“Energy visualization” as a tool to influence the energy use in a municipality kitchen

Gireesh Nair
Department of Applied Physics and Electronics
Umeå University
Umeå
Sweden
gireesh.nair@umu.se

Erik Eklund
Environmental and Health Department
Umeå Municipality
Umeå
Sweden
erik.eklund@umea.se

Keywords

energy use, visualisation, displays, Sweden

Abstract

In Sweden, municipalities' own and operate the kitchens that cook food for pre-schools, schools and the elderly care facilities. There are 68 kitchens in the municipality of Umeå and providing feedback to the kitchen staff on energy use could facilitate them to reduce the energy use in these facilities. Accordingly, an “energy visualization” project was initiated in one of the kitchen: Nordstjärnan, which is a newly built kitchen equipped with separate meters for appliances that continuously record the energy use.

For the “energy visualization” project, a visualization design software called “Siemens Control Point” is used. The software is integrated with the existing steering and control system and connected to almost all sensors/meters in the building. The electricity use data from the kitchen was collected for 5 months prior to installation of the “energy visualization” project to establish a base line for the energy use. The average electricity use is referred in this paper as “Electricity budget”, which is calculated for each kitchen appliance that has an electricity meter.

A trail was started in the kitchen from December 2018 onwards, wherein a display unit was designed to project the electricity use of the kitchen. The display unit, which is a large television screen, has different “slides”. For example, one of the slide is modelled to energy labelling. The energy labelling in the display has a rating from A^{+++} to D, which is calculated continuously based on the daily electricity use and the electricity budget. If the kitchen uses more electricity than budgeted then the rating will drop, and if the electricity use is less than the budget then the rating will increase. Furthermore, depending upon the energy performance of the kitchen the visualization screens also display “smileys” which are used as injunctive norms.

Introduction

The energy use reduction from the building sector is an important strategy by European Union to mitigate greenhouse gas emissions. The occupants, by their behavior, is a key actor to reduce the energy use from the existing buildings. Nevertheless, it is not easy to motivate building occupants to take energy reduction actions. This is because energy cannot be seen and also often it is an abstract term for many users who find it difficult to relate energy with their daily actions (Burgess and Nye, 2008). Providing feedback on energy use may facilitate users to connect with their energy use and thereby motivate them to take actions to reduce energy use. It was reported that, depending on how the feedback is provided the energy use may be reduced by up to 20% (Darby 2006). Feedback on energy use can be provided in different ways such as through billing, metering, display units, energy advice and energy audits. The energy monitoring through metering that provides only an aggregate energy value is considered less effective as it is incomprehensible, or not bench marked against historical energy use or daily activities thereby making it irrelevant (Burgess and Nye, 2008; Kempton and Layne, 1994). Smart metering that provides real-time energy use and frequently communicate information in more detail is a better alternative to the conventional energy metering. Unlike the consumer goods, energy is invisible to its consumers as they often associate energy indirectly with the service provided such as heating or cooking. As per Fischer (2008), due to the “invisibility aspect" of energy use the consumers usually receive little feedback on their consumption. The energy display unit which is connected to the smart meters could communicate the energy use visually in real time through images, diagram, pictures, and graphs. Accordingly, energy display units reduces the "invisibility barrier" associated with the energy use. The display units by providing images, could draw the consideration of the viewers as it can facilitate the affective feelings that could influence and shape perceptions and thereby decisions (Leiserowitz, 2006). Furthermore, vivid images were found to communicate much more effectively than information in texts (Doyle, 2007). In this study context "smart energy display" (SED) refers to electronically displaying the electricity consumption, based on meters that measures electricity in real time.

Previous research on households' experience with "smart" energy display (SED) suggest that the SEDs have helped households to know their baseline energy use and also improved their awareness on energy use (Hargreaves, et al., 2013). Several research has been done on the effect of SED units in residential sector (Bonino et al., 2012; Hargreaves, et al., 2013; Faruqui et al., 2010). Earlier research on household energy display units suggest that after an initial interest in the display units, at least in some instances, they are unable to engage the households and may fade into the "background" (Hargreaves et al., 2013). This may be because households could feel that they understood what is shown in the display units and it does not provide any new information. Furthermore, according to Hargreaves et al. 2010), it would be good if the display units are able to present information in different formats.

