Household Indicators for Developing Innovative Feedback Technologies

Iana Vassileva, Student Member, IEEE, Fredrik Wallin Member, IEEE, Yong Ding, Student Member, IEEE, Michael Beigl, Member, IEEE, and Erik Dahlquist, Member IEEE.

***Abstract*—Numerous studies have shown that households' consumption is an important part of the total energy consumed in different countries. However, there is very little work done on finding appropriate strategies of giving households' effective feedback on their energy consumption. This study analyzes several indicators that could be considered before analyzing residential overall energy consumption and providing information, feedback, or developing demand-response measures. A questionnaire sent out to 2000 households having 33% response rate shows that the total households' income and characteristics, occupants' age and users' energy attitudes and interest are the key components designing relevant energy information strategies .**

***Index Terms*—Electricity, Questionnaire, Sweden, Consumer's behavior, Energy efficiency.**

I. Introduction

THE energy consumption of households in buildings attracts a lot of attention of researchers and local authorities within their efforts aimed at overall energy savings and sustainable use. In Sweden, the total energy demand is approximately 400 TWh per year, 25% of which is used in the housing sector. Energy consumption in buildings accounts for 39% of Sweden's total final energy consumption and for about 50% of the total electricity consumption [1]. Therefore it is important to explore different energy information strategies in order to increase energy awareness, influence consumption behavior and reduce energy consumption. Energy efficient consumption can be achieved by different information strategies directed at influencing people's behavior. In order to provide the consumer with the most effective feedback, it is crucial to decide what the information or feedback should include (prices, consumption values, environmental impact, etc.) and the way it should be presented (letters, web-sites, displays, etc.).

Iana Vassileva, Fredrik Wallin and Erik Dahlquist are with the Mälardalen Energy, Environment and Resource Optimization (MERO) profile, School of Sustainable Development of Society and Technology (HST), Mälardalen University Sweden, (e-mail: firstname.lastname@mdh.se).

Yong Ding and Michael Beigl are with the Research Group of Pervasive Computing Systems (TecO), Karlsruhe Institute of Technology (KIT), Germany, (e-mail: firstname.lastname@kit.edu).

In a recent study, Karjalainen [2] tested eight prototypes providing different type of information (historical comparison, goal setting, consumption, power, cost, environmental factor, table, etc.) in 14 households giving them the option to choose one of them. The interviewees preferred receiving electricity consumption feedback from a bill, a web-site or an in-home display rather than mobile phones. In his study Karjalainen concludes that presenting the costs over a period of time is one of the most valued features by the consumers, together with appliance-specific breakdown and historical comparisons.

Similarly, in her report, Fischer [3] concludes that for instance a time of the day, room or appliance breakdown would be helpful in cases where consumers are charged based on a time and week dependent tariffs. Moreover the disaggregation per appliance would provide an important insight into how much electricity the different household appliances consume. This possibility could persuade consumers to change some of the most energy consuming appliances with others that are more energy efficient. In all the different studies included in her report, the computerized feedback that includes multiple feedback options at the consumer's choice was selected as the best option.

However, there is an important question that remains unanswered in a majority of the studies presented, namely, what does the energy consumer prefer when being able to choose freely?

The main purpose with this study is to find out a set of indicators or parameters that could be used when designing and developing information and/or feedback strategies targeting different consumers' in order to achieve behavioral changes and more efficient energy consumption.

II. Methods

The households (situated in the city of Växjö, in the South of Sweden) included in this study were selected due to being provided with a web based consumption feedback during several years.

The web-site, called EnergiKollen (EnergyCheck), aims to increase the awareness of energy consumers by making it easier and more interesting to monitor and change their energy usage. It contains easy-to-follow graphics outlining changes of energy consumption. The customers of the local energy supplier are able to analyze their usage of electricity: their daily consumption and also compared to previous month/years etc. They can also see energy costs, outside temperature, average consumption and even get general energy saving tips. Consumers are also able to compare the energy consumption of different households and see how much energy is being used by people living in a similar sized apartment.

