 74
Figure 32 Integrated Decision Process 76
Figure 33 Building Energy Data Personnel and Resources 78
Figure 34 Sample Energy Consumption Graph (Data from Table 6) 80
Figure 35 Energy Utilization Index Sample Graph 83
Figure 36 ECM Identification and Analysis Goals 84
Figure 37 Identification & Analysis of ECMs based on data from 12 Organizations 85
Figure 38 Energy Identification Elements 86
Figure 39 Energy Analysis 88
Figure 40 Financial Assessment Type Used Based on data from 12 Organizations 96
Figure 41 Preferred Payback Period based on data from 12 Organizations 97
Figure 42 Funding Source Utilized based on data from 12 Organizations 99
Figure 43 Suggested Design Process Implementations for a Retrofit 101
Figure 44 Suggested Planning Considerations 102
Figure 45 Integrated Decision Elements Used based on data from 12 Organizations 105

Figure 46 Prioritization of Retrofits base on data from 12 Organizations.....109

Figure 47 Financial/Environmental Indicators, Rate of Return & EUI % Savings.....113

Figure 48 Financial/Energy, EUI % Savings & Rate of Return - Minus the Outliers.....114

Figure 49 Barriers for Success based on data from 12 Organizations.....116

Figure 50 Expected Accuracy of Estimate based on data from 12 Organizations.....120

LIST OF TABLES

Table 1 Financing Options for Energy Projects (Zobler & Hatcher, 2003).....29

Table 2 Organization Interviewed 36

Table 3 Energy Utilization Index (EUI) Information based on Organization 4 data.....53

Table 4 Organization Decision Steps for Implementing ECMs 70

Table 5 Energy Performance Indicator Options (MacDonald, 2000).....78

Table 6 Sample Energy Consumption Data Table.....80

Table 7 Comparison Methods.....82

Table 8 IDAA List of Retrofit Options.....90

Table 9 The IDAA for Assessing a Retrofit for Energy Efficiency 92

Table 10 Goal Indicators for Organization Approval.....103

Table 11 Organizations Utilization of Integrated Process Steps(Y=Yes, N=No) 104

Table 12 Energy Conservation List and Data.....111

Table 13 Energy and Cost Estimate for the Financial & Energy Indicator 115

Table 14 Lease Agreements based on data from 12 Organizations.....121

Table 15 Updated Lease Agreement Cost Breakdown Example.....122

Table 16 Level of Retrofit Descriptions - based on data from 12 Organizations.....126

Table 17 Re-Commission Retrofit Energy Cost and Consumption Data 130

Table 18 Energy Upgrade Retrofit Energy Cost and Consumption Data.....131

Table 19 Renovation Energy Cost and Consumption Data 135

LIST OF ACRONYMS & KEY TERMS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu	British Thermal Unit
CBECS	Commercial Building Energy Consumption Surveys
ECM	Energy Conservation Measure
EIA	Energy Information Administration
EPI	Energy Performance Indicator
ESP	Energy Service Provider
EUI	Energy Utilization Index
GHG	Greenhouse Gas
HVAC	Heating, Ventilating & Air-Conditioning
IB	Intelligent Building
IDAA	Integrated Decision Assessment Approach
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
kBtu	Thousand British Thermal Units
KPI	Key Performance Indicator
kW	Thousand Watts
kWh	Thousand Watt-hours
LCCA	Life Cycle Cost Analysis
LEED	Leadership in Energy & Environmental Design
LEED-EB	Leadership in Energy & Environmental Design – Existing Building
NPV	Net Present Value
PACE	Property Assessed Clean Energy (Bonds)
PV	Photovoltaic
QBtu	Quadrillion British Thermal Unit
Therms	100,000 British Thermal Units

CHAPTER 1 INTRODUCTION

1.1 Overview

Energy use and production is an important topic for engineers, politicians, utility providers, building owners, and many other sectors. The commercial building sector, which is the focus of this research, contributes greatly to the overall energy consumption of all the building sectors combined. There are over 4.9 million commercial buildings in the United States as of the year 2003 that together consumed about 19 quadrillion Btu of energy in one year (EIA, 2009). One Btu is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Basically a Btu is the amount of heat produced by the ignition of a single match.

Commercial building energy consumption has drastic and detrimental effects on economics and the environment. Energy conservation certification schemes, such as Energy Star and Leadership in Energy and Environmental Design (LEED), promote energy conservation within existing buildings. Additionally the Kyoto Now (KoyotoNow, 2009) and 2030 Challenge (2030 Inc./Architecture 2030, 2009) are advising organizations and the building community to incorporate new technologies, behavior changes, and other techniques to reduce their carbon footprint to zero. Government agencies and utility companies are also offering incentives to reduce the incremental cost of an upgrade. These incentives and challenges are made to organizations, who own existing buildings, to help them reduce their greenhouse gas emissions, energy demand, and ultimately cut their overall energy costs. Yet building owners can be hesitant and may not understand energy production, consumption, and the benefits of pursuing energy efficiency. This lack of knowledge and understanding can be attributed to the absence of an established decision process. The decision process determines the necessary steps to provide systematic direction to achieve cost effective energy efficiency. It also allows for proper examination of essential criteria and issues that can eliminate misconceptions and lead to decisions that implement effective energy systems.

1.2 Research Objective

The research was structured to determine the best decision process for existing commercial building owners to execute when considering a retrofit that includes energy conservation measures. It will explore the decision steps that organizations currently follow. Then determine a set of decision steps that organizations should follow. Finally it will research how organizations can improve their current decision process.

The research explores the current practices and essential elements of a building owner's decision process for determination and implementation of the appropriate energy conservation measures. The intent is to document current practices then compare, contrast, and evaluate the different processes utilized to help develop a best practice approach. The best practice approach will include essential decision process steps, criteria, and considerations. The research touches on critical elements and considerations to help decision makers improve their process. The results will be based on literature review and observations of actual organizations.

1.3 Methodology Overview

The evaluation of the decision process utilized qualitative data. This data was collected through a literature review and interviews with twelve organizations. The review of literature included books, manuals, and articles. The interviews with the various organizations followed a collective case study approach. The data was then collected from both the literature review and the interview process to be analyzed appropriately. The analysis compared, and evaluated current process. The evaluations considered the financial and environmental factors that affect the process and organization decisions. The research methodology used a collective case study approach that synthesized organization practices and literature review.

Literature review was an important aspect in the data collection process. It identified steps, technologies, barriers, and environmental considerations. These identifications stated the importance of retrofitting buildings for energy efficiency. Additionally, the review clearly justified the research by identifying gaps, strengths and weakness in how organizations are approaching the energy efficient retrofit process.

Finally the literature review defined the relevant and already known information that the research could utilize.

The collective case study research approach was conducted through a series of interviews with various organizations. The interviews consisted of meeting with representatives from twelve organizations. Each of the organizations was met with at least twice to gain an understanding of their decision process and key criteria or considerations. The organizations were made up of building owners of public school buildings, university buildings, government facilities, hotel, offices and warehouses.

The data collection consisted of first identifying key participants. The key participants were selected based on ownership of institutional and commercial buildings. The next step was to develop an interview guide. The interview guide development was followed by conducting the actual interview. During the interview open ended questions were asked and answers or discussions were recorded through handwritten notes.

The data analysis consisted of comparing, evaluating and identifying successful and non-successful decision steps. The comparisons took into account each of the organization's structure and goals. The evaluation reviewed the effectiveness of each step through qualitative appraisal and comparison of their results.

1.4 Readers Guide to Thesis

The research is structured to provide information on the current status of commercial building's energy consumption and how owners should evaluate their building's potential for energy conservation.

The **Literature Review in Chapter 2** begins by discussing *energy awareness*. Energy awareness touches on environmental issues and what the built environments affects are on climate change. It also considers *buildings energy use* by documenting the energy consumption of buildings, the types of energy sources utilized, and the extent of Greenhouse gases emitted by commercial buildings. The *building energy retrofit market* is examined by documenting considerations, areas of interest and potential barriers owners are encountering. The literature review is concluded by examining *current*

organization practices. This section touches on documented processes, building energy data information, assessment considerations, and the integrated approach.

.

The **Methodology in Chapter 3** elaborates on the research question, approach, data collection and analysis method.

The **Case Study of Organization Decision Processes in Chapter 4** describes each of the decision processes utilized by the twelve organizations interviewed. The research describes the organization structure and the specifics to their decision process.

The **Energy Retrofit Integrated Decision Process in Chapter 5** defines the integrated decision process for determining the integration of energy efficiency into an existing building retrofit. The research defines the step by step process and each of the steps in detail. The integration of each of the steps by the organizations is described as well.

The **Decision Improvements in Chapter 6** describe considerations that organizations should take into account to improve their decision process. The research describes the importance of establishing appropriate goals. It identifies a Financial/Energy Indicator. The indicator provides a means for planning and prioritizing energy efficient projects based on both financial and energy factors. The research also elaborates on decision barriers and levers that organizations should consider.

The **Conclusion in Chapter 7** wraps up the research by providing an overview and possible future items for consideration pertaining to energy retrofits.

The **Appendices** provides details on the different energy retrofit levels. Additionally, example projects for each of the three identified levels are discussed.

CHAPTER 2 REVIEW OF RELATED LITERATURE

2.1 Building Energy Consumption Impacts

Scientists have observed a warming of the climate system. The average global air and ocean temperatures have increased which has prompted extreme polar ice melting and rising of average sea levels (IPCC, 2007). Additionally ecosystems and hydrological systems are being affected by the earlier arrival of spring. The frequency and intensity of tropical cyclones in North America have also increased. The rise in global temperatures is likely due to the increase in anthropogenic greenhouse gas (GHG) concentrations (IPCC, 2007). Scientific modeling shows that the past 50 years would have experienced cooling when considering the solar and volcanic forces, but with the inclusion of anthropogenic forces the Earth has experienced warming patterns. The modeling and research concludes that the actions of humans are producing drastic effects on the global environment.

Human activity is causing excessive GHG to be emitted into the atmosphere. These GHG's are altering the atmospheric composition of the Earth which impacts the climate system negatively (Hansen, et al., 2008). Carbon Dioxide (CO_2) is a major GHG that is impacting the global environment. Hansen et al (2008) states that due to the high amounts of CO_2 currently in the atmosphere the climate requires that the reduction in emissions be reduced to almost zero. The 2030 Challenge, initiated by 2030 Inc./Architecture 2030 director Edward Mazria, recommends that the building industry adopt emission reduction targets through energy efficiency investments and measures (2030 Inc./Architecture 2030, 2009).

The production of electricity for buildings from coal is a major contributor of CO_2 emissions into the atmosphere. Coal is responsible for 81% of the emissions, and 76% of all electricity generated by the power plants in the United States is for building operations (Mazria & Kershner, 2008). Developing a strategy to decrease these emissions is difficult. This reduction requires the replacement of the coal power plants and/or the elimination of the demand (Mazria & Kershner, 2008). An effective strategy is to invest in building energy efficiency. Mazria & Kershner (2008) states that an investment of $21.6 billion into building energy efficiency would significantly reduce dependency on

electricity generated from coal. The reduction in electrical demand from coal would be equivalent to the production of 22.3 conventional 500 MW coal fired power plants. It would reduce CO_2 emissions by 86.7 million metric tons, save users $8.46 billion annually in energy bills and create 216,000 jobs. Additionally the authors provide a comparative example of the cost of energy production to produce one Quadrillion Btu (QBtu) of delivered energy. Coal costs about $256 billion, and nuclear power is about $222 billion to produce and deliver the energy. The investment of $42.1 billion applied to energy efficiency measures for residential and commercial buildings could result in the reduction of one QBtu of produced and delivered energy. The 2030 challenge presented by Mazria & Kershner provides steps to achieve a goal of being carbon neutral by the year 2030. The challenge requires that an equal number of existing buildings be renovated to achieve a 50% reduction of energy.

The impacts that humans have on the natural environment is a critical issue. The built environment, which includes existing buildings, affects natural resources and its surroundings (ASHRAE, 2006). These effects highlight the need for existing buildings to take on new strategies and technologies to reduce environmental damage. This includes the minimization of natural resource consumption, the emissions of air pollutants, the discharge of solid waste and other effluents, and also the maximization of the indoor air quality (ASHRAE, 2006). ASHRAE (2006) states that energy efficiency must be driven by the desire to do the right thing, conformance to regulations, lowering ownership costs, increasing productivity, and educating all who are involved.

The sustainability of energy production and use requires the analysis of human activity. Energy use has been influenced dramatically with the increase in population, and the per capita consumption. The incorporation of technologies to improve the energy efficiency of equipment cannot advance quickly enough to balance the growth (Schipper, et al, 1994). This implies that reduction in energy use cannot rely on new system implementations alone. The control of energy use must also come through policies and procedures to promote behavior modification. Energy retrofits can implement energy savings through the incorporation of new systems and improve awareness that can alter

human behavior. The combination has the potential to reduce high energy use activities considerably.

2.2 Commercial Building Energy Consumption

The United States consumed about 102 quadrillion Btu of energy in 2008 (EIA, 2009). The majority of the energy was produced by nonrenewable sources. These types of sources are not sustainable because they cannot be regenerated, or reused. The resources have the potential to be produced but are consumed at a considerably much faster rate. For example it takes millions of years for plant matter under considerable pressure to transform into coal. Therefore, the resources are considered to be at a fixed amount in relation to human existence. The sources consist of petroleum, natural gas, coal, and uranium. Figure 1 shows that theses energy sources supply the majority of the U.S energy consumption, which is about 93%. The other sources are renewable and are comprised of biomass, hydropower, wind, geothermal, and solar. These renewable sources, that can be regenerated, supply about 7% of the U.S energy consumption.

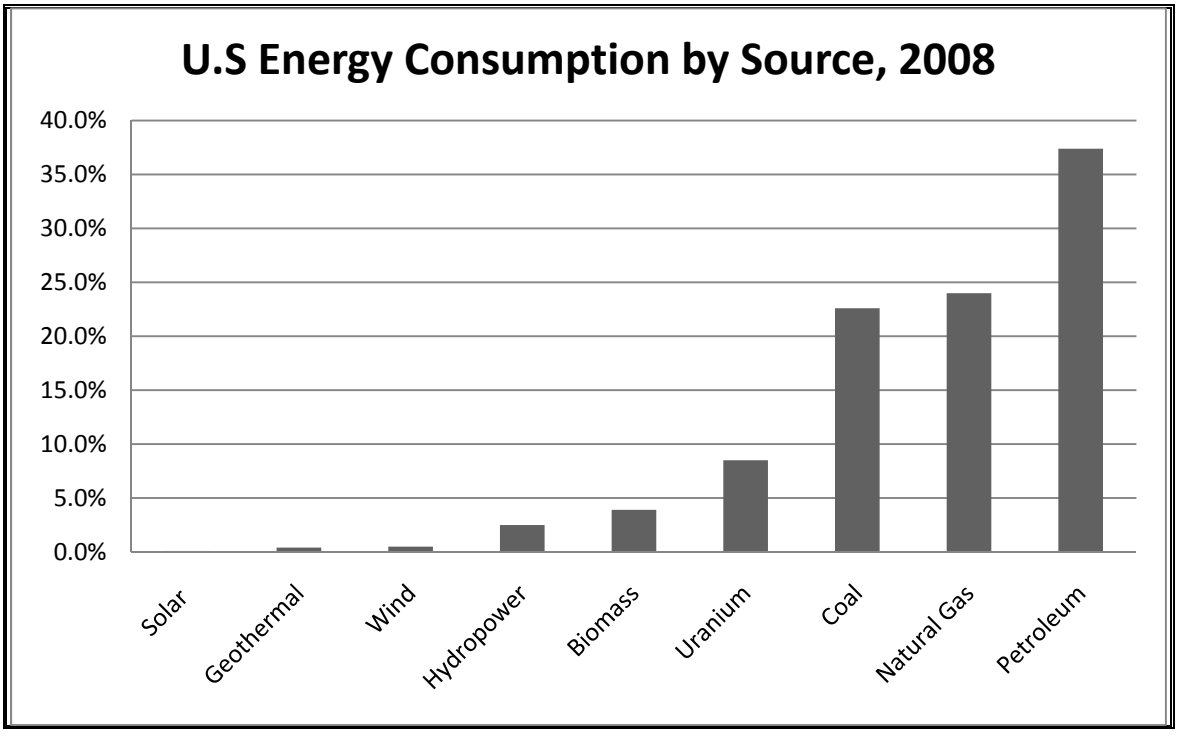

Figure 1 U.S Energy Consumption by Source 2008 (EIA, 2009)

Figure 1 shows conclusively that the U.S relies heavily on nonrenewable sources. The major units that use the majority of energy are buildings and transportation. Buildings are comprised of commercial, residential, and industrial sectors. Figure 2 shows that the commercial sector uses about 19% of the total energy consumed in the U.S.

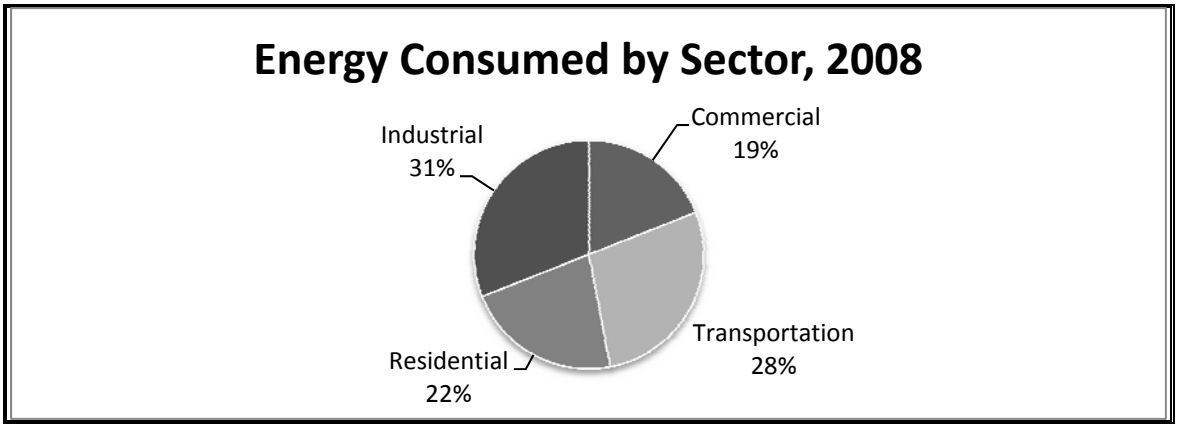

Figure 2 Energy Consumed by Sector 2008 (EIA, 2009)

The total energy consumed by all commercial building is 19 quadrillion Btu (EIA, 2009). Commercial buildings total about 71.6 billion square feet of floor-space in 2003 (EIA, 2003). The commercial space can be broken down into different sectors such as office, mercantile, education, warehouse and storage, and lodging. Office space accounts for the most total square footage of the mentioned sectors at about 17% (EIA, 2003). The major energy sources are electricity, natural gas, fuel oil, and district heat.

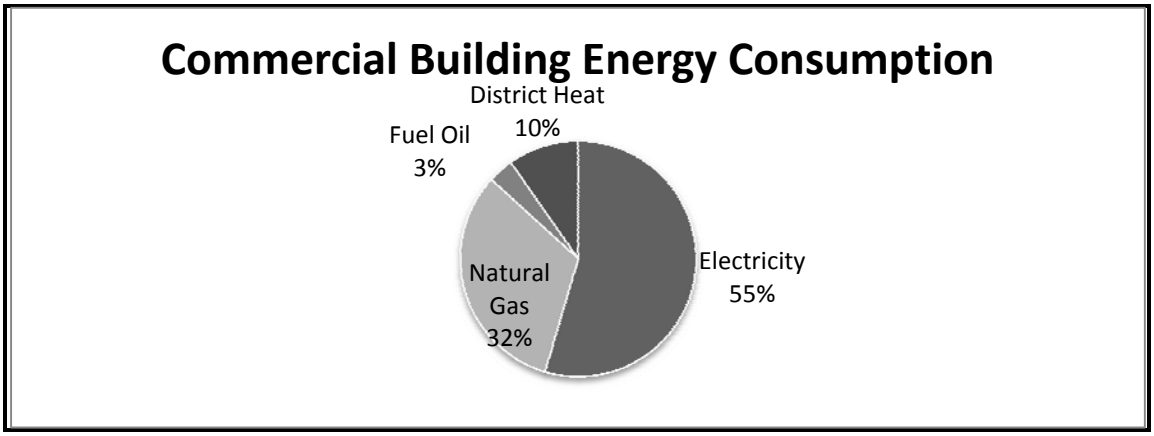

Figure 3 Commercial Building Energy Consumption Breakdown (EIA, 2003)

The total energy consumption of commercial buildings has been fluctuating since the Energy Information Administration (EIA) has been performing the Commercial Building Energy Consumption Surveys (CBECS) in 1979. There has however been a noticeable increase in consumption since 1992. CBECS data indicate that the increase in overall consumption has coincided with the increase in electricity use. Building owners and occupants have been implementing more and more electrical equipment and devices. Computers, office equipment, telecommunications and other types of electricity consumers such as cooling, heating and ventilating equipment have increased electricity consumption. Figure 4 shows the energy consumption distribution within a typical commercial building. Space heating, lighting, cooling, water heating and ventilation account for the most energy consumption.

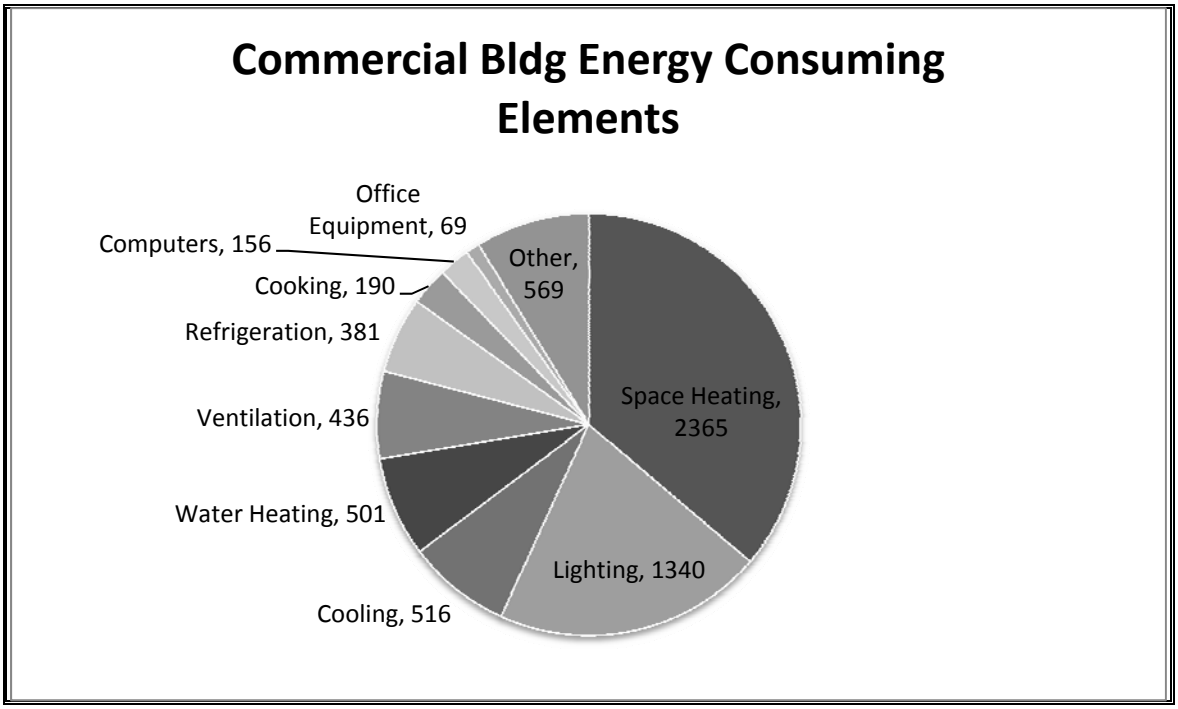

Figure 4 Commercial Building Energy Consuming Elements (EIA, 2003)

Commercial building's energy consumption is increasing due to new equipment and the increased energy demand of the occupants using the equipment. There are various techniques for conserving energy that are important to implement. The effective techniques for conserving energy must consider the energy source. Understanding the

energy source will help decision makers determine the most appropriate measures for reducing energy.

2.2.1 Electricity

Electricity is a commonly utilized energy source for commercial buildings. The basic concept of the energy source is the flow of electric charges, known as the electrical current. The electrical current supplies energy that can power lights, appliances, heating systems, motors and many other elements in a building. The electricity utilized in buildings is considered a secondary energy source. The primary energy is created at the power source where coal, natural gas, oil, nuclear, and renewable energies are converted to create electricity. Figure 5 shows the main sources for primary energy in the production of electricity for the U.S in 2007 were coal (48.5%), natural gas (21.6%), nuclear (19.4%), Hydro (6.0%), and petroleum (1.6%) (EIA, 2009).

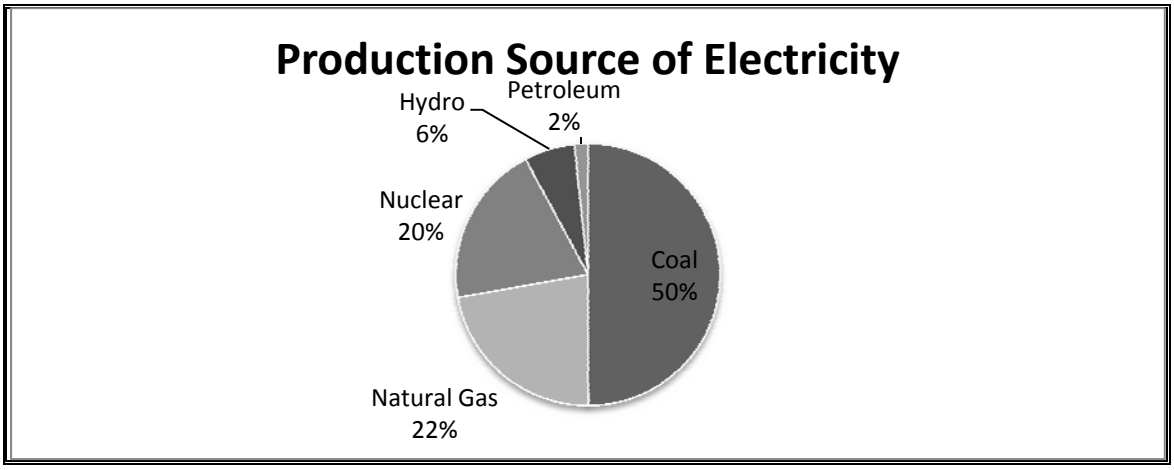

Figure 5 Production Source for Electricity (EIA, 2009)

Electricity is a very useful form of energy for the operations of a building. The current production and distribution comes at a cost that is relatively cheap when compared to energy from renewable sources. The combined commercial, residential, and industrial buildings in the U.S account for about 65% of the country's total electricity consumption (EPA, 2009).

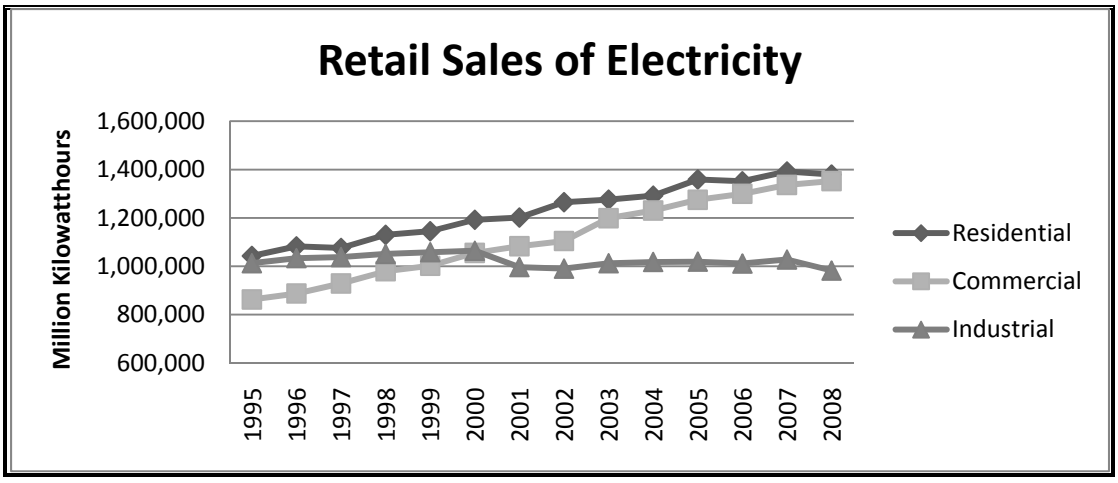

Figure 6 Retail Sales of Electricity in the U.S (EIA, September 2009)

The residential and commercial sectors have increased their demand for electricity from 1995 to 2008 by almost 50% as seen in Figure 6. The residential sector does account for most of the electrical use but commercial buildings are not far behind. The 2007 data showed that the U.S spent $128,903 million for electricity in the commercial sector, and $148,294 million in the residential (EIA, August 2009). Commercial buildings within the state spent a combined amount of about $685 million for electricity in 2007 (EIA, August 2009).

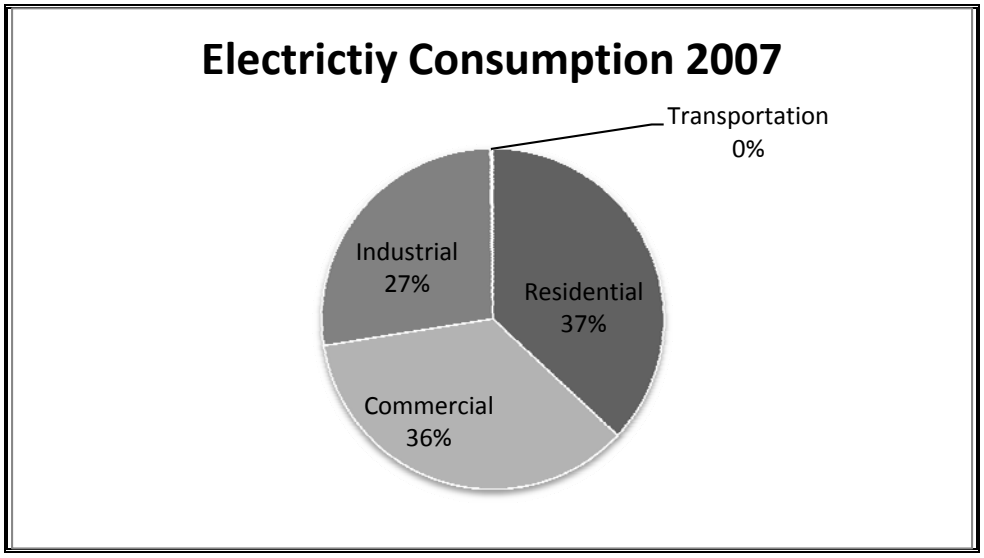

Figure 7 Electricity Consumption in the U.S. 2007 (EIA, September 2009)

Additionally in 2007 the U.S consumed a total of 3,764,561 million kilowatt-hours of electricity (EIA, September 2009). The breakdown of each sectors contribution to the overall consumption is shown in Figure 7. The residential sector consumed 1,392,241 million kilowatt-hours, commercial contributed 1,336,315 million kilowatt-hours, industrial was about 1,027,832 million kilowatt-hours, and transportation used 8,173 million kilowatt-hours (EIA, September 2009).

High energy costs due to inefficiencies can be a driving factor for an energy retrofit. The owners and managers of these buildings can minimize operating costs and increase profits by efficiently using electricity (Turner, 2001). The energy costs for electricity are either in the form of demand or consumption charges. An effective electrical retrofit would factor in these charges to effectively reduce costs. For example reducing the usage during high demand/high cost periods will significantly reduce costs.

2.2.2 Natural Gas

The major component of natural gas is the chemical compound, methane. Methane is a product found in the earth. It is formed from the decay of organic material that has been sitting for millions of years. The U.S is capable of producing natural gas in states such as New Mexico, Texas, Oklahoma, and Louisiana. The standard measure for quantifying gas is the amount of natural gas in a volume of cubic foot. The energy can be quantified in Btu, where a typical a cubic foot of gas produces about 1000 Btu.

Natural gas is used directly for industrial, residential, commercial, as well as electric power generation. Commercial buildings utilize natural gas for space heating, water heating, water cooling, and cooking equipment.

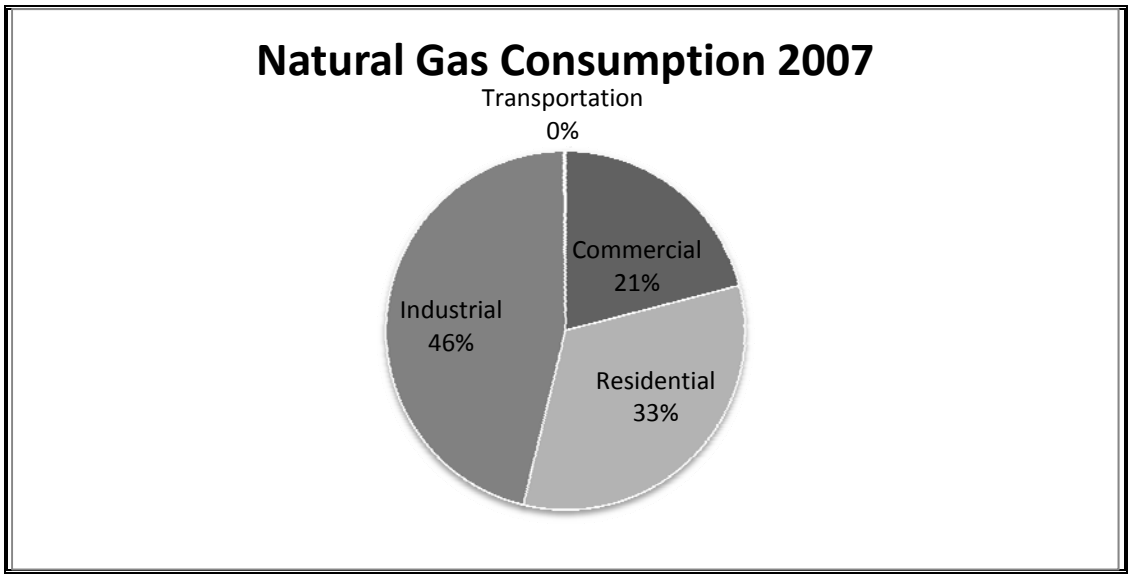

Figure 8 Natural Gas Consumption 2007 in the US (EIA, September 24, 2009)

Commercial buildings account for 21% of all natural gas use (Figure 8). The decrease in this fossil fuel dependency has the potential to have future impacts on economics and the environment. Decision makers can compare the natural gas and electricity to cut cost and improve their environmental impact. Data from 2006 describe the costs of electricity and natural gas in the commercial building sector. Electricity was about $0.027/kBtu and natural gas was about $0.011/kBtu (EIA, September 2009).

