Challenges in Energy Awareness: a Swedish case of heating consumption in households

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Abstract

An efficient and sustainable energy system is an important factor when minimising the environmental impact caused by the cities. We have worked with questions on how to construct a more direct connection between customers-citizens and a provider of district heating for negotiating notions of comfort in relation to heating and hot tap water use. In this paper we present visualisation concepts of such connections and reflect on the outcomes in terms of the type of data needed for sustainability assessment, as well as the methods explored for channelling information on individual consumption and environmental impact between customers and the provider of district heating.
We have defined challenges in sustainable design for consumer behaviour change in the case of reducing heat and hot water consumption in individual households: (1) The problematic relation between individual behaviour steering and system level district heating, (2) The complexity of environmental impact as indicator for behaviour change, and (3) Ethical considerations concerning the role of the designer.

Keywords: Energy awareness, district heating, sustainable design, environmental impact, ethics in design

1. Introduction

An efficient and sustainable energy system is an important factor when minimising the environmental impact caused by the cities. In the EU 20/20/20-package from 2008 one of Sweden's focus areas is near-zero energy buildings along with energy efficiency in older buildings, which will lead to reduced energy usage. One further step towards a more energy efficient society is the issue of when is the right time to use energy and when will have the least environmental impact.

A new urban area in Stockholm is being developed between 2011 and 2030 and has a strong sustainability profile and high requirements on new buildings in terms of energy efficiency etc. The goals for the area include having a smart energy grid based on the "trading" of renewable energy between the network and the individual buildings, households and businesses. The aim for a smart energy grid is to give residents a means to manage and control their energy consumption in an environmentally efficient and profitable way, and that the measurement and visualisation of energy usage and its impact on the climate will be possible. This project is part of the measures being undertaken to meet the above objectives.

The pre study "Energy Awareness" has examined the degree to which property owners and apartment residents can reduce their carbon footprint and adjust their heat usage by an automated active usage management of district heating (Energy Awareness project group, 2012). The project has aimed to examine how benefits for the climate and economic benefits can be achieved by shifting the heating loads in a building. The project has also focused on investigating how visualisation of the heat usage affects the consumption behaviour of the residents. Time perspectives have been 2015 and 2030, including implementation of energy consumption information from Smart Grid functionalities in a combined service. However, there are significant prerequisites, which we found to be very different between district heating and electricity consumption. The most significant difference is that the electricity grid can react on a changed behaviour faster since the optimisation of the system is fairly easy to regulate. The district heating system on the other hand is very difficult to regulate to meet changes over the day. The production systems have high inertia, which is also the case with the customers' heat usage, due to the fact that buildings themselves can store energy. Since there is no immediate link between heating and changed behaviour of customers, we have studied how other considerations can become a more prominent incentive for customers in relation to resource uptake. For example by encouraging some kind of planning in people's activities and negotiating comfort levels, other ways than merely reducing people's uptake have been explored.

1.1 Aims and goal paper

In the case study we have explored possibilities and limitations of consumer behaviour steering through developing concepts for district heating. Our part of the development process was to provide visualisation concepts for consumer behaviour steering in a certain direction, which we will present in this paper. The goal of the paper is to point out challenges for (urban) developers when aiming for Energy Awareness.

We will discuss this through making a comparison between household consumption of district heating and electricity, and by providing a brief overview of the notions awareness and comfort. We will then present our process of developing incentives and visualisation concepts for behaviour change in this particular case, and our exploration of providing information on environmental impact. Finally, we will touch upon the ethical considerations when it comes to designing for behaviour steering in this district heating case. But first, we will provide an overview of the Swedish district heating system in relation to residential areas.

2. Background

2.1 Energy efficiency and the Swedish district heating system

Existing buildings if compared to the Stockholm urban area’s new buildings, and among these buildings built between 1946 and 1975, have by far the largest potential in district heating savings and thereby the largest potential for climate impact reduction. Consequently, the potential for the Energy Awareness project concepts is the highest for these buildings. However, the impact on lowering peak load oil production of district heating and thereby the CO_2e emissions stemming from this production is only short-lived in the Stockholm area due to gradual renewal of production units. The oil will gradually be phased out and only very small amounts will be used in the production by 2030, mainly for start-ups of production plants.

