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

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ABSTRACT

The process by which a building owner evaluates and decides upon energy conservation measures (ECMs) for a building retrofit is key towards achieving efficient results. However, many owners rely on unsophisticated evaluation methods, which potentially limits the amount of energy reduced in the commercial building. Reducing energy in the nearly 4.9 million commercial buildings is critical because they account for approximately one fifth of the total energy consumption in the United States. Reducing their energy consumption levels will have significant impacts on energy dependency, Greenhouse Gas emissions (GHG), and operations costs. The decision processes of twelve private and public organizations in New Mexico were evaluated through collective case study research. The processes of each organization were compared and key steps were identified. Then the most used and critical steps were combined to create an integrated decision approach that optimizes cost savings and GHG emission reductions. This integrated decision process involves five main steps: (1) Building Energy Data; (2) Energy Identification and Analysis; (3) Assessment; (4) Design and Planning; and (5) Approval.

KEYWORDS

sustainable buildings, energy efficiency, building retrofits, energy conservation, financial performance

1. INTRODUCTION

The decision process for identifying energy efficient retrofits is imperative to bridge the gap between the technical information of a building's energy elements and the organization's economic considerations. Improving the decision process can lead to improved energy efficiency which reduces operations costs, lowers the dependency on nonrenewable energy sources, and decreases overall Greenhouse Gas (GHG) emissions. Current practices for evaluating and deciding upon retrofit options lack a common process. Building owners may not be engineers, they may not have financial expertise, nor may they have a means to link monetary considerations with environmental issues. In these cases, building owners need a defined process to evaluate the building's condition and the potential energy retrofit options, while considering environmental and economic issues simultaneously.

Building energy retrofits are comprised of energy conservation measures (ECMs), which are techniques and technologies that can be implemented to reduce the overall energy consumption of an existing building. Improving the decision process is critical for determining viability and deciding upon the most energy and cost effective retrofit options. These retrofits are necessary to cut operating costs and reduce the high demand on nonrenewable energy sources. The commercial building sector is comprised of about 4.9 million buildings that account for 19% of the total energy consumption in the United States (EIA, 2009). The majority of the total energy (93%) in the U.S is produced from nonrenewable sources, such as coal, natural gas, and petroleum (EIA, 2009). Energy efficient retrofits are crucial for providing a cost effective way to offset nonrenewable energy dependency. They also have the potential to reduce carbon emissions by 1.7 billion tons by the year 2050 while saving a total of $68 billion (NRDC, 2007).

2. BACKGROUND

Organizations must use a clear decision process to analyze and justify energy conservation investments. Information such as energy labeling and rating is important but does not guarantee that the appro-

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priate measures will be evaluated and implemented by the organization. Schipper et al. (1994) notes that, even when information is available, decision-makers may not perform economic calculations in their decision process. Therefore the decisions are based on immediate financial returns and long-term investments are not considered.

The decision process for an energy retrofit project provides information on how to evaluate economic and environmental constraints (Gatton et al., 1995). The objective of the process as described by Gatton et al. (1995) is to discover the potential reduction in energy consumption through the selection of the most cost effective alternative. The basic process uses a three phase approach. The first phase includes the inspection and review of a building's current utility use. The second step examines the specific elements of the potential retrofit. Finally a detailed cost/benefit analysis is performed to determine the actual costs. These basic steps guide the decision-makers in determining which energy conservation upgrades to pursue.

The process should contain important steps for gathering and analyzing information. The steps are useful for decreasing uncertainties (Ruiz, 2005). Ruiz (2005) suggests that the decision-maker should go 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. These steps will improve the overall understanding of the project and direct the decision-maker towards key considerations and past common barriers. Parker et al. (2000) present a method for decision making as well. The decision steps include: 1) tracking of problems and needs, 2) investigate and access equipment options, 3) financial analysis, 4) selection of preferred option, 5) approval, and 6) procurement. The research conducted by Parker et al. (2000) provided insight into twenty-six (26) current organizational practices but did not detail each organization's practices.

Improving energy efficiency through building retrofits is important for environmental reasons. The anthropogenic CO_2 concentrations in the atmosphere have been identified as the leading cause for the rise in global temperatures (IPCC, 2007). The CO_2 emissions are highly affected by commercial buildings and therefore are a clear target for reducing the amount of emissions. Implementing energy retrofits can reduce building CO_2 emissions and have a significant impact on the overall total. The 2030 Challenge recommends that the building industry adopt emission reduction targets through building energy efficiency investments and measures (2030 Inc./Architecture 2030, 2009). These programs are encouraging but there are many barriers that the industry and consumers must overcome to realize emissions reduction goals in a timely and cost effective manner (DeCanio 1993). Overcoming the barriers requires the combination of decision methods, technologies, environmental awareness and government incentives.

Available research has clearly identified environmental issues that are caused by the excessive use of fossil fuels to power commercial buildings. There is a definite need to reduce consumption and past research has identified the importance of a decision process to discover key measures of an energy retrofit. Yet, the research has not outlined a defined process based on an in-depth review of current practice. The research presented in this paper took a case study approach to observe, document, compare and evaluate the process that organizations used when evaluating building retrofit options. The observations included review of building energy audits, inspection of retrofit work completed, and observations of informational and decision making meetings. Based on the interviews and observations a decision process for each organization was identified. Then through a review of literature and actual organization processes, an Integrated Decision Process with detailed steps was defined.

3. METHODOLOGY

Energy efficient retrofits have the potential to achieve economic benefits while simultaneously decreasing the amount of GHG emissions. Yet the contrary can also be true, where the cost to install environmental friendly systems does not always result in a quick return on investment. The responsibilities and decisions for these energy conservation scenarios fall to the shoulders of the building owner. This research highlights actual organizations who are involved in making upgrades to existing buildings with the hopes of reducing energy consumption. In particular, the focus is on the building owner's decision process for determining the specific energy conservation measures. From this focus, the following research questions are posed:

- What decision process should building owners use to identify 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 developing a process that owners can use to ensure that the appropriate issues are considered for the execution of an energy efficient retrofit. The approach will offer decision makers a means to compile and review relevant information, make assumptions, and perform calculations to consider both economic and environmental issues.

