Mona Prisa: A Tool for Behaviour Change in Renewable Energy Communities

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Abstract. Innovative construction projects, such as Energy Communities, are crucial to meet challenging climate objectives. However, currently residents of shared energy projects receive no feedback about the real-time consumption in the building and they cannot adjust their behaviour according to the needs of the community. In this paper we introduce the "Mona Prisa", an interactive prototype dashboard with the looks of a painting at the entrance of a building which is part of an Energy Community. The design is based on the results from 51 interviews with 37 experts living or involved in an energy community and 14 non-experts. We question the level of openness of participants to energy behavior change and how this information should be visualized for a community, not on an individual level. We present the translation of these insights into a prototype with real-time energy, water and heat flows. The content is based on three important features of energy consumption feedback: awareness, action-based feedback and gamification. Interaction with the prototype is possible by infrared sensors and a camera for face detection. In this paper we focus on the design process and components of the product. We conclude with future development ideas.

Keywords: Energy consumption feedback · Prototype · Energy community · Feedback · Information · Interface · Behaviour change

1 Introduction

As a result of depletion of fossil fuel resources, technological and institutional changes and increased awareness about climate change, the energy systems are going through a radical transformation. Progressive cities, such as the city of Ghent in Belgium, want to be climate neutral by 2050 and in the meantime reduce 40% of its CO_2 emissions by 2030 [10]. New CO_2 neutral construction projects that meet strict environmental standards are crucial to meet these objectives. Renewable energy communities (RECs) where citizens, business or other community organizations invest, produce and use renewable energy,

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are viewed as one way of reducing fossil fuel dependency [23, 35]. While the behaviour of people living in RECs impact the water, energy and heat balance (e.g. energy usage is preferable low on energy shortage moments, and high when much energy is produced and batteries are full), they have low control and feedback over the system. Energy analysis has focused largely on the technological aspects of energy use and on the effects of price fluctuations; limited research however, looks at the human perspective [26]. While Strengers describes a "Resource Man" [36], an ideal type of smart energy consumer seen as a knowledgeable micro-resource manager; other research contests this view with a passive and carefree energy consumer who is not engaged with energy consumption and becomes inattentive to energy feedback platforms over time [37]. Furthermore, there is a lack of research that looks beyond individual housing and meters, and that gives users information about a broader living context [17] and engages with emerging energy systems such as distributed or renewable generation [32].

We present the "Mona Prisa", an interactive design for increased awareness and pro-environmental behaviour based on energy, water and heat consumption of habitants of renewable energy communities. Instead of an app or desktop based solution which are currently the standard, it presents energy feedback on a screen, framed like a painting. The prototype attempts to move an individual from the previous described careless category into the "Resource Man", who desires to reduce carbon emissions and create an energy efficient power generation. The remainder of this paper is structured as follows. First, we review prevalent research within the domain of energy feedback. Secondly, we discuss the methods used in this study, results of our interviews and present our tangible design. We conclude by highlighting attributes of the design leading to ecologic behaviour change.

2 Related Work

2.1 Renewable Energy Community

The Renewable Energy Directive (EU) 2018/2001 in the European Union [11] aims to support the increase of locally, community-driven production of renewable energy. The most common energy model today is called a centralized energy distribution model. The participant is called a consumer. He is connected to an energy supplier and network operator. Energy is produced centrally, such as in nuclear power plants or large wind farms. Large energy plants are switched on and off to keep the energy supply and demand in balance. In new, distributed energy models, energy can be generated and consumed locally. Participants are called prosumers, they produce, share and store energy with e.g. solar panels, wind mills, and (community) batteries. Such Renewable Energy Communities (REC) are viewed as an alternative to traditional energy production [22]. They accelerate the transition towards carbon-free energy [5, 35]. Renewable Energy Communities (REC) are also known under terms such as low-carbon communities [20], clean energy communities (CEC) [7, 30] and community renewable energy' (CRE) [21].

