# EnergyScout: A Consumer Oriented Dashboard for Smart Meter Data Analytics

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**Abstract**— The increasing popularity of monitoring devices for household energy consumption, also known as smart meters, is providing consumers with unprecedented opportunities for understanding and modifying their use of energy. However, the lack of effective visual analysis tools has been a significant obstacle towards wide adaptation and application of this concept. We have been interested in understanding what kind of visual interface might be appropriate for these purposes, particularly keeping in mind that the complexity of this interface should not hamper the usability of the overall system. Throughout this effort we worked with real household data, collected over a period of more than a year, and in close collaboration with consumer experts of a large local utility company. Based on their continued feedback we designed what we call the EnergyScout – a dashboard with a versatile set of highly interactive visual tools by which consumers can understand the energy consumption of their household devices, discover the impact of their usage patterns, compare with usage patterns of the past, and see via what-if analyses what effects a modification of these patterns may have, also in the context of modulated incentivized pricing. An important feature of EnergyScout is also that it allows consumers to visualize and annotate their time-series energy data in the context of other temporal information, such as outside temperature, weather, and personal and social events which all could explain certain usage patterns and help motivate a modification of behavior. Throughout development, we placed great emphasis on making EnergyScout a playful interface that doubles as an awareness and educational tool. We tested our system with various groups of people with households and energy bill responsibilities in order to see if our design can actually make any impact.

**Index Terms**— Smart meters, Energy data, Time series analysis, Information visualization, Interaction,

## 1 Introduction

Smart meters and other energy monitoring devices come in many different setups and platforms, but all of them serve a common purpose. They record total energy consumption of a device or a set of devices in the household periodically. For utility providers, this means they have better understanding of the load distribution and can make plans for improving power quality. Apart from such benefits for utilities, smart meters also hold a tremendous potential for positive impact on consumers. One of the most important aspect in energy conservation is considered to be consumer awareness and it can only come through availability of information and corresponding education. Smart meters provide us with all the data for a home owner to take away the guesswork that came with monthly bills which only reported the total, sometimes even just estimated, amount of energy utilized during the past month. Yet, despite the great promise, having all this information available can present a large challenge to the average consumer. Just looking at a stream of data points in a line chart can quickly lead to information overload. Automated appliance scheduling, possibly even done by the utility can somewhat eliminate these problems, but this deprives the consumer of self-control and misses out on the educational benefits that the presentation of these data might have. While systems do exist that convey energy data via visual modalities more sophisticated than line plots, they still mostly support overview tasks but are not overly engaging, exploratory, and comparative. The framework we developed – the EnergyScout – fills this void.

Existing consumer facing commercial interfaces (e.g. eMeter[1]) mostly concentrate on having a dashboard that gives quick glance onto real-time consumption monitoring, sometimes with added convenience of controlling smart devices through web or smartphone. Past usage almost always is represented through a long line chart with little to none emphasis on visual data analysis. We felt the missing connection between user and the ample data collected is acting as a big obstacle for wide impact from such devices. Projects like OPower [3], emphasises heavily on behavioural changes through making impact on user through data but, keeps its tools limited within social aspects like competition among neighbors. Some notable research have been done for data analysis at the distribution end [2]. On the consumer end interfaces concentration was mostly on very light information feedback and awareness [4], rather than deep analysis. Sophisticated tools can be employed to visually analyse the data to the fullest, but generally they require steep learning curve and most likely will fail to attract most consumers, beating its purpose as whole. EnergyScout takes on this challenge of creating a visual analytics tool for deeper understanding of energy consumption history without hampering its usability and appeal to an average consumer.

In section 2 we discuss the overall approach taken in our research. Section 3 explain our current design. Section 4 narrates the outcome of our initial study. Section 5 concludes the paper with a conclusion.

## 2 Design Process

From the very moment we set out to design such a system, we had to ensure we understood user expectations and their acceptability level well enough. Generally, in design of a visual analytics system, the overall flow follows a sequential waterfall approach, with design phase kept separate from user feedback or evaluation. For our work, we decided to involve such feedbacks an integral part of the design process. We were lucky enough to have a panel of domain experts who were already heavily involved with expansion of smart grid, understood the need of the consumers and had good first-hand experience of using different existing commercial interfaces. To maximize utilization of such wonderful resource, we laid out our design process around them into three phases. In the first stage, we try to understand what functionalities the system should include and how they should behave. We do so by analysing the features offered by different existing interfaces and understanding our supporting panel's experience, preference and desires. In the second phase, we take an incremental approach to design our prototype. In each iteration, we design a new feature or modify the existing one and have it tried out

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by the domain experts. Depending on their feedback and experience we modify our design goal and move onto the next iteration. Once we reach an agreement on that the interface can be considered functioning and useful, we move to the last phase. In phase three, we did a user study with human subjects from varying background to evaluate success of our design.

