Co-design of a technological solution for the promotion of eco-responsible behaviors in family homes

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ABSTRACT

The design of energy awareness solutions for the residential sector is a popular topic within research and innovation communities, with major industrial players being active in the field; the massive roll-out of smart energy meters in several countries acting as a catalyst factor. However, the majority of existing solutions do not fully meet user requirements, thereby compromising their efficiency on the long term. A wider analysis is required, involving service designers, social sciences, contextual factors, and usability research. The aim of the ECOFAMILIES project presented in this article was to co-design with French families an innovative technological solution for getting a concrete understanding of their household energy use and consumption, and the choices that are available to improve it. The participatory design protocol went through three incremental workshops organized between March and June 2012 with thirty-three volunteers, complemented by a profile questionnaire, an online blog, the use of an eye tracking system and the making of a documentary film. The research contributed to discover the real behaviors, attitudes and needs of these families when it comes to energy efficiency. A new prototype was developed alongside: it features a fully customizable interface with widgets grouped by key topics of interest.

INTRODUCTION

The residential sector accounts for one-fifth of global energy consumption, resulting from the requirements to heat, cool, and light dwellings. A large majority of households have low energy literacy and awareness in their accommodation (Brounen et al. 2013), while occupants behavior can have a significant impact on annual energy usage (Clevenger et al. 2014). Energy is hardly visible: in most households, the only way to monitor energy consumption is to watch at the energy meter or to collect bills. Neither of those are proper tools to manage energy or to understand factors or behaviors which influence consumption. Conditions are not met for empowering dwellers and allowing them to control their energy expenditures.

The design of energy awareness solutions for the residential sector is a growing topic for research and innovation communities, with key players such as Intel, Google, or Microsoft (HEMS, Power Meter, Hohm) being active, although some of those initiatives are not yet business success (Castle 2011). The latest Energy Efficiency Directive (EU 2012) from the European Commission will encourage further efforts, since it sets a right for consumers to know how much energy they consume, with a plausible impact on the supplier-customer relationship (Smithers and Wood 2010).

A benchmarking overview of existing solutions was conducted to identify existing trends in terms of design and functionalities. 26 tools were identified and mapped within 4 categories: 'Information and Awareness': *give user access to the information*; 'Monitoring, visualizing, managing': *make the information understandable and interactive to the user*, 'Engagement': *How to keep the user acting*, and 'Make the energy physical': *integrate unobtrusive information in the user's daily life* (Visciola et al. 2012). A report to the UK Energy Saving Trust (Anderson and White 2009) concluded that the majority of home energy displays currently on the market do not have the functionality that consumers identify, in practice, as being critical to display design. A Dutch study (Van Dam et al. 2010) exhibits unstable results about the impact at middle-term of the first devices and systems available on this market of energy consumptions display (HEMS - Home Energy Monitoring/Management System) for the consumers. It concludes that for HEMS to be effective, a deeper understanding is needed that embraces social science, contextual factors, usability, and interaction design research.

The ECOFAMILIES project was initiated in this context, and proposed to prototype an innovative technological solution to promote energy-aware behaviors at home, with the users being at a central stand through a participatory design approach with a panel of voluntary families. The overall objective set for the solution was to provide users with appropriate information, at the right time and with adequate style, which would allow them to identify energy consuming processes and to take educated decisions to reduce their consumption. The project ran from November 1st, 2011 to December 1st, 2012. The multidisciplinary research team gathered experts in buildings, construction, energy, ICT, academic researchers focused on behavior analysis, as well as interaction and graphic designers.