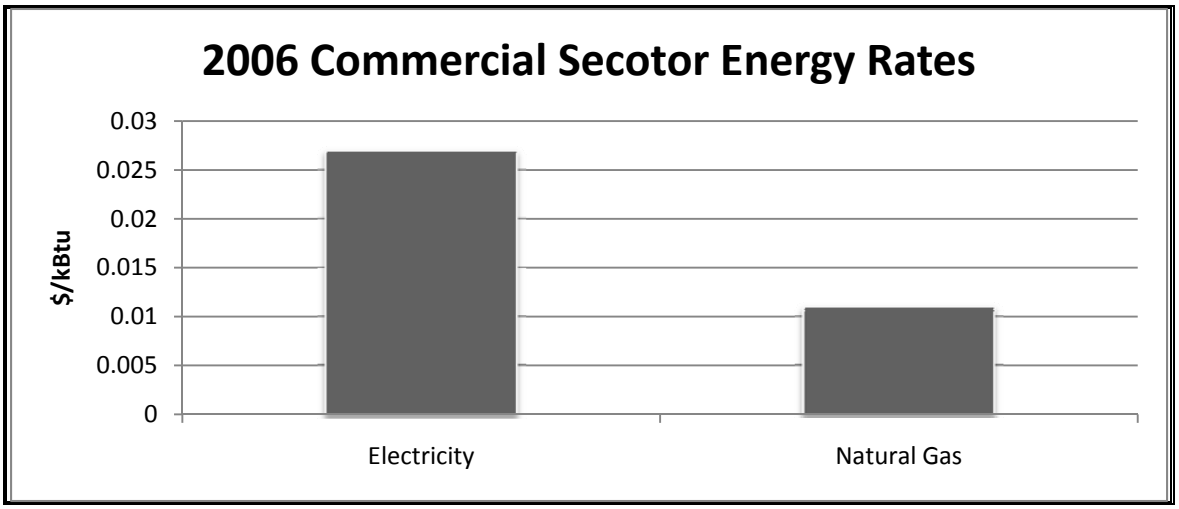

Figure 9 Electricity vs. Natural Gas Rates 2006 (EIA, September 2009)

Figure 9 shows the difference in cost per kBtu for electricity and natural gas in 2006. The data shows that even with the higher electrical costs considerably more electricity (55%) is consumed than natural gas (32%) in the commercial sector according to Figure 3.

2.2.3 Greenhouse Gas Emissions

The earth's atmosphere consists mostly of the gases nitrogen and oxygen. The remaining gases, which account for about only one percent in the atmosphere, are the greenhouse gases (GHG). GHG is comprised of carbon dioxide (CO_2), methane and nitrous oxide. These gases are naturally occurring in the atmosphere. Their function is to absorb and radiate heat to help maintain a habitable environment on Earth's surface (Grant, 2008). The increase in GHGs, especially CO_2, through anthropogenic emissions has caused negative environmental effects. Scientists have observed an increase in global average temperatures due to this increase. CO_2 from burning fossil fuels is the leading anthropogenic emission effecting climate change (IPCC, 2007).

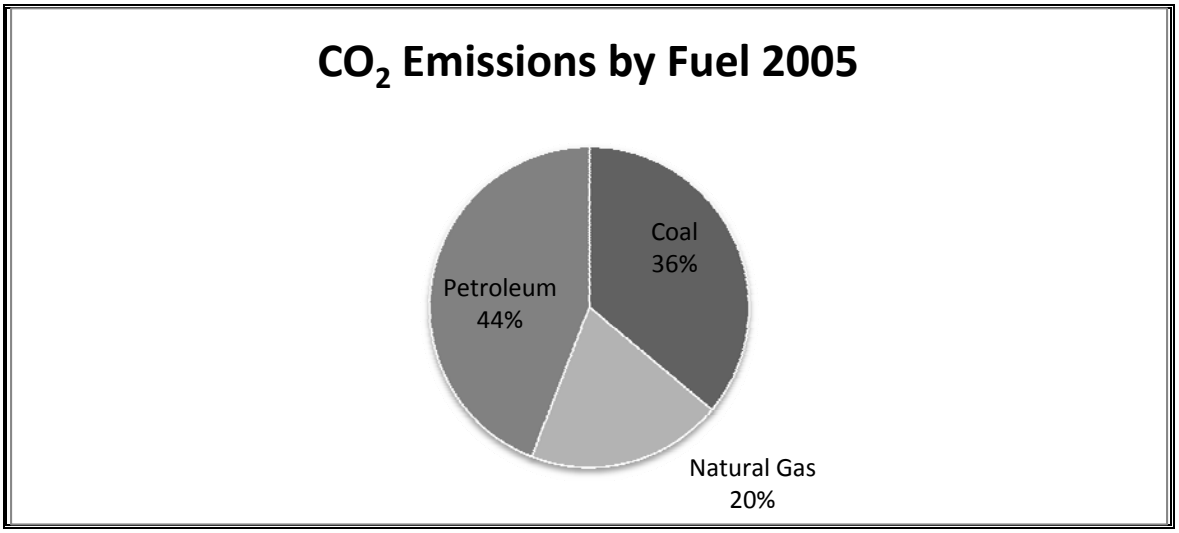

Figure 10 U.S Carbon Dioxide Emissions by Fuel (EIA, October 2009)

Figure 10 shows the amount of CO_2 emissions by fuel source. The use of coal to provide energy has steadily been a leader in CO_2 emissions, second only to petroleum. Coal accounted for about 2156 million metric tons, petroleum was 2639 million metric tons, and natural gas contributed around 1183 million metric tons of the CO_2 emissions in the

U.S during 2005 (EIA, October 2009). The commercial, electric power generation, residential, industrial and transportation sectors in the U.S emitted a total of about 5,978 million metric tons of carbon dioxide in 2005 (EIA, October 2009).

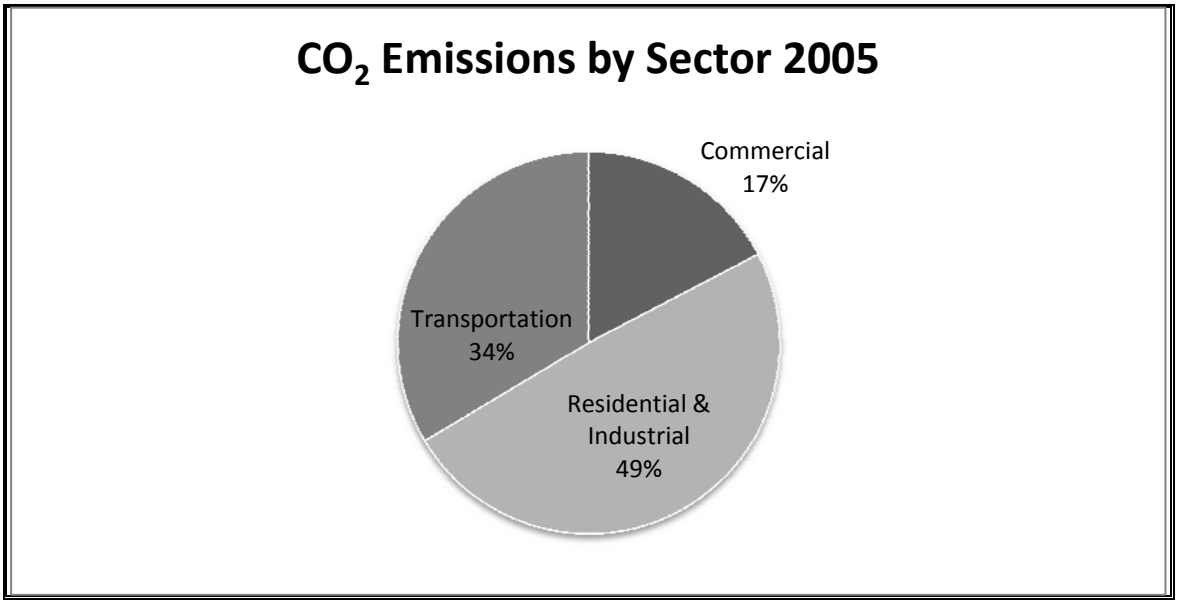

Figure 11 U.S Carbon Dioxide Emissions by Sector in 2005 (EIA, October 2009)

Electrical power generation accounted for the most CO_2 emissions in the U.S during 2005 at 2,386 million metric tons. Electrical power generation contributes about 34% of total emissions from the commercial sector, and the other 66% is attributed to the industrial and residential sectors. Figure 11 shows the distribution of CO_2 emissions by sector. Transportation accounted for 2,008 million metric tons, industrial and residential was about 2934 million metric tons and commercial was 1036 million metric tons (EIA, October 2009).

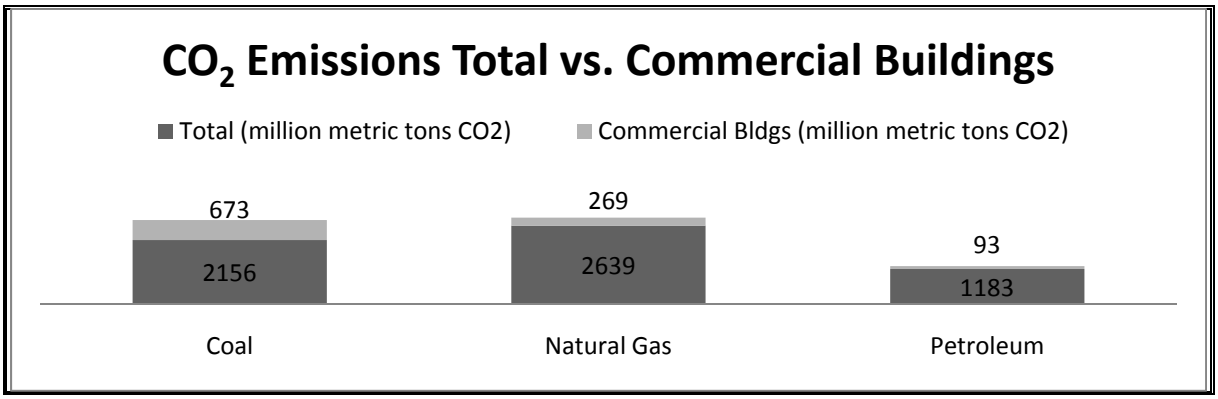

Figure 12 U.S. CO_2 Emissions Total vs. Commercial Buildings (EIA, October 2009)

The three main contributors of CO_2 in the Commercial Building Sector are burning coal, natural gas, and petroleum. Figure 12 shows the comparison of CO_2 emissions between the overall total and commercial buildings contribution to the total. Commercial buildings emitted about 673 million metric tons of CO2 from burning coal which accounts for about 31% of total emissions. Natural gas from commercial building use accounts for 269 million metric tons which is about 10% of the total. Lastly, petroleum use for commercial buildings is about 93 million metric tons, and is about 8% of the total. Understanding and making educated decision to limit the use of these energy sources is a key ingredient for the reduction in commercial building energy demands and lowering the amount of GHG emissions.

2.3 Building Energy Retrofits

Energy conservation in existing commercial buildings is a popular subject when considering the overall increase in human generated greenhouse gas emissions and the declining availability of energy resources. Reducing greenhouse gasses and the rising cost of energy are not the only driving factors for implementation of energy conservation measures. Deloitte Consulting et al (2008) reports that companies are motivated to implement energy conservation in their building with the intent to improve market value and worker satisfaction over operations cost savings. These factors strengthen employee attraction and retention. Worker satisfaction and retention is an important consideration for companies in all industries. Younger employees entering the work force poised to take over for the retiring Baby Boomer generation feel a strong obligation to work for employers who show environmental and social responsibility. Companies can utilize energy retrofits to promote an environmentally friendly atmosphere and attract and retain young and valuable talent.

Improving energy efficiency is an important target for reducing GHG emissions in a cost effective manner. Energy efficient retrofits can ultimately reduce carbon emissions by 1.7 billion tons by the year 2050. While reducing emissions it has the potential to save a total of $68 billion. In comparison it would cost $14 billion to target renewable energy production to reduce carbon emissions by 1.4 billion tons. (NRDC,

2007) These estimates come from the synthesis of a recent report focused on the efficient use of energy to meet future energy needs. The report identifies methods for providing upfront funding for projects, forge greater alignment between utilities, regulators, government agencies and energy consumers. Additionally it promotes innovation in the development of next generation energy technologies (McKinsey & Company, 2009). There are many barriers that industry and consumers must overcome to realize emissions reduction goals in a cost effective manner. Overcoming the barriers requires the combination of decision methods, technologies, environmental responsibilities and government incentives.

Energy cost savings may not be the main driving factor for energy conservation retrofits in some companies (Deloitte Consulting and Charles Lockwood, 2008). One major barrier to the implementation of an energy retrofit is tied to the upfront financial investment. Many companies are structured to promote the realization of short term successes in conjunction with high returns on investment (DeCanio, 1993). Energy efficient retrofits are viewed to not have an immediate financial benefit, yet DeCanio (1993) comments that the median payback for a particular energy conservation measure was only two years. The payback period of two years has a very high rate of return for equipment that will have a lifespan over 10 years. This indicates that managers can incorporate energy efficiency measures that have almost immediate financial profit success.

A distracting factor affecting the energy retrofit process is the low priority many managers place on energy conservation (DeCanio, 1993). Energy conservation measures are considered small projects that result in minimal annual savings and hence low profitability. Because of the low priority assigned to energy savings retrofit it is subject to be given little attention, or delegated to an employee who lacks experience or knowledge of how to implement the action. Decisions within a company structure without a defined process can be difficult to analyze.

Lack of information and understanding of energy conservation initiatives act as barriers against informed decision making. The financial impacts and the means of obtaining funding for investments can be difficult due to this lack of knowledge

(Schipper et al, 1994). The energy retrofit processes could be improved greatly if more reliable information was made available. Such things as energy labeling, and energy rating help provide information and set a basis for informed decision making. Additionally, Schipper et al (1994) notes that even when information is available decision makers may not perform or do not include economic calculations of costs and benefits in their decision process. Therefore the decisions are based on immediate financial returns where payback periods for the energy efficient investment are very short. Long term investments are not considered due to a perceived risk and uncertainty about unknown factors. But, financial incentives in the form of low-interest loans, direct payments, and tax incentives promote investments.

Building owners with tenants are focused on the immediate issues pertaining to building expenses, tenant needs, and satisfying shareholders (Fickes, 2006). But, implementations of energy efficient measures have the potential to lower operating expenses and raise net operating income. Fickes (2006) describes that lower operating costs improves the quality and market value of the building which makes the building more competitive. Tenants in commercial buildings are increasingly expecting energy efficiency. Their goal is to be environmentally and economically responsible. This type of tenant is increasing in numbers and building owners are adjusting to their demands by providing energy efficient buildings. Investors are also encouraging and contributing to the more desirable, energy efficient building investments. There is a movement for businesses to place higher priority on environmental and social accountability over profitability (Novelli, 2007). Liberty Property Trust, which is a $5.4 billion real estate investment trust that owns 77 million square feet of space, states that there is an increase in investor interest in green projects. More investors prefer companies that are environmental friendly. Along with the social issues comes the possibility for the increase in energy production costs. The increase in energy costs may rise so high that it will pass through the tenant and be the responsibility of the building owner (Fickes, 2006). In this scenario energy costs will cut into the net operating income of the building. The only option at that point is to perform an energy retrofit.

The building owner's decision process for determining energy conservation measures has been effected by the current recession. Owners are faced with strained budgets, cutbacks, and reduced profits. When considering investing in sustainability owners will most likely prefer to implement energy efficient measures (Burr, 2009). The energy efficient upgrades will potentially cost less and produce defined paybacks. Owners can begin energy conservation retrofits by first implementing low-cost/no-cost measures.

Existing commercial buildings demand high amounts of energy to maintain minimum desired living and working environments. The primary source for reducing the current demand must come through energy conservation. A recent study was conducted that compared energy efficient retrofits with the installation and use of renewable energy sources (Yalcintas & Kaya, 2009). The study stressed that energy conservation is best achieved through building retrofits that focus on energy efficient upgrades to high energy users such as the systems and components that provide space heating, air-conditioning, and lighting. It also warns that renewable energy production, that is heavily favored in state and federal incentive programs, cannot independently solve commercial building's high emissions production and their reliance on nonrenewable energy sources. The importance to pursue energy conservation measures prior to installation of renewable energy sources was made clear in four case studies. The case studies first examined the energy efficient retrofit measures, the energy savings realized, total construction cost, and the payback period. The second step reviewed the necessary photovoltaic (PV) system to match the energy savings of the retrofit, the PV cost for installation (including tax incentives), the payback period, and the site feasibility of a PV system. The four studies concluded that the energy retrofit would have a much better payback period. Additionally, the existing buildings did not provide enough roof space for installation of the PV area needed to match the energy savings of the retrofit.

The establishment of building codes is a continually evolving process. Updates and additions are common due to the growth in technologies and also in response to social and economic policies. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) developed Standard 90.1 for building energy

conservation. The standards define such elements as building envelope, Heating Ventilation and Air-Conditioning (HVAC) system, service water heating, power, and lighting. A study was conducted in Connecticut to review the cost effectiveness of upgrades to an existing building to meet ASHRAE Standard 90.1 and an alternative standard that establishes energy savings above Standard 90.1 (Brancic & Peters, 1991). The Micro-Doe 2.1D computer program was used to evaluate the energy performance of a typical office building. The base building was developed to meet the normal Connecticut building code. Additionally, energy conservation alternatives considered where lighting, motors, variable speed drives, air conditioning, heat production, HVAC controls, wall and roof thermal performance. Construction costs were estimated for the additional alternatives which were based on RS Means and past energy conservation projects. Then a benefit versus cost analysis was performed. The analysis used the calculation of the net present value (NPV). The findings determined that upgrades to an existing, code compliant, office building to meet the 90.1 Standard are cost effective. Additionally, most upgrades that went beyond the 90.1 Standard were also cost effective. Another note worthy finding was that the more stringent lighting standards offer the highest electrical savings compared to other energy conservation measures.

Energy efficient retrofits to obtain an Energy Star or Leadership in Energy and Environmental Design (LEED) Certification have environmental and financial benefits. The comparison of non-green buildings (buildings that do not have and Energy Star or LEED Certification) with green buildings for elements such as occupancy rates, rental rates, sales prices, and lease structure were discussed in a recent research publication (Miller, 2008). The research utilized CoStar data of about 1200 buildings encompassing the retail, office, industrial, and hospital sectors. The results showed that between the years 2004 and 2008 green buildings had higher occupancy rates, higher rental rates, and higher sales prices. LEED buildings have over 4% higher occupancy over the non-LEED buildings. Additionally Energy Star buildings have over 3% higher occupancy than non-Energy Star buildings (Burr, 2008). These numbers provide compelling arguments to create energy efficient buildings. The cost to implement green features does however come at a higher initial investment cost. The financial incentives in the form of tax

credits, tax incentives, and rebates help drop the initial capital cost and improve the net rate of return.

2.4 Decision Process

The design, construction, and operations of a successful energy retrofit begin with the owner's initial dedication to the project. There are many different types of buildings and retrofit projects and all of them must be initiated by the direction of the owner. The owner is responsible for expressing enthusiasm and making a commitment to reach specific goals. Achieving energy conservation retrofit goals requires engaging a capable design team. The design team must understand and implement strategies to meet the schedule and budget that is defined by the owner. Throughout the design, construction and operations of the project the owner must maintain interest, commitment and a high level of enthusiasm. (ASHRAE, 2006) The owner's role in an energy conservation project, as defined by ASHRAE, requires a high level of understanding of the process and considerations.

Building owners and companies must utilize a clear decision process to analyze and justify energy conservation investments. The decision process for an energy retrofit provides information on how to build and maintain energy systems. This is done through evaluation of economic and environmental constraints (Gatton et al, 1995). The objective of the determination system as described by Gatton et al (1995) is to discover the potential reduction in energy consumption through the use of the most cost effective alternative. The research takes a three phase approach. The first phase includes the inspection and review of building utility current use. The second step examines the areas for potential upgrades. Finally a detailed cost/benefit analysis is performed to determine the actual costs. The decision support system guides the decision makers in determining which energy conservation upgrades to pursue.

Decision makers consider and authorize capital expenditures to improve the economic and energy related performance of their facilities. These decisions are made through the incorporation of practices, processes, and criteria. The decision makers consider four primary criteria: 1) Financial Performance, 2) perceived effects on tenant

comfort and satisfaction, 3) technical track records and 4) technological reliability (Parker et al, 2000). These criteria are integrated into a decision making process. Figure 13 below describes the decision process steps and pertaining criteria.

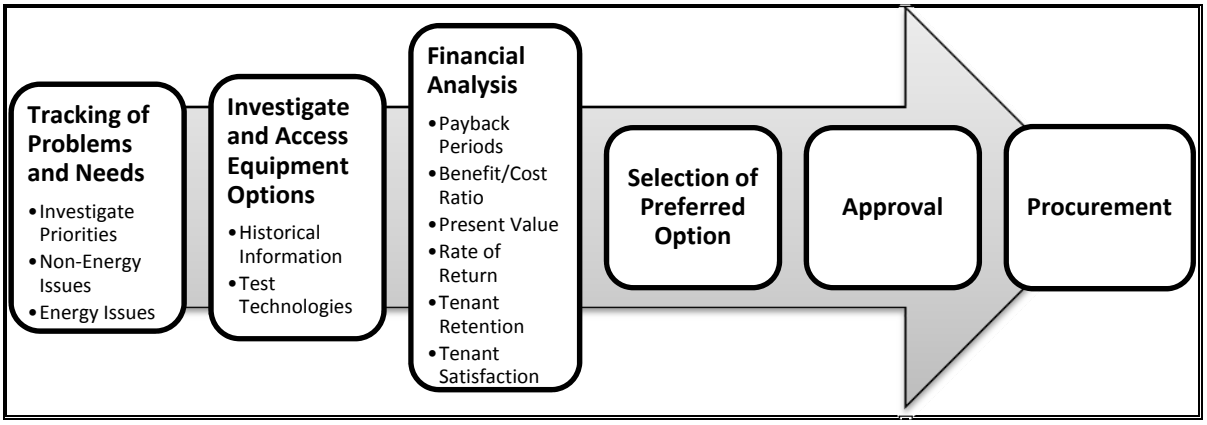

Figure 13 Owner Decision Process (based on Parker et al, 2000)

The decision process contains important steps for gathering and analyzing information. The company's integration of certain decision steps aids the retrofit process by decreasing uncertainties (Ruiz, 2005). Decreasing uncertainties requires the process to take the decision maker through a series of stages: 1) understanding, 2) development of interest, 3) a means for evaluation, 4) measure and verification of new systems, and 5) commitment to proper use of new systems. Ruiz (2005) identifies these stages as key factors for implementing energy conservation and argues that the fundamental barrier to success is the lack of understanding. The decision process must provide a means for eliminating these shortcomings.

For example, Dow Chemical Company is committed to sustainability and attempts to balance economic, environmental and social responsibilities (Tannenbaum, 2005). Dow realized that they can make a significant reduction in energy that could have definite impacts on the environment, improve productivity, and realize financial savings. Their goal was to reduce energy consumption by 20% by the end of 2005. Dow Chemical reduced energy consumption by 6% in 2004 (Tannenbaum, 2005). This reduction in electricity use is equivalent to the need of over 330,000 homes in one year. The energy conservation program at Dow established an energy management division called the Energy Business Unit and the incorporation of a Global Energy Conservation

Leader. This Business Unit is responsible for managing fuel and energy purchases as well as influencing energy efficiency behavior throughout the whole company. The Leader networks and oversees management decisions for energy efficiency. Management's goal is for energy efficiency to be implemented into their entire organizational structure. The full implementation required that two barriers needed to be overcome. First, cost effective upgrades to existing technologies needed to be identified. Second, energy conservation measures must be able to compete for time and resources with other important company priorities. This requires the development of a strong business case for energy efficiency that includes the implementation of pertinent data collection, Six Sigma methodology, internal communications, and clear organizational structure. The data collection includes metering, monitoring, and energy intensity graphs. The implementation of Six Sigma provides a methodology to upgrade the existing operations by defining how to measure, analyze, improve and control. Dow uses the company intranet to communicate energy efficiency projects and directions. They also developed an energy efficiency and conservation website that provides information on the current energy performance, energy conservation implementations, and other usefully information to encourage and provide visibility to energy efficient behavior.

Energy efficiency can reduce the cost of doing business and help provide profitable growth. The specialty materials company, Rohm and Haas, believes in perusing energy efficiency within their business (Baker, 2005). Energy excellence is defined by reducing utility costs and energy consumption due to human or process behavior. Additionally, Baker (2005) states that energy overuses can be avoided by eliminating short term fixes. Rohm and Haas believe that to achieve energy efficiency goals a metrics need to be established. The metrics system was established to measure energy usage amounts and time of use. It also allows for accurate measurement of actual production and energy use that allows for internal building energy data to occur. Their implementation includes a stakeholder and working team that each focus on energy. Their initial goal is to reduce energy consumption by 15% within five years. This is done by using site based programs that conduct energy assessments, analysis, monitor and

target energy consumption. Additionally the programs focus on energy management systems, and leak, maintenance and thermal imaging audits.

Successful implementation of energy conservation can be a difficult task. Available capital, limitations of equipment, convincing management of the benefits, and the diminishing value of implementing lower-payback projects can present various challenges (Baker, 2005). The challenges can be confronted by in the establishment of programs and in the retrofit process. These process allow for management to implement work force awareness, energy teams, stabilization of product planning and scheduling, ISO 14001 targets, capital allotments for energy optimization, and an established a corporate goal (Baker, 2005). Additionally continuously monitoring of energy use, brainstorming new techniques and opportunities, and working as a team will help overcome barriers.

The different types of energy retrofits of a building can be analyzed in an advantageous manner. The Optimal Energy Retrofit Advisory (OPERA) model is a valuable tool to find the optimal retrofit strategy (Gustafsson & Karlsson, 1991). The optimal strategy is based on Life-Cycle Cost (LCC). This type of analysis incorporates an interaction between the different measures that may be neglected in a regular retrofit analysis. The OPERA model uses input of almost 200 values that describe the building in detail. The program calculates the existing LCC of the building to establish a baseline. Once the existing LCC has been calculated retrofit solutions are introduced. Building envelope, windows and heating systems and other retrofits can all be entered and analyzed separately or in different combinations

The OPERA model was developed at the Institute of Technology in Linkoping, Sweden. The case study described by Gustafsson (1991) was a building called Uppland 5. This building was said to be in poor thermal and aesthetic shape. The building was modeled with the implementation of various retrofit assets and two different degrees of shading coefficients. The shading factor had an influence on the energy demand for space heating. The LCC was then calculated for the combined and incremental retrofits. Then OPERA performed energy balance calculations for various retrofit alternatives.

The energy balance numbers were compared and LCC were computed for each to determine the most appropriate scheme for the retrofit.

Intelligent Buildings (IB) are buildings that have the technology and controls to respond to individual, organizational and environmental requirements (Yang & Peng, 2001). There are two layers to this type of building - physical building, and the management and operations of the building. IBs have not been implemented widely. Building owners and developers are yet to recognize the potential energy savings and flexibility that the intelligent building can provide. Contractors are also skeptical of the concept because they feel that it could make their job more difficult and increase project risk and cost.

The incorporation of design, construction, and operations of energy retrofits rely on the owner's understanding of its benefits. Building owners should understand the energy consumption reduction, and energy savings that can occur with the implementation of an energy retrofit. This understanding and by-in requires the use of a clear decision process. The decision process helps the owners understand the needs, how to investigate the need, the type of financial considerations, and the selection of the proper alternative.

2.4.1 Defining the Energy Status of a Building

Defining the overall energy consumption of a building is an important step in the decision process. It provides a basic understanding of the building and a base to establish the preliminary evaluation. Currently benchmarking and certification processes define the energy status of a building. There are many helpful tools available to building owners for helping them quantify their buildings use. Such tools include Commercial Building Energy Consumption Survey (CBECS) data, Energy Star, and LEED. CBECS is managed by the Environmental Information Administration and provides information on average and target energy usage for commercial buildings. The data is specific to the type of building and the climate zone that the building is located in. Energy Star is a service provided by the Environmental Protection Agency (EPA). The service allows users to log on to an internet site and enter information about their building. The website

will then provide the user with information regarding the buildings status and how it ranks in comparison to other buildings. LEED provides a means to understand the existing building energy use and a way to verify that the energy consumption has been reduced. Yet, LEED is an in-depth process that requires consultants and considerable time to perform. The CBECS data and the Energy Star website provide the owner with a means for benchmarking their building.

Benchmarking is a useful tool for establishing an understanding of existing building energy consumption. The energy utilization index (EUI) is a common tool for quantify and comparing the energy consumption of a building. The index can be used to determine and compare the energy use of a particular building (Abouzelof, 2007). The EUI is the ratio of energy consumption to a measure of demand for energy service, for example Btu per square foot. This index is important for an initial analysis of the energy conservation potential. It is easily used for measurement and comparisons with other comparable buildings. Abouzelof (2007) states that verification of the type of indicator to use is critical, and depends on the building. The indicator can be based on energy use per square foot of space, or energy use per occupant. Possible inconsistencies can be found in developing an index based on occupancy, where 95% occupancy can be documented when actually only 80% of the building is occupied.

The EUI can also be affected by the initial design, building automation system (BAS) and operation and maintenance. Additionally, collecting and displaying the data are important considerations for insuring appropriate benchmarking of the building. The gathering of information includes energy consumption data and monthly utilities bills for at least two years of consumption. The information gathering should take into account errors or discrepancies due to dissimilar billing periods, electric meter audits and corrections, electric power billing schedules, actual versus estimated bills, and approved allocation bills. The EUI can be displayed effectively in a chart format. One good approach is to display the energy consumption for each month within the year, and then compare the consumption fluctuations for each month and the difference in each month from year to year. A second option is to display the energy consumption for each year. The charting scheme may vary depending on what baseline the building is being

compared with. The EUI information gathering and charts have the ability to provide data to aid in the assessment of the buildings status and help prioritize energy conservation measures.

The building industry has attempted to improve energy efficiency, minimize energy consumption and identify building deficiencies through the establishment of certifications (Perez-Lombard, et al, 2009). The certifications simplify the verification of building performance. They also provide a means for encouraging energy savings through mandates and regulation. The certification process can be complicated and confusing. The confusion can begin with the understanding of terms, available tools, and requirements. To help, practitioners have developed clear benchmarking tools, energy ratings, and energy labels to clarify the three critical issues within the retrofit decision and implementation process. Those issues are definition of scope for energy efficient measures, energy classification, and final implementation of energy certifications. Scope is the overall energy performance index for the building, energy consumption of each component, and establishment of the energy conservation goal in relation to energy savings and energy label. Classification determines the building's energy use in relation to other comparable buildings. Implementation of the energy certificate includes the final determination of the limit of energy efficiency, the improvements necessary to achieve the certification, and the information that should be included to achieve the certification.

There is an increasing demand for environmentally friendly buildings (Sidebottom, 2006). Building owners can consider two types of certifications – Energy Star or LEED-Existing Building (EB). Energy Star is a well know certification that is backed by the U.S Environmental Protection Agency and Department of Energy. The LEED certification is growing in popularity and acceptance. Many local, state and federal organizations and private businesses are requiring this kind of certification for their buildings. The Energy Star Rating System is based on the buildings energy use index that is given in Btu/sf/yr. This index can be compared with equivalent buildings to discover its degree of energy efficiency. It is well documented that building that earn an energy star rating use about 40% less energy than non-certified buildings. The two certifications are effective means to reduce the building impact on the environment. The

Energy Star rating is most effective approach for an organization wishing to reduce its current energy usage. But, if the organization wishes to improve the entire sustainability of the building the users the LEED certification is the most appropriate certification. LEED is a more comprehensive overall building sustainability certification, while Energy Star is more limited to energy conservation.

Utility cost tracking, identification of significant energy uses, and development of key performance indicators are included in an energy profile of a building (Meffert & Brown, 2005). This energy profile is useful to reveal trends, anomalies, price signals and provide insight for energy and cost allocations. According to Meffer et al (2005) the data and information is important to collect. It is important to know the costs for each rate schedules, production, and financial information. The component costs include energy cost, demand cost, fuel cost, transportation cost, fees due to penalties, and sales tax. The evaluation reviews charts and tables of the described data can be created to easily evaluate and identify potential red flags. The next step is to define a key performance indicator (KPI). The KPI will help indentify operational efficiencies and show improvements of energy conservation actions. It can also be used to identify building energy use overtime, and also compare it with other similar buildings. The KPI is based on input divided by output and the exact units often depend on the business sector and the building. The goal is to lower the KPI to the lowest possible value. Energy managers can use the KPI to help understand the energy balance in the building. The energy balance analysis defines where the incoming energy eventually gets used. This knowledge helps the management team define the scope for energy conservation measures and opportunities.

2.4.2 Assessment

Considering cost and financing is an extremely important aspect of an energy efficiency project assessment. Organizations have the opportunity to make decisions for energy efficiency based on first-cost or life-cycle cost to determine new equipment purchases for their existing building. They are faced with limited funds and lack of resources to plan and implement economic improvements. Zobler et al (2003) compares

four financing options available to organizations for building energy retrofit projects which is described in Table 1.

Table 1 Financing Options for Energy Projects (Zobler & Hatcher, 2003)

	Cash	Bonds	Municipal Leases	Performance Contracts
Interest Rates	N/A	Lowest tax exempt rate	Low tax-exempt rate	Can be taxable or tax-exempt
Financing Term	N/A	>20yrs	10-15 yrs	10-15 yrs
Other Costs	N/A	Underwriting, legal, insurance	None	Engineering Costs if contract not executed
Approval Process	Internal	Approved by referendum	Internal Approval	RFP – Internal Approval
Approval Time	Current budget period	>1yr	<1 week	1-2 weeks
Funding Flexibility	N/A	Difficult to go above maximum	Master lease that allows the drawdown of funds as needed	Relatively Flexible
Budget Used	Either	Capital	Operating	Operating
Greatest Benefit	Direct access	Low interest rate	Buy capital equipment using operating funds	Performance guarantees – help approval process
Greatest Hurdle	Never enough money available	Time consuming	Identifying the project	Identifying the project and ESP

Capital funds are difficult to employ, because they are often scarce, committed to other projects, and have to compete with other priorities. Energy performance contracts and lease-purchase agreements are useful for financing energy efficiency projects (Zobler & Hatcher, 2003). These agreements allow for the owner to use funds from operating budgets and not capital investments or increases to tax payer contributions. Tax exempt lease agreements use money that is already in their annual utility budget to fund the energy efficiency project. Energy performance contracts are comprised of three agreements: development, energy service, and financing. These contracts are established between the building owner and the private energy service provider (ESP). ESPs are commonly used as a guaranteed savings agreement that bundles equipment purchasing and performance guarantees, while also including financing, maintenance and energy costs.

There are several investment principles that are imperative to consider for building retrofits that incorporate energy efficiency. The assessment process can include these principles so that proper finical factors are considered for decision making. These principles include identify all cash flows, avoid investing in simple projects with low cost and quick paybacks, focus on life cycle cost, and select an effective cost benefit method. The appropriate implementation of the investment principles will help inform decision makers on the benefits of long-term profitability decisions (Zelinski et al, 2009).