## 3 System Overview

EnergyScout (Fig. 1) is designed as a single view dashboard with multiple connected interactive visual analytics components. Each of these components provides high level of interactions and always reflects its results to the other parts of the interface for providing a unified analysis environment. We discuss in short about how each of these components are used in following paragraphs.

Fig. 1. EnergyScout interface.

### 3.1 Data Exploration

At the very bottom, the whole history of energy consumption is shown as a traditional area chart. A smaller time span can be selected by dragging mouse over it. The rest of the interface then only reflects analysis on the selected time-window. This time window can be adjusted interactively and rest of the interface gets updated dynamically Just above the overview chart, lies the details view of energy history. This detailed chart, for the sake of smoother experience, always automatically adapts to a correct resolution of data depending on the time-span selected. Two types of contextual data is provided with the detailed view: weather information of that day and an active editable calendar. Having such context helps the user understand the cause of the energy consumption much easily. Also, he can use the calendar panel annotate any part of the energy time-line to record his findings.

### 3.2 Data Filter and Summary Analysis

Panel on the top left provides quick data analysis by showing average energy consumed over day/month/hour over the time-span selected. This data can also be put on top of most recent usage to understand if they are doing better or worse than past. The data filter panels provide a way of forming simple queries by filtering the data. Users can ask questions like: How much more did I spend on average over the weekend nights compared to weekdays in last summer – only with a few clicks.

### 3.3 Devices and Comparisons

On the center and at the heart of our interface is an animated weight scale. This gives a real life analogy of how much the overall house and the devices are consuming. All consumptions are shown as circles or 'weights' on this scale with area being proportionate to the weights. The users can pick a device from their house profile, modify its periodic usage by adding events through intuitive clock interface and immediately see the scales move according to weight. We created such playful interface to engage the users to understanding how their habits effect energy usage and also looking at the sizes of those balls immediately clears up their misunderstanding of energy cost of the devices. Also, we split up the devices into three easy criteria and give them visual comparisons through thin bar lines.

### 3.4 What-If Analysis

Our most significant contribution comes through this tool. In this mode, a user can use our weight scale to compare between his current device profile and a hypothetical one to understand how his costs change based on his decisions. The user has the option of adding, removing or modifying the device, modify usage patterns through changing events or even change rate plans provided by the utility companies. Users can ask question like- 'How much would I save if I buy that new model of fridge?' or 'Would it be better if I did my laundry over weekends rather than weekdays?'. Having such sand-box style tools gives control to the hand of the users and their engagement through such interface goes a long way in educating about impacts of their everyday habits and help them make informed decisions.

## 4 Evaluation

We hosted a user evaluation session on our prototype with 17 test subjects. The test subjects were chosen from varying background, of them 11 were female and 6 male. In our study, we first demonstrated our system and explained how it functions. After that we let the subjects try out the system by themselves, recording any comments/suggestions. Then we asked them to perform a specific task, recording time and interactions used. Then we asked them to fill out a questionnaire and eventually finished the session with open discussions. Our study, in summary revealed that people found the system useful enough to adopt on their own. In particular, people found the experience from What-If analysis and the exploration tools to be novel enough to take notice. Also, playing around with different device profiles and seeing their impacts on energy cost intrigued them. But, in general, the most common complaint was, it took some time to understand the advanced features and how they worked, which can be troublesome for attracting new users.

## 5 Conclusion

The trade-off between usability and functionality is always challenging. We tried to take on such challenge in case of smart meter data. Our initial evaluation shows that our prototype paves the way towards a brighter future in such endeavor. Our current implementation, even though handled many key challenges well enough, it still suffers from a glowing concern that an average user may get disinterested in the system during the learning phase. To ensure better adaptability, in our continued work, we intend to refine our system to a phase where users can learn the interface without having to go through a tutorial or external demonstration.

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