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INTEGRATING RENEWABLE ENERGY FORECASTING WITH HOME ENERGY MANAGEMENT SYSTEM AND DEVELOPING IT WITH BOTTOM-UP APPROACH

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ABSTRACT

This paper introduces how weather forecasting could help in more efficient energy management for smart homes with the use of Home Energy Management Systems (HEMS). The paper also focuses on educating consumers and helping them make more informed decisions while using the HEMS. HEMS is generally used to remotely monitor and switch appliances on/off. The increase in renewable energy installations at home creates the need to forecast renewable energy generation for the next day and help HEMS with better management. Better energy management practices can be performed by shifting the time of use of energy intensive appliances in accordance with renewable energy generated, as well as by determining the heating/cooling load. To make the system more effective, a bottom-up approach with the needs of the consumers as the starting point has been explored. Using a questionnaire survey, thorough analysis of consumer needs is done to frame a web based application for the system. The aim of the system will be to inform and educate the consumers about the various options available to conserve energy and let them make conscious decision on their own.

KEYWORDS

HEMS, smart grid, bottom-up approach, user defined, renewable energy forecasting, weather forecasting

1. INTRODUCTION

Texel, one of the Wadden islands in the north of the Netherlands, plans to be an energy independent island by the year 2020. One of the entrepreneurs on the island wants to build 10 energy efficient holiday homes. The aim is to provide electricity and heating in these homes with solar photovoltaic and ground source heat pump (GSHP) respectively. Also, batteries would be provided to store the electricity generated through solar photovoltaic. For further management of energy for all the houses, the entrepreneur wants to establish a micro grid, which could be controlled remotely. Thus, a central Home Energy Management System (HEMS) is being hypothesized, which could do the following:

- Manage electricity production and consumption.
- Inform grid operators about the amount of energy that would be required from the grid during the next day
- Interact with customers and motivate them to save energy.

Figure 1 illustrates how the holiday homes would be connected to the renewable energy system. Furthermore, all these homes would be connected to central HEMS by Wi-Fi. This would help in monitoring generation and consumption of energy centrally for each home.

