Using Data Visualization to Better Understand Electric Load and End-Use Data

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Data visualization is used to represent data in an easily comprehensible manner, In the utility industry data visualization has consisted primarily of 2 dimensional (measurement interval, and demand or load) load shapes. While useful, load shapes can only show part of the picture. The third dimension of change in demand for all measurement intervals over time is impossible to display in a two dimensional format like a load shape. This paper presents new three dimensional data visualization techniques that use color to represent the demand. These new techniques allow the viewer to see patterns and relationships that were never readily apparent before.

Introduction

Data visualization is the graphic representation of numeric data. Bar charts, pie charts and load profiles are all examples of data visualization. So are EKGs, x-rays and satellite photos. Eyesight is the most highly developed of the human senses; it gives us the ability to process incredible amounts of data. So we turn to graphic representation of data to help us understand large amounts of data that might otherwise be overwhelming. This is especially useful in understanding metered end-use and total load data.

End-use and total load data is dynamic. It changes over time, has characteristic patterns and is influenced by a variety of outside influences. Understanding these patterns and the effect of external stimuli allows the utility planner, rate maker or load researcher a more complete understanding of the end user. As the utility industry is deregulated, understanding the customer becomes more important. Data visualization has always added to the understanding of the customer, and as that knowledge of the customer becomes more important so do the visualization tools that the utility uses to add to that understanding. This paper will describe some new and evolving data visualization techniques and explore some possible areas for further development.

The Energy print

The load profile is by now familiar to most people involved in the electric utility industry. It has been very useful in understanding how energy is being used. Load shapes for different sectors can be compared to help in strategic targeting of demand side management (DSM) programs. They can by projected to expanding populations to determine when and where new resources may by needed. Load shapes for specific end-uses have been used to evaluate the impact of that individual end-use technology. Load shapes are limited though. They don't readily show the change in a system over time, nor do they easily show the relationships between different end-use technologies. One strategy to partially address these limitations is to develop a three dimensional wire frame plot as shown in Figure 1.

This plot shows large changes over time, but part of the information is always hidden from view. Another problem with the three dimensional wire frame plot is the difficulty in comparing one to another to see relationships between them. A new method for displaying these three dimensions (usually measurement interval, day, and demand) has been developed that uses color to represent the third dimension (the metered demand). We call the new images energyprints.

An example of an energyprint for the total load for a small grocery is displayed in Figure 2, in this example we are limited to black and white, but the posters and computer example demonstrate the full effect of using color. The energyprint is developed by taking data, in this case fifteen minute metered data, and assigning one of 255 colors to the metered demand for each interval. We use lighter colors to represent higher metered demand, and darker colors to show lower demand. The energyprint is then displayed with the metered interval as the Y axis, the date on the X axis and the color coded demand is shown at each corresponding X and Y coordinate. Another way