CO-DESIGN RESEARCH PROTOCOL

When designing a service in a complex system to support consumers in making a significant behavioral shift, participatory design practices can generate significant benefits (Charlier and Henri 2007). The involvement of the system stakeholders and of the community of final users within the solution-seeking process guarantees interest and feasibility from the business perspective and ensures people that their opinions and feedback are considered in the development. Moreover, participatory processes can also encourage buy-in to the ideas and values of the project, both by service providers, clients and end users of the system, who invest in the solution as they get involved in its creation. To address the complexity of behavioral change and energy management, a broad, multi-faceted approach is needed. Home energy consumption should be considered as a part of general domestic management and of the entire daily energy needed to support lifestyles inside and outside the home. To develop this level of comprehensive understanding, the user research was structured into two layers of analysis: the private sphere and the public sphere (Visciola et al. 2012). The private sphere explored the user's personal attitudes and behaviors in relation to the household. Moving to a broader perspective, the public sphere focused on the patterns and behaviors that define users and their families in relationship with the values, reference points and rules of their own community: previous research addressed the importance of considering collective impact (Chetty et al. 2008), and investigated the potential use of social networks for conservation (Gulbinas et al. 2012). Insights and opportunity areas coming from this analysis enabled researchers to gain deeper knowledge of what drives behavioral change and an understanding of the most critical barriers.

An open call for participation was published in December 2011 to recruit French families living in Region PACA around Nice and Antibes areas. 33 participants were selected covering a good variety of ages (26-40: 40%; 41-55: 45%; 56-65: 5%; 65+: 10%) and occupations, ranging from students to retired persons. Among represented socioprofessional categories, 35% of the participants belonged to the upper classes. The panel included 62.5% of home owners, with a larger representation of 2-3 bedrooms apartments and single houses.

The user-centered research protocol (Figure 1) included:

1) A preliminary online questionnaire to categorize families' profiles, and answer preliminary questions related to energy consumption consciousness, information channels, and engagement within the community. This questionnaire was filled-in by the participants at the beginning of the research. It helped the research team to explore areas associated with both the private and the public sphere of research: awareness and practices related to domestic energy consumption, relationships inside the community, energy consumption trends and dynamics, and social collaboration initiatives. A survey was also designed and conducted in parallel for the research team members, considering the variety of their background and expertise, to ensure shared views over the project objectives and global picture.

2) Three iterative co-creation workshops were held in Nice, over a four months period from March to June 2012. Workshops were used to investigate behavioral patterns and to gather ideas, visions, experiences and design orientations from the participants. Outputs from each workshop were used to feed-in the prototype incremental design. The first workshop introduced the project and invited participants to brainstorm on the ideal tool, potentially drawing inspiration from the benchmark (Table & Figure 1) of existing solutions. The second workshop was focused on collaborative writing of use scenarios, and participants were offered the opportunity to sketch "look & feels" for the tool. Scenarios were imagined for 2 situations: a regular winter day at home; and a day before leaving home for summer vacations. The third workshop was dedicated to usability tests of the prototype, some of them using an eye tracking system for a precise analysis. By recording eye movements,

facial expressions, and interaction with the prototype, the system provided additional validation elements for both contents and design (Debos 2013).
3) A dedicated online blog, allowing a continuous interaction between the families and the project team throughout the project: the blog was used for launching short surveys / polls related to the prototype design, and for regularly publishing updates about the project as well as the outcomes and photos from the co-design workshops. Families were offered the possibility to comment and react to any article on the blog.
4) A documentary film was recorded during the project: the objective was to capture families' involvement in the co-design process, and to examine their perception of their role and involvement within this particular project. The film shows the incremental expertise gained by the participants from one workshop to another.
A final workshop was organized in October 2012 in Sophia Antipolis, to expose to the families the final prototype resulting from their proposals and to present the documentary film. This final event acted the co-design process wrap up. It was also a way of pursuing discussions with the families (Cyrulnik 2012). Through the participatory process, service developers acquired useful information to help them deliver solutions that reflect the community's shared values and leverage evident behaviors as well as promising nuances that emerged from the user research.