One further aim with the project was to discuss and illustrate the complexity of energy savings in relation to savings of carbon dioxide. Depending on the choice of system boundaries, the evaluation of carbon dioxide and the span of time over which the carbon emissions are calculated, the answer to what the optimal way of saving energy is will differ. In order to reach the goals for the Stockholm area on the way towards 2030, sustainable decisions on energy issues have to be made at present time.

Today most energy companies have a heating contract with the real estate owner. The heat is delivered to the substation within the building, where the measure point is placed. The heat is distributed in the buildings secondary system to the heating system. The contract for district heating is between the energy company and the real estate owner. The real estate owner distributes the cost for heating, based on statistical calculations, to the residents, mainly through the rent.

District heating is divided into two areas, separated from each other in terms of the end customer's conception, behaviour and habits:

1. Heating
2. Hot tap water

With this in mind the concepts were divided into these two areas. It was determined in another part of the project that affecting the hot tap water consumption is an easy and direct way of affecting the total district heating consumption for the end customer, whereas controlling the heating is dependent on the total temperature balance of a building. For new buildings tap water usage represents the major part of the total district heating consumption, making it an interesting target for behaviour changes in Energy Awareness concepts.

The focus in the project regarding energy efficiency today is mainly on decreasing energy usage for heating and cooling of buildings, especially on extreme cold or warm days. However, it is important not only to reduce the energy usage, but also take into account when the reduction is done. Reducing it at the right time it can decrease peak loads and thus also the climate impact. The technical conditions and issues need to be highlighted from a consumer perspective, since it means that they will have to change their routines at very specific moments and days, not just randomly. It is ultimately their behaviours that will lead to change, which is quite extensive here considering the extent of what is asked from them in terms of awareness and comfort.

2.2 Awareness

Mills and Schleich (2012) studied the influence of household characteristics on energy consumption behaviour. From a study of more than 5000 households from 11 countries in Europe they showed the role of family age-composition patterns. Households with young children were more likely to adopt energy efficient and energy conservation measures and technologies for environmental causes. Households with a large share of elderly people placed more importance in financial savings. Education was also found to affect the adoption of energy conservation and energy efficiency measures and technologies in a positive way. Different consumer segments needs different intervention strategies if they are to adopt energy conservation technologies or change their behaviour (Gaspar and Antunes, 2011). High awareness of energy related problems among customers have shown to thoroughly increase the belief in the consumers' ability to make a contribution through their own energy saving actions (Sütterlin et al, 2011).

The electrical market is some steps ahead when looking at consumer visualisation and the possibility to monitor and in some means also control consumer's energy use. The market of district heating (and cooling) normally set up by a producer/distributer and a customer; who in many cases is a housing cooperative (in Swedish: Bostadsrättsförening). The end user of the heat/cool and hot tap water generally has no contact or communication with the district heating company. This might be a reason why the market of consumer oriented products and services focused around the district heating is still not developed. There are however some products and services on the market today, which aims to give the user information of the energy consumption of district heating and by that, create motives, or merely tools, for a change in behaviour in a conscious or unconscious way.

In Swedish housing, utility metering is mostly set in separate small spaces together with other storage devices. These spaces are not regularly visited, sometimes not well lit and generally only by one or a few members of the household. There is a gender implication to this, since these spaces are usually associated with male territories (Ehrnberger et al, 2013). Earlier research indicated that an ambient interface is seen as important in order to achieve a long-term change in behaviour (Broms et al., 2010), since the end user will need to be reminded of their energy consumption in their daily routines to obtain a change in behaviours.

