Design and Development of an Energy Efficiency Knowledge Center (EEKC)

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Abstract: Over the last two decades, the Industrial Assessment Center (IAC) at West Virginia University has worked with more than 500 small and medium sized manufacturing companies to identify energy and productivity saving opportunities. The savings, which keep adding up year after year, are appreciable but do not fully capture the potential impacts of the IAC Program. On average, the implementation rate of the recommendations has been only about 40%. This rate was expected to improve with the use of a knowledge center. Energy Efficiency Knowledge Center (EEKC) is a regional system which includes the development and deployment of technical resources to assist industrial facilities in energy assessment phases. It supports continuous improvement by incorporating the knowledge of IAC experts and the plant personnel. The EEKC provides information to clients on how to obtain baseline energy use for their specific energy systems using tools such as Quick Plant Energy Profiler (Quick PEP) by the US Department of Energy (DOE). It helps users to evaluate the energy efficiency measures during the pre-assessment and assessment phases. In this research, the IAC activities and tasks are studied and the steps to develop an online knowledge center are reviewed.

1 INTRODUCTION

Industrial Assessment Centers (IAC) are supported by the US Department of Energy's Advanced Manufacturing Office (AMO). The objectives of the IAC program are energy savings, resource efficiency and a trained workforce for addressing energy challenges, waste reduction, and productivity enhancement. Incessant improvement in work processes and assessment reports is one of the main assignments of the IAC program (US DOE, 2011). It is anticipated that managing information and knowledge within the IAC program augments the continuous improvement process of the centers. To manage the information and knowledge, a dynamic and secure system is needed in which information and knowledge can be saved, maintained, and shared. Recently knowledge management systems (KMS) have gained wide acceptance as enabling technologies for effective and efficient knowledge management (Maier, Hädrich, 2006). The primary goal of a KMS is to bring knowledge from the past to bear on present activities, thus resulting in increased level of organizational effectiveness (Lewin, Minton, 1998).

1.1 Research Objectives

This research project aims to design and develop a KMS, called Energy Efficiency Knowledge Center (EEKC), for energy efficiency projects at the IAC at West Virginia University. Research objectives include the extraction of knowledge from regular energy assessment reports and enter them into the knowledge center database; save and share the obtained knowledge; as well as archive, maintain,

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and manage the documents so that the IAC members, plant personnel, and other stakeholders can continuously interact with the knowledge center.

1.2 Needs for a Knowledge Center to Improve the IAC Processes

Continuous improvement in energy assessments requires that the knowledge is captured and shared efficiently so that it is readily accessible and manageable by the IAC members. The EEKC will become a source of information for knowledge developed by the IAC at West Virginia University through energy assessments at regional medium to large manufacturing plants under Enhanced Energy Assessment Process (EEAP). The targeted region to use the EEKC includes West Virginia, western Pennsylvania and eastern Ohio. The expanded region also includes Tennessee and Kentucky. The EEKC will utilize database driven internet protocols containing energy efficiency knowledge. The clients from industrial facilities will be able to access the EEKC via a secure portal. The EEKC will provide information and knowledge to clients on how to obtain baseline energy use for their specific energy systems, provide the client plant with specific details regarding a particular assessment recommendation, any tax incentives or rebates available for implementation in that geographical region, or a sensitivity analysis of product, process, and system related parameters with respect to energy savings and payback.

2 LITERATURE REVIEW

In this section, the basic materials for design and development of the EEKC are briefly reviewed. The general concepts of knowledge management, knowledge modeling methods and knowledge engineering process as well as Web 2.0 tools, Wiki pages, and their applications in the EEKC are reviewed.

