Enhancing Knowledge on Sustainable Energy Technologies of Thai Communities by Using Web GIS - A Case Study

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Abstract

The lack of knowledge on sustainable energy technologies is a main obstacle to adopt sustainable energy technologies for local community. Knowledge Management (KM) platform is a media to assist the community to learn and to understand more on sustainable energy. This is the main objective of this study. This paper represents a KM platform based on Web GIS server-side application which is implemented at Phitsanulok, Thailand. The platform provides information on sustainable energy technologies for three categories of local users: normal browsers, academics and local government officers. Each group of users got different priority to access to the KM platform. Pre and post questionnaires are distributed in order to measure the impact of KM platform and the improvement of knowledge of local community.

Keywords: Geographic Information System (GIS), Sustainable Energy Services, Knowledge Management (KM).

1. Introduction

Sustainable energy is an alternative energy which is important in today's world due to the decline of and the high demand for energy resources. Sustainable energy technologies can build up a variety of energy services such as solar home system, pico-hydro power systemetc [1]. Besides creating energy services, the utilization of sustainable energy also helps to preserve the environment, and to save and increase the economic cost for local community. Therefore, the dissemination of knowledge on sustainable energy is significant to the community. However, the knowledge on sustainable energy should be stored or shown in the appropriate form for users. In this paper, knowledge on sustainable energy technologies is distributed via the web application called web GIS. The following sections outline KMS on sustainable energy services, technologies and tools, a case study – a KM platform based on web GIS for Thailand and conclusion.

2. Knowledge Management System (KMS) on Sustainable Energy Services

The success of KMS has been demonstrated in many organizations. It can be seen that KMS has provided an increment in the organizational values, which include assets, properties, organizational data (organizational memory), and customer satisfaction among many business organizations [2] [3] [4] [5]. For example, KMS assisted a company in Taiwan in the tape-carrier-package integrated circuit smart-card assembler and testing business to gain a huge profit within two years [3]. The company launched the KMS in 1998, and by the end of 2000 it had reported a profit gain of 700%. Another example is a dice-and-mould company [2]. The experience and lessons learned from previous projects had been used to enhance the quality of the products and to improve the efficiency of the production. This has led to improved levels of satisfaction among the customers. Experience is important in this dice-and-mould company as well as in many other companies. On the other hand, the lack of experience is a major cause of mistakes and design failures related to the products [2]; this is another area KMS can assist in. Lessons learned from previous projects are captured in various forms of documentation. The company can reuse them for other employees in each process step. An example of the use of KMS is Infosys [5]. The company has demonstrated that knowledge from previous cases or projects is useful for all employees in every branch across the continents. For example, in the case of an employee in the US who is scheduled to give a presentation to a customer, the KMS of Infosys allows the employee to retrieve previous projects from branches in different countries in order to find out relevant information from these past projects [5]. Considering the example above, the functions of KMS are significant factors that assist the company to flourish due to the use of the KMS functions in order to support the company's goals and mission. By the same token, by deploying KMS in other sectors, such as education, science and energy, and using a similar approach, KMS has the potential to assist organizations to attain success.

In the case of the energy sector, the lack of knowledge is the main obstacle that prevents the local communities from using the local energy resources efficiently. This leads to community problems including poverty, environmental degradation and poor health [6] [7]. Government energy organizations and related agency groups have been employed and worked on pilot studies on sustainable energy services projects for many years. However, the inherent problems of these projects are the high turnover of experts and specialists and the lack of in-depth knowledge of the systems among the local users [8]. The high costs of the systems, tools and equipment, and the limited budget for planning, research and development are other main obstacles [1] [9] [10]. The KMS has the potential to solve the above mentioned problems and to support the facilitation and efficient utilisation of sustainable energy technologies. In other words, the implementation of KMS can address the issues of the lack of knowledge in sustainable energy technologies and promote the utilization of sustainable energy services.

