# GreenLite Dartmouth: Unplug or the Bear Gets It

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**Abstract**

This paper introduces *GreenLite Dartmouth*, an animated world which displays real-time power consumption information in order to educate students about the impact of their power consumption on the world.

**Keywords:** *Information Aesthetics, Design, Game, Real-time Display, 3D graphics, Animation, Information Visualization, Human-Computer Interaction, Interactive Design.*

## 1 Introduction

We present an information visualization system we call "GreenLite Dartmouth" which is used to collect, analyze and display complex energy use data using animations. The use of animation—as opposed to charts and graphs—creates an emotional connection between energy use and its impact.

### 1.1 Motivation

With glaciers melting, sea levels rising and natural disasters—such as hurricanes and cyclones—intensifying, climate change is a growing concern. While innovations in renewable energy are critical, research shows that changing energy use behavior has become increasingly important in the fight against global warming.[1] GreenLite Dartmouth focuses on changing behavior by making energy conservation an attainable goal through the use of a sophisticated information display system. We believe that if people feel both an intellectual and emotional connection between daily actions and their adverse effects on the environment, they will make better choices around resource use. We combine computer graphics, art, engineering, sociology, environmental science, systems-thinking and behavioral psychology to turn real-time energy use data into a meaningful interactive display. GreenLite employs innovative methods for displaying complex data using interactivity, storytelling, animation, competition and goal-setting. Appealing animated information-display and "mood" algorithms put data into context to make it meaningful. We incorporate a system of digital energy meters, a custom database, computational analysis, 2D and 3D animations, interactive design and a game-engine to spur behavior change and, hopefully, reverse the course of climate change.

As smart-grid technology brings digital meters into businesses, institutions and homes, there is a growing interest in displaying energy-use data via the web or mobile devices. Data is generally displayed using charts and graphs that focus on the amount of energy used and the monetary cost. Over 40 studies have shown that this type of display can reduce energy use by 5-10%. [2] [3]

Charts and graphs show important information, but they are not appealing to a wide demographic. Our work tries to appeal to a wider group, tell a bigger story and produce a larger reduction in energy use. We translate data from ticks on a meter to numbers in a database and then into interactive animation. We use appealing animated characters in settings affected by climate change to turn real-time energy use into a meaningful story about consumption behavior and trends, information about where energy comes from, how our usage behavior compares to others and the impact of our behavior on the environment. We believe this emotional connection will produce a significantly larger reduction in energy use and appeal to a wider group of people–including children and teens who could become the driving force in energy conservation.

Figure 1: Bear and cub as ice breaks apart

We begin with a polar bear. When electric use is low, the polar bear is happy. As use increases, the bear's health and happiness are endangered as shown in Figure 1.1. We use a "mood" algorithm to determine which animation to call up, based on predictions of what energy use should be at a particular time and day. At Dartmouth College, we use a mix of low-energy displays in dormitory halls, a website and a desktop widget to display our content. We

chose the polar as the first character for the animation because it is an animal whose existence is significantly impacted by climate change. In our animated world, the actions of the bear reflect the amount of energy being used; to keep the bear safe and happy, dorm power use must improve. We supplement the animation with text and images about a user's goals, progress towards these goals, and information about current energy use. With just a quick glance, students can monitor the polar bear's state and instantly be informed about their energy impact without having to ponder any difficult graphs or trying to decipher scientific units.

# 2 Method: The GreenLite System

Our information visualization system is based on five components: polling of real-time energy data, data aggregation, data analysis, visualization content, and multimodal display.

## 2.1 Real-time energy data

We poll digital electricity meters for data several times per minute and store the data in our database. We utilize a variety of types of commercially available meters with both wired and wireless communication. In most dorms, we poll meters that measure the electricity that dorm residents use directly—lighting and plug load—and avoid metering devices that the students do not control, such as HVAC systems. We also collect data on heat, water and hot water in some of the dorms as well as college-wide printer usage. Data becomes available to our web-application within seconds providing an essentially real-time experience.

## 2.2 Data aggregation

We compute one-minute averages of power consumption data and store these averages in our database for analysis and graph generation. In addition, we aggregate data from several meters together to compute power consumption at building and campus-wide levels. Data aggregation is controlled through an aggregation hierarchy shown in Figure 2.2. Electricity data from the leaf-nodes in the hierarchy "sum-up" to the parent nodes.

