Embedding IoT in Large-scale Socio-technical Systems: A Community-Oriented Design in Future Smart Grids

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Abstract In traditional engineering, technologies are viewed as the central piece of the engineering design, where the physical world consists of a large number of diverse technological artifacts. The real world, however, also comprises a huge amount of social components – people, communities, institutions, regulations and everything that exists in the human mind – that have shaped and been shaped by the technical components. Smart urban ecosystems are examples of such large-scale socio-technical systems that rely on technologies, particularly IoT, within a complex social context where the technologies are embedded. Despite that the two aspects are deeply intertwined, designing applications that embed IoT in large-scale socio-technical systems is slowly transitioning from a traditional engineering approach towards a socio-technical approach. The latter has not yet entered the mainstream of design practice. In this chapter, we present our experience of adopting a socio-technical approach in designing a community-oriented smart grid user application. The challenges, implications and lessons learned are discussed. The chapter is concluded by offering a set of good design principles derived from this experience, which are also relevant to the design of other smart urban ecosystems.

1 Introduction

The traditional science and engineering philosophy is dominated by technological determinism, the idea that technology determines societal development [21, 28, 33]. Within this reductionist view, technologies are the central piece of the engineering design, where the physical world consists of a large number of diverse technological

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artifacts. The plausibility of this view is challenged by the socio-technical systems view [37] which argues that technological and social development form a "seamless web" where there is no room for technological determinism or the autonomy of technological systems [12]. The latter view is premised on the interdependent and deeply linked relationships among the features of technological artifacts or systems and social systems (i.e. the mutual constitution) [28], since the man-made world also comprises a huge amount of social components – people, communities, institutions, regulations, policies and everything that exists in the human mind – that have shaped and been shaped by the technological components [14, 37]. Engineering design is hence identified as a process through which technologies materialize into products, a process that substantively shapes and reshapes our lives and societies and vice versa [18]. This focus on socio-technical interconnectedness becomes even more visible in designing new emerging technologies [18].

Smart cities, for example, use technologies such as Internet-of-Things (IoT) within a large complex social context where they are embedded. The goal is to facilitate the coordination of fragmented urban sub-systems and to improve urban life experience [13]. The rise of the IoT has important socio-technical implications for people, organizations and society – it is obvious that connecting devices is possible, we yet know little about its implications [30]. A socio-technical perspective can be insightful when looking at dynamic technological development and when considering sustainable development [30]. Although socio-technical systems have been studied for decades, socio-technical approaches are relative new to the design and systems engineering communities [1, 23, 28]. Such approaches are not widely practised despite growing interests [1].

Through this chapter, we review the literature and present our experience of adopting a socio-technical approach in designing a community-oriented smart grid user application. We discuss the challenges, implications and lessons learned from this design experience, and conclude the chapter by offering a set of good design principles which are also relevant to the design of other smart urban ecosystems.

2 Designing in Large-scale Socio-technical Systems

The term "socio-technical" embodies both a research perspective and a subject matter [19]. The socio-technical systems view can be articulated as the recognition of three fundamental concepts [28] as follows. First, the *mutual constitution of people and technologies*. This mutual constitution generates complex and dynamic interactions among technological capacities, social norms, histories, situated context, human choices and actions, etc. Second, the *contextual embeddedness of the mutuality*, where the context is not taken as fixed or delineable. There are dynamic situational and temporal conditions that influence mutual adaptations throughout the course of design, development, deployment and uses of the system of interest. Third, the *importance of collective action*, the joint pursuit of one or more shared (potentially conflicting) goals by two or more interested parties such as problem owners, shareholders, users, communities affected (without implying positive or negative outcomes). The collective action shapes and is shaped by both the context and the technological components.

Researchers who hold a socio-technical systems view investigate more than just the technological system or just the social system or even the two side by side, but also the phenomena that emerge when the two interact [19]. A socio-technical approach tries to abstain from oversimplifications that seek a single or dominant cause of change, but studies the complexity, dynamic and uncertainty in the networks of institution, people and technological artifacts in the process of technologically involved change [28]. Taking a socio-technical approach towards design has a number of implications for (i) the formulation of the design problem, (ii) the products of the design process, and (iii) the design process itself (BootCamp, BC?).