KMS has been in existence for over two decades. The challenge for research in this area is how to enhance the utilization of KMS in the community by using the facilities offered by the latest information technologies, such as the Internet, intranets, browsers, data warehouses, filters and software agents, to systematize, facilitate, and expedite knowledge management within the communities. Some previous examples on the use of KMS about sustainable energy technologies in the communities are presented briefly as follows:

1. **Mini grid system for un-electrified villages in the North of Thailand** [8]

In August 2002, the mini grid system was implemented for two villages: Baan Pank Praratchatan (25 households with 65 inhabitants) and Baan Pank Sumnakngan (4 households with 11 inhabitants). The system consists of a renewable energy hybrid power plant, a low voltage grid line, loads and energy management system. This system generated 170 kWh per month, which could be converted and used. The total plant efficiency was calculated to be 60.5%. The energy management system is a dedicated computer control system, which determines the most effective energy sources to supply the required load and coordinate the various energy sources.

2. **Integrated Renewable Energy System (IRES)** [10]

The Integrated Renewable Energy System (IRES) has been designed as a knowledge-based system that has been used for designing and planning the utilization of available local renewable resources. It was implemented in a rural community in a developing country in 1992. The IRES was a stand alone system that used a relational database and search algorithm. The objective was to find an optimal combination of PV and/or Wind-Electric Conversion System (WECS) rating and the size of storage that minimizes capital cost, without compromising the loss of power supply probability.

3. **Computer-based system on education of renewable energy technology** [11]

In 1998, the Internet-based teaching course in Renewable Energy (RE) technology was created in a university in Melbourne. This course is used by undergraduate students in the electrical engineering programs. The course covers the knowledge of basic principles of energy and advanced RE technology, including the environmental impacts. The course materials also include information on the availability of different non-renewable sources of energy, biomass energy system, and barriers to the development of RE sources. The benefits of this course as claimed by the authors are:

- Allowing the learning to take place at locations suitable to the students, making it suitable for both on and off-campus learning.
- Giving students an alternative learning style and makes the learning process an enjoyable experience for students.
- Offering a virtual implementation of RE technology without any investment on physical equipment.

The above examples show inadequate services to the wider community. Firstly, all of them are working with stand-alone systems. The ability of these systems is inadequate to build up the energy services, as data on the databases is not up to date. Next, the user interfaces of the mini grid system and IRES are very complicated. They are not appropriate for local or normal web browsers in communities. Also, some results of the above examples have revealed that the lack of communication between the technicians and local people has led to delays for system repairs and maintenance. However, a positive result is illustrated in the teaching courses at a University in Melbourne. Students who took the course were able to understand RE technology better due to the use of web-based and multimedia technologies. Both web-based and multimedia technologies are well suited to illustrate the implementation process for RE. However, these applications of KMS for sustainable energy technologies have not shown all the potential they have. Therefore, it is appropriate to look for a new approach or a suitable solution that can offer a better KMS for sustainable energy technologies [12]. The next section will recommend various tools that can lead to the development of KMS for communities in order to achieve the goal of promoting sustainable energy services.

3. Technologies and Tools for KMS on Sustainable Energy Technologies

Information Technology (IT) has significant positive effects on the KM process by providing capabilities such as knowledge sharing across the organization boundaries [4] [13] [14] [15] [16]. IT offers many additional benefits. For example, the application of electronic mail, the Internet, collaboration technologies, bulletin boards, and newsgroups support the distribution of knowledge throughout an organization. It also provides a forum for employees to debate, discuss and interpreted knowledge via multiple perspectives. Most importantly, IT enhances the sharing of knowledge by reducing the restrictions pertaining to time and distance [2] [16] [17]. A web-based approach is behind all those applications. The architecture of this approach is shown in Figure 1.

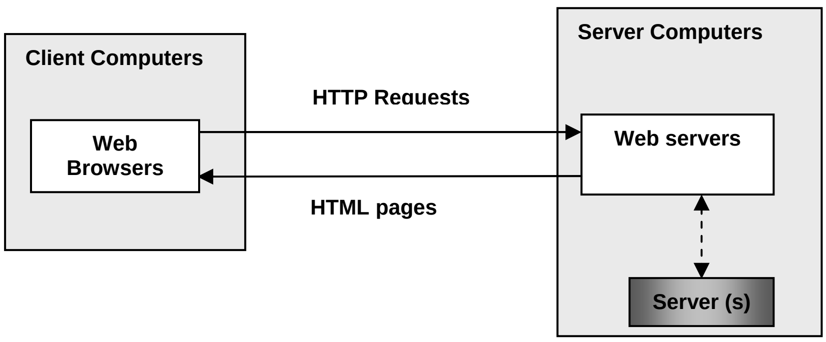

Figure 1: The fundamental of Client/Server (C/S) Architecture [11] [18]

