THE DEVELOPMENT AND ADAPTATION
OF THE COMPUTER AIDED ENVIRONMENT TO FACILITATE INDUSTRIAL
ENERGY AUDITS

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CHATCHAI PINTHUPRAPA

Dr. Bin Wu, Thesis Supervisor

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

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Presented by Chatchai Pinthuprapa

A candidate for the degree of Master of Science

And hereby certify that in their opinion it is worthy of acceptance.

______________________________
Dr. Bin Wu

______________________________
Dr. James Noble

______________________________
Dr. Sanjeev Khanna
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ABSTRACT

Industrial Energy Audits became more significant in the last several decades in response to increasing rates of energy cost and sustainable awareness. The Industrial Assessment Center supported by the U.S. Department of Energy is an organization that helps participating industrial facilities to identify and evaluate opportunities for energy savings and conservation. This research proposes ‘The Development and Adaptation of the Computer Aided Environment to Facilitate Industrial Energy Audits’ to accommodate the one-day energy audit for Industrial Assessment Center. It will present a development model of industrial energy audits and a logical approach of processes using web-based technology with integrated and sustainable framework. The objective is to propose a development platform to support the participating companies and energy audit team members to understand the logic of the energy audit process and utilize potential assistance tools to achieve a common vision among users. With this development, users will have a vision of energy audit processes in several functions simultaneously and understand logic concept of actions thought out the complete energy audit processes.

This Webtools online effectiveness is validated through actual users from Missouri Industrial Assessment Center as a part of development model through an evaluation of essential key attributes to ensure a continuous development in order to meet the needs of users and plan for a future research.
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Chapter 1

INTRODUCTION

1.1 Motivation

In the United States, thirty-two percent of energy used in the country is consumed by the industrial sector in 2006 (Figure 1-1. Missouri share 1.2% of the total energy consumption of 33,415 trillion BTU across U.S in 2004. See Figure 1-2). In particular, small and mid-sized (SME) manufacturers are a vital contribution to the U.S. economy. There are approximately 296,000 SME in the nation and they represent more than 99 percent of the nation’s manufacturers. Also, forty percent of the value of U.S. production is from this sector, responsible for 15 percent of the nation’s manufactured goods exports. (The Manufacturing Institute, the NAM and RSM McGladrey, INC 2006)

Industrial Assessment Center is a program, supported by the U.S. Department of Energy, to help small- to medium-sized business to identify and evaluate opportunity for energy conservation. There are 26 IAC centers across the nation recently. According to the US Department of Energy’s requirement, the ultimate goal of an IAC Center is to be “The center of resources and services in industrial energy efficiency” for industries in the state. Specifically, the aim of Missouri IAC is to promote best practices in energy efficiency, reusable energy, waste reduction and productivity through integration of activities involving the University, the state agencies, the University Extension Program, the Manufacturing Extension Partnership program (supported by the U.S. Department of
Commerce), the major state-wide and local utilities, and industrial associations. The new Center has four areas of activities in education, energy audit, outreach and research.

One part of the center’s task is to perform energy assessments for small or medium-sized manufacturers in the state, defined as those that pay between $100,000 and $2.5 million annually for energy. Each IAC assessment will include a written survey, an on-site review of the plant and a list of specific energy-saving recommendations based on a detailed analysis of the plant’s energy profile. Those recommendations may call for measures as simple as exchanging fluorescent light bulbs for incandescent bulbs or as significant as the installation of a new air compressor or a HVAC system. Plants that have had such energy-saving suggestions can expect to save on average about $60,000 per year, according to the Department of Energy’s historical statistics (DOE, IAC Web site, 2007).

Although the energy audit processes carried out by the IACs in the nation involve a one-day on site visit, many documents, manuals, data forms, tools, and analysis are involved in the pre-, during, and post-audit stages. A logic understanding of the purposes and uses of them, together with a thorough understanding of the procedures and logics involved, are a prerequisite for a successful audit. Although materials such as books, manuals, and individual tools, etc, have been developed and are readily available (Thumann and Younger 2003, Turner 2006, Capehart el al 2005, Moss 2006, Wulfinghoff 2000, Muller el al 2001, Muller 2003 and 2005, and Industrial Technologies Program 2007), these are all available on an individual basis. So far, there has not been an integrated environment that links all these information and tools together to help an auditing team to plan, coordinate, and execute an audit in a logical and structured way.
Many computer aided environment has been design and implement to achieve an advancement of the usage in various situations by many developers and researchers. Here the author has identified an opportunity to develop a logical computer environment model that will assist the energy audit process for small- to mid-sized manufacturer and industrial assessment center in order to identify potential savings, energy efficiency and productivity improvements.

Figure 1-1: United States energy flow, 2006 (Quadrillion BTU)(Energy Information Administration 2007)
1.2 Problem Statement

To conduct an industrial energy audit, auditors are required to have a logical understanding and accessibility to the overall processes where documents, inputs and requirements are monitored. Computer aided environment can assist users and improve the productivity of auditing process.

The development of a web-based environment to support the entire process of a typical industrial energy audit is proposed for this project (Energy Audit Web Tools). This tool should be able to guide users to available sources and link to users’ responsibility and contribution for the planning and execution of an audit, and simultaneously update the resultant documents. The paper-based model shows a strong evidence of the limitation of accessibility, availability, error and loss of completion. The proposed work aims to provide an effective means to minimize the limitations of the
paper-based manuals and tools, and facilitate an audit project in order to enhance the productivity of audit processes as well as to improve the quality of report generated by such audits.

It is also necessary to evaluate the effectiveness of such a computerized environment, in order to monitor the impact of its, and to ensure its performance and continuous improvement for future research and development. It is proposed that the evaluate methodology should be based on an integration of Multi-attribute matrix and gap opportunity, specially adopted for the evaluation of the effectiveness related to industrial audit processes, where usability, responsibility, procedures and information are essential.

1.3 Research Objectives

Therefore, this research aims to establish a computer-aided training/audit tool for industrial audit. It should provide an environment that links many relevant materials (process flowcharts, checklist, forms, samples, text files, etc) in a structured, logical and practical way. In particular, it should provide and support “live” Pre-, During, and Post-audit forms that allow the audited company and the audit team to exchange information in an interactive manner on-line, and to support a set of materials/tools together, following the logical audit planning and execution steps. This tool should have the potential to be used for both training and audit purposes.

The project also aims to investigate into the effectiveness of such a tool when put into practice. Tasks here will involve surveys to gather comments and suggestions, with the
intention to further develop it into a practical tool. Ideally, the end result should effectively support, for the industrial energy audit purposes:

- Information accessibility
- Data gathering and integration
- Tool accessibility and application
- Identification of energy-saving recommendations
- Calculation and justification of recommendations
- Error reduction and completion of project activities
- Overall effectiveness of audits

The study will also aim to investigate whether this development and adaptation promote logical understanding and meet user needs towards the perception to use of a computer-aided tool for industrial energy audit.

1.4 Research Approach

The following project activities have been necessary to the project to achieve its goals:

- Firstly, it is necessary to carry out an extensive literature survey to provide an overview of the current practices in the energy efficiency domain, and to develop an extensive collection of materials related to industrial energy efficiency and audit
processes. These will include guides, forms, training materials, web links, and software tools.

- Secondly, the project needs to logically link these items in a logical and structured way that should be the most effectively to support the audit processes.

- Identify an effective approach as the basis to develop the computer-aided environment, and develop a prototype that has the potential to satisfy the project objectives. This prototype should support the functions and activities of the main parties involved in an industrial audit exercise: audit team members, industrial personals, and educators/instructors. It should be user-friendly and easy to navigate, and includes integrated data acquisition for pre-audit, logic approach by flowchart, discussion board for individual team members, sources of supplemental documents and guidelines, and energy audit training materials.

- Validation and improvement of the prototype.

1.5 Validation Approach

The project activities have resulted in an initial tool that seemed to have satisfied most of its intended goals. However, an extensive literature research, as reported in Chapter 2, has indicated that there is a lack of a precise methodology to evaluate the scale of success and improvements in this particular area of application. In order to effectively evaluate the performance of the project outcomes, therefore, an approach based on the integration of Multi-attribute matrix and opportunity algorithm was suggested, so that the important
perceptions from the potential users, and evaluation of the features of the tool could be obtained and used as criteria for its future development and application.

The surveys from experienced Missouri Industrial Assessment Center members were collected, and used to validate the general approach as a whole, as well as the specific contents to support individual tasks, both qualitatively and quantitively. Validation of feedbacks involved conducting an integration of Multi-Attribute matrix analysis and the opportunity algorithm methodology from user responses to refine the scales of this development and to identify gaps for each of attributes (e.g. learning curve, data integration, accessibility, etc) that have not met the user needs.

1.6 Thesis Organization

This thesis is developed and structure into six chapters. Chapter 1 briefly covers the introduction included with motivation for this thesis, identified problems, Research objectives, research approach and validation of the approach.

Chapter 2 provides a report of the extensive literature review carried out for the project.

Chapter 3 a model of the energy audit processes is presented, that is based on the current industrial practices.

Chapter 4 explains the methodology of development, which is based on the so-called Task-Centered Methodology as a skeleton for a proposed development of the computer-aided environment application. Reasons why this is suitable approach for energy audit process support are also presented.
Chapter 5 describes in details the structure, contents, processes, and flows of the computer-aided auditing environment.

Chapter 6 describes the validation methodology with an integration of opportunity algorithm analysis for the developed environment, the feedback obtained up to date, and recommendations for further development.
Chapter 2

LITERATURE REVIEW

2.1 Introduction

Energy is a key factor for the social and economic development. The prosperity of the nation is indicated by the level of energy used (Hepbasli and Ozalp 2003). Industrial energy creates the largest portion of total energy consumption. The higher degree of industrialization, the more will be the energy consumption (Rajan 2006). By far, the United States is the largest energy consumer in the globe, with a total consumption of 101 Quadrillion BTU in 2006 (EIA). New opportunities including new jobs for implementing energy efficiency and energy cost savings are in demand because of the high consumption of energy and high raises energy costs (Capehart et al 2005). In the U.S. industry, increasing profit and reducing costs are of dominant importance. Energy audit to MSEs therefore offers a great opportunity to help the industrial sectors to because more profitable and sustainable. Capehart et al (2005) claimed that “Energy management is one of the most promising profit improvement-cost reduction program available today”. Particularly under the current economic and political conditions, it is obvious that energy audit program is an essential element that it is needed as a part of economic growth of the nation.

Industrial energy audit is an energy efficiency and energy conservation approach to assess energy usage and identify potential energy and cost savings. However, from planning to reporting, a typical industrial energy audit requires a large number of
tasks to be carried out, dealing with a large amount of data and a multitude of analysis and decisions. To help facilitate the processes involved in a typical industrial audit, Wu and Khanna (2007) developed the concept of a computer-aided audit workbook to serve as a guide and a tool guide through the complete processes involved in an industrial energy audit. It is suggested that the best way to accomplish this is through a so-called task-centered approach (Wu 2001). That is, industrial energy audit tasks and all other required items (manuals, guidelines, data forms, task flowcharts, and analytical tools, etc.) should all be integrated logically in one single location where it is convenient to navigate through the overall systems. Greenberg (2002) also suggested a rework of steps to task-centered system design as a tool of interface development platform concerning usability of the design. In addition, a monitoring tool is necessary for a well-constructed task-centered approach for a continuous improvement that reflects user needs. Ulwick (2002) proposed opportunity algorithm to evaluate customer desires and put them into a new development of the product.