In this study we discuss the "energy visualization" project initiated in a municipality kitchen in Northern Sweden. Apart from the electricity use information, the visualization slides have "smileys" which are used as injunctive norms.

The case study building

There are 68 kitchens in Umeå where the food for schools, preschools and for the elderly care centers are prepared. The average annual electricity use in the 5 largest kitchens varies from 130 MWh to 300 MWh annually. The aim of the project is develop an "energy visualization" interface to provide feedback in an "attractive" manner to help the kitchen staff to reduce their energy and water use. Accordingly, one of the large municipality kitchen "Nordstjärnan" which is also an elderly- and child care center was selected for conducting the energy visualization trial. The kitchen employs 10 personnel and is operational 365 days a year.

The building was chosen as it is equipped with energy and water meters in the kitchen connected to the steering and control system of the building. "Nordstjärnan" built in 2017, is equipped with electricity meters for almost every kitchen appliance. The control and steering systems used in the buildings has recently upgraded their interfaces to make it possible to use web interface by HTML5 coding. This makes it possible to conduct editing/programing in Siemens Control Point, which is an energy management tool, by a web browser. This tool could be used for displaying energy use, monitoring and controlling of buildings, collecting data from the sensors connected to the system and to generate reports. In this study we used the data collection and energy display features of this tool. The advantage felt with this system is that it is relatively easy to build/create simple information slides by using drag and drop functions to display real time data in various ways. The information screens/interfaces can be displayed in Google Chrome web browser, which at the moment is the only compatible browser. The disadvantage is that if one require advanced information screens, for example, with animations then more knowledge and experience is required as it involve some programming. Figure 1 shows the screen shot image of Siemens control point editor where one can create different screen/slides based on data from building's energy meters.

Method

The method involves the following:

- Collect historical electricity use data and establish a baseline
- Survey of the kitchen staff to understand their perspectives on energy use in the kitchen
- Develop a visualization screens/slides in collaboration with the company that deals with energy systems of Municipality buildings

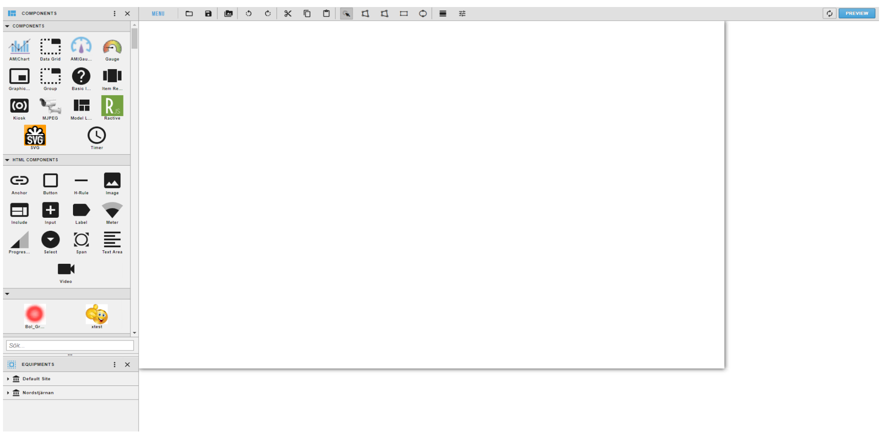

Figure 1. A screenshot of the Siemens control point editor.

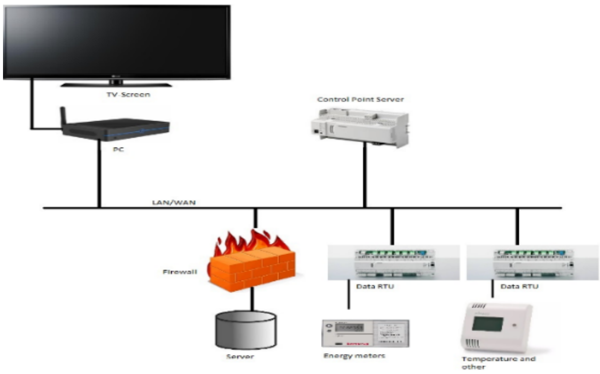

Figure 2. The energy display unit system.

