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Watt-I-See: Probing Future Distributed Energy Scenarios

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Abstract. This position paper discusses a novel perspective on eco-feedback that goes beyond changing consumption behaviours through accountability. Here we describe an interactive installation that displays the ratio of current power generation sources and the percentage of renewables in the grid in an attempt to incite intrinsic values in order to persuade behaviour change. We build upon design insights that strike the complex balance between the awareness of the realities and complexities of user lifestyles on one hand, and a desire to influence their use and consumption behaviours and practices on the other hand. Our preliminary results show an increase in energy literacy and awareness as well as identify high consumer preferences towards simple, representative interfaces and ubiquitous immediate energy production feedback. Our study shows potential in terms of future scenarios for eco-feedback in distributed energy, micro-generation and other inevitable disruptive changes.

1 Introduction

Electricity is the cornerstone of our modern lives. Electrical devices support most of our daily activities as they power our social, governmental and health services. However, our society's increasing demand for electricity (and energy in general) is plainly unsustainable. Notwithstanding, disruptive changes seem inevitable due to a convergence of factors, including climate action, economic downturn, falling costs of energy resources and public policy incentivizing the adoption of new energy technologies. These factors are making distributed micro generation desirable and affordable for consumers. Recently, innovative companies such as Tesla, are pushing technology aiming at reducing the costs of batteries that could take houses with renewable micro-generation off the grid. Still, the increased penetration of renewables poses many challenges for energy management systems and does not necessarily generate a more sustainable future.

Unfortunately, fuel based production still accounts for approximately 40% of the worldwide total energy production of which 28% is accountable for residential use, with an estimation to increase to 32% by 2040 [10]. The attempts to reduce residential consumption through increased efficiency are not reverting this tendency, as households now own more appliances than in the past. Small appliances proliferating in houses are currently estimated to account for half of the consumption, providing a significant margin for individuals to manage residential consumption. HCI research is looking at these phenomena typically from the perspective of encouraging sustainable energy consumption from end-users. Regrettably the results are far from the initial expectations [1,9].

This position paper follows a conviction in which “in order to assess the potential and effectiveness of HCI in environmental practice, it is necessary to inquiry into the contexts in which those practices arise, and to recognize the potential contradictions between the goals of our intervention and the forces that shape their deployments” [2].

2 Watt-I-See: Visualising Energy

HCI research mostly focuses on raising awareness and promoting sustainable energy consumption. These approaches usually rely on some form of eco-feedback technology, i.e. technology that provides feedback on individual or group behaviours with the goal of reducing environmental impact [4]. Our approach builds on the state of the art in a twofold way. First it explores how HCI and design research envisioned energy and, in particular, the tension between the seamless and ubiquitous nature of energy as a service provided to consumers, and the inherent intangible and invisible nature of the underlying commodity [6]. Secondly it tries to go beyond traditional eco-feedback by combining production and consumption information coming from a medium size closed grid with a high penetration of renewables.

Both these approaches have been tested in small isolated studies in which the source of the energy was included in the eco-feedback visualization (e.g. [3,7]), and in studies that aimed to present the intangibility of energy (e.g [5]).These studies reported an increase in consumer’s interest and knowledge about electricity consumption.

Watt-I-See (WISE) is an interactive installation constructed with the ambition to raise awareness about energy production. Our goal with WISE was to first explore a tangible design that could reconcile the seamless and ubiquitous nature of the electricity. Secondly to approach the design challenge and go beyond the conventional micro-generation scenarios, combining production and consumption information from a medium-size grid setup. The aim with WISE was to provide actionable design guidance for creating novel eco-feedback systems based on real time consumption and grid power generation data. This is particularly valuable because literature lacks designs that explore the disruptive changes emerging from the convergence of economic, technological and environmental factors. This study is further relevant because it provides actionable design guidance for creating novel eco-feedback systems based on mixed real-time production and consumption information.

WISE explores a large ecosystems taking advantage of a closed circuit energy system of an island in Europe with more than 270 thousand inhabitants. The average yearly electrical distribution is as follows: 78% of all energy is produced from thermoelectric plants, 11% from hydroelectric stations, 9% from wind parks and 2% from dispersed photovoltaic sources. We argue that our deployment in medium-sized isolated grid anticipates several issues that go beyond micro-generation scenarios and where the complex balance between the production / consumption reality and the individual / collective behaviours are closer to the future scenarios we might envision in the evolution of larger grids.

3 Interaction

Participants could interact with the Watt-I-See installation in three modes:

- *Physically engaging with the installation*: participants have to pedal on an exercise bike to surpass a micro-generation step to "power up" the installation. The energy produced does not influence the installation or the data it displays, rather its goal is to contextualize one's physical effort in producing electricity through a questionnaire on a tablet lying on the bike handle (See Figure 1 left).
- *Acknowledging the visual interface*: learning about percentages of renewable versus fossil energy being produced in that moment on the island. The WISE presents viewers with the real time values for the electricity produced locally.
- *Querying the interface of the installation*: the third mode of interaction allows participants to construct different days through cards representing several weather conditions and time-of-day. The visualization is then updated with the view its corresponding (real data) production quotas for those conditions.

