HOMES ACROSS FIVE EUROPEAN CITIES GET PIONEERING ENERGY MANAGEMENT TOOLS

By Martine Tommis and Pukul Rana

The Digital Environment Home Energy Management System (DEHEMS) combines specifically developed hardware and software, which has helped households reduce their energy usage by an average of 8%. The system, which has been rolled out to 250 households across Manchester, Birmingham, Bristol in the UK and Plovdiv and Ivanovo in Bulgaria, measures the home's energy usage in 6 second intervals and presents this data to the end-user via in online dashboard.

The dashboard allows users to interpret their data as meaningful information. Through interaction, users are encouraged to make changes to their behaviour through recommendations and tips designed to help them become greener citizens and hopefully, save a few pennies along the way.

Figure 1 – Clamp transmitter (current transformer sensor)

The objective of DEHEMS is to integrate and test the effectiveness of persuasive strategies delivered via an intelligent electronic system infrastructure that is able to infer and reason the energy behaviour of the households. To understand a household's energy behaviour, the project uses a number of number different sensing technologies which have been placed around the home. These include (Figures 1 and 2):

- Electrical mains circuit sensing – via a clamp transmitter
- DEHEMS gateway or data collector
- Individual appliance level sensing – via appliance monitors
- Gas mains sensing – via an optical reader
- Ambient sensing such as temperature – via existing web-based solutions.

The project aims to test the effectiveness of:

- Multi modal user interfaces using a web-based dashboard as dedicated real time energy display device, which in turn is accessible via other displays such as digital photo frames and mobile phones.
- Data visualization or feedback of energy consumption via graphical information, colour coded alerts, contextual tips and alerts and emotionally engaging narrative or pictures that reflect the state of a household's energy usage, against that of its neighbourhood and DEHEMS average.
- Data interpretation: real time energy consumption, historical consumption, family member consumption, comparison against general households in DEHEMS, comparison against grouped households of similar characteristics, comparison for online social networking users and context aware personalized energy saving tips and alerts.

Led by Manchester City Council, the project consortium is made up of local authorities, private business and universities and funded by European Union's (EU) Framework 7 programme (FP7), under the theme of cooperation. The objective of ICT research under the programme is to improve the competitiveness of European industry, as well as to enable Europe to master and shape the future developments of these technologies in order that the demands of its society and economy are met.

DEHEMS uses a "living lab" or "user driven innovation" (UID) approach to development, which allows users to become part of the improving and refining process – giving the end product higher user value, in terms of understanding the benefits and proposition. Early stage user engagement is an essential characteristic when translating energy consumption data from sensors to useful information, which can be communicated via the online dashboard.

The DEHEMS Living Labs form part of an EU-wide network of test beds that enable experimentation and co-creation with real users in real world environments. The Living Labs are managed by City representatives, working alongside technical specialists from SME's Hildebrand, Clicks and Links, the University of Salford, Coventry, Rouse and Cluj-Napoca, the Institute e-Austria in Timisoara and the Energy Agency Plovdiv.

Based on Living Lab principles, DEHEMS has applied a cyclic learning and development process that undergoes stages of requirements gathering, design, implementation, deployment and behaviour assessments. The system is progressively incorporated with new influencing strategies and techniques based on the feedback from the end-user as active contributors to the learning process. The stages of the project can be broken down into three cycles:

- Cycle 1 where user requirements are gathered by understanding the different facets of the users' "wants" in terms of technical and usability and "challenges" faced when the technology is deployed within homes.

Figure 2 – Data collector

- Cycle 2 focuses on testing the effectiveness of the different feedback strategies, from simple display web pages to interactive graphs and contextual tips. A limited number of homes were provided with plug level monitoring of electricity.
- Cycle 3 centres on integrating new ideas for user interface design and combining this with the most effective feedback and behaviour change strategies. Thirty users were invited to participate in gas metering.

To help develop genuine user insight, which in turn forms an integral part of the DEHEMS learning process, a number of online surveys and focus groups have been conducted with the participants across the Living Labs. One of the Manchester project volunteers described her involvement: "I think I am doing things better. I think I'm looking at some of the appliances in my house which I would not ordinarily look at because I notice them on screen and if you didn't have something to see then you wouldn't be able to do something about it." When she turns the kettle on, she can see how much energy she is consuming and what it costs. "I think it has been the easiest technology anybody could use. I will definitely carry on using it, and I hope the project will allow me to keep some of it, but if not, then I think I will go out and buy myself some equipment."

The basic DEHEMS metering equipment consists of a gateway or data collector, current transformer and Ethernet cable. The current transformer sensor is coupled to a 433 MHz FM radio modem and clamped around the electricity mains circuit. The gateway, or data collector, comprises a data collection mechanism and data aggregation function for processing data received from the sensors. An external communication module uses TCP/IP to communicate with the DEHEMS server via the in-home broadband router. All data received by the gateway is forwarded to the web service and attributed to the household at the server.

Figure 3 – Plugwise unit at the socket

Units were installed in 250 homes across the five Living Labs. There were significant differences encountered between installations in Bulgaria and the UK. In Bulgaria, electricity meters are often in locked cabinets which are accessible only by the electricity supply company and installations in Bulgaria have often required electrical skills.

To provide appliance level monitoring the project looked at both powerline and wireless-based network solutions. For pragmatic and technical reasons, the wireless sensor network solution commercial solution by a Dutch company, Plugwise was selected (Figure 3). They have a smart plug product which is sited between the outlet and the plug of the appliance, using the 2.4 GHz ZigBee standard. The plug measures the energy consumption and transmits the data wirelessly. A ZigBee USB data stick acts as a data sink for the wireless sensor network and receives data from the plug level meters. Software was developed in DEHEMS to interface this to the data collector. The received data is packaged and sent to the DEHEMS server where it is further processed and reported back to the user via the dashboard.