2.1 What Is Knowledge?

Knowledge can only be completely understood if two things are known (Milton, 2007): (1) How it is structured, i.e. what components it is made from, and (2) the ways they are linked together. Knowledge can be generally divided into three categories: Explicit knowledge which is the type of knowledge that an individual has acquired mainly in the school and university; Explicit knowledge that implies factual statements about material properties, technical information, and tool characteristics; and Tacit knowledge which is deeply rooted in an individual's experience (Nonaka, 1995). Knowledge Engineering involves integrating knowledge into computer systems through which acquired knowledge is organized, shared, and validated. Figure 1 presents a simplified overview of the knowledge engineering process.

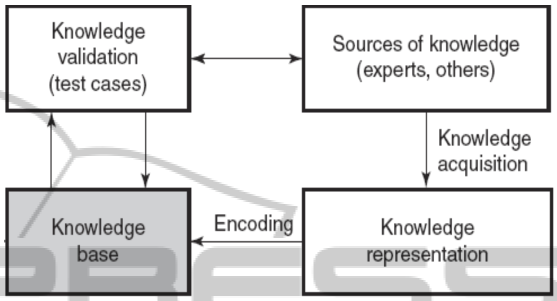

Figure 1: Simplified process of knowledge engineering. (Turban, Aronson, et. al., 2006).

2.2 Web 2.0

The term "Web 2.0" refers to the second generation of the web that aims to facilitate communication and to secure information sharing, interoperability, and user centered design. The principles of Web 2.0 and Knowledge Management (KM) are very similar. Most of the Web 2.0 attributes have roots in KM tools. Wiki page is a common application of Web 2 which facilitates the creation and editing of web pages using a simplified markup language based text editor. Wiki is chosen as the main platform in the EEKC.

2.3 Semantic Wiki

Wiki is essentially a database for creating, browsing, and searching through information. A semantic Wiki is a Wiki engine that uses technologies from the semantic Web to embed formalized knowledge, content, structures, and links in the Wiki pages Formalized knowledge is represented using semantic web frameworks and is accessible and reusable by web applications.

2.4 Knowledge and EEKC

Knowledge may be viewed from several perspectives including a state of mind, an object, a process, a condition of having access to information, or a capability (Alavi, Leidner, 2001). Knowledge, especially tacit knowledge, needs to be modeled using automatic methods and documented into the EEKC. This starts the development of the EEKC. The users would be able to update the knowledge. To extract and model the knowledge in processes, some protocols need to be designed to use the EEKC by the members. Information should be evaluated to ensure that they are reliable. All documents and files can be archived and members can upload and download the last version of each Assessment Recommendation (AR). Once information is saved and archived under a respective domain, the IAC directors would be able to monitor the system.

3 IAC WORK PROCESSES AND APPLICATIONS IN EEKC

An important step in designing the EEKC is to understand the work processes at the IAC. The IAC work is generally divided into three main processes: pre-assessment, assessment, and post-assessment.

3.1 IAC Assessments

IAC assessments and tasks are performed by local teams of engineering faculty and students from 24 participating universities across the country. IAC team conducts a survey of the eligible plant, followed by a one or two-day site visit, taking engineering measurements as a basis for recommendations. The team performs an analysis related to the energy use, energy savings, and estimate of costs, performance, and payback times. The DOE Best Practices software tools (Milton, 2007) such as Process Heating and Assessment Survey Tool (PHAST), AIRMaster+, Fan System Assessment Tool (FSAT), Pump System Assessment Tool (PSAT), Steam System Assessment Tool (SSAT), and Steam System Scoping Tool (SSST) are also used. Within 60 days of the on-site visit, a confidential report with details and recommendations is sent to the plant (Milton, 2007). The main stages of the assessment processes are pre-assessment, assessment, and post-assessment. A traditional IAC cross-cut assessment process is represented in Figure 2.

3.2 Better Buildings, Better Plants Program

Better Buildings, Better Plants Program is another form of IAC assessments which pays attention to, and provides services at, various stages of the assessment process with a strong focus on enhancing the implementation of Energy Efficiency Measures (EEM) as well as training of plant personnel. These assessments include activities described in the following pre-assessment phase, assessment phase, and post assessment phase sub-headings.

