A Stakeholder Planning Support System for District Heating Systems

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ABSTRACT

Energy conservation measures are needed to prevent the world to move in an unsustainable direction. Especially actions targeting the building sector are vital since it stands for a large share of the total energy use. The objective of this research is therefore to provide a framework for using visualization of aggregated energy use over time in a district heating network to stakeholders. This is fulfilled by integrating building information and energy data from a district heating supplier. The integration of building information and energy data makes it possible to identify high energy consumers through a performance visualization interface. Furthermore, the interface is connected to a collaboration hub, which offers a communication opportunity between consumers, suppliers, energy advisors and urban planners. Additionally, a stakeholder management approach is proposed to support the energy advisor to manage and select the consumers to target with advice and actions. The visualization, collaboration and the stakeholder component of the proposed system creates a Planning Support System (PSS) by which the citizens, energy advisors and urban planners can monitor the use of energy and also suggest actions to decrease the energy use of buildings. The next step of this research will be to evaluate and test the PSS together with energy advisors of 20 municipalities in Sweden.

INTRODUCTION

Currently, there is a consensus among scientist and politicians that the world is moving in an unsustainable direction (Yang, 2010; Rotmans et al, 2000). A large share of the energy use is caused by our built environment. As a result there is a need improve the energy efficiency in the building stock. Renovation of existing buildings is an important step but consists of a large variety of buildings with heterogeneous properties. It is therefore a challenging task to identify which buildings that have the highest potential to lowering the energy use. There are a number of approaches that are using energy data and GIS building information to identify low performance buildings within an existing stock of buildings (Kim et al, 2012; Yeo et al, 2013; Ruiz et al, 2009; Carrión et al, 2010). However, these frameworks are limited to identify and monitor energy use and they are not integrating stakeholders methods. The proposed conceptual Planning support system (PSS) offers opportunity to both analyze the energy performance and link it to collaboration hub for further communication with the appointed energy advisor in the city. Furthermore, the stakeholder management theories propose different strategies to be used in the information and support when communicating with the consumers which is included in the PSS.

STATE OF THE ART

There are several proposals of Planning Support Systems and Spatial Decision Support Systems (SDSS) found in the literature aimed to lower energy use. GIS building data is often combined and integrated with real or simulated energy use data. Thuvander and Tornberg (2005) presented an energy performance visualization of housing stock in Gothenburg by using GIS data combined with energy data. The model was limited to a static time interval and was also dependent on manual work to integrate building and energy data. Carrión et al (2010) overcome these limitations by presenting an automated process based on an integrated Spatial ETL (Extract, Transform, and Load) tool. Later, the tool was used as the information core in creating a framework to rank buildings by their energetic rehabilitation state according to identified performance of the buildings. A similar approach were presented by Dall'O'(2012), which described a methodology mostly based on information that is already available on housing stock such as cartographic documentation, thematic maps, geometric data etc. Energy performance data of buildings was collected using energy audits on sample buildings. The GIS integration enhances data integration and allowed low cost comprehensive framework of the energy performance of building. Kim et al (2012) presented an energy monitoring and visualization of aggregated and real time states of various energy usages. Data series were collected from location-based sensors and by combining it with GIS data, it was possible to display geo-location characteristics in relation to respective energy use. The client were capable of processing and displaying real time and aggregated data in different dimensions such as time, location, level of detail and mode of visualization. Yeo et al (2013) presented an environmental and energy PSS that combines energy information and planning information for environmental friendly urban planning based on a lifecycle perspective.

There is also work done that examines behavior science and how to convince household owners to lower their energy use. Vassileva et al (2012) claimed that major variations are found in use patterns between individual households rather than households groups. Therefore, individual and specific feedback was considered more important. In order to obtain this personalized specific feedback related to difference preferences, characteristics and needs should be provided to the households instead of generalized tips and information applicable to all households. Thuvander et al (2012) have a similar point of view and argued that measurements to lowering energy use is strongly connected to household understanding of energy use and cost. Furthermore, also individual households understanding of impacts of acts and measurements and how it influences the energy use are vital. Ellegård et al (2011) claimed that it is important to relate information and feedback from energy use of everyday activities, in order to make it relevant for consumers.

