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► **To cite this version:**

Maxime Daniel. Designing and Evaluating Ambient Tangible Interfaces for Shifting Energy Supply in the Workplace. 3rd European Tangible Interaction Studio, Jun 2017, Esch/Alzette, Luxembourg. hal-01685710

**HAL Id: hal-01685710**

**<https://hal.science/hal-01685710>**

Submitted on 16 Jan 2018

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

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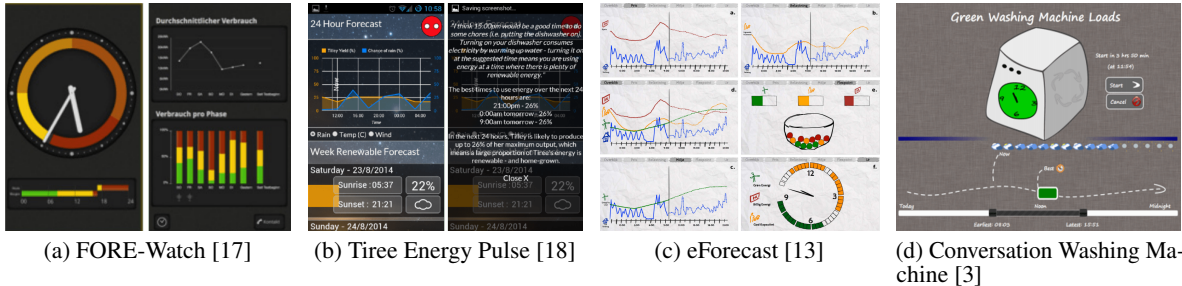


Figure 1: Four graphical interfaces for shifting energy supply in households.

## 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 subtly 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 Persistence; 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%,



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<sup>1</sup>. 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).

#### 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 availability 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,

<sup>1</sup><http://itame.estia.fr/simulator/>



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.

## REFERENCES

1. Sara Backlund, Magnus Gyllenswärd, Anton Gustafsson, Sara Ilstedt Hjelm, Ramia Mazé, and Johan Redström. 2007. Static! The aesthetics of energy in everyday things. In *Proceedings of the Design Research Society International Conference: Wonderground 2006 (DRS '06)*. 14 pages.
2. Saskia Bakker, Elise van den Hoven, and Berry Eggen. 2015. Peripheral interaction: characteristics and considerations. *Personal and Ubiquitous Computing* 19, 1 (2015), 239–254. DOI: <http://dx.doi.org/10.1007/s00779-014-0775-2>
3. Enrico Costanza, Joel E. Fischer, James A. Colley, Tom Rodden, Sarvapali D. Ramchurn, and Nicholas R. Jennings. 2014. Doing the Laundry with Agents: A Field Trial of a Future Smart Energy System in the Home. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 813–822. DOI: <http://dx.doi.org/10.1145/2556288.2557167>
4. Frontier Economics and Sustainability First. 2012. Demand side response in the domestic sector-a literature review of major trials. *Final Report, London, August* (2012).
5. European Union (EU). 2015. Statistiques sur la société de l'information - entreprises. (2015).
6. European Union (EU). 2016. *Energy balance sheets 2014 data*. Publications Office of the European Union. DOI: <http://dx.doi.org/10.2785/795827>
7. Brian J. Fogg. 1998. Persuasive Computers: Perspectives and Research Directions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '98)*. ACM Press/Addison-Wesley Publishing Co., New York, NY, USA, 225–232. DOI: <http://dx.doi.org/10.1145/274644.274677>
8. Brian J. Fogg. 2002. Persuasive Technology: Using Computers to Change What We Think and Do. *Ubiquity* 2002, Article 5 (December 2002). DOI: <http://dx.doi.org/10.1145/764008.763957>
9. Sean Follmer, Daniel Leithinger, Alex Olwal, Akimitsu Hogge, and Hiroshi Ishii. 2013. inFORM: Dynamic Physical Affordances and Constraints Through Shape and Object Actuation. In *Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology (UIST '13)*. ACM, New York, NY, USA, 417–426. DOI: <http://dx.doi.org/10.1145/2501988.2502032>
10. David Hafemeister. 2010. Sustainable energy without the hot air. (2010).
11. Jaap Ham and Cees Midden. 2010. Ambient Persuasive Technology Needs Little Cognitive Effort: The Differential Effects of Cognitive Load on Lighting Feedback Versus Factual Feedback. In *Proceedings of the 5th International Conference on Persuasive Technology (PERSUASIVE '10)*. Springer-Verlag, Berlin, Heidelberg, 132–142. DOI: [http://dx.doi.org/10.1007/978-3-642-13226-1\\_14](http://dx.doi.org/10.1007/978-3-642-13226-1_14)
12. William R. Hazlewood, Erik Stolterman, and Kay Connelly. 2011. Issues in Evaluating Ambient Displays in the Wild: Two Case Studies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 877–886. DOI: <http://dx.doi.org/10.1145/1978942.1979071>
13. Jesper Kjeldskov, Mikael B. Skov, Jeni Paay, Dennis Lund, Tue Madsen, and Michael Nielsen. 2015. Facilitating Flexible Electricity Use in the Home with Eco-Feedback and Eco-Forecasting. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction (OzCHI '15)*. ACM, New York, NY, USA, 388–396. DOI: <http://dx.doi.org/10.1145/2838739.2838755>
14. James Pierce and Eric Paulos. 2010. Materializing Energy. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS '10)*. ACM, New York, NY, USA, 113–122. DOI: <http://dx.doi.org/10.1145/1858171.1858193>
15. Filipe Quintal, Clinton Jorge, Valentina Nisi, and Nuno Nunes. 2016. Watt-I-See: A Tangible Visualization of Energy. In *Proceedings of the International Working Conference on Advanced Visual Interfaces (AVI '16)*. ACM, New York, NY, USA, 120–127. DOI: <http://dx.doi.org/10.1145/2909132.2909270>
16. REN21. 2016. Renewables 2016 Global Status Report. (2016).
17. Johann Schrammel, Cornelia Gerdenitsch, Astrid Weiss, Patricia M. Kluckner, and Manfred Tscheligi. 2011. FORE-Watch – The Clock That Tells You When to Use: Persuading Users to Align Their Energy Consumption with Green Power Availability. In *Proceedings of the 2nd International Conference on Ambient Intelligence (AmI '11)*. Springer Berlin Heidelberg, Berlin, Heidelberg, 157–166. DOI: [http://dx.doi.org/10.1007/978-3-642-25167-2\\_19](http://dx.doi.org/10.1007/978-3-642-25167-2_19)

