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A PERSONALIZED PRO-ACTIVE SMART ENVIRONMENT TO SUPPORT A SUSTAINABLE MEDIA USAGE

Pottier¹, G., Berger, M. ^{1,2}, Fransen, K. ² and Bernhaupt R. ^{1,2}

¹ ruwido GmbH, Austria,

² Eindhoven University of Technology

ABSTRACT

This research investigates how to design for a smart home that supports a more sustainable media usage. The goal is to create a technological landscape that enables consumers to become aware of their media-based energy consumption and supports them in consuming media overall more responsibly.

Therefore, we developed a pro-active smart home assistant that is connected to all the appliances and devices. The smart home assistant makes suggestions and pro-actively changes setting, to achieve a greener lifestyle. The interventions refer to the current energy consumption in the house such as when multiple appliances are turned on, or suggesting the user to reduce energy consumption by turning off the appliances that are not necessary with their current activity.

To validate the technological concept we used a Wizard of Oz method in combination with focus groups and assessed the acceptability of the different features and gathered qualitative feedback on possible improvements and functionalities that must be included for a successful pro-active assistant. Based on these insights we identified the ideal context parameters to create behavior change towards a more sustainable media usage. In this article, we report on the best ways to motivate users and how different behavior change strategies can be an incentive for a greener lifestyle based on a pro-active system.

INTRODUCTION

Climate change is threatening our world and our society. The impact of human activities on the planet and their effects cannot be countered without changing our lifestyles. While industry has a big part of responsibility in this, the part of households also needs to be reduced to reach climate goals. Households' energy consumption (electricity, gas), water consumption, need for transport, food efficiency, waste generation, and consumption in general can all be optimized by adjusting individuals' lifestyles.

Public policies have shown to be efficient to a certain degree when it comes to greenhouse gas emissions, but they do not affect mundane, in house behaviours, that would lead to consumers' habit change. Not every body is aware that their lifestyle has an impact on their

environment. Even among sustainability aware consumers, not all of them are aware that some of their behaviours can be refined to reduce their impact. Technology has the responsibility to improve behaviours and consumption at home. This applies to all sorts of behaviours going on at home, like cooking or enjoying leisure, but also maintaining the standard of living like heating the place, setting lighting, cleaning. In this paper, we will focus on essential activities (food, heating...) and multimedia consumption, and how to support inhabitants to adopt more sustainable behaviours in these situations using a pro-active smart home technology concept.

For this, we will first have a look at the literature on sustainability and behaviour change. Then we will present the study conducted to gather ideas and data on what aspects would lead to a behavior change. We then reviewed these ideas with a team of usability, user experience and human factors experts to identify the criteria for creating acceptable behaviour-changing technology that must be included in a pro-active smart home technology concept. Finally, we relied on these results to design a system to create sustainable behaviour in connected homes. Based on a smartphone, connected to the household's devices and services, and a universal remote control with a display, the two work together to both inform the inhabitants and provide means to adopt energy-saving measures.

RELATED WORK

The World Commission on Environment and Development defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. Regarding multimedia content, Microsoft and Dentsu Consulting defined a sustainable media as designed and delivered in a way to limit its environment impact. This definition covers the whole lifecycle of the content, from its planning and production, to its consumption by the consumer [2]. European environmental policies protect natural habitats, keep air and water clean, ensure proper waste disposal among other [3]. These policies are targeted at both industries and consumers. Consumers' behaviours must answer to the same criteria: reaching the desired goal with a minimal impact on the environment. The impact of a consumer's lifestyle is multiple: energy and water consumption, transport, waste, food, tourism, goods [4]. All these behaviours have an environmental impact, pollution, greenhouse gas emissions, degradation of air quality, and more. A sizeable portion of human behaviours that have an impact on the environment take place at home. Households consume electricity, gas, water, and generate waste and pollution depending on the activities. Daily life involves satisfying basic needs, such as heating the place to a comfortable temperature, eating, drinking, sleeping; and higher-level needs such as living a social life, working, and enjoying leisure. All of these will consume the energy and waste mentioned earlier, multiplied by the number of inhabitants.

Back in 2001, Lorek and Spangenberg [5] described the areas of consumption of daily lifestyle that have the most impact on the environment. They assessed 95% of household consumption comes from nutrition, housing, transport, social choices (education, health provision etc), financial investments, leisure activities, holiday, cleaning, personal hygiene, clothing, domestic appliances and domestic durables.