In summary, there is a need to integrate PSS with methods to manage household owners both to identify their activities but also to communicate relevant management strategies to lower energy use. If such an integration is achieved a PSS that visualize real time and aggregated data can work more efficient if a link is established between individual householders preferences, their potential savings and a well-established stakeholder communication strategy to achieve understanding by the end-users. Stakeholders are all, directly or indirectly, actively or more passively engaged in the decision-making process Walker et al (2008) and Johnson and Scholes (1999) argued that a stakeholder’s relative importance should be classified according to their interests and power, related to the specific organization. They created a stakeholder map in an attempt to explain how different stakeholder groups should be managed in relation to power and interests. Within the next part we explain how a PSS that includes stakeholder management were developed through a system development processes.

METHOD

To develop the PSS a system development process were used, which is a special case of action research using case studies to collect data (Chiasson and Dexter, 2001) This enhances possibilities to implement the end-result of the research to practitioners by use of implementation cycles on the information system (Hartmann, 2009). The system development process includes:

1. Weaknesses with the current way of evaluate energy use
2. Define requirements and functionalities
3. Build a prototype system
4. Observe and evaluate use
5. Develop new theories/models based on observation and evaluation of usage

Steps 1 – 3 of the research method are described in this paper applying a case study approach. This method is suitable when studying complex processes, (Yin, 2003). The city transformation of Kiruna was selected because of its availability, stakeholder and time-space complexity and high pressure on urban planning processes.

CASE STUDY DESCRIPTION

The world’s largest underground mine is located in the north of Sweden, 150 km above the Arctic Circle; in the town of Kiruna with around 20 000 citizens. The northern position of the town results in an annual average temperature blow 0 °C. With a cold climate the need for energy to heat buildings is high. Kiruna has a well-established district heating network that supports buildings with thermal energy for heating and hot water. The district heating system in the town of Kiruna is owned by a municipality company named TVAB. TVAB owns the network and heat productions plants connected to the network. When the heat is produced it is transported in a primary piping network in the ground from the production plants to the buildings that is connected to the network. A subcentral is then transferring heat from the primary network to a secondary network (radiator network) and for hot water production. The secondary network has lower pressure level and lower temperature then the primary network, normally two heat exchangers, one for the heat generation and one for the water production is used.

Energy use

The sub central that transfers heat from the primary network is equipped with measure equipment and it measures:

- Power, momentarily [kW]
- Flow, momentarily and in total, [m^3]
- In and out going temperature, momentarily[°C]

The recordings are used for calculating the energy use and the difference between in and out going temperature. The energy use is accumulated and the total amount is stored. The recordings are once a day transferred, by radio link or wire, to a database. This results in a database that contains all measure data on a daily basis for all consumers in the network. The area that is chosen to be applied for the visualization is an area that contains different kinds of buildings such as villas, apartments, schools and industries.

Data collection and analyze

Energy data from the municipality owned Energy Company were collected and analyzed. From the archival data the recorded heat consumption for each consumer was chosen. The archival data is not homogenous, measurement error occur and creates lack of data. When a measurement error occur measured heat consumption accumulates to the next day and so on until a correct measurement is done. The lack of data is treated by dividing the accumulated heat consumption in the number of days when the lack occurs, as shown in figure 1, see day 6-10.