2.3 Comfort

Personal heating and space heating are more related to norms and values around comfort than electricity uptake, as one of the basic needs of humans. For instance, heating contributes to ambient (surrounding) indoor temperature, which in turn influences the experience of comfort. The experience of comfort is not the same for everybody and preferred indoor temperature is no constant. There are cross-cultural differences in preferred ambient temperature as well as a change over history of what level of ambient temperature is preferred. According to one study ambient temperature considered comfortable among Americans has changed over time (Rohles, 1975). In 1924 an indoor temperature of 64°F (17.78°C) was considered comfortable; by 1950 this had increased to 68°F (20°C); and to 76°F (24.44°C) in 1972. Apparently, there's more to thermal comfort than just temperature. Perception of temperature involves physical as well as psychological components. One major physical component is, obviously, the amount of heat in the surrounding environment – measured on the Fahrenheit or Celsius scale. Psychological components of perception of temperature have to do with internal temperature of the body and receptors in the skin (Bell et al., 1996). Although some receptors seem to be sensitive to lower temperatures and others to higher temperatures, both types respond to change in temperature more than to absolute temperature. This is why we may perceive even mildly warm water as very hot when our hands are very cold from being exposed to winter air.

Thermal comfort has been defined as "that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE Handbook of Fundamentals, 2009). Thermal comfort reports have been shown to be affected by relative humidity, by clothing and by activity level (Rohles, 1973).
Comfort is an understanding that is negotiable and constantly evolving (Shove, 2006). Heating is regulated through building requirements in terms of space heating and ventilation, with changed expectations and patterns of heating since 1970s (Kuijer and de Jong, 2012).
When looking at consumer behaviour from a practices perspective, people are carriers of the practice of indoor climate regulation and they have different embodied habits with regards to how they interact with radiator valves, doors, trickle vents and windows every day (Gram Hanssen, 2010). Changing such habits takes time and a certain effort. We have been looking for ways to go about in

this case study by looking for different incentives, not just pricing, for people to change behavior in ways that takes the practice perspective into account.

2.4 Incentives for behaviour change

This section describes a selection of incentives that we have found useful in our case study, without the intention of providing a complete overview. The following incentives for behaviour change within sustainable design have been applied in the project, based on Gregory and Mazé (2011):

1. *Rational decision making*. This proposes people as rational decision makers based on proper information for changing behaviour. For instance, Home Energy Management Systems, e.g. energy monitors, are intermediary products that can visualize, manage, and/or monitor the energy uptake of other products or whole households. However, to date no studies are known that have analysed positive long term effects on reduction of energy uptake of such systems (Van Dam et al., 2012). Moreover, the idea of changing other people's behaviour on the basis of rationality of choices is a limited view, according to multiple research studies considered in this project (see also Brynjarsdóttir et al., 2012).

2. *Ethical ideology*. Through addressing the responsibility of people for the environment, for instance as citizens, people may be become proactive. For instance through energy saving games that are organised within families or neighborhoods to make people environmentally aware, competitive, and taking the lead. People see this as a fun and engaging exercise (Strengers, 2010). However, such approaches have been criticized for their lack of continuation after the game since it does not stick in everyday life. There is much to be gained though by optimizing systems, in terms of sensitivity to users' practices at home. For instance, people who are at home all day have more options to change routines than people who work all day away from home (Strengers, 2010).

3. *Personal gain, economic growth and convenience*. This takes a person's individual interest as the main factor that determines their actions. For instance through dynamic pricing systems, that offer a reduced price on peak hours. Still, prices incentives are only partly functioning, for instance when the expectations about savings are not reflected in the total amount of savings, and as Strengers (2010) concludes: '"Its not so much the price in Dynamic Peak Pricing systems, but more the notification of the price change that is motivating people to take action." Abrahamse et al (2005) reviewed research on the effectiveness of interventions to encourage household to reduce energy consumption, such as price systems. Reward schemes for reduced energy consumption only showed short term results, although frequent feedback showed merit. Increased availability of information resulted in increased knowledge among consumers, but did not necessarily result in energy conservation.