3.1 Data Collection

The development of this research relied on qualitative data collected through case study research. The case study research approach involved the selection of a single issue (Creswell, 2007)which was the decision process and data were collected through interviews, observations, and document review. The cases studies defined the processes being used in actual practice. Table 1 provides a breakdown of the twelve organizations that participated in the case studies.

Qualitative data, that was collected through the interviews with organizations identified to be involved in energy efficient building retrofits, provided important insight into current practices and revealed how the available assessment methods and resources are currently being used. The collection of information through interviews is similar to the research by Parker et al. (2000), where decision makers were interviewed concerning their energy related investment practices, processes and criteria.

TABLE 1. Case study organizations.

Organization Type	Number
Public school	3
University	1
Government	1
City/municipality	2
Hotel	1
Office	2
Warehouse	2
Total	12

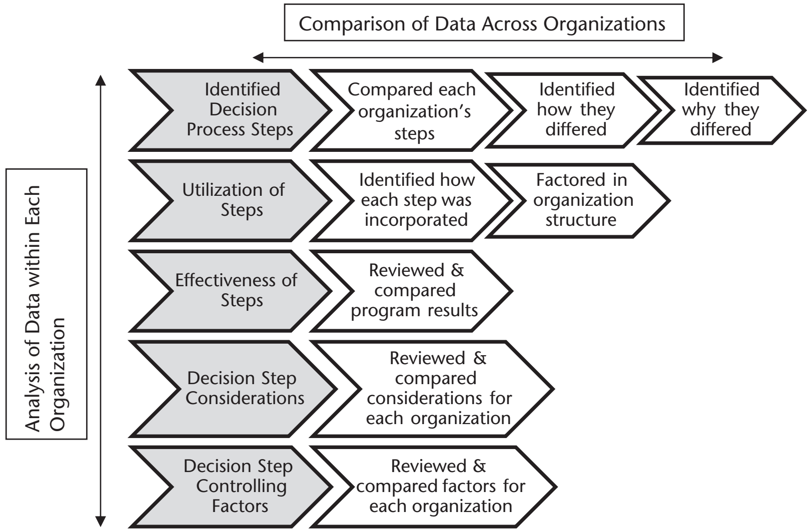
Case study interviews were complimented with a literature review. The literature review included the overview of existing published articles, books, and manuals. Further review included websites and reports pertaining to the subject. The information was synthesized and documented (Hancock & Algozzine, 2006) so that information such as the current status of energy efficient retrofits, energy considerations, and descriptions of evaluation methods could be integrated into the research. The literature was analyzed to identify gaps, strengths and weaknesses.

3.2 Data Analysis

The qualitative analysis approach provokes an infinite cycle of thinking, noticing and collecting information (Seidel, 2008). The theory refers to continually checking conclusions but in actual practice the data analysis quickly comes to a consensus. The recognition of important elements of the collected data was done by continual review and re-reviews of the documents and recorded text from the interviews as suggested in Taylor-Powell & Renner, (2003). Once the in-depth understanding of the gathered information was concluded, a focused analysis identified key elements from the interviews. This required review of the questions or the topics discussed and an analysis of how the individuals or groups responded (Taylor-Powell & Renner, 2003). The analysis identified consistencies and differences among the respondents and then categorized the information (Taylor-Powell & Renner, 2003). Each of the organization's decision process steps was identified. Then the extent of actual utilization and the effectiveness of each step was analyzed. Finally the decision process controlling factors were grouped for comparison purposes.

The final step was to examine and analyze the categorized information (Seidel, 2008). This step was used to better understand the information,

FIGURE 1. Evaluation of categorized information.



identify patterns and relationships, and recognize significant findings (Seidel, 2008). This process allowed for the identification of decision process elements lacking and possible areas for improvement.

The decision process for each organization was compared with each other and with the reviewed literature. Figure 1 describes the evaluation system used for the categorized information. The evaluation compared steps, how the steps differed from one organization to the next, and also considered reasons for why the steps did not match. Each organization's method for incorporating each step was identified and compared. The comparisons took into account the different organizational structure and goals. The evaluation also reviewed the effectiveness of each step and the controlling factors by reviewing and comparing results.

4. FINDINGS

4.1 Current Practice

The twelve organizations interviewed each expressed a desire to produce and maintain an energy efficient building, but the means for reviewing and implementing potential energy retrofits varied among them. The variations were evident even though past and more current programs such as the "Green Lights" and Leadership in Energy and Environmental Design (LEED) can be used for guidance. The variation was due to organization structure, expertise of the energy manager, and the financial constraints of the organization. Three organizations did not integrate a repeatable decision process in their operations. The remaining nine organizations used a decision process but they were not documented or well-defined.

Table 2 provides a breakdown of the steps used by each organization and the total number of organizations that used each step.

The decision steps used by each organization were important to evaluate. The building energy data step involved the accumulation and initial evaluation of the current energy consumption of the building. The cause step indicates an outside reason that pushes the need for an energy retrofit, such as a tenant request or a totally inoperable heating system. The energy identification and analysis step describes what energy items are in the building, how they interact with each other and what affects new equipment would have on the overall energy use. The assessment step involved a financial and feasibility review of the analyzed information and potential retrofit scope. The design and planning steps are where the designer and contractor develop documents and strategies for the installation process. The approval stage is where upper management can perform a final review to make sure necessary considerations are met. The bid step is a submission of construction documents to find the most appropriate manufactures and/or construction contractor.

TABLE 2. Organization decision steps.