3.1 The Vortices: Disaggregated Production Quotas

WISE resorts to an analogy of "x-raying" a household wall, displaying four glass pipes containing a colored vortex, each representing a energy production source available locally: thermoelectric power stations, wind parks, hydroelectric stations and photovoltaic. The glass pipes contain distilled water and liquid paraffin. Each vortex is colored in order to represent a different energy source: dark purple for thermal energy, clear color for wind, dark blue for hydro and yellow for solar energy source. The size of the vortex, ranges from very low to very high in nine levels representing different quotas in percentage. The size of the vortices is measured from the top of the tube 0cm to the bottom 30cm. The highest level creates a more aggressive vortex to represent over 91% (limit selected by average maximum thermal quota) of quota from an individual production source. These levels represent the quota of energy produced and available to final consumers, thus the sum of all four vortices totals 100% (See Figure 1 right).

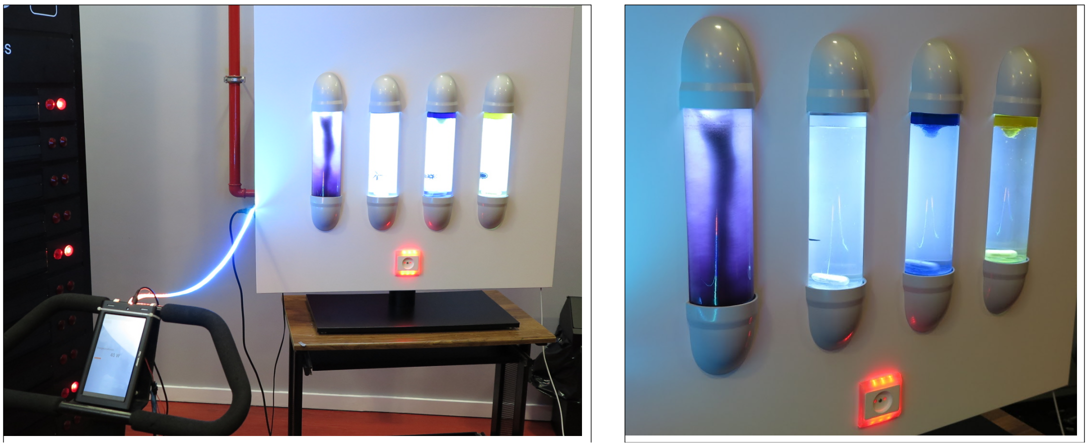

Figure 1: Left: Set up for the study with the exercise bike and the panel with the vortices. Right: Fossil source over 91%, 0% wind, hydro and solar sources between 1-3%. The socket is glowing red.

3.2 The Glowing Socket: Renewable Energy Feedback

In addition to the vortices, the power socket provides additional feedback on the overall quota of renewable energy in the grid. While the glass tubes and vortices display individual source production quotas, the power socket displays the cumulative quota of renewable energy in the power grid. Five renewable feedback levels were defined based on three years of disaggregated production quotas. Each level displays on the power socket a corresponding pulsing color (See Figure 2).

4 Implementation

4.1 Grid Electricity Production Data

The electricity production data, updated every fifteen minutes, is obtained directly from the regional energy provider currently the primary entity responsible for the distribution of electricity in the island. Additionally, the regional provider distributes, through a prediction model, the estimate production quotas for the next 12 hours.

4.2 Production Visualization

Watt-I-See measures 1.22m x 0.9m built from wood and covered in matte white vinyl. Four glass tubes (9x30cm) are used to represent the individual production sources. Vortices are created by DC motors controlled by an Arduino microcontroller. The DC motors rotate a large magnet that subsequently rotates a magnetic bar inside the glass tube creating the vortex. A smaller magnet and Hall effect switch is used to calculate the rpm's of each motor in order to leverage the rotation between the different tubes. Additionally, LED strips and drivers are used to retro-illuminate the glass tubes that are covered in tracing paper and contain the printed icons for each energy source.

The electricity socket is a common power socket where the outer bezel was 3D printed using a transparent PLA. The color of the socket is obtained by RGB LEDs and is based on several conditions queried in real-time to the database: 1) current real-time production quotas; 2) current day averages; 3) week averages; 4) month averages; 5) five hour prediction quotas. When providing feedback to consumers (or suggesting usage), WISE queries the database for the updated production data, to display through the vortices, and queries the database for a feedback value (between 1 red, and 5 green). An algorithm, which takes into account current and historical productions values, and the forecast for the rest of the day, returns a weighted value that measure how "green" the current production values are. The weighted value is finally compared to the overall three-year production averages, where minimums, maximums, averages and standard deviations were calculated to define the five feedback regions (see Figure 2).