Then the section proceeds with discussing the three implications (1) making relation to the three fundamental concepts (2) using the literature mentioned (can be expanded) in the next grey box

Understanding and formulation of the design problem or situation The understanding and formulation of the design problem

It is not straightforward what needs to be taken into consideration in relation to the design. What systems boundaries to choose. the question of systems boundaries is an issue for technical systems and even becomes more difficult for social technical systems what are the issues to be addressed.[BC]

Ill-structured problem

Products of the design process these not only consists of technological artifacts but also may include rules for behaviour, policies, etc. through which the designer wish to intervene in social-technical systems. what is it that we are designing?

Design process The design process can be seen as a decision-making process where the problem owners, shareholders, users, etc. participate to represent their interests. It is often conceived and implemented in participatory decision-making processes actively involving stakeholders

Large-scale socio-technical systems are often not designed as a whole but incrementally "piece by piece" evolving from legacy systems (BC). Designers are therefore working *in* the context of some socio-technical system with the intention of changing or improving some part of that system [BC]. This means that what matters more in the design is the design process itself, more than the "final status" of the system [30, **?**] because the socio-technical system keeps evolving and exhibits emergent behaviour [22]. An important goal of the design process is to make the design (a product or system) relevant to the evolving context [30, **?**] as social and technical artifacts exist within their socio-technical context [BC].

can be put in the discussion: acontextual and detemporalized perspective approaches , general solution ., is self-limiting focus on situating work and seek to examine all contextual factors , this types of inquiry attempt to construct a holistic view of context: one that does not diminish or remove contextual elements, even those with limited influence. paying little attention to the environment of the organization and temporal dimension of technological innovation [28]

Use and combine content in: (the literature can be connected, e.g. problems mentioned in Norman and Baxter can be mapped to the four layers in Whitworth)

1. [23] (design problems in large-scale socio-technical systems) and
2. [1] (socio-technical approach to systems engineering)
3. [40] (four system levels of Socio-tehnical systems);
4. [30] (a very good article about IoT, socio-technical perspective)
5. see also https://medium.com/rettigs-notes/notes-on-sociotechnical-systems-design-178f161bc9e8

3 CIVIS: A Community-Oriented Design in Future Smart Grids

Discuss the CIVIS project making relation to the previous theory section.

The discussion shall not be limited to the app YouPower, but also the other efforts made around it (if they are related to the discussions in the previous section), e.g. the user stories, focus groups workshops, interviews, participatory budgeting, etc.

Use the YouPower paper as much as possible.

3.1 Understanding and Formulation of the Design Situation

[note by GP] Giacomo can write this part. To be expanded/integrated by all.

It will focus on CIVIS project by outlining its foundations (as fp7 R&I project) and approach (interaction with local stakeholders + incremental design & development of platform architecture). It will describe the inital, explicit objectives (+ simple rationale/roadmapp to achieve them) and it will provide an overview of the local contexts (from social, technical and energy point of view), in order to make clearer who are the involved stakeholders and their context.

Since more than two decades the ongoing and long-term energy transition shifted the energy domain towards decentralization, distributed production and renewable sources [26, 34]. Several general and intertwined aspects contribute to this transition: (*i*) the awareness of the inherent complexities that exist among energy systems, societies and the environment [3, 36]; (*ii*) the widespread diffusion of new, enhanced technologies and their hybridization with contemporary ICTs [25, 29]; (*iii*) the pursuit of national and supranational energy policies around energy efficiency, sustainability and low carbon emissions [7]; and (*iv*) the emergence of new actors in the energy value chain, such as energy cooperatives and energy communities [38], or the transformation of old ones, such as housing associations, and amateur energy managers [15].

CIVIS work took place under European Unions interest to foster energy transition by tackling the so called societal challenge of efficient energy. The vision of smart grids and the use of ICTs were the main drivers for the project's ambition to reconfigure the relationships among traditional and emerging actors in the energy value chain – *i.e.* distributors, producers, retailers and prosumers, cooperatives. In particular, CIVIS was a three year, EU project[1] funded under the *FP7 Smart Cities* framework, that pursued the design, prototyping and real-life testing of a platform for the improvement of energy behaviours in the domestic sector. The project was structured around three main areas of interest – *i.e.* energy, ICT, and social innovation – and organized into three broad phases that roughly overlapped with the project years and that ensured a close interaction with the local realities and contexts of the pilots: (*i*) an exploratory phase, used to align CIVIS overarching objectives with the local contexts needs; (*ii*) a prototyping one, which concerned the actual design and development of the platform (from data monitoring devices to the front-end applications); and (*iii*) a final testing phase which included the full scale deployment of the platform in the pilots for usage and assessment purposes.