Organization	Organization Decision Steps							
	Building Energy Data	Cause	Energy ID & Analysis	Assessment	Design	Plan	Approval	Bid
1	✓	✗	✓	✓	✓	✓	✓	✗
2	✗	✗	✓	✓	✗	✗	✗	✗
3	✗	✗	✓	✓	✓	✓	✗	✗
4	✓	✗	✓	✓	✓	✓	✓	✗
5	✗	✗	✗	✗	✗	✗	✗	✗
6	✗	✗	✗	✓	✓	✗	✗	✗
7	✗	✗	✓	✓	✗	✗	✓	✓
8	✗	✓	✓	✓	✗	✗	✓	✗
9	✗	✗	✗	✗	✗	✗	✗	✗
10	✗	✗	✓	✓	✗	✗	✗	✗
11	✗	✗	✗	✗	✗	✗	✗	✗
12	✗	✗	✓	✓	✓	✗	✓	✗
Total orgs. using steps	2	1	8	9	5	3	5	1

Key: ✓ - Step Used by Organization, ✗ - Step Not-Used by Organization

The most popular use and sequencing of steps were Energy Identification and Analysis, Assessment, Design, and Approval. The steps are illustrated in Figure 2.

The four steps described in Figure 2 are based on frequency of use from the twelve organizations interviewed. It is worth noting that a potentially significant step is missing from the four identified above, which is the building energy data step. Only two organizations used the building energy data step, yet this can have a significant impact on the retrofit decision process. According to the representative from Organization 1, "Understanding where each building stands should help us tackle the most appropriate projects."

4.2 Integrated Decision Process Steps

From the case studies, decision steps were identified and analyzed to determine each step's use and effectiveness. The four main steps most used by the twelve organizations were energy identification and analysis, assessment, design, and approval. The building energy data step was missing from a majority of organizations but was recognized as a very useful tool for the decision process. The neglected step was recognized through the evaluation of the step's effectiveness and the decision step considerations.

The organizations who performed this step displayed an ability to set goals and monitor results that was not seen in the other ten organizations that did not use the step. Additionally, consider-

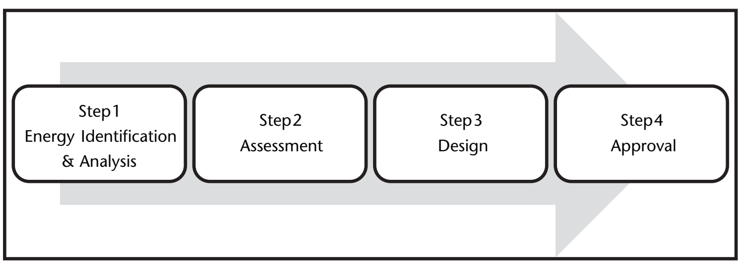


FIGURE 2. Common steps used by organizations.

able published literature recommended the building energy data step, also known as benchmarking. By completing the building energy data step, organizations could get a clear understanding of a building's improvement potential. This allows organizations to set clear goals and verify results to a degree that the other organizations not. Additionally, the literature review describes the importance of outlining the energy consumption and benchmarking the building to understand the retrofit potential.

Benchmarking is a simple evaluation that can be a convincing indicator of the improvement potential. Perez-Lombard et al. (2009) describes that benchmarking is a critical procedure that allows for the determination of the quality of a building in comparison with others. Additionally, Energy Star, the well known certification that is backed by the U.S Environmental Protection Agency and Department of Energy uses benchmarking information for the basis of the certification. The Energy Star system uses the Energy Use Intensity to compare like buildings and discover the degree of energy efficiency for the building in question (Sidebottom, 2006).

The recommended decision process which is to be referred to as the Integrated Decision Process (IDP) contains the following steps:

1. Building Energy Data
2. Energy Identification & Analysis
3. Assessment
4. Design & Planning
5. Approval

Organizations may have different approaches to energy conservation based on the funding stream, company structure, building type(s), number of occupants, and type of occupants. The integration of these steps will help owners understand the current condition of the building, make an assessment of the building's energy potential and identify potential retrofit options by considering all of the systems in the building working together. It will act as an aid to organize multiple retrofit options so that the most cost effective option is chosen. The process will also create a more effective design, approval and implementation process. These defined steps incorporate a critical component lacking in many organization's processes, which is goal setting. Current practice may incorporate goals but are ill-defined and poorly achieved. By setting goals, organizations can make plans while considering users, the environment, and economics. The goals will also set benchmarks to insure that actions are kept on track.

The defined steps are considered the IDP because they combine key energy information of the building with environmental and economic considerations. This combination allows the owner to see the whole picture and make efficient decisions. Figure 3 provides a breakdown and description of the IDP.