The transition towards renewable and sustainable energy is being accompanied by a transformation of communities and neighbourhoods [2]. Since Energy Communities are new, participants are scare. Existing research focussing on the participants of such projects question motivations and barriers [3,21,28]; willingness to actively be engaged, co-create and share energy [25] and the design of such systems [39].

2.2 Energy, Water Feedback and Smart Meters

The compulsory roll-out of smart meters in many European countries led to a great deal of research into smart metering (SM). A smart meter has proven his effectiveness in raising energy awareness and creating behaviour change in the form of reduced energy consumption [3, 16, 40]. Early trails reported expected energy saving of 5 to 15% when feedback on energy meters or associated displays is provided to the user [9]. More recent large-scale studies lower the change in energy usage to around 3% [1]. Important reasons for limited energy reductions and fall backs in old habits after a short time are the lack of interest of householders, difficult or confusing feedback, and an overemphasis on financial motivations [6, 19].

Energy and Water Feedback Guidelines

Clear energy feedback, is a necessary element in learning how to control energy usage and eventually achieve an ecologic behaviour change [9]. Energy feedback literature addresses two questions: how to visualize feedback? And how to create behaviour change through feedback [29]. For the visualisation of feedback, Fisher [12] describes in a study on household electricity consumption that most successful energy feedback combines the following features: data is given frequently and over a long time, provides an appliance-specific breakdown, is presented in a clear appealing way, and uses computerized and interactive tools. When looking at guidelines for in-home water consumption, Froehlich [13] identifies four eco-feedback design elements that should be used: data granularity (e.g. breakdown of data per individual fixture, fixture category or activity); time granularity (time window with which data is calculated and presented such as per day, week or month); comparison (to reveal whether usage is normal) and measurement unit (metrics used to present usage data such as litres, or monetary).

Above mentioned visualization guidelines lead to better comprehension and follow up, but they do not necessary lead to behaviour change. Next to guidelines on visualisation, following research suggests ways of changing consumption behaviour. First, the provision of action-oriented tips is a common strategy used in both water as energy applications [13, 14, 29]. Second, increased awareness has a proven effect to eventually stimulate behaviour change [1, 4]. Finally, gamification appears to be a frequently used tool within the domain of energy consumption leading to positive behaviour change [24].

However, the guidelines and tools described above are designed for in-home, single family consumption feedback. They do not encounter more complex settings such as energy communities where - example given - data granularity is not shared on a personal level due to privacy reasons. Moreover, the pursued behaviour change in the mentioned research only focusses on a reduction of the total energy or water usage. Sharing of energy and water and reduced usage of energy at peak moments -which can be explored in amongst others energy communities- are not taken into account. The three mentioned tools to stimulate behaviour change in energy behavior are action-oriented tips, increased awareness and gamification will be further used as guidelines during the design of the concept (Table 1).

Table 1. Overview of literature energy feedback guidelines (EFG)

Type of EFG	Guidelines	Sources
Visualization guidelines of energy feedback	Use data granularity (per fixture, category) Use time granularity (per hour, month) Use comparison (social) Use of measurement unit (euro, liter)	Froehlich et al. [13]
	Give data frequently, over a long time Appliance-specific breakdown Present data in a clear appealing way Use computerized and interactive tools	Fischer et al. [12]
Behavior change guidelines of energy feedback	Increase awareness	Fischer et al. [12]
	Feedback on consumption should be action oriented	Froehlich; Gamberini; Micheel [13, 14, 29]
	Use gamification of consumption stimulate competition	Johnson et al. [24]

Energy Feedback Prototypes

"Energy is doubly invisible" [8]. It is not experienced directly but is best experienced by its absence, such as realizing the importance of electricity when the power is off. Devices that generate, manage and monitor energy at the household level make electricity visible. Making energy visible might be crucial for future energy communities that rely on smart users: being flexible, responsible and engaged in the electricity system's functioning. The majority of the papers in the literature review on energy related work in Human–Computer Interaction (HCI) by Paulos and Pierce [32], focus their work on electricity consumption feedback "feeding back" electricity consumption data to users via a computational display. Next to these energy displays such as screens, apps and web platforms to give energy feedback, we take a short look at three energy artefacts which are designed to create awareness about energy, water or heat consumption and aim for a positive behaviour change.