Among these behaviours, multimedia consumption has a significant impact. The International Energy Agency (IAE) estimated one hour of Netflix consumption will emit 36 equivalent grams of CO₂ per hour [6]. This number depends on the type of consumer device involved, the bitrate, the type of network, and the energy mix in the country. All devices' consumption is not the same, a smartphone being more efficient than the television's screen.

The bitrate and the type of network have the lowest impact on the total of CO₂ emissions, meaning the most important in this number is the consumer devices and the energy mix. In the U.S.A. in 2017, Urban et al. [7] estimated multimedia devices (television, set-top boxes, sound systems, video game consoles, computers, modems and routers) consume 11% of the residential energy consumption. Among these devices, the television and computers are the biggest consumers of electricity: TV active-mode draws 74W and computers in active-mode draw 85W in average. These devices are turned on and working several hours a day, i.e. the average time spent in front of the TV is 4 hours 49 minutes in the U.S.A. in 2022 [8], explaining the impact.

In order to reduce human life's impact on our planet, we need to improve behaviours that are unnecessary inefficient, reduce their frequency, and their duration. Technology can support inhabitants to change their own behaviours.

In [9], Papagiannidis and Marikyan discuss the technology acceptance of sustainable solutions (energy efficient hardware, smart infrastructures, sensors and meters) and the lack of research on technology that integrates a sustainability aspect. The authors put an emphasis on users' knowledge and sensibility to sustainability that is not covered in current technology acceptance models – yet can affect the acceptance of sustainable systems. Among the world population, it is recognized that there are several profiles regarding the environment. The OECD [4] describes three different personas:

- “environmentally motivated”, aware that reducing their impact come at a cost for their lifestyle and comfort. According to the survey, this profile was the most common (46% of the sample).
- “environmental sceptics”, thinking environmental problems are exaggerated. They are the largest group in Japan, the Netherlands, Spain and Australia.
- “technological optimists”, who rely more on technological progress to solve the problems. Chile and South Korea have the biggest groups of all countries but they are never a majority (in the countries surveyed).

Another model describe users on a two-axis representation: one axis describing the motivation of the user to act (will to reduce comfort for the environment) (low to high) and the opportunity to act (e.g. physically, financially, structurally) [10]. Verplanken describes a third dimension to this model with the user's habits, affecting the likeliness of changing a behaviour. According to this model, users most likely to engage in sustainable behaviour are the ones that are both willing and enabled. Others users need to be either sensibilized to the cause of sustainability (by teaching, exemplifying, or rewarding them), or enabled by their environment (by giving them the means to change their behaviours), or both. To change behaviours, Michie et al. [11] defined eleven categories of “interventions” likely to motivate users to change their habits:

- Enablement: Increasing means/reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring)
- Education: Increasing knowledge or understanding
- Persuasion: Using communication to induce positive or negative feelings or stimulate action
- Training: Imparting skills
- Modelling: Providing an example for people to aspire to or imitate

- Restriction: Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)
- Environmental restructuring: Changing the physical or social context
- Incentivisation: Creating an expectation of reward
- Coercion: Creating an expectation of punishment or cost

These interventions can either affect a user's will to change her behaviour (education, awarding or punishing) or her opportunity to act (enablement, training). Wood et al [12, 13] experimented with breaking bad habits and creating good habits. They reported ways to create good habits by: repetition of a good behaviour (for a few days to a few weeks, depending on the difference it makes), relying on stable cues and creating links between the target behaviour and the clues, and by presenting positive rewards at random or predictable occurrences. Breaking bad habits was achieved successfully by disrupting the user's context (e.g. physical, social, or technical) and creating an opportunity window the change the behaviour, and monitoring and identifying slipups to eliminate them.

PROBLEM STATEMENT AND METHOD CHOICE

The key research problem when it comes to smart home solutions for sustainability is to understand what strategies to support to really effect behavior change. To be successful with an application to achieve sustainable behavior it is necessary to investigate the design space, the motivations and then implement them in the technological solution.

There is a basic understanding on when and how it would be appropriate to interrupt users in the home, to inform them about sustainable choices or control options [15], what is missing is a detailed understanding how this would be supporting behavior change, and what this would mean in terms of technological framework that has to be established in the smart home.

