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

Pottier[1], G., Berger, M.[1,2], Fransen, K.[2] and Bernhaupt R.[1,2]

[1] ruwido GmbH, Austria,
[2] Eindhoven University of Technology, The Netherlands

ABSTRACT

The modern lifestyle has a huge impact on the planet and contributes to climate change. Even though industry has a major responsibility to reduce environmental impacts, the contribution of individual households should not be neglected in order to achieve climate goals. In this paper, we investigate design ideas for enabling sustainable behaviour in the smart home to make users aware of their energy consumption and to support them in spending energy more responsibly.

We conducted a co-design session and expert interviews to identify key design elements that constitutes towards a more sustainable behaviour in the smart home. Based on the insights gained, we demonstrate a pro-active smart home assistant that makes suggestions and pro-actively changes settings, to support a greener lifestyle. Interventions refer to suggesting to turn on or off specific appliances depending upon users' behaviour and home situations to reduce energy consumption. We contribute design aspects for supporting behaviour change towards a more sustainable living and lifestyle and demonstrate how these aspects can be integrated in the smart home.

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 the industry has a big responsibility in this, the contribution of individual households also needs to be considered to reach climate goals. Private households' energy consumption (e.g., 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 behaviour, that would lead to consumers' change of habits [12]. Not everybody is aware that their lifestyle has an impact on their environment: individuals follow their own personal life-defining values [15], dictating their attitudes towards sustainability among other aspects of life [2]. Even among sustainability-aware consumers, not all of them are aware that some of their behaviours can be refined to reduce their impact. Technology can be designed in a way that we can improve behaviours and consumption at home. This applies to all sorts of behaviours related to typically energy consuming activities, be it cooking or enjoying leisure, but also maintaining the standard of living like heating the place, setting lighting, or cleaning. In this research, we will focus on essential activities (e.g., food, heating) in combination with multimedia consumption, to investigate 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 present the current state of the art on sustainability and behavioural change. Then we will present the study conducted to gather ideas and data on what aspects of daily life would lead to a behaviour 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 smart home control with a display, we show how to inform the inhabitants of a home and how they can adopt energy-saving measures.

RELATED WORK

The *World Commission on Environment and Development* (WCED) defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [20]. Regarding multimedia content, *Microsoft* and *Dentsu Consulting* define sustainable media as designed and delivered in a way to limit its environmental impact. This definition covers the whole lifecycle of the content, from its planning and production to its consumption by the consumer [4]. European environmental policies protect natural habitats, keep air and water clean, and ensure proper waste disposal among other [5]. These policies are targeted at both industries and consumers. Consumers' behaviour 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, and goods [12]. 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 their activities. Daily life involves satisfying basic needs, such as heating the place to a comfortable temperature, eating, drinking, and sleeping; but also higher-level needs such as living a social life, working, and enjoying leisure. All of these require energy and produce waste as mentioned earlier, multiplied by the number of inhabitants.

Back in 2001, Lorek and Spangenberg [8] described the areas of consumption of daily lifestyle that have the most impact on the environment. They assessed that 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 CO_2 per hour [6]. This number depends on the type of consumer device involved (e.g., TV, smartphone), the bit-rate, the type of network, and the energy mix in the country. Thye consumption of all devices is not the same; a smartphone being more efficient than a television screen. The bit-rate and the type of network have the lowest impact on the total CO_2 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. [16] estimated that 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 on 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 [11], explaining the impact.

In order to reduce human life's impact on our planet, we need to change behaviours and reduce energy-consuming tasks in both duration and frequency. Technology can support inhabitants to change their behaviours in various ways.

Papagiannidis and Marikyan [13] 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 [12] describes three different personas:

- "**environmentally motivated**" users, aware that reducing their impact comes at a cost for their lifestyle and comfort. According to the survey, this profile was the most common (46% of the sample).
- "**environmental sceptic**" users who think that environmental problems are exaggerated. They are the largest group in Japan, the Netherlands, Spain, and Australia.
- "**technological optimistic**" users who believe technological progress will compensate the issue. Chile and South Korea have the biggest groups of all countries but they are never a majority (in the countries surveyed).

Verplanken's model [17] describes 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). Verplanken also 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 who are both willing and enabled. Other users need to be either sensitized to the cause of sustainability (by teaching, exemplifying, or rewarding them), enabled by their environment (by giving them the means to change their behaviours), or both. To change behaviours, Michie et al. [9] 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 behaviour (education, awarding or punishing) or to create opportunities to act (enablement, training). Wood et al. [18, 19] experimented with breaking bad habits and creating good habits. They report 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 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 to 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 really support and help to change behaviour. To be successful with an application to achieve sustainable behaviour, it is necessary to investigate the design space, and the motivations and then implement them in the technological solution.