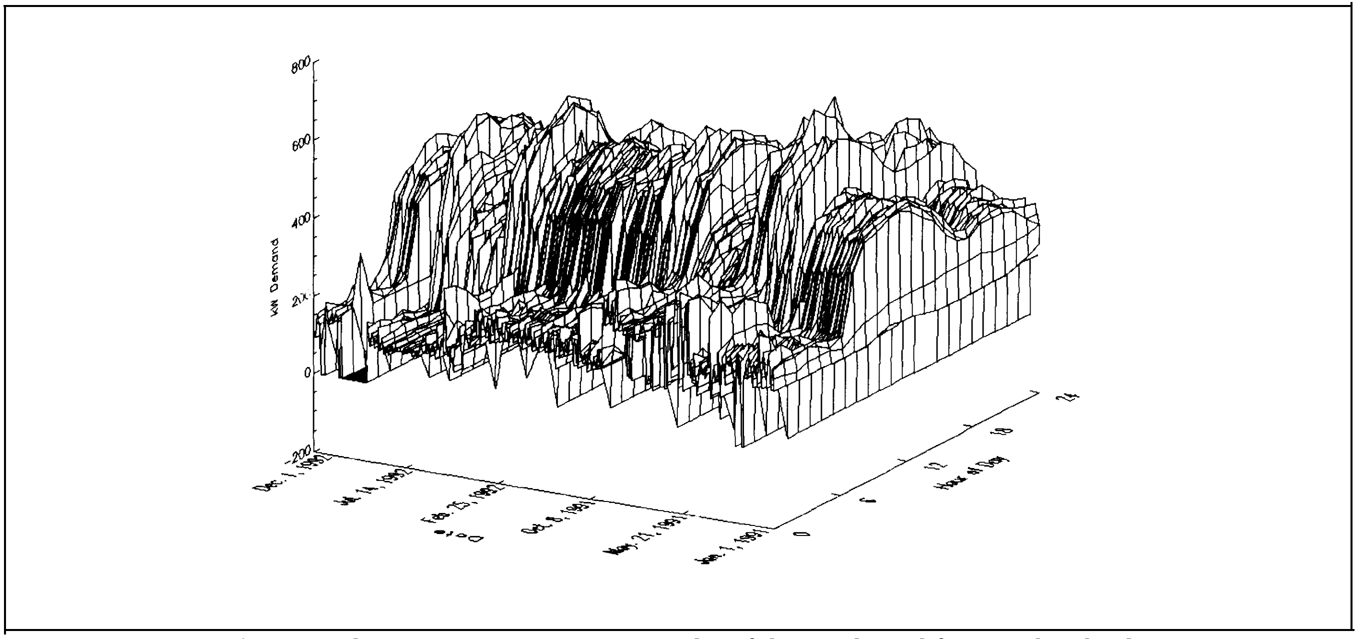

Figure 1. Three Dimension Wire Frame Plot of the Total Load for a High School

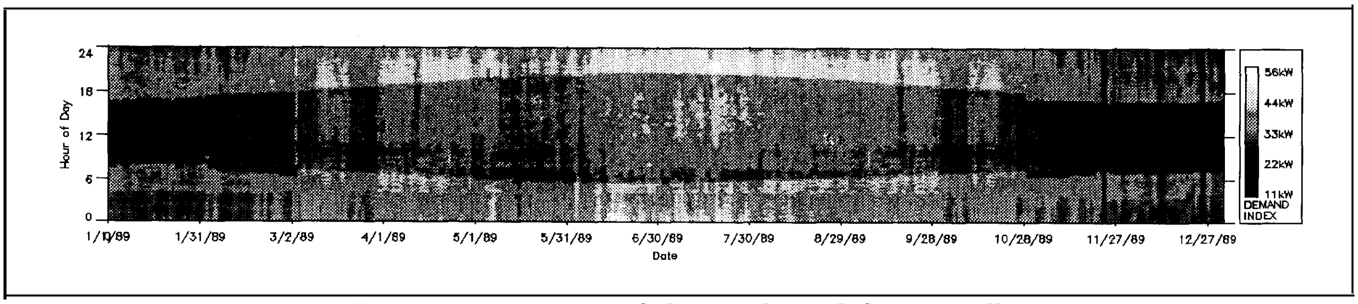

Figure 2. Energyprint of the Total Load for a Small Grocery

to think about the energyprint is to think of the whole dataset that you are interested in. Find the minimum and maximum data points, and gave them the colors black and white respectively. Then look at the load shape for each day under study, color coding the load shape so that the highest point is the lightest in color and the lowest is the darkest. These colors must be relative to the overall maximum and minimum for the dataset. Then take all of the daily load shapes and stack them next to each other. Now rotate the whole set so that you see it from the top. In this energyprint we can see the reduced use on Thanksgiving and Christmas, the influence of the A/C system during the summer, and the influence of outdoor lighting seen as the extended wave shape in the 5pm to 9pm time period, at this small grocery.

Figure 3 shows multiple energyprints displayed together. These energyprints can be made of any related data such as multiple metered end-uses at one site, the same metered end-use from similar sites, or ancillary data like temperature data, flow rates, sum of the end-uses, or residual (unmetered) loads. In this example we see three of the eight metered end-uses, the total load, sum of the end uses, residual load and temperature from a medium sized grocery.