3.2.1 Pre-Assessment Processes

This step involves engaging the plant personnel and utility company personnel through conference calls

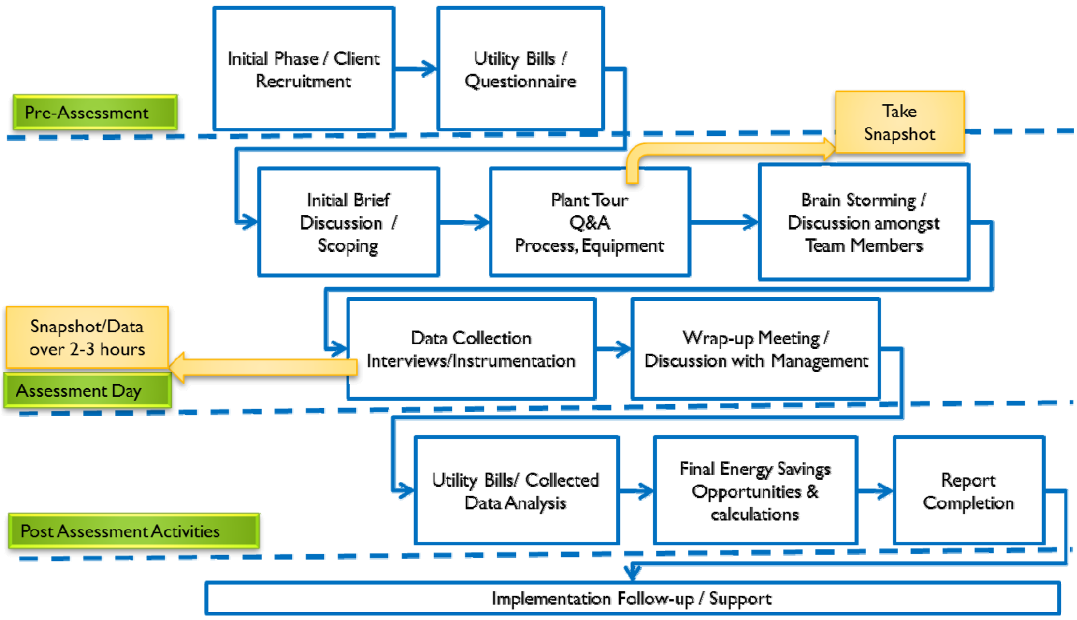

Figure 2: Traditional IAC cross-cut assessment process (Chaudhari, Gupta, et al., 2013).

to discuss energy consumption, manufacturing process, and key energy utilization indicators.

Information gathered during this process would be the first to be entered into the EEKC which initiates the energy profile for the company. Then a QuickPEP analysis is done to identify potential Energy Efficiency Measures (EEMs). There is a specific section in the EEKC for the QuickPEP results providing solutions to benchmark and compare the savings with other companies' results. Using the IAC database, same type of manufacturers can be studied. The IAC database is analyzed on potential EEMs based on the manufacturing characteristics of the plant. This knowledge needs to be entered in the specific Wiki page for particular AR. Then, the main function is to benchmark the energy usages of the facility with similar facilities that have had an IAC assessment from the IAC at West Virginia University in the past. This capability can be expanded to include other databases such as US Department of Energy's (DOE) IAC database. Using the other similar reports, the EEKC will be able to generate useful information to benchmark the energy usage of the plant.

The rebate and incentive programs section in the EEKC archives all programs offered for different manufactures. The assessment team will be able to identify existing rebates and incentives offered in the local area from the state and federal sources as well as from the utility companies. A review is done on the DOE's Best Practices fact sheets for possible application in development of an EEM. The DOE's Best Practices fact sheets are gathered and hyperlinked in the respective sub-systems in the EEKC. These pages are also linked to the related ARs in respective report.