Projects with low initial cost and quick paybacks may seem attractive due to the initial returns on investment, but these retrofits capture less energy and cost savings over the long run compared to the more extensive energy retrofit projects. Zelinski et al (2009) provides a comparison between a comprehensive and non-comprehensive energy retrofit project. The non-comprehensive could simply include lighting system improvements. The improvements have low initial cost, with a high savings to cost ratio. The particulars of the lighting upgrade have the potential to save 30-40% of the energy used by the lighting system and have a simple payback of 1 to 2 years. This information makes it appear like a good retrofit project, but consider that lighting only accounts for a third or less of the total energy use of the building. The implementation of a comprehensive retrofit project requires planners to recognize unexploited energy and cost savings with longer paybacks and larger initial investments are considered. Planners and decision makers should consider including both short and long term energy conservation measures. The short payback elements such as lighting can be used to offset costs and help the viability of the comprehensive project.

Zelinski et al (2009) states that cash flow scenarios that identify costs and savings over the life of a project are important elements of a financial analysis. Planners should consider four key cash flow components of a typical project: Planning and management, capital acquisition and financing, installation and commissioning, and operations and maintenance. The primary goal for planning, design and implementation of the energy conservation measures is to have positive cash flow as quickly as possible. Planners should keep in mind that when striving to achieve positive cash flow up-front project investments will have short term negative cash flows a majority of the time.

The next investment principle is to focus on Life-Cycle Costs (LCC) (Zelinski, Gatlin, Werner, & Goldberger, 2009). LCC are important for measuring and comparing alternative proposals. The analysis includes all costs that are associated with the project. The use of the LCC approach allows planners to produce profitable projects because it accurately compares the value of different alternatives. Another method for determining the best alternative is through an effective cost-benefit analysis (Zelinski, Gatlin, Werner, & Goldberger, 2009). There are three primary cost-benefit methods: 1) simple payback analysis, 2) internal rate of return (IRR), and 3) Net Present Value (NPV).

The simple payback calculation involves dividing the total project cost by the cost savings achieved by the energy savings. Zelinski et al (2009) notes that decision makers proceed with caution when using the simple payback approach. The first concern is that it does not reflect savings that will continue to accrue after the payback point has been reached. Additionally it does not account for the time value of money. The IRR and NPV methods for cost-benefit analysis are more in-depth but provide more information for the decision maker. The IRR has the capability to understand the useful life of an improvement and incorporate the time value of money. The basic principle is that it provides an annualized rate of return for an investment that is based on negative and positive cash flows. The final cost-benefit method is NPV which is a profitability indicator. NPV considers the cash flows, energy savings estimates, investment hurdle rates, and the time value of money. Zelinski et al (2009) believes that NPV is the best financial tool for decision makers.

2.4.3 Integrated Approach

Energy conservation measures are analyzed by design teams through modeling techniques that account for the integrations between various elements (Vaidya et al, 2009). The practice of integrated design and costing is not widely accepted by building owners because of the high upfront cost. However, the practice can be advantageous for several reasons. The integrated approach helps confirm that capital cost savings are included in the design and provides an early design and cost estimate. Vaidya et al

(2009) developed and tested an integrated design and cost estimation framework to help justify its use, eliminate uncertainties in the industry, and attract incentives.

Vaiday et al (2009) states that owners and firms are unfamiliar with the process and without a clear understanding will side with the norm. The integrated process requires owners to discard traditional methods and accept an approach that requires more involvement from stakeholders, architects and engineers early in the process. It institutes a new fee structure for the design because of the increased requirements within the schematic design. A case study of an office building in Las Vegas, Nevada implemented an integrated approach for design and cost estimation and compared the results with a non-integrated process (Vaidya et al, 2009). The alternative with no integration exhibited energy savings of about 34% and a simple payback of 3.3 years. The alternative with just a single interaction integration method had an energy savings of about 42% and a simple payback of 1.4 years. The study demonstrated the value of integrated design and cost estimation for projecting cost savings and payback periods. Integrated design requires the incorporation of accurate cost estimating to justify its benefits and overcome perceived negative impacts of upfront cost.

Office buildings require some degree of retrofit during their lifetime. The need for a retrofit can be due to normal aging, alterations of occupancy requirements, and the development of new technologies (Nilsson et al, 1994). Nilsson et al (1994) states that energy savings retrofits depend on the levels of current usage and the reliability of potential energy savings. The effectiveness of the estimate is best completed through the utilization of simulation techniques. Simulation techniques are important because of the complex components of building performance such as thermal interactions, indoor air control, and solar radiation. The analysis of energy conservation measures should be based on the total energy balance of the building. The balance consists of heat generation, heat flow through the envelope, and the degree of climate control achieved by the HVAC system.

Company profits will begin to decline with the increase in energy and maintenance costs for existing buildings. The standard project delivery methods for providing upgrades to buildings must change to promote an integrated approach

(Hellmund et al, 2008). The integrated approach is conducive to an open exchange of ideas and expertise throughout the design and construction phases. Hellmund et al (2008) provides an example project that utilized the integrated approach. The general contractor was brought early into the process to collaborate with the architect/design team. Additionally an independent commissioning authority was used during the design phase to evaluate the mechanical, electrical and plumbing systems. The building systems were analyzed using energy modeling techniques. The modeling determined the energy performance requirements of the envelope in conjunction with the HVAC system. The energy performance model was then integrated into the design to produce the construction documents. The collaboration of organizations helped define a system to provide the occupants with the best comfort and also produce energy savings.

The integrated approach does, however, have some challenges. The most hindering factor may be the upfront design cost is higher than typically methods. The interaction between contractors and designers early in the process is a new concept that may take some getting used to. Contractors may also need to adjust their management processes to execute effective integrated project delivery. Hellmund et al (2008) adds that successful implementation of the integrated approach begins with the owner setting high energy savings goals. The goals are then targeted through detailed analysis to aid the decision process, integration of the appropriate entities, and overall teamwork.

The technologies for energy saving building components have been developed and are in use, but the decision and selection of the building components to be used in the building must be considered carefully in the design process. The integrated approach for analyzing and design a building for energy efficiency must consider a balance of building components (de Wilde & van der Voorden, 2004). But there are barriers that need to be overcome such as limited availability of appropriate computational tools and expertise, lack of trust in simulation results, problems in data exchange, and costs connected with extensive design and simulation. Additionally about 80% of all the surveyed energy saving building components are selected without considering alternatives. This survey stresses that it is important to review design process using accurate computational tools. De Wilde et al (2004) describes a suggested decision process that includes five key steps:

1) identification of options for space and building component, 2) identification of relevant functions of the space and building component options, 3) specification of performance indicators, 4) prediction of the performance of each option, and 5) evaluation of predicted performance. The available tools suggested are modeling tools, design tools (automated design, assisted design), analysis tools (energy efficiency analysis, daylighting analysis), planning tools, communication tools, and construction tools. The tools can work together to help the decision, design, and construction processes.

CHAPTER 3 METHODOLOGY

3.1 Research Questions

Economics and environmental/social responsibilities are issues that have the potential to complement or contradict each other when considering operations and energy system upgrades within a commercial building. There is a potential balance between these issues in the implementation of an energy retrofit. Retrofits that include Energy Conservation Measures (ECMs) have the potential to exhibit economic benefits while simultaneously decreasing the amount of Greenhouse Gas emissions. Yet the contrary can also be true, where the cost to install environmental friendly systems does not match the potential return on investment. The responsibilities and decisions for these energy conservation scenarios fall to the shoulders of the building owner. This research highlights these existing building energy retrofit situations and focuses on the building owner's decision process. The following questions are to be addressed in the research:

- What is the best decision process for existing commercial building owners to execute when considering a retrofit that includes energy conservation measures?
    - What decision steps do organizations currently follow?
    - What decision steps should organizations follow?
    - How can organizations improve their current decision process?

The research questions are focused on the process that owners can utilize to insure that the appropriate issues are considered for the execution of an energy efficient retrofit. The presented questions will lead to answers that provide a meaningful decision process approach. The approach will offer decision makers a means to compile and review relevant information, assumptions and calculations. The best decision process provides owners with a means to make educated decisions on possible energy conservation measures based on economics and environmental issues.

3.2 Research Approach

The development of this research relied on qualitative data collected through case study research. The unit of analysis is the decision process of each building owner. The case study research provided information though interviews, observations, and review of documents. The means for research took a collective case study (Creswell, 2007) approach. The research method involved the selection of a single issue. The selected issue was the owner's decision process for evaluation of a building retrofit that implements energy conservation measures. Several organizations were selected for analysis. The multiple cases were useful to help define the process in actual practice and describe different perspectives depending on the building type. The organizations interviewed for the case studies included organizations such as public schools, university, government, cities, office buildings, and hotel buildings. See Table 2 for a breakdown of the respondents.

Table 2 Organization Interviewed

Organizations	**Number**
Public School	3
University	1
Government	1
Cities	2
Hotel	1
Office	2
Warehouse	2
Total	**12**

The research approach used a combination of literature review and case study interviews. The literature review included the overview of existing published articles, books, and manuals. Further review included websites and reports pertaining to the subject. The literature review was conducted by first identifying material, then analyzing it and performing a critical review. The information was then synthesized and finally documented (Hancock & Algozzine, 2006). The identified material included the current status of energy efficient retrofits, energy considerations, and descriptions of evaluation methods already available. Energy efficient retrofit literature was analyzed to identify gaps, strengths and weaknesses. Following the critical review the material was

synthesized in Chapter 2 to summarize the relevant and known information in an organized manner.

Case study interviews were the second major source for research information. Interviews were conducted with organizations who were identified to be involved in building retrofits that included Energy Conservation Measures (ECMs). The qualitative data received from the interviews provided important insight into current practices and revealed how the available assessment methods and resources are currently being used. The research approach is shown in Figure 14.

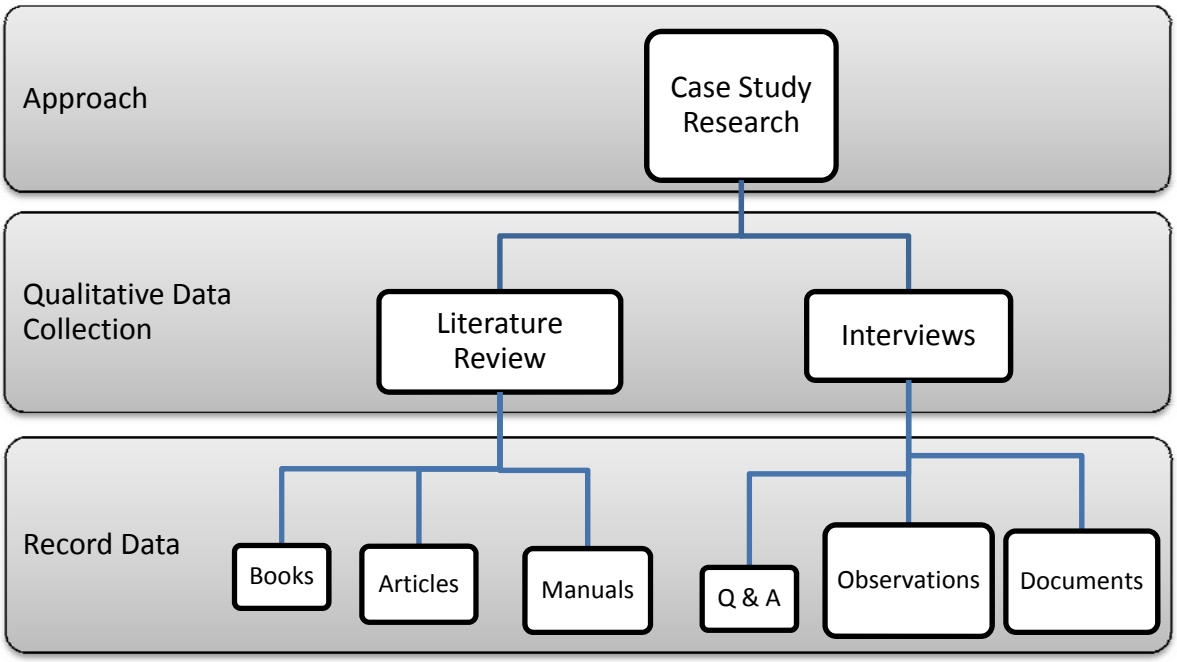

Figure 14 Research Approach

3.3 Data Collection

The data collection consisted of gathering qualitative data through the collective case study design approach. The main source of information gathering was done through interviews, with each of the organizations identified in Table 2. The collection of information through interviews is similar to the approach utilized by Parker et al (2000). Their research surveyed 26 corporate decision makers concerning their energy related investment practices, processes and criteria. Their research used an interview schedule

that included a series of open ended questions geared toward the corporate decision process and the types of technical information required by the decision maker.

This research included interviews that followed key steps and criteria as defined by Hancock et al (2006). The first step in the interview process was to identify key participants whose knowledge and opinions could provide important insights. The second step was to develop an interview guide that structured the talks to have predetermined, yet open ended questions. The third step was to conduct the individual interviews. The interviews were prepared to have one hour duration. The one hour time period provided sufficient time to gain insights concerning the fundamental research questions. The interviews were conducted in an appropriate setting at the interviewee's office. This was done for convenience of the interviewee and also was conducive to any gathering or displaying of pertinent documents. Handwritten notes were utilized to record the information gained in the interview. The interviews followed standard research practice, where the interviewee provided necessary consent for divulging information. The overall interview structure was predetermined but flexible. The interviewee was allowed to elaborate on information that they deemed most important. The fourth step was to compile the acquired information. The information from each interview was compiled similarly, and was in the form of short summaries and outlines with identical formats. This allowed for key elements to be identified and compared. The fifth step was to perform follow up questions with fixed responses which were emailed, discussed on the phone, or gathered in face to face meetings to complete the interview process. The data collection process is shown in Figure 15.

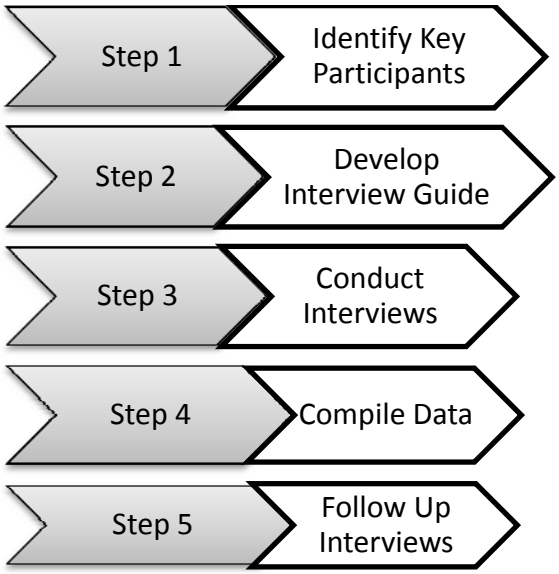

Figure 15 Data Collection Process

There were some initial concerns with the data collection process. The concerns were the number of willing participants, the variation in the type of participants, and proper interpretation of the various decision processes for energy conservation retrofits discussed. Numerous organizations were contacted to participate in the case study research. The final number of participants came down to twelve. The information gained from each has provided in-depth insight into their process and criteria. The quality of the information obtained was the priority over the quantity. The variation of participants was initially a concern but turned out to be beneficial. The participants in the varying building sectors were able to provide insight and opinions that came from different backgrounds and perspectives. Each of the participants did not have a defined or documented decision process which provided issues for initial interpretation and information gathering. This was overcome by in depth note taking and structuring questions and discussions accordingly.

3.4 Data Analysis

The interpretation and organization of the text and narrative data must be done appropriately. The qualitative analysis approach provokes an infinite cycle of thinking, noticing and collecting information is shown Figure 16 (Seidel, 2008).

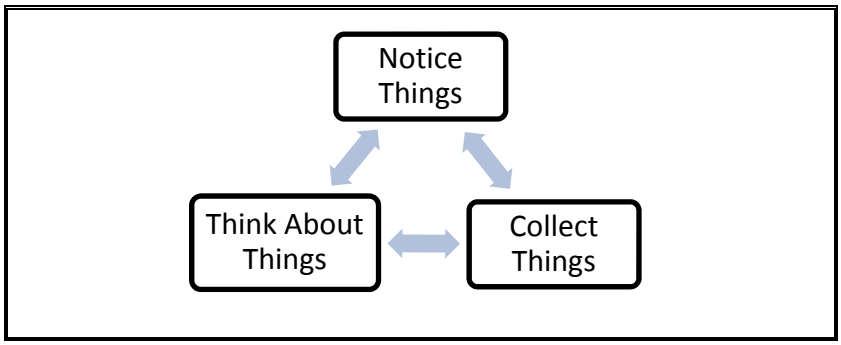

Figure 16 Qualitative Data Analysis Process (Seidel, 2008)

The collection of data began with the identification of key participants, then the development of an interview guide, followed by interviews. The data from the interview was then compiled, and finally follow up interviews were conducted. This process is described in more detail in Section 3.3 Data Collection.

The recognition or noticing of important elements of the collected data (Seidel, 2008) were done through review and organization of the data. This meant continual review and re-reviews of the documents and recorded text from the interviews (Taylor-Powell & Renner, 2003). Once the in-depth understanding of the gathered information was concluded, a focused analysis identified key elements. The focus centered on the questions or the topics discussed and how the individuals or groups responded (Taylor-Powell & Renner, 2003). The analysis identified consistencies and differences among the respondents. The next step was the categorization of the information (Taylor-Powell & Renner, 2003). This is where each organization's decision process steps were identified, the extent of utilization of each step, the effectiveness of each step, decision process considerations, and finally the decision process controlling factors were grouped for comparison purposes.

The final step was to examine or think about the categorized information (Seidel, 2008). This step was instituted to make sense of the information, identify patterns and relationships and also recognize significant findings (Seidel, 2008). Additionally this process allowed for the identification of lacking elements and possible areas for improvement.

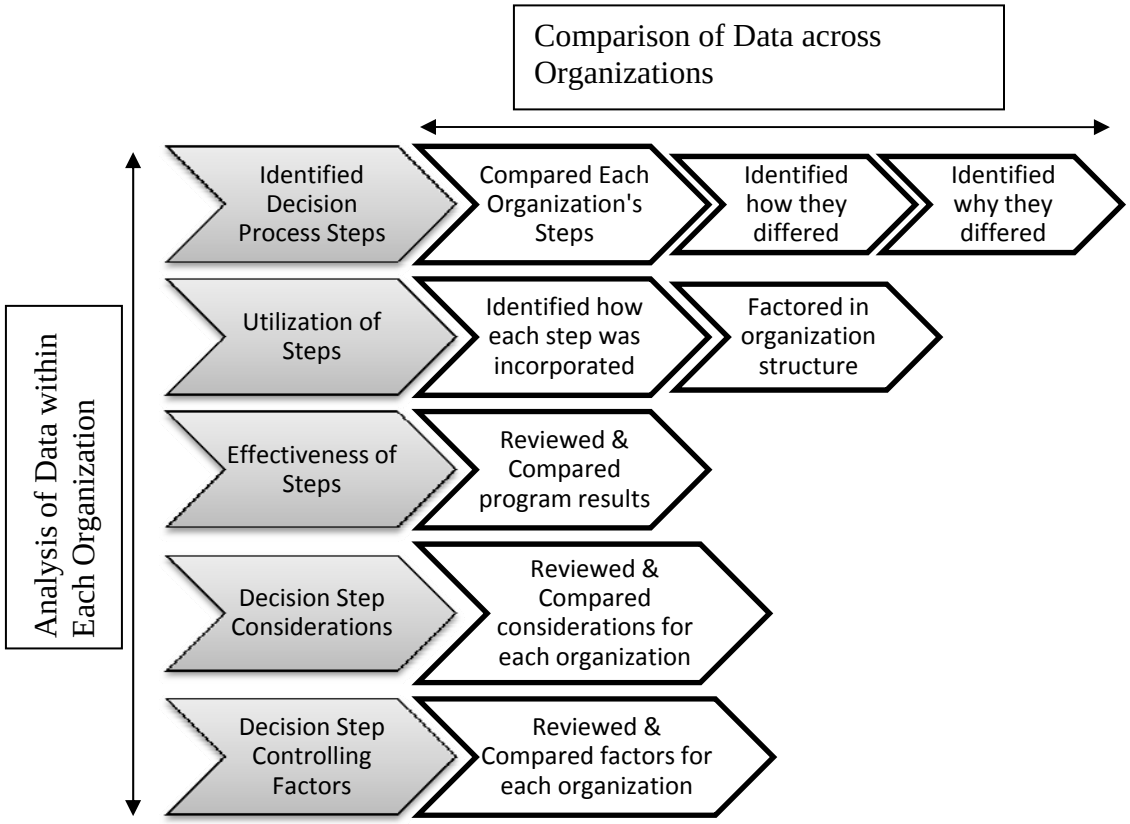

Figure 17 Evaluation of Categorized Information

The decision process for each organization was compared with each other and with the reviewed literature. Figure 17 describes the evaluation of the categorized information. The evaluation compared steps, how the steps differed from one entity to the next, and also considered reasons for why the steps did not match. The incorporation of each step for the organizations was identified and compared. The comparisons took into account the different organizational structure and goals. The evaluation also reviewed the effectiveness of each step by reviewing and comparing results. The considerations and controlling factors were also evaluated through review and comparison techniques.

CHAPTER 4 CASE STUDIES OF ORGANIZATION DECISION PROCESSES

4.1 Organization 1

4.1.1Organization Description

The organization owns, operates, and maintains at least 65 buildings in Albuquerque, New Mexico. The buildings vary considerably in type and in age, with the oldest building originally built in 1916 and the newest within the last year. The building types consist of general use, apartment style, lab and partial lab. The organization has a facilities department that provides services such as engineering, energy, environmental, finance, maintenance, planning and utilities. They are also responsible for the upkeep of all the buildings and maintain the district energy system. The district energy system supplies electricity, steam, chilled water and domestic water.

The engineering and energy division provides project management for utility projects. They develop and monitor the engineering design standards for all construction projects. Additionally they plan and review capital projects where the scope includes HVAC, and electrical retrofits. The existing building performance optimization and conservation of energy are a priority. They strive to obtain and maintain energy savings to provide a comfortable environment and also to cut utility costs.

The Physical Plant Department provides upkeep to the multiple buildings. The department is made up of an office for accounting, administrative, maintenance, custodial services, automotive center, engineering and energy division, environmental service division, finance and services division, grounds and landscaping, and various other groups. The engineering and energy division is comprised of an Associate Director, a manager, facilities engineers, energy services manager, operations specialist and an administration assistant. This division performs analysis and assessments of energy conservation measures and presents them in report form to the Physical Plant Director or a senior manager for approval. The only exception to this approval structure is when there are department sponsored grants that specify where the funds must be allocated.

Energy efficiency is a priority for this organization. There are various planned and potential energy retrofits that are driven by the equipment feasibility, a need, capital

cost, payback period, and maintenance and operations costs. The driving factors guide them to eventually achieving their commitment to accomplishing a 25% reduction in energy by the year 2030. The organization must also follow state regulations to reduce energy 20% by the year 2015. Eventually they would like to be carbon neutral but lack appropriate funding. Carbon neutral potentially could be achieved by implementing measures that would improve system efficiency by 20%, improve the envelope effectiveness by 30%, and utilize clean energy to accomplish the final 50%.

4.1.2 Description of Decision Steps

The organization performs a detailed decision process to determine the feasibility of an energy retrofit. The facilities department strives to identify problems and opportunities that if implemented could improve energy conservation. The decision steps employed are 1) building energy data, 2) ECM analysis, 3) Assessment, 4) Design and 5) Approval. Figure 18 shows the steps used by Organization 1.

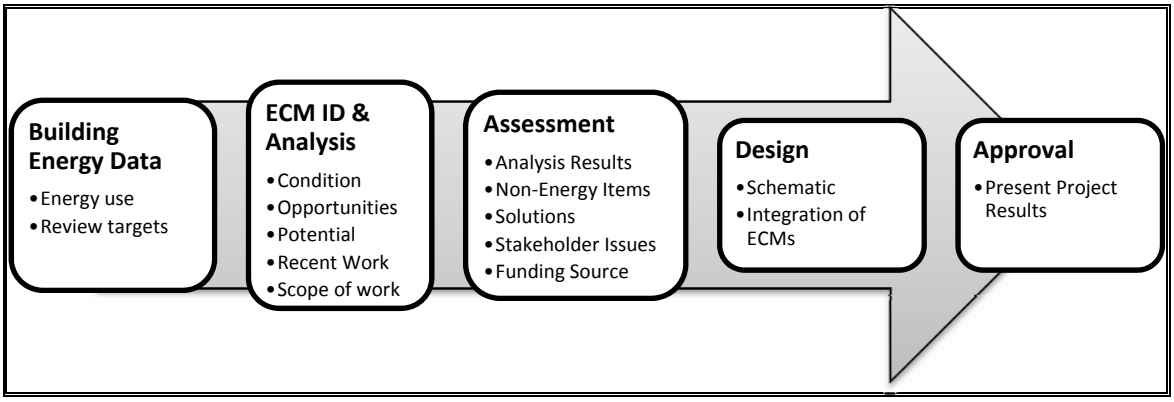

Figure 18 Organization 1 Decision Process

The decision process described above helps Organization 1 meet energy conservation goals. Their main objective is to implement energy conservation measures that cut costs and also provide better control of space. The control of space is accomplished through the implementation of Direct Digital Controls (DDC) with alarms, full and continuous commissioning, and proactive maintenance.

4.1.2.1 Building Energy Data

The Engineering and Energy Division maintains a log of the total energy use of all their buildings. The total energy use of the buildings is described by the Energy Use Index (EUI) that is expressed in thousand Btu per square foot. The EUI benchmarking tool provides a means for comparison with the other 65 buildings as well as with the Commercial Building Energy Consumption Survey (CBECS) tables for average and target use. The benchmark can be considered an indication of the energy retrofit potential. This means that the building with the lower EUI designation could have a lower potential for a cost effective improvement. However the benchmark is not necessarily used to plan or prioritize energy retrofit projects. This conclusion was developed based on discussion and observation of a provided list of potential retrofits that had three projects proposed in buildings with EUI below the campus average and four retrofits above the average.

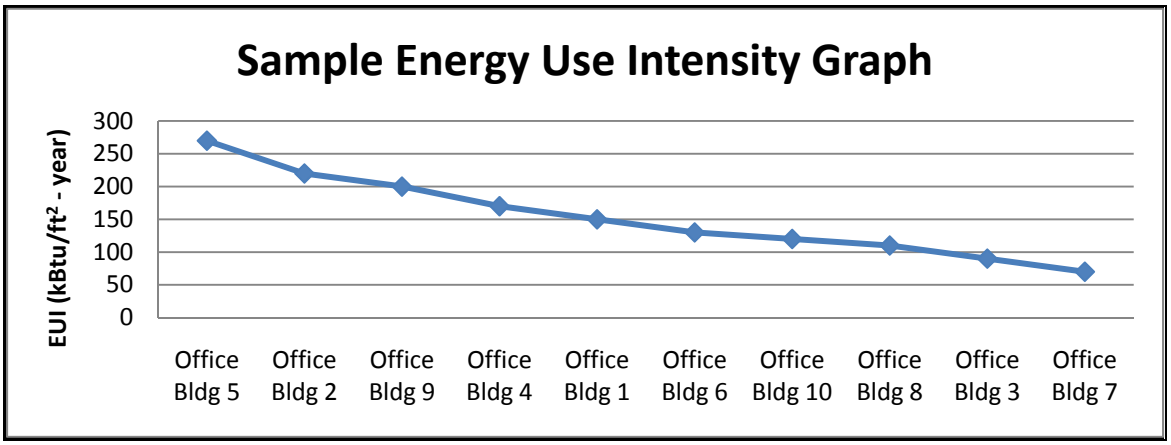

Figure 19 Sample Benchmarking Tool based on data from Organization 1

Organization 1 maintains a log of each building energy use and is able to display the EUI on an intensity graph similar to the sample in Figure 19. The Energy Use Intensity Graph is a quick tool for comparing the energy use of the 65 buildings. It is a good way to set targets and also a resource to confirm that targets are being met.

4.1.2.2 Energy Conservation Measure Identification & Analysis

Organization 1 uses the ECM Analysis to help determine the scope of work. This process is commonly performed by an outside consultant. The consultant's goal is to identify opportunities based on the energy savings potential. The analysis begins with review of the benchmark data, and then establishes gross estimates of work. The estimates of work are based on an inventory of energy items and also non-energy items that would have to be upgraded as well. The key indicators for identifying the potential deficiencies are age of equipment, status of equipment, type of equipment, energy engineer report, energy audit, energy usage, and user comfort level. Identifying the deficiencies can also be as simple as conducting a walk through and review of plans and specifications. The major component of the walk through is the discussions with the occupants concerning their use and comfort level.

Organization 1 does not require or perform an energy model or simulation at this stage to identify deficiencies. The consultant report, energy audit, simple walk through, and the review of energy use are sufficient to develop a scope of work, estimate of cost, a basic work schedule, and the potential energy and cost savings. Organization 1 warns that they must coordinate with the user and other decision makers to check on what recent work has been done or any work planned for the future. This helps to determine the type of retrofit needed and the timing of the retrofit. It also defines the financially viable scope of work.

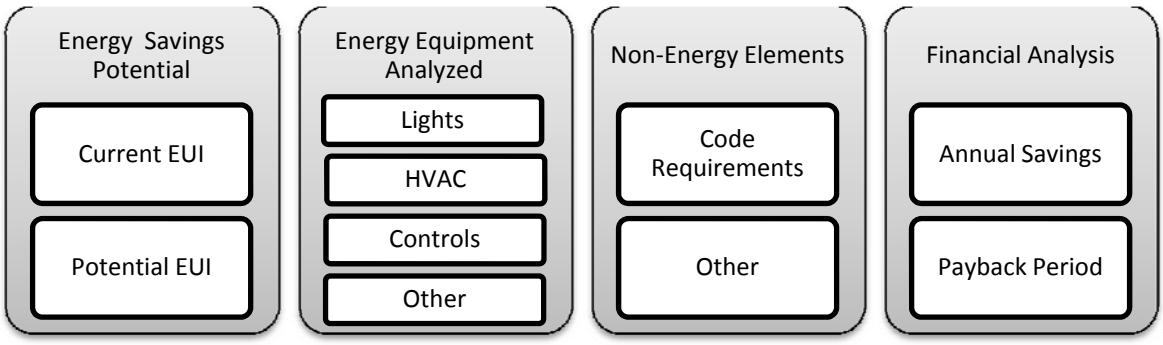

Figure 20 Organization 1 Basic Analysis Information Produced

The analysis deliverables include an estimate of energy savings, the new energy equipment to be installed, non-energy elements to consider, and the calculation of the financial considerations (see Figure 20). The financial analysis for Organization 1 focuses on the annual savings and the payback period.

4.1.2.3 Condition and Use Assessment

The building assessment includes reviewing the documents produced in the analysis stage and a further review of the current conditions of the building. It also brings all the stakeholders together to determine the viability of the energy efficient retrofit project. The stakeholders include the occupants and administrators involved in any decisions for the 65 buildings. The most important aspect of this step is the review of the financial analysis to determine how to pay for the improvements. The financial investigation calculated in the analysis stage produced an upfront capital cost, annual savings and payback period estimates. These elements must fall into a particular funding stream and also be approved by upper management before the project can go through procurement. The funding sources for Organization 1 are capital budget and grants. The capital budget is difficult to utilize due to the many different areas of improvement requests. The capital budget is a limited resource for funding energy retrofits since many non-energy projects compete for funding. Grants are also a difficult funding source because they can be tied to one particular building. The particular building targeted may not be a priority energy retrofit project as other buildings may have a higher calculated EUI.

4.1.2.4 Design

The design stage includes a schematic interpretation of the ECMs. The intent is to create a design to quantify, and specify the proposed ECMs in-order to develop an installation estimate.

4.1.2.5 Approval

The approval process is a simple but critical step in the decision process. The analysis and assessment results are combined in a short report that is presented to the Physical Plant Director or a senior manager for approval. The director and senior managers review the ECM proposal reports to confirm findings. The evaluation includes the confirmation of available funds, extent of installation time, and the effect on occupants during construction.

4.2 Organization 2

4.2.1 Organization Description

Organization 2 has two entities involved in the decision process of reviewing possible energy retrofits to existing buildings: The Facilitates Department and the Energy Council. The Facilities Department consists of an energy specialist and a facility manager. The Energy Council incorporates nine members with different areas of energy expertise. The Energy Council acts within the direction of the Facilities Department to provide appropriate evaluation and feedback on potential projects. Their overall intent is to effectively reduce energy consumption in existing buildings.

4.2.2 Description of Decision Steps

Organization 2 follows a series of decision steps to determine the feasibility and prioritization of energy retrofit projects. The first step in the process is the identification of the project and the ECMs. The next steps are to analyze and assess the potential ECMs. The final step prior to implementation is the approval process. The organizations steps are defined in Figure 21.

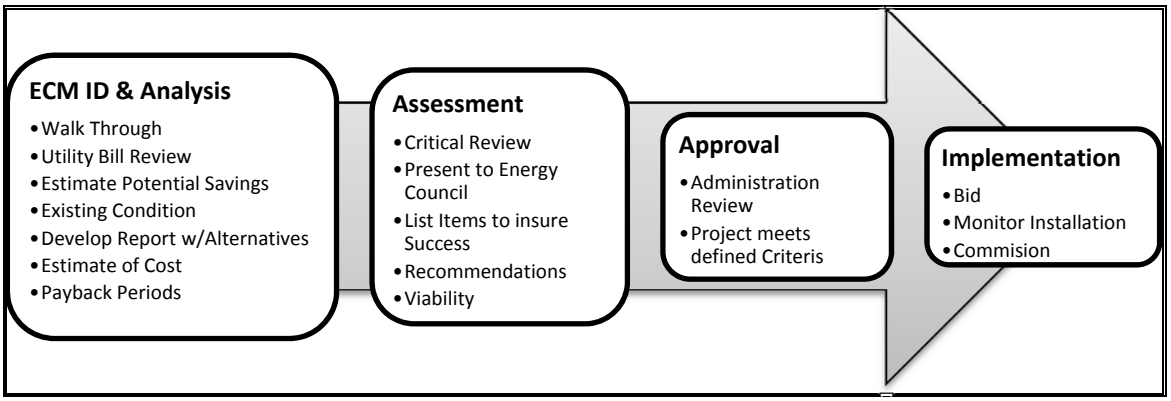

Figure 21 Organization 2 Decision Process

4.2.2.1 ECM Identification & Analysis

The Energy Specialist helps building managers initiate the energy retrofit process. This entails the identification of ECM through energy audits and reports administered by the Facilities Department Energy Specialist. The Energy Specialist begins the process with an initial walk through energy audit of the building. This incorporates feedback from the manager of occupant use and comfort. Additionally the Energy Specialist reviews the utility bills to determine an estimate of the energy savings potential. He then investigates possible alternatives that incorporate new technologies to estimate the energy and cost savings.