This study has looked predominantly to ethical considerations, in terms of 'care for the environment', which were explored in different concepts to point at possibilities for changing behaviour in relation to heating of homes. These will be explained in the next sections.

3. Design concepts for District Heating Awareness

The design concepts have on a high level been based on the electricity smart meters. Hence, there are of course similarities between the two. However there are significant prerequisites, which are different (Energy Awareness project group, 2012):

- The electricity market has hourly pricing in place since October 2012. The district heating in Stockholm has had hourly measuring for several years but does not have hourly based price models

- The electricity consumption in a household is usually measured and billed individually, while the household's heating is divided between the apartments in the building and charged through the rent. Hence, there is no direct kick back for a resident to save heating.

- The electricity distribution company as well as the market company have direct contact with the end user. Meaning that there is a billing system and a customer service organisation in place. The district heating company often has a relationship with the housing cooperative or real estate owner and no direct contact with the residents.

- The most significant difference is that the electricity grid can react quicker on changed consumption patterns since the optimisation of the system is fairly easy to regulate. The district heating system on the other hand is very difficult to regulate to meet changes over the day. The production systems have high inertia, which is also the case with the customers' heat usage, due to the fact that buildings themselves can store energy.

Since there is obviously no immediate link between production and changed behaviour, we aimed at encouraging long-term changes in user behaviour or creating new ways of doing. We have first sought to find ways to represent information on environmental impact to consumers that they could make sense of for understanding how their heating and hot water uptake would affect the production system.

3.1 Development Environmental impact system, point system

The project has the aim to develop a system for communicating uptake and environmental impact of district heating. First, the meaning of CO2 will be explained. Then we will describe the process where we have explored a conceptual alternative feedback system in which consumers can relate to environmental impact of heating and water uptake through eco points.

3.1.1 Feedback through CO_2

First, we will point out the difference between carbon dioxide (CO_2) and carbon dioxide equivalents (CO_2e). CO_2 is the result of most combustion processes. At the same time CO_2 has been identified as the most important of the greenhouse gases (GHG) contributing to global warming (Stern, 2006). Aside from CO_2 there are other GHGs and to enable comparison it is common to translate the green house potential of other gases into corresponding amounts of CO_2. This normally referred to as CO_2e.

The use of CO_2e as the climate impact factor communicated to the end customer has been widely discussed in the project since this may be counterproductive and in fact e.g. encourage heat usage during peak load production using bio oil and on the other hand discourage heat usage during summer when mainly waste fuel is used in the base loads production. There will also be an expectation from end customers of a correlation between price and CO_2e signals, which is not always accurate.

3.1.2 Eco points

The unit of CO_2e was adopted early in the project since it is a commonly used factor for describing climate impact from energy consumption (Energy Awareness project group, 2012). However, the use of CO_2e was shown to be complex and difficult to communicate to the user in a simple way. Communication of only the CO_2e signal could actually affect the customers' behaviour in a direction, which is not desirable from a climate or production point of view. If the signals to the end users leads to a decrease in heating usage during summer and a “waste” of heating during winter due to the low CO_2e emissions, the whole concept of district heating as the utility that makes use of energy, which would otherwise be wasted, will be challenged.

Additionally, there is not always a correlation between price and CO_2e, which would be expected by the end customers and thereby bring confusion to which signal to "obey". Due to these reasons, the term "Eco points" was created to simplify the communication to the end user. The term is not defined in this project but intended to include several environmental parameters to give a wider picture of the environmental footprint, also facilitating for the solution to guide the end customer in the direction desirable from an environmental and operational point of view.

3.2 Visualisations of information

The visualisation concepts consist of 3 levels of information, which were based to higher or lesser degree on the different incentives for behaviour change as explained before:

1. Two physical objects, called the Water meter and the Smart thermostat. They both work as ambient interfaces since they are always present and remind the user of his/her energy consumption.
2. Digital applications, which work as a support and an addition to the physical objects. The applications offer more detailed information and trigger a behaviour change. They are easily accessible on any compatible user device.
3. The Energy Awareness Website is an online platform that enables users to learn how they consume energy and how they can improve their daily routine in order to optimise their consumption. This website is the touch point of many awareness initiatives, promoted by the Stockholm area for ‘greener’ living.