Figure 3.The display unit on the kitchen wall.

Table 1. Electricity and food portion cooked during five months prior to the trial

Months (2018)	kWh/month	Average kWh/day	Cooked portions/month
June	13,619	454	30,720
July	13,020	420	32,271
August	13,045	450	31,961
September*	10,511	438	31,110
October*	12,718	437	31,961

** In September and October, the energy meter was faulty for a few days and the energy use for those days are not included to calculate the average energy values.*

- Install an energy visualization monitor in the kitchen
- Conducting a trail run for 3 months (December 2018 – February 2019) and then collect the feedback of the kitchen staff on their experience with the "energy visualization" device

The electricity measurement is collected through M-Bus communication from the electricity meters up to the Siemen's (Data Utilization Center)/Data RTU for control equipment. The system collects both instantaneous and accumulated electricity consumption. In a web server made by Siemens (control point server), the collected measurement data is "visualized" on a web page to give the staff information about the instantaneous and daily electricity consumption. The energy display unit, which is a 44 inch television screen, was connected to the energy meters (Figure 2). After a few weeks of installation of the display unit, we noticed some issues such as problems of the IT infrastructure to connect to the PC on the building local area network (LAN), to remotely monitor the system and also to get the display unit work without logging off.

THE ENERGY BASELINE

The kitchen produces on an average 31500 portions/month and includes appliances such as cooking pots, freezers, dishwashers, electric ovens, garbage disposer. Data from the kitchen (Table 1) was collected for 5 months (June – October 2018) to establish a baseline and to analyze the electricity use pattern. The baseline was established by calculating an average electricity use from the historical data. The average electricity use for the kitchen from now on is referred as "Electricity budget". The electricity budget was calculated for each kitchen appliance that has an electricity meter.

PERCEPTION OF THE KITCHEN STAFF ON ENERGY USE

The perception and attitude of end-users towards energy use may affect their actions to reduce the energy use. For example, if potential adopters are satisfied with their existing energy use or if they do not have a positive attitude towards energy use reduction then they may be less likely to take actions to reduce energy use (Nair, 2012). In October 2018, prior to the trail, a survey was conducted among the kitchen staff to understand their perspectives on energy use in the kitchen. Eight employees responded to the survey and majority of the respondents (5 out of 8) consider that the electricity use in the kitchen is high and all of them think it is important to reduce the kitchen's electricity use. Four respondents thought that technological measures have larger potential to reduce energy use in kitchen while three of them believed behavioural measures have larger potential to reduce energy use. Five respondents thought that the energy efficiency measures could reduce the energy use of the kitchen by more than 5 %. Four respondents thought that feedback could help them to reduce the energy use in the kitchen.

THE ENERGY DISPLAY

Before the installation of the display unit, one of the author of this paper who is also an energy adviser with the municipality, held a few meeting with the kitchen manager to discuss about the project. This was followed by a meeting with all the kitchen staff to provide them with information about the visualization project. In the first phase of the visualization project, it was decided to provide a visual information to the kitchen staff on how the electricity is used in the kitchen. The intention was to create an awareness of electricity use in the kitchen and to provide them with a feedback.

As a start of the trial, it was decided to use four different screens/slides in the television monitor. The slides will change