Consumer A	Measured heat consumption	Treated heat consumpion
Day	KWh/day	KWh/day
1	5000	5000
2	5000	5000
3	5000	5000
4	5000	5000
5	5000	5000
6	Lack of data	5000
7	Lack of data	5000
8	Lack of data	5000
9	Lack of data	5000
10	25000	5000
11	5000	5000
12	5000	5000
13	5000	5000
14	5000	5000
15	5000	5000

Figure 1. Measured data series and treated data series

RESULTS OF THE SYSTEM DEVELOPMENT PROCESS

The case study showed that there is currently no system in use for the energy company TVAB for evaluating the energy use by different buildings in city of Kiruna. As a result, there is no efficient performance visualization of buildings and the following problems were found:

- TVAB is limited to manual and time consuming methods to analyze the use of energy by different household. Currently no efficient support system exists which integrates information and monitor the energy use of different buildings within the city.
- In Kiruna energy data are scattered and difficult to understand for both for professionals and citizens. For instance, as a result, the energy advisors are limited to use generalized tips and hints instead of customize package for the households.
- Even if a PSS exists, energy data is in general not communicated properly for the public to be able to understand there energy use and which potential relevant measurements that they can take. Furthermore, the methods used in the academy are normally not suitable and adaptable for practitioners needs since they have not been involved in the development process. This is a general conclusion from theory.

Based on this weakness a number of requirements are defined in the next part.

REQUIREMENTS AND FUNCTIONALITIES

As a conclusion from the literature review and case study the following requirements and functionalities are proposed:

- Sorting functionality by building, area characteristics, high and low energy use values.
- Automated integration of building and energy data.
- Web-interface, easy to use and share both by planners and residents
- Performance visualization based on kWh, year build, floor area (m^2) in a 4D environment
- Two-way asynchronies communication. Possibility for households to leave their feedback and information
- Create a stakeholder management model, to identify household groups and communicate with them related to a pre-defined strategy, according to interests, ability and cost/benefit.

A PSS PROTOTYPE FOR ENERGY PERFORMANCE

Based on the requirements a prototype system was created, see figure 2. The model automatically integrates the building and the energy information with a spatial ETL (extract, transform and load) tool e.g. Feature manipulation engine FME 2013 and prepares it for a visualization tool e.g. Google Earth.

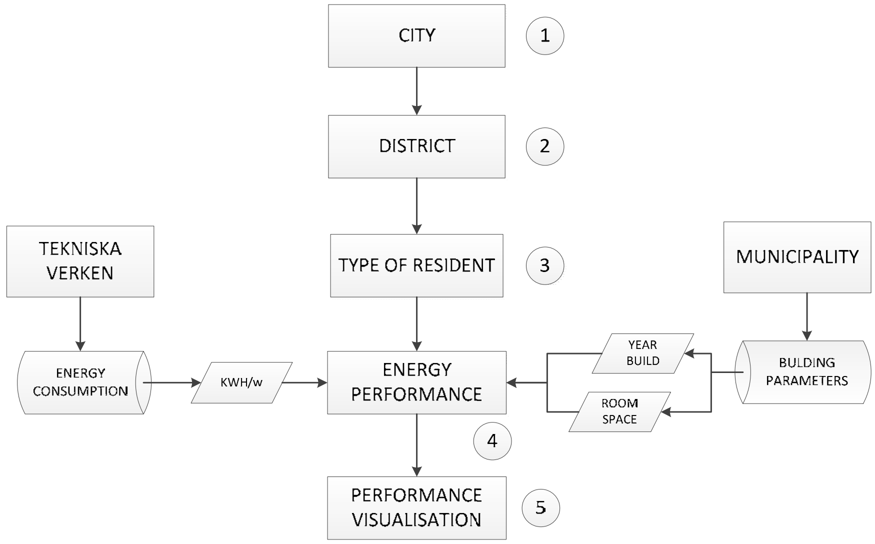

Figure 2. The information process model

The process model can create energy use pattern for different buildings at any given time. The functionality offers opportunities to show the energy use pattern for a housing stock that is grouped by district (e.g. house type) and type of resident. It consists of the following steps:

1. An area is selected within the municipality to analyze energy use for the build-up environment
2. Urban planners and the energy advisor select a suitable district to analyze buildings of same type with similar climate conditions.
3. To create a building set with same properties, the households are clustered by year build, building use, floor size and type of energy used.
4. Energy performance operation is done by integrating building parameters with the energy use for the users that earlier were clustered. Here the 10% highest and lowest energy consumers are sorted out based on a weekly use.
5. The performance visualization can be used to analyze the energy pattern of the district by a 4D map with time-liner, where it is possible to switch to street to inspect the buildings characteristics view, see figure 3.