The analysis step includes the development of the energy retrofit reports. The Energy Specialist coordinates the energy audit with potential upgrade elements. The report begins with a description of the project and then illustrates the proposed alternatives. The breakdown of alternatives includes a list of existing and proposed energy use, energy costs, and the potential energy savings. The analysis takes into account the life span of the new equipment options, the potential maintenance cost, disposal cost, and the estimated simple payback.

4.2.2.2 Assessment

Organization 2 employs the Facilitates Department and the Energy Council, for the assessment step. The assessment is basically a critical review of the energy reports

produced by the Energy Specialist. The critical review lists items that will insure success for the implementation of the project and additionally provides recommendations to implement into the project. The organization is reviewing numerous projects at one time, which means the assessment must also prioritize the projects. The funding stream does not seem to have a large impact on the assessment step. The funds come in the form of grants specific to existing building energy retrofits. They do however have to meet specific criteria such as it must realize full payback within the life span of the proposed equipment installed. Even though they state this is a rule of thumb they reiterate that they prefer paybacks that are less than five years.

4.2.2.3 Approval and Implementation

The approval stage involves administrative review to make sure the project meets the predetermined criteria. Additionally the review covers the analysis and assessment utilized in the decision process to confirm that all issues and criteria were considered. Once the project has been confirmed by the administration the facilities group takes control and begins the process to bid, award bids, monitor installation and commission the ECMs.

4.3 Organization 3

4.3.1 Organization Description

Organization 3 currently owns and operates 52 buildings. The organization plans to introduce energy efficiency projects. Many of the buildings are outdated and the potential cost benefits, the reduction in greenhouse gas emissions, and energy efficient buildings require smaller, less expensive renewable energy systems. The decisions are made by an Energy Team that is lead by an Energy Specialist. The Energy Specialist coordinates the energy retrofit projects with the Capital Improvements and building maintenance staff to implement energy efficiency into the buildings.

4.3.2 Description of Decision Steps

Organization 3 is attempting to reduce greenhouse gas emissions through the utilization of efficient operations techniques, performing renovations to buildings using green building techniques, and have an existing building be audited for energy consumption with recommendations for improving the energy performance. The process includes the identification of ECMs, the assessment of financial situation and carbon emissions issues, the planning and design, and finally the approval and bid step as described in Figure 22.

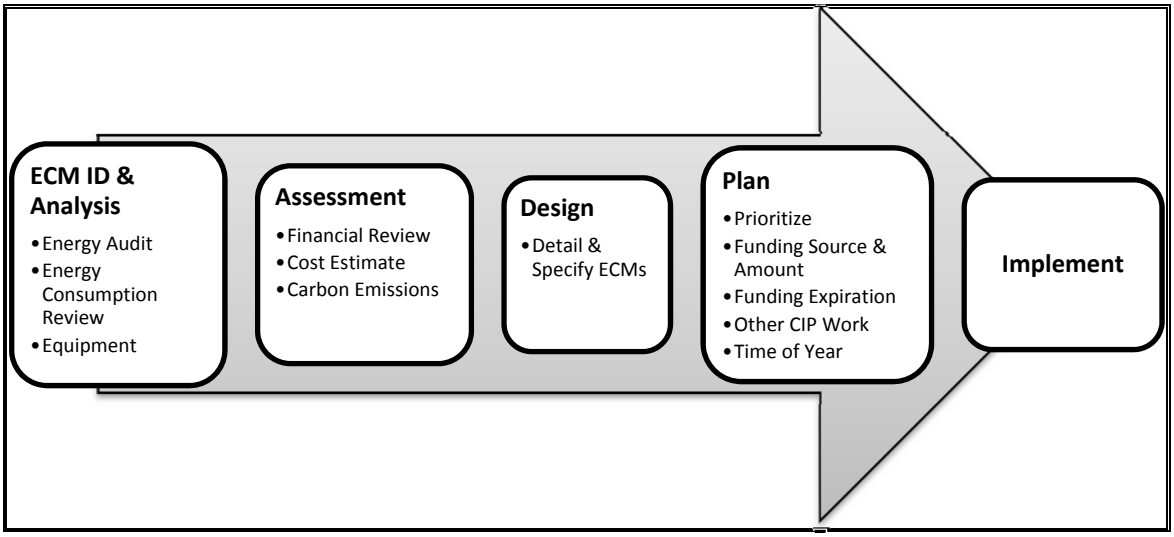

Figure 22 Organization 3 Decision Process

4.3.2.1 ECM Identification & Analysis

The current Energy Department recently decided to perform energy audits on 12 buildings. The audits identified 62 recommendations for ECMs. The ECMs include retrofits to the lighting, heating, cooling, domestic hot water systems, and the building envelope. The energy audits reviewed the energy use of the building, energy use of specific equipment, and estimates of cost to implement. The reports also include a financial analysis that will be reviewed by the organization to determine the best ECMs to retrofit. The organization notes that this step is considered the most critical because it identifies deficiencies and the potential upgrades. This step must be accurate so that proper savings are actually achieved.

4.3.2.2 Assessment

The assessment includes review of the energy audit reports produced by the Energy Specialist. The review focuses on the financial elements as well as the amount of carbon emissions reduction. The financial analysis consists of review of the life span of the new equipment, the payback period and the life cycle cost analysis. The payback period is the most important element of the assessment process. The organization prefers a payback period under seven years.

4.3.2.3 Design & Plan

Organization 3 plans and designs the energy retrofit projects to aid in the accurate determination of the costs and the schedule for construction. Once the cost and schedule restrictions are established the projects can be planned and the ECMs prioritized. The prioritization is based on funding sources, amount, restrictions, and expirations. Additionally prioritizing energy conservation projects must be done in conjunction with other non-energy capital improvement projects, and with considerations for the time of year for construction.

4.3.2.4 Implement

The implementation stage involves the request for proposals and bids. The project is then awarded and construction commences. The organization is involved in monitoring the construction and installation activities. The monitoring includes reviewing construction change orders, and also reviewing schedule and budget status. Once the construction and installation is complete the organization tests the ECMs. This process is known as the ECM commission process and could require a third party consultant. The third party is required if the organizations feels that the system is too complicated for their expertise of the system. The organization considers the commissioning process a critical step for insuring the ECMs are incorporated correctly.

4.4 Organization 4

4.4.1 Organization Description

Organization 4 is actively trying to improve the energy conservation of their school buildings. The energy conservation improvements are considered and implemented by two departments within the organization. The two groups are the HVAC Department and the Energy Conservation Department. The goal of the Heating Ventilation and Air Conditioning (HVAC) Department is to implement energy efficient systems to replace old and dilapidated systems. The Energy Conservation Department includes an Energy Coordinator who assesses and recommends potential ECMs. The assessment includes the evaluation of energy bills, occupant behavior, and the current lighting system. Occupant behavior is addressed through the implementation of behavior modification techniques. The lighting system is corrected through lighting retrofits.

4.4.2 Description of Decision Steps

The two departments, HVAC and Energy Conservation, have separate means for achieving energy savings. HVAC Department tackles issues with the heating, cooling and ventilating systems. The Energy Conservation Department tackles lighting improvements and occupant education to tackle energy demand. Their work is done separately but they communicate openly and collaborate when needed. The decision process for the HVAC Program includes building energy data, identification and analysis of ECMs, assessment of the ECMs, design, approval and implementation. The described process is shown in Figure 23.

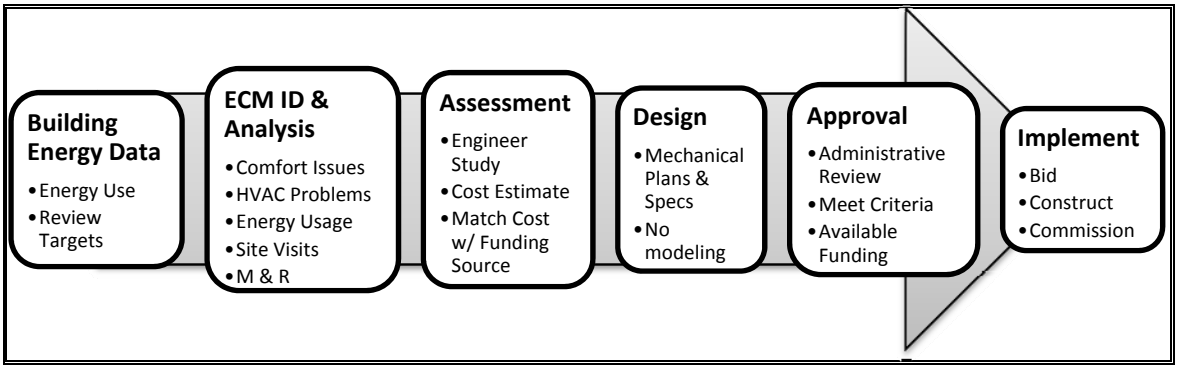

Figure 23 Organization 4 Decision Process for the HVAC Program

The Energy Conservation Program decision process incorporates building energy data, the identification and analysis of ECMs, assessment of the ECMs, planning, and then the implementation. The described process is shown graphically in Figure 24.

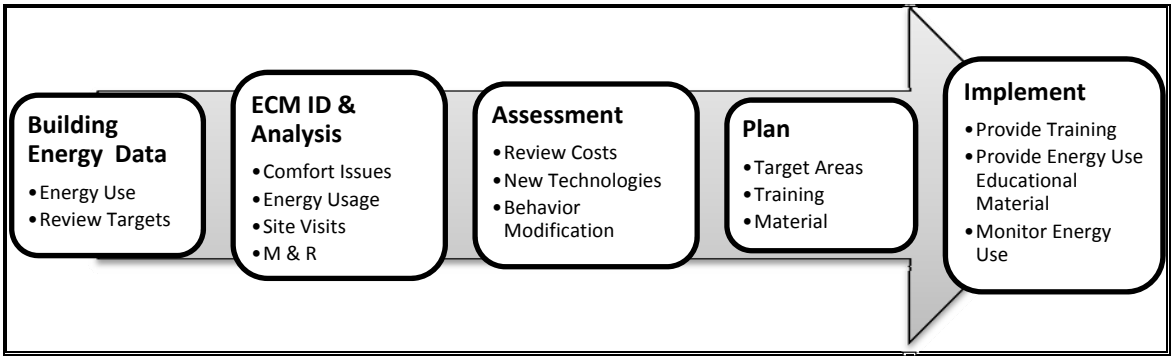

Figure 24 Decision Process Energy Conservation Program

4.4.2.1 Building Energy Data

The building energy building energy data is performed by both the Energy Conservation and HVAC Department. The energy consumption of the buildings is collected and monitored. The majority of the collection and monitoring is performed by the Energy Conservation Program. The Energy Conservation Department utilizes the information to identify targets and confirm results.

The HVAC Department uses the benchmark data primarily to review results. The energy data is used to compare with the established base to confirm energy savings after ECMs have been implemented. The organization feels it is important to understand consumption to aid in the decision process. Although they do not directly base decisions on energy use it is important to have an overall view.

Table 3 Energy Utilization Index (EUI) Information based on Organization 4 data

	Square Feet	Electric Usage (kWh/sf-yr)	Electric Usage (Btu/sf-yr)	Natural Gas Usage (Btu/sf-yr)	Total Usage (Btu/sf-yr)
Totals of Bldg Type 1	3,882,903	6.94	23,675	42,072	65,747
Totals of Bldg Type 2	3,240,026	5.42	18,485	46,499	64,984
Totals of Bldg Type 3	4,879,724	5.45	18,615	48,637	67,252
Total or Average	12,002,653	5.92	20,217	45,936	66,153

The implementation of ECMs is not driven by the energy data, instead the analysis, assessment and design of an ECM usually attempts to meet the priority need of improving user comfort. The integration of ECMs into this organization's buildings through the HVAC Department is driven by the experience and environmental motivation of the engineer in charge. The department's goals are to maintain user comfort and secondly provide energy efficient alternatives. This implies that decisions are not being driven or made based on the consumption data. The data are merely reference material and background information for application when designs for user comfort are being made.

4.4.2.2 ECM Identification & Analysis

The two departments use the same techniques to determine the ECMs. The ECMs are determined through a review of comfort level, energy usage, energy problems, energy bills, and the extent of operations and maintenance. The organization values the importance of talking with the occupants to make sure their needs are meet while integrating energy efficiency projects. The Energy Conservation Department focuses its attention to the occupant's behavior in utilization of energy elements. Such things as thermostat and lighting management are monitored to discover possible alternatives to save energy. The maintenance and repair activities are analyzed to see if modification can be made to save time, money, and energy. The HVAC Department performs an analysis of the condition of the existing systems such as air flow, ability to cool and heat, controls, and overall functionality.

4.4.2.3 Assessment

Following the analysis the HVAC Department reviews the findings. The findings are documented in the form of an engineer's study in which the engineer in charge reviews the analysis to establish a scope of work and an accurate estimate of cost. The projects that include ECMs should have a payback period of less than ten years to be viable in this program. The cost estimate is used in the overall budgeting exercise that

includes the consideration of multiple projects. The projects are listed with cost and description and prioritized according to need with consideration for available funding.

The Energy Conservation Department reviews the identified areas of improvement in the assessment process. The assessment includes the understanding of cost and potential cost savings. The Energy Coordinator reviews all construction plans to discover energy deficiencies such as lights near windows or skylights. Additionally the coordinator is constantly monitoring energy use and seeking ways to modify behavior use to reduce energy consumption. This involves working with the occupants on a daily basis to check progress and provide suggestions or recommendations.

4.4.2.4 Design or Plan

The design stage for the HVAC Department is straight forward. The organization hires an outside engineer to create the design documents. The engineer utilizes the analysis and assessment to create the appropriate system that meets personnel comfort and energy efficiency standards. The design requires the creation of drawings and specifications that meet the needs of the organization. The organization and the designer work together during the design process to make sure the need is met.

The planning stage for the Energy Conservation Program involves reviewing the target areas, establishing training workshops or talks, and providing necessary materials to the occupants. The training and materials are focused on the behavior modification techniques to save energy in a low or no cost manner. The organization stresses the importance of the social interactions to get the occupant's "buy in" of the modification techniques. The occupants treat the work space differently than home. They do not pay the bills and also lack a sense of ownership. The Energy Conservation Program attempts to enforce the social and environmental responsibilities of energy conservation, as well as the cost savings the organization can attain.

4.4.2.5 Approval & Implementation

The HVAC Department requires an administrative review for approval for all HVAC construction projects. The administration reviews the projects to make sure

criteria for comfort level are met and that the budget matches a particular funding source. The approval has influence on the type of systems implemented based on preference or a perceived idea of how the system operates and uses energy. The interview process revealed that opinions varied on the most appropriate systems. Following approval the program puts the project out to bid, monitors the construction process, and insures that the equipment is properly commissioned and meeting the needs of the occupants.

The Energy Conservation Department does not have a defined approval process. The approval of ECMs seems to rely on the Energy Coordinator primarily due to the fact that minimal funds are invested into the program and the extent of expertise of the Energy Coordinator. The implementation includes training, workshops, and education material. The energy manager institutes a program to alter the energy consumption through occupant behavior modification. The implementation also includes monitoring and verification of energy reduction results.

4.5 Organization 5

4.5.1 Organization Description

Organization 5 operates and maintains approximately 31 buildings. The Purchasing and General Service Department within the organization oversees new and retrofit construction projects. The construction projects follow specific guidelines for review, selection, design, and construction. The Chief Operations Officer and staff of the General Service Department coordinate the implementation of retrofit projects.

4.5.2 Description of Decision Steps

The organization has made some attempt to reduce energy consumption through lighting retrofits. The lighting upgrades have included the replacement of energy systems with more efficient ballasts and lamps. Additionally, eighteen buildings have been assessed for renovation upgrades. Description of the tasks and rationale presented to the administrators for approval include items such as renovation to restrooms, cafeteria, classroom and other areas. The description of tasks for one of the building upgrades includes the installation of a new mechanical system, but the other renovations do not

mention ECMs. The ECMs may be built into the design but there is no clear indication of ECM consideration presented by the organization. They do, however, have a separate energy package that allocates $4.5 million to lighting and HVAC system upgrades for four buildings. It is unclear how the four buildings were chosen for the HVAC upgrades, but from discussion it is most likely based completely on age of equipment.

They do not have an established means for monitoring, measuring and verifying energy consumption decreases or increases in their buildings. There is no defined decision process for ECM projects at this organization. Their decisions are based on a specific need and available funding. There is no indication that a financial analysis such as payback period, or life cycle cost analysis is utilized for energy improvements. They realize there is an importance but have not implemented a specific process for reviewing, comparing, analyzing, and assessing the energy conservation potential.

4.6 Organization 6

4.6.1 Organization Description

Organization 6 represents building owners who rely on outside contracted professionals for conducting the decision process steps and making necessary ECM recommendations. Designers are responsible for educating owners on energy and cost savings potential. Many owners are not knowledgeable about energy conservation and the proper implementation of an energy retrofit. Owners are more likely to make a commitment to ECMs if they have a competent professional who can guide them through the process.

This organization provides project programming, master planning, site evaluation and assessment, building design, construction documentation, energy modeling and LEED and sustainability consulting. The services provided have the ability to outline a decision process for an owner who lacks energy efficiency knowledge.

4.6.2 Description of Decision Steps

Organization 6 has a process for evaluating existing building retrofits for energy efficiency. Although there are varying constraints to the process depending on the building type and owner needs, there are defined elements to the progression that do not change. This organization provides an existing building assessment, design of energy and non-energy conservation elements, and lays out a procurement procedure to insure that ECMs are properly identified, considered and implemented. This process is shown in Figure 25.

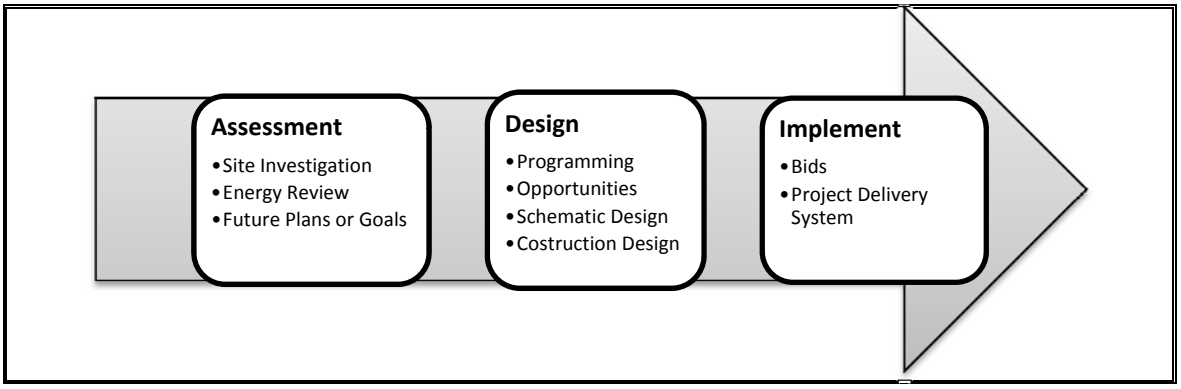

Figure 25 Organization 6 Decision Process

4.6.2.1 Assessment

The assessment begins with the evaluation of site attributes and constraints. This includes review of all current energy elements and potential energy contributors. The organization stresses the importance of realizing the factors that influence the building's energy usage. They look at items such as use patterns, weather, exposure, and many others. Additionally the organization evaluates the utility bills. They establish the Billing Performance Baseline that correlates the energy use with the occupant usage. The next item in the assessment stage is to gain an understanding of the long term plans and goals of the owner. It is important to incorporate possible use changes, or other capital projects that potentially could change the use patterns or building layout. The last element of the assessment is to highlight the goals of the owner. It is imperative that budget and environmental savings be established early. Understanding of these two items helps develop alternatives and evaluation criteria for the design.

4.6.2.2 Design

The design stage includes the review of opportunities, incorporation of programming, and finally to schematic and construction design. The development of the project program involves communication with the owner and evaluation of the current building to create an outline of the ECMs. Then there is a review of the potential energy efficient retrofit opportunities. The review includes identification of current building advantages and disadvantages in relation to energy efficiency. The design intent is to enhance the current advantages while attempting to remediate the disadvantages. The ECM opportunity review is then incorporated into the program established at the beginning of the design phase. Once this integration is complete the actual development of schematic design can commence.

4.6.2.3 Implement

The procurement process is actually a critical element to include in the decision process. It can be overlooked because most of the decisions have already been made and the construction drawings have been put out to bid. Yet putting the specifications and drawings out to bid does not insure that the developed ECMs will be incorporated. Many contractors can find ways to submit alternatives to the design that are cheaper. These alternatives can ultimately negatively affect the performance of the new ECMs. Owners must be aware of this and develop an appropriate project delivery system to avoid late changes to the design.

4.7 Organization 7

4.7.1 Organization Description

Organization 7 operates and maintains numerous warehouses, laboratories, and office buildings. The evaluation of the energy consumption of the buildings is conducted by an Energy Manager within the Facilities Department. The energy manager evaluates the building's energy consumption to determine if proposed ECMs can be implemented as an operation expense or capital project.

4.7.2 Description of Decision Steps

The decision process used by Organization 7 includes the identification of ECMs, analysis of the ECMs, assessment, bid of project improvements, and a final approval stage. This process is shown in Figure 26.

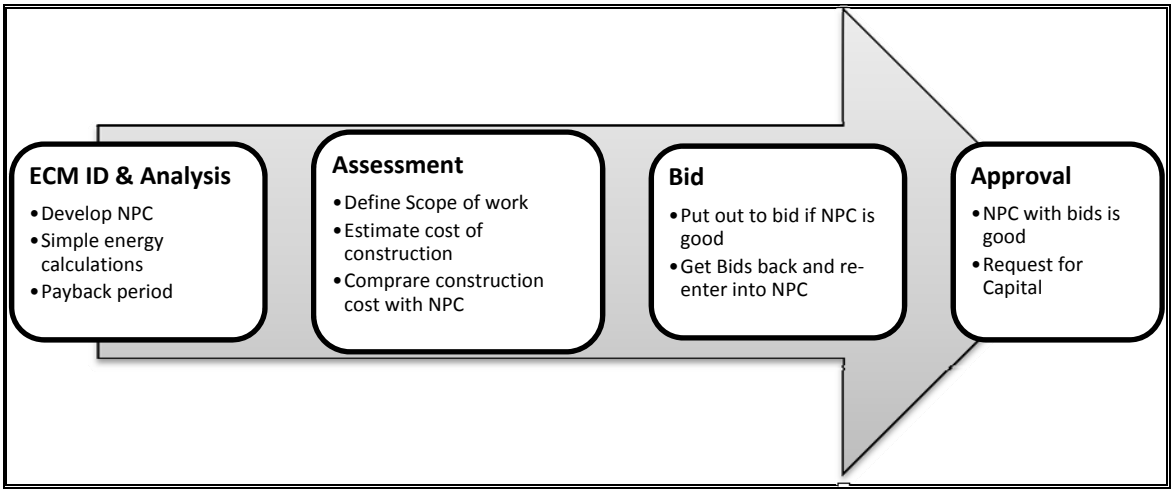

Figure 26 Organization 7 Decision Process

4.7.2.1 ECM Identification & Analysis

The identification of ECM opportunities begins with locating easy, short payback items. This is done by using a simple payback analysis. The simple payback uses an estimate of cost to install the ECMs and then divides by the estimated annual cost savings to discover the number of years it will take to recover the investment. The cost savings is usually driven by the amount of energy saved immediately. These scenarios are based on low simple payback and do not have to go through further analysis. The payback periods for these kinds of projects are usually 1 year or less. Elaborate financial analysis is not required because savings are realized very quickly.

This organization performs simple energy calculations and review of energy consumption to understand the building energy potential. Simulation or modeling software is not used to analyze their office buildings. The typical modeling programs and techniques are difficult to use to analyze the equipment and support systems within the warehouse. The organization uses the Supervisory Computer Aided Data Acquisition (SCADA) system. This system is able to evaluate the equipment and processes that go

on in the warehouse to produce accurate energy use numbers. SCADA system can also identify changes in the equipment use that affect the overall energy use.

The calculations and evaluation of potential ECMs are made and are followed by a financial analysis. The more extensive ECMs with longer paybacks are evaluated using the Net Positive Cash (NPC) flow method. The NPC is calculated using the project first cost, depreciation, and energy savings costs.

4.7.2.2 Assessment

The assessment process is an important step to provide guidance for developing the scope of work and the estimate of cost. The energy manager develops a scope of what needs to be done to implement the ECMs. The project is then handed over to a Construction Group that develops a detailed cost estimate. The detailed estimate is then factored back into the NPC calculations to verify that the value becomes positive before the end of the fifth year. If the NPC is still attractive then the design is developed and set out for construction bids.

4.7.2.3 Bid & Approval

The bid process solicits cost proposals from various contractors to implement the ECM construction. This process includes a review to insure that the contractors understand the scope of work and then the costs are compared. Then the desirable bid is inserted into the NPC for a recalculation. The new calculation with the construction bid is then assessed to determine if it is still viable. If the NPC has a positive cash flow on or before the fifth year then the project is deemed feasible. At this point the project is qualified to request capital funds. The submittal is made to administrators who oversee the distribution of capital investments.

4.8 Organization 8

4.8.1 Organization Description

Organization 8 is one of the largest private owners of commercial real estate in New Mexico and the United States. Nationally they own over 200 properties that include

office, industrial, retail and multi-family residential. The total properties combine for a total worth of more than $2 billion. The organization manages their properties to gain profits for their over 4,000 domestic and international investors. This organization recognizes the need to have energy efficient buildings but currently finds it hard to justify the retrofit costs of their existing buildings. The justification lies in the various types of lease agreements and who is paying for the utilities. In many of the buildings, the tenants pay for the utilities so the owner has no way of realizing the benefits for an energy retrofit. Additionally it is difficult for owners to quantify the value of the building after the retrofit.

4.8.2 Description of Decision Steps

Organization 8 does employ a decision process for reviewing the potential for energy efficient retrofit projects. The process is described in Figure 27. The process begins with a building status review that is triggered by an event or need. The next step is the identification of ECMs, followed by an assessment. The approval process is based on the findings from the assessment process to make sure tenants are maintained and also that cash flow to investors secured.

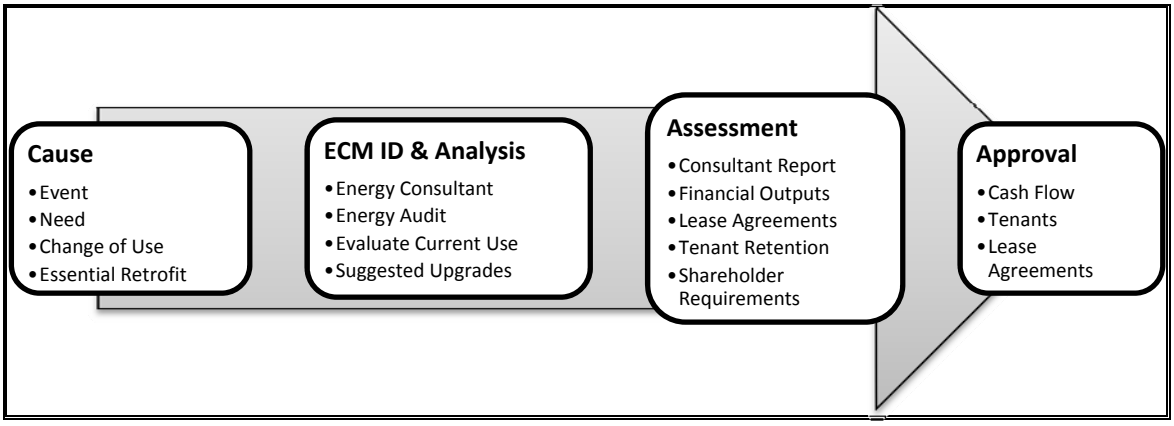

Figure 27 Organization 8 Decision Process

4.8.2.1 Cause

The first step in the decision process for Organization 8 is the identification of an event or need. Currently the mindset is that energy retrofits are not feasible and the only way ECMs are to be implemented is if triggered by a need, change in use or a necessary

upgrade. The identification of a need promotes the next step, which is the identification of potential ECMs.

4.8.2.2 ECM Identification & Analysis

Organization 8 does not have any in-house engineers or maintenance departments. The identification of ECMs requires them to hire an energy consultant to produce an energy report for their review. The consultant performs an energy audit, reviews current energy use, identifies the current energy inventory, and provides suggestions for ECM implementation. The implementation proposal includes a gross estimate of installation cost and also a financial analysis that describes the payback and the aggregate return on investment.

4.8.2.3 Assessment

The assessment stage involves the review of the energy consultant report. The financial numbers are the most important elements for Organization 8 to assess. The funding stream for an energy retrofit would either come from the building income or from the organization cash flow. The net income of the building is comprised of the building revenue, operating expense and non-operating expense costs. The assessment criterion for this organization prefers a payback period of less than five years for project consideration. This organization also notes that cash flow is a huge consideration in the financial analysis. Their priority and responsibility is to maintain the profit cash flow for their investors and in these scenario paybacks is not as important of a driver as it is with other organizations.

The barriers for implementation of an energy retrofit are tenant lease agreements, and shareholder cash flows. The standard lease agreements require that the tenant pay the utility bills. This simple requirement does not allow the building owner to receive the financial benefits of the retrofit. Additionally cash flows for the shareholders must be maintained for a successful business relation and retention. Organization 8 feels it must continue the current approach to operations that ensures the shareholders are content with their management and profits.

4.8.2.4 Approval

When considering an energy retrofit the approval process for Organization 8 requires that the cash flows are maintained and that tenants remain in the building. Organization 8 realizes this can be difficult. Cash flows are maintained by tenant retention and tenants are retained through the aid of building upgrades and investments. The case of energy efficiency tenant lease agreements may need to be analyzed and altered to increase the probability of an energy retrofit approval. The organization feels that energy retrofits are not feasible in the tight economy, where shareholder money and support is imperative.

4. 9 Organization 9

4.9.1 Organization Description

Organization 9 is a State of New Mexico Department that supports school building construction and retrofits across the state. The organization does not have a structured approach to perform building retrofits specifically for energy efficiency. The department funds multiple building upgrade projects each year with the main intent to improve the structural integrity or aesthetic appearance of the buildings. Individual school systems submit applications for funding to the department where a priority list is developed. The department does recommend energy savings equipment and techniques when providing funding but ultimately the decision is left up to the discretion of the individual school districts.

The department has developed a behavior modification plan to help school districts develop a program to reduce their energy consumption. The description is relayed to school districts through a pamphlet and a 26 minute DVD. The information provides basic understanding of energy consumption and techniques. The exact method for reducing energy consumption must be established by the individual school district.

4.10 Organization 10

4.10.1 Organization Description

Organization 10 operates and maintains a warehouse and office space. They are a privately owned company producing and selling products locally. The owner is extremely environmentally conscious and would like to retrofit buildings to be LEED certified.

4.10.2 Description of Decision Steps

The decision steps for Organization 10 include ECM identification and analysis as well as ECM implementation. The organization would like to implement ECMs with the intent to produce an environmentally responsible building. Their knowledge of the energy retrofit process is very limited and requires outside consultant help. Figure 28 describes the decision process used by Organization 10.

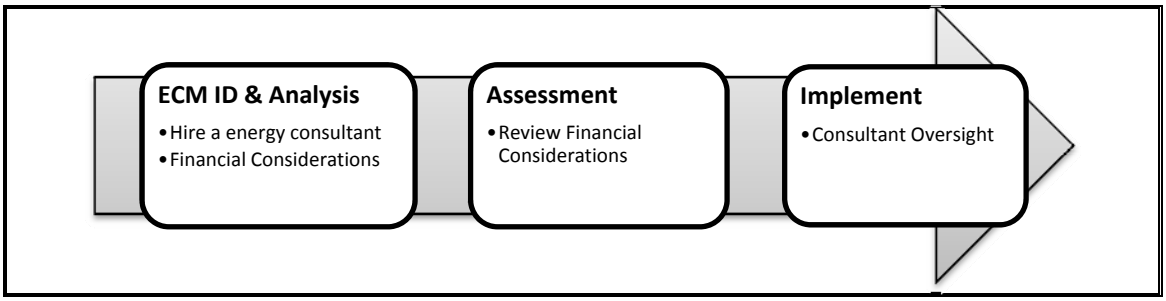

Figure 28 Organization 10 Decision Process

4.10.2.1 ECM Identification & Analysis

The organization hires an outside energy consultant to identify and analyze ECMs for their buildings. The consultant reviews the existing building and produces a draft scope of work for the potential ECMs. The analysis determines the cost of implementation to be used for the financial analysis to describe the payback and benefit potential to the organization.

4.10.2.2 Assessment

An assessment is performed with the aid of the consultant to review the paybacks and the benefit to cost ratio. The organization requires the paybacks for the ECMs to be within four to six years.

4.10.2.2 Implement

The implementations of the ECMs are managed by the consultant to insure proper compliance.

4.11 Organization 11

4.11.1 Organization Description

Organization 11 does not analyze or implement energy efficient retrofit measures to their existing buildings. Many of the facilities have extreme operational and maintenance demands that use considerable amounts of energy. Yet there is no system in place that meters the energy use. The lack of knowledge of the energy use at the building inhibits analysis and determination of retrofit options.

4.12 Organization 12

4.12.1 Organization Description

Organization 12 is a national real estate firm that has experience in construction management and leasing of commercial buildings, such as shopping centers, industrial property, office buildings, and hotels. The organization structure is comprised of an owner and employees. The owner has the ultimate authority and approves all major decisions. The employees organize daily operations, meetings, and relay the intent of the owner. They recently completed a $30 million renovation of an historic hotel. The design and construction of the renovation followed the Leadership in Energy and Environmental Design (LEED) criteria. One of the six LEED rating areas is energy and atmosphere, and the firm incorporated many ECMs to fulfill this category. For example

the hotel will now generate 100% of its guest room hot water using solar energy, and new windows and window coverings have been installed to reduce heat loss during the winter and counter heat gain during the summer. The boilers and chiller plant have been replaced with a more efficient system. The lighting system has been upgraded to incorporate fluorescent and LED lamps. Lastly the organization has instituted a system that provides management controls to the heating/cooling and lighting systems in each of the guestrooms.

4.12.2 Description of Decision Steps

This organization took an ideological approach to their energy retrofit decision process, which is shown in Figure 29. There first step in the process for integrating energy efficiency was stressing their commitment to sustainability. They did not perform a complete analysis of the building's existing condition. They instead established a goal without a complete understanding of the existing energy consumption and its potential. Their goal was simple: create the most energy efficient building that they could.