Through this project, the development of computer-aided environment to support the audit processes will be a transition from paper-based to web-based system. This transition should be evaluated to illustrate perceptions of users with the new tool. The basic multi-attitude model proposed by Wilkie and Pessemier (1973) will be used to evaluate and confirm the result of this transition.

It is realized that the development of a well constructed computer-aided environment is necessary to support the industrial energy audit processes. In essence, the monitoring tool is necessary to support the process of development, and help to make the end result a usable and a sustainable tool.
2.2 Task-centered Methodology and the Audit Processes

The task-centered approach was first used by Wu (2001) extensively to present a task-centered MSM (manufacturing system design and management) workbook which provides a step-by-step cycle of strategy analysis, system design, system performance monitoring, and system improvement. The concept of task-centered is the integration of necessary components of tasks such as tasks descriptions, instructions, processes, drawings, tools and data into one platform. This single platform will allow users to navigate throughout relevant processes in a focused way. This concept can be support by a web-based design to further enhance its usability, where users usually focus on the relevant content and ignore irrelevant elements such as navigation aids or structure of the site (Kitajima et al 2002).

More specifically, Wu and Khanna (2007) proposed the conceptual structure of a computer-aided audit workbook as a complete guide to energy audit processes, tasks and outcomes of an energy audit. This conceptual structure is outlined in a task-centered manner which integrates all relevant entities such as data collecting tools, instructions, procedures of analysis and calculation and worksheets. It is intended to supports the kind of diagnosis-solution problem solving required to perform a competent energy audit. The justification for such a task-centered approach is that analysis and design of energy-efficient industrial processes requires a combination of two skill sets from the auditor: technical knowledge of the systems and problem-solving ability, therefore:

- As a learning aid, a task-centered provides an intensive, interactive environment that is more effective for the students to gain such skills
Once the basic knowledge and understanding are developed, such an approach will comprehensively present the task contents and provide background conceptual materials. Auditors are therefore provided with a complete set of easy to use tools that are required to analyze the problems and identify the possible solutions.

Figure 2.1: Conceptual structure of a task-centered audit learning tool and workbook (Wu and Khanna 2007)

The basis element of this conceptual design is illustrated in Figure 2.1. As can be seen, from the initial audit planning to the final recommendation and follow-up, the
workbook utilizes a front-end flowchart to specify the steps and tasks involved, and then logically integrate all the relevant entities such as instructions (Figure 3, a), data collecting tools, procedures of analysis and calculation, and worksheets to support task execution and project management (Figure 3, b, c). Other notable features include links to other resources (Figure 3, a), the experts/expertise database (Figure 3, e), and a specially developed worksheet for calculating organization-wide energy consumption (Figure 3, d). With the completion of the necessary steps, the workbook provides templates for generating final recommendations and report (Figure 3, f). In essence, it is a unified project tool that organizes and links instructional materials,

2.3 Task-Centered System Design Approach and System Usability

Greenberg (2002) proposed a walkthrough and rework of Lewis and Rieman’s Task Centered System Design methodology (TCSD) (Lewis and Reiman, 1993) in development of applications and software systems by using example from catalogue of the low cost merchandise department store. Greenberg shows how to identify key tasks of the system and use the tasks to conduct an analysis so one could develop a prototype design by using this methodology. The core concepts of TCSD for designer are:

- Elaborate the descriptions of real users doing the real tasks
- Identify user types by using description and identify tasks requirements to support the system
- Create an interface layout that supports the requirements
- Evaluate the interface by walk-through the system
Regarding to the usability of the web-based system, Kitajima, Blackmon and Polson (2000) used the comprehension-based linked model of deliberate search model to explain the use of usability guideline in thee major areas.

- Web designer should create links and navigation that base on the goal of users. A major successful navigation is determined by the quality of description of consequences on the click of a link.

- Clear verbal link labels must be clear to support users’ finding. Therefore, users can precisely predict the consequence of page after the click on a link. Longer links labels has high success rate since they provide more information and less ambiguous than the short label links. (Spool et al 1999)

- Deep hierarchy site has low success rate to achieve the goal of users. A well-designed site usually has a shallow hierarchy since it is closer to accomplish the users’ goal. If user has 90% of picking the right link towards there goal, 81% of success is for user to pick the right links in two level platform, and 53% of success for a six-level platform (Kitajima et al, 2002).

A set of general guidelines is also provided by Shneiderman (2006), as summarized as follows:

“Web sites should be designed to facilitate and encourage efficient and effective human-computer interactions. Designers should make every attempt to reduce the user’s workload by taking advantage of the computer’s capabilities. Users will make the best use of Web sites when information is displayed in a directly usable format and content organization is highly intuitive”.

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2.4 Opportunity algorithm

In a web-based computer aided environment, plenty of emerging technologies and applications are available to support the development of a transition from paper-based platform to online platform. In parallel, customers’ expectations on products are changing dynamically over time. Therefore, to cope with the new edge of a rapid growth, the development should respond well to the requirement to match with dynamic needs. This will ensure improvements and future development of the tool.

New technologies and sophisticated applications are not always the solutions of the web development of a particular system. Many authors (Squire, Redman, Brown and Bessant 2004; Keeney 2004; Matthing, Kristensson, Gustafsson and Parasuraman 2006; Klien, Tellefsen and Herskovitz 2007, Ulwick 2002) discuss the approach that can reveal the application’s particular needs and the end-users’ desires. Ulwaick (2002) proposed a way to turn users’ response into a product/system innovation by extracting information from users and identifying key values by using the opportunity algorithm. Ulwaick explained further that what users want to see in new systems or services are not a bottom line of the key value for an innovation or system development. Users usually provide solutions with their experience and provide what they want to see in the new development. They may not be informed enough to come up with a creative solution (Kusiak and Tang 2006). They commonly have limitation knowledge about emerging tools, new materials, new technologies, new application and the like.

The outcome-based strategy (Ulwick 2002) can reveal the covered desire by focusing on making a distinction of outcomes and solutions. Bo Edvardsson (2006 p.24) described a very interesting beneficial and consequences on this strategy:
“An outcome-based strategy also stimulates customers to suggest ideas beyond their usual frame of mind. In contrast, the firms that adopt a solution-based interviewing approach may end up developing incremental innovations.” (Bo Edvardsson 2006)

The translation of user survey or interview by focusing on expected achieving outcomes of users will identify key values and the level of importance on each of the attributes by using mathematical formula. The formulation of the Opportunity Algorithm is given by:

\[
\text{Importance} + \max[\text{Importance} - \text{Satisfaction}, 0] = \text{Opportunity}
\]

This calculation will reveal opportunity areas for system development can have a significant improvement. The information can also be used to formulate a new concept in a response to the opportunity.

2.5 Inspiration

One of the adventurous key for developing industrial energy audit processes is that the expectation of users is dynamic and changes as the project progresses. Robinson and Pidd (1998) confirmed this statement through a project that was used to monitor the reaction of end users. In practice, users can get tired with many necessary tasks, documents, manuals, workbooks, datasheets and software tools.

One of the main challenges of this project is to provide a user-friendly environment that is user-centered, problem-centered, and task-centered, so that all the necessary tasks and materials are presented logically in a focused way, so that they do not get lost in this sea of information and tasks.
Taking all the above into consideration, the proposed project must work closely with audit teams so that all the parameters as outlined above can be taken into the development process. Furthermore, the resultant tool must provide task-documents specifically designed to help analysis a set of problems (e.g., insulation, heating system, machinery system, and lighting system). Each problem will include a problem representation, a multi-layered conceptual model of the systems being analyzed, a computer-aided workbook, and ideally a case library of similar analyses. Relevant technical knowledge will include topics such as: introduction to energy management, fundamentals of industrial systems analysis and design, heat transfer, fluid mechanics and electrical science, boilers, furnaces, motors, lighting, HVAC, compressed air, electrical energy management, insulation use and design, waste reduction, performance of building envelopes, alternative energy sources, energy policy and codes, and economic analysis.

In essence, as an aid to teaching, training and auditing, this computer-aided audit workbook should be developed in such a way so that it provides a complete guide to the processes, tasks and outcomes of an energy audit (Wu and Khanna 2007).

Once in place, this learning-and-doing environment can be linked to utilize the database of the U.S. Department of Energy’s IAC program (www.iac.rugters.edu/database) to develop a number of audit cases. In a simulated environment involving these cases, student teams can be asked to use the audit book to go through the audit process, covering all the necessary skills such as site evaluation, data analysis, recommendation recognition, and report preparation. Results will be compared with those from the real situation, and the process repeated until lessons are learned. This
will be used for the initial training of new recruitments and skill improvement for the more experienced center students.

Additionally, it will also be used as an on-site tool for energy, as follows:

- a copy of this workbook will be made for each of the audit client and taken to the site,
- the audit team will follow the procedures as specified, populate the relevant worksheets, and carry out analysis and calculations, and generate recommendations as the audit progresses,
- when complete, the populated workbook will provide comprehensive documentation of the audit, including data, analysis and report.

2.6 Multi-Attribute attitude models

Brandt and Shook (2005) discussed that many research has been carried on the quantitative measurement of personal attitudes which related to product attribute analysis. Wilkie and Pessemier (1973) proposed a basic model to measure the attitude of customers in the same marketing segment, the steam research in this area. The basic linear model is listed below. The basic model is relevant in this study for evaluation of feedbacks on the usefulness of prototype tools.

\[ A_{jk} = \sum_{i=1}^{n} I_{ik} B_{jk} \]

Where:
- \( i = \) attribute or product characteristic,
- \( j = \) brand,
- \( k = \) consumer or respondent,
- such that:
  \( A_{jk} = \) consumer \( k \)'s attitude score for brand \( j \),
$I_{ik} = \text{the importance weight given attribute } I \text{ by consumer } k, \text{ and}$

$B_{ijk} = \text{consumer } k \text{'s belief as to the extend to which attribute } I \text{ is offered by brand } j.$
Chapter 3

REVIEW AND ANALYSIS OF ENERGY AUDIT PROCESSES

3.1 Introduction

For industrial energy management, various energy audit standards and practices can be found. Choice of the suitable procedures depend on the size of a facility, the amount of energy that a plant consumes, the production processes involved, the technology used to conduct energy audits and the auditors expertise and resources. The audit can vary from one-day audit, one-week audit, two-week audit to one-month audit.

This study focuses on one-day audit which considers small- to mid-sized manufacturers, as they are one of the most significant industrial sectors in the U.S. economy, as discussed in the first chapter. In addition, the Missouri Industrial Assessment Center where the author currently works with is a center for industrial assessment of small- to mid-sized manufacturing plant sites to minimize energy usage and improve energy efficiency.

In this chapter, the energy audit processes of one-day audit project will be presented, reviewed and analyzed for the propose of the development and adaptation of the intended computer-aided tool. The illustration of the one-day audit project will be given in a logical manner, outlining the tasks and relationship which will be described in details together with their associated tools. The problem description will be given with respective to the tasks and their relationships. After the description of all tasks, their
characteristics and identified problems, the analysis of one-day energy audit project will be explained.