The web browsers send the Hypertext Transfer Protocol (HTTP) requests to the server. The servers process the requests and send the result back to the web browsers via Hypertext Markup Language (HTML). Web-based approach is supporting KM activities. The approach offers the opportunity for communities to gain benefits from KMS and provides high quality knowledge content and user-friendly interfaces [11] [18].

As with most KMSs, information and knowledge on sustainable energy technologies are represented in various forms, such as text, diagram and figure. The location or spatial data of sustainable resources are beginning to emerge as an important aspect of knowledge. In order to enhance and promote sustainable energy technologies, the most effective KMS has to support these various forms of data. A web-based application is called Web GIS (Geographic Information System). The details of Web GIS are illustrated in the next section. Web-GIS provides the abilities to serve and support KMS functions. In particular, it enables knowledge sharing or distribution of sustainable energy technologies over the Internet including spatial information [16] [19] [20].

3.1 Web GIS

Web GIS is the name describing the integration of web-based application and GIS. It is able to serve multiple users with both spatial and non-spatial information on a variety of platforms over the Internet [21]. Web GIS also has significant benefits for data managers and developers alike. It provides an environment for rapid system development. In addition, because the information is served from dedicated servers it has the potential to address such issues as security, updating and licensing [22] [23]. The way of the connection between client computers and server computers of Web GIS is the same as normal C/S architecture (Figure 2). Web GIS requires HTML in order to display the information to a user via a web browser. HTML is a data formatting language designed as a means of presenting static information for display purposes [19]. However, HTML is inadequate for Web GIS users, as the information cannot be precisely defined within the limited tags set in HTML. The transmission of GIS data over the Internet relies on the capacity of the programming language for the precise data during transfer. It requires the integration of another programming language which is Extensible Markup Language (XML) [19].

In addition, Web GIS requires a GIS server, also known as Internet Map Server (IMS). IMS is a spatial server which processes the GIS operations based on the request from web servers. IMS connects or collects information from the database server in order to process the GIS operation as required by the users. The IMS is required to be set up with additional programming languages for the implementation of the GIS features. There are both commercial and open-source IMS available. An example of a commercial Web GIS package that includes IMS is ArcInternet Map Servers (ArcIMS) produced by the Environment System Research Institute (ESRI). This software is classified as a Web GIS server-side application. It offers ease-of-use, GIS web publishing capabilities, metadata services, data integration, multi-services architecture and scalable architecture. In order to implement Web GIS by ArcIMS, the developer needs to meet the licensing requirements. Depending on the functions of the features of the application program, other Arc softwares may be required. Examples of open-source IMS are MapServer and Google Map.

MapServer specialises at rendering spatial data (maps, images and vector data) for the web. Beyond browsing GIS data, MapServer permits the user to create “geographic image maps”, that is, maps that can direct users to content [24] [25]. Some features of MapServer are as follows:

- Advanced cartographic output, such as label collision mediation, map element automation (scale bar, reference map, and legend), etc.
- Support for popular scripting and development environments, such as PHP, Python, Perl, Ruby, Java and C++
- Cross-platform support, such as Linux, Windows, Mac OS X, Solaris.
- A multitude of raster and vector data, such as ESRI shape files, PostGIS, Oracle Spatial, MySQL, Open Geospatial Consortium (OGC) web applications, WMS (Client/Server), non-transactional WFS (Client/Server), and others [25].
- Map projection support.

Google Maps is a free mapping service application and technology provided by Google. Features of Google Maps are zoom in, zoom out, search, driving direction and so on. In order to implement the

Web GIS, Google Maps needs to be integrated with Google API. Google API is used to facilitate developers integrating Google Maps into their web sites, with their own data point. Both MapServer and Google Map TM are only analogous to the spatial server. Other features can be added by using the other web tools or other programming languages. The major difference between them is the programming languages that are used to perform the GIS operation. MapServer uses Common Gateway Interface (CGI) program that can be written in any languages such as C, C++ PERL, etc while Google Map application uses a large amount of JavaScript [23] [24]. There are two types of Web GIS: client-side application and server-side application. The following section gives further details about them.