Concretely, CIVIS' platform goals were to increase energy awareness, by making energy behaviours more visible, to promote environmental and social values, to increase citizens' know-how about sustainable consumption, and to help them in improving energy behaviours in their everyday life and together with local communities.

These interests built upon existing research and emerging trends. For instance, research topics linking the potential of Social Networks (SNs) with that of smart

[1] http://cordis.europa.eu/project/rcn/110429_en.html

grid applications have caught great attention in recent years, following the success of several popular platforms [2, 5, 10, 11, 17]. Some conducted surveys to understand user needs for energy services combining SNs [31]. Some studied connecting smart meters (or smart homes) for energy management and sharing [6, 35]. Simulation models are developed to study value-added web services [8, 20, 4] and to demonstrate the feasibility of coordination in meeting energy targets [41, 32]. Finally, works that visualize smart meter and appliance-level consumption data to enable comparative feedback among households are also increasing [24, 39, 9].

However, we also wanted the overarching purpose, the underlying infrastructure and the core features of **CIVIS Platform** *[how do we refer to it? as platform or as STS?]* to be able to integrate into rather different contexts, to meet diverse needs and expectations as well as to serve various types of user. This is why, in CIVIS, the pilot sites were understood more as sources of collaborative design and development, rather than just as possive recipients of a technology to be tested.

Italy and Sweden hosted two pilots each. In the former, the work focused on cooperative owned electricity provision. In the latter, it concerned housing cooperative's energy management in apartment buildings. In brief, the two municipalities of Storo and San Lorenzo, in Trentino Alto-Adige (a region in north-west Italy), included the Italian pilots. Here, two electric cooperatives, producing and selling 100% renewable energy to their associate members, together with two samples of recruited associate member households acted as the main stakeholders. The regional distribution system operator (DSO), the institutional representatives of the two municipalities and two local cultural associations participated as stakeholders in various phases of the project, by providing knowledge and support for technical aspects related to energy and households engagement. Similarly, the area of Stockholm hosted the two Swedish pilots. One involved the residential and central neighbourhood of Hammarby Sjöstad, which included apartment buildings owned by housing cooperatives[2]. Recruited households from the cooperatives and cooperatives' board members acted as key stakeholders here. ***[NOTE: Do we want to include Fardala?]*** The other pilot concerned a townhouse area in the outskirts of Stockholm: Fårdala. In this townhouse area the local residents association and some of its member households participated to CIVIS.

Ultimately, and at the general level, the design problem areas converged on two different sets of problems depending on the two countries. In Italy, the platform should integrate into energy communities to support efforts of demand-side management[3]. In Sweden, should have supported knowledge sharing about energy management practices at building and apartment levels.

[2] In Sweden, those who buy a home officially own the right to inhabit the estate and must join a corresponding *housing cooperative* that owns and maintains the estates. The members of a cooperative annually elect a board that makes energy related decisions on behalf of the members.

[3] *E.g.* Moving peaks of electricity demand, towards peaks of local energy production or, in other words, improving the self-consumption capabilities of the electric cooperatives and their associate members

3.2 Design Process (or participatory design?)

[note by GP] Giacomo can write most of this part.

3.3 Products of the Design Process

[note by GP] Do we include here the main outputs only (I would suggest yes), or also the intermediate artifacts (mockups, user stories, etc...) of the process?

3.3.1 YouPower

[IMPORTANT] THIS IS JUST A PLACEHOLDER COPIED&PASTED FROM CONF PAPER. *IT NEEDS ADJUSTMENT*

Given time and resource constraints, the YouPower app can not be developed all-in-one cross-platform (for phones, tablets and computers). We chose to design the front-end as a hybrid mobile phone app, i.e. its UI design has layouts that suit phone screens, since mobile apps can be more easily transformed to web browser versions, while the reverse is more difficult. The back-end of the YouPower platform will remain mostly the same independent of the front-end alternatives.

Housing Cooperatives

This part of the YouPower app is designed for the community of housing cooperatives (*Bostadsrättsförening* or *Brf* in Swedish) in the Stockholm test site [16]. Similar housing ownership and management models exist in a number of EU and non-EU countries, which allow potential wider application of the design. A housing cooperative annually elects a board which manages cooperative properties and decides on energy contracts, maintains energy systems, and proposes investments in energy efficient technologies. Since board members are volunteers who may have limited knowledge of energy or building management, this part of the app aims to support board members in energy management, in particular energy reduction actions. Cooperative members can also use the app to follow energy decisions and works of the cooperative. Additionally, the app can be of interest by building management companies working with housing cooperatives. The information presented in the app is visible for these user groups and shared between housing cooperatives. This openness of energy data is key to facilitating users in sharing experiences relevant for taking energy reduction actions.