There is a basic understanding of when and how it would be appropriate to interrupt users in the home, to inform them about sustainable choices or control options [14], what is missing is a detailed understanding of how this would be supporting behavioural change, and what this would mean in terms of a 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 [1]. 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 into 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 demonstrated to them a fictional household with an ideal technological environment, without limitations: no compatibility issue, 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 child. 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 sensitive 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 behaviour’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 solutions to improve the behaviour’s efficiency, the persona’s acceptance and their own acceptance of the idea, and whether they would accept spending more money to acquire this solution versus a traditional equivalent.

During the session, the participants were given coloured pens and paper to draw on. On the table were dice, and transparent acrylic crystals to represent resources and energy, to in a game-like way. Additionally, a smartphone with a text-to-speech application was available to simulate smart speaker interventions.

As a result, we collected 33 descriptions of ideas of systems or services aimed at changing user behaviours or reducing behavioural 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 when consuming 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 imported from a different continent), 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 sustainability (by helping them cook and helping them pick ingredients).

A solution the participants described and expressed great interest for, is to have better recommender systems to find content. The average time to find content to watch was estimated to be over 7 minutes per day in the U.S. in 2019 [10], 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 a more energy-efficient device like a smartphone or a tablet.

When asked about their will to spend in order to acquire the product or service imagined, participants expressed several needs. In the case where the product replaces an existing equivalent, they wanted to know about the energy-saving potential and the carbon emissions reductions first. They stated this data should be available before buying the product. In this case, they also expressed the need to know about a return on investment. For concepts requiring heavy infrastructural changes or expensive investments (e.g. setting up exercising equipment to fill batteries), participants judged the solution would never be worth the investment, even when the idea is judged efficient at changing behaviour.

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 up 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 in 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 were 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 [3]. 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).

Regarding the cost of the solutions proposed, the experts concluded that thirteen ideas would impact the consumer (e.g. adding sensors or replacing a device with a compatible one), while for the other ten ideas, the cost would mostly lie with the industry (e.g. updating a service to provide sustainability features). For the cost of the solution for consumers, eight ideas were rated as "close to zero". These ideas rely on products and services already exisiting and in use, with no expected additional cost to the consumer when changing behaviour. For example, allowing VOD users to look-up content on their mobile phone instead of the TV can be used without any implementation on the TV platform. Seven ideas were rated “cheap”, obtaining the desired effect by replacing a device or a service or adding a new one at a reasonable expense for the consumer. As an example, a smart television that is able to turn off its screen when nobody is watching,: the price of the production of a smart television with and without such a sensor is rather similar. The last eight ideas were rated “expensive”, requiring substantial changes in the household or more expensive appliances, like installing connected panels in all rooms to enable energy monitoring and consumption notifications. Finally, the cost of the implementation for industries varies depending on the requirements. For the cost of the implementation we used three categories: The first category is related to software and infrastructure, for example the development of new services or modification of existing ones like adding game-like features to reward the user for using a device in a more sustainable way. The second category is hardware, new products, or new versions of existing products, enabling more sustainable behaviours compared with the traditional device it replaces. An example is a new version of an appliance with energy-sensing capabilities that provides energy information to a monitoring system (e.g. the smart home hub). The third category is logistical impact, requiring different or additional workflows during the product lifecycle. For example, providing sustainability-related information on a product or service means researching the impact of the product or service first (carbon emissions, waste, during production and usage), and then making the information available to the consumers.

Results of the Design Phase

After this design phase, a refined list of ideas for pro-active elements in a smart home was available. Due to the experts’ involvement, we also were able to identify success criteria to achieve acceptable and efficient behaviour-change design proposals. The acceptance is the balance between the consumer’s will to reduce their impact (save energy, reduce emissions) and the will to affect their lifestyle to do so. This balance can be affected in favour of sustainability by making the users aware of their own impact, and by offering easily accessible opportunities to adopt energy-saving measures. Changing the consumer’s behaviour depends on the feature’s impact on 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 in the long term.

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

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 AND IMPLEMENTATION

We selected some of the participants and experts' ideas to implement them on a smart home remote control. The liza remote is a universal remote control (Figures 1, 2) that connects to a smartphone and its companion application, which then fulfils the role of 1: a hub to send commands to appliances and be aware of their current state, and 2: a configuration tool to set up and manage the different functionalities available on the remote control. The liza remote control has a screen and can display the status of the devices connected. Users can scroll to reach the other pages with different functionalities. The companion application enables adding and customizing pages with any device, service, or customizable scene. As an example, users can create pages for music playback (managing outputs, volume, playback and playlists), a page for all lighting appliances (all lightbulbs, colour and intensity), or pages for specific rooms (e.g. a living room page with the television, music playback and lighting).