We thus chose to follow a design-oriented process, applying a double-diamond design process to pinpoint the limits of acceptance for automation and intrusiveness of features. This allowed us to create numerous features, ideas and scenarios as a basis to iterate on. During this first step, we wanted to generate ideas without taking into account technical limitations or user concerns, with the broadest design space possible. Then, we invited experts to review the sustainability, acceptance and cost aspects of the results, and iterate on the solutions. In a third step we integrated the required features in a technological framework to demonstrate the solution and understand the technological constraints for such systems.

DESIGN TOWARDS A PRO-ACTIVE SMART HOME SOLUTION

Co-design Workshop

We invited six 19 to 22 year old IT students and described for them a household with an ideal technological environment, without limitations: no compatibility issues, seamless connectivity and data streams, with the ability to notify anything on any other device. This fictional household is also equipped with all kinds of connected devices: smart thermostat, speaker, white goods, and especially the ability to monitor all energy and resources

expenses (electricity, gas, water). Finally, we described a central intelligent system that is connected to everything and aware of the state and consumption of all the devices.

During the co-design sessions, the participants were shown this ideal technological environment along with two personas and two situations. The two personas are presented as dynamic, 36 year old parents living with their young kid. The difference between the two come from their sustainability awareness: the first one is aware of her impact on her environment, and already adapting her behaviours to act more sustainably (sustainability-aware and practicing). The second persona is sensible to sustainability but not aware of her impact and not currently practicing sustainable behaviours (sustainability-sensible but not aware). The first situation describes several energy-consuming activities taking place in parallel in the household and the second describes a session of media consumption.

The participants had to come up with ideas fitting for the persona and scenario combination in order to reduce the environmental impact of the behaviours taking place. This could be achieved by reducing the behaviour time or frequency or optimizing the behavior's impact. They could rely on any device or service in the household to achieve what they imagined. Then, the participants had to judge each other's' solution at improving the behavior's efficiency, the persona's acceptance and their own acceptance of the idea, and whether they would accept to spend more money to acquire this solution versus a traditional equivalent.

During the session, the participants were given coloured pen and paper to draw on. On the table were dice, and transparent acrylic crystals to represent resources and energy, to describe gamification ideas. Additionally, a smartphone with a text to speech application was available to simulate smart speakers interventions.

As a result, we collected 33 descriptions of ideas of systems or services aimed at changing user behaviours or reducing behaviours impact on the environment. Some of the descriptions were very simple solutions, like showing the user the energy consumption of an activity, or descriptions of objects that already exist, such as a thermostat. Ideas pushing further to the limit of acceptance involved significant automation or intrusiveness, like turning the television's screen off when watchers are falling asleep in front of it, relying on the television's camera and sensors.

Some out of the box ideas mentioned were the setting up of exercising equipment at home to use during the day to store energy in batteries, that inhabitants can empty later to be enabled to consume media. While this idea was not particularly welcomed by participants, it was judged as efficient to create and motivate behaviours.

In order to improve habits in the kitchen in general, participants imagined a "most efficient" way to cook all their meals. Under the form of a smart cooker, able to cook by using less energy than traditional means, and connected to a smartphone application to deliver instructions. The arguments were that such a device would motivate cooking more – versus buying pre-cooked plastic-packaged meals, ordering meals, meals that would generate more waste. The application can suggest seasonal recipes, carefully chosen to reduce the frequent use of carbon-intensive food (e.g. beef meat, coming from a far place), and to maintain a healthy diet. The participants perceived high benefits in the solution in terms of cost (expecting a return on the investment) and of sustainability (by helping them cooking and helping them pick ingredients).

A solution the participants described and expressed great interest for, is to have better recommender systems to find content. Average time to find content to watch was estimated to be over 7 minutes per day in the U.S. in 2019 (Nielsen Total Audience Report Q1 2019), or almost 43 hours a year with the screen turned on but not actually playing video content. While the sustainability benefits are minimal, and reducing this duration to zero is impossible, the amount of energy spent on this activity can still be reduced. Aside from making it faster, participants also mentioned the screen can run in energy-saving mode during this activity by displaying only a portion of the screen, like only a useful quarter or third of the display. They also mentioned offsetting this activity to another device like a smartphone or a tablet, which consume less energy.

When asked about spending more money to acquire the idea (versus a traditional equivalent without sustainability benefits), the participants answered and insisted the benefits should be written down and communicated to the consumer. They wanted to know the energy saved during use, carbon dioxide emissions reduced, and that the money spared should be predictable (return over their investment versus the traditional system).