4.2.1 Step 1: Building Energy Data

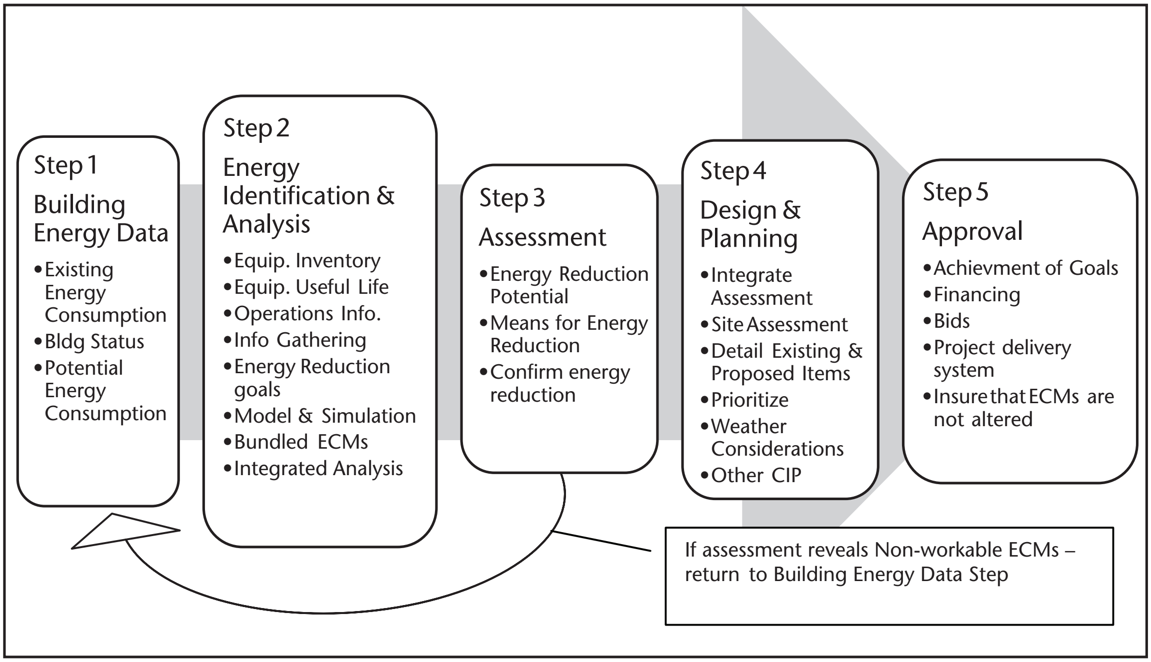
Collecting good building energy data is essential for a building owner to accurately evaluate the energy consumption levels of current maintenance and operations practices, and also ensure the appropriate implementation of ECMs (Greenaur, 2006). Greenaur (2006) states that without existing condition knowledge capital could be wasted on ineffective improvements.

Perez-Lombard et al. (2009) comments that energy service companies use an Energy Performance Index (EPI) as a starting point in conducting energy audits and assessing saving opportunities by comparing similar buildings. There are four stages in the building energy data process: 1) develop a database of the current energy performance of the building, 2) gather information to compare with the database, 3) perform a comparative analysis of the building performance with buildings of similar uses and construction, and 4) determine recommendations for energy efficient measures that are both economically and technically feasible (Perez-Lombard et al., 2009).

4.2.1.1 Database Establishing a database of the building's energy use is essential for benchmarking and evaluating of energy trends. With a large enough sample size to account for fluctuations in weather, number of occupants and type of occupants (a three year minimum is recommended), a simple, well-organized database can be arranged to display monthly and annual Energy Use Intensity (EUI), and help a decision-maker set appropriate reduction goals.

4.2.1.2 Energy Use Intensity Comparison The overall energy efficiency of a commercial build-

FIGURE 3. Integrated Decision Process (IDP).



ing is difficult to quantify. The effectiveness of energy-consuming elements can vary due to factors like their original efficiency capability, age, maintenance, and occupant utilization. The unrealized energy savings cannot be quantified without an extensive initial engineering review, which typically requires a large investment. An alternative method, which would require little to no cost, would be to use the building's base energy consumption data and compare it to similar buildings.

The EUI represents total energy consumption divided by the square footage of the building. Reviewing this information is a great place to start, however the information is not completely accurate: commercial buildings can vary drastically in their energy system and in size, and so comparison cannot be perfect.

The graph shown in Figure 4 makes it possible to visually compare the EUIs of different buildings. It also provides a visual comparison with the surveyed EUI numbers provided by the Commercial Building Energy Consumption Survey (CBECS). The graph arranges the buildings in order of largest to least EUI to clearly define where each building stands. 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 item is the target energy consumption per square foot as defined by CBECS. This technique provides an initial comparison to show that building B has the highest potential

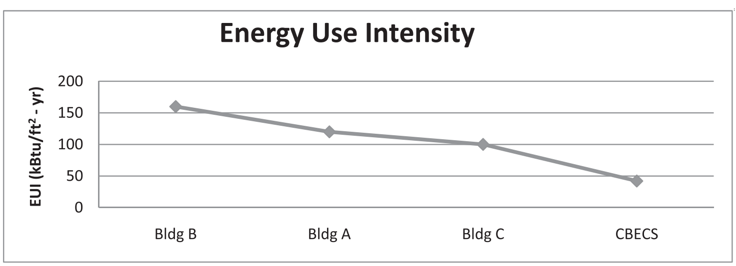
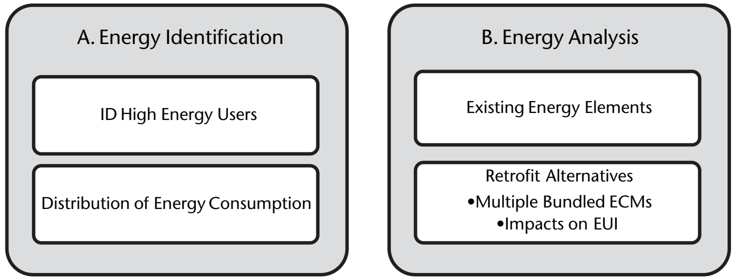


FIGURE 4. Energy use intensity sample graph.

FIGURE 5. Energy identification and analysis breakdown.



for energy conservation and should be considered for an energy retrofit before buildings A and C.

4.2.2 Step 2: Energy Identification and Analysis

The intent of the identification and analysis step is to evaluate existing and potential energy elements for the building. This evaluation requires an understanding of the current condition and consideration of multiple potential bundled retrofit alternatives.

Figure 5 provides a breakdown of the energy component identification and analysis objectives. In this step, decision-makers must consider all the energy elements working together to discover the most cost effective way to reduce energy use by the greatest amount.

