Designing and Evaluating Ambient Tangible Interfaces for Shifting Energy Supply in the Workplace

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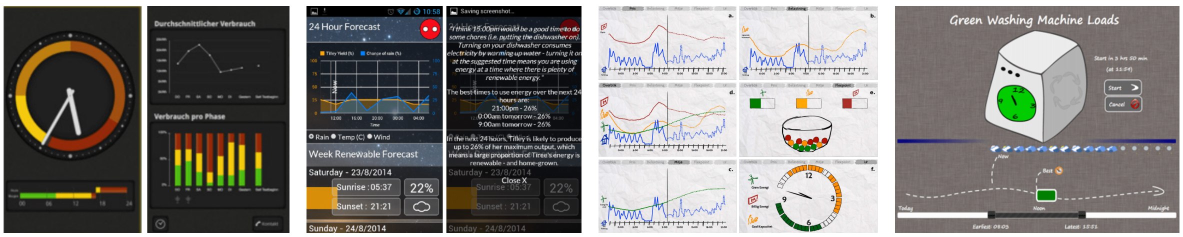


(a) FORE-Watch [17] (b) Tiree Energy Pulse [18] (c) eForecast [13] (d) Conversation Washing Machine [3]

Figure 1: Four graphical interfaces for shifting energy supply in households.

ABSTRACT
The electrical grid must always be supplied with as much electricity as is taken from it. However, the greater the share of fluctuating renewable energy sources, the more difficult it becomes to manage power supply. In order to help, interactive systems have been designed to encourage users in using renewable energy when there is plenty of it rather than when there is little (i.e. shifting energy supply). Most of these systems use ambient interfaces to represent forecast information on the availability of renewable energy. Yet, it is unclear which ambient interfaces are more effective in enhancing ambient awareness and maintaining new practices for shifting energy supply. We think that parameters such as perceptible artefacts (e.g., shape-changing, color-changing) influence the effectiveness of ambient interfaces. To answer this concern, we study shifting energy supply with laptops in the workplace. Because practices for shifting energy supply with laptops have yet to be identified, we introduce a tool for simulating and exploring such practices. Furthermore, we evoke the design of a dynamic bar chart for visualizing renewable energy forecasts. Using different ambient parameters, we will study how this design enhances ambient awareness and helps employees to shift energy supply with laptops in the workplace.

ACM Classification Keywords
H.5.2 User Interfaces: Interaction styles, Theory and methods; H.1.2 User/Machine Systems: Human factors

Author Keywords
Sustainable HCI; Persuasive Technology; Calm Technology; Peripheral interaction; Tangible interaction; Energy; Workplace.

INTRODUCTION
In 2013, the world capacity to generate renewable energy increased by 8.5%. As a result in 2014, the renewable energy share of global electricity production reached 23.7% [16]. As energy generation shifts to renewables and microgeneration, the interplay between supply and demand will be increasingly difficult. Critical problems such as peak demand can lead to power outages, and make current grids inefficient [4]. These issues will be exacerbated due to the supply of renewables fluctuating with the weather (e.g., sun, wind, wave, tide) and limited storage capacity [10]. Unless storage of energy becomes viable to avoid blackouts becoming normality [21], we will need to synchronize our consumption with the availability of this resource.

Recently, interactive systems have been designed to encourage users in using renewable energy when there is plenty of it rather than when there is little. This strategy called *Shifting Energy Supply* is being actively studied by HCI (e.g., [3,13,17,18]). For now, most of the designed systems help households to plan their everyday energy usages with forecast information on the availability of renewable energy. These systems use a variety of ambient interfaces to subtlety inform inhabitants without being intrusive. Yet, it is unclear

(a) Flower Lamp [1], using a shape-changing artefact.

(b) Energy Local Lamp [14], using a color-changing artefact.

Figure 2: Two ambient tangible interfaces using different perceptible artefacts.

which ambient interfaces are effective in enhancing ambient awareness and maintaining new practices for shifting energy supply. In our work, we wish to study the influence of parameters such as perceptible artefacts (shape-changing (e.g., Figure 2-*a*), color-changing (e.g., Figure 2-*b*)) on the effectiveness of ambient interfaces. To answer this concern, we will design and evaluate *in the wild* an ambient tangible interface for encouraging employees to shift energy supply with laptops in the workplace.