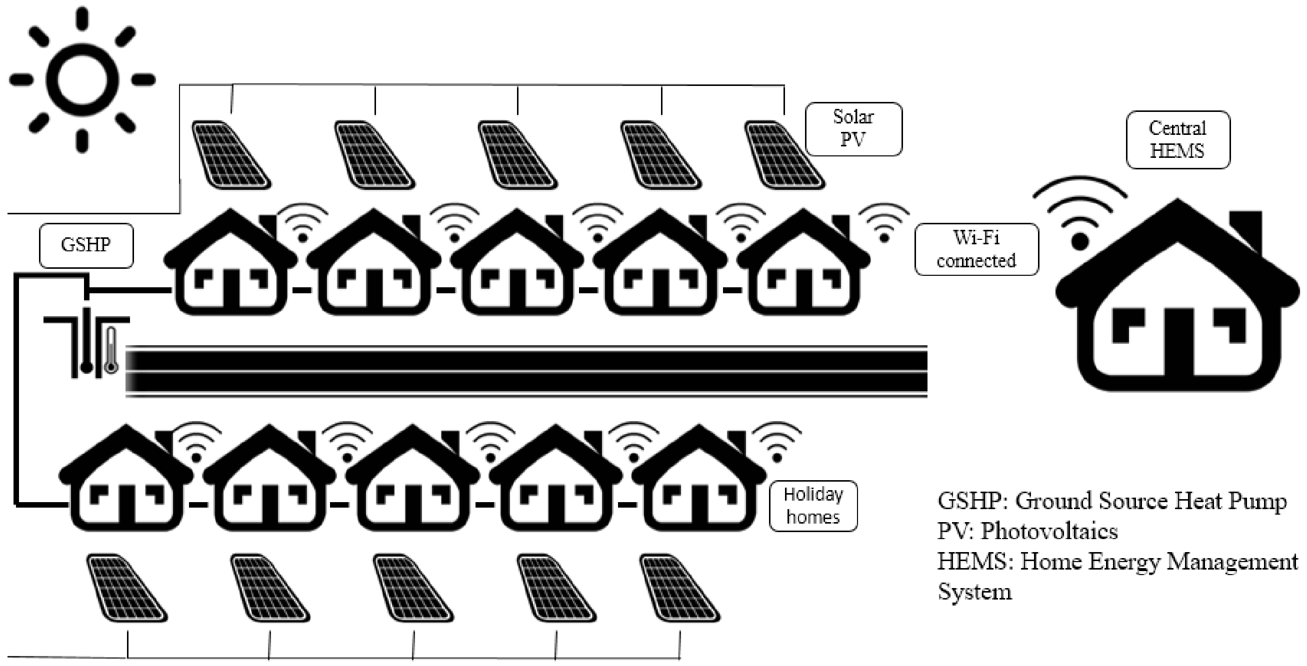

Figure 1 Arrangement of Holiday Homes, central HEMS and renewable energy system

2. BACKGROUND

A Smart Grid can be defined as an electric network which helps in managing and monitoring of the transport of electricity from all different sources of generation with the help of digital and other advanced technologies to meet the varying needs of electric demand of the end user [1]. Some of the characteristics of smart grid are as follows:

- Enables informed participation by consumers.
- Accommodates all generation and storage option.
- Enables new products, service and markets.
- Provides the power quality for the range of needs.
- Optimizes asset utilization and operating efficiency [1].

Similarly, Smart Homes can be defined as houses which use information technology to monitor the environment, control the electric appliance and communicates with the outer world [2]. They are equipped with smart meters which help in two way communication with the electric grid [3]. In addition to a smart meter, they are also equipped with HEMS and assisted living for improving the consumer lifestyle [4]. HEMS help in monitoring the power generated and consumed by the house, in order to balance the electricity system [5]. They can also manage and monitor energy consumption of individual appliances and help in shifting the usage of non-essential appliances at later stage of time [5].

According to the aim, the grid had to be informed about, how much energy would be consumed from the grid during the next day. To do so, the HEMS should have knowledge about the day ahead energy consumption of the house as well as energy production from the renewable energy system installed. Energy consumption could be taken as the average energy consumption of the house per day, to simplify the calculation. Energy production could be calculated with the help of weather forecast, as the variability in the energy generation for renewable energy depends on the weather. Sharma et al. [6] mentioned in their report that weather forecast is the best option in the range of 3 hours to 3 days for forecasting. Further, Inman et al. [7] added that, the numerical weather prediction method allows for a better modeling of the temporal progression of cloud cover in locations where no extensive ground networks were available.

To optimize the forecasted value, Sharma et al. [6] mentioned that, the weather conditioned moving average (WCMA) is better than the exponentially weighted moving average (EWMA) and simple moving median (SMM). However, [8], [9], [10] and [11] used Artificial Neural Networks (ANN) method during their research to optimize the forecasted value. As the weather forecast would not always be accurate, it would be possible to optimize the renewable energy forecast solutions by complex methods like ANN as well as simple methods like WCMA, EWMA and SMM.

The next step for research is identifying how users perceive HEMS and check the possibility of improving the perception for the same. This created the need to develop the HEMS with a bottom-up approach. A Bottom-up approach concentrates more on specifying the details of the base element, which in turn would form a larger subsystem and eventually a complete system [12]. Details about some of the options given by HEMS are outlined. Keyson et al. [13] mentioned that their HEMS toolkit had options to switch lights on/off, change light intensity, turn the plugs on/off, particular window screen on/off, show an overview of the consumptions and tariffs on a weekly, monthly and yearly basis and at last heating control of the floor zones and cooling in the roof. Further, hydro-one smart grid pilot project [14] also mentioned that they displayed savings in dollar and carbon emissions. They also displayed current kWh usage, total kWh usage and predicted kWh usage.

Zoha et al. [15] suggested that, direct feedback (real-time) led to more energy savings compared to indirect feedback (monthly/weekly bills). It was further confirmed by Grønhøj & Thøgersen's [16] study that, direct feedback helped in 5-15% of electricity savings, while indirect feedback helped in 0-10% electricity savings. Gram-Hanssen [17] stated that, different consumers have different energy consumption in the same house and that can vary as such as three times. Hargreaves et al. [18] also independently agreed that the energy consumption in a house was performed by multiple users with different logic and rationalities and that often resulted in negotiations between different users, which changed over time in different contextual forces.

Geelen [19] and Van Dam [20] both suggested that, the HEMS should be developed with a user perspective. They further mentioned that, a detailed insight about energy use should be given in such products. Van Dam [20] further added that, the energy savings are visible only for first four months after which the consumers lose the motivation to use the system. To make the user use these types of product for a longer period of time, it was important to adapt the system to the consumers needs instead of making consumers change their behavior.