First, "The 'Power-Aware Cord' [18] is a re-design of a common electrical power strip that displays the amount of energy passing through it with electroluminescent wires moulded into the transparent electrical cord." The power-aware cord, lays the focus on awareness, but does not give an answer on how preferred behaviour to reduce energy consumption can be achieved. A second example is The Shower Calendar [27]. When showering, a dot –visualizing 60L of water- becomes smaller until it almost disappears. Aesthetic, large visualizations can be obtained when less water is used. This prototype on the contrary gives real-time feedback on the location of consumption (water usage in the shower) which opens up the possibility for the user to adjust his behaviour. Last, much commented, energy related design example is the Energy Babble [15]. It is an automated talk-radio that is obsessed with energy and the environment. Is has been developed with, and deployed to, a number of existing 'energy communities' in the UK. The Babble can be considered both as a product and as a research tool, in which role it worked to highlight issues, understandings, practices and difficulties in communities. From the review of energy feedback prototypes, we can conclude that the large majority of the energy prototypes are designed for an individual user or appliance. To our knowledge, only the last example addresses broader communities.

ICT Platforms

Next to previously discussed individual smart meters and prototypes, recent studies focus on interfaces for energy, heat or water sharing in groups. Three found examples communicate personal data through an ICT platform. Anda and Temmen [3] demonstrate that the use of advanced metering infrastructure coupled with community based social marketing (CBSM) can achieve a reduction in peak demand and overall energy consumption in an urban electricity meter replacement program. From a second study with an ICT platform for energy sharing in the Netherlands, we learn that participants engage with energy through the concept of energy practice [37]. E-practices go beyond managing energy with smart devices, and can include being actively involved in an energy collective, generating, trading, storing or discussing energy. A third, Swiss pilot study, implements an ICT platform for water sharing. First results indicated reduced water consumption, positive user feedback and suitability of the designed incentive model [31].

Conclusion

From previous research we can conclude that Renewable Energy Communities are relatively new in the energy domain. Current studies focuses on motivations and barriers, they describe the concept from a technical perspective and are less concerned about the needs of the people living in them. When energy feedback is provided to participants, a positive effect on reduction of consumption can be noticed. Guidelines on visualization and feedback to increase awareness and behavior change of the participants have been formulated. However current guidelines focus on individual houses. They don't take newer types of living into account such as projects with collective energy production and sharing or energy management systems where energy can be stored when there is over production in a common battery and use it at a later moment. Therefore we find that guidelines for the design of an interface for a Renewable Energy Community are lacking. Based on interviews, we want to understand

- the openness of REC participants to change energy consumption behavior and how energy consumption feedback guidelines can be applied
- their information needs and the way they want this information to be presented.

These insights will be translated in a design suited for energy, water and heat feedback in a Renewable Energy Community in the city of Ghent, Belgium.

3 Method

3.1 Context of the Renewable Energy Community

Prior to the design, workshops took place with potential habitants of a Renewable Energy Community (REC) and people who recently bought an apartment in the new development. The "Nieuwe Dokken" ("New Docks") is a real-estate development realized in the old harbour of the city of Ghent, in Belgium. The phased construction site will be completed in 2025 and will settle 400 new apartments and houses, shops, offices and various public facilities. In 2020, first residents move in. At full deployment, the district will be an example of a circular economy. It strives to be self-sustaining on 3 levels: water, heat and energy. On a water and heat level, the district will amongst others yearly re-use over 30.000 m^3 of city water (which is over 90% of the total consumption), use of over 500 MWh of waste heat from wastewater of a neighbouring soap factory and produce biogas from local organic waste. On an energy level, the district will supply and store renewable energy with the possibility to store surpluses in a community battery. It will balance energy and avoid dependence on the energy grid. Electrical vehicles will be loaded depending on the supply and demand.