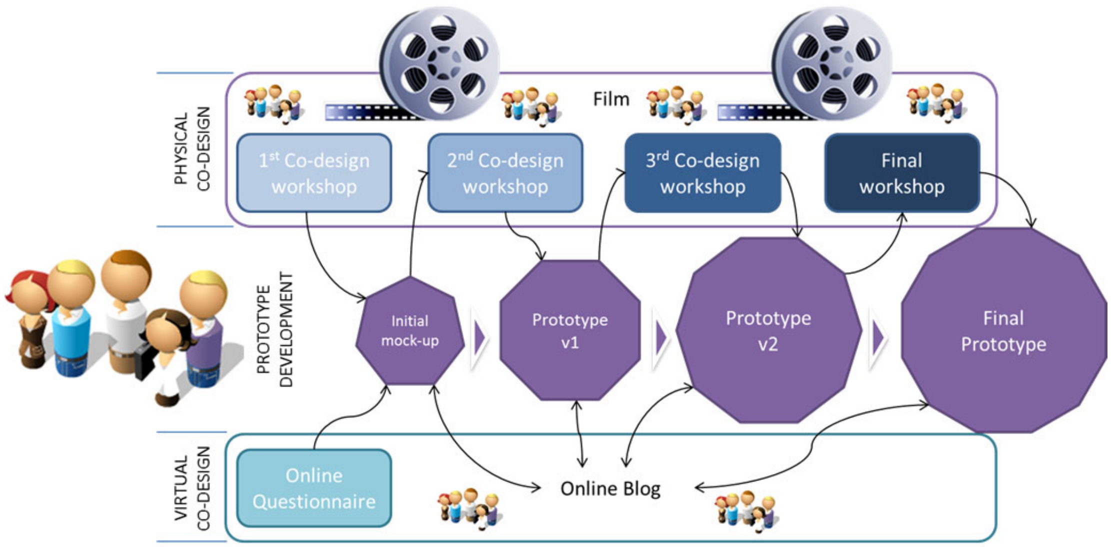

Figure 1. ECOFAMILIES user-centered research protocol

RESULTS

The main challenge of the project was the design of a responsive and flexible system to better manage domestic energy consumption, in order to increase people's quality of life while decreasing their consumption. Designing to decrease energy consumption implies behavioral change, but this shift cannot be forced. Tools must enable people to make conscious and informed daily decisions and then successfully integrate them into their life contexts. The questionnaire and the first workshop contributed to better understand the basic needs of the families, thereby offering guidance for the global design and content for the solution. A set of main findings came out:

1) Traditional energy meters and energy bills are not satisfactory for an actual energy monitoring. They do not meet the families' needs because they are perceived as non-interactive, not issuing clear and complete information, and unattractive.
2) Elaborated "design objects" - e.g. Flower-lamp (Interactive Institute 2010) - are appealing but are considered inadequate in terms of information and interactivity.
3) Dedicated tools which are built-in physical devices are judged rather negatively. Families don't want to buy a new "gadget" and consider they will not use it on a long-term basis. Most participants prefer a tool they can access through digital devices (computer, smartphone, tablet, etc.) that they already own.
4) Web interfaces are enjoyed by a majority of participants because of the simplicity to watch data from any digital device, and from anywhere: at home but also outside.
5) Regardless of the device, information must be rendered in a clear, attractive and accessible form. The tool must be simple, both in terms of usage and visual aspect.
6) The tool must adapt to each accommodation, thus being easily programmable, configurable and customizable by the user. Databases of energy conservation suggestions and tips are evaluated as an interesting feature, and are even more appreciated when information is tailored to household and family profiles.
7) A warning/alert notification system is required by all participants. Consumers want to be alerted (for instance through a colored visual notification, or a text message on their phone) when problems might occur. The need is even more significant when they are absent from their home (at work, during holidays, etc.). Those notifications act as incentives which should drive higher engagement with tool (Jain et al. 2012).