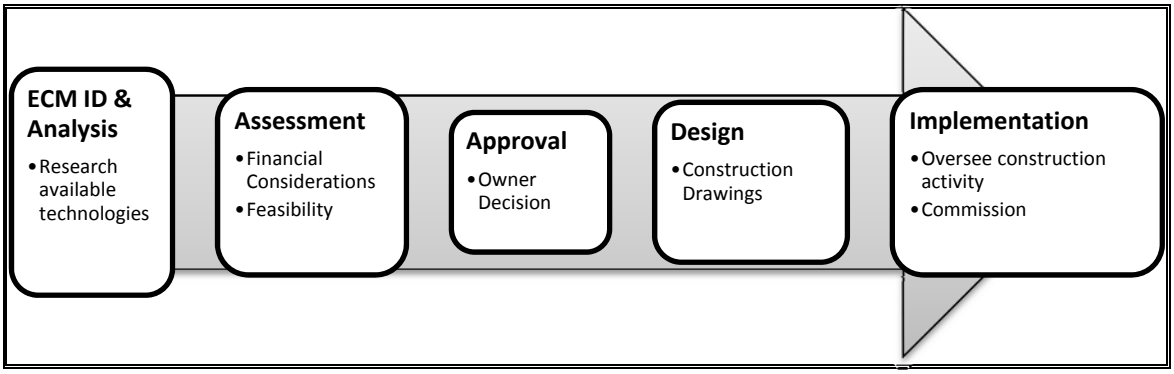

Figure 29 Organization 12 Decision Process

The decision process used included the identification of ECMs, assessment, design, approval and implementation.

4.12.2.1 ECM Identification & Analysis

Their first step after defining their ideological approach was to identify the ECMs. This was conducted by researching the available HVAC, electrical and other systems that

contribute to the energy consumption of the building. This research evaluated the technologies and strategies available that met the buildings needs.

4.12.2.2 Assessment

Once the technologies and strategies were identified a feasibility assessment was conducted. The assessment included considerations of LEED points, energy efficiency, life-span, impacts on the rest of the building systems, and cost. The cost assessment was based on the simple payback and benefit cost analysis.

4.12.2.3 Approval

The approval step is relatively straight forward. The organization does not have a defined review process with documented criteria and assessments, as decisions are ultimately made by the owner of the company. The owner uses his discretion and overall view of organization direction to influence the decisions. Many of the decisions are not cost driven but follow the ideals of the owner.

4.12.2.4 Design

The design stage utilized the services of professional designers. The designers produced construction drawings that included the recommended ECMs determined in the analysis.

4.12.2.5 Implementation

The implementation stage of the process involved the review of construction drawings, monitoring and managing construction progression, and finally commissioning of the systems. The review of the drawing included a cursory review to make sure the plans meet defined scope of work. The code and permitting requirements are left up to the design professional. The organization is involved in construction meetings, construction staging issues, and scheduling decisions. They monitor the construction activity and negotiate any change orders. Following the completion of the installation

and construction activity the organization is actively involved in the commissioning of the new equipment. The commissioning is important to insure that the design and implemented systems and components provide optimal energy efficiency.

4.13 Summary of Case Study Observations

The twelve organizations interviewed each expressed a desire to produce and maintain an energy efficient building. The means for establishing goals, reviewing the existing condition, analyzing the energy systems, assessing the findings, and implementing potential ECMs varied between the organizations. The variation is due to organization structure, expertise of the energy manager, and the financial constraints of the organization. Not all of the organizations utilized a decision process. Figure 30 shows the breakdown of the percentage of organizations that use a defined decision process.

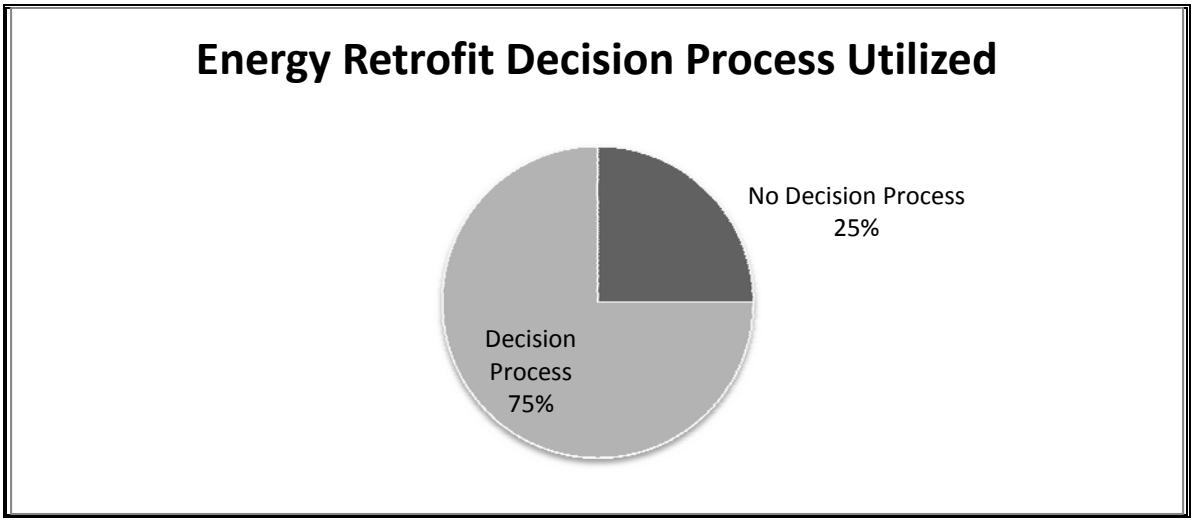

Figure 30 Utilization of a Decision Process - Based on data from 12 Organizations

Three organizations did not integrate a repeatable decision process in their operations. The remaining nine organizations used a clear decision processes but they were not all well documented. An understanding of how each organization made decisions was determined by the interview process.

The decision process of each organization used in implementing ECMS is defined in section 4.1 through 4.12. The summary of each organization's decision steps are

described in Table 4. Note that for comparison purposes the terms used to describe each step for the different organizations are arranged to be consistent. The actions or criteria within the step may be different.

Table 4 Organization Decision Steps for Implementing ECMs

Org.	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
1	Building Energy Data	ECM ID & Analysis	Assessment	Design	Approval	-
2	ECM ID & Analysis	Assessment	Approval	Implement		-
3	ECM ID & Analysis	Assessment	Design	Plan	Implement	-
4	Building Energy Data	ECM ID & Analysis	Assessment	Design or Plan	Approval	Implement
5	No Defined Process – Integrate into non-energy retrofits					
6	Assessment	Design	Implement	-	-	-
7	ECM ID & Analysis	Assessment	Bid	Approval	-	-
8	Cause	ECM ID & Analysis	Assessment	Approval	-	-
9	No Defined Process – Integrate into non-energy retrofits					
10	ECM ID & Analysis	Assessment	Implement	-	-	-
11	No Defined Process – Integrate into non-energy retrofits					
12	ECM ID & Analysis	Assessment	Approval	Design	Implement	-
Most Popular	ECM ID & Analysis	Assessment	Assessment	Design	Approval/ Implement	
Integrated Process	Building Energy Data	ECM ID & Analysis	Assessment	Design & Planning	Approval	

Three organizations lacked a defined decision process. They did however incorporate energy efficiency into their non-energy retrofits. The integration was sporadic and varied depending on the experience level of the decision maker involved. The most popular use and sequencing of steps, as described in Table 4, are as follows: 1) ECM Identification and Analysis, 2) assessment, 3) design, and 4) approval/implementation.

4.14 Development of Integrated Decision Process

The recognition of key steps was done through review of the interview results. The four most popular steps were: 1) ECM Identification and Analysis, 2) assessment, 3) design, and 4) approval/implementation. The described four steps are critical elements

for determining the viability of different ECMs. The recurrence or the steps among organizations made it clear that their inclusion into the Integrated Decision Process was necessary. The building energy data step, described in the Integrated Decision Process, was used by only two organizations. This step was added to the process because the two organizations that were using the step were identified as prominent organizations for energy efficiency. The other organizations that did not use the step lacked critical elements such as goal setting and a means for verifying results. The establishment of goals and verification of results relies on the data and actions performed in the building energy data step. The representative from Organization 1 noted, "Understanding where each building stands should help us tackle the most appropriate projects." The building energy data step reveals the overall status and potential of a building in question. Additionally, the literature review described the importance of outlining the energy consumption and benchmarking the building to understand the retrofit potential.

CHAPTER 5 ENERGY RETROFIT INTEGATED DECISION PROCESS

The establishment of a standard decision process for considering energy efficient retrofits is important for an organization to implement. The decision process involves judgments to be made at different phases. The absence of certain judgments and evaluations within defined steps in the process can have significant impacts on the outcome. If effective decisions are not made in the appropriate order and manner the project will likely require more time, resources, and most detrimentally, require more money to rectify the overlooked issue. Additionally, ECMs could be missed or inappropriately integrated into the retrofit. In this situation organizations end up with a less desirable end product. The budget and overall flow of the project could improve if elements are evaluated and decided upon in an effective and standard manner. The sequencing of decisions and evaluations are to be set in a standard format for the energy team to follow. Standards enable us to communicate, drive learning, allow for comparisons, fuel creativity, and promote human partnership (Buckingham & Coffman, 1999).

The preliminary steps of the decision process require a background condition statement and the establishment of a goal or set of goals. The background assessment provides information about the current condition of the problem in question. It highlights the key factors and identifies the quantitative measures that depict the status of the current state (Sobek II & Smalley, 2008). It is imperative that the owner or decision maker set a goal. Setting an objective provides a basis for the organization to manage and plan activities. This allows for proper development of targets, required indicators, a means for investigation, proper evaluation criteria, sufficient outputs for authorization, and execution techniques.

There are two fundamental issues of a goal statement which are the establishment of the means for determining if the project is successful at the end of implementation and also the utilization of the standard or basis for comparison (Sobek II & Smalley, 2008). Sobek II et al (2008) additionally states three clear points for establishing a goal. The three points are as follows:

1) Set a clear goal or target for the situation

2) Clearly state the performance measure(s)

3) Consider the data collection method(s) for evaluation and confirmation

Once a goal has been set and the performance measures have been identified the next step is perfuming the data collection. This step involves gathering and sorting through information to best support the analysis. The collection of the information can be done through qualitative and quantitative means. The qualitative data is in the form of interviews and observations. The quantitative data can be collected or developed from models, and numerical results. The collection of data is important to support the analysis. The analysis stage investigates the collected data of the current condition to uncover the problems or areas for improvement (Sobek II & Smalley, 2008). The possible causes of the inefficiencies are then reviewed by comparing the collected data with the established performance measures.

Performance measures are used to help identify how the analysis is to be assessed. The analysis produces data that can be compared with the performance criteria to determine the assessment results. Considerations such as efficiencies, dependability, durability, applicability, and affordability are assessed and compared with target information. This is followed by the integration of the assessed outputs into the planning and design phase of the project. This decision process for energy retrofits must include gathering of background information of the building, establishment of goals, an analysis, identification, assessment, and modeling of ECMs to create an effective design and implementation plan.

5.1 Retrofit Overview

The decision process for an energy efficient retrofit is only a piece of the entire retrofit process. It is important to understand where it fits into the process so that it can be properly implemented. This overview is described in Figure 31. The process begins with a pre-retrofit building, where the owner would like to explore retrofit options to improve operations costs and also reduce GHG emissions. This brings the process to the next step which is the retrofit stage. The retrofit state includes the decision process,

installation of energy conservation measures and other non-energy items, and then the commissioning of the energy items.

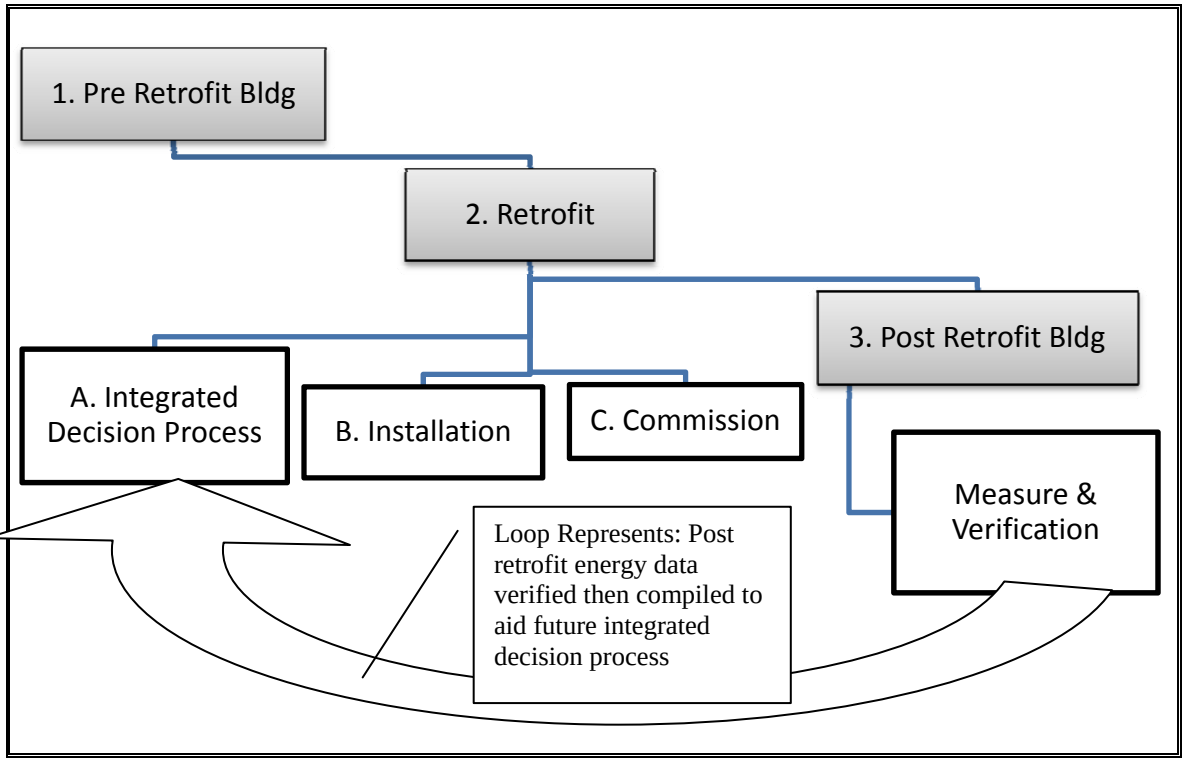

Figure 31 Retrofit Process Overview

The final stage of the retrofit process is the operations and use of the post retrofit building. During this final stage, measuring and verifying the energy consumption is a critical element. Following this stage the process reverts back to the integrated decision process where the acquired data is compiled and compared with the original building energy data. Compiling and comparing the data helps the owner verify energy reduction results. This is important to make sure that the conservation measures were analyzed, assessed, and designed appropriately. Additionally, it confirms that the commissioning was conducted accordingly and if the operations are meeting the intent of the design.

This research focuses on the decision process for determining the appropriate energy conservation measures to implement into the pre-retrofit building. This process is to be called the Integrated Decision Process. This process, as described in Figure 31, occurs during the retrofit stage. The title of the process includes the word 'integrated' to stress the importance of team work, innovation, and consideration of multiple

alternatives. It includes the gathering and review of building energy data, identification and analysis of energy conservation measures, assessment of the measures, design and planning, and finally approval of the proposed measures.

5.2 Integrated Decision Process

The decision process for determining the feasibility of an energy retrofit can have different approaches depending on the organization. Some key factors that can affect the process are funding stream, company structure, and type and number of occupants in the building targeted for a retrofit. The decision process should be structured around clear goals with relevant indicators. The goal must consider three components: people, the planet, and economics. It is important that the owner and the occupants buy-in to the reason for implementing the retrofit. The owner must display responsibility towards the environment and economic considerations. The owner must establish goals that improve GHG emissions, while also considering profit margins and returns on investment. These three components must be considered simultaneously during the decision process to produce maximum desired results.

The Integrated Decision Process was developed through the review and in-depth evaluation of the practices used by the interviewed organization. Figure 17 describes the evaluation process of the interviewed organizations. The evaluation included comparisons, identification of critical steps, incorporation of steps, and decision step outcomes. The development of the decision process combined literature and energy manuals to identify critical steps and potential means to achieve the superlative energy reduction outcome.

The decision maker should be able to understand the current condition of the building, single out potential ECMs, and make an assessment of opportunities through an integrated approach. The integrated approach provides an assessment of the building's energy potential through the consideration of all the systems in the building working together. The decision process incorporates the procurement, design and implementation stages as well. The inclusion of these elements is important so that the owner can insure that items from the assessment are included within the retrofit in a cost effective manner.

Figure 32 provides a breakdown and description of the integrated decision process for owners to consider when determining feasibility and implementation of ECMs within a building Retrofit.

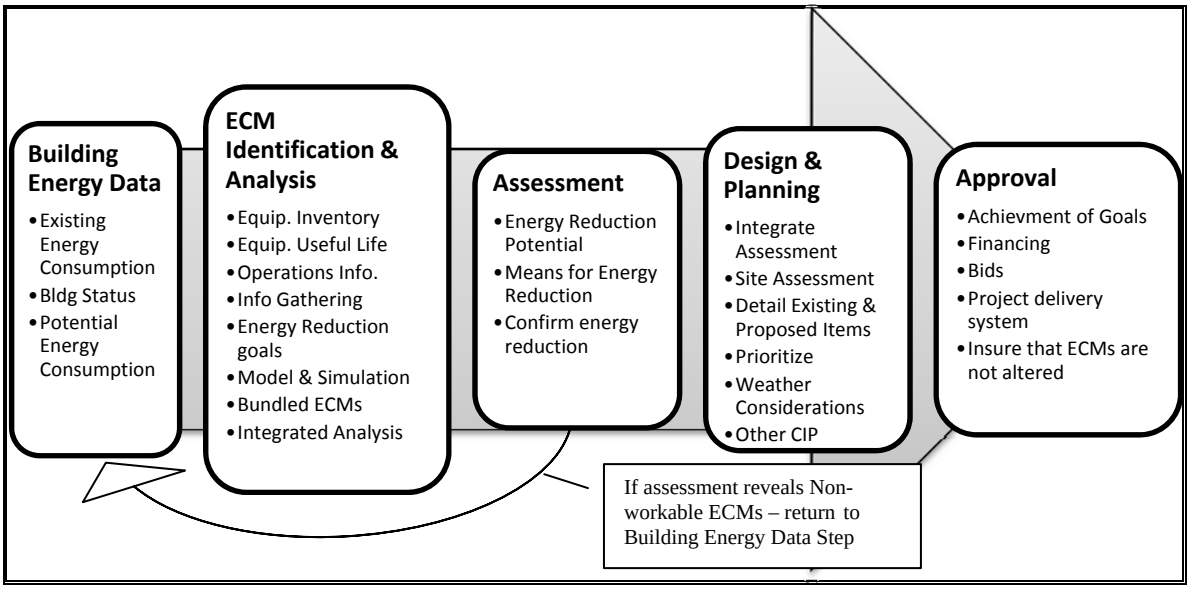

Figure 32 Integrated Decision Process

The integrated decision process for organizations to follow when considering a building retrofit that incorporates ECMs begins with condensing and reviewing the existing building energy data. The next step is ECM identification and analysis followed by the assessment. The assessment step may not produce a viable bundle of ECMs, and the process must then revert back to the building energy data stage to begin the process again. This situation is represented by the arrow shown in Figure 32 that points from assessment step to the building energy data step. The final stage in the retrofit decision process is the approval step which confirms goals and sets the project up for construction or implementation.

5.2.1 Step 1 Building Energy Data

Reducing the total energy consumption of a commercial building and performing it in a manner that is financial feasible are the ultimate goals of the energy efficient retrofit. The achievement of these goals begins with knowledge and understanding of the current energy consumption of the building. The current condition provides information

about the energy savings potential of the existing building. This knowledge enables the decision maker to accurately evaluate the current maintenance and operations practices impacts, and also ensure adequate implementation of ECMs (Greenaur, 2006). Greenaur (2006) states that without existing condition knowledge capital could be wasted on ineffective improvements.

Perez-Lombard et al (2009) comments that energy service companies use the energy performance index as a starting point in energy audits and assess saving opportunities by comparing similar buildings. There are four stages in the building energy data process: 1) Hold or develop a database of the energy performance of the building, 2) gather information for evaluation of the index, 3) perform a comparative analysis of the building performance with buildings of similar uses and construction, and 4) produce recommendations of energy efficient measures that both economically and technically feasible (Perez-Lombard et al, 2009).

The building energy data step is often overlooked but is an important aspect in the decision process. It is a practical and empirical way to tackle the big issues. Issues such as performance and limiting factors can be addressed in benchmarking (Birchfield, 2000) which is included in the building energy data step. Effective benchmarking requires the understanding of resources, the development and maintenance of a database, use of Energy Performance Indicators (EPI), and appropriate comparison methods.

5.2.1.1 Resources

The personnel involved in the building energy data process can include the energy manager, and the energy engineers. The personnel meet with the maintenance crew, and occupants to understand techniques and procedures that support or prevent energy conservation. The energy managers and engineers acquire, arrange and then review energy consumption information.

The acquisition of the information can be completed through on-site metering or requesting data from the utility company. The energy data is then organized in groups, graphs, and tables to appropriately display the energy use numbers. Organizations with multiple buildings of similar type can arrange the data to produce internal Energy

Utilization Index (EUI) information. Additionally the Energy Information Administration (EIA) provides Commercial Building Energy Conservation Surveys (CBECS) that describe standard, mean, and target total EUI. The mean and target consumption information is based on ASHREA 90.1 Standard. The information is grouped by building type, and climate zone. Figure 33 displays the personnel and resources involved in the building energy data stage.

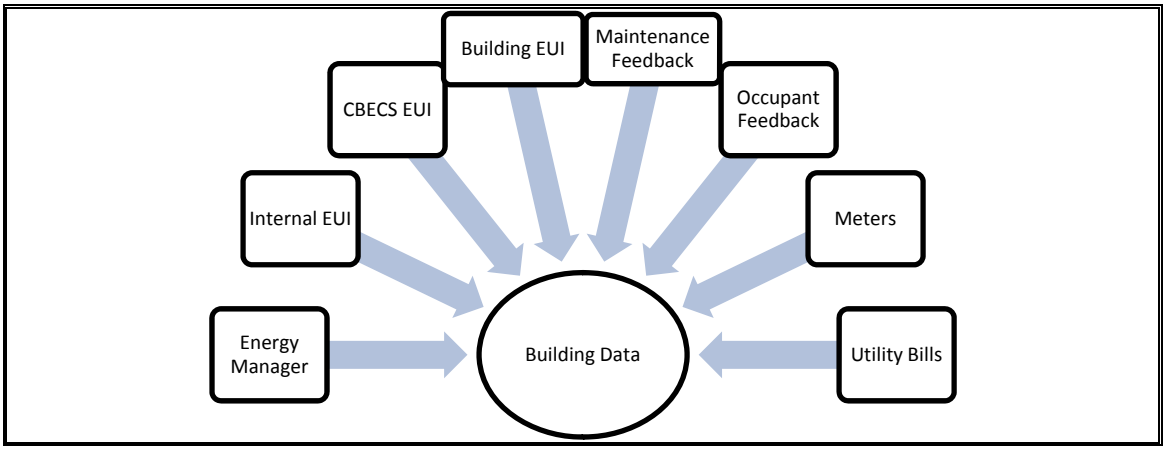

Figure 33 Building Energy Data Personnel and Resources

5.2.1.2 Energy Performance Indicators

The Energy Performance Indicator (EPI) is used to describe the total energy consumption of the building. There are many forms of the indicator that are used for benchmarking. Benchmarking is comparing the energy consumption with other buildings to understand the buildings status and potential. This comparison strategy is described in section 5.2.1.4. The EPI is able to describe energy use in terms of gross floor area, energy costs, and number of occupants.

Table 5 Energy Performance Indicator Options (MacDonald, 2000)

EPI	Units	Description
1	kBtu/ft^2	Energy Use Index (EUI) – total energy use divided by gross floor area
2	$/Btu	Dollars per total energy source use
3	$/ft^2	Dollars per gross square foot of total gross area
4	$/Occupant	Dollars per Occupant

Table 5 describes four examples of EPI options. The most commonly used EPI in the commercial building sector is the EUI. The EUI describes the energy consumption in $kBtu/ft^2$. The utilization of relating energy to the square footage of a commercial building is commonly used because it is related to capital expenditure through the leasing and also due to the fluctuation in number of occupants (van der Merwe & Grobler, 2003). Additionally the EUI is also utilized by CBECS, which provides a useful means for comparison.

The EUI is essential for determining the current status of the building, possible savings that can be accomplished, and the building's progress towards energy efficiency (van der Merwe & Grobler, 2003). The current status of the building is determined by comparing the EUI with other similar buildings. The analysis of the energy usage in comparison to other buildings provides the energy team with target ECMs. The target ECM alternatives are analyzed to meet a reduction goal based on a comparison review of other buildings with higher energy efficiency. The record keeping provides a means for evaluating progress, and to verify the achievement of goals.

5.2.1.3 Database

Establishing a database of the building energy use is an essential for benchmarking and evaluation of energy trends. An accurate data base provides a means for establishing a goal, measuring, recognition of high energy usage and times. It also allows for simple comparisons with itself after a ECMs has been implemented or against other buildings. The data is arranged accurately in a method that is easy to understand, evaluate, and compare. It is important to consider the sample size of the database. The energy consumption numbers from one year may not portray the typical consumption of the building. Fluctuations in weather, number of occupants and type of occupants can alter the annual energy use. It is suggested that the database include data for at least three years. The review of at least three years of use is necessary to eliminate an off year. The data can be arranged to display monthly and annual EUI.

The database and the calculated EUI provide help for the decision makers to start the decision process by understanding the current energy consumption of the existing building.

Table 6 Sample Energy Consumption Data Table

Year	Annual Electrical (kWh)	kBtu/ kWh	Annual Electrical (kBtu)	Annual Natural Gas (Therms)	Therms/ kBtu	Annual Natural Gas (kBtu)	Area of Bldg (ft^2)	EUI
1	428,010	3.412	1,460,370	4,674	99.976	467,318	24,000	80.3
2	419,938	3.412	1,432,830	4,586	99.976	458,506	24,000	78.8
3	430498	3.412	1,468,860	4,701	99.976	470,035	24,000	80.7
4	340,919	3.412	1163216	3,723	99.976	372,229	24,000	63.9
5	298,304	3.412	1,017,814	3,257	99.976	325,700	24,000	55.9

Table 6 displays a sample energy consumption data table that includes the building area and EUI. This is a simplified table that shows the annual electrical, and natural gas consumption over a five year period. This particular organization collected data for three years and then implemented ECMs to reduce the total energy use. It is evident that a drop in energy consumption occurred over the fourth year and again in the fifth. This is clearly identified by simply viewing the EUI displayed on the far right in Table 6.

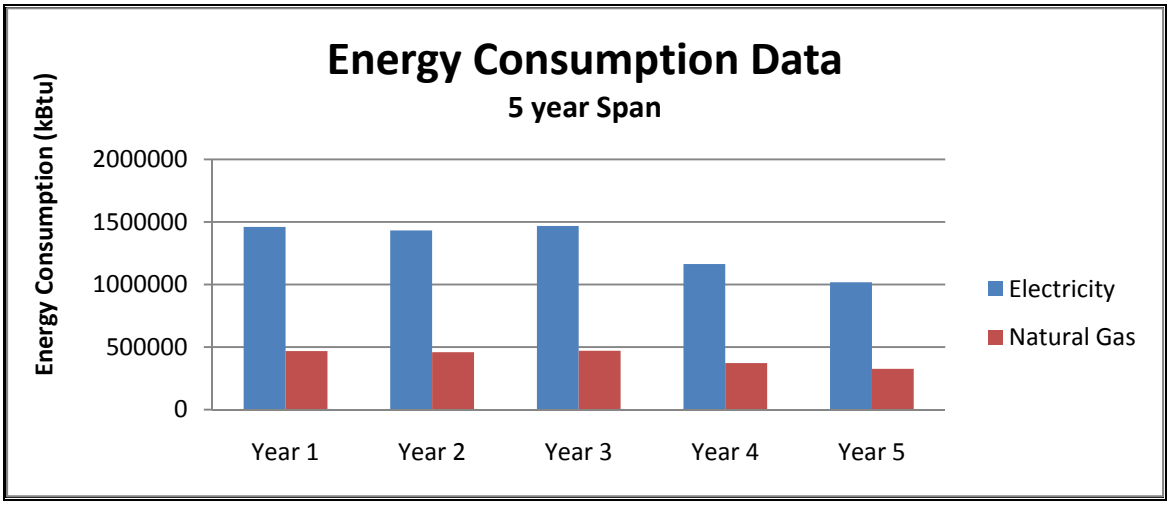

Figure 34 Sample Energy Consumption Graph (Data from Table 6)

The data in Table 6 is graphically displayed in Figure 34. The graph clearly shows that the energy consumption over the first three years was the same. The forth year shows a

total energy reduction of 20% and the fifth year recorded a reduction of 30% from the year 3 base. Clearly the database provides a simple means to display and measure the data for each year and recognize shifts in energy consumption. The database provides a means to verify the energy efficiency level of the building. This verification is done by comparing the EUI with CBECS data. The data can also provide insight when developing energy reduction estimates during the analysis of future projects.

Establishing a database is also useful for reviewing and recognizing energy trends. Recognizing trends in energy use will help owner's direct their attention to useful ECMs. The ECMs can be used to lower energy use during high peak demand times, where the energy costs are escalated. The trends can also identify energy consumption that does not match with occupant usage. For example owners can see energy trend lines that indicate excessive energy use in the building during the night when the occupants are not in the buildings. Simple ECMs, such as thermostat setbacks to reduce heating and cooling during the night, or introducing daytime cleaning to eliminate any sort of usage during the night, are easily identified through evaluation of the database displaying energy trends.

5.2.1.4 EPI Comparison

The overall energy efficiency of a commercial building is difficult to quantify. The energy elements can vary in efficiency based on their original efficiency capability, age, maintenance, and occupant utilization. The energy savings missed cannot be quantified without extensive engineering review. The engineering review would require a large initial investment. An alternative, which would require little to no cost, would be to use the base energy consumption data and compare it to similar buildings. The comparison would quickly show energy teams where the building stands in relation to others.

There are two types of comparison methods that this research will recommend and discuss and are described in Table 7.

Table 7 Comparison Methods

	Method 1	Method 2
Energy Personnel	Energy Manager Energy Team	None
Database Detail	Consumption Graphs & Tables Monitoring Graphs & Tables Comparison Graphs & Tables Verification Graphs & Tables	Consumption Table
Database Extent	At least 3 years	At least 1 year
Comparison Data	EUI (kBtu/ft^2-yr)	EUI (kBtu/ft^2-yr)
Comparison Resource	Internal CBECS	CBECS

The first method is for organizations that have the resources to employ an energy team. The energy team is able to create an extensive database and continually evaluate and update the database. The database is extensive and constantly scrutinized. The data should include information for at least three years of energy usage. The data can be compared internally for determining the energy efficiency status and saving potential. This approach of comparing building energy use internally would work well for school districts, where the buildings are relatively similar in regard to energy systems. Additionally the buildings are located in the same climate zone. This allows for comparisons to be accurate and provide a clear indication of which buildings require attention. The buildings can also be compared externally through the use of CBECS data.

The second method is for organizations that have limited energy conservation resources. These organizations require quick evaluation and answers that pertain to the energy cost savings potential of their existing building. A database is created quickly and usually with help from the utility company. The extent of the database should have at least one year of energy usage. The data can then be used to compare with the information provided in the CBECS. The energy consumption tables provided by CBECS have information on the target, good, and mean EUI of existing buildings. The organizations can easily calculate a EUI as defined in section 5.1.1.2 to compare with the CBECS data.

EUI information provides the energy team a great place to start, however the energy team should understand the comparison process utilizes data of unspecified square

footage. Meaning the EUI is the total energy divided by the square footage of the building. Commercial buildings can vary drastically in area and can incorporate different systems based on the amount of area. The EUI comparison methods are a good starting point but cannot be totally accurate.

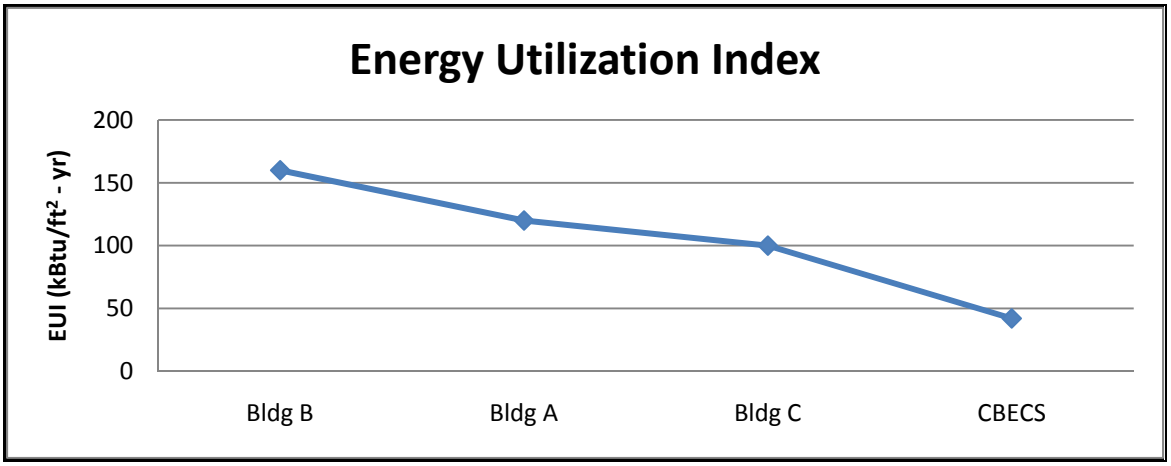

Figure 35 Energy Utilization Index Sample Graph

With the graph shown in Figure 35 one is able to visually compare the EUIs of different buildings and also the surveyed EUI defined by CBECs for a particular building type and location. It is evident that Building B has the highest annual energy consumption per square foot, followed by Building A and then Building C. The final graphed point is the target energy consumption per square foot as defined by CBECS. This graph could provide organizations with limited funds or who want to follow a master plan for reducing energy with enough information to decide on which building to analysis first.

Organizations that utilize comparison method 2 will most likely employ the services of an energy engineer. The engineer will produce reports that will evaluate the current consumption and breakdown the cost of energy and also the amount of energy consumed per square foot. Then they will display the same numbers for an average building and the target building. This provides the organization with an initial idea of what it will take to produce a building that meets energy efficiency standards. Setting a base and establishing a goal are the important first steps in the energy retrofit decision

process. The next steps will help breakdown the scope of work, the construction costs and the energy savings to evaluate alternatives to determine the feasibility potential.

5.2.2 Step 2 ECM Identification and Analysis

The intent of the identification and analysis step is to analyze energy elements within the existing building. The analysis includes an energy audit, which encompasses the review of the existing equipment and their useful life. The analysis also uses the benchmark data to aid in the identification of deficiencies and potential upgrade options. The analysis ultimately produces a set of ECM alternatives that can be assessed in the preceding step.