As sources of renewable energy, water and residual heat are scarce for a crowded neighbourhood; consumption is smartly controlled through an Energy Management System (EMS) based on the expected solar energy and the trends in energy demand during the day. Currently, studies take place to demonstrate an economically viable innovative business model. However, the future habitant is not actively involved. He is currently seen as a passive subject, information about consumption balances are shared with them through yearly meetings, newsletters and can be consulted on a website, which is still under construction.

3.2 Focus Groups

To gather information about the user needs and interactions, we used generative focus groups [42]. We give preference to this technique, because as noted by Visser et al. [38], generative techniques give access to latent and tacit knowledge, while techniques like observations and interviews are more likely to reveal explicit and observable knowledge. In total, n = 51 people participated in a total of five focus groups. Of these, n = 35 consisted of people already living, or are actively involved in an energy community.

Since Renewable Energy Communities are very novel in Belgium, participants are scarce. Recruitment of the REC participants was organised by the managers of two RECs that where just running at the moment of the interviews. Participants had already signed for their participation in the community, but they did not experience it yet since the building was still under construction. The 14 remaining respondents were recruited through an online platform. No knowledge about the topic of energy communities was required, but participants needed to own or rent a dwelling. A majority of participants were male (59%), average age was 42 years.

Beside this, n = 2 additional expert interviews with the building promotor specialized in environmental technologies of the district and the company responsible of the ICT platform were held to better understand the technical specifications. The focus groups took a maximum of two hours, and participants where offered a small compensation for their time. The goal of the workshop was twofold. First, we wanted to understand the motivations and barriers to participate in a REC. Respondents actually living or involved in a REC (37 of the 51 participants) could share their experience, others shared how they think and wish to participate in one. Secondly, we questioned their intention to change their behavior being part of an Energy Community and how they would like to be interact with it. The focus groups all followed the same structure and were executed by two researchers. The workshops started by open questions and a discussion on participation in a REC, followed by an exercise with pictures of small and big appliances such as an iron, a dishwasher, an electric vehicle… Participants indicated on the pictures how they would be willing to adapt their consumption according to energy peaks. This, in order to obtain "peak shaving", achieve auto-consumption and production of energy within the district. Finally, potential interfaces to communicate this information were discussed.

4 Development of the Prototype

4.1 Focus Group Results

Main conclusions and their impact on design requirements for a tool to inform and change behavior of participants in an energy community are discussed below in four points.

Knowledge about the Working Principle of a REC

Participants of the newly built REC do not indicate the energy community as the primary reason to purchase a dwelling in the building. The location of the project was generally the main reason for their participation in an energy community, the REC was for the majority of them seen as a nice extra. Consequently, the knowledge about energy communities, functioning and suited behaviour of the people participating in a REC was often low. Participants feel proud to be involved in an ecologic sustainable project and are interested to learn more about it.

> "*I bought a property in the* "*Nieuwe Dokken*"*project. The location was the main reason for that. But if I had the choice between two residents on the same location, one with and one without sustainable energy, I would definitely choose the sustainable one.*" – woman, REC participant

A barrier for many, however, is the fear for the technical aspect. *"What if it breaks? How does it work?"* Participants want to be unburdened. Habitants wish that technical problems are taken care off by experts. Currently, participants are informed about the technicalities and the infrastructure through a yearly meeting with all habitants. In the future they will also be informed by newsletters. There is a concern that habitants are not well informed; this due to newcomers moving in the building in the following years that didn't receive the same information; or people not attending the meetings. This will result in frequent reparations, low efficiency of the system and high maintenance costs.