3.2 Energy audit processes

Since the author has an experience in conducting a one-day energy audit with Industrial Assessment Center, University of Missouri-Columbia, the study of the energy audit processes will use one-day audit project with this center as a case study. The aim of the audit is to analyze, as thoroughly as possible, the current situation of the site visited and identify opportunities for improvements and the financial justification for the recommendations, as shown in Figure 3-1.

**EXECUTIVE SUMMARY**

On June 27, 2007, a team from the Missouri Industrial Assessment Center performed an industrial assessment at your manufacturing facility. After analyzing the data gathered, our team has made five formal Assessment Recommendations (ARs) that could result in significant cost savings for your plant. The total annual savings for the recommendations made in this report is $34,800.

In addition, the team has also identified several areas where the facility could potentially become more energy efficient and further reduce its energy costs. Although these are not readily quantifiable at this stage, they deserve serious consideration from the plant management – statistical data from the IAC database regarding their implementation illustrate clearly their significant saving potential.

The annual savings, implementation costs, and the estimated simple payback period for each of the recommendations are listed in the following table.

A summary of the five recommendations and several potential areas is also provided, with a more detailed analysis starting on page 17.

<table>
<thead>
<tr>
<th>Assessment Recommendation (AR)</th>
<th>Annual Energy Savings - Electricity (kWh)</th>
<th>Annual Energy Savings - Natural Gas</th>
<th>Annual Costs Savings (f/k)</th>
<th>Implementation Cost (f/k)</th>
<th>Payback Period (Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR 1. Replace drive belts on large motors with energy efficient ones</td>
<td>70,000.0</td>
<td>$4,200</td>
<td>$0</td>
<td>Immediately</td>
<td></td>
</tr>
<tr>
<td>AR 2. Install occupancy Sensors</td>
<td>75,000.0</td>
<td>$4,500</td>
<td>$2,450</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>AR 3. Repair/Minimize compressed air leaks</td>
<td>250,000.0</td>
<td>$15,000</td>
<td>$1,150</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>AR 4. Turn metal halides lights off when not in use</td>
<td>85,000.0</td>
<td>$5,100</td>
<td>$0</td>
<td>Immediately</td>
<td></td>
</tr>
<tr>
<td>AR 5. Use variable speed drive for motors</td>
<td>100,000.0</td>
<td>$6,000</td>
<td>$0</td>
<td>Immediately</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>580,000.0</td>
<td>$34,800</td>
<td>3,600</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-1: Sample Executive Summary of the audit results
Six components of energy audit processes shown in this chapter are the common practices adopted by the US IAC program.

3.2.1 Pre-audit form

Once a manufacturer agrees to participate with this program, a pre-audit form will be sent out from the center to plant manager or owner of the facility to fill up general information about the plant. Information that can be obtained from the manufacturer is stated below:

- Company contact
- Raw material and end product(s)
- Plant layout
- Process descriptions
- Energy bills
- Pollution prevention & Water treatment
- Major energy consuming equipment

This pre-audit form will be used as a reference by auditors for utility analysis, equipment identification and energy audit report.

3.2.2 Utility Analysis

Energy cost is one of the most important factors that determine the overall operational costs for the manufacturer. It is often a major element of production cost on their product line. Therefore, it is important for manufacturer and auditor to understand the energy bills in order to find potential energy management solutions.
The plant statistics will give an energy consumption pattern over a time period (12 – 24 months) which will illustrate the peak or low use. Auditor, then, can determine the time of the peak and low, current energy consume and trend of energy used. These data can support an investigation on avoiding irregular use of energy from energy systems in the facility.

Energy sources will be reviewed and identified from pre-audit form for a selection of datasheet to be used. The data will be gathered from pre-audit form and energy bills provided by manufacturer. The next step, the energy usage will be stored in a datasheet to produce utility profile including graphs on energy used and pie charts on major energy sources. Units of energy measurement are important to evaluate plant statistics. The standard engineering measure and the most popular in U.S. is the British thermal unit or BTU. One BTU is an amount of heat required to raise temperature of one pound of water to one Fahrenheit. For electricity, the unit of energy usage is Kilo Watt Hour (kWh) where 1 kWh is 3,412 BTUs. Unit conversions and energy in most common fuels are shown below in Table 3-1.

<table>
<thead>
<tr>
<th>Energy Conversion Factors</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Energy Unit</th>
<th>Energy Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kWh</td>
<td>3,412 Btu</td>
</tr>
<tr>
<td>1 MBtu</td>
<td>1,000 Btu</td>
</tr>
<tr>
<td>1 MMBtu</td>
<td>1,000,000 Btu</td>
</tr>
<tr>
<td>1 therm</td>
<td>100,000 Btu</td>
</tr>
<tr>
<td>1 hp-h (motor horsepower)</td>
<td>2,545 Btu</td>
</tr>
<tr>
<td>1 hp-h (boiler horsepower)</td>
<td>33,500 Btu</td>
</tr>
<tr>
<td>1 ton-h (refrigeration)</td>
<td>12,000 Btu</td>
</tr>
<tr>
<td>1 Cu. Ft. of Natural Gas*</td>
<td>1,000 Btu</td>
</tr>
<tr>
<td>1 Gallon #2 Oil*</td>
<td>140,000 Btu</td>
</tr>
<tr>
<td>1 Gallon #4 Oil*</td>
<td>144,000 Btu</td>
</tr>
<tr>
<td>1 Gallon #6 Oil*</td>
<td>152,000 Btu</td>
</tr>
<tr>
<td>1 Gallon propane*</td>
<td>91,600 Btu</td>
</tr>
<tr>
<td>1 ton coal*</td>
<td>28,000,000 Btu</td>
</tr>
</tbody>
</table>

*Varies with supplier

Table 3-1: Energy conversion factors
In summary, the following are involved in this task:

- Identify source of energy from pre-audit form to understand and analyze the current energy resources of the facility
- Develop 12 month of energy plant statistic by using utility datasheet to produce utility profile (Figure 3-2)

### Natural Gas

**Natural Gas monthly usage cost:**

Total usage cost per year = $126,050  
Average usage cost = $7.44/MMBtu

<table>
<thead>
<tr>
<th>Month</th>
<th>Usage</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2006</td>
<td>1500</td>
<td>$13,000.00</td>
</tr>
<tr>
<td>May 2006</td>
<td>900</td>
<td>$4,200.00</td>
</tr>
<tr>
<td>June 2006</td>
<td>800</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>July 2006</td>
<td>650</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>August 2006</td>
<td>600</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>September 2006</td>
<td>500</td>
<td>$4,300.00</td>
</tr>
<tr>
<td>October 2006</td>
<td>600</td>
<td>$5,500.00</td>
</tr>
<tr>
<td>November 2006</td>
<td>1400</td>
<td>$16,300.00</td>
</tr>
<tr>
<td>December 2006</td>
<td>1600</td>
<td>$13,700.00</td>
</tr>
<tr>
<td>January 2007</td>
<td>2700</td>
<td>$22,900.00</td>
</tr>
<tr>
<td>February 2007</td>
<td>3000</td>
<td>$18,000.00</td>
</tr>
<tr>
<td>March 2007</td>
<td>2400</td>
<td>$15,250.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16450</td>
<td>$126,050.00</td>
</tr>
</tbody>
</table>

**Figure 3-2: Sample results of utility analysis**
3.2.3 Equipment Identification

In the pre-audit form, a list of major energy consuming equipment will be entered to a datasheet by auditor to create equipment list along with their expected amount of energy consume. The operating hours of equipment will be estimated from pre-audit form if there is no straight forward way to obtain energy use. With this information, the auditor can estimate and compare the energy consumption data with the utility analysis. If the energy data from equipment list is not accurate, the auditor can then make notes to find more information from company when conducting a walk-through audit. The cause of inaccuracy can be:

- Major energy consuming equipment is not completely listed by manufacturer
- Estimate operating hours and load of the equipment is not valid
- The information received is wrongly listed

The equipment identification process will provide information for auditor to look for potential systems to reduce energy usage and improve energy efficiency at the facility. (Figure 3-3)
In summary, the following steps are involved in this task:

- Identify and list the energy consuming equipment to the datasheet along with its specification, amount of energy drawn, size, etc.
- Check the equipment load and operating hours. If operating hours and equipment load is not stated in the pre-audit form, estimate the data by hours of operation of the facility and reasonable judgment
- Use datasheet to calculate the energy consumption of listed equipment
- Compare the equipment datasheet with utility analysis datasheet, make notes if it is not accurate for further investigation during walk-through audit.
3.2.3 Baselining

For a better investigation in energy audit process, the baseline of energy usage must be established in preliminary stage. The baseline of the site involved can be determined from equipment specifications from the equipment list. If some of the data are not provided for certain major equipment in this list, for the purpose of baselining, then the auditor should try to find information of that particular equipment from suppliers, vendors, online database or by interview during the plant tour.

The objective of a baselining is to have a baseline of energy consumption of each of major equipment in the plant so that the auditor can compare current energy consumption and suggest potential energy savings or energy efficiency of that energy consuming systems.

Therefore, the following steps are involved in this task

- Review the equipment identification datasheet to identify specification of equipment in order to create energy baseline
- Develop energy baseline by using equipment specification from equipment identification datasheet and standard values from suppliers, vendors or database (Figure 3-4)
3.2.4 Walk-through audit and preliminary recommendations

After all the general background information from utility data, equipment identification and baselining have been collected and analyzed, a detailed examination of the facility, production process and major equipment should be conducted. Within a manufacturing environment, the general focus areas in which to look for potential savings are:

- the compressed air system
- the heating, ventilating, and air conditioning system (HVAC)
- the lighting system
- the motor system
- the boiler system
• the process heating system and the steam system

The inspection for these areas requires the use of measuring instruments, checklist and the expertise and experiences from the auditor.

A on-day walk-through audit starts the facility inspection with a meeting involving the facility supervisor, the plant manager, or the owner for introduction of the auditors, audit program, purpose of audit and type of data to be gathered in the facility during the tour. In addition, the general information regarding with its production process, operation and maintenance of the plant are expected to be presented. During this meeting, equipment identification form and baselining document will be validated with plant manager to ensure the accuracy of energy analysis.

Safety equipment, requirement and practices will be explained to avoid any unexpected accident or injury that could happen during the audit.

The plant tour and walk-through audit will be carried out with an escort of plant manager, supervisor or owner to see the actual operation and their production process. During this time, auditors will gather data by taking notes, interviewing, filling up data collection sheets, using measurement tools, running through a check list of each of the systems that are in their interest area.