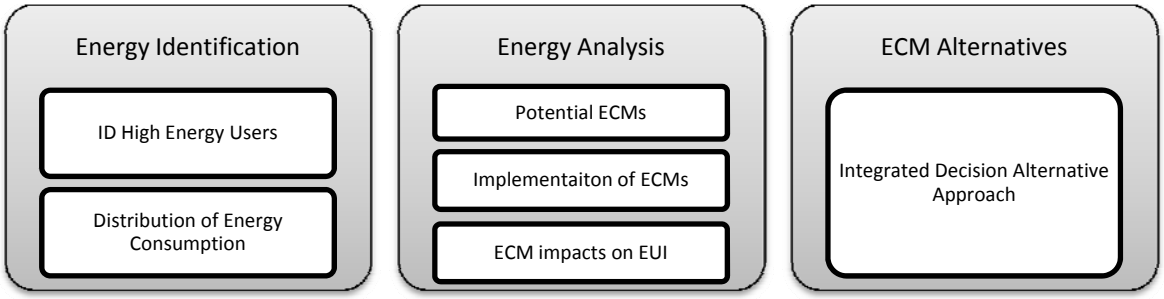

Figure 36 ECM Identification and Analysis Goals

Figure 36 identifies the ECM identification and analysis goals. The energy analysis should identify the equipment that is the high energy user, and then develop a plan to implement possible ECMs. The goal of the integration of the benchmark information is to help the energy analyzer discover the distribution of energy consumption in the building. Additionally the benchmark information helps identify potential ECMs through analyzing their impacts on the defined EUI. The ECM alternatives for the energy retrofit are then determined. Finally the integrated analysis approach is performed in a holistic manner.

The organizations interviewed used several approaches to identify and analyze the potential for ECMs. The results from the organizations are described in Figure 37.

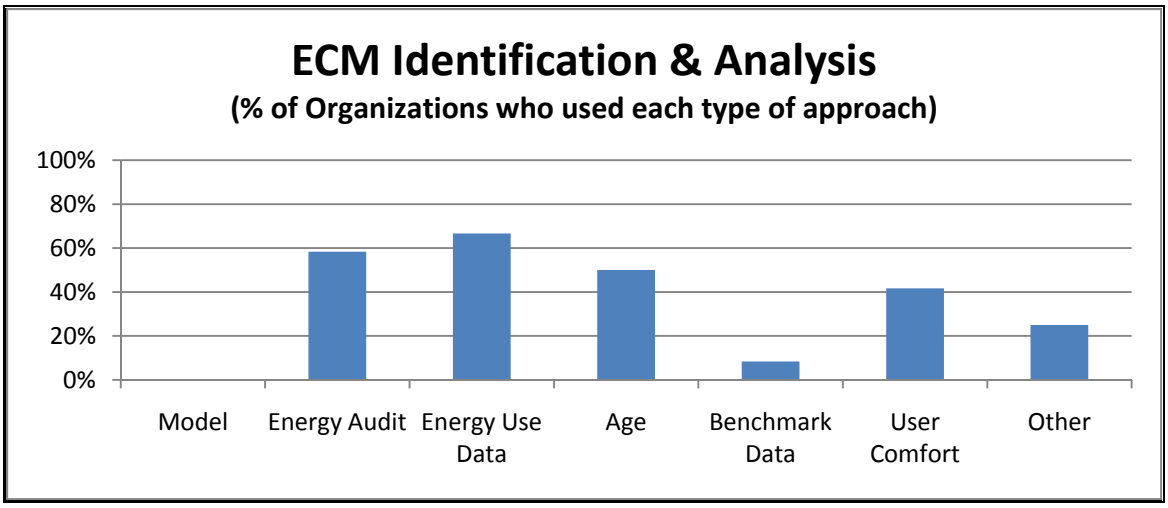

Figure 37 Identification & Analysis of ECMs based on data from 12 Organizations

The energy use data and energy audit were the most popular means for identifying and analyzing the current status and potential ECMs of an existing building used by the interviewed organizations. The ECM identifiers, age and user comfort, were also commonly used. The benchmark data is only utilized by one organization for identification and analyzing ECMs. The other methods mentioned by the organizations were to review the extent of maintenance and operations required for the building systems. The organizations stated that the maintenance and operations requirements are identified and analyzed through oral or written communications. The energy audit described in section 5.2.2.1 provides information on the identification and analysis of ECMs through the review of energy use data, evaluation of age and benchmark data.

5.2.2.1 Energy Identification

The energy analysis examines how the energy is used in the building and the associated energy costs. It also presents a means to improve the deficiencies. The analysis process includes the specific review of energy use, utilization of tools, operations information, equipment inventory, equipment useful life and information gathering.

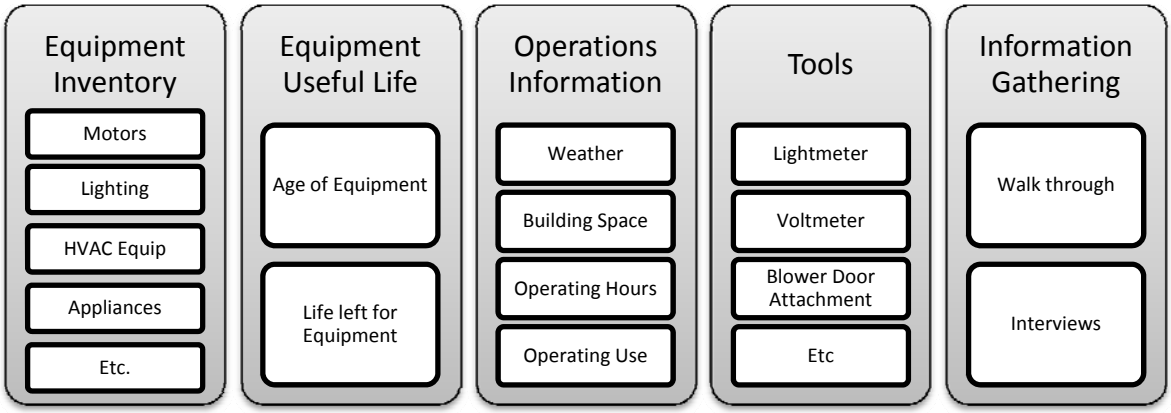

Figure 38 Energy Identification Elements

Figure 38 describes the energy analysis elements. The first element is the energy use data which includes the database created in the building energy data stage and utility rate structure. The equipment inventory is an overview of the energy consuming equipment. The equipment useful life reviews the age of equipment and the amount of life left before it is consider inefficient. The operations information is important to review to understanding the appropriate types of ECMs. It is good to document the location, weather, building space, operating hours, and operating use. The analysis of the building includes information gathering that includes interviews and walk-through. The walk-through can utilize tools such as light meter, voltmeter, blower door attachment and many others.

Equipment Inventory & Useful Life

The energy equipment inventory is another element to the energy analysis step. The analyzer evaluates and records the different energy equipment details. The details consist of documenting the type, condition, size, model, age, and specifications concerning its required energy source. The analyzer must also record the time of use and extent of use of each piece of equipment in the inventory. The lifespan of the equipment is a major consideration in the analysis. The age of the equipment at the time of the inspection describes the efficiency and also status of the original financial investment. Equipment that is relatively new has the potential to be more energy efficient. Yet, even new equipment can have energy deficiencies. Review of relatively new equipment can

be complicated because the organization would rather not reinvest in equipment that is only 5 years into its 35 year life. Analyzers should recognize this issue and devise alternatives that work around the equipment that is to remain in the building. The alternatives are structured so that the overall energy efficiency of the building can be improved yet still keep the equipment that might not be as efficient but still has remaining useful life.

Operations Information

The operations of the existing equipment must be considered in the analysis. The factors affecting operations are weather, building space, operating hours, and operating use. The seasonal temperatures affect the heating and cooling loads of a building. The analysis of these loads are complicated but imperative to insure that the appropriate HVAC systems, and envelope insulation is incorporated in the devised alternatives. The size and layout of the building must be considered in order to most effectively distribute light, heat, conditioned air, flow of air and many other factors. Finally the operating hours and use help define the internal loads created by the occupants. The hours of use will help the analyzer determine the type of systems that can operate in conjunction with the users and the rate schedule. The type of use helps the analyzer review how to best address their needs.

Tools & Information Gathering

The analyzer can utilize various tools, such as light meter, voltmeter, and blower door attachment, to evaluate existing buildings. The type of tools are described and understood by any trained energy auditor. Performing the walk-through is important to visually see the equipment and understand how it is being used. The analyzer should utilize the occupant's feedback to help them develop an efficient system that provides comfort as well. There is no point for the creation of an energy efficient building that is uncomfortable and will not be used.

5.1.2.2 Energy Analysis

The energy analysis uses the identified efficient and deficient energy elements to determine the potential ECMs (Figure 39). The potential ECMs are combined through an integrated design approach to develop energy retrofit options. The options are then analyzed to determine the energy reduction amount.

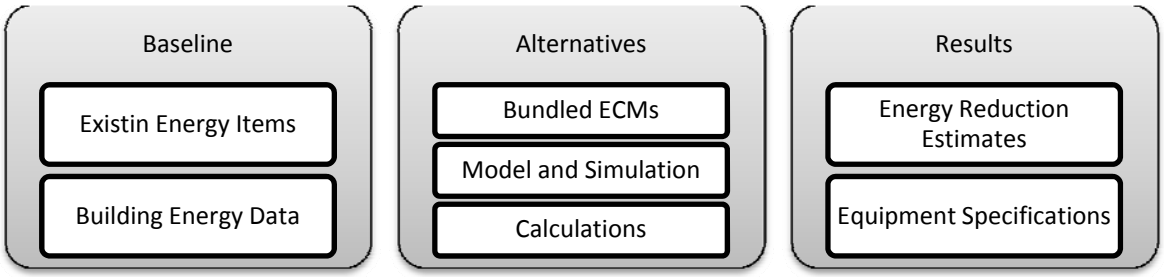

Figure 39 Energy Analysis

There are multiple avenues for determining the potential ECMs. The first step is to review the existing building and create an energy consumption baseline. Then with the knowledge of what is there and how it is working, new technologies can be explored to replace the inefficient equipment. The equipment upgrades are grouped into alternatives to evaluate in an integrated manner. Finally results are produced through calculations or modeling and simulation of the different alternatives. The results consist of energy reduction estimates and equipment specifications.

The integrated process utilizes an integrated analysis approach to evaluate and implement potential ECMs. The proposed Integrated Decision Alternative Approach (IDAA) combines ECMs to provide the best overall energy reduction, and cost. The ECMs are to be analyzed in a holistic manner through the use of advanced energy calculation or energy modeling. The analysis requires at least three significantly different options be explored. The main options that should be explored are the impacts that different HVAC, lighting, building envelope, and fenestration systems have on each other. The analysis should utilize the existing building as much as possible but realize that cost savings can still occur if significant improvements are proposed.

The development of the models can be time consuming but are important for discovering the most appropriate set of ECMs. The lack of modeling will hinder obtaining integrated results. It is also important the organizations understand the maximum potential for energy savings so that more in-depth retrofits can be considered which will result in greater reduction of the overall energy consumption. Additionally the analyzer should have a broad idea of energy costs and installation cost of the potential ECMs. This provides some sort of guidance so that outlandish models that are not realist financial are avoided.

During the modeling process the analyzer should review and recorded the environmental impacts of the ECMs. The impacts that are based on the model results may not be exactly accurate for the real world situation. This barrier can be overcome if the analyzer develops a base model of the existing building and observes energy reduction results in relation to the base. The energy reduction numbers will aid the assessment process were installation and energy costs are compared to examine the feasibility of each of the options.

Modeling and Simulation

The modeling and simulation uses an integrated approach. This stage analyzes the different components and how they interact with each other to save energy. Many organizations do not utilize this stage due to limited available resources and time constraints. Yet modeling and simulation can reduce energy use and cost significantly by considering such elements as how the envelope affects the HVAC system. The HVAC system costs could be significantly reduced or altered if simple heat loss or gain deficiencies are improved. Modeling and simulation is also a good way to check the organizations assessment of the deficient elements and also confirm validity of the potential investment.

There are various programs available for designers and energy engineers to perform energy simulations. Organizations are beginning to realize the importance of the integrated approach and feel that modeling is an important tool for achieving an integrated design as the organizations are faced with some initial constraint due to lack of

resources and knowledge. Currently there is not an abundance of operators who can maneuver the programs without organizations investing time and training to develop their modeling techniques. Yet with the growing necessity for modeling driven by owner needs and building code requirements organizations should soon realize the benefits, as well as the technology that will help create a more efficient building.

Integrated Decision Analysis

The IDAA is a more intensive approach for analyzing and assessing retrofit options. It benefits the organization by providing a more in-depth decision process where multiple options are reviewed. The review includes an integrated approach that is an intensive analysis of how all the ECMs work together to receive the best energy reduction possible. The approach does require more upfront time and cost. Organizations must realize that the long-term cost savings could be greater with this approach and eventually pay for the increased investment.

The process includes the identification of ECMs and an intensive modeling process. After the modeling process is substantially complete, the analyzer develops sets of alternatives. The alternatives integrate various improvement options. Table 8 describes a mock list of retrofit options. Three possible options are shown that include upgrades to the HVAC, envelope, fenestration, and lights. Each of the options is to be modeled and compared with the existing building model to estimate the difference in energy use.

Table 8 IDAA List of Retrofit Options

	Existing	Option 1	Option 2	Option 3
HVAC	Boiler, Electric Chiller	Chilled System	Boiler, Evaporative Cooling, w/ improvements to VAV System and Duct Work	Boiler & Absorption Chiller
Envelope	Batt Insulation	Batt Insulation	Batt + 4" Rigid Foam Insulation	Batt + Spray Foam on the outside
Fenestration	Double Pain Windows	Double Pain w/ Low-E Film	Double Pain w/ Low-E Film	Double Pain w/ Low-E Film
Lights	Incandescent	T-8, Fluorescents	Increased Daylighting, with LED	Fluorescents and LEDs

The model should produce certain results for the organization and Energy Analyzer to evaluate during the assessment process. The results include energy reduction amounts, equipment specifications, and installation requirements. The equipment specification should list such things as useful life, cost, and operations requirements. The installation requirements can tough on the potential construction schedule, the cost for construction, and the expertise or extenuating recourse required for the installation.

5.2.3 Step 3 Assessment

The assessment of the bundled ECMs is the stage where the feasibility of the potential upgrades is determined. This stage reviews the benchmarking information to establish and reiterate the overall goal. Then it assesses the analysis to discover the best option for reaching the goal. This is followed by a confirmation step that confirms that the analysis was reviewed correctly and that it meets the desired goal. Ultimately the assessment will define the ideal scope of work to improve the overall energy efficiency of the existing building.

Currently it is common practice to rely on the designer or energy engineer's expertise for determining the energy efficiency of a building. Their expertise is valuable but does not guarantee that the best retrofit options have been chosen or even considered. This integrated process, and in particular the assessment step, is to provide the owner with a process that can identify that the best approach is being provided. The IDAA considers multiple options to clearly identify the most appropriate energy retrofit system that achieves the maximum allowable energy efficiency within the parameters of the financial requirements.

5.2.3.1 Integrated Decision Assessment

The Integrated Decision Alternatives Approach (IDAA) is a proposed method for assessing the analyzed results. It should be utilized by organizations to assess the building energy data and analysis information. Organizations must consider the following questions when assessing an energy efficient retrofit:

1) What is the maximum energy efficiency potential of the building?

2) What is the best way to achieve the maximum energy efficiency?
3) What is utilized to confirm that the maximum energy efficiency is achieved?

These questions guide the organization in the assessment of the most appropriate retrofit option. The questions are answered through a series of defined steps. The assessment steps begin with the 1) Building Energy Data Assessment, 2) Analysis Assessment, and 3) Confirmation of Assessment. Table 9 describes the three assessment steps for reviewing energy retrofit options.

Table 9 The IDAA for Assessing a Retrofit for Energy Efficiency

	Building Energy Data Assessment	Analysis Assessment	Confirmation of Assessment
Question	Maximum energy efficiency Potential?	Means for achievement of energy efficiency?	Means for confirmation of energy efficiency?
Process	Review Building Energy Data	Review the Analysis Data into at least 3 alternatives	Review the alternatives and determine the best one to establish the scope of work
Evaluation	Energy Consumption Comparisons	• Occupant Type of Use • Occupant Plans • Non-Energy items • Energy Items • Integrated Energy Systems Analysis • Financial Review	• ECMs meet occupant use and plans • Retrofit Scope Includes Non-Energy Items • Energy reduction goal • All financing resources are explored • Funding Source
Indicators	EUI	EUI, CIP List, Inventory, Model Results, LCCA, Funding Applications	(Indicators are Compared)
Goal	Define Target EUI	Develop Retrofit Alternatives	Confirm which option best meets targets
Keys to success	Building Energy Data provide correct information	Analysis provide integrated ECM alternatives	Establish clear comparison evaluation criteria

Building Energy Data Assessment

The existing building energy data defines the overall energy consumption of the existing building. Once the consumption amount is known it can be used to compare with other comparable buildings to understand the energy reduction potential. The comparison process described in section 5.1.1.4 (EPI Comparison) does not produce exact results but it does provide the organization a starting point for understanding how to

evaluate and integrate ECMs into the building. Benchmarking the building establishes the energy consumption goal for the energy retrofit. It should be used throughout the analysis and confirmation stages of the assessment to verify that the target reduction will be met.

The energy reduction goal is an important aspect of the assessment process. Establishing a suitable goal that will help reduce GHG emissions is essential. The established goal can be considered unreachable based on known financial situations or business as usual standards. The perception that energy reduction goals cannot be met must be eliminated so that innovation, alternative financing options, and long-term financial considerations can be made possible. The building energy data assessment must consider high energy reduction targets so that innovation and creativity is implemented in the analysis and confirmation assessments.

Analysis Assessment

The analysis stage of the assessment process requires in-depth understanding of the proposed ECM alternatives. This stage defines how the maximum energy reduction will be achieved. This is done by reviewing and comparing the retrofit options defined in the analysis. The review includes assessing the occupant use and their future plans. It also includes the assessment of non-energy items. The non-energy items could have a significant impact on the installation, permitting, and certificate of occupancy. The energy items are then reviewed and compared to identify the most appropriate integrated energy system. The analysis assessment concludes with the review of the financial situation of each of the options to confirm the cost feasibility. This includes the use of key financial calculations and indicators.

Occupant Type of Use and Plans

The assessment must highlight the plans of the occupant prior to finalizing the alternatives. The alternatives may have to take into account an architectural change or a change in use. The occupants may also be planning a significant retrofit that could alter the proposed ECM's functions and degrade the newly upgraded energy efficiency of the

building. The assessment must factor the potential plans into the assessment to decide whether to pursue further review or delay the decision process.

Non-Energy Conservation Items

Non-energy items are often overlooked in an energy conservation retrofit decision process. The focus of the analysis and assessment is on the energy consuming equipment. The construction activity or code requirements may require the incorporation of other building elements. The required building elements can be fire suppression systems, structural components, plumbing fixes and many other elements. These elements must be addressed for the sake of building code requirements and overall safety of construction and user needs. The neglect to these items could result in a difficulty in receiving a building permit or retaining occupants. It can also result in a possible delay in receiving the certificate of occupancy from the governing municipality. An organization involved in the research noted that a retrofit to an existing building had been completed but it neglected to include a proper fire suppression system. The building department of the local municipality refused to allow them to occupy the building. At the time of the interview it had been several months since the retrofit had been completed and the occupants had not moved in. The non-energy items must be considered and budgeted for so that permitting and occupancy standards are maintained.

Energy Items and Integrated Energy Systems Analysis

The assessment of the energy items includes calculation estimates of energy consumption. These calculations can be performed by hand, but preferably done through the use of an energy modeling software. Energy modeling and simulation is discussed in section 5.1.4. The assessment of the energy reduction and cost savings potential should be computed and displayed for comparison with other alternatives. The energy items should be assessed in an integrated manner. This type of assessment is best done through the use of energy modeling and simulation. The integrated assessment will project energy savings based on how the systems interact with each other. This has the potential to realize more energy and cost savings than if each element is analyzed individually.

For example the analysis of how a building is heated could simple assess the installation of a new HVAC system that performs better than the existing one. The assessment would compare the existing energy consumed by the HVAC system by understanding how much energy is distributed to the equipment. Then the new HVAC system would be assessed by reviewing the specifications that describe the maximum energy demand of the equipment. This is a simplistic approach that neglects to review the system as a whole. The HVAC system does not just include the heating/cooling generation and the distribution system. The system also encompasses the insulation of the building envelope, the fenestration system, the lighting, the electrical equipment and the occupants. These elements are included in the system because they have a direct effect on the operations and efficiency of the HVAC units itself.

The alternative evaluation process to the simplistic method described is to use an integrated decision process. This would entail the review of the HVAC system demand, occupant loads, appliance loads, lighting loads, and the envelope/fenestration's resistance to heat loss. The combined review could find a more cost effective way to install the system. An alternative could be an upgrade of the insulation on the envelope to reduce heat loss and require a smaller HVAC system. The HVAC system in this case would have a smaller energy demand and result in energy savings. This process could take more time and cost more to assess initially, yet it could recoup the costs through the increased cost savings achieved in the reduction of energy use in the long-term. Ultimately the integrated approach could produce an overall system that would have a smaller energy demand. The reduced energy demand would increase the feasibility of a renewable energy source by reducing the size required and therefore reducing its upfront cost. This approach supports the goal to produce net zero carbon emission buildings.

Financial Review

There are multiple avenues for assessing the cost of an energy retrofit project. The organizations used life cycle cost analysis, annual savings, simple payback and benefit/cost ration as a decision making tool. The life cycle cost analysis was used by 33% of the organizations. Annual savings was used by 25% of the organizations. Simple payback was used by 75%, and the benefit/cost ratio was used by 42% of the

organizations. See Figure 40 for breakdown of financial assessments used by the interviewed organizations.

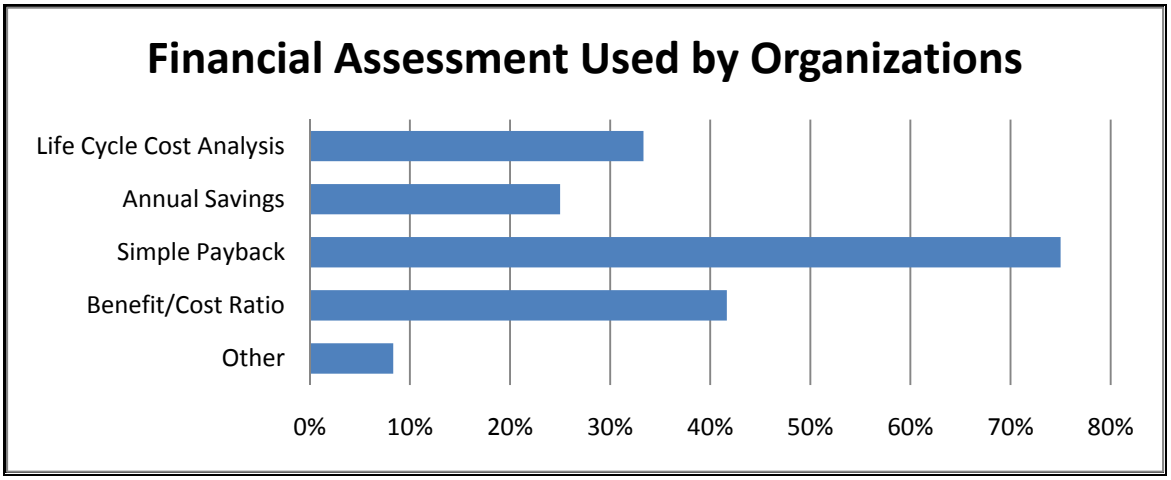

Figure 40 Financial Assessment Type Used Based on data from 12 Organizations

Section 5.1.1.4 described the impact and importance of the EPI for determining the likelihood of an energy retrofit. Yet, the most influential indicator or gauge for assessing the feasibility of a retrofit is the financial assessment. The organizations list various reasons for the utilization of their preferred financial assessment. Three quarters of the organizations, which was all of the organizations who have a definable decision process, preferred the payback period to help them determine the feasibility of a project – by far the most popular approach.

Simple Payback Period

The simple payback is the number of years that is required to recover the initial investment. It is calculated by dividing the annual savings of the ECM into the cost to install it. Organizations mentioned that the simple payback method is preferred because it has minimal variables and it is easy to understand. Additionally organizations are extremely concerned with investments that can be recovered quickly.

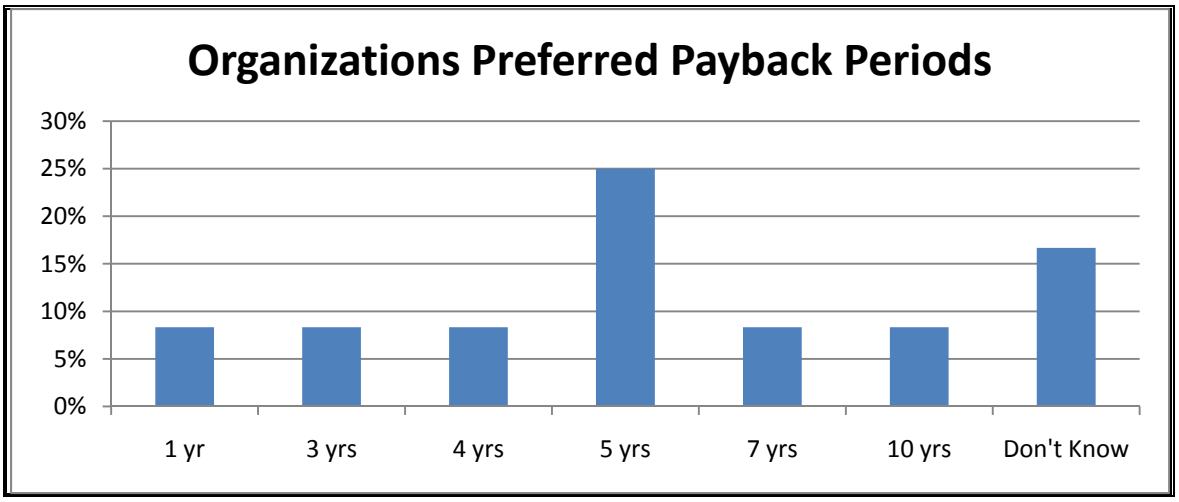

Figure 41 Preferred Payback Period based on data from 12 Organizations

Of all the organizations interviewed, the preferred payback period determined in the assessment procedure was found to be 5 years (Figure 41). Two of the organizations stated that the payback period was important to assess but did not have a defined preference. The payback period of 1, 3, 4, 7, and 10 years each were preferred by the remaining organizations. One organization stated that it was important to have the ECMs achieve a simple payback that is less than the life span of the ECM but ultimately preferred a shorter payback of 5 years. Although the payback period assessment is preferred by the organizations interviewed it is not the integrated method. The sole utilization of the payback period for the financial assessment could result in a less profitable investment. It is important to factor in the effects of interest or escalation rates.

Life Cycle Cost Analysis

The Life Cycle Cost Analysis (LCCA) is a method that factors in the time value of money. This concept converts the cash flow associated with the energy retrofit to a base, which is known as the Net Present Value (NPV). The calculations are set up to find the Net Present Value of the investment, the annual worth, and the internal rate of return. This assessment can be cumbersome but the results are much more advantageous to the decision maker. The decision maker is able to consider the useful life of the equipment

in a more detailed manner. The detailed assessment enables decisions to be made based on the total cost of ownership.

This assessment method is important to utilize for determining the financial feasibility and also for establishing a budget for operating and capital expenses. The organizations did not factor in the capital expenses to perform major repairs or complete replacements to energy equipment. The equipment has a much smaller lifespan that the structural components to the building, meaning the building could last for 60 years but, for example, a required DX Coil Heat Exchanger needs to be replaced up to three times because it has a mean lifespan of 22 years. The simple payback method will not help organizations perform a financial assessment or plan for these upgrades. Then when equipment's useful life has passed, and the energy consumption of the equipment has increased dramatically, the organizations is not prepared to replace the equipment. The organization must compete for capital funds using well thought out reports and a justification process. When, on the other hand, the organization could perform a LCCA at the beginning. The LCCA provides information on costs and equipment useful life, which will help the organizations plan and budget for maintenance, and replacement of the equipment.

Confirmation Assessment

The confirmation that the analysis assessment matches the goals established by the benchmark assessment is the final stage in the assessment process. The process requires a review of the alternatives and the assessment results to determine the best approach. The best alternative must also meet the needs of the occupant and follow with any future plans. It should also include all necessary non-energy conservation items into the cost estimate. The energy conservation items must be properly analyzed in an integrated manner that produces results that meet the energy reduction goal. Once all factors are confirmed, the scope of work is defined, and all cost information finalized then the funding source options can be explored. The funding source review uses the construction cost estimate and the potential calculated cost savings results to help procure the most suitable funding source.

Develop Scope of Work

The final step in the assessment processes is defining the scope of work for the energy retrofit project. The scope of work must be responsive to the elements discovered in the assessment. Specifically, it is developed based on funding available, occupant plans, non-energy items, and the ECMs. The scope of work is a wrap up of the building energy data, analysis and assessment steps to provide specific details for the design, procurement and installation of the ECMs.

Funding Source

The organizations interviewed had little to no control over the funding source that they utilized to fund their energy retrofit projects. The funding source for the organizations came from investors, capital budget, grants, and operations budget.

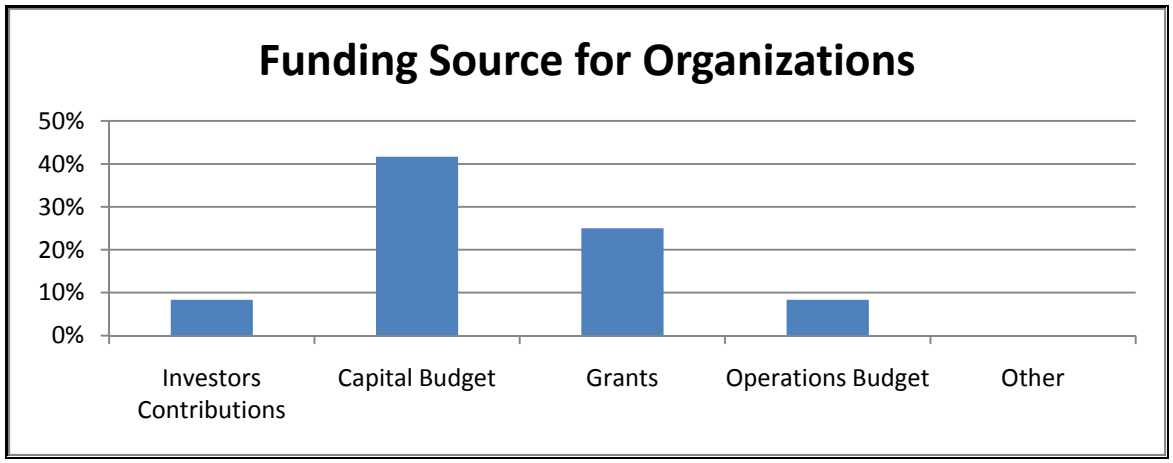

Figure 42 Funding Source Utilized based on data from 12 Organizations

Figure 42 describes the funding sources of the 12 organizations interviewed for energy conservation retrofits. The interviews revealed that the most commonly available source of funding is from their *capital budget* allocations. This is used because it has the most versatility of the four listed, and also the most readily available, but it has some drawbacks. First, there is one *capital budget* for an organization. This single budget must provide funding to other non-energy conservation projects as well as the ECM projects. Energy retrofit project could benefit from the utilization of a designated capital source that specifically funds energy projects. This source could also be maintained to

prepare for routine upgrades to equipment that has reached its lifespan. This type of funding source is also discussed in section 5.1.3.4.2.

The funds from the *investor contributions* are tied to many expectations for profit and growth. Utilizing these funds for an energy retrofit would require buy in from multiple sources with many different values and views. *Operations budgets* are usually not large enough to fund the upfront cost of the energy retrofits but smaller ECMs like lighting upgrades could possibly be funded by this type of source. The capital budget has the most available funds available that can be directed towards the implementation of ECMs.

The *grants* are many times attached to a particular building or type of improvement. This type of funding will not help tackle the easy, quick payback type of project and the best product may not be produced. The *grants* are a viewed as a single lump sum amount, which directs the decision makers to consider the total cost as the main driver for determining feasibility. The use of the total cost as the driver can prevent proper implementation of the analysis and assessment processes. The detailed analysis may be performed to institute ECMs but the process may lack an adequate assessment to review the best alternative. This is not an integrated approach and will not realize the best results.

5.2.4 Step 4 Design and Planning

The design of the retrofit should utilize the expertise of specialized engineers, architects, contractors and as well as the owner. It is important that the owner relay the building needs and requirements to the designers so that proper measures and strategies are incorporated in the design phase. The scope of work developed in the assessment provides much of the information to include in the design.

5.2.4.1 Design Development

The design drawings of an energy retrofit include defining the existing elements, and providing detailed information of the proposed equipment. The suggested design process takes a six step approach as shown in Figure 43.

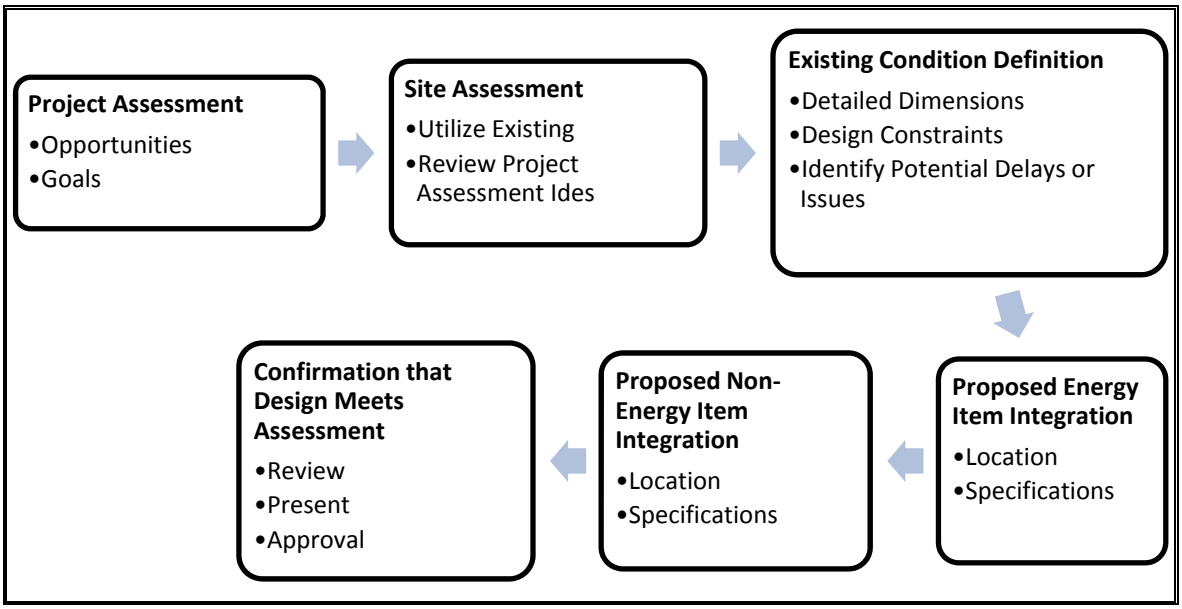

Figure 43 Suggested Design Process Implementations for a Retrofit

The design process begins with the project assessment. The designer discusses the project opportunities and goals among themselves and with the owner. The designers develop a list of potential opportunities for integrating the energy conservation goals of the owner. This is a not a detailed process but enables the designers to utilize their creativity without being hindered by extensive details and requirements. The list can be used later to group or provide ideas when details are considered. The second step is the site assessment. The designer visits the site to review the existing conditions of the building and surrounding area. The designer reviews the list developed in the project assessment to incorporate initial findings. Additionally they review existing conditions that with modifications or upgrade can be utilized in the design to achieve the overall goal of the project.