> "*Living in this REC comes with certain obligations. An example are the vacuum toilets installed in every apartment. Disposal of e.g. sanitary pads can block the*

whole system and will cause high reparation costs. Another example is that the disposal of paint or other chemicals in the sinks could cause an imbalance in our water filtration system. We count on the participation of all habitants to let the community work efficiently". – expert REC project

Motivation to Participate in Peak Balancing

Participants question the effort that the switch to a REC will mean for them. The minority of the participants is willing to change the usage of small electric appliances to decrease their energy consumption (e.g. no use of appliances as TV, radio…). They do not want to lose out on comfort for a minimal financial benefit or for the purpose of a more efficient system. Energy shift of larger energy consuming appliances, however, poses less of a problem. Changing the moment of consumption of devices such as a washing machine, tumble dryer, dishwasher, electric cars is acceptable for most of the participants.

"*I don't want to lose out on comfort. Charging a small device like a camera on a later moment, depending on the energy supply at that time? No way. I'm a professional photographer, I wouldn't allow this*"-man, participant REC project.

"*I want to go reasonably far in adapting my consumption to the energy offering: I see myself cooking at 3 p.m. for a meal in the evening or making Paella outside on a fire to be self-sustaining. I find this need to adapt myself really cool. I find it important to see predictions. Will there be a surplus of energy tomorrow? Then I could prepare myself for this and I will postpone the laundry to the next day.*"– woman, participant REC project

Type of Information Needed

Residents are interested to be informed about incoming and outgoing water, heat and energy flows of the whole district. Also about information which individual habitants can't control such as the litres of water being exchanged with the neighbouring company. They feel proud to be part of such a special project, and wish to understand their impact.

"*I would like to know what the impact is of our community. I would feel proud to know that my ecologic footprint is 10 times lower than the one of someone else in the city, living in a regular home. It would motivate me to behave well.*" – man, participant REC project

In the building all kinds of devices are being monitored in real time: they number of rotations of a pump, the litres of water filtered, the number of cars charged a day, the percentage of the community battery that is filled at the moment… Displaying all the information however would be impossible. The type and depth of information (going from general explanation of the concept to detailed numbers) participants are interested in varies. They are interested to see real-time data and the evolution over time.

"*Today, through my app, I can see my personal data. I would like to know what the largest energy consumers are in the whole building, if we did well, and how I can help in this whole system.*" – man, non-REC participant.

A minority has knowledge about terms like Mega Watt hours (MWh) or m^3 to communicate about the water consumption. There is a general preference to be informed in a rather playful way and receive tips on how to behave. Organising the information by the 3 most important flows: heat, water and electricity responds to the needs of the majority. Clear messages like "don't do the laundry now, but wait until tomorrow morning" will allow people to better adapt their behavior to the needs of the district.

> "*I wouldn't look at graphs and numbers: 30.000 m^3 of city water or 500 MWh. No idea how much this is. For me, the information should be simple and fun to look at. Not telling me the number we have saved, but translating it into Olympic pools of water we have saved or example given in a number of polluting cars less on the road*." -woman, non REC participant

Communication to Involve all Habitants
During the expert interviews with the building promoter and ICT manager, insights on the applied technologies, available sensors, data and the existing communication platform in the building were shared.

Today, they choose to share information through apps, website or message systems. In addition, every apartment will be equipped with a display on which the consumption of all appliances can be consulted. Privacy is respected by showing this on an individual level. Nevertheless, participants indicated that they want information about the entire building. Data about joint achievements are not shared with residents, but participants show their interest and mention the possible positive feeling and motivational effect.

> "*An example of interesting information for me would be the amount of bio waste coming from the wasted shredded in the kitchen that is collected. This would motivate me to sort and give me a positive feeling. These common achievements are not communicated today*." -woman, REC participant

Participants want personal information on a personal device (smartphone, or display in the apartment). However, these displays need to be consulted pro-actively and don't enable them to understand the working of a REC. The need for a public screen with information, tips, realisations of the community are suggested from both community management as habitant side.