Linking energy data to energy reduction actions

The design links energy data with energy reduction actions taken (Figure 1), both at cooperative levels, making the impact of energy actions visible to users. The energy use is divided into heating & hot water (from district heating), and facilities electricity (in apartment buildings). Users can switch between the views per month or per year to show overall changes. Users with editing rights, typically board

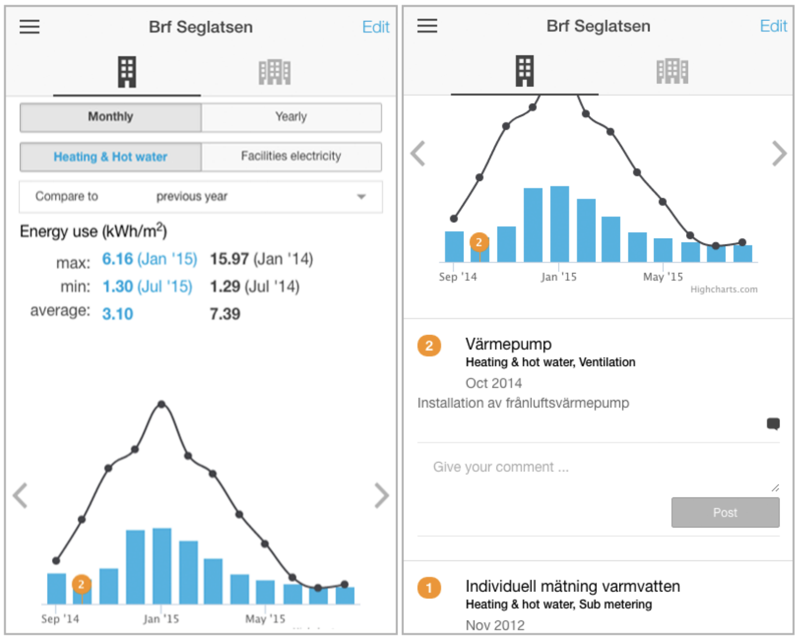

Fig. 1 Heasting & hot water use graph. Blue bars show the current year's use per month; the black line shows that of previous year. Energy reduction actions taken are mapped to the time of action and listed below.

members, can add energy reduction actions that the cooperative has taken, e.g., improvement of ventilation, lighting or heating systems, and the related cost. Trusted energy or building management companies can also get editing rights to add energy reduction actions they took on behalf of the cooperative. Added actions appear at the month when each action was taken and are listed below the graph. When clicking on an action in the list, the details of the action are shown. To make the impact of actions visible, users can compare the energy use of the viewed months to that of a previous year. This can be used e.g. by a cooperative to explore what energy reduction actions to take in the future by learning actions taken by other cooperatives and what the effects were in relation to costs.

Comparing housing cooperatives

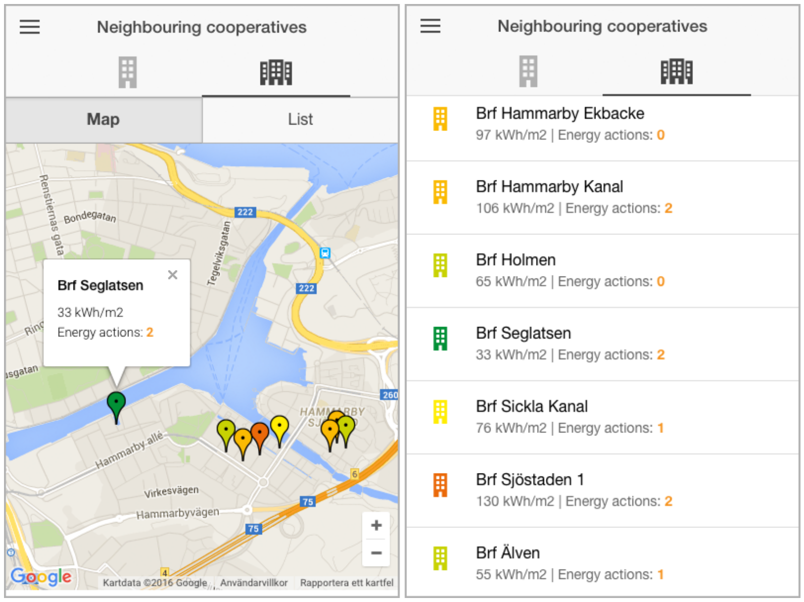

Fig. 2 Map and list view of participating housing cooperatives. The energy performance of cooperatives is indicated by colour and in numbers.