Expert Reviews

We then conducted expert reviews on the results. We invited three experts who relied on their knowledge to iterate on the list of ideas. The goal was to identify the potential impact on sustainability, and to estimate the efficiency and cost of the solution to affect the behaviours taking place. First the raw list was curated to remove one duplicate and merge the nine ideas that were slightly different but working well together – relying on the same system or with the same goal. We ended with a shorter list of 23 ideas. The experts had to fill up a questionnaire (either on Google Forms or in an Excel sheet) to estimate 1. if the energy saved with the solution is significant or not, 2. if the solution can help the user change her behaviour and improve sustainability on the short and long term, 3. the acceptance of users towards the solution, 4. the impact on the infrastructure (system and services it can rely on), 5. if the user would have to spend significantly more to acquire this solution versus an existing equivalent if there is one, and finally 6. to iterate on the idea to make it more concrete or realizable.

The experts concluded the sustainability benefits of the different ideas was varying from insignificant (no reduction of the household's impact on the environment) to very interesting – under the condition the user would accept the solution.

Acceptance in the general sense is determined by the perceived usefulness and ease of use [14]. In our context, experts focused more on the balance between the feature's impact on the inhabitants' habits, and the inhabitants' will to reduce their habits in order to reduce their impact on the environment. Features affecting users' comfort or leisure activities the most (e.g. reducing time spent consuming media significantly) are less likely to be accepted. Users less aware of the impact of their activities on the environment are less likely to accept and implement energy-saving measures. By these criteria the acceptability varied from very easily accepted (especially for seamless systems, and win-win situations) to very intrusive and hard to accept (e.g. too disruptive to habits, or error-prone systems).

In terms of impact on the infrastructure, the experts concluded that thirteen ideas would require modifications in the household (e.g. adding sensors or replacing a device with a compatible one), and the other ten modification of the services (e.g. rewarding sustainable consumption of an application – monitored by the service itself).

The cost to the consumer was rated as close to zero for 8 of the 23 measures. Experts judged some solutions can be implemented by manufacturers, resellers, or services with no additional cost for the users. For example “showing the environmental impact of buying and using this device” implies making this information available early on when discovering the products. This is already mandatory by European Union’s directive 92/75/EC, but the idea iterates on this obligation to cover all consumer devices, and to detail the impact of both the making of the product and the use of the product. The goal there is to make the buyer more aware of their potential impact when choosing and using a new device. Seven other measures were rated cheap for the consumer, by implying that the products would only have a small price difference for implementing sustainability-enabling features compared to traditional products. As an example, a smart television that is able to turn off its screen when nobody is watching: the price of a smart television with and without a camera to implement this feature is not very different. Eight features were rated as expensive, as they relied on high-end systems or product that are not very popular yet. For example, the ability of a laundry machine to weigh the current amount of clothes loaded, and prevent starting cycles without filling it first, ultimately reducing cycles’ frequency. The system was able to notify the user on her device when the load is ready. As these smart models are currently much more expensive than traditional machines.

Results of the Design Phase

After this design phase a refined list of ideas for pro-active elements in a smart home were available. Due to the expert involvement we also were able to identify success criterions to achieve acceptable and efficient behaviour changing design. The acceptance is the balance between the consumer’s will to reduce their impact (save energy, reduce emissions) and will to affect their own lifestyle to do so. This balance can be affected in favor of sustainability by making the users aware of their own impact, and by offering easily accessible opportunities to adopt energy-saving measures. Changing the consumers’ behaviour depends on the feature’s impact on the daily life. Autonomous systems operate by themselves to affect comfort to reduce the household’s impact. Other systems, where the user has to choose between her comfort and increase her impact on the environment, were perceived as more efficient to change behaviours on the long term.

Participants from the co-design sessions proposed more automation (adjusting energy consumption by turning features off) on the sustainability-aware persona, and proposed notifications with suggestions and explanations to the sustainability-unaware persona. Their rationale is that the sustainability-aware persona already understands why some devices or features in the home would turn themselves off automatically, while the sustainability-unaware persona needs things explained first to understand how to reduce her energy expenses.

Participants eventually expressed concerns about their data being collected and exploited. They mentioned physical safety if the data is stolen, a thief can learn about the occupancy in the household and the goods. When told about the potential of exploiting this data for targeted advertisement, participants qualified it as normal and not different from current services.