In this paper, we describe our motivation behind designing and evaluating ambient tangible interfaces for shifting energy supply. We then explain our interest for studying shifting energy supply with laptops in the workplace. Because such practices have yet to be identified, we introduce a tool for simulating and exploring practices for shifting energy supply with laptops. Furthermore, we evoke the design of a dynamic bar chart for visualizing renewable energy forecasts. Using different ambient parameters, we will study how this design enhances ambient awareness and helps employees to shift energy supply with laptops in the workplace. Finally, we present our future works.

RELATED WORKS

Our work intersects two main fields: *Peripheral Interaction* and *Ambient Persuasive Technology*.

Peripheral Interaction

Ambient Awareness makes human beings aware of (changes in) surrounding information [23]. In 1996, Weiser and Brown [22] defined *Calm Technologies* as technologies able to move from the peripheral attention to the central attention of users, and backwards. They affirmed that calm technologies enhance ambient awareness by bringing more details into the periphery: it makes users aware of what is happening around them, what is going to happen, and what has just happened [22]. In line with calm technologies, *Ambient Interfaces* use perceptible artifacts (e.g., shape, motion, sound, color, light, smell, air) to represent unobtrusively (changes in) digital information. In 2015, Bakker et al. [2] noted that recent studies have been conducted under the term *peripheral interaction*, aiming to broaden the scope of calm technology by designing not only for the *perceptual* periphery but also enabling users to *physically interact* with the digital world in their periphery.

Ambient Persuasive Technology

In 1998, Fogg [7,8] defined *Persuasive Technologies* as interactive systems intentionally designed to change attitudes and/or behavior, without using deceit or coercion. In 2010, Ham [11] described *Ambient Persuasive Technologies* as interactive systems intentionally designed to change attitudes or behavior or both, that can be integrated unobtrusively into the environment and exert an influence on people without the need for their central attention.

MOTIVATION

The following subsections described our motivation behind designing and evaluating ambient tangible interfaces.

Designing Ambient Tangible Interfaces for Shifting Energy Supply

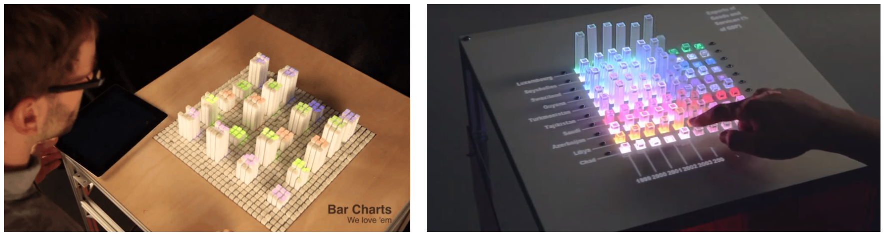
Most of the interactive systems designed for shifting energy supply use graphical interfaces (pixel-based interfaces, Figure 1). To the best of our knowledge, only one work [15] studied ambient tangible interfaces (object-based interfaces, Figure 2) for shifting energy supply. Yet as evoked by Zuckerman [24], tangible interfaces have strengths that can contribute to "change what people think and do" [7] : *Visibility and Persistance*; *Situatedness*; *Tangible representation*; and *Affordances*.

Evaluating Ambient Interfaces in the wild

In 2011, Hazlewood et al. [12] discussed the complex task of evaluating ambient interfaces. They described how these technologies have been evaluated in lab settings, where the focus has been primarily on issues of usability. They argue strongly for the necessity of in-situ evaluation. For example, they proposed to evaluate ambient interfaces by logging the number of times the system is used by conducting interviews or by assessing the effects (e.g., by counting how many people take the stairs instead of the elevator as a result of installing peripheral displays that promote using the stairs).

APPLICATION DOMAIN : SHIFTING ENERGY SUPPLY IN WORKPLACES WITH LAPTOPS

The household is the most common target of the systems designed for shifting energy supply (Figure 1). Yet, collective and public spaces such as workplaces seem to be privileged spaces for encouraging users in shifting energy supply: in 2014, services, transports, and industries counted for 13.3%,



(a) inFORM [9] (b) EMERGE [19]

Figure 3: Two dynamic physical bar charts.

25.9% and 33.2% of UE overall energy demand against 25% for households [6].