3.2.2 Assessment Processes

The first step in the assessment processes is to interview the management personnel at the plant and to discuss the preliminary findings from the pre-assessment. Next, a discussion regarding the characteristics of the manufacturing process and the energy utilization aspects on major energy systems is conducted. The EEKC will help create the energy profile of the company. An assessment tool case in the EEKC is used which includes the checklist and essential questions. The data measurement process is critical as effective control cannot be achieved without effective measurement (IAC – UFL, 2011).

A discussion with plant personnel about operational constraints and barriers to implement EEMs in specific energy systems with respect to factors such as the integrity of the manufacturing process, product quality, and worker safety/health is also conducted. Then, the plant tour and observation of the manufacturing process and operation of the energy systems is done and followed by a planning meeting within the assessment team. After the planning meeting within the assessment team, intensive data collection efforts, observations, and interaction with plant personnel follow. In the energy profile for the plant, there is a data bank which includes all data gathered during the assessment, which is accessible to the EEKC users. Lastly the team exposes the plant personnel to the DOE's services and commercialized energy efficient technologies that may apply and discusses energy efficient technology "gaps" that may be of interest.

3.2.3 Post-assessment Processes

The main objective of the post-assessment process is development of ARs based on EEM calculations. The assessment recommendations that are developed in the report make use of the data measured through loggers and/or instrumentation. The ARs reference best practices knowledge, interaction with company personnel, and solid engineering principles and have a strong potential for implementation. The assessment report consists of: (1) the data and other information derived from discussions, records and measurements made during the assessment; and (2) the specific recommendations, together with respective assumptions and engineering calculations.

An important objective of the EEKC is how it conveys the information about saving opportunities for the company. The final report and full text of each AR are stored in the EEKC, although the objective is not only to show the entire report, but also to present the practical information and knowledge extracted from each particular AR. This may be initiated by summarizing and enhancing each AR.

The information gathered in this process is potentially valuable. The hidden reasons that an energy saving idea cannot be implemented or should not be implemented are identified in this process. Since the plant personnel are granted access to their plant assessment page in the EEKC, they can obtain baseline energy usage for their specific energy systems as well as practical tips to save energy. They can also add information and comments as the implementation and post implementation phase progresses. ARs can be changed to accommodate practical shortcomings. Since improvement in ARs is a continuous activity, having access to all previous versions and the last edited version (and more importantly the validated version) would help the IAC members and other stakeholders save time on preparing reliable results and increase the quality of work for future. The EEKC will also offer a powerful platform to track progress on organizational energy efficiency goals.

4 DESIGN AND DEVELOPMENT OF THE EEKC

This section describes the different aspects of designing the EEKC, its architecture, flow, and core functions.

4.1 EEKC Architecture

EEKC architecture determines how the information and knowledge in the EEKC–its Web pages, documents, lists, and spreadsheets–are organized and presented to the users. For energy efficiency content in the EEKC, the factors in Figure 3 should be considered.

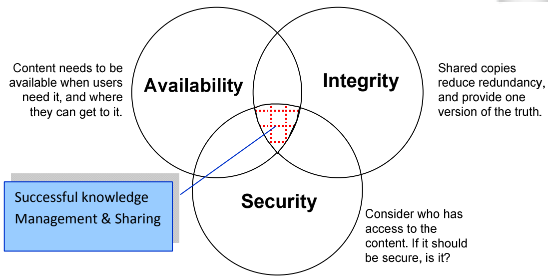

Figure 3: Three important factors to be considered in the EEKC architecture.

4.2 Information Flow in IAC/EEKC

The information flow is presented in Figure 4.

4.3 Design of EEKC

An attempt was made to establish a server and database for the EEKC, but establishing and maintaining a server needs a large amount of resources. Therefore, a built-in server in a third-party company (Google) is used in which high security technologies are used. The next step was to develop the web tools as shown in Figure 5. All pages in the EEKC are created using Wiki technology and are easily customizable. The first page of the EEKC is public and anyone can see the page using with its web address. To get into particular assessments or the private pages, users need to be authorized. The first layer of the client profile is public and lower layers such as pages for AR bank and vendor information are private. Each major equipment type has sub-pages for different kind of ARs. The sub-pages contain AR file, the Wiki (from now on, the page designed for saving and sharing knowledge is called as Wiki), vendor information, rebates, and tax incentives.