18. Will Simm, Maria Angela Ferrario, Adrian Friday, Peter Newman, Stephen Forshaw, Mike Hazas, and Alan Dix. 2015. Tiree Energy Pulse: Exploring Renewable Energy Forecasts on the Edge of the Grid. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1965–1974. DOI : <http://dx.doi.org/10.1145/2702123.2702285>
19. Faisal Taher, John Hardy, Abhijit Karnik, Christian Weichel, Yvonne Jansen, Kasper Hornbæk, and Jason Alexander. 2015. Exploring Interactions with Physically Dynamic Bar Charts. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 3237–3246. DOI : <http://dx.doi.org/10.1145/2702123.2702604>
20. Olivier Tremblay and Louis-A Dessaint. 2009. Experimental validation of a battery dynamic model for EV applications. *World Electric Vehicle Journal* 3, 1 (2009), 1–10.
21. Frank Trentmann. 2009. Disruption is normal: blackouts, breakdowns and the elasticity of everyday life. *Time, consumption and everyday life: Practice, materiality and culture* (2009), 67–84.
22. Mark Weiser and John Seely Brown. 1996. Designing calm technology. *PowerGrid Journal* 1, 1 (July 1996), 75–85.
23. Craig Wisneski, Hiroshi Ishii, Andrew Dahley, Matthew G. Gorbet, Scott Brave, Brygg Ullmer, and Paul Yarin. 1998. Ambient Displays: Turning Architectural Space into an Interface Between People and Digital Information. In *Proceedings of the 1st International Workshop on Cooperative Buildings, Integrating Information, Organization, and Architecture (CoBuild '98)*. Springer-Verlag, London, UK, 22–32. DOI : [http://dx.doi.org/10.1007/3-540-69706-3\\_4](http://dx.doi.org/10.1007/3-540-69706-3_4)
24. Oren Zuckerman. 2015. Objects for Change: A Case Study of a Tangible User Interface for Behavior Change. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '15)*. ACM, New York, NY, USA, 649–654. DOI : <http://dx.doi.org/10.1145/2677199.2687906>