The walk-through examination can provide extensive information such as operation and maintenance practices, production function, operating hours, current equipment load and status, or energy consumption pattern to achieve energy savings in which auditor can analyze and provide a draft list of energy saving recommendations at the end of the audit day.
3.2.5 Evaluate savings

The evaluation of options is an energy audit process that, based on the data gathered through the previous tasks, identifies all potentials to save energy, and list all potential recommendations arising from utility analysis, baselining and walk-through audit. This task also attempts to estimate the potential savings to be expected. Detailed analysis should be carried out that provide meaningful information including the reasons for the recommendation, the costs of the recommendation if implemented, the expected annual savings in terms of energy as well as dollars, and the expected payback period. The savings recommendation will then provide:

- Reduction of natural gas used in BTUs or electricity used in kWh and demand in kW
- Amount of energy cost savings in dollars
- Implementation cost of recommended action
- Simple payback period
- Problem discussion on current operation which effect energy cost
- Recommendation actions towards reduction of energy usage
- Analysis, formulation and calculation of propose recommendation

To evaluate savings, auditor use his/her experience in energy audit processes and extensive research from materials such as IAC Manual, IAC self assessment workbook V 2.0, IAC Database, software tools, energy tip sheets and energy source books.

Therefore, the following steps are involved in this task:
• Create potential list of recommendation from utility analysis, walk through audit, analysis document
  o For equipment, compare with benchmark
  o For maintenance, develop from checklist and iac manual
  o For new technology, develop from source books, iac manual, self assessment workbook
  o For best practices, develop from source books, tip sheets
• Estimate the implementation cost by those important documents, suppliers, previous study
• Develop the economic analysis and recommendation and put them to Assessment Recommendation format (Figure 3-5)

ASSessment recommendATIONS

AR 1: Use variable speed drive for water pump

Estimated Electricity Savings = $2,500/kWh/year
Estimated Implementation Cost = $0,733.12/year
Simple Payback Period = 1.1 years
(ARCHS1474)

Existing Practice and Observation

While touring your facility, our team examined the 50 HP water pump and sprinkler system. The water is distributed through 300 feet pipe line to 10 sprinkler heads (15 feet height) over the logs outside the building to keep logs at certain moisture level. Thus, the area covered by the sprinkler heads is not always occupied by logs. The sprinkler heads are off where the logs are not existed.

The sprinkler heads cannot be turned off lower than 3-4 heads at a time where logs are occupied in area that only 1-2 heads are covered. This is due to the fact that the pressure of water from the water pump is too high to distribute to fewer heads. With the pressure that the water pump produced, it can blow the fewer sprinkler heads out of the pipe. This issue creates a potential energy savings to the current system as the following paragraphs will explain.

Recommended action

We suggest that the variable speed drive can be installed to the water pump motor. The speed of motor can be adjusted to the right level of the pressure distributed to the pipe by determining the sprinkler heads to be turned on. The variable speed drive can be purchased from motor company such as Missouri Electric Motors & Controls, 3903 Big Meadows Road, Jefferson City, MO 65101. The variable speed drive can cost up to $3,000. With a proposed schedule for the occupancy of the logs outside the building, it is estimated that the company would save $2,733.12/year or 72,580 kWh/year, with 1.1 year payback period.
Figure 3-5: Sample summary of a recommendation

As a summary, the nature of tasks, the tasks steps, the tasks materials and references, and the expected task outcomes are outlined in Table 3-2.

3.3 Tasks Illustration

Table 3-2 illustrates an overview of tasks involved with energy audit processes. The relationship of tasks is described with correlated source to find out about the process and tools that will support the particular tasks. For example, in order to develop energy baseline, auditor has to obtain equipment identification datasheet and if the data is still missing, auditor will gather information from vendors. Therefore, the tool that use to develop this baseline is baselining datasheet.

<table>
<thead>
<tr>
<th>No.</th>
<th>TASKS</th>
<th>Sources</th>
<th>Tools used in the task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Provide pre-audit form to potential clients</td>
<td>Pre-audit form</td>
<td>Pre-audit form</td>
</tr>
<tr>
<td>2</td>
<td>Identify source of energy</td>
<td>Pre-audit form</td>
<td>Utility analysis datasheet</td>
</tr>
<tr>
<td>3</td>
<td>Develop energy usage plant statistic</td>
<td>Pre-audit form, Energy bills</td>
<td>Utility analysis datasheet</td>
</tr>
<tr>
<td>4</td>
<td>Identify and list the energy consuming equipment</td>
<td>Pre-audit form</td>
<td>Equipment Identification datasheet</td>
</tr>
<tr>
<td>5</td>
<td>Check and record equipment load and operating hours</td>
<td>Pre-audit form</td>
<td>Equipment Identification datasheet</td>
</tr>
<tr>
<td>6</td>
<td>Calculate energy consumption</td>
<td>Pre-audit form, Equipment Identification datasheet</td>
<td>Equipment Identification datasheet</td>
</tr>
<tr>
<td>7</td>
<td>Compare the equipment datasheet with utility analysis datasheet</td>
<td>Pre-audit form, Utility analysis datasheet, Equipment Identification datasheet</td>
<td>Equipment Identification datasheet</td>
</tr>
<tr>
<td>8</td>
<td>Review and identify equipment for baseline</td>
<td>Pre-audit form, Equipment Identification datasheet</td>
<td>Baselining datasheet</td>
</tr>
<tr>
<td></td>
<td>Task Description</td>
<td>Source/Tools</td>
<td>Note</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>9</td>
<td>Develop energy baseline</td>
<td>Equipment Identification datasheet, standard values from vendors</td>
<td>Baselining datasheet</td>
</tr>
<tr>
<td>10</td>
<td>Record and review walk-through audit</td>
<td>Data collection sheets, checklists, softwares</td>
<td>Data collection sheets</td>
</tr>
<tr>
<td>11</td>
<td>Create potential list of recommendation</td>
<td>Data collection sheets, checklists, softwares, utility analysis datasheet, equipment identification datasheet</td>
<td>Recommendations</td>
</tr>
<tr>
<td>12</td>
<td>Estimate the implementation cost</td>
<td>IAC Manual, IAC Database, self assessment workbook V2.0, source books, tip sheets</td>
<td>Recommendations</td>
</tr>
<tr>
<td>13</td>
<td>Develop the economic analysis and recommendation</td>
<td>IAC Manual, IAC Database, self assessment workbook V2.0, source books, tip sheets</td>
<td>Recommendations</td>
</tr>
</tbody>
</table>

Table 3-2: Task descriptions with related source and tools

3.4 Problem description

From description of a traditional energy audit practice above, many documents from various sources are involved. In addition, these documents and tools are not centralized and sometimes they are not available when needed. Also, with a paper based system, an auditor needs to spend a great deal of time to look for the right tools to be used with the different processes and tasks.

As can be seen, the tasks from table 3-2 illustrate the overlapping use of sources, such as pre-audit form, a complication occurs when team members are assigned for different tasks that overlap in terms of data collection and analysis. Ideally, team members should have a means for sharing common sources and tasks outcomes, which at this moment are not provided by the traditional approach.
3.5 Analysis of the energy audit processes

In relation to the tasks outlined in Table 3-2, Figure 3-6 illustrates a summary of traditional energy audit processes that are followed at the present, listing the tasks and their related documents from various sources, according the actual sequence following the audit flow.

![Figure 3-6: Traditional energy audit flow](image-url)
Referring back to the analysis of the problems regarding the current, paper-based documentation system used widely in the energy audit domain, the following provide some more detailed and/or additional requirements that should be provided or supported by the computerized tool:

- A need of guideline to help the planning of audit, organization of audit teams, assignment of tasks, and distribution of sources and tools. The guideline will support team members to understand the overall view of all elements to be accomplished.

- A centralized management system is needed to reduce the error in overlapping, and to reduce time spent on finding tools, so that productivity is increased.

- A framework that can support tasks to pursue the integration of functionality and requirements of industrial energy audit processes.

- A Web-based environment to provide the support which needs to be a robust system for archiving, retrieving and updating documents and tools.

- A methodology is needed to develop tool to cover tasks and requirements for both actual audit and educational purposes.

By matching the currently practice with the desired needs, Figure 3-7 illustrates the domain of tasks, processes, and documentations that are to be covered, and aided by the new web-based, computer-aided environment, aiming to serve as a centralized system to facilitate industrial energy audit processes.
Figure 3-7: propose energy audit flow
Chapter 4

DEVELOPMENT APPROACH

4.1 Introduction

From the literature review and analysis of tasks and requirements of industrial energy audit processes, as discussed in the previous three chapters, the computer-aided application is developed according to the requirements identified. It is also essential to have an integration of the development methodologies and monitoring approaches for computer-aided supportive system, dynamic expectation of users, logical approach to the industrial energy audits and centralized controlled environment. The search for this ideal platform is necessary because of the currently lacking of centralized system, complication of tasks retrieval and instructions, unavailability of shared sources and great amount of time spending on irrelevant sources. However, there is no evidence in the literature that the ideal platform that would support problems above exists anywhere. Consequently, the propose approach stands to fill in a significant gap in this particular domain.

The main references that laid the foundation for the development of this project include the following:

- Wu (2001) discussed the task-centered development where it is a centralized integrated tool of all necessary functional elements. In this chapter, Wu’s
methodology will be explained in details. In addition, Wu and Khanna (2007) developed computer-aided audit workbook for industrial energy audit processes. This tool is logically integrating all the relevant functions of the audit processes with all worksheets and documents that support the execution of the tasks.

- As the expectation of users or customers dynamically change overtime (Robinson and Pidd 1998), the sustainable model for the development is vital for a new emerging tool to meet the users’ needs and requirements. Ulwick (2002) explained his approach to extract customer response not by what solution that user wants but from how the user wants by translate the surveys and interviews to an outcome-driven approach. Therefore, Wu’s methodology and Ulwick’s approach would be a great framework for the development of this computer-aided environment as a sustainable model.

4.2 Task-centered methodology

As outlined in Chapter 2, the Task-centered workbook developed by Wu (2001) explained the development that support step-by-step guidance through the MSA-MSD-MSO cycle. The task-centered is the integration of information that related to a particular tasks that allow users to navigate through the system and to gain an access to information in focus way. Since the concept of task-centered is the integration of necessary elements such as descriptions, instructions, processes, drawings, tools and data. It is the best fit for a framework to develop a computer-aided environment tool for the purpose of this particular project. It is even more relevant since Wu (2001) discussed supplemental
documents to facilitate the executions of the tasks where they include: data collections, checklists, cause-effect linking tables and tool sheets.

Figure 4-1 illustrates the workbook environment with its essential components integrated in one single page.

Figure 4-1: The structure of an MSM task document (Wu 2002)

4.3 Opportunity algorithm

From the literature review it became obvious that the opportunity algorithm is a suitable tool to evaluate the key value from users’ attribute. The survey will extract users’ desires and translate them by concerning the outcome into key attributes for evaluating process.
Opportunity Algorithm can identify the opportunity of improvement by evaluate a level of importance and a level of satisfaction of attributes. The opportunity occurs when the outcome is important and not well satisfied. The formulation of this calculation is given by:

\[ \text{Importance} + \max\{\text{Importance} - \text{Satisfaction}, 0\} = \text{Opportunity} \]

The high score of opportunity means the high gap opportunity for improvement. If the calculation has more than one attribute, the ranking of opportunity can be arranged. Survey questions are important to justify the opportunity. The questions should lead to the outcome goal of users which can contain both the type of improvement required and a unit of measure. To illustrate the outcome of user, here is example:

If the question asks what features do you want to have for the Web-tools online, the answer could be “I want to have a live video conference on the site”. This answer, by considering the outcome goal, can be translated to maximize the communication on the Web-tools online. After that, the opportunity algorithm will define key values by using a set of formula mentioned above.