The third step is further definition of the existing condition of the building. This requires detailed dimensions, layout of design constraints, and identification of potential implementation delays or issues. The plans should incorporate as much accurate detail on the buildings existing condition to help the contractor or installer prepare and perform the construction activity. The early identification of dimensions, constraints, and issues are helpful for maintaining the construction activity flow. This is also necessary for the next steps of developing the technical specification and locations of ECMs and non-

energy conservation items. Finally the design the design is confirmed for compliance through reviews, presentations, and final owner approval.

5.2.4.2 Planning

The implementation of ECMs into the building retrofit scope of work requires advance planning. ECM projects should consider other capital projects, change in use plans, or other non-energy conservation items when prioritizing ECM projects. Prioritizing projects can be done based on funding availability, restrictions and the expiration. These considerations are shown in Figure 44.

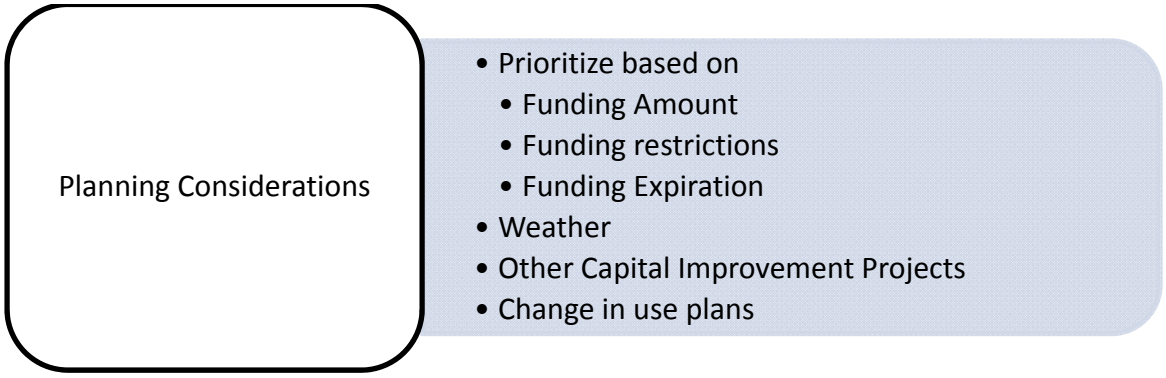

Figure 44 Suggested Planning Considerations

Additionally the projects need to be planned so that weather is not a major factor on the construction activity. For example it is not conducive to perform an HVAC improvement in the middle of winter when occupants are still occupying the facility and in need of heating. The planning process must take into account the current and projected use of the building. Change in occupant use plans must factor into the analysis, assessment and design of the energy conservation retrofit.

5.2.5 Step 5 Approval

The approval step is important for the organization to insure that the project achieves the desired environmental and cost savings goals. The cost of installation of the project must be within the available funds and proposed financing mechanism. The organization must monitor the implementation of construction bids, and the construction

process to insure that ECMs specified are not altered or eliminated. The design intent can be altered if contractor requests for different specified equipment are not evaluated prior to approval. Following construction completion the organization must institute a commissioning process of all the ECMs to confirm that they are working properly and that they can be maintained to work as designed.

5.2.5.1 Achievement of Goals

The organizations interviewed had two main goals in performing an energy retrofit: 1) Low Cost and 2) High energy savings. Organizations must confirm that the ECMs assessed and propoesed in the decision process meet these goals.

Table 10 Goal Indicators for Organization Approval

Goals	Indicator 1	Step Defined In	Indicator 2	Step Defined In
Energy Savings	EUI	Building Energy Data	Calculated Energy Reduction	Assessment
Cost Savings	Financial Calculations	Assessment		

Energy savings can be confirmed by reviewing the benchmark and the assessment information to see if the calculated energy reduction matches with the required EUI. The cost savings considers the financial calculations performed in the assessment step. Additionally the approval process must take the next step to confirm that the assessed and approved ECMs required to meet the owner's goals are described in the design documents.

5.2.5.2 Bids & Construction

The bid and construction implementation must include organization involvement. It is important that measures and monitoring techniques are used during the bid process so that contractors cannot make significant changes through substitutions. The integrated process requires that the integrity of the design is not altered by contractor competition and modifications of the design specifications.

5.3 Organization Integration of Integrated Decision Process Steps

The organizations interviewed utilized some but not all of the steps that are defined in the integrated decision process. The information given by the organizations helped develop the integrated process. Some organizations stated a process that they would prefer to incorporate if provided the time and resources. For example one organization does not perform simulation or modeling of the building but believe it is an important step. Table 11 below indicates what each entity incorporates and does not incorporate into their decision processes.

Table 11 Organizations Utilization of Integrated Process Steps(Y=Yes, N=No)

Organization	Building Energy Data	ECM ID & Analysis	Assessment	Model & Simulation	Design & Planning	Approval & Implement
Integrated	Y	Y	Y	Y	Y	Y
1	Y	Y	Y	N	Y	Y
2	N	Y	Y	N	N	Y
3	N	Y	Y	N	Y	Y
4	Y	Y	Y	N	Y	Y
5	N	N	N	N	N	N
6	N	N	Y	Y	Y	Y
7	N	Y	Y	N	Y	Y
8	N	Y	Y	N	N	Y
9	N	N	N	N	N	N
10	N	Y	N	N	N	Y
11	N	N	N	N	N	N
12	N	Y	Y	N	Y	Y

The interviews revealed that only 17% of the organizations used building energy data and 8% used modeling software and techniques. The underutilization of these steps and critical technique of modeling and simulation could be attributed to lack of knowledge and lack of resources. Additionally 67% used ECM Identification & Analysis, 67% Assessment, 50% Design & Planning, and 75% Approval & Implementation as shown in Figure 45.

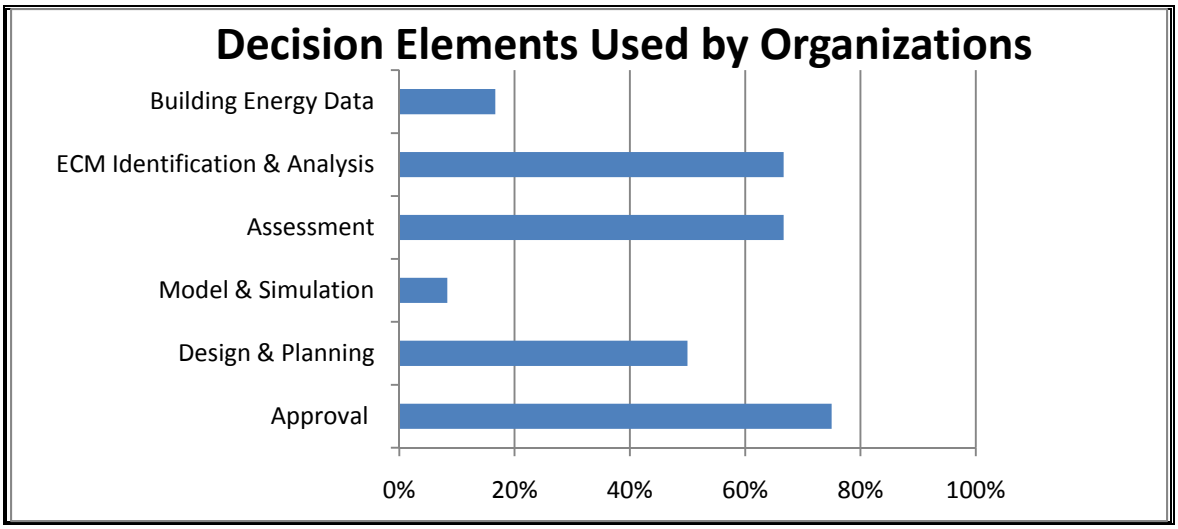

Figure 45 Integrated Decision Elements Used based on data from 12 Organizations

Building energy data and modeling were underutilized by the 12 organizations interviewed. Both elements provide valuable direction for proper implementation of the integrated decision process. The decision process must consider the current condition of the building and ultimate goals of the owner. It should also consider alternatives that have been extensively analyzed through advanced methods such as modeling and simulation.

5.3.1 Building Energy Data

Building Energy Data is an important step in the decision process that many of the organizations interviewed did not utilized. The two organizations that have building energy data in their process were observed to not use it to its full potential. The lack of use can be attributed to the lack of resources available. Organizations are limited in funds and personnel to establish and evaluate the building energy data step. The resources necessary for performing this step are described in section 5.1.1.1, but are actually minimal and many organizations have the resources available already. The real reason for not evaluating the building energy data is due to minimal understanding of how to perform the step and how it can be useful.

The basic concept of the building energy data step is the establishment and comparison of the Energy Performance Indicator (EPI) of the building in question to

similar buildings in comparable climates. The establishment of an EPI has many benefits for an organization. The organizations interviewed lacked the establishment of a defined energy reduction goal. The building energy data process can help the organization establish a goal by creating a database of energy consumption and calculating an EPI for each building. Then compare the EPI of the building with others of similar type and location to understand its energy consumption status. The buildings can provide the organization with a value of what the energy reduction potential is for the building.

The EPI can then be used to verify and confirm that results of the implemented ECMs meet the established goal. Monitoring the EPI can also help in the ECM phased approach, such as in the modification of behavior to reduce energy consumption. The final point for the establishment of an EPI is to aid in the achievement of tax incentives for funding the energy retrofit. The State of New Mexico offers tax incentives to existing buildings that achieve LEED certification as well as an energy reduction of 50% based on a building of similar type that consumes the amount of energy equal to the national average. The analysis and assessment of the 50% reduction utilizes EPI information so that appropriate measures are taken to insure that the most cost effective alternatives are considered.

5.3.2 Modeling and Simulation

Modeling and simulation was used by only one organization. The organization that used this step incorporated the designer's guidance and recommendations from the beginning of the decision process. Designers who focus attention on sustainability and energy efficiency realize the importance of the integrated approach. Other organizations could realize the importance but have not implemented the modeling and simulation to provide accurate analysis and assessment of how the proposed systems will work together to produce the most cost and energy efficient building. The implementation of energy modeling requires upfront costs and time to develop the expertise needed to collect, enter and analyze data using a sophisticated software. Organizations need to realize the benefits of an accurate integrated approach. The benefits are economical in the long-term.

Organizations like ECMs that have quick financial returns. This concept is widely accepted and organizations base their approval process on the assessment of the simple payback method. The quick fix to energy efficiency is not the appropriate approach. Energy efficient retrofits require considerable upfront time and cost to implement for the most appropriate systems, but they will ultimately have a higher potential of producing energy and cost savings. The return on investment may be longer because of the high initial cost but organizations need to accept this in order to achieve eventual high returns and also greater environmental benefits.

CHAPTER 6 DECISION IMPROVEMENTS

The decision process for energy efficient retrofits has multiple variables for consideration. Organizations can have different values and objectives that affect how decisions are made. The types of building systems and components can also have an effect on the analysis and assessment of the current condition and possible upgrade options. Organizations need to identify energy retrofit considerations and the barriers for implementing ECMs. This is important to understand so organizations can implement the right decision steps to properly review and make informed decisions.

6.1 Recognizing Retrofit Goals

Energy efficiency is the proficient utilization of energy resources. Defining energy efficiency of a commercial building can be difficult. The efficiency depends on the type of building systems as well as the building's use. Implementing energy conservation retrofits many times requires long-term planning that does not have immediate benefits. Individual involved in the decision process may have objectives that are not conducive to long-term planning. The twelve organizations interviewed all expressed interest in achieving energy efficiency, yet the priority of their interest varied. Energy upgrades realize small profit margins in comparison to other organization investments (DeCanio, 1993). The reality for organizations is that they must face other profit and expense issues aside from improving energy efficiency.

The research did not elaborate on organization priorities. The research did recognize that the priorities for building retrofits can vary. The building retrofit considerations can broadly be classified into the essential and non-essential retrofits. Essential retrofits are improvements to rectify a safety concern. Two examples are retrofits needed to fix a structural element or repair a leak in the roof. The non-essential retrofits are improvements to improve non-safety issues. They can be conducted to possibly improve energy efficiency, user comfort, operations costs, or even aesthetics. This hierarchy is depicted in Figure 46.

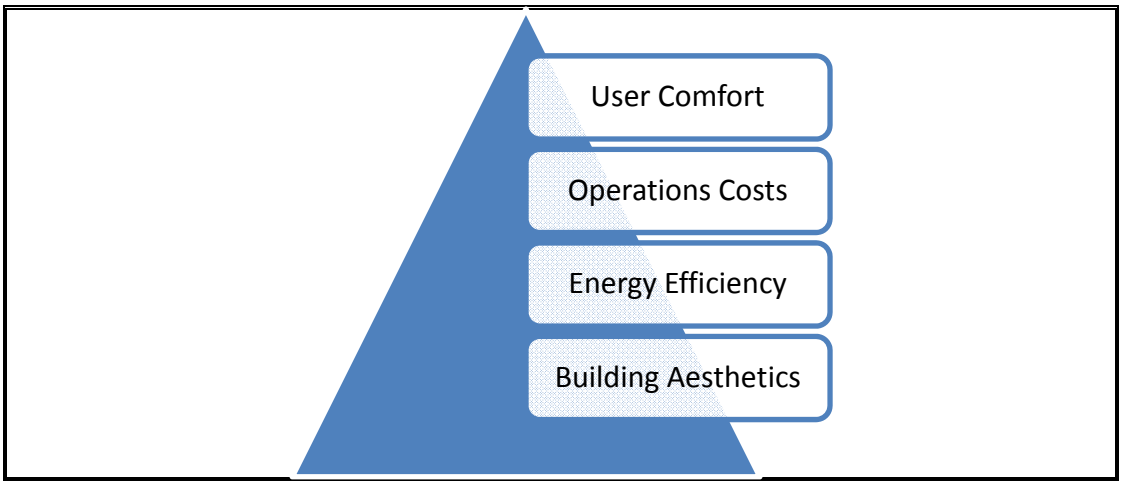

Figure 46 Prioritization of Retrofits base on data from 12 Organizations

The majority of the organizations interviewed communicated that user comfort was the number one element for a non-essential energy retrofit. The next consideration was operations cost, followed by energy efficiency and then building aesthetics.

User comfort and operations costs were found to have precedence over energy efficiency. Because of this, the approval of energy retrofits depends on the decision maker's ability to combine user comfort and operations costs with energy efficiency. This suggests that decision makers should generate multiple goals and combine them to be assessed concurrently in the decision process. The combined goals of a building retrofit to achieve user comfort and energy efficiency have to be financial feasible. Achieving this goal begins with establishment of an indicator for comparison purposes that is to be used during the decision process that combines these criteria.

6.2 Development of Goal Indicators

The development and use of a goal indicator is important to implement in the decision process to insure a desired outcome. Current practice utilizes cost indicators to describe the financial feasibility of a potential project. The common indicator used by many of the interviewed organizations was the payback period. Simple payback was used by almost 75% of the organizations to determine the ECMs implementation feasibility (see Figure 40). Similarly, organizations use environmental indicators to describe the current energy consumption of an existing building. The common indicator

for commercial buildings is the Energy Utilization Index (EUI). The EUI indicator is used to compare the building's energy consumption internally and externally to produce relatively crude assumptions on the energy savings potential that exists within the building. Another component of an indicator is user comfort. User comfort will be determined by the ECMs ability to be flexible and meet user needs. Currently user comfort cannot be quantified numerically. Further research is needed to survey and quantify the flexibility of ECM systems and components but this research will not integrate user comfort into the evaluation.

This research produced a Financial/Energy Indicator, which combines the financial analysis with the building's energy consumption savings. The organizations interviewed attempted to make appropriate decisions on the implementation of ECMs based on the review of the lowest simple payback. There was no indication that the organizations made decisions based on the EUI. The Financial/Energy Indicator will strive to place increase focus on the energy savings. The indicator calculates a percent energy savings and the rate of return on investment percentage predicted for a certain ECM and adds them together to produce an indicator. The indicator is used to compare with other potential ECMs to identify which will realize the most cost and environmental savings. The addition of the energy savings and rate of return on investment percentages to the evaluation provides an indication of the overall potential. The overall potential is important to review so that resources are invested accordingly. Decision makers must insure that funds are being distributed to projects that exhibit the combined financial and energy savings potential. Table 12 describes the ECM and the pertinent data for the Financial/Energy Indicator Analysis for sample projects of a theoretical organization. The table describes 20 different ECM projects that are listed from A to T. Each of the projects has an observed existing EUI, and a proposed EUI based on the ECM(s). The table also describes the installation cost, annual savings, and the payback period for each proposed ECM. The EUI Percent Savings and Rate of Return Percentage were calculated and added together to produce the Financial/Energy Indicator.

Table 12 Energy Conservation List and Data

ECM Project	Pre EUI (kBtu/ft^2)	Post EUI (kBtu/ft^2)	Install Cost	Annual Savings	Payback Period	EUI % Savings	Rate of Return %	Financial/ Energy Indicator
A	72	71	$ -	$ 7,000	0.0	0.01	10.000	10.01
B	54	50	$ -	$ 6,000	0.0	0.07	10.000	10.07
C	60	55	$ -	$ 10,750	0.0	0.08	10.000	10.08
D	73	67	$ 3,000	$ 26,000	0.1	0.08	8.667	8.75
E	67	63	$ 3,000	$ 15,000	0.2	0.06	5.000	5.06
F	77	68	$ 2,870	$ 9,000	0.3	0.12	3.136	3.25
G	82	75	$ 8,000	$ 13,600	0.6	0.09	1.700	1.79
H	113	95	$ 45,000	$ 26,000	1.7	0.16	0.578	0.74
I	114	104	$ 52,064	$ 20,000	2.6	0.09	0.384	0.47
J	250	202	$ 303,000	$ 90,000	3.4	0.19	0.297	0.49
K	75	61	$ 51,000	$ 14,000	3.6	0.19	0.275	0.46
L	184	165	$ 100,000	$ 27,000	3.7	0.10	0.270	0.37
M	71	70	$ 16,000	$ 3,200	5.0	0.01	0.200	0.21
N	98	92	$ 42,000	$ 8,000	5.3	0.06	0.190	0.25
O	60	43	$ 720,000	$ 25,000	28.8	0.28	0.035	0.32
P	220	189	$ 189,000	$ 30,000	6.3	0.14	0.159	0.30
Q	65	64	$ 12,000	$ 1,000	12.0	0.02	0.083	0.10
R	65	55	$ 28,000	$ 8,000	3.5	0.15	0.286	0.44
S	55	45	$ 48,000	$ 16,000	3.0	0.18	0.333	0.52
T	45	35	$ 68,000	$ 24,000	2.8	0.22	0.353	0.58

6.2.1 EUI Percent Savings

The EUI percent savings evaluates the decrease in energy consumption relative to the original energy consumption status. It is the difference between the existing EUI and the proposed EUI divided by the existing EUI.

EUI % Savings = (Pre EUI – Post EUI)/Pre EUI Equation 6.1

The EUI % savings for ECM R is 0.15. This was calculated by subtracting 65 minus 55 to get 10, which is the total EUI upgrade amount. Then 10 is divided by 65 to get the final EUI indicator of 0.15. The numerical tabulation of this is in Table 12.

6.2.2 Rate of Return Percentage

The rate of return percentage evaluates the cost savings potential. The equation below for the rate of return is the annual savings divided by the installation cost.

Rate of Return % = Annual Savings/Installation Cost Equation 6.2

The rate of return for ECM 18 is 0.286. This was calculated by dividing $8,000 by $28,000 is shown in Table 12.

6.2.3 Financial/Energy Indicator

The Financial & Energy Indicator combines the EUI percent savings and the rate of return percentage. The combination is calculated by adding the two percentages together. The higher the indicator value is, the greater the potential for cost and energy savings.

Financial/Energy Indicator = EUI % Savings + Rate of Return % Equation 6.3

Equation 6.3 for ECM R produced a Financial/Energy Indicator value of 0.44. ECM R has a EUI percent savings value of 0.15 which ranks it 7th. Additionally the ECM has a Rate of Return percentage of 0.286 which ranks it 13th. The combination of the two percentages reveals that it is the 14th best ECM to implement out of the 20 considered

ECMs A, B, and C do not have an installation cost which would produce an incomputable rate of return percentage, therefore a factor of 10 was given to ECMs that do not have a payback period. The ECMs without a payback period may not realize a lot of energy saving but the installation comes at no cost and therefore it is an obvious choice for implementation. These estimates and calculations require appropriate expertise and techniques to get acceptable results.

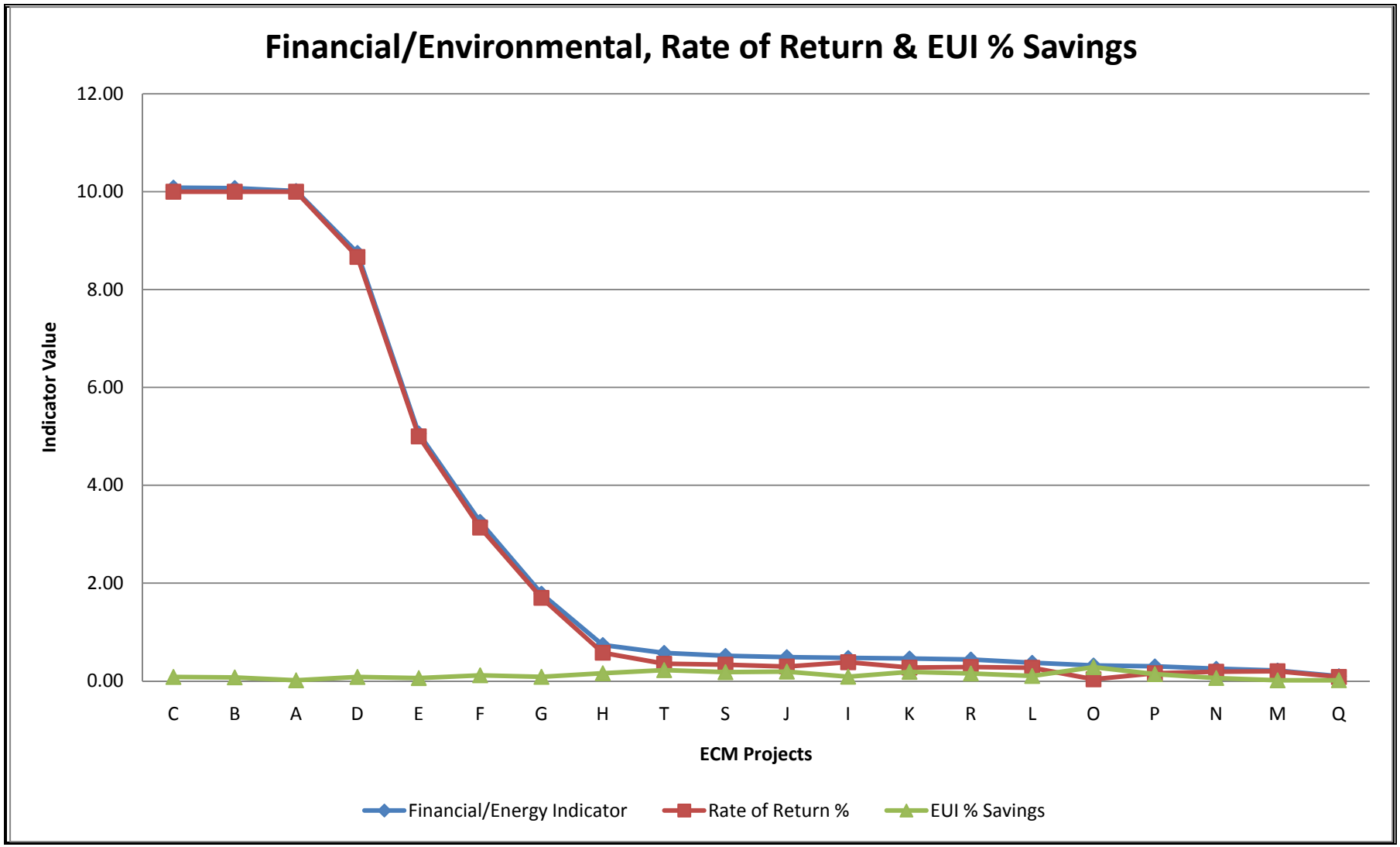

Figure 47 Financial/Environmental Indicators, Rate of Return & EUI % Savings

Figure 47 displays a ranking of the ECMs from highest to lowest energy and financial potential. The ranking is as follows from C, B, A, D, E, F, G H, T, S, J, I K, R, L, O P, N, M, and Q. Additionally Figure 47 displays the Rate of Return Percentage, EUI Percent Savings and Financial/Energy Indicator. The cost savings potential of ECMs C, B, A, D, E, F and G are very high which influences the Financial/Energy Indicator greatly. This is evident in the figure because the Rate of Return and the Financial/Energy Indictor follow very closely for the previously mentioned ECMs. The high cost savings of the mentioned ECMs are due to little to no installation cost, which means that higher influence on the Indicator comes from the Rate of Return.

The influence of the Rate of Return is very high on ECMs C, B, A, D, E, F, and G. For further explanation purposes those ECMs will be considered outliners. Figure 48 focuses on ECMs H, T, S, J, I, K, R, L, O, P, N, M, and Q where the annual savings is considerably less than the installation cost. This figure identifies how the each factor influences the Financial/Energy Indicator. For example ECM I has a lower EUI factor than ECM K, yet the Rate of Return is higher for ECM I. The combination of the factors provide an indication that ECM I has a higher overall financial and energy savings potential then ECM K.

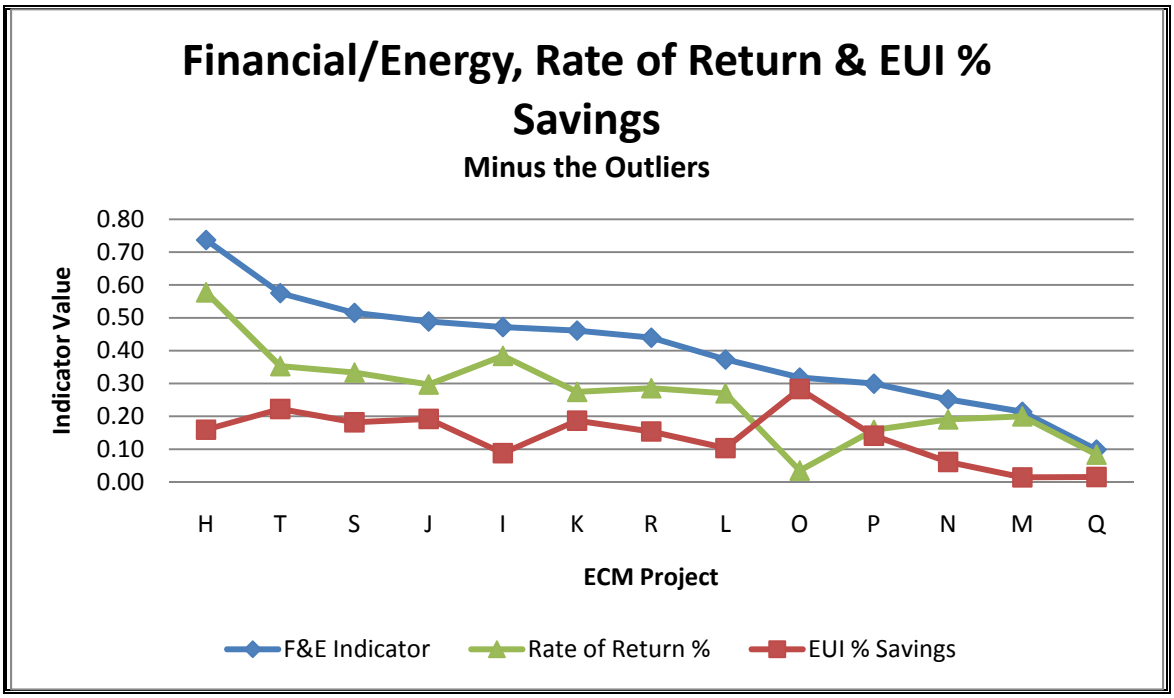

Figure 48 Financial/Energy, EUI % Savings & Rate of Return - Minus the Outliers

6.2.4 Indicator Concerns

The concerns associated with this approach are shown in Table 13. Estimating the Post ECM costs and the EUI can be difficult to perform. The existing information, such as the EUI and the operations cost, can be acquired through review of building energy data database or consultation with the utility company to review total consumption and costs. The calculations and predictions of the post EUI and operating cost can be estimated based on past projects. The energy team can use ECM specifications and perform energy calculations to get a crude estimate. Precise estimates can be acquired through modeling and simulation of the buildings energy consumption.

Table 13 Energy and Cost Estimate for the Financial & Energy Indicator

Elements	Description	Acquisition of Number
Pre EUI	The Energy Use Index before ECM	• Existing Database • Utility Company Data
Post EUI	The Energy Use Index after ECM	• Model • Calculations • Past Project Numbers
Install Cost	The cost to implement ECM	• Contractor Estimate • Past Project Numbers
Pre Operations Cost	The annual existing cost of operation	• Existing Database
Post Operations Cost	The annual proposed cost of operation	• Model • Calculations • Past Project Numbers

The installation cost estimates can be acquired through the review of similar past project and also through contractor estimates of work. It is important to include contingencies with these cost and energy estimates. The estimation process, as indicated by its name, is not an exact science and requires experience. Organization 1 stated, “Triple the cost estimate and divide the energy conservation estimates by 2”. Whether this is true or not is impossible to say but it provides insight into how crude the estimates can be. The estimates are rough, but are essential for providing a starting point.

6.3 Energy Retrofit Barriers

There are many barriers that organizations face when considering energy efficient retrofits. The barriers can completely halt the progression of a retrofit or limit the extent of the retrofit. The major barriers encountered by the organizations, as shown in Figure 49, were upfront cost (33%), lack of knowledge (50%), low returns on investment (33%), time of implement ECMs (8%), and non-energy requirements (17%).

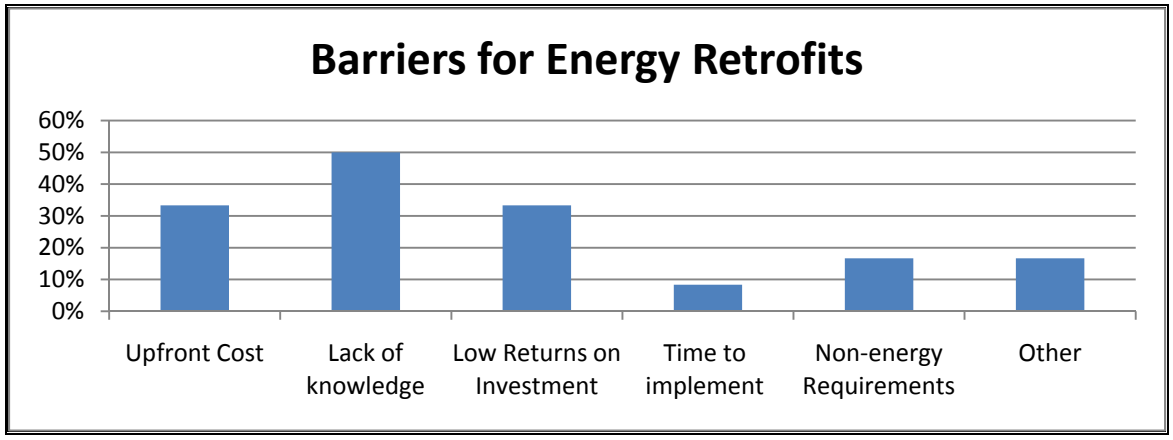

Figure 49 Barriers for Success based on data from 12 Organizations

The types of barriers encountered are important to review. Decision makers need to understand the issues so that they can develop mechanisms for overcoming them.

Organizations should also consider creative ways to approach and finance energy projects. Decision makers who approach projects with creativity and enthusiasm are more likely to accomplish cost effective energy savings. This approach can spark an interest for all involved and promote buy-in. ECM funding can come through typical avenues, or organizations can also use new mechanisms and creative new policies. For example the energy cost saved through behavior modification techniques can be quantified and assembled into a fund that will pay for additional ECMs. Decision makers must also look into new mechanisms such as Energy Performance contracts and Special Assessment Financing.

6.3.1 Upfront Cost

The upfront cost of an energy retrofit is a major barrier to overcome. Organizations have many demands on capital funds beyond energy retrofits. The operations funds are in most cases not substantial enough to cover a major retrofit project. Energy retrofits require incentives or effective means for financing to encourage their implementation. Many financing options are available such as loans, leases, second mortgages, mortgage refinancing, performance contracts, and special tax or assessment levied financing. The new and most effective forms of funding the upfront energy retrofit cost are through the use of Energy Performance Contracts and Special Assessment financing.

Energy Performance Contracts (EPC) is a means for financing that provide no upfront cost to the organization. The EPC funds are provided by a bank or investors. Originally there was a lack of understanding in the banking community, but know banks are getting involved and helping fund these types of contracts. The contract includes all the services required to design, implement and finally monitor and verify the ECM savings (ICF International , 2007). These services can many times be paid through the energy savings produced by the project. The financing is conducted through a third party company, and is typically in the form of an operating or municipal lease.

The special tax or assessment mechanism is very new and just being implemented. State governments have passed legislation giving local government the power to implement Property Assessed Clean Energy (PACE) Bonds. The state of New Mexico passed House Bill 647 which enacted solar energy improvement special assessment but neglected to include energy efficiency. There is currently a movement to include energy efficiency into the bill but is still requires additional legislation. Local governments such as Berkeley (CA), Palm Desert (CA), San Diego County (CA), Sonoma County (CA), Boulder County (CO), and others are actively incorporating the financing mechanism. These entities are recognizing the need to overcome the upfront cost barrier and are forming energy financing districts.

The districts enable local governments to raise money through the issuance of bonds (Fuller et al, 2009). The bonds are used to fund energy efficiency projects. The

financing is then repaid through a special assessment tax that is placed on the property. The financing is secured through a lien that is then placed on the property where the energy retrofit is implemented. This type of financing allows for little to no upfront cost to be incurred on the property owner.

6.3.2 Lack of Knowledge

The lack of knowledge associated with energy efficiency is a major barrier for decision makers. Fifty percent of the organizations interviewed stressed that the lack of knowledge impedes greatly on their process to integrate ECMs. The barrier begins with the occupants who utilize the equipment. The decision makers must also have an in-depth understanding of what energy efficiency is and how to achieve it. The administration individuals who review and approve capital funds for energy efficiency must understand the environmental impacts and cost savings available.