The Energy print as a Tool

Energyprints have been used successfully in a number of impact evaluations and research projects. One of the basic uses has been to use total load data to verify savings associated with the installation of a DSM measure. Figure 4 shows the metered total load data for two years from a hospital that installed an energy management system, plus lighting and HVAC retrofits in the early summer of 1992. The impact can clearly be seen by comparing the summer of 1991 to the summer of 1992. One of the tools that has been developed to verify measure impact allows the analyst to select a pre-measure installation period and a post-measure installation period on the energyprint. The analyst can then easily generate single day and single week, or average day and average week pre-post load shape plots along with associated statistics. Another useful tool is to look at energyprints of a metered load next to

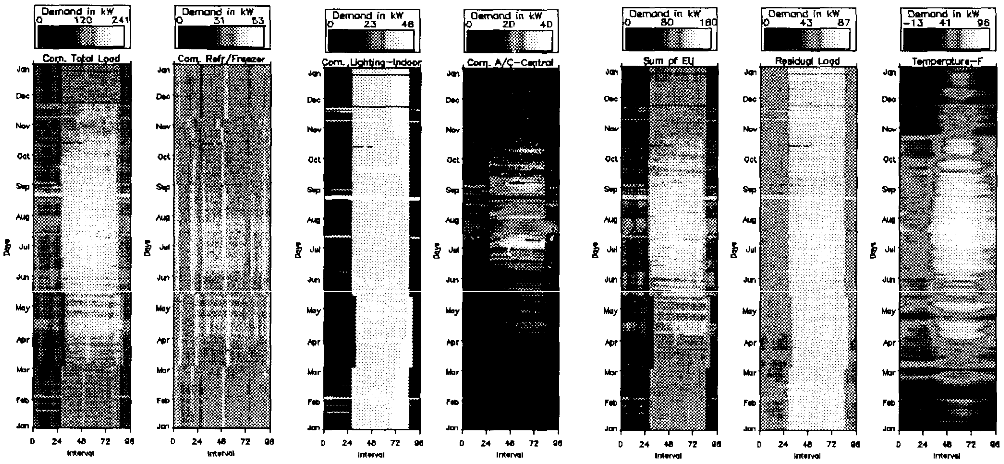

Figure 3. Multiple Energyprints for a Medium Grocery

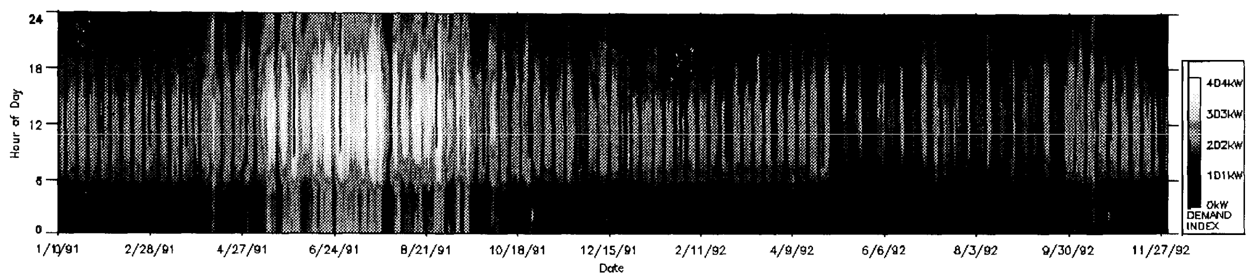

Figure 4. Energyprint Showing DSM Impact at a Hospital

the energyprint of the outside temperature for the same period to investigate weather related load changes. For further discussion of impact verification, please see the following paper: Wilcox, D. E. “Impact Evaluation using Load Research Data.” *Demand and Load Shapes - Proceedings from the ACEEE 1994 Summer Study on Energy Efficiency in Buildings.*

Planning and forecasting departments use the generalized load shapes for whole sectors or classes of customer. To generate this type of data one project using metered data is relying on data visualization techniques to create complete data sets from a statistically significant sample of metered sites from within certain customer groups. The analyst, using energyprints of each metered end-use for each individual site, fills in gaps of missing data for channels that are missing less than 65% of their data. The analysts familiarity with the characteristic energyprint for each end-use give confidence in the data used to fill the gaps. An example of three end-uses before and after gap filling is shown in Figure 5. The three energyprints on the left show the channels before filling, you can see the areas where data is missing from March to May. On the right are three energyprints of the same end-use channels after filling.