A questionnaire was sent out to 2000 households from which 1000 were living in houses and 1000 were living in apartments, selected from different taxation areas (low, moderate and high) of the city. The response rate without sending any reminder was of 33% (660 responses) of the total 2000.

In order to cover different aspects of the households' relation to energy the questionnaire was divided in four major parts with following topics: (1) personal/family characteristics, (2) energy related behavior/attitudes, (3) usage (and number) of appliances, and (4) preferred means of receiving information concerning energy consumption. Questions about structural characteristics were also included in the survey sent to houses.

This type of questionnaire based survey (used also in other similar studies [4], [5]) was chosen due to the large size of the sample investigated and the level of detail covered (personal information, behavior, knowledge, use of appliances, etc.).

III. INVESTIGATED INDICATORS AND DISCUSSION

A. Income

The household's total income is considered by many authors as one of the main factors influencing the total energy consumed [6], [7]. Moreover, the household's total income would directly or indirectly influence the home's size, the number and frequency of usage of the appliances used in the household and in many cases the home structural properties. In general for the high income consumer would be affordable to invest in energy saving measures characterized by a long payback period [8]. It is therefore, interesting to analyze if household with different income levels prefer to receive feedback in different ways (see Table 1).

Table 1. Averaged preferences (1 = very interested,…, 7 = not interested at all) for receiving feedback among household groups with different incomes. Income is calculated as an average per person and month for each household.

Income	Letter	Web site	e-mail	SMS	MMS	WAP	Apps	Display
<10.000	**3.0**	3.4	3.7	5.2	6.0	6.2	5.8	3.8
10-20.000	4.2	**3.7**	3.8	5.6	6.4	6.6	5.8	4.3
20-30.000	5.4	4.3	**3.8**	6.3	6.8	6.9	6.1	4.0
> 30.000	4.6	**3.3**	3.7	6.1	6.6	6.7	6.1	3.8

A possible explanation to the differences obtained could be that the group with lowest income per person is formed mainly by retired people, who have difficulties with computerized information (or do not have computers/Internet) and therefore prefer letters as a main way of receiving feedback.

B. Number of occupants, time spent at home and type of home.

The number of occupants and the number of children living in the household are important determinants of the total electricity consumed. In the Växjö case, within the households that participated in the questionnaire there are 1176 adults and 278 children under the age of 18. The time spent by the occupants at home could also influence the decision when it comes to choosing the way of receiving consumption feedback. In Table 2, the average of preferences according to adults' responses are presented (graded from: 1= very interested, to 7 = not interested at all) divided in three groups depending on the time spent at home.

Table 2. Average of preferences according to households' responses (graded from: 1= very interested, to 7 = not interested at all).

	Letter	Web site	e-mail	SMS	MMS	WAP	Apps	Display
All day	**3.7**	**3.7**	3.8	5.6	6.3	6.6	6.3	4.5
½ day	4.4	**3.7**	4.1	5.6	6.1	6.2	5.7	4.2
Evenings/ nights	4.8	**3.5**	**3.5**	5.6	6.3	6.3	5.2	**3.5**

It could be assumed that the main part of adults tat spending the whole day at home (463 adults) are retired. Older people might have difficulties using web-sites, and therefore letters is the most preferred way of receiving feedback.

One of the most preferred ways of receiving feedback within the occupants that mostly spend only evenings and nights at home (582 adults), is the display (not within the most preferred amongst the other groups). This result could be explained by the working status of the adults, most probably working during the day. The possession of a display could be one of the modern ways of receiving information which is not very time consuming (no computer, web browsing or use of passwords are needed).

On the other hand, the type of household (apartment or house) could also affect the chosen tool for receiving feedback. In Fig. 1 households' most preferred tools for receiving information about their own energy consumption are shown. Respondents were given the possibility to grade from 1 (most preferred) to 7 (least preferred), eight alternative ways (letters, web-site, e-mail, SMS, MMS, WAP, applications for smart phones and in-home display).