The cooperatives that are registered for the app are displayed in a map or list view (Figure 2). Their icons are color coded (from red to green) based on each cooperative's energy performance, i.e. from high to low energy use per heated area, scaled according to the Swedish energy declaration for buildings[4]. Users can also see the energy performance as a number (in kWh/m^2), and the information about energy reduction actions of the cooperatives. During stakeholder studies, energy managers in cooperative boards stressed the importance of knowing the difference between cooperatives in order to understand the difference in their energy performance. Thus, the design also includes information about cooperatives (Figure 3) such as the number of apartments and heated areas in a cooperative, a building's construction year, and types of ventilations (e.g. with or without heat recovery). Users can compare a cooperative's energy use per month or per year to another cooperative or to the neighborhood average. The electricity use is also displayed per area (kWh/m^2) to make it comparable.

Sharing experiences

A cooperative interested in taking an action may wish to know more, e.g. which contractor was chosen for an investment and why or how to get buy-in from cooperative members. The design provides commenting functions for each action added, where users can post questions and exchange experiences. The cooperatives can

4 http://www.boverket.se/sv/byggande/energideklaration/energideklarationens-innehall-och-sammanfattning/sammanfattningen-med-energiklasser/energiklasser-fran-ag/

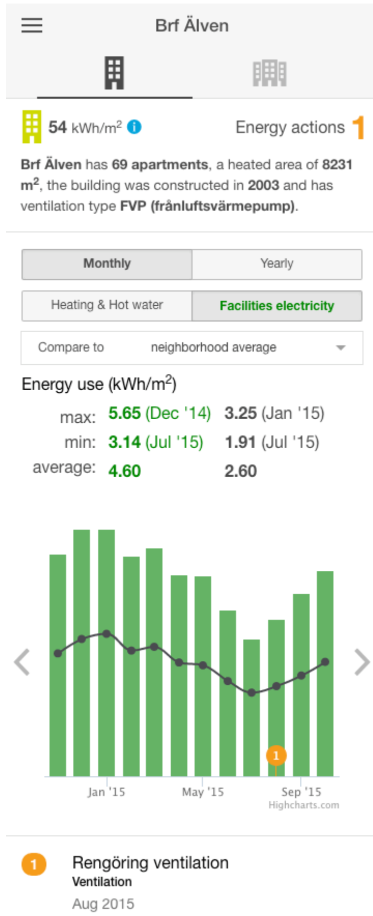

Fig. 3 Facilities electricity use graph. Information about housing cooperatives and actions is displayed at the top. Green bars show the housing cooperative's current year's use per month; the black line shows the average use of all housing cooperatives

also add email addresses of their contact persons, which are visible on each cooperative's app page. Sharing experiences certainly also happens outside of the digital world, e.g. during meetings of cooperative boards or with local energy networks. The app aims to support discussions and knowledge exchange also in such situations, where someone can easily demonstrate the impact of an energy investment with smart phones.

Demand-Side Management

This part of the YouPower app is designed for the Trento test site and can have wider application. It provides users historical and quasi real-time consumption and production information, and facilitates users to leverage load elasticity in order to maximize self-consumption of rooftop PV productions. Energy data is displayed at appliances (if smart plugs are installed), household, and electricity consortia levels. Consumption at the appliance level enables users to gain deeper understanding of their daily actions and the resulting energy use. Historical and current consumption and production at the household level allow users to compare those two and potentially maximize self-consumption. Aggregated and average consumption at the consortia level informs users of neighborhood energy consumption and allows comparisons. In addition, dynamic Time-of-Use (ToU) signals are displayed to assist users in load shifting during their daily actions.

Historical and quasi real-time consumption and production

At the household level, electricity consumption and PV production levels (in W and Wh) are displayed in quasi real-time and updated for the latest six minutes[5]. This information can also be displayed as a bar chart for a chosen period (in the past) to provide an aggregated daily overview of consumption vs. production (Figure 4). When smart plugs are installed, users can view the daily electricity consumption (in Wh) of the corresponding connected appliances of their own household for a chosen period (Figure 5 a). This helps them to gain better insights into the individual appliance's consumption level and its daily or seasonal patterns. With the aggregated energy data provided by the two local electricity consortia, users can also compare their own households' hourly consumption profiles over a chosen day to the averages and totals of the consortia to gain a sense of their relative performance compared to their peers (Figure 5 b).