### 4.4 Development Discussion

From this workbook and Task-centered methodology, it is clear that the conceptual framework of Wu and Khanna (2007) will provide a good starting point for the development of this research. Even extensive integration of computer-aided audit workbook has been proposed by Wu and Khanna (2007) but the missing part is the interactive components of the workbook to be able to navigate through the processes. In addition, its stand-alone nature is limited in terms of accessibility by different members.
of an audit team, and communications within the team, and between the team and the audited organization. Furthermore, the relevant entities in industrial energy audit processes are increasing where a single hierarchy is becoming more complex to display to users.

Therefore, the development on this research pursues the fulfillment of the original concept of computer-aided environment for the industrial energy audit, but with a much extended model that make the end results potentially much more practical and useable.

4.5 Development Approach

The purpose of the development is to create and promote computer-aided tool to facilitate one-day industrial energy audit activities by using Missouri Industrial Assessment Center as a case study base. The development model show in figure 4-3 consists of five major components:

Task Description:

- Identify tasks involved from the beginning of the project to the end
- Describe in details on what is being discovered
- Arrange all the tasks in sequence and categories: utility analysis, equipment identification, baselining, walk-through audit and evaluate savings

Supporting Systems:

- Identify sources and tools needed for each of the tasks from task descriptions
- Categorized the task into energy audit steps

Interface Design:
• Identify web attributes to implement the web design: usability, reliability, availability, accessibility, security

• Design layout prototype by following the web attributes guideline

**Adaptation:**

• Publish the website by uploading the web design to online server

• Use the developed application to an audit case

**Monitoring:**

• Create and dispatch survey form

• Gather response and analyze using opportunity algorithm

• Identify important key values

• Conduct a research to find solution for the key attributes

• Go back to the supporting systems and interface design where new documents & technologies and new attributes for interface design can be added or modify for improvements

**NOTE:** If the organization allows the change in tasks, the cycle will be started from the task descriptions

Task-centered mindset is applied in task descriptions, supporting systems and interface design to enhance the concept of a logical integration of all necessary entities for energy audit processes and be able to navigate through all the entities in focus way.
Figure 4-2: Development approach
5.1 Introduction

The development of computer-aided audit workbook by Wu and Khanna (2007) presents supporting tools for teaching, training and auditing purposes where it includes flowchart, steps, tasks, worksheets and calculators to enhance task execution and project management. However, the workbook is lacking in terms of support for data collection during industrial energy audit processes, including general information from facility, plant layout, production process, energy usage statistics, waste management and major consumption equipment. This data collection is required for energy data analysis at a pre-audit stage where it consists of utility analysis, equipment identification and baselining procedure. Also, the workbook is not a feasible solution for implementing and utilizing in user friendly manner where data information and tasks can be entered, stored, retrieved, achieved and logical linkage to the energy audit stages: pre-audit, during audit and post-audit processes. It is obvious that a intuitive centric online tool is necessary to conduct industrial energy audit where facility information, tasks documents, worksheets, checklist, logical flowcharts, literature documents and trainings, and collaboration notes can be accessed at any location with internet access.

The author proposes a development of computer-aided environment tool online called Webtools online to facilitate problems mention above. The Webtools online will
serve as a logical online platform for energy auditors and management officers to conduct energy audit project, and for educators to learn and conduct research for a future development.

5.2 Technology used for system development

- Computer
  - PC running on the Windows operating environment

- Software
  - Macromedia Dreamweaver 8
  - Macromedia Fireworks 8
  - Macromedia Flash CS3
  - Adobe Photoshop CS2
  - Adobe Acrobat 7.0 professional
  - Microsoft word
  - Microsoft Excel

- Application
  - Caspio Bridge online

5.3 Navigation map

Webtools online is an integration web-based application which displays involved tasks to conduct energy audits and facilitates users to achieve their goal to produce energy audit reports and to learn energy audit processes. Webtools online is currently
embedded on Missouri IAC website as shown in Figure 5-1 which illustrates overall site map of Webtools online.

The entire website is intended to have a shallow level to enhance the success rate of accomplishing the goal of users discussed in the literature review. Supporting elements such as HTML pages, document files, navigation images, Flash media and web application are utilized to meet all requirements of tasks.

Website database system is enhanced by web application called Caspio bridge online. This application is a database solution for web forms, data searches, reports auto-response emails, record-level security and real-time updates. Author and IAC team member employed this application to transform pre-audit form from paper-based approach to online approach. The advantage of adapting this technology is significant as it will be described in the next chapter.
Figure 5-1: Webtools site map
5.4 Webtools site content

In the introduction page, clear label links with description are mandatory so that users can expect what they will experience after the click on links (Figure 5-2). All these links show the list of tasks that move toward goals to be accomplished for energy audit processes. Bright colors on label links are used so that users can differentiate group sections of the processes intuitively. This feature helps users to quickly select the link in their interest and recognized the drill to access contents. Tasks and goals are divided in four sections:

1. MoIAC online tools: This section includes real-time pre-audit form online activities for both IAC clients and auditors. The pre-audit form can be entered, stored, updated, retrieved and export through these links. This section is also the initial step of an energy audit where participated manufacturer provides general information about his or her facility.

2. MoIAC energy flowchart: The flowchart represents the integrated group of tasks to be accomplished by auditor. The flowchart is well discussed in section 5.5.2.

3. Energy audit links: Topics included are links to Quick PEP, Google group and IAC Documents where later discussed on this research paper.

4. MoIAC training video & document: Training sessions held by Missouri IAC center are recorded and rerun by video and links to document and presentation involved for educational purpose in vary potential energy savings areas.
INDUSTRIAL ENERGY AUDIT TOOLS

MoIAC ONLINE TOOLS

Pre-Audit Form DATA ENTRY
This preaudit form is for potential clients or MoIAC team members to create new entry of companies' record before conducting an industrial energy audit at the facility.

Pre-Audit Form UPDATE
This update form is for clients or MoIAC team members to update information in this form. Please have your password ready.

Pre-Audit Form EDIT & SEARCH
This search & edit is only for IAC team members to search for companies' record and work on pre-audit process to prepare for a trip to the company. For Tutorial, click here.

MoIAC ENERGY AUDIT FLOWCHART

Flow Chart
The flowchart shows the process flow of Industrial Energy Audit for Mo IAC center. Tools and calculation tables are attached to the flowchart.

ENERGY AUDIT LINKS

Quick PEP
Quick PEP is a pre-assessment tool from Department of Energy.

Google Group
This is a link to our MoIAC discussion board for our MoIAC team.

Figure 5-2: Webtools homepage
5.4.1 Pre-audit form data entry

The first links of the Webtools online is Pre-audit form – data entry. This links will guide the user to register (Figure 5-3) and enter the required general information about the facility to be assessed by energy audit team (Figure 5-4). This link is intended but not restricted to be utilized by participated client to fill up the form. In some occasion, if the pre-audit form are received in the form of paper-based, energy audit team can also use this tools to enter required data to this web-based pre-audit form.
Figure 5-4: Pre-audit form online
After the user fill in the registration form, the auto email notice will be sent for username and password confirmation for a future use. Simultaneously, the auto email will be sent to IAC team to notify for a new entry. The username and password given by user will be used to access the pre-audit form that allow user to enter information about his or her facility. The content of pre-audit form includes company contact information, General plant information, electricity consumption, fossil fuel consumption, plant layout, process descriptions, pollution prevention, water consumption and treatment and major energy consumption. With this online pre-audit form, not only the text can be filled. Electronic energy bills, plant layout and process description can be uploaded and store online.

In general, it normally takes more than one time to complete this form. User can submit the form and continue his or her form later by using the link called pre-audit form update.

**5.4.2 Pre-audit form update**

Pre-audit form – update allows user to make correction and enter additional data to the electronic form. The lay out of the pre-audit form is identical to the data entry form in the initial stage. This site is also password protected where only user can have an access to edit his or her company profile. Once the pre-audit form has been updated, the confirmation email will be sent to user and IAC team to confirm and notify the update activity.
5.4.3 Pre-audit form edit & search

The edit and search functionality are designed for IAC team to search for companies’ entry and edit internal notes that can be seen only IAC team. In this stage, the pre-audit data can be accessed but cannot be modified since it is restricted to participated manufacturer only. Internal notes is an integrated note to share among team members regarding to a particular facility. It includes car rental status, trip duration, name of attendance, audit date, special equipment requirement, report due date, lease student and safety officer, and notes.

The team can use this link to retrieve general information of the facility from centralized online database that will support their tasks to conduct energy audit and complete multiple datasheets and energy audit report in later process. Sample pages of pre-audit form edit and search can be found in Appendix B: Pre-form 1 – 6

<table>
<thead>
<tr>
<th>Related Link</th>
<th>Sources/Tools</th>
<th>Sample Report (Appendix A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-audit form online</td>
<td>Pre-audit database</td>
<td>Doc A2</td>
</tr>
</tbody>
</table>

Table 5-1: Sample relationship of the deliverable

The relationship above (Table 5-1) shows the sample accomplishment of using pre-audit form online. The energy audit report in plant description (Appendix A: Doc A2) can be completed by data retrieval from the pre-audit database.
5.4.4 Energy Audit Flowchart

Energy audit tasks, documents and tools are organized and integrated in a logical manor by an establishment of flowchart. This development is based on the computer-aided audit workbook from Wu and Khanna (2007). This development is an enhancement in details of each of audit tasks with additional software tools, datasheets and monitoring systems.

The energy audit process flowchart web pages contain three major components (Figure 5-5):

1. IAC homepage link located on the top left of the screen. This link will direct the user to IAC Center homepage
2. Navigation tab bar to six major set of flowcharts for energy audit process
3. Flowchart map which is an interactive image to navigate to its set of flowchart, document or software tools

The navigation tab bar provides a short cut to set of flowchart that user is interested in for the first and the second level of hierarchy included with overview, utility analysis, equipment identification, baselining, walk-through audit and recommendation, and evaluate savings. This design can reduce unnecessary clicks that are not relevant to the interest process and can increase successful rate of completing tasks.
Figure 5-5: Energy Audit Flowchart main page
Figure 5-6: Equipment Identification Flowchart

Equipment identification flowchart is an example of a second level from the main flowchart. The click at pre-audit form will direct you to the pre-audit form process discussed in section 5.4.1 – 5.4.3. The pre-audit form will provide major energy
consuming equipment details (Table 5-2) that users can identify and record as a deliverable shown in a sample report (Appendix A: Doc A3)

<table>
<thead>
<tr>
<th>Related Link</th>
<th>Sources/Tools</th>
<th>Sample Report (Appendix A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Identification</td>
<td>Pre-audit database</td>
<td>Doc A3</td>
</tr>
</tbody>
</table>

**Table 5-2: Sample relationship of the deliverable**

In this design, the second level and the third level page has additional component to go back to the flowchart main page in the lower right corner (Figure 5-6, 5-7). If users would like to proceed to the next step, the box at the end of the flowchart will direct to a consequence process.