Thus, to summarize the background research:

- Day ahead renewable energy forecast could be calculated with the help of numerical weather prediction and further optimized with the help of ANN, WCMA, EWMA or SMM.
- Direct feedback with better user perception could lead to longer use of such products.

3. METHODOLOGY

Lots of HEMS are available in the market. They have a wide variety of options to control energy usage. Thus, it would be futile to develop one such HEMS again. The aims of the HEMS to be developed are management of energy and informing the grid about the day-ahead energy usage for the holiday homes. Thus, if prediction of energy consumption and production for 10 homes is simulated then, it would be easier to conduct the above given tasks in the micro grid developed at Texel.

Electricity consumption in homes is due to lights, television, laptops, etc. as well as due to high energy intensive appliances like washing machines, dryers, dishwashers, etc. The high energy intensive devices generally cause peaks in the energy usage, apart from using multiple electrical appliances at any given time. With traditional HEMS, it is possible to change the time of use of high energy intensive appliances to the low electricity tariff times, to reduce the electricity bills. Therefore, it was believed that these high energy intensive appliances could be shifted to the time of maximum generation of energy from the solar photovoltaic system installed. Thus, the houses would not have to buy energy from the grid or they would have to buy as minimum energy as possible, which would lead to financial savings for the consumer.

With the help of renewable energy forecasting it would be possible to develop a system that could predict the energy generation from the solar photovoltaic system installed at the house. This would help in making autonomous decision for the HEMS to predict the best time to use energy intensive appliances during the next day. Therefore, reducing the consumer effort to operate the system.

The next research topic was the usability and convenience of the system. Here the aim was to develop a system with user perspective i.e., with the bottom-up approach. For this, a user survey had to be conducted and its result was analyzed to give the suggestions for the user interface design as well as for the options/features that users would like to use in the system.

Thus, development of HEMS is divided in two parts. First, the algorithm development for the technology and second, the user interface development.

3.1. Technology Algorithm

HEMS are used to monitor and efficiently manage the energy usage in homes. When a renewable source of energy is installed at home, it would also be possible to monitor and manage it with the home. Renewable energy forecast solution can help in better management of the energy resources. Thus, if such solution were provided, users could be informed about the energy generation pattern for the next day. Therefore, users could try to utilize the renewable energy generated by their own home the most optimum way.

It was assumed that the house would have either a solar photovoltaic system or a wind turbine to generate electricity. Ground Source Heat Pump (GSHP) was to be used for heating of the homes. This would also utilize the electricity generated. The home would be provided with sufficient battery capacity to provide electricity for 3 full days. The majority of the electricity load in the house would be as a result of the use of energy intensive appliances.

To identify the time for maximum energy production, it was important to know the weather forecast data for the next day in a one hour time range. This would help in calculating the energy to be produced by the renewable energy source installed in that particular hour during the next day. Also, it would help in determining the heating/cooling energy that would be required for the home, which would account for a major amount of load apart from energy intensive appliances.

The weather forecast data in the above algorithm would give the global horizontal solar irradiance for the surface. This when multiplied with area of solar photovoltaic panel and the panel efficiency would give the power generated. For the heating/cooling load, energy transfer equations were used with considering house as a rectangular box.

The algorithm was developed as a Matlab model and checked for three continuous days to confirm that the logic of the algorithm was functioning properly. Figure 2 shows how the algorithm would function.

Therefore, with the help of the renewable energy forecasting system, it was possible to feed in the following data in the HEMS developed in this research:

- Time of use of energy intensive appliances for the next day based on renewable energy forecast solutions.
- The calculated amount of heating/cooling required by the house.
- Energy required/supplied from/to the grid during the next day, to inform the grid operator for the same.