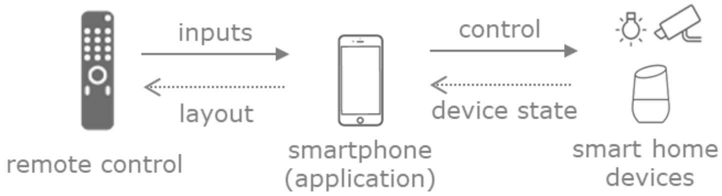

Figure 1 – architecture of the liza universal remote environment. The liza remote connects to the smartphone, which handles home devices.

Figure 2 – picture of the liza smart home control and its companion application.

We relied on this platform to design the following features: energy consumption monitoring, using the remote control's screen as a beacon to indicate current energy consumption, and the application to display a breakdown of past energy consumption. Then multimedia credit, where users set a limit on their own video consumption, visible on the remote control's screen and on an overlay on the television.

Energy consumption monitoring

We designed the following features relying on the ability to poll the household devices' state, and energy sensors, to assess the consumption of the household. The electricity consumption of the household is displayed on the screen under the form of a colored gauge (Figure 3). We also associated different colours to the appliances (whose status is displayed on the current screen) depending on their electricity consumption: grey 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

Figure 3 – remote's screen with the "consumption" gauge on top, and devices below. On the left a situation with low energy consumption, in the center more devices turned on and average consumption, and on the right, all the devices turned on and a higher consumption.

current draw, and instead depends on the average draw for every type of device. 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 smart home is able to notify the users by vibrating and providing visual coloured feedback (blinking) when reaching “average” and “high” consumption. Notifying the inhabitants can create an incentive to reduce energy consumption. The breakdown of current energy consumption, via an icon’s colour, helps to explain 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 that the inhabitants may not notice. This way the users can associate their behaviours with the impact they have, and therefore reduce the frequency, or the intensity of this 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 4). This allows inhabitants to match their daily activities and energy consumption easily, therefore creating an incentive to reduce or optimize consumption-heavy habits.

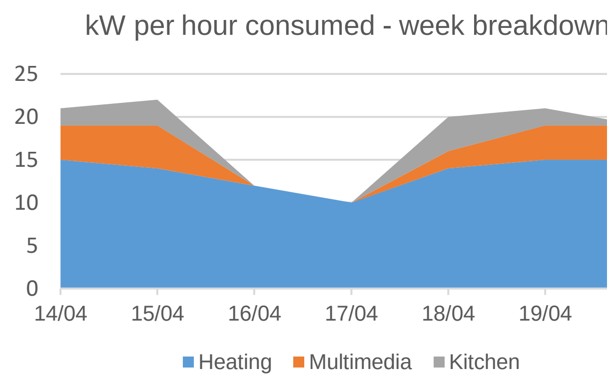

Figure 4 – Breakdown of electricity consumption per day and per domain over a week. The unit in this picture is kilowatt per hour equivalent, but could be displayed as carbon emissions or cost on the bill.

The smart home control and the application allow the suggestion of the automation of energy-saving measures. 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). Alternatively, they can choose to receive a suggestion, and the remote control and the application will deliver a notification when the consumption of this device will go, or goes over a threshold (Figure 5). For example, 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.

Figure 5 – remote’s sequence of screens when suggesting energy-saving measures

This set of features aims both to inform the user about his impact, and to motivate the user to take energy-saving measures. We expect sustainability-sensitive users to apply most or a portion of the energy-saving measures easily, while the less sensitive 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 costs, 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 6). 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 applications menus and on the remote control. Inhabitants can decide to set a soft limit 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 sensitizing inhabitants, some households may decide to reduce consumption time overall, to stop consuming content with the least interest to them, or to economize on viewing sessions by sitting together more often.

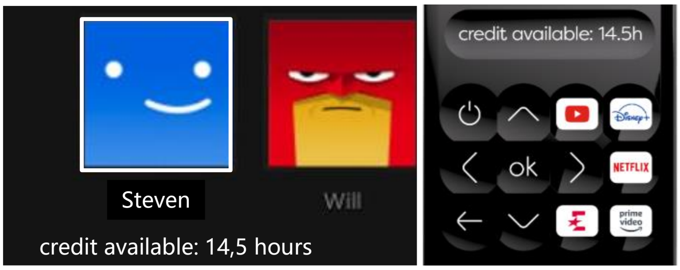

Figure 6 – Netflix profiles screen with the multimedia credit left

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 make the individuals more environmentally responsible.