DESIGN OF THE SOLUTION

We relied on these findings to design a prototype. We selected ideas compatible with the system architecture of our platform: a universal remote control, connected over Bluetooth to

a smartphone, which is connected to the household's appliances and services. The remote control has a screen and can display the status of the devices connected. It is possible to scroll horizontally to display more devices on additional pages, and the application allows customizing page. As an example, a page dedicated to music playback, a page dedicated to all lighting appliances, a page for all the appliances of a specific room. The remote allows controlling everything connected, from the usual television and air conditioner to the more complex services such as music streaming or connected lighting.

Energy consumption features

We designed these features relying on the ability to poll the household devices' state, and energy sensors, to assess the consumption of the household. The current electricity consumption of the household is displayed on the remote control's screen under the form of a colored gauge (Figure 1). We also associated different colors to the appliances (whose status is displayed on the current



Figure 1 – drawing of the remote control's screen with the colored gauge on top, and devices below. The left picture shows a situation with low energy consumption, the center picture with more devices turned on (lights, heating, media devices) an average consumption, and the right picture a high consumption.

screen) depending on their electricity consumption: gray for devices that are turned off, green for devices that consume a low amount of energy, to yellow and red for devices that consume a higher amount of energy. The scale is not decided by the current draw, and instead depends on the average draw for every type of devices. This is to prevent displaying energy-intensive devices (e.g. heating or air conditioning) always in red, and other devices always in green (e.g. lighting). This way, the heating is shown in green when it is working in an energy-saving way (low difference between current temperature and target), while the lighting is red when set to 100%, even if the current draw is higher from the heating system than from the lighting.

The remote control is able to notify the users by vibrating and blinking its screen with a color when reaching "average" and "high" consumption. Notifying the inhabitants can create an incentive to reduce energy consumption. The breakdown of current energy consumption, via the icons' color, helps understanding why consumption is rising, as it may come from the heating suddenly turning on, the overall number of devices turning on in the household progressively increasing, and other behaviours the inhabitants may not notice. This way the users can associate their behaviours and the impact they might have, and therefore reduce the frequency, or the intensity of the behaviour.

The smartphone application logs the electricity consumption of the household and is able to show a breakdown of the consumption over time and per device or groups of devices (Figure 2). This allows inhabitants to match their daily activities and energy consumption easily, therefore creating an incentive to reduce or optimize consumption-heavy habits.

The remote control and the application allow the suggestion or the automation of energy-saving measures (Table 1). The user can choose to let the system handle a sub-system in an energy-saving way, potentially affecting inhabitants' comfort (e.g. the thermostat will allow less heating). They can choose to receive a suggestion instead, and the remote control and the application will deliver a notification when the consumption of this device will go, or goes over a threshold. For example

features list	suggest only	automate
optimize lighting		✓
reduce screens luminosity		✓
optimize heating/AC	✓	

Table 1 – Example of features up for suggestion or automation

during a cold wave, the heating system will have to consume more energy than usual, the remote control can suggest reducing the thermostat's target temperature.

When the users adopt the energy-saving modes, the remote and the application deliver visual awards to incite and maintain energy-saving behaviours. The remote displays a green leaf along the current energy draw gauge, and the smartphone application shows them in the energy consumption breakdown.

This set of features aims to both inform the user about his impact, and motivate the user to take energy-saving measures. We expect sustainability-sensible users to apply most or a portion of the energy-saving measures easily, while the less sensible users might require a deeper awareness of their own impact. By synthetizing and showing their impact directly, users can learn about their behaviours, become aware of their cost, and act accordingly. The different means offered are designed to be easy to apply (selecting a suggestion, autonomous solutions), as poor usability would only hinder adoption of the features.

Multimedia features

The system displays an overlay on the smart television with information on the watching session. It shows the duration of the current session, and the impact of his consumption in carbon emissions or cost in kW per hour, depending on the type of content. The user can decide to enable a "multimedia credit" feature in order to create an incentive to reduce his consumption (Figure 3). In the application's menu, where we describe the impact of media consumption on the environment, the user can decide how much she will be allowed to consume media content, in hours, carbon emitted, or kW per hour per week. This credit is then displayed in menus and updated accordingly. Inhabitants can decide to set a soft limit