Dynamic ToU signals

Dynamic ToU signals are provided to facilitate users' self-consumption of local PV productions. They give clear indications to encourage or discourage electricity consumption at a certain moment based on the forecasted local renewable production level calculated with open weather forecast information (in particular solar radiation data) and the local rooftop PV production capacity. The signals are at 3-hour intervals for the forthcoming 30 hours (Figure 6 a), and are updated every 24 hours. A green smiley face signals a time slot suitable for self-consumption where the forecasted local PV production exceeds the current local consumption, while an orange frown face signals otherwise. On a weekly basis, users get a summary of the proportion of their own household consumption that took place under green or orange ToU signals to allow them to reflect on their levels of self-consumption (Figure 6 b). The same information is also provided at the consortia level to enable peer comparison.

[5] For technical reasons such as households' data transfer connections and processing time, there can be up to 2-min delay between the time of actual power measurement and the data displayed.

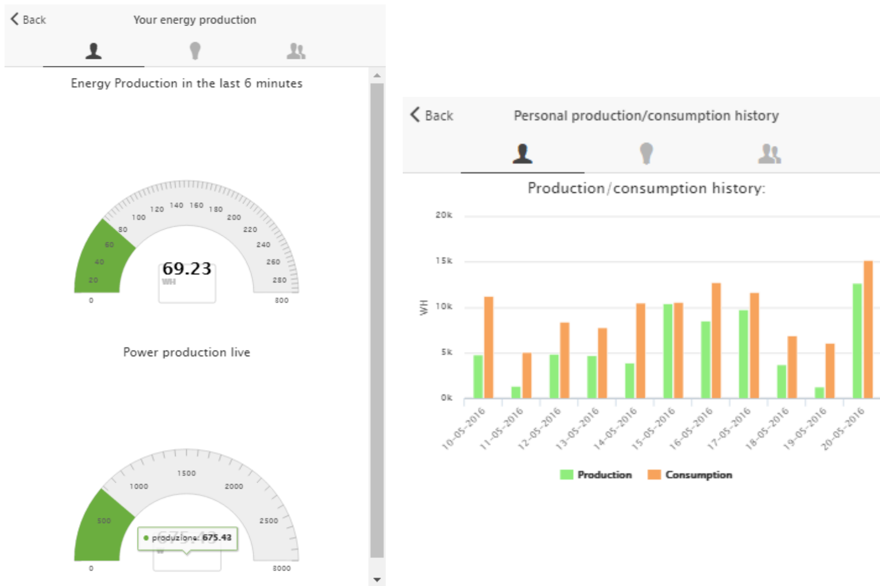

Fig. 4 (a) Quasi real-time meters for household PV production; (b) Household consumption vs. production for a chosen period

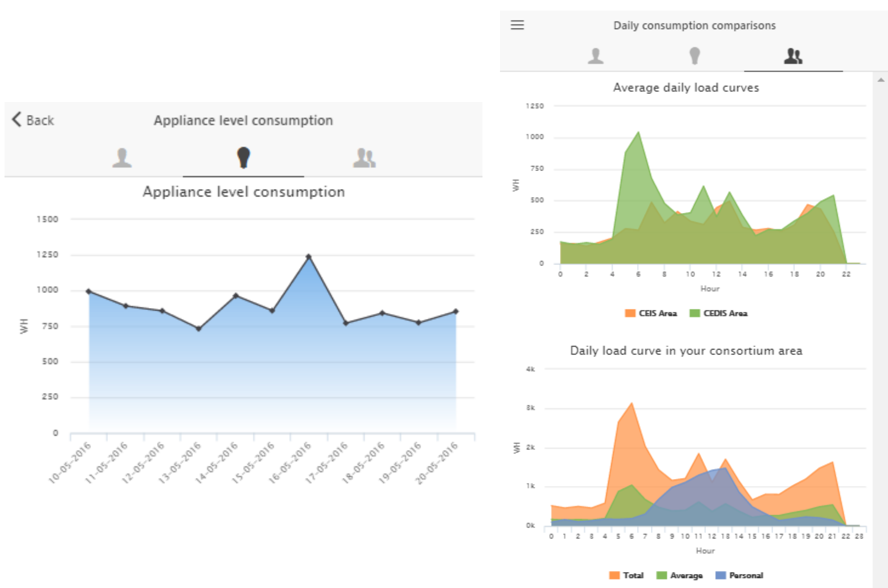

Fig. 5 (a) Daily electricity consumption at the appliance level for a chosen period; (b) A household's hourly consumption profile over a chosen day compared to the averages and totals of the consortia