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 [7]. 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 reliy on these requirements, and cannot work without them.

Our contribution here lies in the exploration of what users would accept and how services should be adapted. To achieve sustainable behaviour, 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: sensitizing 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 a means to achieving 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.

REFERENCES

1. Banathy, Bela H. 1996. Designing Social Systems in a Changing World. Springer US. p. XV, 372. ISBN 978-0-306-45251-2.
2. Berger, M., Pottier, G., Pfleging, B. Bernhaupt, R. 2022. Considering Users' Personal Values in User-Centered Design Processes for Media and Entertainment Services. Human-Centered Software Engineering. (LNCS, volume 13482, August 2022)
3. Davis, F.D., Bagozzi, R.P., Warshaw, P.R. 1989. User acceptance of computer technology: a comparison of two theoretical models. Manage. Sci. 35, 8 (August 1989), 982
4. Dentsu consulting, Microsoft. 2021. The Rise of Sustainable Media https://sustainablemedia.dentsu.com/home1/home (last accessed 20/05/2022)
5. European Union Law. Towards a greener and more sustainable Europe, https://eur-lex.europa.eu/summary/chapter/environment.html?root_default=SUM_1_CODED=20&locale=en (last accessed 20/05/2022)
6. International Energy Agency. 2020. "The carbon footprint of streaming video: fact-checking the headlines". https://www.iea.org/commentaries/the-carbon-footprint-of-streaming-video-fact-checking-the-headlines (last accessed 20/05/2022)
7. Kim, W., Lee, S., Chang, Y., Lee, T., Hwang, I., & Song, J. 2021. Hivemind. Proceedings of the 19th Annual International Conference on Mobile Systems, Applications, and Services. doi:10.1145/3458864.3466626
8. Lorek, S. and Spangenberg, J., 2001. Indicators for environmentally sustainable household consumption. International Journal of Sustainable Development, 4(1), pp. 101-120.
9. Michie, S., Atkins, L., and Gainforth, H. 2016. Changing Behaviour to Improve Clinical Practice and Policy. In Novos Desafios, Novas Competências: Contributos Atuais da Psicologia (pp.41-60) 10.17990/Axi/2016_9789726972679_041
10. Nielsen. 2019. Total Audience Report Q1 2019. https://www.nielsen.com/wp-content/uploads/sites/3/2019/06/q1-2019-nielsen-total-audience-report-one-sheet.pdf (last accessed 05/07/2022)
11. Nielsen. 2022. State of Play. https://www.nielsen.com/us/en/insights/report/2022/state-of-play/ (last accessed 20/05/2022)
12. Organisation for Economic Co-operation and Development. 2014. Greening Household Behaviour. Environment Policy paper no. 3. December 2014.
13. Papagiannidis, S., Marikyan, D. 2022. Environmental sustainability: A technology acceptance perspective. International Journal of Information Management, Volume 63, 2022,012, https://doi.org/10.1016/j.ijinfomgt.2021.102445
14. Reicherts, L., Zargham, N., Bonfert, M., Rogers, Y., & Malaka, R. 2021. May I Interrupt? Diverging Opinions on Proactive Smart Speakers. CUI 2021 - 3rd Conference on Conversational User Interfaces. doi:10.1145/3469595.3469629
15. Schwartz, S. H. 1994. Are There Universal Aspects in the Structure and Contents of Human Values? Journal of Social Issues, 50(4), 19–45. doi:10.1111/j.1540-4560.1994.tb01196.x

16. Urban, B., Roth, K., Singh, M., and Howes, D. 2019. Residential Consumer Electronics Energy Consumption in the United States in 2017. Proceedings of the 9th international conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL '17) 10.2760/667696
17. Verplanken, B. 2018. Promoting Sustainability: Towards a Segmentation Model of Individual and Household Behaviour and Behaviour Change. Sust. Dev. 2017, 26: 193–205. doi: 10.1002/sd.1694.
18. Wood, W., Tam, L., & Witt, M. G. 2005. Changing circumstances, disrupting habits. Journal of Personality and Social Psychology, 88(6), 918–933. doi:10.1037/0022-3514.88.6.918
19. Wood, W., & Rünger, D. 2016. Psychology of Habit. Annual Review of Psychology, 67(1), 289–314. doi:10.1146/annurev-psych-122414-033417
20. World Commission on Environment and Development. 1987. Our Common Future. Oxford: Oxford University Press, 1987.