Time-load: Visualization of Energy Consumption Loads Over Time

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ABSTRACT

It has been suggested that providing feedback allows people to better understand their energy consumption behaviour and take the necessary actions to reduce energy consumption. Here, we present the *time-load* visualization, which shows percentages of energy usage by different categories of devices that contribute to the total energy consumption load over time. Time-load aims to assist users with visualization of variations in energy consumption by different categories over time, and their respective, and often very unbalanced, contributions to the total energy usage load.

CCS Concepts

•**Human-centered computing** → **Visualization techniques; Information visualization;**

Keywords

Energy usage visualization, energy usage load, energy usage monitoring, time-load visualization, timelines.

1. INTRODUCTION

Despite a number of initiatives aimed at promoting energy saving, changes in the behaviour of ordinary energy users have been notoriously difficult to achieve. A potential solution is to provide users with better feedback about their energy consumption, especially to help them make *historic* and *normative* comparisons (i.e. compare their own current and past energy usage data, and with those of others) [4].

Since energy usage data are usually collected across time, most visualizations of energy use adopt time lines [1] or space filling variants [5]. While time-series are useful for visual exploration of energy consumption trends across time, mainly by expert users, most ordinary people do no really understand metrics used for measuring energy use (e.g. kilowatt hour). Therefore, despite their widespread adoption, time-series often are of limited value to such ordinary users.

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Another commonly used visualization for energy use data is pie charts. Pie charts provide overviews of total energy consumption broken down by categories of devices, activities, users, etc. However, although pie charts are easy to understand by non-expert users, they do not include the important dimension of time. While alternative visualizations [6] have been proposed to incorporate time, as Bertin [3] has indicated, visualizations relying on comparison of area sizes of visual marks (e.g. pie charts) can be more challenging to interpret than those which allow comparison of the length of visual marks (e.g. bar charts).

A widely used type of visualizations that rely on comparison of length rather than area is timelines [1]. Although timelines allow effective comparison of time-based data using parallel lines, they generally do not show variations in the amount of data stream over time, beside the fact that a data stream is occurring or not at a particular point in time (i.e. binary status of the data stream).

In this paper, we present a modified form of timelines visualization, called *time-load*, which incorporates temporal variations in data values into timelines. *Time-load* aims to improve visualization of energy consumption data by allowing users to see: 1) variations in energy consumption by different categories of devices over time, 2) variations in the amount contributed by different categories of devices to the total energy consumption over time, and 3) variations in total energy consumption load over time.

2. TIME-LOAD VISUALIZATION

We use the idea of *color-coded* timelines of *LifeLines* [7], which represent required actions or different events along each timeline segment. Similarly, Bade et al. [2] adopt color-coding to represent regions of different qualitative characteristics of timeline values (e.g. using red to show critical fever values, yellow for moderate fever, and green for normal body temperatures). In both these cases, the number of colours used is limited to a handful, as changes in body temperature, for instance, is limited to a small range — thus a limited number of categories being needed. Furthermore, in neither of these cases, there is an ordinal relationship between the colours used and the values represented along the timelines. Although Bade et al. [2] introduce a number of alternatives to color-coded timelines, including *height-coded* timelines, to represent changes in ordinal scale of data values, their alternatives are only useful for cases where the range changes in values is small (e.g. changes in body temperature).

Taking these issues into account, we adopt the idea of *color-coded* timelines, but instead of using different colors to represent different categories, we use tonal variations (i.e. changes in brightness) of a single hue (e.g. red) to represent changes in data values (e.g. amount of energy used) along individual timelines representing a category of devices (e.g. lights). However, as mentioned earlier, most people find it difficult to understand metrics used to measure energy use (e.g. kilowatt hour), while they are more familiar with the concept of percentages shown in pie charts. Therefore, rather than showing the amount of energy being used by a device (or category of devices) in, say, kilowatt hours, we represent the percentages of energy being used in relation to the total wattage of a device (or category of devices).

Figure 1 shows an example of our proposed *time-load* visualization. *Time-load* inversely maps brightness of the colour used to changes in percentage values along each timeline. As can be seen, water heater always uses the same amount of energy at regular intervals for a specific duration, while the aircondition uses different amounts of energy for different durations at varying intervals due to thermostat settings, air temperature, level of humidity, etc. Other devices, such as a washing machine or dishwasher, use different amounts of energy when they are turned on based on their programme settings and different cycles. In the case of lights, on the other hand, the amount being used at any point in time is represented in relation to the total amount used, if all the lights were turned on. Although in the case of this example these percentages are hand-coded for demonstrative purposes, in real-life settings they would be calculated based on historical energy usage data and device energy profiles.

The total energy usage load for the household is also represented using tonal variations, but in this case, in grayscale. The total load values are calculated by adding the load percentages of individual devices (or category of devices), as percentages of the energy usage of the entire household.

The *time-load* shown in Figure 1 does not represent any information about the level of contribution each category of devices makes to the total energy consumption load (i.e. its respective percentage of the total). These percentage levels of contribution can be shown with an additional pie chart, as is currently done in many energy usage visualizations. Alternatively, the colour of timelines for each category of devices could be selected based on their percentage contributions using a heat-map such as the one shown in Figure 2.

Further changes could be made to provide other means of comparison. For instance, an average energy usage line could be shown based on historic consumption data per device category. The timeline segments could then be drawn against these respective average lines, as shown in Figure 3. Alternatively, the timeline segments could be *height-coded*, as proposed by Bade et al. [2], to allow comparison of current

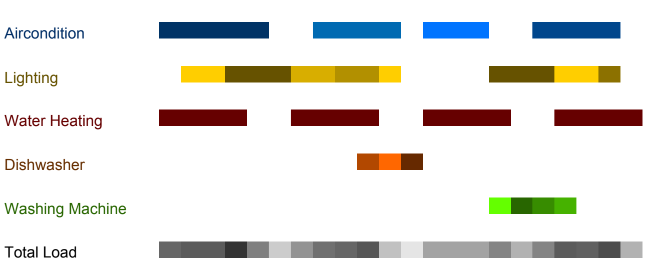

Figure 1: *Time-load* visualization of energy usage.

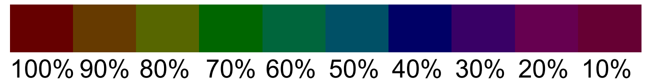

Figure 2: Heat-map for timeline colour selection.

Figure 3: *Time-load* with average consumption line.

Figure 4: *Time-load* using *height-coded* averages.

usage with historic or normative averages. Figure 4 shows an example of *time-load*, with segments of energy consumption by lighting devices *height-coded* using a historic average.

3. FUTURE WORK

Although here we have mainly focused on static *time-load* visualizations of energy consumption data, there are clearly many potential benefits in supporting dynamic, as well as interactive, visualizations of this type of data. It is easy to consider cases where *time-load* visualization is dynamically updated as more data becomes available based on current energy usage in real-time.

Interactive visualization techniques such as brushing, filtering, zooming, etc. could also be employed to enhance users' visual analytic processes, where they utilize the visualization to analyse and better understand their energy consumption behaviour. Furthermore, an interactive *time-load* visualization would be a valuable tool for supporting people in scheduling their future energy-consuming activities (e.g. when to do their washing) based on past consumption data, so that they can better manage their total load, and hence, reduce reliance on energy especially during peak load times.

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