

# Designing Information Technology for Sustainable Energy Use

A Practice Centered Approach to Consumption Feedback  
Technologies in Private Households and Work  
Environments

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Dissertation

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Tobias Schwartz

zur Erlangung des Doktorgrades Dr. rer. pol.

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Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9

Internet: [www.shaker.de](http://www.shaker.de) • e-mail: [info@shaker.de](mailto:info@shaker.de)

## Foreword by the Institute Director

„Resource efficiency“ as the basis for sustainable economic activity is a key goal of the Fraunhofer Society. The Fraunhofer Institute for Applied Information Technology FIT approaches sustainability from three angles: cyberphysical systems support for energy efficiency, financial sustainability by risk management in private business and the public-sector, and the adaptation of and to human qualifications and competencies in a time of demographic change.

This book builds an innovative bridge between two of these aspects : human-centered IT design and energy efficiency. It questions the popular hypothesis that electricity users will automatically reduce energy consumption if confronted with information about their energy usage and its consequences, by analyzing in depth under what conditions such informative Information Technology is adopted by users at all, how it will impact their consumer behavior, and how sustainable this influence of IT on behavior will be in the long run. Design criteria that take these aspects into account have been developed and empirically evaluated in the context of several Living Lab studies both in a business and in a domestic context.

To our knowledge, the book is unique in that it presents the first in-depth empirical studies of energy feedback systems, combined with an iterative design of specific suitable technological solutions that appear to have a good chance to successfully address the above issues. The international recognition that Dr. Tobias Schwartz has already received from this work, is reflected in the fact that partial results have been published in both the top journal (ACM Transactions on Computer-Human Interfaces ToCHI) and three times in the top conference (CHI) of the Computer-Human Interaction field. The University of Siegen accepted this work as a doctoral thesis awarded with distinction in the summer of 2013, with Professors Gunnar Stevens and Volker Wulf as supervisors.

The book should be of great interest to researchers in the fields of energy sustainability and human-computer interaction from a methodological point of view, but also to companies and homeowners aiming at sustainable energy savings. Besides the specific study results, an excellent overview of the issues and state of the art in the introductory chapters make the book interesting reading not just to specialists.

Aachen, October 2013

Prof. Dr. Matthias Jarke

Institute Director, Fraunhofer FIT

Die Institute des Fraunhofer-Verbunds Informations- und Kommunikationstechnik (IuK) entwickeln gemeinsame Strategien für die anwendungsorientierte Forschung. In der Reihe „Fraunhofer Series in Information and Communication Technology“ publizieren die IuK-Institute Dissertationen, Habilitationen sowie herausragende Diplomarbeiten, wissenschaftliche Monographien und Forschungsberichte. Diese Publikationen dienen der Fundierung der anwendungsnahen Fraunhofer-spezifischen Forschung und Vorlaufforschung.

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## **Abstract**

One of the great challenges of the current century is moving away from an increasingly energy hungry society towards a society that is less consumptive and more sustainable. For this “energy turnaround” to happen, one important element is the reduction of residential and workplace energy consumption by encouraging and fostering sustainable behavior and lifestyles.

As a reaction to the discussion on global warming, research in the field of Sustainable Interaction Design (SID) has started to explore the design of tools to support responsible energy consumption. An important part of this research focuses on motivating people to save energy by providing them with feedback tools presenting consumption metrics in an interactive way. In this line of work, the configuration of feedback has mainly been discussed using cognitive or behavioral factors. This focus, however, misses a highly relevant perspective in the design of supportive technology, namely, the multiplicity of forms in which individuals or collectives actually consume energy and the related socio-technical context around the use of feedback technology.

This thesis presents the results of an in-depth exploration of the practice of using interactive feedback systems. In contrast to existing research focused on the cognitive aspects of the use of feedback, in this work I follow a practice-centered approach. I conducted a series of extensive ethnographic studies based on the introduction of prototypes and design probes in several contexts, both in workplace environments and in private households, in order to observe how people understand, explain and incorporate feedback systems into their daily lives.

I analyze and discuss the results of my studies, paying special attention to the social configuration of energy consumption. This exploration resulted in the description of several sophisticated methods used by people to organize their energy practices; and revealed how people make their consumption accountable and explainable with the help of

interactive feedback systems. The observation of a self-developed consumption feedback system within a living lab setting led my work to provide rich descriptions of nine relevant and meaningful issues emerging from aspects of appropriating consumption feedback in real live environments. These issues show how consumption feedback systems support the creation of energy literacy and influence important values such as trust and identification. These issues provide the basis for a description of relevant elements to support a design rationale for designing ICT technologies supporting more sustainable lifestyles.