The two physical objects including digital applications were worked out as concepts, which will be presented here.

3.2.1 Water meter + digital application

The water meter is a small physical device that should be positioned close to the faucet (one for each faucet) in order to visualise data about daily hot water consumption and provide real time feedback during activities. The objects are small “pucks” that can be taped on different surfaces close to each faucet. They communicate data from water meters and visualise a limited set of information to influence users’ behaviour in the way that they can make a difference:

- Using water only during certain intervals of time and avoiding to turn on the faucets during peak hours visualised with green and red windows.
- Reducing litres of water used, for example taking a shorter shower, or with a lower water pressure.
- Using colder water, that requires less energy

Figure 1: Illustration of the water meter

For users who require more information and interaction, there is the additional digital application. The digital application enable users to check their consumption, track their progress, analyse history charts, control their billing, customise their visualisation and switch quickly to the thermostat application. It is also possible to analyse user's consumption from different perspectives: green/red time windows for use, length of activity and temperature. In this way users can discover their weakness and focus on that for a faster improvement. Highlighting the problem from all these angles explains to the user which changes can be made that have a bigger impact on the overall consumption. They can also estimate their Eco point consumption and compare different scenarios to learn how they can make a difference in their Eco point use.

3.2.2 Smart thermostat + digital application

The smart thermostat enable users to decrease their energy consumption related to space heating, by changing individual behaviour with the help from smart suggestions and optimizing energy consumption on a building level. The smart thermostat can also be implemented on district cooling systems in residences.

Figure 2: Illustration of smart thermostat

The interface of the object is organised in two parts: (1) information generated by users' behaviour and (2) suggestions calculated by the building/smart heat central.

1. Eco points on individual level
The first month(s), meters will simply collect information about users' district heating consumption (with an outdoor temperature neutralisation), to define a baseline. The collected data will enable the system to detect the family routine and calculate their energy consumption while using hot water or heating. This will be translated into Eco points, giving a sum of Eco points as a baseline for the household. The users now have this set amount of Eco points to use every day.
If the system is implemented as a payment system; the district bill is based on this data. If the users are using more Eco points than the baseline, an extra charge is added to the bill, meaning that the Eco points over the baseline limit is over charged.
As the users start changing their behaviour and hopefully use less Eco points, they save points during a day or a month, and the baseline is slowly decreasing. The system will automatically know when to set a new goal (a lower baseline) for the users, giving them enough time to enjoy improvement and transform occasional better behaviours into routine.

2. Smart heat central on building level
On building level; there is a heat central (heat exchanger) were a smart system is implemented, in order to prevent sub-optimisations on apartment level. This program collects real-time information about each apartment's temperature, building insulation, weather forecast and user preferences etc. and calculates the optimal temperature for each one of them with the final aim to save energy on a building level. The system communicates on apartment level, building level and also externally; to the energy company and the district heating system. There is a minimum and a maximum temperature in the thermostat and system (around min 19°C to max 25°C (Social styrelsen, 2012-10-11). The optimal temperature is visualised on the thermostat, to enable users to make a conscious choice.

4. Discussion

We have developed conceptual visualisations for feedback to consumers on their heating and hot water consumption, as well as the environmental impact of it. We have designed both devices and applications indicating current uptake, and also providing overviews and histories of previous data. The environmental impact feedback was based on a point system that was explored for visualising absolute numbers of environmental impact in a calculated number that can be used to relate to other experiences, activities and people. In this pre-study, we have not yet prototyped or tested the concepts, hence the evaluation in terms of effectiveness remains to be seen.