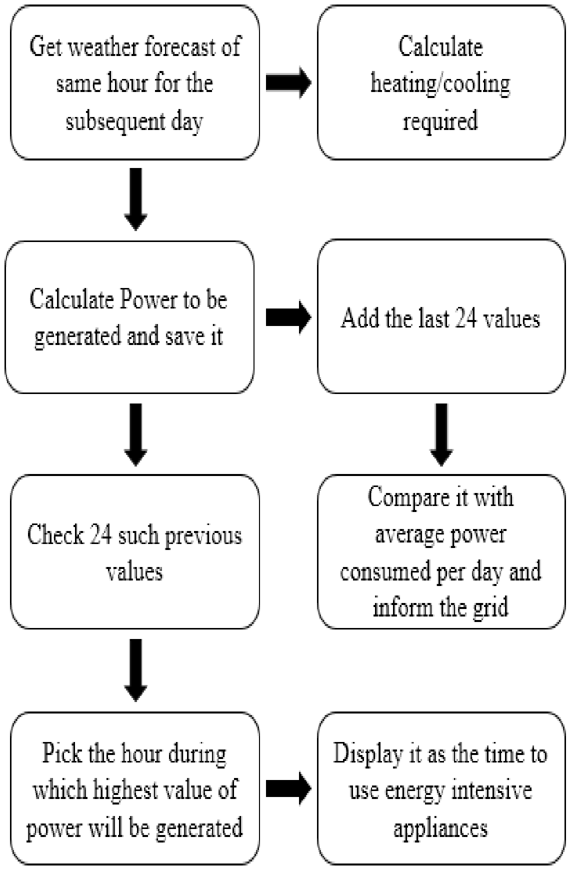

Figure 2 Algorithm showing renewable energy system and its application

3.2. User Interface Development

User Interface plays an important role in the usage of the product. Therefore, it would be important to check what the preferences off the consumers are, to design a user interface with a bottom-up approach. Therefore a survey was conducted, and their basic analysis is done in this section to get a perspective, if users would like to use certain kinds of services or not when they interact with the interface. Also, recommendations for the services they would like to have, has been asked for. This would lead to a designing of a system in which better utilization and more user interaction with the HEMS could be envisaged. Hence, a survey was conducted which had 41 questions, which were divided into 5 sections:

- Basic information
- Current energy use
- Energy labels
- Renewable energy system
- Interface design and services for HEMS

The survey was conducted in such a detail, to understand why users expected certain things. The survey also helped in understanding if the users were aware of energy conservation in homes. The survey was distributed to Dutch speaking people above the age of 30 years. The age above 30 years was selected because that is the average age of marriage in the Netherlands and it was considered that, married people had a higher probability to own or rent a property and therefore were more likely to buy such systems.

The user survey was sent electronically to approximately 600 people of whom 75 responded and 59 were completely filled and therefore, were considered for analysis. Thus, the survey was statistically analyzed with 90% confidence and 9.6% error of margin. Though the sample space does not account for the whole of the Netherlands but it can be assumed that it can be accounted for the initial segment of people who could move the technology in the new direction. The general results of the user survey can be concluded as follows:

- Most respondents in the survey were living in an independent house and those houses were at least 15 years old.
- Generally people try to consciously monitor their energy use. They also give more importance to energy savings when compared to comfort. Though not many people have heard about the HEMS, they were curious about using it to save money and the environment.
- The majority of the respondents use energy efficient labels and almost every one of those was comfortable in using those appliances. The people who did not know/use about these labels responded in general that more economic incentives would motivate them to buy and shift to energy efficient labeled appliances.
- Major issue with not installing renewable source of energy is that, people do not have enough money or they live in a rented house. They were however motivated to install such systems in order to save money and the environment. Those who have installed renewable energy, the majority of them have solar panels installed for at least 2-3 years and they are satisfied with its output.
- The users could change their behavior to a certain extent to use the appliances and to adjust to the situation, but they would not like interference in their comfort level. Users were more interested in saving energy and would like to receive information via graphical data for the same. The majority of the users are not too interested in community games or comparison. Also, they would prefer to get some advice when buying new appliances.

To further validate the results, statistical analysis was performed for the survey. It was observed that the variables were of categorical type as they were independent and did not follow any intrinsic pattern [21]. Therefore, variables could be analyzed by chi-square, fisher-exact or McNemar's test. McNemar's test was rejected, as the variables would have to be analyzed before and after the survey [22]. As some of the expected values were less than 5 in the contingency table, chi-square test could not be conducted and therefore, fisher exact test was done [23].

Fisher exact test uses hyper geometric distribution to compute the p-value, which makes it more exact [24]. P-value or probability value helps in defining, how extreme is the contingency table in the particular scenario (i.e. the combination of cell frequencies) in relation to all possible ones that could have occurred given the marginal totals [25]. If the calculated p-value is less than 0.05, than the null hypothesis (i.e. two variables are independent) between the two categorical variables can be neglected. Thus, giving a better insight on why consumers would like a certain kind of services.