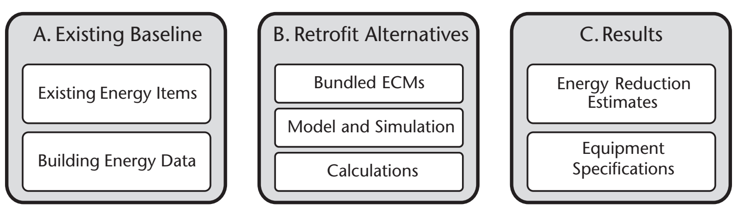
4.2.2.1 Energy Identification The identification of energy elements requires an energy audit that reviews the existing equipment for their use and age. This step involves reviewing the age of equipment, operations information, and document the equipment inventory. Naturally, newer equipment tend to be more energy efficient than older ones, and among older equipment, higher quality products are often significantly more energy efficient than lower quality ones. Yet, even new equipment can have energy deficiencies but are not cost effective to replace. Analyzers should recognize this issue and devise alternatives that work with the equipment that is to remain in the building.

Also important is to review the operations and inventory information, which provide insight into the time and the extent of use of each piece of equipment. The inventory documents the existing equipment type, condition, size, model, age, and specifications. The operations of the existing equipment are affected by weather, building space, operating hours, and operating use. Seasonal temperatures affect the heating and cooling loads of a building. The size and layout of the building must be considered in order to most effectively distribute light, heat, and conditioned air. Finally, considering the operating hours can help define the internal loads created by the occupants. The hours of use will help the analyzer determine the type of systems that can most economically meet the needs of and still take advantage of the optimal rate schedules. The inventory and operations information are then used in the analysis to discover retrofit alternatives that will produce the maximum reduction in energy use.

4.2.2.2 Energy Analysis The Energy Analysis uses the information accumulated in the Energy Identification step to evaluate the existing building and then considers multiple retrofit options to improve the energy use of the building. Figure 6 describes the basic elements of the energy analysis.

The analysis begins with understanding the existing energy use by creating a baseline, which is the normal energy use of the building. Then multiple

FIGURE 6. Energy analysis.



retrofit alternatives with various energy conservation measureas are considered. The bundled alternatives are analyzed as a single system, or in other words as a whole building where it considers system interactions. The results from this analysis are then compiled to easily compare energy reduction estimates.

4.2.2.2.1 Existing Baseline The existing building must be reviewed to create an energy consumption baseline. To do this, the analyzers must create a model of that building by considering existing energy items and collected energy data. This model allows analyzers to experiment with potential new technologies and calculate accurate energy consumption numbers.

4.2.2.2.2 Retrofit Alternatives The existing baseline and the equipment upgrades are grouped into alternatives to evaluate in an integrated manner. That is to say, each option contains a unique combination of ECMs, such as HVAC, lighting, building envelope, and fenestration systems. The ECMs are to be analyzed in a holistic manner through the use of advanced energy calculation or energy modeling, which enable analyzers to measure the impacts that each of the ECMs have on each other.

Table 3 describes a mock list of three retrofit options. Each of the options is to be modeled and compared with the existing building model to estimate the difference in energy use.

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

4.2.3 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 financial assessment that verifies that the project can be implemented.

Currently it is common practice to rely primarily on the expertise of the designer or energy engineer for determining the energy efficiency retrofits for a building. This expertise is valuable but does not guarantee that the best retrofit options have been chosen or even considered. The Integrated Decision Process, and in particular the assessment step, provides the owner with a process that can identify the best approach. This approach considers multiple options to clearly identify the most appropriate energy retrofit system that achieves the maximum allowable energy efficiency within the parameters of financial limitations.

The proposed method for assessing the analyzed results should consider the following questions:

1. What is the maximum energy efficiency potential of the building?
2. What is the best way to achieve the maximum energy efficiency?
3. How to pay for the retrofit project?

TABLE 3. Example retrofit alternatives.

	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 Pane Windows	Double Pane w/ Low-E Film	Double Pane w/ Low-E Film	Double Pane w/ Low-E Film
Lights	Incandescent	T-8, Fluorescents	Increased Daylighting, with LED	Fluorescents and LEDs

The questions can be answered by completing a series of defined assessment steps, which include: 1) Building Energy Data Assessment, 2) Analysis Assessment, and 3) Financial Assessment. Table 4 describes the three assessment steps for reviewing energy retrofit options.

4.2.3.1 Building Energy Data Assessment The Building Energy Data Assessment Step verifies that the analysis has produced alternatives that meet desired energy reduction goals. The energy consumption numbers of the different alternatives computed in the analysis should be compared with other similar buildings. The numbers can also be compared with the baseline to discover the percent savings of each alternative. This comparison will reveal which retrofit alternative most closely reaches the maximum energy efficiency potential.

4.2.3.2 Analysis Assessment This stage evaluates the financial considerations and outside influences that affect an owner's capacity to achieve maximum energy reduction. This is done by reviewing and comparing the retrofit alternatives created in the analysis stage with various considerations in mind, including:

1. **Future Plans** The analysis results must be reviewed with consideration to the long-term plans of the building owner and occupant. For instance, a change in building use from office space to residential will have significant impacts on the building's energy consumption in the future. Future plans can also include potential capital improvement projects such as remodels to interior space or installation of new windows.
2. **Non-Energy Items** The installation of the energy items may require the implementation of non-energy-related items. Such things as special permitting, certification of occupancy, hidden safety issues, building code requirements and other items may increase the cost and lengthen the construction process.
3. **Financial Review** Cost estimates for each alternative can be calculated by one of two financing-forecasting models: *Simple Payback Period* method or the *Life Cycle Cost Analysis* method. The Simple Payback Period considers the number of years required to recover the initial investment by dividing the annual savings of the ECM into the cost to install it. Many organizations interviewed preferred the simple payback method because it has minimal variables and is easy to understand. Additionally, organizations preferred investments that can be recovered quickly; typically less than 5 years.