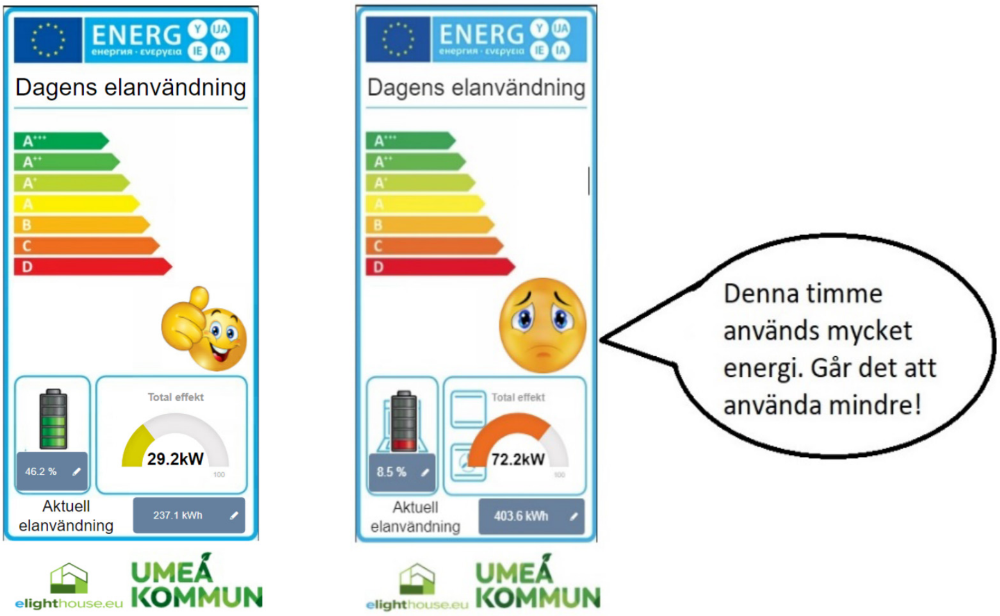

Figure 4 Energy readings in the "energy dashboard".

Table 2. Energy values for the kitchen's energy rating.

Energy rating	Daily KWh
A+++	< 353
A++	353 –374
A+	375–397
A	397–419
B	419–441 (Electricity Budget)
C	441–463
D	>485

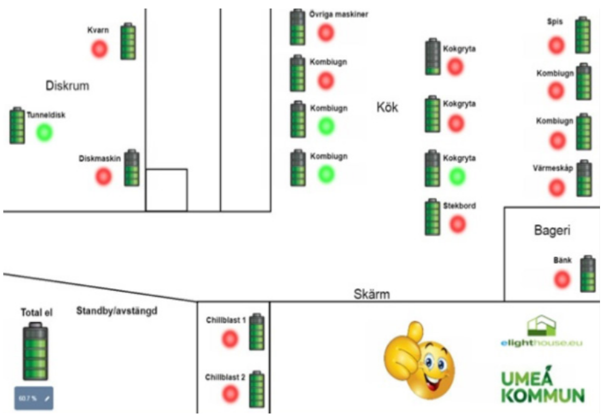

Figure 5. Energy visualization display on appliances.

every 60 seconds. The reason for limiting the slides to four is partly attributed to "Siemens Control Point" which is a new software that required lot of time from the software developer to customize the slides. However, in future it is planned to add a few more slides such as a dynamic energy use curve for the kitchen. The following sections discuss briefly the various slides currently displayed in the television screen.

Figure 4 shows what we define as the "energy dashboard" for the kitchen. This will be the first slide displayed in the 44 inch TV monitor. It uses the European energy label as a model to rate the kitchen's energy performance. The battery displays the daily electricity budget and indicates how much is left. Furthermore, the slide also has a smiley face. The smiley is used as an injunctive norm (that indicate which behavior is approved or disapproved). Smiley indicator is based on the electricity use during the current hour. If the electricity use is below 80 kWh/h (an average hourly electricity consumption based on historical data) then a happy smiley will be shown in the energy dashboard, while if the electricity use exceeds 80 kWh/hour a sad smiley with a "text bubble" will be shown indicating high electricity use than the average.

The energy rating A+++ to D are calculated intervals from historical data with ± 5 % change for each interval ratings (see Table 2 for the set values). The electricity budget for the kitchen is set to B (see Table 2 for the set values). The reason for setting the energy rating for the electricity budget value to B is to provide an impression to the kitchen staff that achieving average energy performance is not something that they should be content with. The kitchen staff may increase the energy rating by actions such as optimization of the use of kitchen appliances, setting the appropriate temperature in ovens, use of variable fan speeds in the ovens, minimize the door opening of freezing rooms.