Figure 5-7 shows the third level of the flowchart where it is dominated by checklists of energy systems. The compressed air flowchart as show in the figure is linked with checklists, documents, datasheets and software tools. This relationship can also be found in any third level pages throughout the flowchart such as in lighting system, HVAC system, Motor system, etc. The sample relationship to deliverable is shown in the table 5-3. Compressed air flowchart can help auditor to acquire all tools discussed above for the analysis. The analysis will then be part of energy audit report shown in Appendix Doc A6 and Doc A7 where the evaluate savings will fulfill the cost analysis part.

<table>
<thead>
<tr>
<th>Related Link</th>
<th>Source/Tools</th>
<th>Sample Report (Appendix A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressed air system</td>
<td>data collection sheet, Software tools, IAC Manual, Check lists</td>
<td>Doc A6, Doc A7</td>
</tr>
</tbody>
</table>

**Table 5-3: Sample relationship of the deliverable**
Figure 5-7 Compressed air flowchart
5.4.5 Quick PEP

Quick PEP is a software tool by department of energy to help manufacturer identify how the energy being used at their plant and to find potential energy and cost savings base on the industry standard. It is design in such a way that company can have it completed by an hour. This software tool can be used by both manufacturers and auditors to seek for energy savings possibility. This is a compact tool for auditor to see and overall energy consumption and preliminary utility analysis.

5.4.6 Google Group

Google group is a communication channel among IAC team members. User can post forum, send email message to all members, create web page to share with groups, upload and share files, and check current calendar of activities on this site. The google group is a portal bay that broadcast our discussion and it enhances the involvement to IAC center.

5.4.7 IAC Document

IAC document link is directed to webpage that contains essential energy reference document such as IAC manual, self assessment workbook, report sample, tip sheets and source books in variety energy systems. These documents are used for energy system research for potential recommendation and during the energy audit project. Sources of these documents are from Department of Energy website, IAC Database and Rutgers IAC website.
5.4.8 MoIAC Training

MoIAC center has established training series in various energy systems. Therefore, to promote, train and educate auditors, potential members and interested personnel, the Webtools online has included MoIAC training link to available media such as training video and materials online. The topics include motor system, lighting system, process heating, compressed air, and pump.

5.5 Survey

For continuous improvement of the site, the survey form (Figure 5-8) is used as a monitoring tool for a future development of the Webtools online. This survey is available for users to evaluate the Webtools online. The current survey includes question about overall usage of this site and, particularly, the pre-audit form online. This survey will be collected in centralized database and will be analyzed to meet requirements, user desire and functional tasks to accomplish energy audit project.
Figure 5-8 Survey form online

5.6 Benefits of the development

This development support users in various aspects as explain below:

- Provide a task-centered platform for conducting energy audit with complement materials, training and communication channel among energy audit team.
- Provide a logical approach to conduct energy audit by the designed lay out and energy audit flowchart.
- Incorporate necessary tools and software for energy collection and analysis.
- Provide a centralized database server and 24/7 access with real-time manner, data can be updated, stored and retrieved at the same time.
- Provide user friendly manner tool for intuitive understanding throughout the project by concerning the usability technique.
- Save environment by reducing the use of papers and inks

Benefits to participating facility

- Customers can edit and update the pre-audit form online while auditors can simultaneously validate right after the submission.
- Reduce errors on filling up the pre-audit form since customers can come back and update information online at anytime.
- Reduce an operation cost of receiving and shipping pre-audit form.
- Save environment by using less papers, shipping materials and fax ink.
- Learn the energy audit processes online by browsing the logical flowchart.
- Be able to use this website as a portal to conduct research and share relevant energy audit documents and trainings among the company members which will increase awareness of energy conservation and efficiency at the company.

Benefits to auditors

- Provide an overall guideline to conduct industrial energy audit project.
- Reduce redundant work among team members since the Webtools online will give a visualize idea of the overall energy audit processes and tasks involved
during the process. Team members once assigned to the task will know how to achieve and know what is deliverable.

• Provide a portal to conduct a research on energy systems through IAC documents, manuals and training

• Reduce time spending on searching for tools and consequence tasks

• Help tracking the status of industrial energy audit process by flowchart.
6.1 Introduction

This chapter will present the validation of the proposed methodology by illustrating the benefits gain on adaptation of the developed Webtools online. Currently, the Webtools online is introduced to active members of Missouri Industrial Assessment Center. Therefore, the usage survey is conducted to evaluate performance and identify key attributes for continuous improving as a part of the proposed model.

The pre-audit form section on the survey will be analyzed by using opportunity algorithm and multi-attribute matrix approach. As a supplemental, the author will present additional satisfaction analysis from survey to illustrate the usefulness of the Webtools online in overall.

6.2 Benefits gained from proposed methodology

The Webtools online was implemented and has been tested extensively since it first launched by IAC team members. The benefits gained from using this Webtools online can be listed below:

- Users can use the Webtools online as a portal to all sources necessary to conduct industrial energy audit processes since it is an integration of
necessary tasks, data collection sheets, calculators, materials, and software tools in a focus way.

- Complication of sharing sources is reduced since the sources are archived in centralized database server. For example, pre-audit form can be easily access online where it will enhance the work flow in organization to finish the report
- User can navigate through the system logically by the flow of content.
- Time spending on searching for irrelevant information is shorten down where most of relevant sources are available on the Webtools online.
- Users can gain an access to this Webtools online 24/7 where it is secured and reliable
- Web developer can understand what user needs to interact with the website from a monitoring tool for development. He or she can use the key value to develop the next version of the Webtools online to meet the user requirements and regulations.

In addition, here are future benefits can be gained once this tool is enforced as a mandatory application for energy auditing

- Team members understand and aware of their responsibility of the energy system assigned by navigate through the interactive flowchart.
- Team members will be able to learn cross-functional energy system from both flowcharts and training section interactively.
• Increase a successful communication both within organization and with clients since in the pre-audit form online, the form and the internal note is a real-time update. Therefore, team members can get real-time information from the site.

6.3 Overall satisfactory rating

Table 6-1 and figure 6-1 illustrate a perception of Webtools online users by asking four criteria: ease of use, time savings, logical approach, and usefulness. The result shows that the logical approach and usefulness have a full score of five. The time savings and ease of use are 4.50 and 4.83 respectively. Time savings and ease of use can be from learning curve and complication of the first use. The help function on the website can support the tool to be more efficient.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
<th>User 4</th>
<th>User 5</th>
<th>User 6</th>
<th>Average Score</th>
<th>Full score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4.83</td>
<td>5</td>
</tr>
<tr>
<td>Save Time</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4.50</td>
<td>5</td>
</tr>
<tr>
<td>Logical Approach</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5.00</td>
<td>5</td>
</tr>
<tr>
<td>Usefulness</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5.00</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 6-1: Customer’s response for Webtools in overall
### Figure 6-1: Overall rating of Webtools

#### Table 6-2 Opportunity Algorithm result

<table>
<thead>
<tr>
<th>Desired outcomes on pre-audit form online</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
<th>User 4</th>
<th>User 5</th>
<th>User 6</th>
<th>Average Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Data integration: Centralize data integration of all the tasks to accomplished</td>
<td>5 5 5 5 5 5 5 5 5 5 5 5 4 5 4 5 3 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.17</td>
</tr>
<tr>
<td>2. Learning curve: Ease to get started to use</td>
<td>5 5 5 3 5 3 2 4 2 5 5 5 4 4 4 4 3 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.00</td>
</tr>
<tr>
<td>3. Data availability: Be able to access the pre-audit form up on a request</td>
<td>5 5 5 5 5 5 5 4 6 4 5 4 4 4 4 5 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.83</td>
</tr>
<tr>
<td>4. Tasks reduction: Reduce number of tasks to accomplish</td>
<td>4 5 4 4 5 4 5 5 5 5 5 5 4 4 4 4 2 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.67</td>
</tr>
<tr>
<td>5. Additional notes: Ease of acquiring and modifying responsibility on audits</td>
<td>5 5 5 5 5 5 4 4 4 5 5 5 4 4 4 4 4 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.50</td>
</tr>
<tr>
<td>7. Errors and completeness: Reduce error during data gathering and help of completeness of data</td>
<td>5 5 5 5 5 5 5 4 6 5 5 5 3 2 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.00</td>
</tr>
<tr>
<td>8. Notification capability: Be able to remind you when summtted, updated or modified</td>
<td>5 5 5 4 5 4 5 2 8 4 4 4 4 4 3 3 3 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.67</td>
</tr>
</tbody>
</table>

I = Importance, S = Satisfaction, O = Opportunity

Opportunity Calculation = [Importance + Max(Importance - Satisfaction, 0) ]
6.4 Opportunity Algorithm

From table 6-2, the opportunity algorithm ranking yields an opportunity score of 5.17 for data integration, 5.00 for errors and completeness, 4.83 for data availability, 4.67 for task reduction, 4.67 for notification capability, 4.50 on additional notes, and 4.00 for learning curve. This ranking shows the key attributes that will generate a bold improvement of the Webtools online. The most attractive attribute that should be first improved is the data integration. This is not interpretation that the data integration of the Webtools online is not well established, but it shows an opportunity that can generate a faster growth of Webtools online capability to meet user needs.

The future improvement will change the satisfaction level in overall (Ulwick 2002). Therefore, after the new improvement has been implemented the product should be re-evaluated to find the new attributes.

6.5 Performance evaluation of pre-audit form by MAM

<table>
<thead>
<tr>
<th>Average Importance (I)</th>
<th>Attribute</th>
<th>Average Belief of pre-audit form online (B1)</th>
<th>Pre-audit form online (B1 * I)</th>
<th>Average Belief of traditional pre-audit form (B2)</th>
<th>Traditional Pre-audit form (B2 * I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.83</td>
<td>Data integration</td>
<td>4.83</td>
<td>23.36</td>
<td>3.2</td>
<td>15.47</td>
</tr>
<tr>
<td>3.83</td>
<td>Learning curve</td>
<td>4.33</td>
<td>16.61</td>
<td>4.6</td>
<td>17.63</td>
</tr>
<tr>
<td>4.83</td>
<td>Data availability</td>
<td>4.83</td>
<td>23.36</td>
<td>3.4</td>
<td>16.43</td>
</tr>
<tr>
<td>4.33</td>
<td>Tasks reduction</td>
<td>4.33</td>
<td>18.78</td>
<td>3.4</td>
<td>14.73</td>
</tr>
<tr>
<td>4.50</td>
<td>Additional notes</td>
<td>4.50</td>
<td>20.25</td>
<td>4</td>
<td>18.00</td>
</tr>
<tr>
<td>4.67</td>
<td>Errors and completeness</td>
<td>4.33</td>
<td>20.22</td>
<td>3.6</td>
<td>18.80</td>
</tr>
<tr>
<td>4.17</td>
<td>Notification capability</td>
<td>4.17</td>
<td>17.36</td>
<td>3.2</td>
<td>13.33</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td></td>
<td><strong>139.94</strong></td>
<td></td>
<td><strong>112.40</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 6-3 Multi-attribute Matrix of Pre-audit form

From table 6-3, the pre-audit from online has a total attitude score of 139.94 and the traditional pre-audit form has 112.40. By using MAM as a comparison tool, this result
indicates that users are more satisfied with the pre-audit form online than with the traditional pre-audit form online.