Especially older participants prefer having information presented to them instead of looking it up. The entrance of an apartment building, with the possible extension of the same product at other entrances such as the garage or bicycle shed are preferred locations to present the information.

4.2 Focus Group Conclusion and Design Requirements

Based on the most important conclusions of the interviews we want to list up the following requirements. We conclude that there is a need both from the habitants as from the management of the building, to inform people about the working principle of the REC. This to avoid reparations of the recycling system, increase the efficiency and increase awareness about the impact of behavior on the whole system. Currently there exists no such tool. The tool should focus on the information of the district, not about personal data since this could violate privacy and this data is already available on a personal level for the habitants. The participants are motivated to adapt their consumption to current availability of energy resources. Therefor real time data and previsions should be provided. The information should be grouped by topic: heat, water and energy and vary in the depth of information. The majority wants the information presented in a playful way with recommendations on actions to take. On a lower level, more specific data can be shared. Gamification, especially by comparing the own results with results of neighbouring areas is appealing. Finally, participants believe that active participation and awareness will increase by displaying this on a larger interface, instead of having it on a personal device like a smartphone or desktop (Table 2).

Table 2. Translation of interview conclusions into design requirements

Conclusions interviews	Design requirements
Knowledge of the working principle of a REC is low	Habitants should be informed about not only their personal use, but also about the joint achievements of the whole community
Participants are motivated to adapt consumption to the energy offering	Information should be real-time and provide previsions
Information needs of the habitants differ	Information should be grouped by topic (e.g. heat, water, energy) and vary in depth of the information
	Information should contain tips and actions
Need to involve and inform all habitants	Information should be communicated in a playful way, gamification helps to reach these means Information should be displayed on a larger interface, which pulls the attention of all habitants

4.3 Content Development

Based on the results from the interviews and literature, we proceeded with the development of our prototype, the Mona Prisa. The name is a wordplay on the artwork Mona Lisa by Leonardo da Vinci and the French word “prise” (socket). The Mona Prisa is not just a screen, it is a real-time dashboard for renewable energy communities of the future. It displays energy, water and heat flows and informs habitants about ideal consumption patterns based on the expected solar energy and the trends in energy demand during the day. The prototype is designed to be located at the entrance of an CO_2 neutral building with around 100 Units that are part of the Renewable Energy project described above. It will display information about the whole district. Personal information on the consumption (such as the energy usage of every appliance in an apartment, the amount of water used a day) is already foreseen to be displayed by unit, this on a fixed display in the entrance of a dwelling (Figs. 1 and 2).

Fig. 1. Face detection to attract the attention to the screen.

Fig. 2. Background of the painting adapts according to the current energy balance in the district

When a resident enters the hall, the screen switches on by detection with a motion sensor. First, the resident sees an image of the painting. We chose for the Mona Lisa as this is an internationally renowned work, it is characterized by its mysterious smile and creates some curiosity. In addition, the background is a pure, natural landscape. Through capacitive buttons at the bottom of the frame, the user can browse through consumption data in the district and scroll through the pages for more detailed information. We continue to describe the concept based on 3 important features of energy consumption feedback: awareness creation, action-based feedback and gamification.

Awareness Creation

Static images receive less attention. Moving images will better capture the attention of the passing person. The resident's attention is drawn to the digital painting because he sees himself in an environment reflecting the current air pollution. In normal conditions, The Mona Lisa is located in greenery. However, she will be covered in a grey mist when water, heat or energy resources outside the community need to be exhausted to meet the consumption needs of the community at the time of viewing. Research on the long-term use of more traditional smart meters shows inattentive participants over time. Without triggers or invitation to take part in specific activities, the average user loses interest to take part in learning activities to reduce or shift energy consumption [37]. To retain the novelty aspect, we plan updates on the screen. For example, the Mona Lisa can be on a beach in the summer, in a snowy landscape in the winter. Or she could make way for Santa Claus or other moment-bound characters.