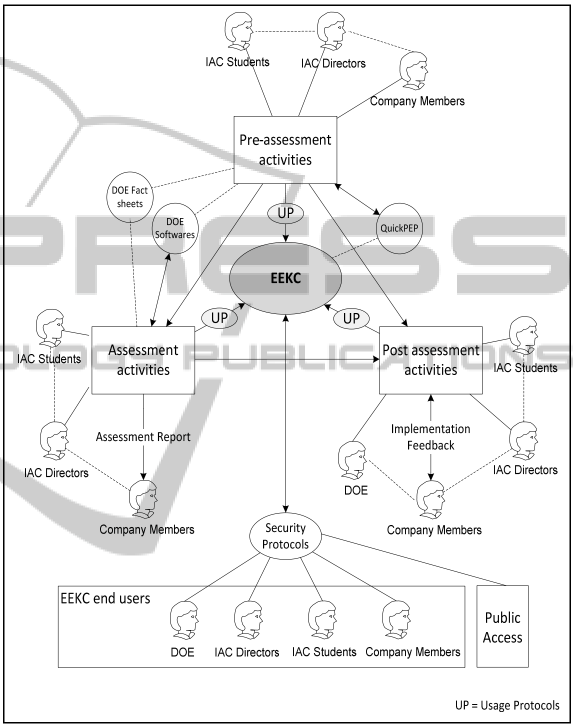

Figure 4: Information flow in IAC.

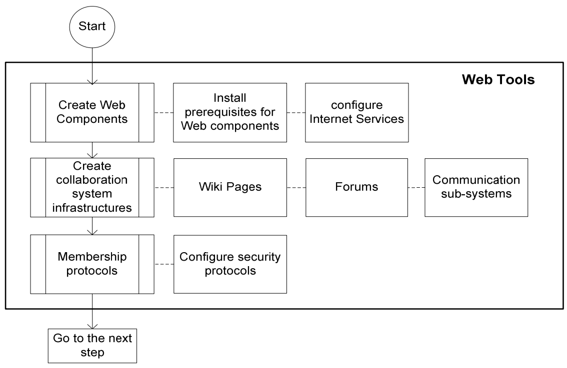

Figure 5: Steps to prepare the web tools.

4.4 Usage Protocols

The output of this study is not only to design a knowledge center but also to develop protocols to use the EEKC in energy efficiency assessments. Three protocols are designed to use in each of the pre-assessment, assessment, and post-assessment phases. An example protocol for post assessment is shown in Figure 6.

The protocols should be reviewed after few assessments and updated on a regular basis to catch proper results and facilitate continuous improvement. In order to improve the protocols, feedback from IAC members, plant personnel, and other stakeholders is crucial. The EEKC platform facilitates feedback, response, and interaction through the system.

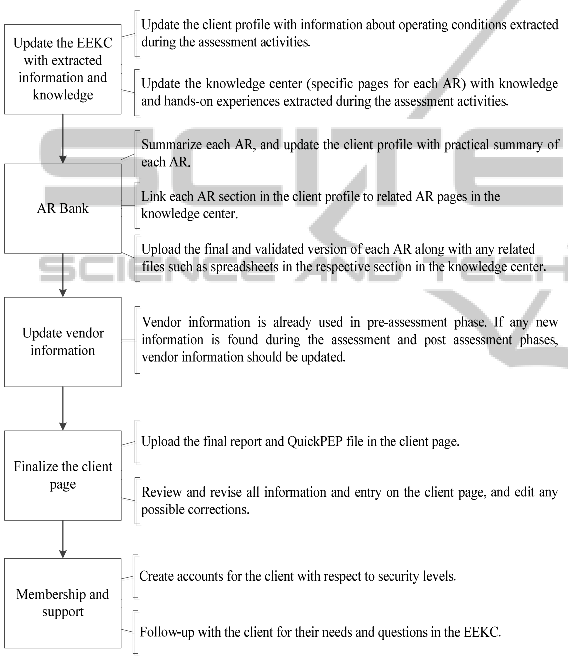

Figure 6: Post-assessment protocol.