3.2 Web GIS Client-Side Application

The Web GIS client-side application (Figure 2) is a client-dependent platform configuration, which requires the client machine to process all such GIS operations as spatial query, buffering, overlay and network analysis [22] [25].

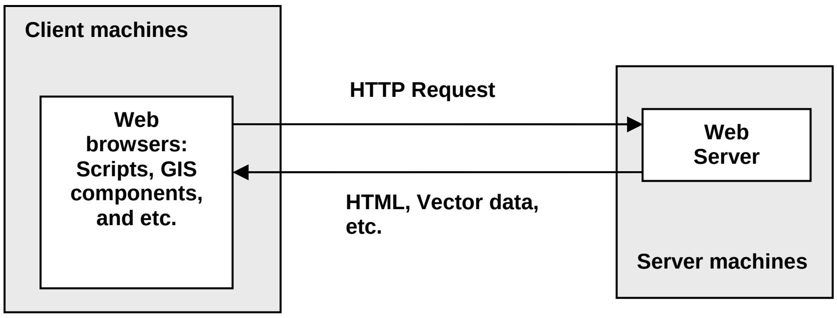

Figure 2: Architecture of web GIS client-side application (adapted from [22] [24]).

The server machine obtains the required data from the database and wraps it with the XML format, then sends it to the client. Once the data is on the client machine, the application is capable of manipulating the data locally. The web browser with the client-side programming language (such as script language, web-enable programming) can assist the client machine to perform the GIS operations. Two clients may receive the same data from the server but different outputs of the GIS operations depending on processing speed and graphical presentation. Data from the server is both vector and raster data, which is proprietary data supported by GIS operations. The developer can create complicated GIS operations on the client machine to manipulate the proprietary vector data that usually offer more efficient and flexible data processing than the generic web-recognized data format [22] [24].

Nevertheless, there are several disadvantages associated with the client-side application, as stated by Nengcomma [24], which developers should be aware of. Firstly, the security issues related to the licensing of GIS software and the copyright of the vector data should not be abused. Secondly, in order to ensure transmission of vector data across multiple platforms, the vector data must follow the standard format of the World Wide Web Consortium (W3C). Thirdly, as the vector data is transmitted over the Internet, heavy communication load is unavoidable.

3.3 Web GIS Server-Side Application

Figure 3 illustrates the Web GIS server-side application architecture. A web browser is used on the client machine to generate server requests and to display the results. The host machine usually consists of a Web and a GIS server together with other servers. Users or clients send their requests to a Web server. The web server passes the request to a GIS server, which runs a GIS application and a GIS database. Then the GIS server will wrap the result into the HTML format and sends it back to the web server, which will return the response to the user as a standard web page. All large GIS databases are on the GIS servers thereby allowing a simplified development and maintenance process. Only the result of the GIS operations is converted into the standard HTML format and is transmitted to the web client.

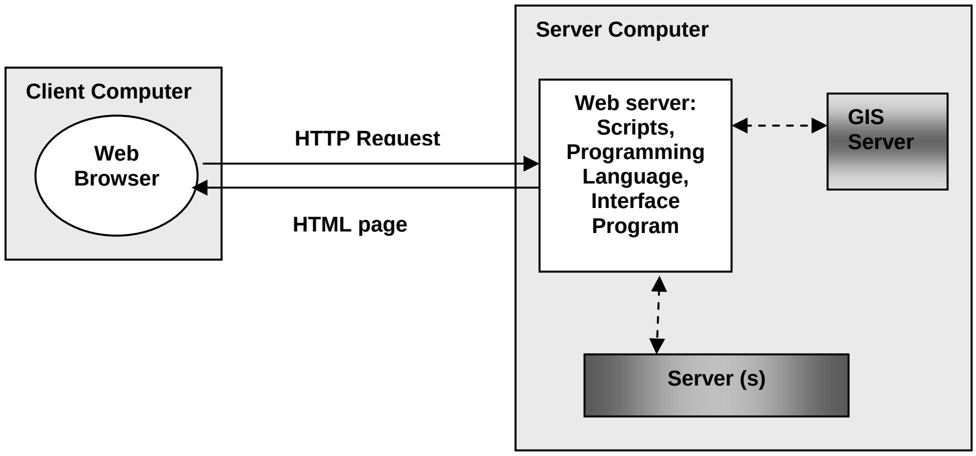

Figure 3: Architecture of web GIS server-side application (adapted from [22] [24])