After the filling process the data is then expanded to the total population and energyprints and load shapes for the entire population of that segment are produced.

The resulting energyprints and loadshapes in conjunction with the individual energyprints for a targeted customer can be used in one-on-one interactions between the customer and the field rep to show areas of excessive energy use or to demonstrate the successes of their efficiency efforts. We have found that the lay person, with a small amount of introduction, grasps the meaning in the energyprint readily, and comes away with a much more profound understanding of their energy use.

Conclusion

This paper has demonstrated some possible applications of one new data visualization technique. Hopefully it will stir discussion and the imagination about other possible visualization techniques and uses.

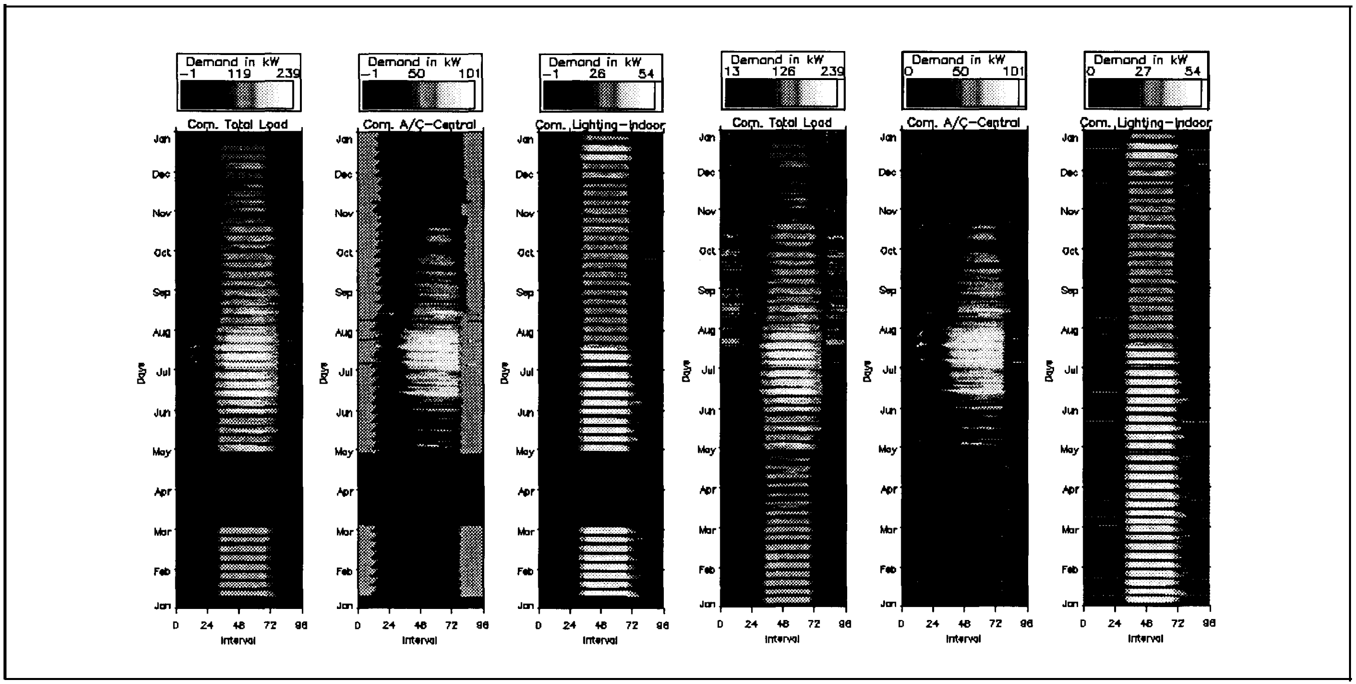

Figure 5. Energyprints Showing the Effect of Data Editing