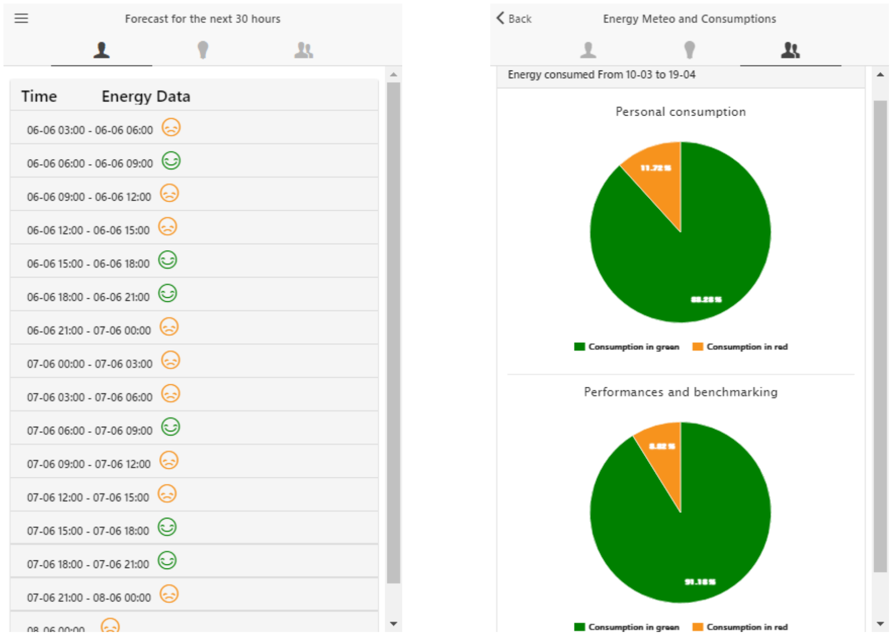

Fig. 6 (a) Dynacmie ToU signals at 3-hour intervals for the forthcoming 30 hours; (b) A household's hourly consumption profile over a chosen day compared to the averages and totals of the consortia

Action Suggestions

This part of the YouPower app aims to facilitate all household members to take part in energy conservation in their busy daily life. About fifty action suggestions are composed to provide users practical and accurate information about energy conservation. They include one-time actions such as "Use energy efficient cooktops", routine actions such as "Line dry, air dry clothes whenever you can", as well as in-between actions (reminders) such as "Defrost your fridge regularly (in x days)". Some suggestions may seem obvious and trivial, but as indicated by literature, people often has an attitude-behavior gap when it comes to environmental issues. The goal is to facilitate the behavior change process to bridge the attitude-behavior gap, making energy conservation new habits integrated in everyday household practices.

Free choice and self-monitoring of energy conservation actions

The actions are not meant as prescriptions for what users should do but to present different ideas of what they can do (and how) in household practices. Users can freely choose whether (and when) to take an action and possibly reschedule and repeat the action according to the needs and interests in their own context (Figure 7). After all, users are experts of their own reality. They also have an overview of their current, pending, and completed actions. A new action is suggested when one is completed. When an action is scheduled, its reminder is triggered by time. Users' own choices of actions and the action processes facilitate the sense of autonomy which enhances and maintains motivation [27].

Promoting motivation and engagement

The design uses a number of elements to promote users' motivation and engagement. The suggestions are tailored to the local context by local partners and focus groups. Each action is accompanied by a short explanation, the entailed effort and impact (on a five-point scale) and the number of users taking this action. The design encourages users to take small steps (and not to have too many actions at a time) and gives positive performance feedback. In addition, users can invite household members, view and join the energy conservation actions of the whole household (Figure 8 a). Users can also login with Facebook, like, comment, share actions, give feedback (Figure 8 b c) and invite friends. Users are awarded with points (displayed as Green Leaves) once they complete an action, or provide feedback or comments.

3.3.2 Engagement approaches

[note by GP] Participatory energy budgeting process in trento + Training sessions in sweden (if you find any info about these Swe activities - from deliverables or kth publications, please send me a note).