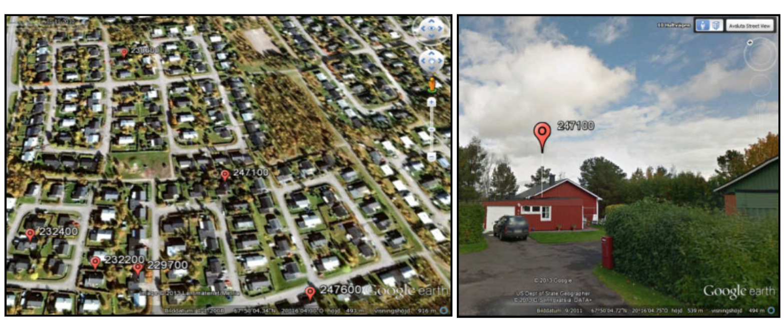

Figure 3. Shows the map and street view of users with a high kWh/day on 2010-11-09 the number indicates a specific household owner

The visualization itself is not enough to convince and make citizens to understand how they can lower their energy use. The citizens need to understand how their energy uses are connected to their buildings and household activities. Energy use scenarios and support by expert can enhance understanding of their situation. In figure 4 the internal stakeholders´ experts supports this work by making scenarios for different household groups, which is later communicated by the energy advisors to the households. A collaboration hub enhances these possibilities, by use of a web-interface with a map and communication opportunities divided in two basic permission levels. First, the professional view use by energy advisors and urban planners which have a full overall image of the energy performance. Second, the user interface, the general public and interested citizens are here limited to see their own consumption and household owners that have given permission to share their information.

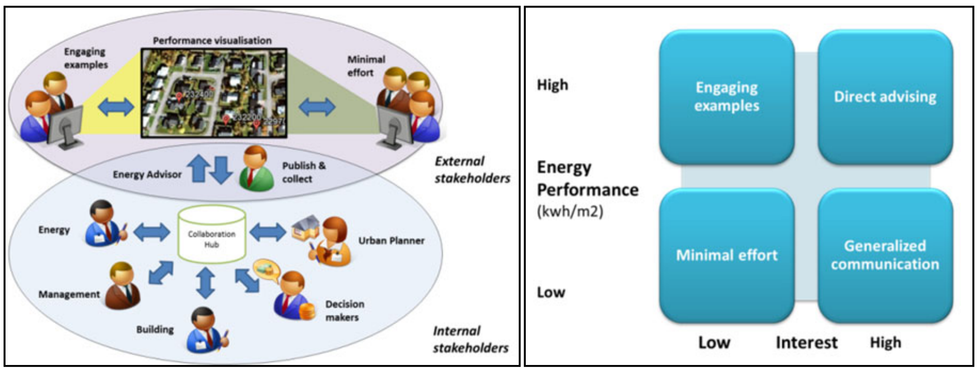

Figure 4. The proposed collaboration hub and the proposed energy performance and interest matrix

The energy advisor is suggested to manage the stakeholders in terms of energy performance and interests´ matrix, which is showed in figure 4. This can support the energy advisor to use different strategies for different stakeholder groups such as direct advising, showing engaging examples, generalized communication and minimal effort due to the stakeholder characteristics.

CONCLUSIONS

A stakeholder PSS for district heating systems was proposed, which consisted of three parts. First a method to integrate basic building information with energy data was proposed. Second, an automated process for performance visualization of past energy consumption per m2 heated area and year (kwh/m2) was created. Third, a framework to visualize high energy consumption pattern to stakeholders together with strategies for stakeholder management was suggested. There is still a lack of knowledge how such a PSS can be used in relation to stakeholder management strategies. Therefore the next step of this research is to evaluate and test the system together with energy advisors of 20 municipalities in Sweden.

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