The face detection by camera is only used to replace the Mona Lisa face on the painting by the face of the participant. There was a suggestion to use the face recognition to show personal data such as your score compared to the neighbours… Due to privacy reasons, and due to the fact that also many other non-residents will enter the building, this option was not selected.

Action Based Feedback

Real-time data allows for real-time actions. There are 4 buttons (Fig. 5, 6) representing the data categories: a building (for general information), a lighting (energy balance), a water drop (water balance), and fire (heat balance). For all of the data categories there are 3 types of visualisations: an animation with coloured dots moving over the screen visualising the source and consumption, real-time data, and action tips. By turning the knob, the habitant scrolls through the different screens. The real-time data of amongst others the solar panels, car chargers, battery storage and water consumption are displayed to provide the residents with accurate information (Fig. 3). Example given: Is there an energy shortage? Then the building will give instructions on how energy usage can be reduced or postponed in time. Froelich [13] describes the need for granular data, so that data about water consumption in a home should e.g. be divided per faucet. However, interviews revealed granular data on a personal level is not suited for shared buildings. Furthermore, interviewed experts felt it could violate the privacy and lead to an overload of data. Following information is very valuable to the respondents. They would like to be informed and behave according to the needs:

Energy: level of energy production of solar panels and wind mills, level of the community battery which stores energy and number the of electrical vehicle that are disposable to (dis)charge, largest energy consuming devices in de building, tips to adapt consumption in case of low or high production.

Water and Heat: Production of soap by the neighbouring company from which water and heat is exchanged, communication about possible low production due to technical failure or holidays, percentage of water and heat being recycled and reused, largest water and heat consumers in the building, tips to adapt consumption.

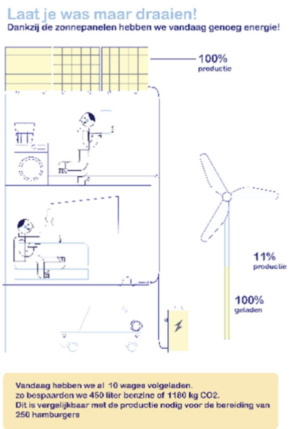

Fig. 3. Action based feedback with real-time data

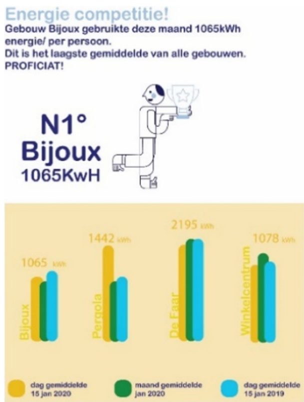

Fig. 4. Gamification through competition between the buildings

Gamification

Sustaining environmental behaviour isn't easy. As an additional motivation to maintain an ecological behaviour, the Mona Prisa adds a gamification element. The gamification element in this prototype has not fully been implemented yet. Currently a simulation is made (Fig. 4). Our expert interviews revealed that comparison between buildings of an energy community will need a corrective factor due to difference in use of the buildings. If one building has a residential purpose and consumes a lot especially in the evenings and weekends. Another building houses a primary school with a very different users. This comparison is perceived unfair by the participants. In a final prototype it might therefor be more appropriate to compare the consumption of the whole district with a regular neighbourhood in the city. This will allow and have a view on how much better the community scores. Next to comparing, it is also possible to set goals that the community wants to reach. example is obtaining a reduction of 2% of water consumption compared to the same month in the previous year. It facilitates comparison of energy consumption between the buildings and enables a fun competition between the residents of the different buildings. The tool does not only compare consumption with neighbouring buildings, but will also compare its consumption with the average consumption of people in the city of Ghent.

4.4 Hardware Development

In the following we give an overview of the different hardware components used in the prototype. Four IR sensors and a rotation encoder (Fig. 5C, D) – read in by Arduino (Fig. 5E)- are used to scroll through the different pages. Main reason not to choose for a large touch display was the price. By holding the hand in front of the icons, the IR sensor switches to the according page.