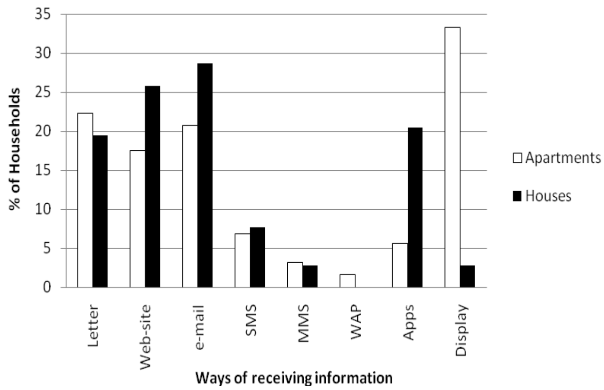

Fig. 1. Most preferred tools for receiving feedback, chosen by occupants living in apartments and houses.

In this case the ways of presenting feedback graded by the respondents with 1 or 2 points (most preferred) in the 7- point scale are presented. Clear differences between the respondents living in their own houses and those living in apartments can be observed. Display devices are the selected ones by 33% of the respondents living in apartments, while the consumers living in houses preferred e-mail, by 27% (and web-sites, 26%). That could explain why only 23.5 % of the total households living in apartments have been visiting the web-site provided by the electricity supplier. These differences in preferences can be due to possession (or lack of it) of computers/Internet. The respondents living in apartments might not have computers/Internet and therefore, prefer having in-home displays.

C. *Education levels*

The households' education level is believed to be an important factor determining the type of information that will be provided to the consumers and also when purchasing new appliances [9]. When considering all the households, there are 458 occupants with finished high school and 467 adults that have a University degree.

If divided by type of household (house or apartments), almost equal amount of respondents living in houses and in apartments has a University degree (41% and 45%, respectively).

Table 3. Averaged preferences (1 = very interested,…, 7 = not interested at all) of occupants with University degrees and those who have Secondary School degree (graded from: 1= very interested, to 7 = not interested at all).

	Letter	Web site	e-mail	SMS	MMS	WAP	APPS	Display
Univ. Degree	4.6	**3.4**	3.8	5.7	6.4	6.5	5.6	3.7
Sec. School Degree	4.4	3.7	**3.6**	5.7	6.2	6.5	5.7	4.0

Table 3 presents the results from the average preferences (1 = very interested,…, 7 = not interested at all) of occupants with different education background. The two groups (University degree and Secondary School degree) show almost no differences answering the question on how they want to receive energy related information.

D. *Current knowledge and Energy related interests*

The feedback should contain information important and relevant to the consumers in order to increase their motivation to save energy [10].

On the other hand, in order to maintain the positive behavioral changes for longer, some researchers suggest that factors such as human motivation and energy related interest should be included in the feedback developing process [11]. Several studies show that most of the targeted consumers do not understand much about scientific units [12] and therefore, feedback providing only consumption values would not be very effective.

Households' energy related knowledge and interests have been analyzed in this paper by including specific questions in the survey (some of them presented in Table 4).

Table 4. Energy related knowledge and interest. Average results from 1 = very positive,…7 = very negative.

	Average
Are the occupants interested in energy related questions?	*3.1*
Are the occupants trying to reduce the electricity consumption?	*2.8*
Are the occupants aware of the measures to take to keep low electricity consumption?	*2.8*
Are the occupants interested in increasing their knowledge on how to maintain low electricity consumption?	*3.2*
Do the occupants know about their own consumption?	*2.7*

From the results presented in Table 4, it could be concluded that the respondents have a good knowledge about their own consumption and know how to maintain it low; they also try to reduce their electricity use. However, the results are less positive with respect to increasing their knowledge on decreasing electricity consumption. Probably due to the fact that they already state they have a high knowledge level.

Nowadays many consumers state they are environmentally aware and would save energy simply because for environmental reasons. In fact, 25 % of the total households included in this study responded that they would save energy for the environment (20 % would do it for economical reasons and 37.6 % for a combination of both, environment and prices). Some authors however, argue that independently of what they think, people are largely unfamiliar with environmental impact presentations and cannot estimate for example, the CO_2 emissions related to their electricity consumption [2]. In Table 5 we can observed the most preferred ways of receiving feedback by occupants who responded they would save energy for the environment (web-site was the main one) and those who would do it for economical reasons (they chose e-mail as main source of feedback) .