However, shifting energy supply in workplaces can be frustrating: when little renewable energy is available, employees may have no other choice but to use energy to achieve their everyday tasks. A recent study [13] mentions that shifting energy supply in households was more realistic with appliances that could be de-coupled from everyday routines such as washing machines, dishwashers, or battery chargers. In 2014, 66% of the companies of the UE-28 had equipped their employees with laptops, smartphones, and others mobile devices [5]. Mobile devices such as laptops can run on battery, allowing employees to shift energy supply without interrupting their everyday tasks that require computation: when there is plenty of renewable energy, employees can plug their laptop to consume and store renewable energy. On the contrary when there is little of renewable energy, employees can unplug their laptop and proceed with their laptop running on battery.

WORK IN PROGRESS: IDENTIFYING PRACTICES FOR SHIFTING ENERGY SUPPLY WITH LAPTOPS

Before encouraging employees for shifting energy supply with their laptop, we need to identify appropriate practices to promote. For the moment, most of the laptops available on the market come with Lithium-ion (Li-ion) batteries which are widely used as power supply for consumer electronics. However, Li-ion batteries do not have linear (dis)charge curves, meaning that specific levels of battery take more time to charge and less time to discharge than others: several short (dis)charges between two specific levels of battery could be more appropriate for shifting energy supply than a deep (dis)charge.

To answer this concern, we designed a tool for simulating laptop practices for shifting energy supply [1]. The tool implements a Li-ion Battery Dynamic Model [20]. It takes in input: the energy production mix (e.g., 10:00-11:00 – 90% renewable and 10% nonrenewable); the laptop configuration (e.g., nominal power consumption, nominal current of charge, current state of charge), and the laptop practices (e.g., 10:00-11:00 – laptop with battery plugged to the grid, 11:00-12:00 – laptop with battery unplugged from the grid). The tool gives in output the consequences of laptop practices on the sector energy consumption (e.g., 100 Wh taken from the grid at 40% renewable and 60% nonrenewable) and on the battery energy storage (e.g., 80 Wh stored in the battery at 30% renewable and 70% nonrenewable).

[1] http://itame.estia.fr/simulator/

WORK IN PROGRESS: DESIGNING A DYNAMIC PHYSICAL BAR CHART FOR RENEWABLE ENERGY FORECASTS

The stability of the electrical grid requires power supply to constantly meet power demand. Since energy generation started to shift to renewables and microgeneration, forecasting the fluctuation of renewable energy sources has become essential for balancing supply against demand. Such forecasts are commonly used by the interactive systems we identified, helping users to plan their every day energy usages according to the avaibility of renewable energy [3,13,17,18]. These systems use a variety of dynamic graphical visualizations of renewable energy forecasts: FORE-Watch (Figure 1-a) uses a graphical clock for each minute of the next hour and a graphical timeline chart for the next 24 hours; Tiree Energy Pulse (Figure 1-b) uses a graphical line chart for the next 12 hours; and eFORECAST (Figure 1-c) uses a graphical clock for each minute of the next hour and a graphical line chart for the next 12 hours.

Bar charts are data visualizations commonly used for showing the differences, or making comparisons, between different variables. Inspired by several works on dynamic data visualization such as EMERGE [19] (Figure 3a) and inFORM [9] (Figure 3b), we will design a dynamic physical bar chart for visualizing renewable energy forecasts of each hour of the workday. We think such design can help employees to quickly identify hours of the workday when there will be plenty of renewable energy.

CONCLUSION & FUTURE WORK

In order to reduce environmental impact, interactive systems have been designed to encourage users in using renewable energy when there is plenty of it rather than when there is little (i.e. shifting energy supply). These systems use a variety of ambient interfaces to unobtrusively inform users on the availability of renewable energy. Yet, it is unclear which ambient interfaces are effective in enhancing ambient awareness and maintaining new practices for shifting energy supply. We think that parameters such as perceptible artefacts (e.g., shape-changing, color-changing) influence the effectiveness of ambient interfaces. To answer this concern, we will design a dynamic physical bar chart for visualizing renewable energy forecasts, helping employees to shift energy supply with laptops in the workplace. However, laptop practices for shifting energy supply have yet to be identified. Therefore, we developed a tool for simulating such practices. Using this tool, We will identify laptop practices to promote with the dynamic data visualization we proposed.

Through a longitudinal approach in a workplace, we will evaluate the effects of different parameters such as perceptible artefacts (shape-changing (e.g., Figure 2-*a*), color-changing (e.g., Figure 2-*b*)) on the effectiveness of our design in enhancing ambient awareness and maintaining practices for shifting energy supply with laptops.

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