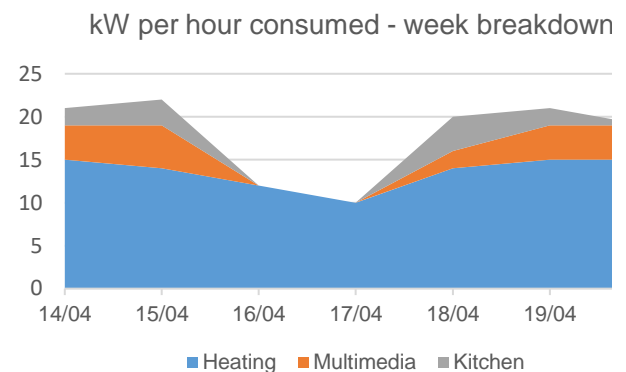


Figure 2 – Breakdown of electricity consumption per day and per domain over a week. The unit in this picture is kilowatt per hour equivalent, but could be displayed as carbon emissions or cost on the bill.

or a hard limit, where content consumption can be interrupted at the end of the current piece of content (e.g. end of an episode) or interrupted immediately when reaching the limit. The time available and associated impact on the environment can motivate smarter media behaviours. By sensibilizing inhabitants, some households may decide to reduce consumption time overall, to stop consuming content with the least interest to them, to factorize viewing sessions by sitting together more often.



Figure 3 – Netflix profiles screen with the multimedia credit left

The video platforms can implement this feature directly and display the kW per hour consumption in the household, or the overall carbon emissions during a watching session. It can be implemented on a per profile basis or a common basis with a breakdown per profile in order to responsabilize the individuals.

DISCUSSION

For the above designs it is assumed that a fully functional technological infrastructure is given. Current developments in this area make us hopeful that very soon virtual layers in software solutions for smart homes will allow a seamless connectivity of all devices and infrastructures. The essential requirement is the ability to connect and drive devices and services in the home, like today's smart home hubs aim to achieve, for example smart assistants as in Amazon Echo or Google Home smart speakers, or homebrewed systems such as home-assistant.io. Another requirement is the generalization of standardized interfaces for monitoring and controlling connected devices. To support sustainability features better, this interface must provide as much data as possible including the current energy and other resources consumption. The behaviour-enhancing features described here relies on these requirements, and cannot work without.

Our contribution here lies in the exploration of what users would accept and how services should be adapted. To achieve sustainable behavior, technology could become “less good” instead of better, given the suggestions for example to have only parts of the screens used, to become “more invasive” by automating things in the home for the user, and even lead to (self-chosen) limitations, like credits available to consume content, instead of having access 24/7 and being able to consume. We felt in our explorations for this technological framework that people are accepting that less might be more.

In order to implement other interesting features, we need to go beyond the current technological state of the art in the home. The environment would need to implement activity recognition. Identifying undergoing activities would prevent undesired interventions from the environment (e.g. inappropriate timing, wrong device) and optimize resource-saving measures. The issue with activity recognition is shifting the concerns about the system's suggestions and automation features, to the activity recognition mechanism itself.

Saving energy and showing the benefits may cause a rebound effect. By implementing the measures, adopting more efficient behaviours, and making the user aware of their reduced impact, they can also lower their efforts to save energy in other domains.

CONCLUSION

Changing lifestyles in the household is the key to achieve sustainability goals. We identified essential aspects to create sustainable behaviours via technology: sensibilizing users to sustainable goals (potential environmental gains), acceptance of feature (reducing comfort as a trade-off), and justifying the cost of a solution versus a traditional equivalent (return on the investment).

At this point we designed a solution that we think can be efficient and should be widely accepted by users. The different features aim to inform the user of their own impact on the environment to create the necessary awareness, and to give cues and means on how to save energy.

In the future, the prototype will be evaluated in real life conditions to assess the actual benefits and acceptance. The plan is to recruit households representative of the big values groups: self-transcendence (benevolence, universalism), openness to change (self-direction, stimulation), self-enhancement (achievement, power), and conservation (conformity, tradition). We expect to find differences in terms of improving the sustainability of the households, and acceptance of the system in general. It is likely that these different values groups will need adjustments to fit their own expectations and needs.

To conclude, we see a growing awareness toward sustainability and an acceptance of pro-active advice when it comes to sustainability. Unfortunately from a business perspective such an acceptance might not go in-hand with traditional expectations of pricing. The expectation that less resource consumption would be also mean a lower price does not hold true. Sustainable solutions require us to rethink technology, redesign services and re-evaluate material and infrastructure choices. A key lesson learned can be that sustainable services will be more expensive than traditional ones. This will be a key aspect to be investigated in future research when it comes to setting up the general technological framework for a circular economy with re-use of materials and the corresponding services that are available within the smart home and entertainment domain.

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