But using only the Simple Payback Period for the financial assessment will result in a less profit-

TABLE 4. Assessment steps

	Step 1: Building Energy Data Assessment	Step 2: Analysis Assessment	Step 3: Financial Assessment
Question	Maximum energy efficiency Potential?	Means for achievement of energy efficiency?	How to pay for the retrofit project?
Process	Review Building Energy Data	Review the alternatives created in the Analysis to find best one	Review the financing or funding available
Evaluation	Energy Consumption Comparisons	• Future Plans • Non-Energy items • Financial Review	• ECMs Alternative meets financial requirements • Funding or Financing Source
Indicators	EUI	EUI, CIP List, Inventory, Model Results, LCCA, Funding Applications	Financial Limitations
Goal	Define Target EUI	Review Retrofit Alternatives	Confirm financing or funding
Keys to success	Building Energy Data provide correct information	Analysis provide integrated ECM alternatives	Consider multiple financing and funding options

able investment, because the method leaves out important factors such as interest, and escalation rates. It also does not consider final benefits after the simple payback has been reached. A more inclusive method is the Life Cycle Cost Analysis (LCCA). This method converts the cash flow and interest rates associated with the energy retrofit to a base, which is known as the Net Present Value (NPV). The NPV can then be easily compared with other retrofit options to find the most financially beneficial retrofit option. This assessment can be cumbersome but the results are much more useful to the decision maker since he or she is able to consider the benefits of the equipment over its entire lifetime in a detailed manner. This long-term assessment enables decisions to be made based on the total cost of ownership.

4.2.3.3 Financial Assessment In this step, the analyzers confirm that the retrofit alternative can be funded. Unfortunately the organizations interviewed had little to no control over the funding source for their energy retrofit projects. Retrofit projects would benefit greatly from more flexibility in the availability of funding and financing mechanisms. Additionally, there are many incentives available in the form of tax credits/deductions and rebates at the local, state and federal level (DSIRE 2010). The incentives will add to the viability of available funding and financing.

4.2.3.3.1 Funding Sources The funding sources for the organizations came from capital budgets, investors, operations budget and grants.

1. **Capital Budget** The interviews identified that the most commonly available source of funding is from capital budget allocations. This is because it can be used to fund a variety of projects, and it is also the most readily available. But it has some drawbacks. First, there is only one capital budget for an organization. This single budget must provide funding to other non-energy conservation projects as well as the energy retrofit projects. Energy retrofit project could benefit from the use 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 the end of its lifespan.
2. **Investor Contributions** The funds from the investor contributions are often tied to short-term 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. The issue is that there are many different investors with different values and views. The solution would be to get a collection of investors with similar values and views, ones that are compatible with long-term energy retrofits investments.
3. **Operations Budgets** Operations budgets are usually not large enough to fund the upfront cost of the energy retrofits. Smaller ECMs, such as lighting upgrades, could be funded by this type of source.
4. **Grants** Grants are often attached to a particular building or type of improvement. This type of funding is best for long-term ECM projects because the grants are a viewed as a single lump sum amount. This allows the decision-makers to consider the total cost of the project as the main indicator for its feasibility
5. **Revolving Investment** This type of funding was not used by any of the twelve organizations interviewed. Revolving investment funds are structured for recirculation of the investment and the realized cost savings: the circulation replenishes or pays back the original investment. The process starts with an initial investment to install energy conservation measure or measures. The savings are accrued (sometimes over a longtime period) and are earmarked for the revolving fund. The revolving fund then replenishes the investment and allows for the possibility for the funding of more conservation projects.

4.2.3.3.2 Financing Mechanisms There are multiple financing mechanisms available that organizations can utilize. Debt financing usually comes in the form of loans or bonds. Loans are providing by a lending institution to a borrower, and the bonds are issued to investors in the open market. The loans are usually used for small, short-term projects, whereas bonds are most appropriate for large projects, or a series of smaller projects. This type of financing allows for energy savings to be retained. It also allows for the depreciation of equipment to be tax deductible. It is important that organizations consider the retrofit projects as investments where they will achieve savings and profitable returns. Sample financing options are as follows:

1. **Direct Loans** These are loans to a borrower from a lending institution. The terms of the loan can be negotiated to make sure that the energy savings can provide a cash flow to generate a profit or at least to break even.
2. **Municipal Bonds** These are long-term debt obligations that are usually issued by municipalities or government agencies
3. **Energy Performance Contracts** Building owners are hindered by the upfront cost and lack of knowledge of the implementation and operations of energy conservation measures. The measures can be implemented and financed through a performance contract which is an agreement between a building owner and a contractor. The contractor designs and installs the measures under a guarantee of the cost savings to be achieved. The cost of the installation is then repaid through the cost savings achieved from the implemented measures.

   This type of contract is good for owners who do not have the technical expertise nor the free time to manage the project, or are unable or just unwilling to finance the project. The performance contract will not work in every situation: the project must be a of significant size, contain multiple measures with short paybacks, and must be in a building that is consistently used.

4.2.4 Step 4: Design and Planning

The design of an energy efficient building 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 be used in the design.

The design documents of an energy retrofit project define the existing elements and provide detailed information of the proposed replacement equipment. The suggested design development process uses a six-step approach as shown in Figure 7.

The design process begins with the project assessment. The designer discusses the project opportunities and goals with the building owner before developing a list of potential opportunities for integrating the energy conservation in a way that achieves those goals. This is not a detailed process but it enables the designer to use his or her 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. While at the site, the designer reviews the list developed in the project assessment to on-site findings. Additionally the designer reviews existing conditions that, with modifications or upgrade, can be used in the design to achieve the overall goal of the project.