Slide 2 (Figure 5) displays an over view of the kitchen appliances. The major kitchen appliances with energy meter are displayed in the shape of a battery. The battery is a symbol for the electricity budget of kitchen appliance and will show the energy use of each appliance over the day by draining the battery. This slide gives information about how the equipment is used compared to its electricity budget. The green and red dot indicates if the appliance is "on" (green) or "off" (red). By analyzing electric power during night, we established a baseline for power off mode. An indicator, similar to the "parking brake light", in the display (see Figure 5) will be shown when the power of the kitchen reduces below 2 KW. This indicator should be visible when the kitchen is shut off and provides information on possible accidental high standby power consumption.

Figure 6 is the third slide on the display unit which provides information on the historical (previous day and weekly average) electricity use along with the current day. The full bar (grey area) displays the weekly and daily electricity budget and the green area is the actual energy use.

The energy dashboard will also show the accumulated electricity saved by comparing the daily electricity consumption with the electricity budget (fourth slide). This slide that shows the daily cumulative electricity use will be displayed every day at 16:00 hrs (Figure 7). Based on the daily electricity use of the kitchen different smileys will be shown with a short comment (Figure 7). This screen provides a feedback about an indication on the electricity used in the kitchen for a given day as compared to the average daily electricity use.

KITCHEN STAFF'S PERCEPTION ON THE ENERGY VISUAL DISPLAY UNIT

In March 2019, a survey was conducted to understand the kitchen staff's experience with the energy display unit. Eight employees responded to the survey and five of them stated that every day they often check the display unit. Seven respondents thought that the visualization display unit is an effective way to facilitate energy use reduction. Five respondents consider that the display unit has improved their understanding on the energy use in the kitchen. Six respondents agreed that smileys in the slides provided an effective feedback on whether the kitchen's electricity consumption is good or bad.

Future activities

At present the various slides shown in the display unit is based on five months of data. The kitchen is rather new and there is a possibility that the energy use may evolve depending on better streamlining of cooking operations. Hence, it may be good to set the energy performance of the kitchen based on data from a whole year. The kitchen prepares breakfast, lunch and dinner

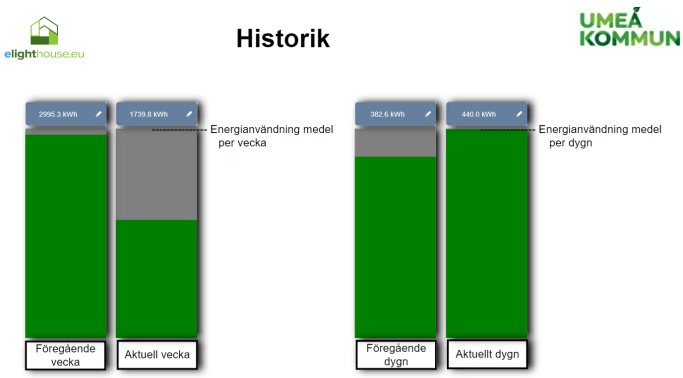

Figure 6. Electricity use of previous and current week and on right actual day and previous day.