Table 5. Sources of feedback (averages; 1 = very interested, …, 7= not interested) chosen by occupants that would save energy for the environment and those who would do it for economical reasons.

	Letter	Web site	e-mail	SMS	MMS	WAP	Apps	Display
Environm.	4.0	**3.7**	3.8	5.6	6.2	6.3	5.4	3.9
Economy	4.7	4.2	**3.9**	5.8	6.5	6.6	6.0	4.3

Table 6 shows the averaged preferences for the households who answered that they are very interested in energy related questions. The most preferred way of receiving energy feedback is through displays (2.6) followed by letters and web sites (3.6).

Table 6. Chosen ways of providing feedback (1 = very interested, …, 7 = not interested at all) among households with high interest in energy related topics in general.

Letter	Web site	e-mail	SMS	MMS	WAP	Apps	Display
3.6	3.6	4.5	5.6	6.4	6.2	4.9	**2.6**

In Table 7 it can be observed that there are almost no differences between the preferences of occupants who said they already have a good knowledge on their electricity consumption and those who said they did not know their consumption well. The only difference is that more households with knowledge on their consumption prefer web-site providing feedback than those who do not have knowledge currently.

Table 7. Average (1 = very interested,…, 7 = not interested at all) of the most preferred ways of providing feedback by household with and without knowledge on their own electricity consumption.

	Letter	Web site	e-mail	SMS	MMS	WAP	Apps	Display
Have knowledge	4.3	**3.6**	**3.6**	5.5	6.2	6.5	5.7	4.1
Without knowledge	4.5	4.7	4.5	6.3	6.5	6.7	6.3	**4.4**

Differences were found between households with interest in energy related questions and that have knowledge on their consumption and those who do not have the knowledge. E-mail and web-site were the most preferred by the group with knowledge and displays were chosen by hosueholds without any knowledge. It is interesting to note that households that state not having a good knowledge on their own electricity consumption might not have it due to having strong preferences for displays instead of web based information, which they have been provided with.

E. Occupants' Age

The age of the consumers is also an important factor when choosing the way of receiving information. The elderly might prefer displays because they seem to be easier to use and there is no Internet/computers involved. Information via e-mail might be more suitable for consumers that are working and have to consult their e-mail accounts anyway. Young people would most likely prefer mobile applications with a more interactive and game oriented approach. There might be differences between male and female consumers too. Many studies [13]-[15] conclude that when applying energy conservation actions their acceptance should be differentiated with regards to consumers' economic and socio-cultural demographic characteristics (age, sex, education, income, etc). Consumers should be considered as a diverse group of people with different needs, histories and aspects of lifestyle.

Therefore, we have further analyzed households' preferences depending on the different age groups of the respondents (see Table 8). The most preferred ways of receiving feedback chosen by the youngest group of occupants (18-24 years) were displays, followed by mobile phone apps and e-mail. Web-sites and e-mail were the selected ones by the three following age-groups, while the oldest occupants preferred letter as a main way to receive feedback on their consumtpion.

Table 8. Most preferred ways of receiving feedback averaged by different age groups (on a scale from 1 to 7: 1 = very interested,…, 7 = not interested at all).

Age	Letter	Website	e-mail	SMS	MMS	WAP	Apps	Display
18-24	6	3	1.5	4	7	7	1.5	**1**
25-34	4.8	3.5	3.9	5.1	5.9	5.7	5.3	**2.6**
35-44	4.9	**3.8**	4	5.8	6.2	6.7	5.1	4.1
45-54	4.1	**3.5**	**3.5**	5.2	6.0	6.4	5.1	3.6
55-64	4.9	**3.5**	3.6	5.8	6.4	6.6	6.3	4.5
>65	**3.6**	4.1	4.1	6.0	6.5	6.9	6.8	5.1

The results show the significance of including the age of the targeted households groups when developing an effective feedback.