The third step is to further define the existing condition of the building. This requires identifying

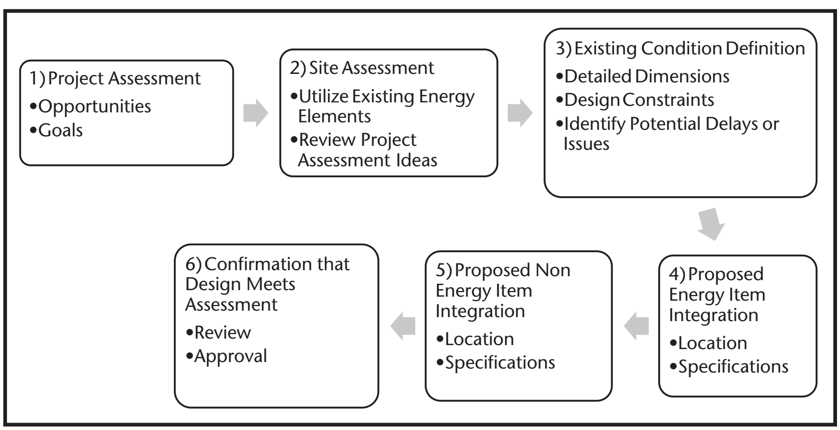


FIGURE 7. Suggested design process implementations for a retrofit.

existing equipment, detailed dimensions, layout of design constraints, and identification of potential installation delays or other issues that require consideration. The plans should incorporate as much detail as possible on the building's existing condition to help the contractor or installer prepare for construction. This all helps prepare for the next steps of developing the technical specification of ECMs. The design is then submitted to the owner and governing agency to ensure approval and obtain necessary permits.

Installing ECMs requires advance planning. The planning should consider any other capital projects, any change in use plans, or any other non-energy conservation items when prioritizing ECM projects. Prioritization of projects is based on funding amount, restrictions and length of time that the funding is available. These considerations are shown in Figure 8.

Projects must be planned so that weather is not a major factor for the construction activity. For example, it is not ideal to perform an HVAC improvement in the middle of winter when occupants in the facility are in need of heating. Additionally, the planning process should take into account both the current and the projected use of the building.

4.2.5 Step 5: Approval

The approval step is important because any organization must ensure that the project achieves the desired energy and cost savings goals. The cost of installation of the project must be within the available funds and comply with the proposed financing mechanism. The organization must monitor the construction process, from the solicitation of bids to the ultimate completion of the project to ensure that the ECMs specified in the plan are not altered or eliminated. Following construction completion, an 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.

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 proposed in the decision process meet their goals. Energy savings can be confirmed by reviewing the benchmark and the assessment information to see if the calculated energy reduction meets the targeted EUI. The approval process must confirm that the approved ECMs are reflected in the design documents.

The bid and construction process must include constant organization involvement. It is important that oversight techniques are used during the bid process to ensure that contractors do not make significant changes that affect the intent of the project.

5. CASE STUDY COMPARISON

To illustrate the different approaches that organizations currently use and the advantages of the IDP, a small case study comparison is made between organization 1 and 8. Organization 1 uses a decision process that was similar to the IDP and is shown in Figure 9. The organization owns, operates, and maintains at least 65 buildings on a school campus. The buildings vary considerably in type and in age. The organization has a facilities department that manages and provides services for engineering, energy, environmental, finance, maintenance, planning and utilities.

Organization 8 uses the decision process shown in Figure 10. The organization is a large commercial real estate owner, with about 200 properties nationally. The properties include office, industrial, retail and multi-family residential. The organization manages the properties to gain profits for their investors. They recognize the need to have energy efficient

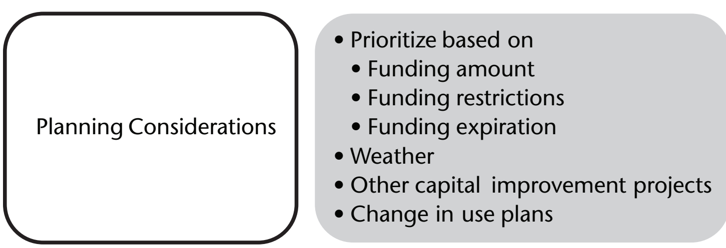
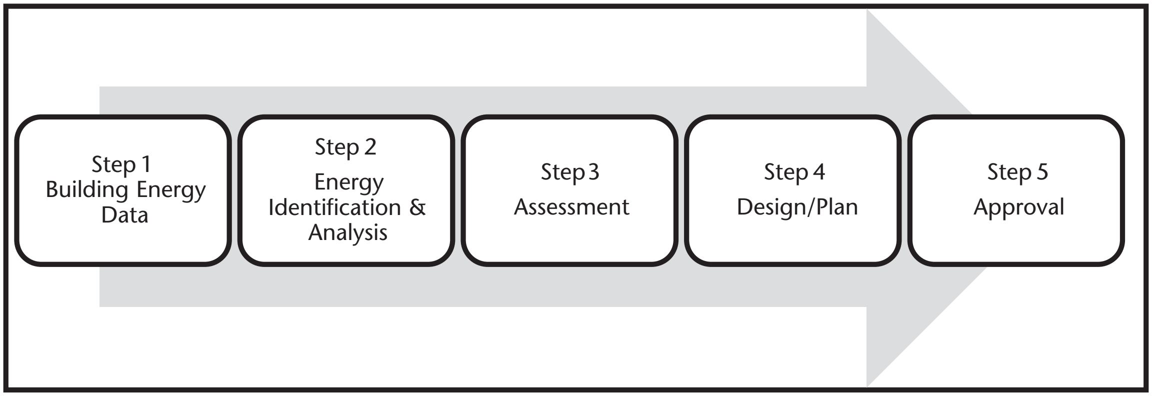


FIGURE 8. Suggested planning considerations.

FIGURE 9. Organization 1 decision process.