From the survey, 23 questions were selected and checked for, if null hypothesis between them could be rejected or not.

Table 1, shows the p-value for comparison between all the 23 selected questions and the number 1, 2, 3, etc. represent questions from the survey (Appendix). Grey color boxes represent; null hypothesis is rejected between those two particular questions.

The survey conducted had some shortcomings. Firstly, it was 10 minutes long, thus majority of respondents are believed to be interested in energy conservation that have filled it up. It can also be confirmed for the general conclusion. Secondly, age of the respondent was not verified again during the survey. Lastly, loss of information would have taken place. The survey was prepared in English, distributed in Dutch and results were again analyzed in English.

Table 1 P-value calculated by fisher exact test. Grey boxes show rejection of null hypothesis between respective two questions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1		0.0011	0.1153	0.8305	0.8948	0.5531	0.2333	0.395	1	0.0167	0.647	0.9921	0.1261	0.1506	0.6501	1	0.1253	0.3993	0.5669	0.5558	0.6121	0.822	0.1528
2			0.263	0.9183	0.6772	0.1962	1	1	1	0.0254	0.5595	0.6048	0.1484	0.631	0.6394	0.2457	0.1978	0.2526	1	0.0329	0.714	0.8588	0.7687
3				0.0715	0.6101	0.1083	0.8821	0.3508	1	0.1715	0.5305	0.6667	0.7928	0.6776	1	0.1854	0.5885	0.2377	0.4259	0.2913	0.0392	0.3443	1
4					0.0183	0.4876	0.5415	0.7548	0.3333	0.1216	0.0926	0.4808	0.4585	0.2327	0.0097	0.6071	0.1692	0.4482	0.0049	0.0982	0.00009	0.084	0.086
5						0.8675	0.8196	1	0.4	0.6195	0.487	0.1242	0.2324	0.0063	0.1457	0.1409	0.003	0.6807	0.2799	0.0005	0.0674	0.773	0.037
6							1	1	1	0.4032	0.0842	0.2384	0.2384	0.4993	0.6766	1	1	0.6604	1	0.7747	0.0426	0.3296	0.3937
7								0.7128	1	0.2222	0.5284	0.6897	0.4703	0.2184	0.8867	0.4525	0.6852	0.8748	0.2771	0.6251	0.6214	0.1435	0.0137
8									1	1	1	0.7036	0.6406	0.2723	0.3685	0.4164	0.331	0.1442	0.348	0.7153	0.2099	0.3113	0.187
9										1	0.2857	0.5973	1	1	1	1	0.0666	1	0.6	0.2063	1	1	0.2857
10											1	1	0.2682	0.1302	0.7778	1	0.7727	0.3734	0.5699	0.8724	1	0.7541	0.9068
11												0.241	0.1232	0.2753	0.0662	0.3704	1	0.2153	0.0945	0.1044	0.6009	1	0.1709
12													0.5942	0.9605	1	1	0.0802	0.705	1	0.27	0.8285	1	0.859
13														0.0453	0.5966	0.3721	0.0959	0.0202	0.7836	0.5649	0.7525	1	0.5054
14															0.7547	0.5584	0.2259	0.6738	0.6535	0.0913	0.0046	0.6523	0.2316
15																0.1463	0.2727	0.383	0.175	0.3667	0.0824	0.5286	0.7531
16																	0.6474	0.001	0.0563	0.2342	1	1	0.0341
17																		0.5375	0.7833	0.3401	0.3522	0.7497	1
18																			0.0054	0.6882	0.4887	0.3183	0.2029
19																				0.0183	0.3658	0.7474	0.00006
20																					0.0122	0.5925	0.241
21																						0.000002	0.4352
22																							1
23																							

4. RESULTS

The solution development for the technology algorithm and user interface development was relatively different. But, it could be observed that, doing so might help in better product development. As, it would lead to a good amalgamation of solution based on a better technology and easy user experience to use the product. Therefore, such a product development could lead to a more efficient usage of technology compared to developing a product which is highly efficient and not used properly.

The technological algorithm was developed as a Matlab model and tested for 3 continuous days to confirm if the logic of the system works properly. Thus, the renewable energy forecasting system helps in better decision making of the smart grid system. It further helps HEMS in managing the energy consumption and production in a more systematic way. In this way, the system supports the consumers with financial and energy savings.

