Counter Entropy: Visualizing Power Consumption in an Energy+ House

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Abstract
This case study presents the design and evaluation of an end-user energy consumption display for an energy+ house. The goal of our application is to give an easy overview over the power balance and to provide the user with the necessary information to understand specific consumption patterns. We defined the unit of *Counter Entropy points* and used it to create several visualizations showing the consumption of appliances, climate control, and lighting. Our evaluation showed that users easily understand where the currently consumed power is sourced and which factors influence the overall power consumption.

Author Keywords
Energy consumption; visualization; home automation

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces.

Introduction
The work presented in this case study is part of RWTH Aachen University's participation in the 2012 Solar Decathlon Europe competition. The goal is to build an energy+ house, which means that over the year, it produces more energy from renewable sources than it consumes. As according to the competitions' rules,

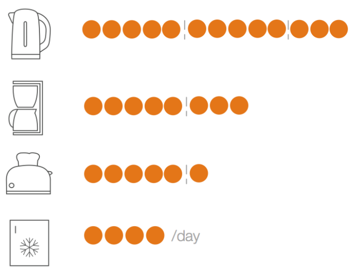

Figure 1: The consumption of the different appliances is visualized in points.

Figure 2: Visualization of the power balance and the currently running devices. The green leaf indicates that power is sourced entirely from photovoltaics.

sourcing electricity from the grid reduces the overall score, it is essential to see how much 'good' energy is available and which appliances can run without requiring additional power from the grid.

Related Work

The yearly or even monthly electricity bill is the most widely spread, but also the least informative consumption feedback modality. If not memorized somehow, it is not possible to see which factors influenced the electricity consumption over the reported timeframe. Personal energy meters (PEMs) allow end-users to measure the consumption of a specific appliance in order to get an estimate on the average consumption of their household's installation. However, if they are not interconnected, getting a detailed overview is tedious. Devices like the PowerSocket [4] map the consumption information to an ambient visualization using simple metaphors like color and rotation. The energy aware clock [1] shows a daily consumption overview for an entire household. However, these abstract visualizations do not take into consideration the environmental conditions that eventually lead to the specific consumption and they do not allow to see the consumption of different appliances in relation to each other. As reported for water consumption in [2], such detailed feedback is an essential part of an informative display.

Home Automation Control

Since smartphones and tablets are already in our environment, we opted for a tablet as control panel for our home automation infrastructure. The main tasks our application supports are the following: comparison of the consumption of different appliances, visualization of current power balance, showing available headroom to run additional appliances, and finally, visualization of parameters influencing the climate control's power consumption, such as the weather, open windows, or used appliances. For each of these tasks, we designed dedicated views and evaluated how good they are to understand, especially w.r.t. visualization parameters such as the timeframe covered by the comparison.

Counter Entropy Point

In order to facilitate the monitoring of the current power balance and to allow an easy comparison between the consumption of different appliances, we decided to convert the physical units of W and Wh into our own unit: the *Counter Entropy point*. Depending on whether it represents current consumption or total consumption over time, one point represents $150W$ or $150Wh$. We assign each appliance the according number of points (cf. Figure 1) and present an overview where the user can see if appliances are turned on or off.

The *current consumption* view (cf. Figure 2) shows two important informations: how much power the currently running devices consume and where this energy comes from. A green leaf appears if the power is currently sourced entirely from photovoltaics. With this information, the user can quickly estimate if there is remaining capacity which could be used to run additional appliances.

Providing Evidence

For a deeper understanding of the power consumption leading to a maintained sustainable behavior [3], the visualization of the current situation is not sufficient. For an analysis over time we visualize daily consumption side by side using the concept of small multiples [5] (cf. Figure 3). This allows the user to detect trends and patterns. To understand these patterns, we designed a

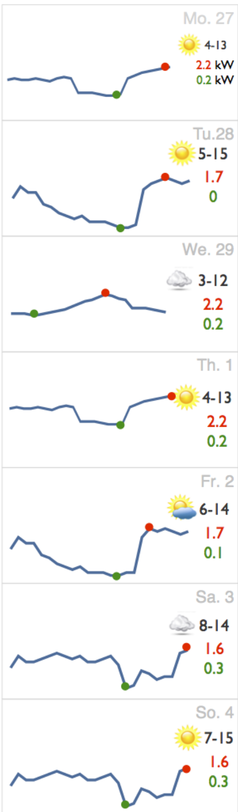

Figure 3: Daily consumption plotted side by side allows to detect specific patterns.

view that shows their possibly influencing factors. Aligned with a graph showing the energy consumption of the HVAC (heating, ventilation, and air conditioning) system over a day, the view contains information about the inside and outside temperature, running appliances, and if the windows were open for more than 10 minutes (Figure 4).

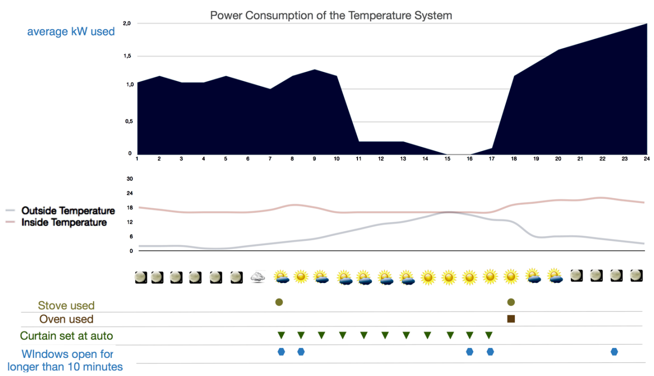

Figure 4: Power consumption of the HVAC system and visualization of influencing factors.

Conclusion

In this case study, we present a series of visualizations designed to facilitate the understanding of power consumption. We iteratively designed views that allow to assess the current power balance and available headroom, and views to analyze energy consumption patterns.

In combination with modern home automation systems, we believe that this technology can support the inhabitants to make the best use of the available energy. Being aware of the current power balance and the weather forecast, a user can distribute non-time-critical chores to, e.g., the sunny afternoon where the photovoltaics provide enough power.

Acknowledgements

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