## Acknowledgment

This research project would not have been possible without the support of many people.

I wish to thank, first and foremost, all my colleagues at Fraunhofer FIT, especially Leonardo Ramirez, Sebastian Deneff, Tobias Dyrks and my supervisors Gunnar Stevens and Volker Wulf, head of Usability Engineering Services group at FIT, for the invaluable assistance, support and guidance. Without the thoughtful discussions and inspiring guidance this research would not have materialized. I am especially grateful to Gunnar Stevens for his tutorage and all the inspiring thoughts. Many of the ideas and insights of my research are based on the interesting discussions we had during the time I worked on my thesis.

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I also thank the participating households, workers and our project team for their invaluable support in my study. Furthermore, I would thank the Ministry of Innovation, Science, Research and Technology of North Rhine-Westphalia, Germany and the European Commission in the context of the Ziel 2 framework (No. 280411902) who partially funded this research.

Last but not least, I cannot find words to express my gratitude to my beloved parents for their encouragement and my friends for their help for the successful completion of this research. Especially, to my girlfriend who has always supported me through the years; without their support and encouragement, this dissertation would not have been possible. Thank you.

## Related Publications

The research presented in this work has partly been previously published, presented and discussed with scientist in the field of Human-Computer Interaction and Sustainable Interaction Design. The following list provides an overview of the published articles.

### Full Papers

#### **Soziale Dimensionen von Smart Metering am Arbeitsplatz.**

Betz, M. and Schwartz, T., in *Proc. Multikonferenz Wirtschaftsinformatik 2010*, Universitätsverlag Göttingen (2010), 341-352.

#### **Sustainable energy practices at work: Understanding the role of workers in energy conservation.**

Schwartz, T., Betz, M., Ramirez, L. and Stevens, G., In Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries (Reykjavik, Iceland, October 16 - 20, 2010), NordiCHI 2010. New York, NY: ACM Press. p. 452-462.

#### **Smart Metering für Büroarbeitsplätze -BUIS als soziotechnische Gestaltungsherausforderung.**

Schwartz, T., Betz, M. and Stevens, G., In HMD - Praxis der Wirtschaftsinformatik, HMD 278 (2011), 104-113.

#### **EnergyPULSE: Tracking Sustainable Behavior in Office Environments.**

Jahn, M., Schwartz, T., Simon, J., and Jentsch, M. 2nd International Conference on EnergyEfficient Computing and Networking 2011, (2011), 87-96.

#### **Cultivating Energy Literacy— Results from a Longitudinal Living Lab Study of a Home Energy Management System.**

Schwartz, T., Deneff, S., Ramirez, L., Stevens, G. and Wulf, V., In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Paris, France, April 27 - May 02, 2013). CHI'13. New York, NY: ACM Press. p. 1193-1202.

**Uncovering practices of making energy consumption accountable. A phenomenological inquiry.**

Schwartz, T., Stevens, G., Ramirez, L. and Wulf, V., In Journal ACM Transactions on Computer-Human Interaction (Volume 20, Issue 2, May 2013), ToCHI 2013.

**Workshop Contributions**

**Know Thyself: Monitoring and Reflecting Energy Consumption.**

Betz, M., Schwartz, T., and Ramirez, L. Workshop “Know Thyself” Extended Abstracts of the ACM CHI Conference 2010, ACM (2010).

**Energy Awareness and Conservation through Pervasive Applications.**

Betz, M., Schwartz, T. and Ramirez, L., Workshop “Energy Awareness and Conservation through Pervasive Applications” at Pervasive 2010, (2010).

**Making energy practices accountable: Framing the design of systems to support sustainability using an ethnomethodological lens.**

Schwartz, T., Ramirez, L., Betz, M., Stevens, G., Wulf, V., Workshop 'Everyday practice and sustainable HCI, In *Proc. CHI 2011*, ACM Press (2011), May 7–12, 2011, Vancouver, BC, Canada.

**TV as an interactive medium to reflecting Energy consumption in daily life.**

Schwartz, T., Johanna, M. and Betz, M, Proceedings of the 8th international interactive conference on Interactive TV&Video, EuroITV10, Tampere, Finland 2010.

**Putting the user in charge: end user development for eco-feedback technologies**

Jakobi, T., Schwartz, T., SustainIT 2012, Work in Progress.

**Other Publications**

**Smart Metering 2.0**

Schwartz, T. and Betz, M., eta[energie]-Energieeffizienz u. Kohlenstoffarme Energietechnik, 2010, 15-18.

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