Although the fisher exact test on the user survey is based only on the limited number of survey responses, it helped in giving the following insights for the development of the product:

- People are conscious about their energy usage and pictorial feedback is important for them. Majority of them are also willing to change their behavior to a certain extent to conserve their energy usage.
- Different services/features can be used to provide better convenience and hence lead them to better energy conservation.
- Majority of the people are willing to use the home energy management system to save the environment.
- An app that can be downloaded on multiple devices would help in better use of home energy manager.
- The system should be autonomous and learn from the consumer behavior, but it should also give consumers freedom on how they would

like the HEMS to function according to their convenience.

- Consumers are not in favor of applications which lead to comparison and competition between their neighbors.

Thus, realizing a technological and user solution, an interface has been thought upon as shown in the Figure 3. On the left hand side, the user interface device is provided with four options on the top: money saved, carbon emissions saved, electricity generated, heating/cooling energy required respectively. All the options could be displayed with graph for better illustrations. At the bottom of the graph, it would be possible to look at each of the values for past, present and future (up to one day). Thus, monitoring for consumers can be made easier. On the right bottom corner, time would be displayed to use energy intensive appliances based on the renewable energy forecast. Above that, options for switching on/off energy intensive appliances would be given. Also, an option to remotely control the lights would be given.

The HEMS currently developed is in two different parts: A technical model on Matlab and a design for user interface based on one user survey conducted. The result provided in this research tries to solve the problem of how users can use HEMS for a longer period. For better development of this HEMS, a physical model integrating two solutions should be tested with the consumers and its solution should be re-iterated after market validation. Also, in the real system, electricity load will not be same every day (as assumed here) and would vary depending on many factors (weather, no. of people, holidays, etc.).Thus, while developing the physical system, appropriate care should be taken.

To conclude, it can be stated that, while developing a technological solution it is important to realize how consumers would like to work with the product being developed, so that maximum efficiency for the system could be attained.