F. Users' behavior

Users' behavior is one of the most important key components when trying to implement energy saving measures and increase energy efficiency in households [16]. Large differences in electricity consumption have been found between totally identical households (same size, number of occupants and same building characteristics) only explained by behavior and income [17]. Since energy use behavior varies significantly among different individuals [18], it is essential to analyze and understand households' attitudes, preferences and practices in order to apply personalized approaches and demand-response measures.

Therefore, one of the main cores of the questionnaire used is the behavioral related questions.
For instance, as an average there are still less LED bulbs (10.8 light bulbs per household) than conventional light bulbs (21.7 light bulbs per household).
On the other hand, when divided into apartments and houses, most of the participants in the survey consider that the standby power of their appliances do not have any effect on the final household's electricity consumption (see Fig. 2).

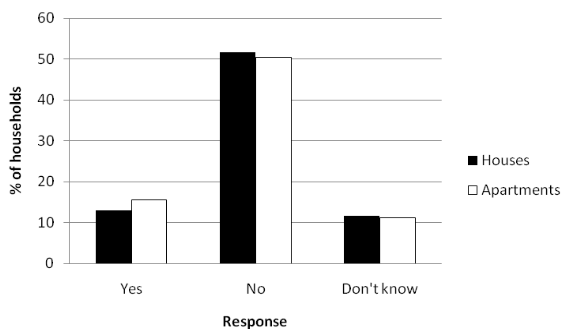

Fig. 2. Responses received from the households concerning effect of standby on the total electricity consumption.

The lack of knowledge on the effects of standby consumption should be taken into account when developing feedback. Including the "invisible" electricity consumed by some of the home appliances in the feedback, would make users more aware of the effects and could help saving this type of consumed energy. Adittionaly, the average preferences for receiving feedback by households that consider that the standby affects their final electricity consumption and by those who think standby has no effect on the consumption are presented in Table 9.

Table 9. Averages (1 = very interested,…, 7 = not interested at all) of the most preferred ways of providing feedback by household that consider that standby consumption affects the total electricity consumption and those who consider no effects at all.

	Letter	Web-site	e-mail	SMS	MMS	WAP	Apps	Display
Standby has effects	3.6	**3.2**	3.3	5.3	5.5	5.9	4.9	**3.2**
Standby has no effects	4.4	**4.1**	4.3	6.0	6.6	6.7	6.1	4.4

Surprisingly, households that answered that the standby consumption of their appliances has a significant effect on the overall electricity consumption, preferred having a display (and web-site) as main provider of feedback, if we consider displays as another standby consuming device.

Another three energy consuming activities dependent on beahvior and energy awareness (use of lights, washing machine and dishwasher) have been presented in Table 9. The responses have been averaged for the total households (1 = always do,…, 7 = never do).

Table 10. Household behavior regarding the way of using lights, dishwasher and washing machine (1= always do,…7= never do).

Activity	Average
Do the occupants usually turn off lights in unoccupied spaces?	*3*
Do the occupants fill up the washing machine before using?	*2.1*
Do the occupants fill up the dishwasher before using?	*1.6*

The three activities included in Table 10 reveal more details about the attitudes the consumers have towards energy consumption. In almost all households dishwashers and washing machines are always filled up before use. Another important fact is that in most of the apartments there are no private washing machines, but shared laundry facilities (shared laundry facilities are a common in many multifamily buidlings in Sweden). However, the responsents do not seem to be so strict regarding switching off the lights in empty rooms. A great part of the electricity consumed in households is used for lighting. In Sweden, for instance, the household electricity used for lighting and different electric appliances, has more than doubled between 1979 and 2006 (from 9.2 TWh to 22.1 TWh) [1].
It is therefore, important to make sure consumers know about the percentage of their electricity used for lighting and focus on some of the strategies towards lowering this type of electricity use. For that reason, presenting real-time consumption of electric power (in Watts) would allow the consumers to observe the instant effect on the total power when switching different appliances on and off [2], [19].
Table 11 shows the preferred tools for providing feedback chosen by the households that are showing energy awareness (by turning off the lights in unoccupied rooms and filling up their washing machines and dishwashers before using them) and those who are not making efforts to reduce their electricity consumption.