4.5 Knowledge Center and Company Profile

The table of content of the company profile is shown in Figure 7. Contents are made up with information and knowledge extracted from different assessment phases. To develop a new profile, the first step is to create a new page for the company. A company profile can be created as shown in Figure 7.

Knowledge Center is accessible through the site navigator. The categories and subtitles are created based on the particular assessment selected. For future assessments, more categories and subtitles can be added as appropriate. DOE tip sheets are also available in the related page linked into the Knowledge Center page. To ensure that all users can share their feedbacks on any content, a section to

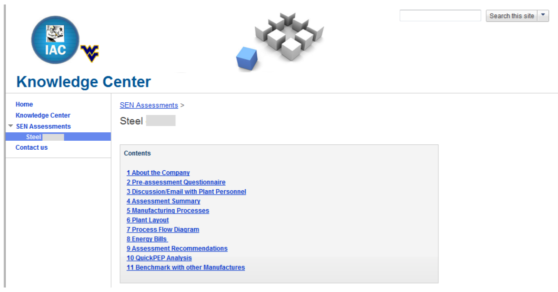

Figure 7: Table of content for a company profile.

upload attachment and comments is designed on the bottom side of pages. The Knowledge Center section becomes more and more comprehensive over time. Currently, to log into the EEKC, users need to have a Google account which uses (hypertext transfer protocol secure) https protocol. If the IAC directors or the EEKC administrator would like to give permission to some people to view or edit the private sections of the EEKC, they can easily invite those people by entering their email addresses into permission section on top of the page.

4.6 Case Study, Company X

The protocols were followed for the selected assessment (Company X) and the information was entered into the EEKC as shown in Figure 8. Pages and sub-pages presented in Figure 8 along with explanations to prepare their required contents were based on the pre-assessment, assessment, and post-assessment phases.

4.7 Subscriptions

The EEKC users can sign-up for email notification. Once a user is subscribed, an email will be sent each time the site or page is updated, someone makes a comment on the site or page, or someone uploads an attachment to the site or page. If they prefer not receiving notification emails in their Gmail but in another email address, they can auto-forward their Gmail account to any other address. The Google interface covers variety of Web 2.0 technologies.

4.8 Evaluation and Continuous Improvement

The EEKC needs to be continuously evaluated to find any possible bugs or improvement suggestions. The Plan-Do-Check-Adjust (PDCA) cycle can be used for continuous improvement of the EEKC. Not only the system should be evaluated by the IAC directors and lead students but also user collaboration level with the system needs to be evaluated. Then, based on needs identified, the PDCA could be used to implement identified improvements.

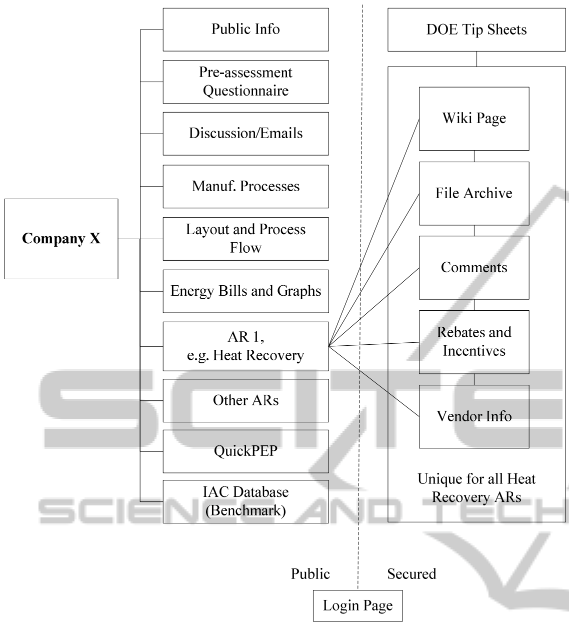

Figure 8: Profile and related pages for company X.