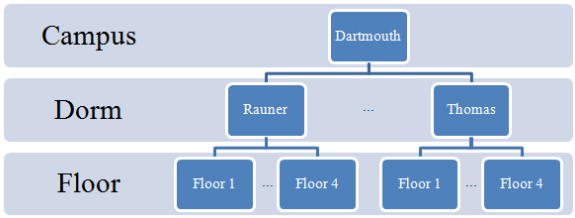


Figure 2: Aggregation hierarchy

## 2.3 Data analysis

Various "mood algorithms" analyze the data and determine the current animation. In our initial implementation, four discrete Flash animations show the bear in various stages of distress. We also show additional statistics (such as daily and weekly trends) on the side of the screen. A forthcoming version of the animation will incorporate the additional information directly into the animated scene. In this forthcoming version, short-term power consumption trends drive the bear's actions whereas long-term trends control the state of the bear's environment as well as his health. We apply a "mood algorithm" to analyze current (real-time) power consumption and compute our short-term score. To determine the score for a particular Wednesday at noon, we build a histogram of power data from previous Wednesdays collected between noon$-x$ minutes and noon$+x$ minutes, where $x$ is typically about 30[1]. We use the histogram to compute a probability statistic for the current power consumption value. We use this statistic to drive the animation. As noted above, we also compute long term mood scores such as the daily, weekly, and monthly change in power consumption and make these statistics available to the front end. Our server can use per-person usage statistics rather than total usage statistics at the option of the administrator.

## 2.4 Visualization Content

We created three-dimensional animations using motion capture and Autodesk Maya. At runtime, the animations run in the powerful Unity3D browser plugin; we also have a flash version of the animations. We script various interactive interface elements using Unity3D. Google Web Toolkit (GWT) generated javascript controls additional elements of our site, such as the graph interface and RPC plumbing which obtains data from our server. We implemented the backend using Java Servlets (deployed in Apache Tomcat) on top of MySQL.

Our visualization turns energy use data into a meaningful real-time, interactive story. We utilize either Flash or a 3D animation/game engine to create the animations (two versions are available). Everything in the visualization reflects real-time data:

- An animated character's health and happiness depends on students reducing energy use.
- The animated environment reflects long-term goals and success in achieving those goals. With electricity, for example, at the beginning of the term, the environment is in trouble. As students work towards their goal (set by either an administrator or the user), the environment improves.
- Time of day (and weather) are reflected in the display to reinforce the connection between the user's

[1]When a week's worth of data is not available we hold constant time, but use data from different days. When a day's worth of data is not available, we use data from the previous hours

world and the animated world. Similarly, the display reflects real-world changes between night and day.

- Animations reflect the energy source. Electricity is displayed with a polar bear in the Arctic. Dartmouth generates heat with oil and the animated environment is that of an oil field. We use animations of trees being cut down to reflect paper use on campus.
- Graphs show additional detail over varying lengths of time (recent, hourly, weekly, monthly) and compare current use to historical data to put the chart into context so users understand how they are doing relative to the norm.

### 2.5 Display

We display data with energy efficiency in mind. We use low-energy displays when possible, utilize a motion-detection system to put monitors to sleep when nobody is around and are working on ways to have GreenLite system show on devices students already look at, rather than adding new displays to the mix. We provide our data in several ways:

- Touchscreen monitors placed in dormitory hallways, in dining halls and libraries, allow students to see their own energy use as well as that of others on campus.
- A website provides real-time data and is accessible on any browser.
- An animated desktop widget appears on computers across campus so that when a student checks email, they see the widget.
- Student computers purchased from the Dartmouth computer store will soon have the widget pre-installed.

## 3 Results

In the Spring of 2008, we launched a prototype using Flash animations. We measured reductions of 22% and 14% from a combination of plug-load and lighting in dormitory floors with GreenLite systems installed. These results are significant compared to other real-time display systems, especially considering that we only measure a portion of total electricity use in the buildings. We are conducting additional user studies and working with sociologists and behavioral psychologists to better understand social norms and conservation psychology. [4]

## 4 Scalability and Future Work

The success of GreenLite Dartmouth is evident in a number of ways: energy savings were achieved, students named the bear and cared about its well-being enough to turn things off, and the story generated lots of press. This success inspired interest from other institutions (colleges, prep-schools, K-12) as well as interest from several companies in utilizing our visualization for home use. People of all ages have expressed interest in putting our system into their home and we are working towards a system that could be deployed as part of smart grid technology. Future work includes integrating control systems and cell phone apps.

## References

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