In the Web GIS server-side application all clients use the same GUI to perform the same set of GIS functions on the web browsers. All GIS operations are processed by the dedicated server as clients' requests. Thus, the problems related to data incompatibility, data inconsistency and data unreliability are eliminated.

4. Web-based KMS on Sustainable Energy Technologies – A case study for Thailand

A KM platform has been implemented using a web GIS server-side application [26] and it was installed at the School of Renewable Energy Technology, Naresuan University, Phitsanulok, Thailand. Prior to the implementation of the KMS on sustainable energy technologies, data and information on sustainable energy technologies had been collected. They are classified into two categories: knowledge on sustainable energy technologies and regional data of sustainable resources around the region of Phitsanulok, Thailand. The first category of knowledge was created and captured from the stakeholders and experts among the energy sectors and the electrical power industry. The second category, local data about the Phitsanulok region, was collected from related public organizations such as the District Agriculture Extension Office from each district (called as "Ampher" in Thai). The information is in the form of text, figures, tables and spatial data. Both categories of data are then converted to the appropriate formats and stored on the server. Figure 4 shows an example of a screen display of the system.

Figure 4: Main page of the KM platform on sustainable energy technologies

Each link will connect to another page that shows particular features. For example, the link on operation shows a number of sustainable technologies that are used to generate services for the community. The KM platform helps local users to access knowledge on sustainable energy technologies, in their local area. Figure 5 describes the groups of participants and their permissions to access the features on the platform. There are three groups of users: general users, researchers and local government administrators. The general users may browse and learn information on sustainable energy and how to operate the sustainable energy system with better efficiency. Researchers are divided into two categories: normal users and administrators. Normal users are researchers who have access priority similar to the browsers. In the case of researchers with administrator status, the researchers have additional privileges in accessing additional knowledge that is related to their research work or to provide advice in the forum. In the context of Thailand, each province is divided into sub-districts which are known as “Tambons”. The Tambon council members are the local government administrators (LGAs) who will provide and access local information from the system [27] [28]. LGAs are responsible for the development and are responsible for improving the quality of life among the local communities [27].

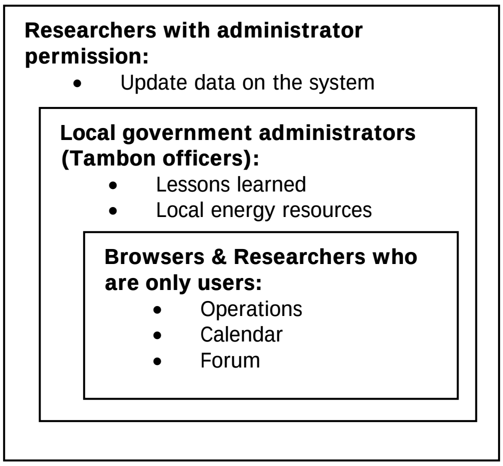

Figure 5: Permission to access to features of participants

The KM platform has been launched to the public since February, 2007. Surveys in the form of questionnaires were used to evaluate the effectiveness of the platform. The purposes of the pre-questionnaires are to gather information on the participants’ background, participants’ knowledge on sustainable energy and the internet infrastructure of the community. In this study, there were 142 respondents: 15 LGAs, 32 researchers and 95 general users. The results show that all the participants know how to access the Internet. The popular places that they use to access to the Internet are: 64.79% accessing from home, 81.69% accessing from their offices, 14.08 % accessing at the library and 14.79% accessing at the Internet cafe. The majority of the Internet activities of LGAs and general users are browsing or researching. E-mail is the most popular form of communication among the researchers. The survey also involves a set of "pre-test" questions, which comprise of fifteen multiple choice questions in order to evaluate the participants' knowledge on sustainable energy. The mean values of the pre-test are shown in Figure 3. Similar tests were conducted after the participants had used or accessed the KM platform for a minimum period of time. This is called the "post-test". The results of these testsindicate that the web application is an appropriate tool to communicate and facilitate the transfer of knowledge. The results also demonstrate that most of the participants are familiar with the World Wide Web (www) and they prefer to use the features on the web such as e-mail and news. In addition, access to the www is also sufficiently supported by both private and public internet service providers.