Table 11. Preferences for receiving feedback (1 = very interested,….7= not interested at all) by groups of households that are trying to save electricity (aware) and those who are not (not aware).

	Letter	Web-site	e-mail	SMS	MMS	WAP	Apps	Display
Aware	4.0	4.0	**3.7**	5.6	6.2	6.5	5.9	4.0
Not aware	6.2	3.2	3.4	7	7	6.2	5	**2.2**

Households that are not trying to save electricity prefer displays for receiving feedback on their consumption. Considering displays as electricity consuming devices, the results are not surprising.

The overall analysis of all the previous household related factors, shows that most differences in preferred tools for providing feedback have been found among households with a different level of knowledge on their own consumption, the occupants' age, the energy awareness (and consequently behavior) and the type of home (house or apartments). Possible relations could be found between the mentioned factors: it could be supposed that younger people (that prefer displays) would live in apartments and their income would be low (or none). Additionally, young people, although aware of the existence and defects of standby consumption, are not trying to save electricity and therefore, are not aware of their electricity related activities (which could explain the results shown in table 11).

E-mails and web-sites are the most preferred ways of receiving feedback by the respondents living in houses. It could be assumed that houses would be occupied by middle age people with high incomes and probably families with children. The occupants could also be elderly people who do not work, with low income (pensions) but that have been working until not so long ago. The two types of house occupants would have computers and Internet at home and would be spending time using them (for entertainment or work). It would be therefore, easier for them to receive computer based feedback.

IV. CONCLUSIONS

Nowadays, energy saving campaigns are directed at large parts of the population without considering household on an individual level. Therefore, these campaigns cannot reach the desired effects. After an in-depth analysis of responses received from a questionnaire based survey sent to Swedish households, a set of indicators for developing consumption feedback providing technologies was proposed. The level of interest in energy related topics, the age of the consumers and their income should be taken into account when developing and providing information-feedback.

Therefore, an individual and personalized information approach is highly recommended (based on specific indicators).

On the other hand, household energy consumption should not only be presented quantitatively (as monthly/annual consumption or according to the size of the household) but other values should also be included, such as comparison with similar households, environmental impact caused by the consumption, appliance specific breakdown, etc.

To achieve long lasting effects, the feedback needs to be dynamic, as consumers preferences, knowledge or others can change with time.

Many people behave differently in their ordinary domestic life, have different knowledge and understandings and are driven by different forces during the decision making process. Therefore, this paper addresses the importance of collecting data and analyzing the previously mentioned indicators before elaborating information and/or feedback oriented strategies which should also be more personalized.

These indicators should be considered in combination with others depending on different circumstances (location, directives, etc.) and therefore, our future work will be directed at finding out the correlation of these complementary indicators.

V. REFERENCES

[1] Swedish Energy Agency 2007. www.energimyndigheten.se, Accessed on Apr. 15th, 2010.

[2] S. Karjalainen. Consumer preferences for feedback on household electricity consumption. *Energy and Buildings*, 43: 458-467, 2011.

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

[4] K. Ek, P. Söderholm, The devil is in the details: Household electricity saving behavior and the role of information, Energy Policy 38 (2010) 1578-1587.

[5] K. Genjo, S-I. Tanabe, S-I. Matsumoto, K-I .Hasegawa and H. Yoshino, Relationship between possession of electric appliances and electricity for lighting and others in Japanese households, Energy and Buildings 37 (2005) 259-272.

[6] H. Moll, K.J. Noorman and R. Kok. Pursuing more Sustainable consumption by analyzing household metabolism in European countries and cities. *Journal of Industrial Ecology*, 9: 259-275, 2005.

[7] R. Colton. Energy consumption and expenditures by low-income customer. *The Electricity Journal*, 15: 70-75, 2002.