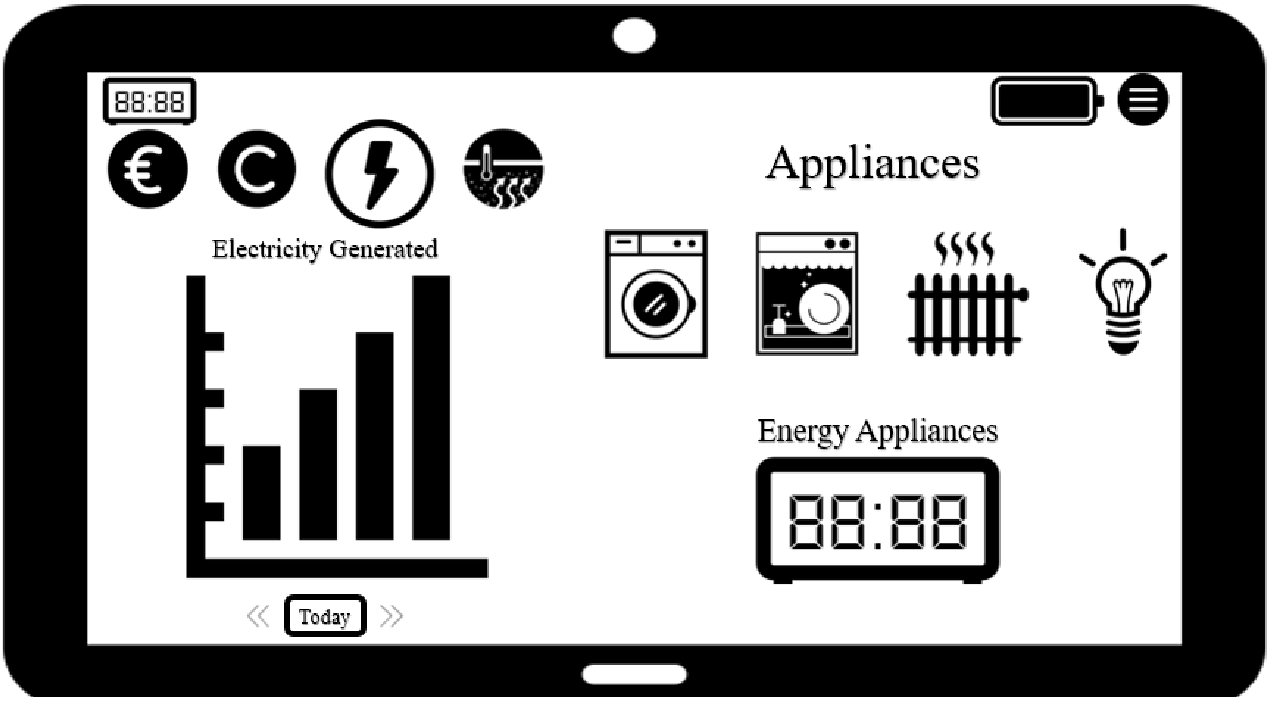

Figure 3 User Interface for Consumers

5. APPENDIX

1	Do you keep record of your home electricity use? (Yes:33, No: 18, Sometimes: 9)
2	Do you consciously try to save energy in the house? (Yes: 42, No: 4, Sometimes: 12)
3	Have you heard about home energy manager before? (Yes: 27, No: 33)
4	Would you like to live in a house with home energy manager? (Yes: 40, No: 8, Comments: 13)

5	What will be your motivation to using home energy management system? (To save money: 15, To save environment: 28, Comments: 15)
6	Do you use energy efficient appliances or appliances with logos or stickers shown above? (Yes: 55, No: 7)
7	If you own such appliance, how do you use them? (I have customized the settings to my comfort: 17, I have changed nothing, I am using it as it is: 34, Comments: 2)
8	Were you comfortable in using those appliances? (Yes: 47, No: 0, Sometimes: 5)
9	If you do not own them yet, would you like to buy such appliances? (Yes: 5, No: 1, Comments: 1)
10	Do you have any renewable energy installed at home? (like solar panel, wind turbine) (Yes: 21, No: 39)
11	If not, would you like to install some kind of renewable source of energy? (Yes: 31, No: 3, Comments: 3)
12	What would be your motivation? (Cost savings: 3, To save the environment: 9, Both: 23, Comments: 2)
13	What kind of energy manager would you like to use? (A system which tells me how to save energy and cost (low-cost system): 25, A system which works on its own and saves energy and money (expensive system): 32)
14	What kind of user interface would you like to use? (Fixed tablet to the wall: 14, A loose tablet: 8, An app on your smartphone: 26, Comments: 9)
15	As you have a renewable source of energy installed at your home, would you like to receive information on your tablet or app about how much energy you will produce during the next day? (Yes: 34, No: 23)
16	With a renewable source of energy installed at your home, would you like to receive information on your tablet or app about when to use high energy intensive appliances like washing machine, dryer and dishwasher? (Yes: 52, No: 5)
17	Suppose your average daily energy consumption is 8kWh, would you like to get notified via tablet or app when you have used 6kWh of your daily usage? (Yes: 20, No: 38)
18	Suppose you switch on 2-3 energy intensive appliances (like oven, washing machine, dishwasher) at the same time, would you like to get notified via your tablet or app to switch off a device and switch it later on for better energy utilization? (Yes: 42, No: 16)
19	Would you like to switch on/off appliances with the help of the tablet or app directly? (Yes: 36, No: 22)
20	What kind of energy /money feedback would you like from the energy manager? (Animated-smile vs frown feedback: 1, Current vs historic feedback: 29, Both: 18, Comments: 9)
21	Would you like to compare and analyse your energy savings with your neighbours or your community? (Yes: 24, No: 32, Sometimes: 3)
22	Would you like to play games with your community for energy savings? (Yes: 13, No: 46, Sometimes: 0)
23	If you plan to buy new appliances for your house, would you like your tablet or app to give suggestions for most energy efficient product available in the market? (Yes: 39, No: 16, Comments: 4)

6. REFERENCES

[1] S. Grids, “Technology Roadmap,” *Current*, p. 52, 2011.

[2] B. Hamed, “Design & Implementation of Smart House Control Using LabVIEW,” *Int. J. Soft Comput. Eng.*, vol. 1, no. 6, pp. 98–106, 2012.

[3] S. Suryanarayanan, S. M. Ieee, R. Roche, M. Ieee, L. Earle, D. Christensen, P. Bauleo, and D. Zimmerle, “Electric Energy Management in the Smart Home : Perspectives on Enabling Technologies and Consumer Behavior,” vol. 101, no. 11, 2013.

[4] Gsma, “Vision of Smart Home: The Role of Mobile in the Home of the Future Contents,” p. 23, 2011.