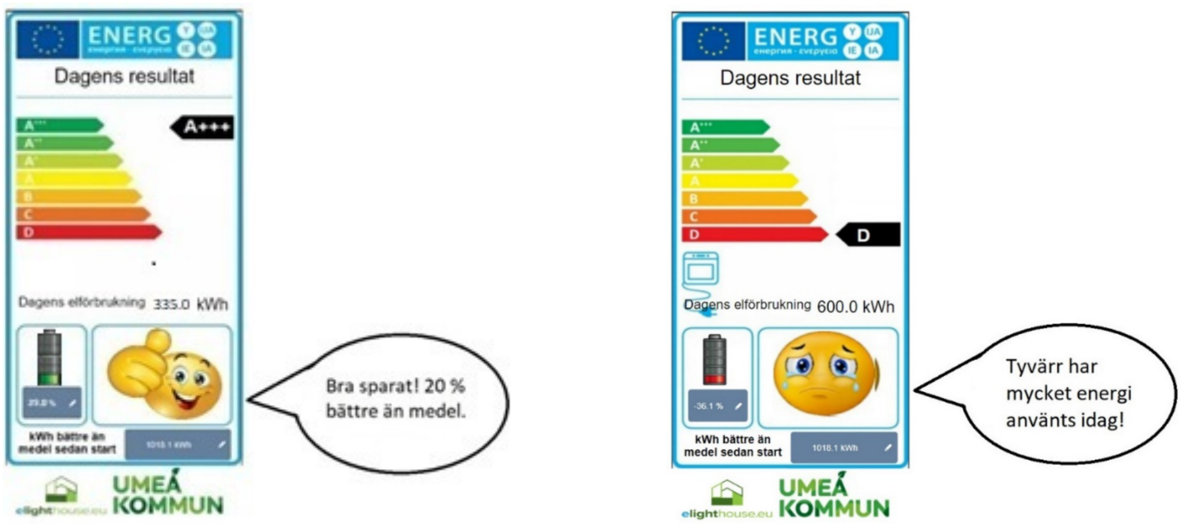

Figure 7. The slide that will be on display at 16:00 hrs (one hour before the kitchen is closed) every day.

and the type of main dish varies daily (for example, a meat or a fish dish). In the next phase it is planned to categorize' the energy performance of the kitchen based on the type of food cooked. In future, it is also planned to provide more information in the display unit (for example, information on water use in the kitchen) and also periodically change the format so that the kitchen staff do not lose interest in the feedback. The Siemens control point software is a *flexible* tool which could present the data in different format. It is also planned to invite an expert to conduct a workshop for the kitchen staff on how to use the kitchen appliances efficiently. Finally, an energy reduction action plan for the kitchen may be discussed with the staff.

Conclusions

The SED was installed in one of the Municipality kitchen to study its effectiveness on energy use in the kitchen and its impact on kitchen staff's perception on energy use. The installation process required more time than that was anticipated mainly due to some metering issues and inexperience in using the new software to provide customized display slides. The SED is installed on a trial basis and the initial experiences from the kitchen staff suggest that the display unit was able to improve the awareness of kitchen staff on energy use. Further, the kitchen staff think that energy visualization is an effective way to facilitate energy use reduction. It is required to continue the trial for a longer duration and the energy performance of the kitchen need to be analyzed to understand whether SED has resulted in energy savings.

References

Bonino, D., Corno, F., RussisL.D., 2012. Home energy consumption feedback: A user survey. Energy and Buildings 47, 383–393.

Burgess, J., Nye, M., 2008. Re-materialising energy use through transparent monitoring systems. Energy Policy 36, 4454–4459.

Darby, S., 2006. The effectiveness of feedback on energy consumption: a review for DEFRA of the literature on metering, billing and direct displays. Environmental change institute, University of Oxford.

Doyle, J., 2007. Picturing the clima(c)tic: Greenpeace and the representational politics of climate change communication. Science as Culture 16, 129–150.

Faruqui, A., Sergici, S., Sharif, A., 2010. The impact of informational feedback on energy consumption: A survey of the experimental evidence. Energy 1598–1608.

Fischer, C., 2008. Feedback on household electricity consumption: a tool for saving energy. Energy Efficiency 1, 79–104.

Hargreaves, T., Nye, M., Burgess, J., 2010. Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. Energy Policy 38, 6111–6119.

Hargreaves, T., Nye, M., Burgess, J., 2013. Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. Energy Policy, 126–134.

Kempton, W., Layne, L., 1994. The consumer's energy analysis environment. Energy Policy 22, 857–866.

Leiserowitz, A., 2006. Climate change risk perception and policy preferences: the role of affect, imagery, and values. Climatic Change 77, 45–72.

Nair, G. 2012. Implementation of energy efficiency measures in Swedish single-family houses, Mid Sweden University, Sweden, ISBN 978-91-86694-68-5.

Sheppard, S.R.J. 2005. Landscape visualization and climate change: the potential for influencing perceptions and behavior. Environmental Science & Policy 8, 637–654.

Acknowledgement

This project is developed as part of the "eLighthouse project" which is funded by Northern Periphery and Arctic program. The authors gratefully acknowledge the financial support of Northern Periphery and Arctic program. The contribution of Jonny Danielsson at Umeå Municipality in accessing the relevant energy data is acknowledged.