[8] Yohanis Y., J. Mondol, A. Wright, B. Norton. Real-life energy use in the UK: How occupancy and dwelling characteristics affect domestic electricity use: *Energy and Buildings* 40: 1053-1059, 2008.

[9] I. Mansouri, M. Newborough and D. Probert. Energy consumption in UK households: impact of domestic electrical appliances. *Applied Energy,* 54: 211-285, 1996.

[10] J. Desmedt, G. Vekemans, D Maes, Ensuring effectiveness of information to influence household behavior. *Journal of Cleaner Production*, 17: 455-462, 2009.

[11] J. Henryson, T. Håkansson and J. Pyrko. Energy efficiency in buildings through information – Swedish perspective. *Energy Policy,* 28: 169-180, 2000.

[12] G. Wood, M. Newborough. Energy-use information transfer for intelligent homes: enabling energy conservation with central and local display, *Energy and Buildings*, 39: 495-503, 2007.

[13] Wood G. and M. Newborough. Dynamic energy-consumption for domestic appliances: Environment, behavior and design. *Energy and Buildings* 5: 821-841, 2003.

[14] Poortinga W., L. Steg, C.Vlek and G. Wiersma. Household preferences for energy-saving measures: A conjoint analysis. *Journal of Economic Psychology* 24: 49-64, 2003.

[15] E. Sardianou. Estimating energy conservation patterns of Greek households. *Energy Policy* 35: 3778- 3791, 2007.

[16] J. Ouyang and K. Hokao. Energy-saving potential by improving occupants' behavior in urban residential sector in Hangzhou City, China. *Energy and Buildings* 41: 711-720, 2009.

[17] I. Vassileva, F. Wallin and E. Dahlquist. Analytical comparison between electricity consumption and behavioral characteristics of Swedish

households in rented apartments. Applied Energy (2011), doi:10.1016/j.apenergy.2011.05.031
[18] R. V. Andersen, J. Toftum, K. K. Andersen, B. W. Olesen. Survey of occupant behavior and control of indoor environment in Danish dwelling. *Energy and Buildings*, 41: 11-16, 2009
[19] S. Darby. The effectiveness of feedback on energy consumption. Oxford, United Kingdom. www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf. Accessed: 2011-06-20.

VI. BIOGRAPHIES

Iana Vassileva received her M. Sc. Degree in Environmental Science from Mälardalen University, Västerås, Sweden in 2007. She is now a doctoral candidate at Mälardalen University working on analyzing consumption patterns, behaviors and how different feedback influences them.

Fredrik Wallin received his Ph.D. degree in 2010 at Mälardalen University. He has been working for 10 years with energy information, metering systems and demand-response issues. Other research interests are small-scale electricity production, renewable energy technologies and improved integration of energy consumers into the energy markets.

Yong Ding received his M. Sc. Degree of Electrical Engineering in 2008 at Karlsruhe University. His employment experience included 15 months Trainee Program in the energy company RWE and project management of electrical engineering in the division of conveyor equipment and process data processing. He is now a PhD candidate at the Karlsruhe Institute of Technology (KIT), working on behavioral change of energy consumption in urban scale and networked platforms for dynamic energy mix and consumption optimization.

Michael Beigl holds a MSc. (Dipl. Inform.) and a Ph.D. (Dr. Ing.) in Computer Science from the University of Karlsruhe. His Ph.D. received the FZI price for the best dissertation of the year in 2000. His employment experience included the chair for Distributed and Ubiquitous Computing at the Technische Universität Braunschweig (2006-2010) and scientific director of the TecO research lab at University of Karlsruhe (2000-2005). Since 2010 Michael Beigl is full professor (W3) at the Department of Informatics and holds the position as chair of the shared new field group Pervasive Computing System at the Karlsruhe Institute of Technology.

Erik Dahlquist received the Ph.D. degree in 1991. He is now a professor in Energy Technology at Mälardalen University. He has earlier worked at ABB as project manager and in different managing positions, in both research and business in the fields of process automation, power technology and energy systems. Dahlquist also is a member of the Royal Swedish Academy of Engineering, IVA.