An application was built in Processing in order to interface the Arduino and the web services allowing for additional interaction, such as choosing specific weather conditions and viewing real production data for those conditions and interaction with the exercise bicycle.

4.3 Micro generation

The micro generation step was performed through a repurposed exercise bike. A stepper motor was attached along with a rectifier circuit (converts AC to DC current) and voltage divider to limited voltage to 5V (input to an Arduino microprocessor) - which is responsible for calculating the electricity generated. An android tablet placed on the handlebars displays the progress. Additionally a digitally addressable (60) LED provides interaction feedback, such as: 1) standby status; 2) production feedback with a flow of energy effect and simultaneous progress bar; 3) goal attained; 4) regress/reset.

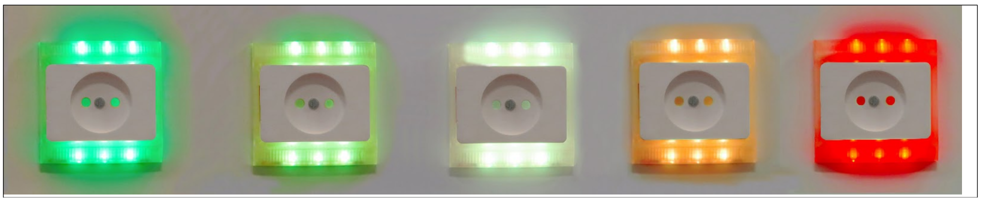

Figure 2: The power socket's five renewable energy feedback levels, from green (over 53% renewable) to red (less than 9%)

5 Results and Discussion

We conducted a preliminary evaluation of WISE using a combination of surveys, observations and interviews before and after 10 participants interacted with it. Figure 1 left displays the set up for this study. Next we present our major observations after all our interactions with participants where transcribed and organized according to the recurring themes.

5.1 Energy Literacy and Renewable Awareness

Being able to observe the values of the local energy production clearly increased participants' knowledge of the local grid and the efforts used to produce electricity. This observation has been called an increase in energy literacy [8] and is the result of an increase consumer's awareness.

5.1.1 Seeing is Believing

Results from the New Ecological Paradigm survey point out to consumers' awareness about the sources of energy, the different generation techniques and natural resources. However, during the study a majority of participants overestimate the impact of some renewable sources such as solar energy and widely underestimate the presence of hydroelectric and wind energy in the grid. Energy awareness, especially pertaining to renewable sources, seemed to have an almost direct relation to participant exposure to the mechanisms used to produce them.

5.1.2 Memorable Events Incite Recall

The follow up survey, performed 8 to 10 days after the short exposure to WISE, found improved energy awareness results. Respondents were more aware of the source of their electricity and showed improved knowledge regarding how local electricity is produced and which sources are present in the grid.

5.1.3 Energy Production Efforts

The micro-generation procedure found a general lack of knowledge on the efforts needed for producing the electricity for domestic consumption. Low power longer usage appliances and devices seemed easier to understand and produced more correct answers, while high power appliances such as kettles yielded the most number of incorrect assumptions. It was clear that the notion of electrical power (watt hour) was complicated to grasp.

5.2 Exploring Materializing Energy through Movement

The simplistic representation of the energy production quotas thought the size of the colored vortex allowed for an attractive, understandable, almost mesmerizing effect, that was suggested to be faster to check and more intuitive. A stronger impact at times was noted. People felt somewhat worried when viewing the fossil vortex at its maximum scale how aggressive it looked. Others commented on the difference between fossil and renewables as depressive, something that needed to be dealt with.

5.3 The Importance of Feedback Immediacy

One of the preferred aspects of WISE was feedback immediacy. Providing immediate feedback was found as a two-fold design concern:

- Immediacy of feedback: Easy to understand, "at a glance" information. The glass tubes and vortices provide just enough information to inform a decision.
- Immediacy of interaction: feedback power socket is as close to the point-of-interaction as possible, however, possible at times not the most visible due to the location of power socket.

6 Conclusion

In this position paper we argue that HCI contributions in the domain of energy awareness and sustainable energy consumption, in particular, conventional ecofeedback, are detached from the wider political and economic contexts in which the utility business is evolving. The various disruptive challenges facing public utilities have different implications, but they all create adverse impacts on revenues, investor returns and ultimately energy price and usage and hence environmental impact. The WISE installation is a first attempt to physically represent grid production sources and quotas with an overall feedback mechanism. As such it was generally well accepted by our sample of users. Our preliminary study showed evidence about increased awareness and stimulated a dialogue about the different sources of energy, their relationship with weather and other context conditions and finally the consumption patterns in households. Here we attempted to provide some preliminary design insights for creating eco-feedback displays that strike a complex balance between the awareness of the realities and complexities of user lifestyles on one hand, and a desire to influence their use and consumption behaviours and practices on the other.

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