Table 1: Mean value of the satisfaction of the KM platform

Criteria	LGAs	Researchers	General users
The graphical user interface of KM platform is user friendly.	3.20	3.29	3.49
The information on the KM platform is up to date.	3.27	2.94	3.47
The KM platform provides communication between you and others or experts i.e. e-mail, forum and etc.	3.27	2.82	3.40
The KM platform provides meaningful information.	3.40	3.18	3.85
The KM platform provides adequate information on Sustainable Energy Services for designing and building sustainable energy services.	3.13	3.29	3.58

The purpose of the post-test is to evaluate the usefulness of the KM platform and to estimate the improvement of participants' knowledge on sustainable energy technologies and services. There were 110 participants who returned the post-test questionnaires: 15 LGAs, 18 researchers and 77 general users. A Likert scale of 1 to 5 was used to measure the satisfaction of participants with respect to the platform by setting up the criteria showing in Table 2. It shows that the participants are in general satisfied with the platform. In particular, item number four (The KM platform that provides meaningful information) gained the average highest score. Therefore, the format of the platform and knowledge on the platform has been well received and accepted by the participants.

The post-test was set up to measure the knowledge on sustainable energy of the participants after they had accessed the platform. The comparison of the pre-test and post-test between each group is shown in Figure 6.

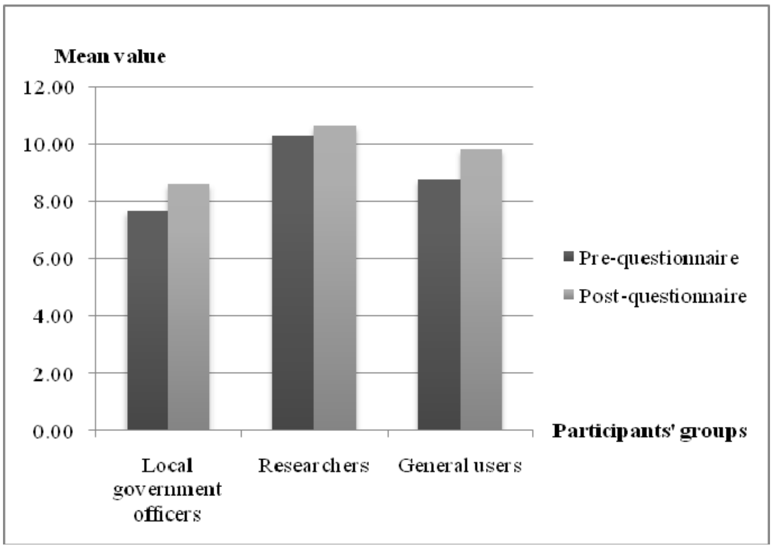

Figure 6: A comparison of the mean values between pre-test and post-test

The mean values of post-test increased in all three groups. It indicated that the knowledge on the platform may have improved the understanding of the participants on sustainable energy. It is expected that a better utilisation and efficient use of the sustainable energy resources will lead to improvement of the life and better environment for the local communities.

5. Conclusion

This paper reports the development and the utilization of a KM platform based on Web GIS as an effective tool to improve knowledge on sustainable energy technologies for communities in Thailand. The background of the research and design of the web-based KMS is reported on. The evaluation of this research has adopted a pre- and post- test approach based on structured questionnaires. The pre-test revealed the participants' familiarity with the world-wide-web and assessed the participants' knowledge on sustainable energy before they tried the KM platform. The post-test aimed to evaluate the usefulness of the platform and to measure the improvement of the understanding on sustainable energy of the participants. The results show that participants are familiar with the web, the KM platform provides a meaningful and useful source of knowledge, and the system also improves the participants' knowledge on sustainable energy in the communities.

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