For face detection, necessary to paste the image of the face of the visitor on the face of the "Mona Lisa" painting, a basic computer Logitech Camera is installed at the top (Fig. 5A). The standard 28-inch TV screen (Fig. 5B) is covered with a laser-cut frame (Fig. 5G). The wooden frame contains the logo of the district, opening for camera and rotation knob and water-, energy- and heat- icons. The number of icons can be expanded depending on the project. Anti-theft measure was considered by placing all valuable components (CPU, TV, sensors) inside the wooden cabinet. We did not opt for extra auditory feedback as this could be disturbing for others in the building and because of the multitude of information this could not be given or updated quickly enough with real-time data.

4.5 Software Development

Data from every device in the building is logged, however for privacy reasons individual data is displayed in the apartments themselves. In the entrance hall, on the prototype, only data of the building and comparisons with the district are showed. The program Unity [41] is used to make the different pages each with their own animations. Running this program was too demanding for the Raspberry Pi, therefor an Intel stick PC' was added. The real-time data used in the animations is recalled from the Api's of the company managing the EMS system; this at a refresh rate of 1 Hz. For the face detection and animation of the Mona Lisa painting filter, a program called Lens Studio was used.

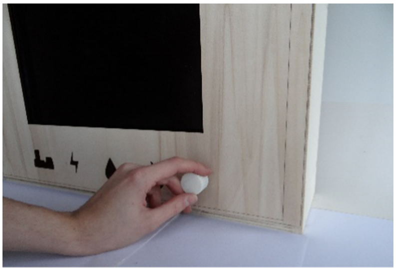

Fig. 5. IR sensors behind the cut-outs and rotation encoder to scroll through the pages.

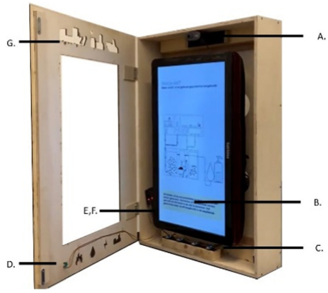

Fig. 6. Components (clockwise) A. camera for face detection, B. 28-inch TV screen, C. capacitive sensors, D. rotation encoder, E. Arduino, F. Intel CPU, G. laser-cut wooden frame

5 Conclusion and Future Work

In this paper, we present the "Mona Prisa", an interactive design for increased awareness and pro-environmental behaviour for habitants of renewable energy communities (REC). Instead of an app or desktop based solution which are currently the standard, it presents energy feedback on a screen, framed like a painting. The prototype attempts to move an individual from being careless about resource consumption to a caring one "Resource Man" who desires to reduce carbon emissions and create an energy efficient power generation. We discuss the user research and literature that were at the basis of the design. Our goal was to understand the openness of participants of Renewable Energy Communities to change their behavior and the type of information that would be suited to help them. Conclusions of 51 interviews have been translated into design requirements for interfaces in energy communities and form the basis of the prototype. Participants of RECs currently have no view on the achievements of the community. An accessible screen, in the entrance of the building with information about the achievements of the community will encourage them to be more aware and change energy behavior. We highlighted 3 features used in the prototype: increased awareness, real-time data and gamification and describe the software and hardware development.

However, the prototype has not been tested with habitants since the building is not fully occupied yet and not all sensor data can be requested. Future tests with the prototype in the hallway of the building, will enable us to better understand which data habitants appreciate most and the impact on their conservation behaviour. Later, the prototype will be refined based on the new acquired insights. Finally, we want to mention that we included non-REC participants to expand our sample due to the limited existence of REC participants. We did not find significant differences of opinion between the groups. However REC participants could be more specific in mentioning the type of interface since they better know the location and the type of information that could be displayed. We aim to continue our collaboration with experts and participants to improve our understanding of design needs for Energy Communities.

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