4.9 Scope and Limitation

The motivation of this research was to essentially develop a regional clearinghouse for energy efficiency for the area served by the Industrial Assessment Center at West Virginia University. There is vast amount of engineering, business, and implementation knowledge already in existence and creating a regional clearinghouse is a massive undertaking. This paper is merely a first step towards achieving the vision of central knowledge center that can act as a smart resource for energy efficiency engineers, project administrators, as well as researchers. The EEKC system was designed to increase the efficiency of report development as well as involve plant personnel as active collaborators. It also presents a platform for company personnel to develop and monitor their energy efficiency targets over time.

This research tried to develop a prototype using few energy assessments undertaken by IAC at West Virginia University. It is not tested by implementing the framework for using knowledge from other assessments. This system is limited to existing recommendations for a given company and does not let them evaluate a different recommendation and its impact on the overall energy consumption of the plant. Though the wiki format encourages interactions, it does not support text mining that could be used in future versions of this system.

4.10 Authors' Contribution to Existing Systems

According to the U.S. Bureau of Labor Statistics in 2012 (US BLS, 2014), private sector workers had median tenure of 4.2 year. Similarly, a major portion of IAC staff consists of center students with an average tenure of less than two years. This results in serious problems in terms of knowledge capture and management. Since most small and medium sized manufacturing companies do not have a knowledge database, the knowledge and expertise developed during a worker's tenure is lost after they leave the company. Development of the EEKC is a step in the right direction to help such companies and capture the knowledge not only from the company people but also from the IAC staff. This is expected to help the company set long-term energy efficiency goals and monitor their progress over time even after changes in the people responsible for the same. Similarly, such a system will help the IAC staff manage this information in an efficient fashion instead of reinventing the wheel after key IAC students graduate and leave the center.

Currently, the IAC program maintains a database for recommendations form all 24 centers without their details (US DOE – IAC, 2014). In fact, it even generalizes the titles of recommendations to maintain confidentiality. The IAC database is designed only to find the extent of savings opportunities. It does not intend to develop or maintain any knowledge and/or collaborative efforts between the plant personnel and the IAC staff. The authors appreciate the maintenance of such a database considering its intended use and the user groups. However, the EEKC is meant to involve the plant personnel as active users during all the phases of an energy assessment.

5 DISCUSSIONS AND CONCLUSIONS

The IAC program helps manufacturing facilities cut back on expenditure from inefficient energy use, ineffective production procedures, waste production, and other production-related problems. Continuous improvement in work processes of the energy efficiency assessment reports is one of the main missions of the IAC program. It is expected that managing information and knowledge within the IAC enhances the IAC assessment process. In addition to the IAC members, clients can also use the EEKC and view their assessment results in the system. If they are given permission, they would be able to navigate into knowledge center and other private parts of the EEKC. The funding agency personnel can also navigate into the entire system and monitor/extract information from it.

To manage the information and knowledge, the EEKC was designed in which information and knowledge can be securely saved, validated, and shared. The EEKC helps the IAC not only reduce the report development time by preparing the necessary applications, information, and knowledge, but also helps increase the productivity and report quality.

Future work can be conducted as an extended study by increasing the number of reports entered into the EEKC. Huge amount of data and information will be saved in the system in which knowledge extracted in Wiki could be still as short as possible. An advanced tool i.e. text mining can be used to analyze the data and text in each AR. The relationships between different ARs and their effects on each other could be automatically identified. This may significantly help the IAC program enhance the energy efficiency reports and improve the implemented amount of savings by manufacturing facilities (Jalali, 2011).

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