The ability to achieve energy efficiency begins and ends with the occupants. The occupants must understand the overall energy consumption and cost of the building and how they contribute to the total. The energy team must present this to the occupants so that they feel a sense of responsibility to help by reducing their impact. This can be done through training, awareness programs, and most importantly by visible support from upper management. The behavior of the occupants is an important consideration for determining the ECMs to implement. Decision makers must remember to consider occupant behavior effects on energy consumption when considering ECMs.

It is important for decision makers to have a defined process for understanding, analyzing, assessing and implementing ECMs. They must understand the individual systems within the building and how they interact with one another. Their knowledge can be expanded by constant review of new technologies and literature. They must actively pursue training classes and seminars to stay current on recent developments. It is also important that decision makers share their knowledge with others in the organization. Sharing of information can be a difficult issue for some organizations because they feel that sharing could divulge secrets that will help their competitors. This idea should be reconsidered due to the many new ideas that can be learned from other

organizations to help improve their own. Sharing can also provide an organization with a means for comparing their process, and results with others to determine where they can improve.

The administration may be reluctant to approve funds for projects that receive little immediate financial benefits. Therefore the administration must understand the decision maker's process, and the various means for financing the project. This understanding will help promote a decision process that includes a link to the particular funding or financing mechanism most appropriate for the organization or project. The administration should be able to support the decision maker's assessments since it is based on appropriate analysis. Administrators who show bias or exclusion to various ECMs must have legitimate reasons.

6.3.3 Low Returns on Investment

The low returns on investment occur through the combination of high upfront cost and low cost savings. This barrier can be addressed through the integrated decision approach, the accuracy of construction cost estimates, and financing options. The first option for addressing the issue is to evaluate multiple ECMs in an integrated manner. The integrated approach will evaluate the interaction of multiple ECMs to create the optimal energy retrofit alternative. The integration of multiple ECMs into one project will allow the ECMs with high returns on investment to offset the ones that have low returns on investment. This type of assessment relies on the integrity of the estimate to provide a realistic basis for installation or construction of an ECM, and the assessment of the return on investment.

The construction estimate is a major factor affecting the analysis and assessment of the return on investment. The estimates that are used in the assessment are provided to organizations through energy consultant reports, or past project historical numbers. The estimates have the potential to vary greatly from the actual cost. Construction estimates can vary in accuracy depending on the available detail of the scope of work. Most of the organizations interviewed did not take into account the accuracy of the cost estimate, 42% did not know of what kind of accuracy to expect, 17% expected a feasibility

estimate, and 17% expected a concept study estimate. The estimate can range from least accurate, feasibility, to most accurate, bid. Figure 50 shows the breakdown of expected accuracy of construction estimates for organizations to base their financial decisions on.

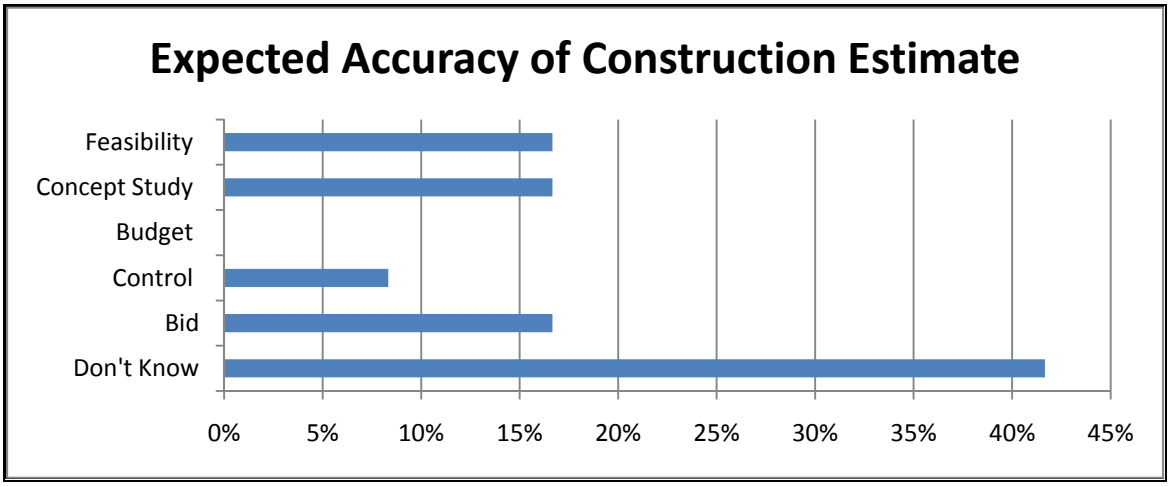

Figure 50 Expected Accuracy of Estimate based on data from 12 Organizations

One organization said that the estimates of construction cost from energy consultant reports were very high and resulted in low return on investment. Realistic cost estimates can improve assessment process and improve the overall results of the return on investment. Organization 7 (described in section 4.7) incorporated an accurate bid estimate effectively in the decision process.

Another method for overcoming the low return on investment barrier is to use the financing offered by an Energy Financing District. This financing mechanism is described in section 6.5.1. It provides a sufficient means for organizations to implement ECMs. The financing eliminates the upfront cost and allows for long term pay payment periods (Fuller et al, 2009). The return on investment is negligible in this financing option because there are no upfront costs required.

6.3.4 Time to Implement

The extensive time to gather information, make decisions, and procure financing needed to implement a project was considered a barrier for one of the organizations. The time needed to implement an energy retrofit is often underestimated. This research identified two ways for improving the implementation time: 1) Establish the means for

financing early, and 2) have a defined decision process. The early identification of the best financing option will help the energy team meet the financing criteria and fill out the needed documentation for approval. A well defined decision process will clarify the role of each individual or entity involved, so that everyone knows their role and responsibility eliminating confusion that can slow the process down. A documented process will also help the decision makers understand sequencing of project requirements early on, eliminating time wasted on searches for information.

6.3.5 Split Incentives

Ideally organizations would receive the financial benefits from the installation of ECMs into their buildings, yet organizations can be faced with split incentives associated with an energy conservation retrofit. This occurs when the organization leases space to a tenant who pays the utility bill and therefore the organization cannot realize the energy cost savings. There are several different types of tenant leases: full service gross, modified gross, commercial gross, single net, double net, and triple net lease. The lease types define who is responsible for base rent, utilities, maintenance and repair, insurance and taxes.

Table 14 Lease Agreements based on data from 12 Organizations

Type of Lease	Responsible Entity (T – Tenant, O – Building Owner)				
	Base Rent	Utilities	Maintenance & Repair	Insurance	Taxes
Full Service Gross	T	O	O	O	O
Modified Gross	T	T	T	T	T
Commercial Gross	T	T	O	O	O
Single Net	T	T	O	O	T
Double Net	T	T	O	T	T
Triple Net	T	T	T	T	T

There is only one lease shown in Table 14, full service cross lease, where the building owner pays for the utilities. This type of lease is not typical for commercial buildings with multiple tenants. Organization 8 noted that modified gross lease with a base year is the typical form of lease utilized.

Organizations in the split incentive situation must consider updating lease agreements to have the potential to realize cost savings associated with energy retrofits.

The agreements could be modified to include a clause that the owner reserves the right to supply their energy at or below the cost of energy supplied by the normal provider. The new lease would require a definition of the base year annual energy cost.

Table 15 Updated Lease Agreement Cost Breakdown Example

Entity	Energy Cost (annual)	Operations Cost Savings (annual)	ECM Construction Cost	Simple Payback Period
Owner Cost	$10,859	$11,008	$140,000	13 yrs
Tenant Cost	$21,867	-	-	-

The owner can then perform an energy retrofit and realize energy savings. The owner would pay the utility company the reduced amount due to the implementation of the ECMs and receive the full amount from the tenant. Table 15 displays example data where the owner would achieve a simple payback of 13 years from an energy retrofit that cost $140,000. That means that after the 13 year the owner would be gaining $11,008 annual profit as a result of the ECM investment.

The implementation of this scheme could be conducted through the incorporation of lease update considerations into the decision process. The suggested method would require careful analysis and assessment to ensure it feasibility. The key consideration would be the building owner's ability to update the tenant leases that eliminates the barrier and actually provides an incentive for all parties to conserve energy and implement ECM projects.

CHAPTER 7 CONCLUSION

The efficient use of energy is an important topic for existing commercial buildings. There are over 4.9 million commercial buildings in the United States that combine to consume about 6,523 Trillion Btu of energy each year. This is significant in regards to dependency, cost, and environmental impacts. Architects, engineers, operations personnel, maintenance personnel, and occupants must understand this impact and how they can contribute to decrease their energy consumption. Building owners have an obligation as well to recognize the status of their building and review possible energy conservation measures. This can be a cumbersome process initially but is necessary to reduce energy consumption and is profitable in the long run.

7.1 Conclusion

The presented research discovered the best decision process for commercial building owners considering a retrofit that includes energy conservation measures. The research described current decision steps utilized by actual organizations. Then it compared, and evaluated their process to determine the best approach and recommended how organizations could improve their decision process.

The research utilized a collective case study design approach. This approach utilized literature review and interviews to synthesis information. The literature review included books, articles and manuals. The interviews consisted of question and answer sessions, observations of process, and review of processes documents provided by the organizations. The relevant literature was evaluated and discussed. The information provided insight and details on information already researched. The interviews provided the current status of energy retrofits, practices utilized in the industry today and details concerning the real life barriers to the successful implementation of need energy conservation retrofits.

The integrated decision process for energy conservation retrofit projects was based on the literature review and organization case study interviews. The recommended decision process should consist of the following steps:

1) Building Energy Data

2) ECM Identification & Analysis
3) Assessment
4) Model & Simulation
5) Design & Planning
6) Approval & Implementation

These steps outline the necessary measures to be taken to ensure the best possible energy reduction and cost savings results. The majority of the case study organizations exhibited practices that were focused on quick results rather than accurate long-term, sustainable savings. The mindset must change and upfront investments need to be made for proper evaluation to improve the overall decision process and retrofit results.

7.2 Future Study

Existing building energy retrofits considerations and potential decision processes are only beginning to be evaluated and incorporated. There is a need for better strategies to overcome the real and perceived barriers encountered by decision makers today.

- Improved Feasibility Indicators
- Improved building energy data evaluation and comparison techniques
- Improved real-time understanding of building energy consumption
- Improved construction cost estimating
- Advancements in financing
- Integrated decision and design approach improvements
- Better building and equipment Modeling and Simulation programs and techniques
- Integrating energy efficiency and renewable energy source into the decision process

The improvement of the decision processes associated with energy conservation retrofit analysis and implementation is essential for reducing commercial building energy consumption. Current practices are hindered by the lack of understanding and support at all levels. Organizations and occupants of buildings must understand the impacts of their

actions or lack of actions on the long-term costs and environmental impacts of operating their buildings. This requires a change that can be difficult for people to accept. Change must be promoted through education, commitment and long term planning that feeds a clear, inclusive, and well thought out energy conservation retrofit decision process.

APPENDIX A - ENERGY RETROFIT LEVELS

Energy retrofits can be conducted in different levels based on certain building and owner constraints. The limitations are defined by the decision maker within the appropriate decision process. The type of retrofit can be defined in three stages: 1) Re-commission, 2) Energy Upgrade, and 3) Renovation. The energy conservation measures that fall within the re-commissioning level are items such as upgrade of light fixtures, fine tuning thermostats, verification of controls, and behavior modification among others. The next level, which is the energy upgrade, incorporates more intensive energy conservation measures. The majority of the installation and construction of an energy upgrade involves energy conservation measure improvements with the possibility for minor, associated structural or architectural improvements. Energy upgrades include retrofits to the HVAC equipment, motor upgrades, fenestration upgrades and many others. The last level is the renovation, which is a project that retrofits a building for a change in use, structural deficiency or architectural improvement while integrating energy efficiency measures. The renovation could include a comprehensive envelope upgrade, on-site solar system, and relocation of interior walls, change in heating and cooling system, and many others.

Table 16 Level of Retrofit Descriptions - based on data from 12 Organizations

	Re-Commission	Energy Upgrade	Renovation
Typical Expected Energy Savings	5-30%	20-50%	20-60%
Degree of Difficulty	Low	Medium	Hard
Degree of Investment	Low	Medium	High
Approx. Time to Implement ECMs	Weeks	Months	Years
Improvements Examples	• Light Fixtures • Resetting Thermostats • Verification of Controls	• HVAC Equipment • Motor Upgrades • Fenestration Upgrades	• Comprehensive envelope upgrades • On-site Solar (PV) • Relocation of interior walls

The re-commissioning process can obtain an expected energy savings of up to 30% if implemented properly. A large majority of buildings have not been maintained with the necessary care and simple tweaks can generate substantial savings. Additionally occupant behavior may not support or encourage energy savings. Behavior modification techniques that are 'low cost, no cost' efforts have the potential to save considerable energy. The re-commissioning process requires little to no monetary investment. The performance of minor modifications to building systems simply requires a facility or maintenance person to spend some time walking the building spaces. The behavior modification entails training, incentives, seminars and reminders to influence occupant energy use. These measures are relatively easy to implement and perform. The ease of implementation warrants a time span from conception to completion of the ECMs to happen within a month.

The expected savings achieved by an energy upgrade can range from 20% to 50%. The extent of the energy savings depends on the owner's commitment to the retrofit. The commitment to attain substantial savings of an energy upgrade requires a substantial investment in design and construction with energy savings as the focus. The implementation of the ECMs can be completed with a medium amount of difficulty. This 'medium' designation for implementation difficulty refers to the amount of planning and construction restraints that a typical project could encounter. Energy upgrade retrofits may be limited by construction activity while occupants remain in the building or possibly within a confined time span where completion time is a major constraint. The energy upgrades have the potential to be implemented in a matter of months.

Renovations are comprehensive retrofits that are usually initiated by a building owner's need or a change in use. The retrofit is all-inclusive because it combines architectural and structural aspects with various ECMs. It is important to realize that this type of retrofit is not driven by energy cost savings. Instead the ECMs are integrated into a variety of facets of the renovation. The energy savings alone cannot justify the costs for the project because of the multiple non-energy aspects that make up the retrofit. Yet energy savings can be obtained with proper implementation of the ECMs. Retrofit

projects were able to achieve 60% more energy efficiency following the renovation. The project can be difficult to administer because it requires a great deal of interaction and production from multiple construction and design organizations. The retrofit production process and management strategies are at their highest level. The renovation process requires a high degree of difficulty and time to complete. The project schedule can extend for at least a year from design to construction completion.

APPENDIX B - ENERGY RE-COMMISSION

Organization 1 has multiple buildings that could benefit from the implementation of various ECMs. The organization has been able to secure funding and institute many of these measures. A particular building that houses administrative offices was re-commissioned through the institution of an off-hour setback schedule through alterations to the existing direct digital control (DDC) system. The DDC system is a computer system that measures particular variables, processes data and controls devises (Turner, 2001). The DDC can be programmed to control the HVAC and lighting systems through electrical peak demand limiting, ambient condition lighting control, and time-of-day scheduling. Additionally, the off-hour setback can be set and controlled by the DDC. This control allows for the building to achieve low temperatures during the night, weekend and holiday hours. It also can control the temperatures for normal occupant use during the day. This type of retrofit usually entails little to no cost if the DDC is already in place. Many times this retrofit is required because the maintenance and operations of the building systems are overlooked and assumed to be working properly. This requires it to be reset and the institution of a program that will monitor and verify that the controls are working.

Decision Process

The decision process for this retrofit was fairly minimal. The first step in the process was to consider the existing energy consumption and costs. This data was already accessible because Organization 1 consistently monitors the total energy use of the building. They also have a clear understanding of the equipment and controls currently in the buildings. The next step was the analysis of the energy elements. The analysis quickly revealed that the current system was not controlling the systems effectively. High room temperatures were being maintained during hours when occupants were not in the building. Immediately without having to assess the financial considerations the organization understood cost savings could be achieved without any investment.

Table 17 Re-Commission Retrofit Energy Cost and Consumption Data

	Pre Retrofit	Post Retrofit
Construction Cost Estimate	$0	$0
Total Annual Energy Cost	$81,000/yr	$75,000/yr
EUI (kBtu/Ft^2)	54	50
Target EUI (kBtu/Ft^2)	42	42
Simple Payback (years)	0	0

Table 17 describes that the upfront cost to perform the re-commission retrofit was zero dollars. This is a key indicator that the risk is very small with the potential for a very high benefit to cost ratio. The annual cost of the pre-retrofit building was about $81,000 each year, and after the alteration to the DDC system the building exhibited an operating cost of $75,000 per year. The building achieved a $6,000 annual cost savings with zero upfront cost which calculates to a zero simple payback. This retrofit project was able to save 4 Btu/ft^2 – year. The current EUI of 50 Btu/ft^2 – year places it 8 Btu/ft^2 – year away from achieving the target of 30% savings relative to the ASHRAE Standard 90.1 building. It is also worth noting that it is also a step closer to having the demand amount be low enough to be offset by a renewable energy source that could possibly make it a net zero building.

APPENDIX C - ENERGY UPGRADE

Organization 8 owns an office building that leases to multiple tenants. Each of the tenants has signed a modified gross lease agreement where they have agreed to pay a base rent and utilities. The organization is concerned with maintaining cash flow from the profit they obtain through owning and operating the building. The initial capital to buy the building and perform capital improvements comes from shareholders. The funds to operate and maintain the building are acquired through tenant rental payments.

The particular building highlighted in this research was analyzed and assessed because a defined need was identified. The push to review potential ECMs was due to pressure from the tenant. The tenant request that the building be upgraded to be more energy efficient or they will consider moving their business. The office building has three floors and encompasses 71,664 square feet.

Decision Process

The organization recognized a cause to evaluate the ECM potential. ECMs had to be considered to understand the implementation feasibility. The first step in the process was to hire an energy consultant. The energy consultant performed an energy audit, where they reviewed the current condition and analyzed the existing systems. The analysis included a cost estimate for construction and installation as well as simple payback and percent savings data.

Table 18 Energy Upgrade Retrofit Energy Cost and Consumption Data

	Pre Retrofit	Post Retrofit
Construction Cost Estimate	$0	$400,000
Total Annual Energy Cost	$124,000/yr	$98,000/yr
EUI (kBtu/Ft^2)	65	57
Target EUI (kBtu/Ft^2)	42	42
Simple Payback (years)	0	15

The energy cost and consumption data provided by the energy consultant is shown in Table 18. The assessment performed by the organization was concerned with the construction cost estimate and the payback period. The energy consumption status and savings was not understood and therefore was not considered. The financial information was all that was considered.

APPENDIX D - RENOVATION

This example looks at an organization that decided to renovate a historical building. The building is used for over 500 academic classes during an average semester was in need of several upgrades. The building is about 37,000 square feet that was originally built in 1950 and has never undergone any major improvements or renovations. The building is in need of upgrades to meet current standards. Additionally the organization is committed to implementing environmentally friendly upgrades to obtain a LEED Silver certification. The planned construction is to commence in January 2009 and be completed by December 2010. The improvements will include classroom technology upgrades, a computer classroom, student and faculty shared lounge, energy efficient windows, upgrades to bathrooms, new interior finishes, and significant upgrades to heating, cooling, and ventilation systems.

Although the EUI of the building is about 144 Btu/ft^2 (about 42 Btu/ft^2 above the weighted mean energy and 102 Btu/ft^2 above the ASHREA Standard 90.1 as defined by CBECS) the building was not chosen for a renovation based on energy efficiency. The organization developed a modernization program that is attempting to improve classroom space to attract and maintain student enrollment. The $9.5 million came from a Revenue Bond proceeding. The bond money was allocated to this particular building because it had been identified by a task force for needed upgrades to classroom and student gathering space.

Decision Steps Utilized

The typical energy retrofit decision process for this particular organization was not utilized for this scenario. The process was different because of the funding source. The energy efficient measures chosen were not based on any particular financial analysis. The new energy systems and other building renovation items had to have a combined cost that was under the budget amount. This basically implies that the renovation was ultimately first cost driven. The analysis and assessments performed were based on LEED certification requirements.

Analysis Considerations

The energy engineer and design team performed an analysis that benchmarked the proposed building with a building was a building that met ASHREA 90.1 standard. The identification and analysis of ECMs were based on age and condition, energy use review, modeling and simulation. The modeling program utilized was Trace700, which is a comprehensive building analysis software produced by Trane®. The modeling process consisted of establishing two baseline buildings, and a proposed alternative. The two baseline buildings included one that utilized the district energy system and one that did not. Then system checksums were calculated that looked at the cooling, heating, airflows, temperatures, and other elements.

Assessment

The assessment of the proposed energy retrofit included a comparison of baseline and potential energy consumption numbers and costs. This information was reviewed using standard reports produced by the model. The energy numbers were itemized for energy consumed by equipment, peak electrical consumption, total energy consumption, and energy cost. Additionally comparisons between the baseline and proposed alternative displayed the first cost difference, down payment difference, net present value of incremental cash flows, life cycle cost difference, simple payback, internal rate of return, cash flow difference, and present value of cash flow difference. Further economic summaries provided information on the construction, utility, maintenance, and life cycle costs. The information provided by the model includes substantial data for performing an accurate assessment to determine the viability of the project, yet none of these were considered. The project approval was based completely on first cost.

The requirement to have an acceptable first cost was evident in the assessment of HVAC system. The engineer proposed a chilled beam system, yet when the organization saw the cost estimate it was immediately denied. The Variable Air Volume system with reheat was chosen instead because of the lower upfront cost. The construction cost of the proposed renovation was estimated to be $8,734,440 and of that the proposed cost for

implementation of the ECMs was about $4,872,000. The annual cost for operations improved from $84,363 per year to $44,458 per year.

Table 19 Renovation Energy Cost and Consumption Data

	Actual Existing Building	Baseline (30% Savings)	Proposed (60% Savings)	Proposed ECM only (60% Savings)
Construction Cost Estimate	$0	$7,087,089	$8,734,440	$4,872,000
Total Annual Energy Cost	$84,363/yr	$64,818/yr	$44,548/yr	$44,458/yr
EUI (kBtu/Ft^2)	144	110	78	78
Target EUI (kBtu/Ft^2)	-	60	42	42
Simple Payback (years)	0	109	196	109

The ECM retrofit was projected to achieve 60% savings of the actual energy consumption of the pre-retrofit building. The savings achieved a EUI of about 78 Btu/ft^2 – yr. This is a significant improvement but it does not match the mean and target energy use intensity relative to the ASHRAE Standard 90.1. The baseline building that was used for comparison based on ASHRAE Standard 90.1 had a calculated EUI of 110 Btu/ft^2 – yr. This particular type of building, according to the 2003 CBECS tables, should have a mean EUI of 60 (compared to 110) Btu/ft^2 – yr, and a target EUI of 42 (compared to 78) Btu/ft^2 – yr.

The lack of compliance of energy use numbers could be attributed to the assessment's driving factor, of achieving a certain upfront cost. This ignored the analysis of other alternatives and neglected the use of other financial measures. The payback period for the ECMs was not considered in the assessment. This is clear because assessment would have calculated a 196 year payback period, which is not acceptable. It could have been appropriate to factor in a Life Cycle Cost Analysis (LCCA) to assess net present value, annual costs, and benefit cost ratio. The use of LCCA could compare various alternatives and discover a cost effective means for reducing the energy demand. The organization spent about $5 million on the installation of ECM in a renovation project that completely gutted the existing building. It is hard to believe that that much

money was spent to achieve a decrease in 66 Btu/ft^2 – yr, and additionally not meet set targets.

REFERENCE

2030 Inc./Architecture 2030. (2009). *The 2030 Challenge*. Retrieved September 2009, from Architecture 2030: http://www.architecture2030.org/2030_challenge/index.html

Abouzelof, Y. (2007). Improving Efficiency and Performance by Analyzing the Energy Utilization Index. *Energy Engineering , 104* (4), 65-76.

ASHRAE. (2006). *ASHRAE Green Guide, The Design, Construction, and Operations of Sustainable Buildings - 2nd edition.* Burlington: Butterworth-Heinemann.

Baker, R. P. (2005). Life Inside a Coporate Energy Consumer. *2005 ACEEE Summer Study on Energy Efficiency in Industry* (pp. 3-9 - 3-16). West Point: American Council for an Energy Efficient Economy.

Birchfield, G. S. (2000). Issues and Challenges In Energy Benchmarking. *Energy Engineering , 98* (2), 38-52.

Brancic, A. B., & Peters, J. S. (1991). Impacts of Optimum Cost Effective Energy Efficiency Standards. *Proceedings of the 26th Intersociety Energy Conservation Engineering Conference*, (pp. 117-121). Boston.

Buckingham, M., & Coffman, C. (1999). *First, Break All The Rules: What the World's Greatest Managers Do Differently.* New York City: Simon & Shuster.

Burr, A. C. (2008, March 26). *CoStar Study Finds Energy Star, LEED Bldgs. Outperform Peers.* Retrieved September 20, 2009, from Costar Group Headlines: http://www.costar.com/News/Article.aspx?id=D968F1E0DCF73712B03A099E0E99C679

Burr, A. C. (2009, March 18). *RREEF Report: Recession Fails to Diminish Demand for Green Real Estate.* Retrieved September 20, 2009, from CoStar Group Headlines: http://www.costar.com/News/Article.aspx?id=EF6D89484B7EDA25DBF66CCFCD8AAE32

Creswell, J. W. (2007). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches.* Thousand Oaks, CA: Sage Publications, Inc.

de Wilde, P., & van der Voorden, M. (2004). Providing computational support for the selection of energy saving building components. *Energy and Buildings* , 749-758.

DeCanio, S. J. (1993). Barriers within firms to energy efficient investments. *Energy Policy* , 906-914.

Deloitte Consulting and Charles Lockwood. (2008). *Deloitte Real Estate.* Retrieved September 2009, from Deloitte Consulting LLP Website: http://www.deloitte.com/dtt/article/0,1002,sid=2232&cid=213564,00.html?id=dtt-gfsi-list-risk

EIA. (2009, July 13). *Energy Information Administration*. Retrieved November 14, 2009, from Use of Energy in the United States Explained: http://tonto.eia.doe.gov/energyexplained/index.cfm?page=us_energy_use

EIA. (2003). *Energy Information Administration: Commercial Buildings Energy Consumption Survey*. Retrieved from Overview of Commercial Buildings: http://www.eia.doe.gov/emeu/cbecs/cbecs2003/overview1.html

EIA. (2009, March). *Energy Information Administration: Office of Energy Statistics for the US Government*. Retrieved September 27, 2009, from Electricity Basic Statistics (2007 Data): http://www.eia.doe.gov/basics/quickelectric.html

EIA. (August 2009). *Energy Information Administration: Office of Energy Statistics for the US Government*. Retrieved September 27, 2009, from Consumption, Price, and Expenditure Estimates: http://www.eia.doe.gov/emeu/states/_seds.html

EIA. (September 24, 2009). *Energy Information Administration: Office of Energy Statistics for the US Government*. Retrieved September 27, 2009, from State Energy Profile: New Mexico: http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=NM

EIA. (September 2009). *Energy Information Administration: Official Energy Statistics for the US Government*. Retrieved September 27, 2009, from Retail Sales of Electricity to Ultimate Customers: Total by End-Use Sector : http://www.eia.doe.gov/cneaf/electricity/epm/table5_1.html#_ftn1

EIA. (October 2009). *Environment energy-related emissions data & environmental analyses.* Retrieved September 29, 2009, from Energy Information Administration: Office of Energy Statistics for the US Government: http://www.eia.doe.gov/environment.html

EPA. (2009, July 10). *U.S. Environmental Protection Agency*. Retrieved September 27, 2009, from EPA Green Buildings: http://www.epa.gov/oaintrnt/projects/index.htm

Fickes, M. (2006, March/APril). *Real Estate Portfolio.* Retrieved 2009, from Features: http://www.realestateportfolio.com/portfoliomag/menu/features.shtml

Fuller, M. C., Kunkel, C., & Kammen, D. M. (2009, September). *Guide to Energy Efficiency & Renewable Energy Financing Districts for Local Governments.* Retrieved October 13, 2009, from Renwable and Appropriated Energy Laboratory: http://rael.berkeley.edu/financing/resources

Gatton, T. M., Jaeger, S., Lee, Y., & Beaudry, M. A. (1995). Expert System to Determine Energy-Saving Retrofit Potential of Public Buildings. *ASHRAE Transactions Research , 101* (2), 163-171.

Grant, N. S. (2008). *The Pocket Idiot's Guide to Your Carbon Footprint.* New York City: Penguin Group Inc.

Greenaur, D. (2006). Adding Value to Energy Management by Benchmarking. *Building Operator Certification Newsletter ,* 3-4.

Gustafsson, S.-I., & Karlsson, B. G. (1991). Window Retrofits: Interaction and Life Cycle Costing. *Applied Energy* , 21-29.

Hancock, D. R., & Algozzine, B. (2006). *Doing Case Study Research: A Practical Guide for Beginning Researchers.* New York City: Teachers College Press.

Hansen, J., Sato, M., Kharecha, P., Beerling, D., Berner, R., Masson-Delmotte, V., et al. (2008). Target Atmospheric CO2: Where Should Humanity Aim? *The Open Atmospheric Science Journal* , 217-231.

Hellmund, A., Van Den Wymelenberg, K. G., & Baker, K. (2008). Facing the Challenges of Integrated Design and Project Delivery. *Energy Engineering* , 36-47.

Hirst, E., Clinton, J., Geller, H., & Kroner, W. (1986). *Energy Efficiency in Buildings: Progress and Promise.* Washington, D.C: American Council for an Energy-Efficient Economy.

ICF International . (2007, October). *Introduction to Energy Performance Contracting.* Retrieved October 13, 2009, from US Environmental Protection Agency - Energy Star Buildings: www.energystar.gov/.../Introduction_to_Performance_Contracting.pdf

IPCC. (2007, November 12-17). *Intergorvernmental Panel on Climate Change - Fourth Assessment Report.* Retrieved September 21, 2009, from Climate Change 2007: Synthesis Report Summary for Policymakers: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

KoyotoNow. (2009, September 28). *Home: KoyotoNow*. Retrieved September 28, 2009, from KoyotoNow: http://www.rso.cornell.edu/kyotonow/index.html

MacDonald, M. (2000, August). *Higher Education Energy Performance Indicators.* Retrieved October 10, 2009, from Oak Ridge National Laboratory: http://eber.ed.ornl.gov/commercialproducts/CCAS9798.htm

Mazria, E., & Kershner, K. (2008, April 7). *The 2030 Challenge - Architecture 2030.* Retrieved September 2009, from The 2030 Blueprint: Solving Climate Change Saves Billions: http://www.architecture2030.org/2030_challenge/index.html

McKinsey & Company. (2009, July). *Unlocking Energy Efficiency in the U.S. Economy.* Retrieved November 1, 2009, from McKinsey Global Energy and Materials: http://www.mckinsey.com/

Meckler, M. (1984). *Retrofitting of Commercial Institutional and Industrial Buildings for Energy Conservation.* New York City, NY: Van Nostrand Reinhold Company Inc.

Meffert, W. A., & Brown, M. L. (2005). Energy Data Modeling and Analysis for Improved Energy Management Planning and Performance. *2005 ACEEE Summer Study on Energy Efficiency in Industry* (pp. 6-115 - 6-126). West Point: American Council for an Energy Efficient Economy.

Miller, N., Spivey, J., & Florance, A. (2008). Does Green Pay Off? *Journal of Sustainable Real Estate* .

Nilsson, P.-E., Aronsson, S., & Jagemar, L. (1994). Energy-efficient retrofitting of office buildings. *Energy and Buildings* , 175-185.

Novelli, L. (2007, September/October). *Real Estate Portfolio.* Retrieved 2009, from Features: http://www.realestateportfolio.com/portfoliomag/menu/features.shtml

NRDC. (2007, December 3). *An Economic Blue Print For Solving Global Warming*. Retrieved November 1, 2009, from Natural Resource Defense Council: http://www.nrdc.org/globalWarming/blueprint/default.asp

Parker, G., Chao, M., & Gillespie, K. (2000). Energy-Related Practices and Invetment Criteria of Corporate Decision Makers. *Efficiency & Sustainability; proceedings, 2000 ACEEE Summer Study on Energy Efficiency in Buildings , 8* (1), 8.257-8.269.

Perez-Lombard, L., Ortiz, J., Gonzalez, R., & Maestre, I. R. (2009). A review of benchmarking, rating and labeling concepts within the framework of building energy certification schemes. *Energy and Buildings* , 272-278.

Ruiz, R. R. (2005). On the Adoption of Improved Energy Efficiency in Buildings: Perspective of Deisgn Firms. *Strategic Planning for Energy and the Environment* , 66-69.

Schipper, L., Meyers, S., Howarth, R. B., & Steiner, R. (1994). *Energy Efficiency and Human Activity: Past Trends, Future Prospects.* Melbourne: Cambridge University Press.

Seidel, J. V. (2008). *Qualitative Data Analysis.* Retrieved from Qualis Research: www.qualisresearch.com (originally published as Qualitative Data Analysis, in The Ethnograph v5.0: A Users Guide, Appendix E, 1998, Colorado Springs, Colorado: Qualis Research)

Sidebottom, K. (2006). Energy Star Rating system & LEED EB Certifcation: A comparison of two complimentary programs. *Strategic Planning for energy and the environment , 26* (1), 25-31.

Sobek II, D. K., & Smalley, A. (2008). *Understanding A3 Thinking: A Critical Component of Toyota's PDCA Management System.* Boca Raton: CRC Press .

Tannenbaum, K. (2005). Tools to Drive Energy Efficiency Improvements. *2005 ACEEE Summer Study on Energy Efficiency in Industry* (pp. 3-153 - 3-162). West Point: American Council for an Energy Efficient Economy.

Taylor-Powell, E., & Renner, M. (2003). *Evaluation Publications.* Retrieved October 4, 2009, from Program Development and Evaluation, University of Wisconsin-Extension: http://www.uwex.edu/ces/pdande/evaluation/evaldocs.html

Turner, W. C. (2001). *Energy Management Handbook 4th Edition.* Lilburn, GA: Fairmont Press, Inc.

Vaidya, P., Greden, L., & Eijadi, D. (2009). Integrated cost-estimation methodology to support high-performance building design. *Energy Efficiency* , 69-85.

van der Merwe, C., & Grobler, L. (2003). How to use the Commercial Benchmarking Database to establish the potential of an Energy Efficient upgrade in a Commercial Building. *Jouranl of Energy in Southern Africa* , 40-45.

Yalcintas, M., & Kaya, A. (2009). Conservation vs. renewable energy: Cases studies from Hawaii. *Energy Policy* , 3268-3273.

Yang, J., & Peng, H. (2001). Decision support to the application of intelligent building technologies. *Renewable Energy* , 67-77.

Zelinski, R. W., Gatlin, D. R., Werner, J., & Goldberger, D. (2009, March 25). *US Department of Energy: Financing Energy Efficiency in Buildings.* Retrieved October 4, 2009, from Oak Ridge National Laboratory: Rebuild America Documents: http://eber.ed.ornl.gov/commercialproducts/RBAProducts.htm

Zobler, N., & Hatcher, K. (2003). Financing Energy Efficiency Projects. *Government Finance Review* , 14-18.