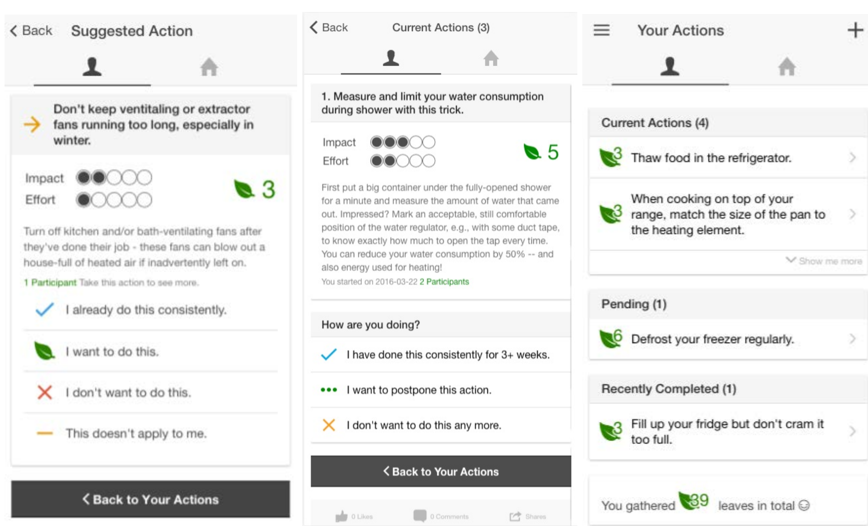

Fig. 7 (a) Action suggestion; (b) Action in progress; (c) User actions

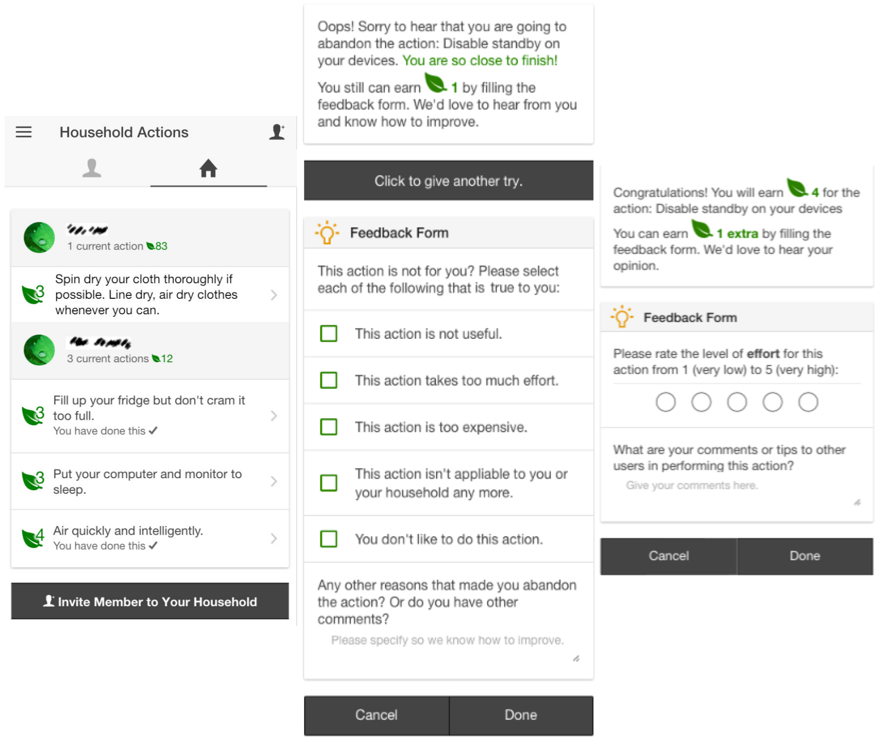

Fig. 8 (a) Household actions; (b) Feedback form – action abandoned; (c) Feedback form – action completed

4 Discussions

Lessons Learned? / Design Guidelines?

5 Conclusions

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Table 1 Please write your table caption here

Classes	Subclass	Length	Action Mechanism
Translation	mRNA[a]	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

[a] Table foot note (with superscript)

Acknowledgements If you want to include acknowledgments of assistance and the like at the end of an individual chapter please use the `acknowledgement` environment – it will automatically render Springer's preferred layout.

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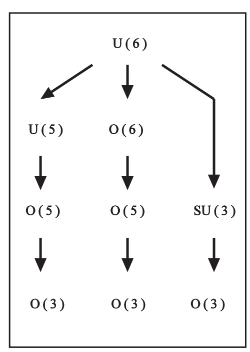

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