[5] A. C. and R. N., “Home Energy Management System for High Power – intensive Loads,” *Emerg. Trends Electr. Electron. Instrum. Eng. An Int. J.*, vol. 1, no. 2, pp. 9–17, 2014.

[6] N. Sharma, J. Gummeson, D. Irwin, T. Zhu, and P. Shenoy, “Leveraging weather forecasts in renewable energy systems,” *Sustain. Comput. Informatics Syst.*, vol. 4, no. 3, pp. 160–171, 2014.

[7] R. H. Inman, H. T. C. Pedro, and C. F. M. Coimbra, “Solar forecasting methods for renewable energy integration,” *Prog. Energy Combust. Sci.*, vol. 39, no. 6, pp. 535–576, 2013.

[8] C. Chupong and B. Plangklang, “Forecasting power output of PV grid connected system in Thailand without using solar radiation measurement,” *Energy Procedia*, vol. 9, pp. 230–237, 2011.

[9] E. İzgi, A. Öztopal, B. Yerli, M. K. Kaymak, and A. D. Şahin, “Short–mid-term solar power prediction by using artificial neural networks,” *Sol. Energy*, vol. 86, no. 2, pp. 725–733, 2012.

[10] Ö. A. Dombayci, “The prediction of heating energy consumption in a model house by using artificial neural networks in Denizli-Turkey,” *Adv. Eng. Softw.*, vol. 41, no. 2, pp. 141–147, 2010.

[11] C. Chen, S. Duan, T. Cai, and B. Liu, “Online 24-h solar power forecasting based on weather type classification using artificial neural network,” *Sol. Energy*, vol. 85, no. 11, pp. 2856–2870, 2011.

[12] J. Wolfe, S. Butcher, C. Lee, and M. Hyle, “Changing your Mind: On the contributions of Top-Down and Bottom-up guidance in visual search for feature singletons,” *J. Exp. Psychol. Hum. Percept. Perform.*, vol. 29, no. 2, pp. 483–502, 2003.

[13] D. V. Keyson, A. Al Mahmud, M. De Hoogh, and R. Luxen, “Designing a portable and low cost home energy management toolkit,” *Procedia Comput. Sci.*, vol. 19, no. Seit, pp. 646–653, 2013.

[14] Hydro-one, “The Impact of Real-Time Feedback on Residential Electricity Consumption: The Hydro One Pilot,” *Study Summ.*, 2006.

[15] A. Zoha, A. Gluhak, M. A. Imran, and S. Rajasegarar, “Non-intrusive Load Monitoring approaches for disaggregated energy sensing: A survey,” *Sensors (Switzerland)*, vol. 12, no. 12, pp. 16838–16866, 2012.

[16] A. Grønhøj and J. Thøgersen, “Feedback on household electricity consumption: Learning and social influence processes,” *Int. J. Consum. Stud.*, vol. 35, no. 2, pp. 138–145, 2011.

[17] K. Gram-Hanssen, “Residential heat comfort practices: understanding users,” *Build. Res. Inf.*, vol. 38, no. 2, pp. 175–186, 2010.

[18] T. Hargreaves, M. Nye, and J. Burgess, “Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term,” *Energy Policy*, vol. 52, pp. 126–134, 2013.

[19] D. Geelen, A. Reinders, and D. Keyson, “Empowering the end-user in smart grids: Recommendations for the design of products and services,” *Energy Policy*, vol. 61, pp. 151–161, 2013.

[20] S. van Dam, “Smart Energy Management for Households,” no. January, p. 336, 2013.

[21] UCLA, “What is the difference between categorical, ordinal and interval variables?” [Online]. Available: http://www.ats.ucla.edu/stat/mult_pkg/whatstat/nominal_ordinal_interval.htm. [Accessed: 18-May-2015].

[22] Yatani, “hcistats:chisquare [Koji Yatani’s Course Webpage].” [Online]. Available: http://yatani.jp/teaching/doku.php?id=hcistats:chisquare#fisher_s_exact_test. [Accessed: 18-May-2015].

[23] J. G. Bennett, “Techniques for the Statistical Analysis of Observer Data"; Camouflage, Concealment and Deception Symposium; Tyson’s Corner.”

[24] K. M. Bower, “When To Use Fisher ’ s Exact Test,” in *American Society for Quality*.

[25] J. V Freeman and M. J. Campbell, “THE ANALYSIS OF CATEGORICAL DATA : FISHER ’ S EXACT TEST,” pp. 11–12.