In the paper we set out to describe the process of an energy management system of district heating with the aim to change consumer behaviour for the purpose of decreasing heating and hot water uptake on peak uptake moments of the day. This has proven to be quite a challenging task, not in the least part because of the various stakeholders and interests involved, including the energy provider, but also from a more ethical point of view, where we have struggled as designers to see how we should position ourselves when aiming to accomplish a 'desired' change in consumer behaviour.

4.1 Challenges for energy awareness

1. Problematic relation between individual behaviour steering and system level district heating: There should be a clear idea what a 'desired direction for change' could be. For example, in the smart grid system the technology-centered design approach involves the risk that possible "un-intended" uses might undermine the intended, systemic benefits from developing smart grid solutions (Haunstrup Christensen and Gram Hanssen, 2012). In this project it became clear that individual actions to lower temperature in apartments can be countereffective, as a result of unanticipated heating effects for the whole building, as well as a time delay of the heating system to consumers' actions. Also, there is still a huge gap between current comfort norms and energy awareness, since its all about bringing down thermostat on really cold days, while the actual effects of changes are in this case limited: no clear price effect for individual consumption billing, individual behaviour change alone causes no real effect on environmental impact, and the 'bigger picture', such as effects of the whole area, is still missing.

2. The complexity of environmental impact as indicator for behaviour change:
It's not evident that showing CO_2 as an indication of impact on the environment and as an indication of energy use provides meaningful feedback to residents. The concept is quite abstract and not something that people usually relate to in their daily energy use. We don't know what is considered normal or abnormal CO_2 emissions, nor do we know what realistic targets for our household would be. This is supported by a usability evaluation of the prototype app Green IT Homes (Katzeff, 2011). In a recent study on sustainable food shopping, which is similar to heating more complex in terms of sustinainability, where information on environmental impact rather than actual uptake was provided to consumers, it is shown that it is rather difficult for people to relate their everyday life and choices to numerical information about environmental impact (De Jong et al., 2013).

3. Ethical considerations concerning the role of the designer:
In the project we have struggled with the designer's role of behaviour steering for sustainable consumption. There are no clear directions or fundamental principles in this research field, see also Power and Mont (2010). It remained unclear throughout the project how the project's goal could be supported by individual consumers and also, how effects of behaviour change would be beneficial and to whom. Another question to address is whether providing end customers with the climate impact as momentary emissions really result in long-term behaviour changes, which is what this project wants to achieve? To provide end customers with a more comprehensive picture of what their behaviour implies, also on a long term basis, other factors should be included, e.g. primary energy.

5. Conclusion

In this Swedish case study we have explored possibilities and limitations of consumer behaviour steering through developing concepts for district heating. The concepts have been developed for reducing heating and hot water uptake for individual households. In the project it was concluded that CO2e as an indicator of customers' individual environmental climate impact is not optimal. A changed uptake based on momentary CO2e emissions might give a negative effect on the emissions in the long term.
Since there is no immediate link between heating consumption and changed behaviour of customers, we have studied how other ethical considerations could be used as a more prominent incentive for customers in relation to district heating. Here, we looked at consumers considerations towards care for the environment and have developed visualisation concepts and explored a point system for providing feedback on environmental impact.

We have defined challenges in sustainable design for consumer behaviour change in the case of reducing heat and hot water consumption in individual households:

- The problematic relation between individual behaviour steering and system level district heating, which suggests rather another approach oriented towards integrating social aspects of heating systems and providing the 'bigger picture' on building or area level rather than on individual level.
- The complexity of environmental impact as indicator for behaviour change, with the uncertainty and the counter effectiveness of the calculations of environmental impact as main obstacles for providing feedback to consumer's behaviour.
- Ethical considerations concerning the role of the designer, in terms of the actual need and benefits as well as for whom this applies, when defining the environmental impact feedback for behaviour change, also on the long term.

Our future research will be geared towards exploring these challenges, so as to gain deeper insight into possibilities of system change rather than targeting individual consumer behaviour, as well as the potential or limitations for the development of an eco point system in relation to ethics for design for sustainability.

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