Design complexity relies on the ambition to change behaviors at an individual level, involving broader influencers, such as shared community values. Shaping this community of values is one of the areas where the participatory design approach revealed its strengths, with the possibility to gather multiple points of view, create early forms of consensus and identify a wide range of opportunity spaces in which to develop the solution. The research highlighted the skepticism of the users towards a new dedicated device and identified the need for a high level of flexibility within the service. The possibility of access from different devices with different screen sizes emerged as fundamental in enabling all the users belonging to the household to have access to the platform in a wide range of situations. Customization of information was another crucial feature to promote a more intimate bond with the tool, in line with the findings from (Ai He et al. 2010) which stated that "one-size-fits-all" solutions, providing the same feedback to differently motivated individuals, are inappropriate. Both these design directions foster higher use by a wide range of people across multiple contexts. Finally, in order to go beyond a tool that would appeal only to "green-geek" users, the platform takes a holistic lifestyle approach. Incorporating information about home issues and transportation transforms the tool into a hub of customized information for the domestic and urban environment. This leads to an open approach to community-oriented services like purchase pools, car-sharing and other neighborhood-level services, and increases the value and the interest of the service. The user research results drove the design of the ECOFAMILIES prototype and ended with the release of the first design concept. Based on the design concept, a first interactive prototype was developed, making interactive some of the features available in the initial design. The findings elicited during both the usability test and the discussions with the families at the third workshop were analyzed and some of them were implemented in the final version of the prototype. The final prototype also includes examples of real-time data coming from a pilot house. The initial design concept was received with mixed feelings by the families. Positive appreciations then gradually increased at the next iterations and with the design progress. Priority was given to a web-based user interface accessible from a computer, while anticipating its adaptation to other kinds of devices (tablet, Smartphone, etc.). When launched for the first time, users have to configure their dwelling and family profile. Default values are used when not filled-in by users. Once completed, the main page (Figure 2) is displayed and can be entirely personalized. Secondary pages offer: energy flows monitoring (heating/cooling, electricity, water); alerts; advices and tips; and a brokering service to compare different offers from energy providers.

Figure 2. ECOFAMILIES final prototype - Main page
(Additional screenshots at http://www.flickr.com/photos/ecofamilies)

The highlights of the final design, which address some of the most important requirements gathered during the participatory design process, include:

1) A **widget-based design**: the interface is highly customizable and configurable thanks to a design based on "widgets". Widgets offer a wide range of services and functionalities such as e.g. monthly energy spending overview, home indoor climate, grid network load, weather forecast, local bus timetable, nearby urban bikes availability, etc. Users can select according to their interests in a "Widget store" what they want to see displayed, especially on the home page. This approach offers interesting perspectives in terms of scalability, as it permits the development and integration of future "Widgets" according to new emerging consumer needs. Widgets

can be minimized, maximized and moved. This flexible concept is close to the way apps can be organized on a smartphone, or to the Google home page customization.
2) **Energy coach**: a dedicated section allows selecting advices & tips for improving energy efficiency. Tips are classified into categories (e.g. home refurbishment, behaviors, community initiatives, etc.) and users can weight their interests with scrollbars. Every tip is associated to a potential monthly saving potential, customized according to the family and household profile. Users can select tips and convert them as objectives in to-do list widget. Potential monthly savings of the total selection are cumulated. The interface acts as an energy coach, encouraging users to implement energy saving measures. This engagement concept is close to those used by virtual coaches for runners (e.g. Runkeeper, Nike+ Running, etc.).
3) **Notification add-ons for external integration**: complementary add-ons offer a simple and intuitive access to the alerts and notifications generated by the tool. They encourage the user to connect to the main interface. Those messages are integrated as sleep mode displays, or directly into the native operating system of any digital device, for instance in the notification panel of mobile devices. ECOFAMILIES messages appear at the forefront next to emails or other social networks notifications.

CONCLUSION

A methodology for co-designing energy awareness solutions for homes was proposed. Needs from a panel of French families were collected and assessed. A prototype with a fully customizable design based on widgets was developed. The comprehensive involvement of the families in the design process showed their growing expertise and interest for energy efficiency. At the final workshop, all participants expressed their interest to experiment the final prototype in real-life conditions in their dwellings. Some envisaged functionalities are a bit ahead of their time since they require smart building technologies which are not yet wide-spread in dwellings. Although based on a quantitative research, it is expected that the findings from the participatory design workshops and the prototype' innovative concepts will contribute to inform future developments of energy awareness solutions.

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Full reports (in French) from the workshops and a DVD copy of the ECOFAMILIES documentary film are available on request at ecofamilies@cstb.fr.

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