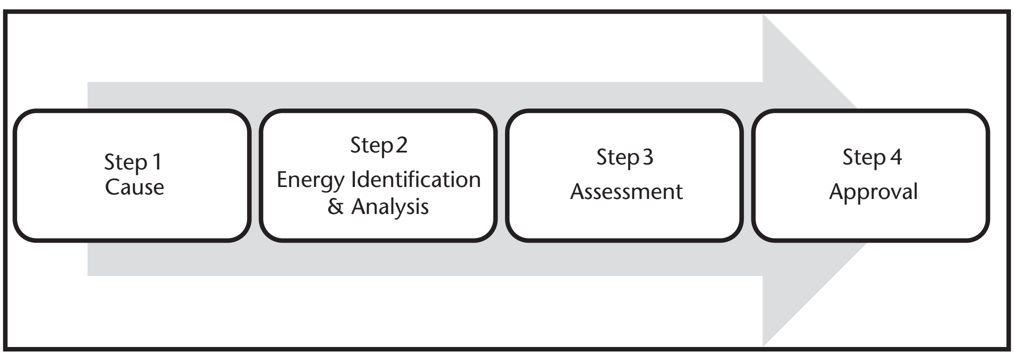
buildings but currently find it hard to justify the retrofit costs of their existing buildings.

There are obvious differences in the decision process between Organizations 1 and 8. For example step 1 for Organization 1 is building energy data and for Organization 8 is cause. Organization 1 has a robust energy database of their buildings that allows them to compare and contract energy consumption and help them set goals for conservation. Whereas organization 8 initiates projects based on a cause, which is a specific reason for the retrofit. The reason can be tenant requirements or complete breakdown of a system.

The second difference between the decision processes is that Organization 1 implements design and planning before approval. Organization 8 does not have a design step and instead goes from assessment to approval. Organization 1 has a more comprehensive process of understanding costs by more clearly defining the scope of work. This organization is able to perform design work because of the resources they have on staff to complete this level of detail. Organization 8 does not have design services in-house and therefore feels they must decide on measures before more details of scope and cost are determined. This could hinder their process because of missed opportunities due to lack of detail. For example costs may be over estimated due to lack of information and Organization 8 will not move forward with a project that with more detailed information could be found to cost less than estimated.

Organization 1 uses steps similar to the IDP and is able to accurately understand their buildings energy consumption and utilize resources to improve their buildings. Organization 8, on the other hand, is not able to develop a sufficient means for improving their energy consumption because they do not understand their current status and therefore unable

FIGURE 10. Organization 8 decision process.



to set effective goals. The implementation of Step 1 of the IDP would allow Organization 8 to understand their buildings improvement potential. This understanding would allow them to quickly outline their commitment level to improving their building based on the cost savings potential. The implementation of Step 1 of the IDP would help them have a better understanding of the energy analysis that is performed by an outside consultant. The improved understanding would help them relate the proposed building improvements to building performance value, market value, and financial value. Additionally, the financial considerations in the Assessment Step need to be expanded to outline numerous funding and financing options. The complete understanding of the risk and revenue potentials provided through financing options should be explored to fully understand the benefits of the improvement.

Once the improvement benefits are understood appropriate design and planning measures can be explored prior to approval. The planning and design step can detail potential non-energy component costs that can be hidden in the initial review. On the other hand, the design and planning can discover cost savings items and initiatives, such as construction streamlining suggestions or utilization of onsite elements.

Organizations 1 and 8 both consider energy efficient building retrofit options but only Organization 1 can affectively understand the risk and revenue associated with the improvements. Organization 1 is able to do this by developing a process that evaluates goals and is able to check that goals can be meet as the project moves from analysis to assessment to design and planning and finally on to approval. And on the other hand Organization 8 is inexperienced in the process and wary of moving forward. Instead of implementing proactive steps to understand risk and revenue opportunities they limit their decision to be based on upfront costs.

6. CONCLUSION

Case study research of multiple organizations identified current decision processes for energy efficient building retrofits. This research also developed a recommended decision process for commercial building owners when considering a retrofit that includes energy conservation measures. The research described the decision process used by actual organizations. Then it compared and evaluated their process to determine a recommended, integrated approach for how organizations could improve their decision process.

The research utilized a collective case study design approach. This approach used literature review and interviews. The literature review included books, articles and manuals. The interviews of actual organizations consisted of question and answer sessions, observations of process, and review of processes documents provided by the organizations. The information provided insight and details on information already researched. The case study interviews provided real world insight into energy retrofit practices utilized in the industry today and details concerning the real life barriers to the successful implementation of needed 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 Integrated Decision Process consists of the following steps:

1. Building Energy Data
2. Energy Identification & Analysis
3. Assessment
4. Design & Planning
5. Approval

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. Industry mindset must change and upfront investments need to be made for proper evaluation to improve the overall decision process and retrofit results.

The building industry is only beginning to incorporate decision processes to evaluate and implement energy efficient retrofits. It is evident that there is a need for better strategies to overcome the real and perceived barriers encountered by decision makers:

- Improved building energy data evaluation and comparison techniques
- Improved real-time understanding of building energy consumption

- Improved construction cost estimating
- Innovative financing
- Integrated decision and design approach improvements
- Better building and equipment Modeling and Simulation programs and techniques
- Integrating energy efficiency and renewable energy 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.

BIBLIOGRAPHY

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

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

DeCanio, S. J. 1993. "Barriers within Firms to Energy Efficient Investments." *Energy Policy,* 906–914.

DSIRE 2010, July 19. *Database of State Incentives for Renewables & Efficiency*. Retrieved July 19, 2010, from http://www.dsireusa.org/.

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. 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.

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.

Greenaur, D. 2006. "Adding Value to Energy Management by Benchmarking." *Building Operator Certification Newsletter,* 3–4.

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

IPCC. 2007, November 12–17. *Intergovernmental 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.

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 Design 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 Certification: A comparison of two complementary programs." *Strategic Planning for Energy and the Environment* 26(1), 25–31.

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.