Additional recommendations:

Data integration, data availability, additional notes and errors and completeness are all scored very high on average importance, 23.36, 23.36, 20.25, and 20.22 respectively. Since these attributes are the key values to the pre-audit form online, the improvement and research can be made to enhance above attributes.

6.6 Pre-audit form satisfactory rating

From table 6-3 and figure 6.1, it is obvious that users have a high satisfaction rate on pre-audit form online. However, it also shows that traditional pre-audit form is perceived to be better for learning curve attribute. It is suggested that the new improvement design should enhancing the initial walk-through as well as providing a help function on the website.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
<th>User 4</th>
<th>User 5</th>
<th>User 6</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data integration</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>4.667</td>
</tr>
<tr>
<td>Learning curve</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4.667</td>
</tr>
<tr>
<td>Data availability</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4.833</td>
</tr>
<tr>
<td>Tasks reduction</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4.533</td>
</tr>
<tr>
<td>Additional notes</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4.533</td>
</tr>
<tr>
<td>Errors &amp; Completeness</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4.333</td>
</tr>
<tr>
<td>Notification capability</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3.833</td>
</tr>
</tbody>
</table>

Table 6-4 Satisfactory rating of pre-audit from online vs. traditional pre-audit from

O = Pre-audit form online, T = Traditional pre-audit form online
Figure 6-2: Satisfactory comparison between pre-audit form online vs. traditional pre-audit form

6.7 Conclusion

Based on this research, it can be concluded that the computer-aided development with sustainable model is an effective method to support industrial energy audit processes. It offers and web-based navigation experience with an integration of all necessary activities in one site. User can utilize the real-time manner of the World Wide Web as described in the use of pre-audit form online and other components. User can also use this site as a web portal to learn more about energy audits at anywhere with an internet access point.

The Webtools online can be a great used for energy audit classroom where it includes all guidelines, training material and template of energy systems. Students will be able to navigate through the overall energy audits at ease.
From a designer point of view, the methodology can provide a guidance to achieve the usability, reliability, accessibility, security and availability. The downside of the development is that user will have to learn new environment to work around the Webtools online. More inevitable way that will support the ease of initial use should be employed.

For future research, this method does not include the evaluation of the usability heuristic evaluation (Nielsen and Mack, 1994) and user testing (Dumais and Redish, 1993) would help to emphasize the usability of the website.

The method is not yet having a robust calculation online Tools and new technology that would support an automated energy cost savings would be a great topic for a future research and development.
REFERENCES


Nielsen, J. and Marck, R. (1994), Usability Inspection Methods, John Wiley & Sons


Rajan, G.G. (2006), Practical energy efficiency optimization, Penn Well Corporation, Oklahoma


APPENDIX A
EXAMPLE ENERGY AUDIT REPORT

EXECUTIVE SUMMARY

On June 27, 2007, a team from the Missouri Industrial Assessment Center performed an industrial assessment at your manufacturing facility. After analyzing the data gathered, our team has made five formal Assessment Recommendations (ARs) that could result in significant cost savings for your plant. The total annual savings for the recommendations made in this report is $34,800.

In addition, the team has also identified several areas where the facility could potentially become more energy efficient and further reduce its energy costs. Although these are not readily quantifiable at this stage, they deserve serious consideration from the plant management. Statistical data from the IAC database regarding their implementation illustrate clearly their significant saving potential.

The annual savings, implementation costs, and the estimated simple payback period for each of the recommendations are listed in the following table.

A summary of the five recommendations and several potential areas is also provided, with a more detailed analysis starting on page 17.

<table>
<thead>
<tr>
<th>Assessment Recommendation (AR)</th>
<th>Annual Energy Savings - Electricity (kWh)</th>
<th>Annual Energy Savings - Nat Gas</th>
<th>Annual Costs Savings ($1)</th>
<th>Implementation Cost ($)</th>
<th>Payback Period (Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR 1: Replace drive belts on large motors with energy efficient cog belts</td>
<td>70,000.0</td>
<td></td>
<td>$4,200</td>
<td>$3,400</td>
<td>0.8</td>
</tr>
<tr>
<td>AR 2: Install Occupancy Sensors</td>
<td>75,000.0</td>
<td></td>
<td>$5,200</td>
<td>$2,450</td>
<td>0.54</td>
</tr>
<tr>
<td>AR 3: Repair/Replace compressed air leaks</td>
<td>250,000.0</td>
<td></td>
<td>$15,000</td>
<td>$1,150</td>
<td>0.09</td>
</tr>
<tr>
<td>AR 4: Turn metal halide lights off when not in use</td>
<td>55,000.0</td>
<td></td>
<td>$3,100</td>
<td>$2</td>
<td>0.00</td>
</tr>
<tr>
<td>AR 5: Use variable speed drives for motors</td>
<td>100,000.0</td>
<td></td>
<td>$5,000</td>
<td>$5,000</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**TOTAL**: 500,000.0 | 0.0 | $35,800 | 3.600 | 0.21 |

**AR 1**: Replace drive belts on large motors with energy efficient cog belts: Energy savings can be achieved by replacing the new efficient cog belts. The new cog belts can increase efficiency to 1%–3% of an overall performance of existing traditional belts.

**AR 2**: Install Occupancy Sensors: In some locations throughout the plant, lights are on with no activities or operators on the floors. Occupancy sensors will automatically switch on-off upon the presence of operators. Minimal estimate savings are calculated to yield a potential reduction of energy costs.

Doc A1: Executive summary
PLANT DESCRIPTION

Plant Background

XXXX is a wood processing facility established since 1912 that supplies wood products. Products are distributed throughout the United States for home construction and furniture. The plant is located in XXXX, MO.

<table>
<thead>
<tr>
<th>Location</th>
<th>XXXX, Missouri</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zip Code</td>
<td>XXXX</td>
</tr>
<tr>
<td>No. Of Employees</td>
<td>100</td>
</tr>
<tr>
<td>Principle Product</td>
<td>Drawers</td>
</tr>
<tr>
<td>SIC Codes</td>
<td>2523</td>
</tr>
<tr>
<td>Plant Operations</td>
<td>1 shift/day, 51 weeks/year</td>
</tr>
<tr>
<td>Annual Operating Hours</td>
<td>3500 hours/year</td>
</tr>
<tr>
<td>Factory Floor Square footage</td>
<td>XXXX, XXXX sq ft</td>
</tr>
<tr>
<td>Energy Sources</td>
<td>Electricity, natural gas, propane</td>
</tr>
<tr>
<td>Annual Average Temperature</td>
<td>78o F</td>
</tr>
<tr>
<td>Other</td>
<td>Factory floor is not air-conditioned</td>
</tr>
</tbody>
</table>

Manufacturing Process

Grading and quality checks are enforced at every stage of the manufacturing process. Random samples are tested for compliance with established standards in our well-equipped quality laboratory. The flake materials are flaked from Wood log, branches, and wood residue. Rubberwood is a light-colored, medium density, homogeneous material suitable for producing high quality particleboard. The rubberwood materials are chipped before being reduced to fine flakes of the desired thickness and length. This contributes to the optimum strength and smooth finish on the surfaces of the boards. The wet flakes are dried in a hot gas dryer to the required moisture level. The dried flakes are then screened to separate fine and core particles and stored in the surface and core bins. The surface and core particles are separately mixed with glue, wax emulsion, and other additives measured accurately to achieve quality of high standard.

The resolved particles are spread by air and mechanical mixing, incorporated by a Computerized Programmable Control System, ensuring consistent mat density and uniform weight distribution. The Hot Press, which operates automatically on Programmable Logic Control, compresses the mat under high pressure and controlled temperature to form boards to precise thickness. The finished boards coming out from the Hot Press is weighed automatically to make sure that the determined density is obtained.
SUMMARY OF PLANT STATISTICS

Plant Energy Consumption
From February 2006 to January 2007

From the energy data collected we found that, from February 2006 to January 2007, the energy consumption was:

- Electricity: 20,000,000 kWh

\[ (68,240 \pm 10^5 \text{ BTU/Year}) \]

Data analysis is recommended to help the record being in the standard form so that the meaningful comparison can be made over the energy usage and the cost analysis. The energy unit that is commonly used for comparison is BTU, British Thermal Unit, or MMBtu, million BTU's. The conversion factors are:

<table>
<thead>
<tr>
<th>Energy Unit</th>
<th>Energy Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kWh</td>
<td>3.412 Btu</td>
</tr>
<tr>
<td>1 kWh/hr</td>
<td>1000 Btu</td>
</tr>
<tr>
<td>1 MMBtu</td>
<td>1,000,000 Btu</td>
</tr>
<tr>
<td>1 Btu/hr</td>
<td>1000 Btu</td>
</tr>
<tr>
<td>1 Btu/hr (boiler)</td>
<td>2820 Btu</td>
</tr>
<tr>
<td>1 Btu/hr (steam)</td>
<td>3480 Btu</td>
</tr>
<tr>
<td>1 Btu/hr (refrigeration)</td>
<td>10,200 Btu</td>
</tr>
<tr>
<td>1 Gal of Natural Gas</td>
<td>100 Btu</td>
</tr>
<tr>
<td>1 Gal of 4% Oil</td>
<td>1440 Btu</td>
</tr>
<tr>
<td>1 Gal of 5% Oil</td>
<td>1520 Btu</td>
</tr>
<tr>
<td>1 ton coal</td>
<td>20,000 Btu</td>
</tr>
</tbody>
</table>

*Uses a mix supplier*

From the conversion, electricity consumption is an equivalent of 68,240 million BTU’s of energy. The total energy costs for the same period were $1,250,000 with unit energy cost averaging $0.06/kWh for electricity.
Natural Gas

Natural Gas monthly usage cost:
Total usage cost per year = $126,060
Average usage cost = $7.44/MMBtu

<table>
<thead>
<tr>
<th>Month</th>
<th>Usage</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2006</td>
<td>1500 $</td>
<td>13,000.00</td>
</tr>
<tr>
<td>May 2006</td>
<td>800 $</td>
<td>4,200.00</td>
</tr>
<tr>
<td>June 2006</td>
<td>800 $</td>
<td>4,000.00</td>
</tr>
<tr>
<td>July 2006</td>
<td>600 $</td>
<td>2,400.00</td>
</tr>
<tr>
<td>August 2006</td>
<td>500 $</td>
<td>4,900.00</td>
</tr>
<tr>
<td>September 2006</td>
<td>500 $</td>
<td>4,900.00</td>
</tr>
<tr>
<td>October 2006</td>
<td>800 $</td>
<td>4,000.00</td>
</tr>
<tr>
<td>November 2006</td>
<td>1400 $</td>
<td>16,000.00</td>
</tr>
<tr>
<td>December 2006</td>
<td>1000 $</td>
<td>13,700.00</td>
</tr>
<tr>
<td>January 2007</td>
<td>2700 $</td>
<td>22,900.00</td>
</tr>
<tr>
<td>February 2007</td>
<td>3000 $</td>
<td>10,000.00</td>
</tr>
<tr>
<td>March 2007</td>
<td>2400 $</td>
<td>15,230.00</td>
</tr>
<tr>
<td>Total</td>
<td>16460 $</td>
<td>126,060.00</td>
</tr>
</tbody>
</table>

Natural Gas Cost

Doc A3-1: Utility analysis
## Major Plant Energy Consuming Equipment

The major energy consuming equipment and their energy consumption profiles are listed below:

### Electric

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Units</th>
<th>Rated Load</th>
<th>Total</th>
<th>Power Factor</th>
<th>KW Equipment Load</th>
<th>Operation Hours</th>
<th>KWm</th>
<th>S</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Compressors</td>
<td></td>
<td>500 hp</td>
<td>750</td>
<td>0.75</td>
<td>4,000</td>
<td>1,000</td>
<td>38.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor Drives</td>
<td></td>
<td>750 hp</td>
<td>1,000</td>
<td>0.70</td>
<td>4,000</td>
<td>2,678,894</td>
<td>12.83</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 1</td>
<td></td>
<td>500 hp</td>
<td>750</td>
<td>0.75</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 2</td>
<td></td>
<td>400 hp</td>
<td>550</td>
<td>0.75</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 3</td>
<td></td>
<td>250 hp</td>
<td>375</td>
<td>0.75</td>
<td>4,000</td>
<td>2,678,894</td>
<td>12.83</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 4</td>
<td></td>
<td>150 hp</td>
<td>225</td>
<td>0.75</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 5</td>
<td></td>
<td>100 hp</td>
<td>150</td>
<td>0.75</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 6</td>
<td></td>
<td>50 hp</td>
<td>75</td>
<td>0.75</td>
<td>4,000</td>
<td>2,678,894</td>
<td>12.83</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Motor 7</td>
<td></td>
<td>2.5 hp</td>
<td>12</td>
<td>0.75</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td>170 kw</td>
<td>170</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Oven</td>
<td></td>
<td>120 kw</td>
<td>120</td>
<td>1</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Oven 1</td>
<td></td>
<td>50 kw</td>
<td>50</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Oven 2</td>
<td></td>
<td>70 kw</td>
<td>70</td>
<td>1</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Chillers</td>
<td></td>
<td>22 kw</td>
<td>22</td>
<td>0.80</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Chiller 1</td>
<td></td>
<td>15 kw</td>
<td>15</td>
<td>0.80</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Chiller 2</td>
<td></td>
<td>10 kw</td>
<td>10</td>
<td>0.80</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Chiller 3</td>
<td></td>
<td>5 kw</td>
<td>5</td>
<td>0.80</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Chiller 4</td>
<td></td>
<td>3.3 kw</td>
<td>3.3</td>
<td>0.80</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>1,007 kw</td>
<td>1,007</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 1</td>
<td></td>
<td>2.25 kw</td>
<td>2.25</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 2</td>
<td></td>
<td>1.1 kw</td>
<td>1.1</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 3</td>
<td></td>
<td>0.25 kw</td>
<td>0.25</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 4</td>
<td></td>
<td>0.1 kw</td>
<td>0.1</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 5</td>
<td></td>
<td>0.05 kw</td>
<td>0.05</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 6</td>
<td></td>
<td>0.3 kw</td>
<td>0.3</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 7</td>
<td></td>
<td>0.15 kw</td>
<td>0.15</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Water 8</td>
<td></td>
<td>0.06 kw</td>
<td>0.06</td>
<td>1</td>
<td>4,000</td>
<td>740,000</td>
<td>37.00</td>
<td>2.02%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>303 kw</td>
<td>303</td>
<td>1</td>
<td>4,000</td>
<td>1,041,360</td>
<td>62.00</td>
<td>2.02%</td>
<td></td>
</tr>
</tbody>
</table>

**Doc A4: Major energy consuming equipment**
BEST PRACTICES

- **Compressed Air Control System** - IntelliFlow sequencing system from Ingersoll Rand is used to efficiently manage air compressors. It automatically manages the on/off sequence of all 4 air compressors as well as maximizes effectiveness of storage and generation equipment.

- **Energy Conservation** - Closed-loop compressed air distribution system increases overall efficiency. Air pressure is the same at all outlet points, reducing pressure required at compressor to properly supply distant usage locations.

- **Monitoring System** - GaugeTracker ensures preventative maintenance operations are organized and scheduled. Air pressure regulators are used to avoid excessive usage pressure.

- **Efficiency Lighting** - Sodium lighting in production areas were replaced with fluorescent fixtures.

- **Maximize Boiler Efficiency** - All of five building furnaces are installed with burner from Honeywell for controlling the AirFuel Ratio. They are all inspected and maintained by contractor every three months.

- **Facility Maintenance** - The plant has in-house maintenance crew routinely work daily, weekly and monthly for major equipment in the facility. Maintenance cabinet and log located on each machine. The plant also has several contractors to regularly checking and servicing major equipment.

- **High Efficiency Motors** - Three standard high efficiency motors are used for vacuum pump at the router table in the wood shop to save energy and utilize high efficiency.
AR 3: Repair/Minimize Compressed Air Leaks

Estimated Kilowatt Usage Savings = 120,000 kWh/Year
Estimated Cost Savings = $14,000/Year
Estimated Implementation Cost = $2,150
Simple Payback Period = 0.08 Year
(APCh 2 425)

Existing Practice and Observation

While the pressure of the system (125 psig at the time of the audit) is satisfactory, noticeable air leaks were found throughout the system, representing a significant source of wasted energy.

Recommended Action

A thorough investigation of leaks should be conducted to find and repair leaks in the compressed air pipes. The most common sources of leaks are couplings, hoses, tubes, fittings, pipe joints, quick disconnects, EFLs (filter, regulator, and lubricator), condensate traps, valves, flanges, packings, thread sealants, and points-of-use devices (Source: US Department of Energy Compressed Air Tip Sheet).

Some of these leaks can be identified by listening for the sound of leaking air during factory downtime when all other machines are quiet, such as shift changes. During normal operation, the best way to detect leaks is with an ultrasonic acoustic leak detector, which recognizes leaks by the high frequency hiss sound they create. Alternatively, a simpler method is to apply soapy water with paintbrush to suspect areas and watch for bubbles created by leaking air. However, this method is more time consuming and messy (Source: US Department of Energy Compressed Air Tip Sheet).

It is also recommended that the plant implement a leak prevention program that emphasizes employee involvement in detecting and fixing leaks in the compressed air equipment they use. A reasonable target to aim for is reducing air leakage to 5%-10% of total system flow.

Analysis

<table>
<thead>
<tr>
<th>Pressure (psig)</th>
<th>1/64</th>
<th>1/32</th>
<th>1/16</th>
<th>1/8</th>
<th>1/4</th>
<th>3/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.29</td>
<td>1.16</td>
<td>4.66</td>
<td>18.02</td>
<td>74.2</td>
<td>167.8</td>
</tr>
<tr>
<td>80</td>
<td>0.32</td>
<td>1.28</td>
<td>5.34</td>
<td>20.76</td>
<td>83.1</td>
<td>187.2</td>
</tr>
<tr>
<td>90</td>
<td>0.35</td>
<td>1.45</td>
<td>7.72</td>
<td>28.31</td>
<td>120</td>
<td>266.6</td>
</tr>
<tr>
<td>100</td>
<td>0.40</td>
<td>1.55</td>
<td>9.11</td>
<td>35.83</td>
<td>160.9</td>
<td>327</td>
</tr>
<tr>
<td>125</td>
<td>0.42</td>
<td>1.64</td>
<td>7.86</td>
<td>30.63</td>
<td>122.2</td>
<td>255.5</td>
</tr>
</tbody>
</table>

*For well-rounded orifice, values should be multiplied by 0.97 and by 0.61 for sharp ones*
Other Potential Areas of Improvement

Checking percentage leakage of your compressed air system

Air leaks in are mostly not noticeable, especially in a plant that has a lot of noise during the processing period. One way to find out if your plant has a significant leakage in the system is to find the percentage air leaks. The percentage leakage is calculated by:

\[
\text{\% Leakage} = \frac{T}{T+t} \times 100
\]

Where,
\( T \) = Time between the compressed air start the cycle and stop
\( t \) = Time between the compressed air stop the cycle and start again

In general, the acceptable \% leakage is approximately 10%. If the measurement shows the percentage leakage over 10%, the energy savings are there to be found. Therefore, the maintenance program should be arranged to find the air leaks in the plant.
## Pre-Audit Online Report Example

**Pre-form 1: Company contact information**

### Nerd Herd Company (Fictitious Sample)

<table>
<thead>
<tr>
<th><strong>Company Information</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company Name</strong></td>
</tr>
<tr>
<td><strong>Company Address</strong></td>
</tr>
<tr>
<td><strong>Company Phone</strong></td>
</tr>
<tr>
<td><strong>Company Fax</strong></td>
</tr>
<tr>
<td><strong>SIC NAICS Codes</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Contacts</strong></th>
</tr>
</thead>
</table>
| **Name:** John Smith 1  
**Position:** Operations Manager  
**Phone:** 416-000-0000 x101  
**Email:** john1@gmail.com |
| **Name:** John Smith 2  
**Position:** Plant Manager  
**Phone:** 416-000-0000 x110  
**Email:** john2@gmail.com |
| **Name:** John Smith 3  
**Position:** Office Manager  
**Phone:** 416-000-0000 x201  
**Email:** john3@gmail.com |

<table>
<thead>
<tr>
<th><strong>Company Information</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Products Produced:</strong></td>
</tr>
<tr>
<td>Computer parts</td>
</tr>
<tr>
<td>Raw Materials:</td>
</tr>
</tbody>
</table>

| **Safety Needs Issues PPI:** |

| **Problem Areas:** |

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Pre-form 2: Company general information
Pollution Prevention

Waste Material:
Hydraulic Oil

Source:

Pounds Per Year:
800 gallons/year

Current Disposal:
Keisel Oil picks up

Cost:
$1.00/gallon

Do you have a current pollution prevention plan?
No

If Yes, please attach the report (File):

If No, please list issues with which you like our assistance:
Suggestions on pollution reductions and recycling

Water consumption and Treatment

Water Source, volume, and costs:
Missouri American Water (see attached bills)

Is water treated in-house?
Yes

Is water recycled in house?
Yes

Describe in-house water treatment facilities if any (filtration, RO, pH, flow rates etc):
Use Fresh "K" additive

Sewage Volume and associated costs:
N/A

Pre-form 3: Pollution prevention and water consumption & treatment
Major Energy Consuming Equipment

Compressors:
- 1 @ 100 HP
- 1 @ 110 HP
- 1 @ 75 HP

All Sulair Brand/120 psi/Synthetic Sump Oil

Pumps:
- 20 hp process
- 7 hp recirculation pump

Large Motor Drive:
See Below

Boilers:
- n/a

Furnaces Ovens:
- n/a

Chiller Fridge Cooling Tower:
- 110 ton Chiller/40-70 degrees F

HVAC:
- 10 ton/office/72 degrees F

Other intensive equipment:
- Blowmold machines/Magic
- 6 @ 70 kW avg. load
- 4 @ 20 kW avg. load

Electricity consumption

Power Company: Ameren UE
No of meters: 1
Approx annual cost: $239,461.48

Are you aware of any power factor issues?
No

Additional Info:

Electric Bill (File):
/Preaudit/Electric Bill/CLS - Electric Bills.pdf

Pre-form 4: Major Energy consuming equipment and electricity consumption
Pre-form 5: Fossil fuel consumption, submitted date and comments from company
Pre-form 6: Internal Notes