Figure 4 – Gas metering test bed

Gas monitoring presented a different challenge with the complication of a more hazardous environment and a lack of products on the market. The approach was to seek a solution using techniques not requiring an interference with existing gas installations. Sensing is difficult because the retrofit of flow meters is complex and requires expensive equipment. DEHEMS found that the best method was to use an optical character recognition (OCR) – the Enica Xemtec Comet optical sensor. The device has a character orientated interface from where commands can be issued that trigger the sensor into transmitting a series of characters that represent the current meter reading digits (Figure 4).

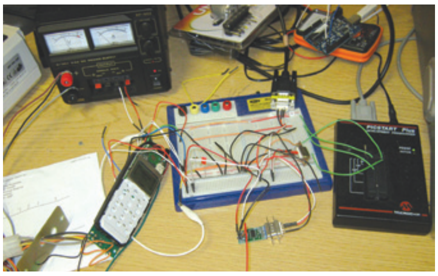

Figure 5 – Gas metering architecture

Gas metering was also a challenge for network communications. Gas meters are often external to the property so a sensor was needed that would communicate data via mobile phone (GSM) text messaging but with the ability to access a 433 MHz interface for integration with the DEHEMS data collector. The system hardware comprises a PIC16F76 based microprocessor board, serial interface, GSM communications module, program and system memory and timers. This approach allowed the team to broaden their research scope to include battery requirements, power minimization, communication protocol and the use of SMS over GPRS. This is the emerging favoured approach in the rollout of smart meters. The communications units were supplied by Salford Electronic Consultants Ltd. The solution adopted for measuring gas consumption can be extended to monitor any form of service consumption providing that usage of that service is recorded via a meter that is compatible with the OCR module (Figure 5).

The Cycle 1 DEHEMS dashboard was intentionally basic in feedback information and simple in its design. The principle of "express enough meaning but not too much" for designing interfaces for home use, as stipulated has been tested progressively throughout the three cycles. The objective is to determine "how much is too much?," to sufficiently produce positive behaviour change in domestic energy users.

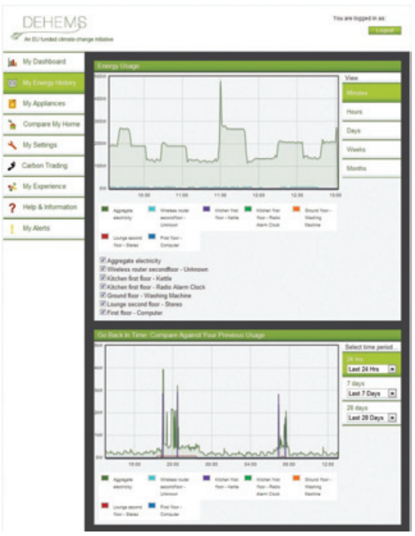

Figure 6 – DEHEMS dashboard

In the next two cycles, by extending the granularity of feedback information, the aim was to determine through analysis, information that does not contribute to behaviour change, or is simply deemed unnecessary by users. Consequently, the Cycle 1 DEHEMS dashboard displayed real time energy usage in kW, cost of energy usage, energy saving tips, energy usage history (hourly, daily, monthly), along with a comparison against DEHEMS-wide average energy usage (Figure 6).

The main project results to date focus on the second cycle of the project, a 12-week period. A full report is available at http://www.dehems.eu/cms/wp-content/uploads/2009/10/Dehems-Deliverable-D7.6.pdf. The third and last cycle is due to be analyzed by July this year. The initial results suggest that the system enables around 8% daily energy saving in the first week of feedback. Not surprisingly the key motivation for people is saving energy for financial reasons, followed closely by environmental concerns, suggesting that to be truly effective in terms of satisfying various motivations, cost information is important.

The top behaviour changes were reported as switching off appliances instead of using standby power; an increased awareness of energy usage of appliances and optimised appliance settings; the reduced use of appliances electric heaters; purchasing new energy efficient appliances to replace those which are inefficient; influencing family members to be more energy conscious and an increased awareness of their household activities and routines. Users also have spoken of an overall increase in gas and other energy usage awareness along with a growing "carbon consciousness". DEHEMS participants have described how they have shared their experiences with family and friends, spreading a positive message about energy saving.

As part of developing extending usability, the team developed a Facebook app. With the increase in global user base for online social networking, it could be surmised that given the right tools, online social norms can become a powerful mechanism for wide-scale energy awareness. Extending the model further, the project has experimented with a "carbon incentives model" where teams have been created in the five Living Labs. The personal carbon trading trial has provided incentives to reward energy consumption behaviour change, rewarding the team/person who achieves the greatest reduction in a carbon equivalent.

The project ends in July 2011. The research work will published on the project website along with relevant academic journals. Other initiatives have been developed on the strength of the research. Partner Hildebrand is launching a service called Energyhive. A second partner, Clicks and Links has developed their Greenica product. Manchester is continuing domestic metering work in a new EU project, European Platform for Intelligent Cities (EPIC). This will look at ways to manage energy data in a cloud computing framework. MI

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ABOUT THE ORGANIZATION:
The Manchester Digital Development Agency (MDDA) is part of the Manchester City Council, with the role to support the regeneration of the city region through the strategic and practical work of its technology-focused projects. The MDDA focuses on how digital technologies can support economic growth, regeneration, social inclusion and sustainable development, and coordinates the City region Digital Strategy.
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