Simulations, Visualizations, Eco-Arts and Warehouses for Energy Sustainability

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Current Understanding and Behavior towards Energy: Caricature or Reality?

- I use energy (at home, at work) but it’s invisible. I don’t consume it directly but only via things I want—like light, heat and refrigeration.

- I rarely think about the energy I’m using, and most of my use is habitual and unconscious. The amount of energy I use is registered on a meter that’s out of sight, unintelligible, and read by someone else.

- At home, I only get feedback about my energy use in the form of monthly bills that present complex data that are a month old, and are boring and impersonal.

- At work, I get no feedback at all — which does not worry me because I do not pay the bill anyway.

- When information is provided to me about how and why I should change my behavior, it is also boring and impersonal and often not even applicable to my situation. Even when I understand it, I rarely act.”
**A Current Power Company Bill**

<table>
<thead>
<tr>
<th>Account Activity</th>
<th>Mar 10, 2010</th>
<th>Previous Balance</th>
<th>$183.01</th>
<th>Total Payments</th>
<th>($183.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Payments Received</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>$0.00</td>
</tr>
<tr>
<td>Number of Days in Billing Period</td>
<td>32</td>
<td>Balance Forward</td>
<td>$0.00</td>
<td>+ Current Bill</td>
<td>$204.16</td>
</tr>
<tr>
<td>Statement Number</td>
<td></td>
<td></td>
<td></td>
<td>Current Balance</td>
<td>$204.16</td>
</tr>
<tr>
<td>Premise Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Electric Service - Account Summary

<table>
<thead>
<tr>
<th>Invoice Number</th>
<th>Rate</th>
<th>Days in Bill Period</th>
<th>Current Reading</th>
<th>Previous Reading</th>
<th>Kilowatt-Hours Used</th>
<th>Residential General</th>
<th>Trans Cost Adj</th>
<th>GRSA</th>
<th>Elect Commodity Adj</th>
<th>Renew. Energy Std Adj</th>
<th>Demand Side Mgmt Cost</th>
<th>Service &amp; Facility</th>
<th>Purch Cap Cost Adj</th>
<th>Total Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>32</td>
<td>42785</td>
<td>41918</td>
<td>867</td>
<td>867.00 x 0.031530</td>
<td>867.00 x 0.000060</td>
<td>867.00 x 0.029340</td>
<td>867.00 x 0.01330</td>
<td>867.00 x 0.012130</td>
<td>$27.34</td>
<td>$15.12</td>
<td>$25.44</td>
<td>$1.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Franchise Fee 3.00%</td>
<td>Sales Tax 3.93%</td>
<td>Total Amount</td>
<td>$94.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Gas Service - Account Summary

<table>
<thead>
<tr>
<th>Invoice Number</th>
<th>Rate</th>
<th>Days in Bill Period</th>
<th>Current Reading</th>
<th>Previous Reading</th>
<th>Measured Usage</th>
<th>Therm Multiplier</th>
<th>Thperms Used</th>
<th>Residential Usage Charge</th>
<th>Interstate Pipeline</th>
<th>Natural Gas 1 Qtr</th>
<th>Service &amp; Facility</th>
<th>Franchise Fee</th>
<th>Sales Tax</th>
<th>Total Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RG-T</td>
<td>32</td>
<td>565</td>
<td>409</td>
<td>156</td>
<td>0.8735</td>
<td>136.0</td>
<td>136.0 x 0.100882</td>
<td>136.0 x 0.061700</td>
<td>136.0 x 0.469200</td>
<td>$13.72</td>
<td>$11.11</td>
<td>$66.53</td>
<td>$10.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Actual 03/09/2010</td>
<td>Actual 02/05/2010</td>
<td></td>
<td></td>
<td></td>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>$3.07</td>
<td>$4.59</td>
<td>$10.00</td>
</tr>
</tbody>
</table>

### Comparison Information

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>This Year</td>
<td>$110.00 per month</td>
<td>$3.44 per day</td>
<td>867</td>
<td>136</td>
<td>33°</td>
<td></td>
</tr>
<tr>
<td>Last Year</td>
<td>$94.16 per month</td>
<td>$2.94 per day</td>
<td>822</td>
<td>53</td>
<td>39°</td>
<td></td>
</tr>
</tbody>
</table>

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**Note:** The table details the breakdown of charges for electric and gas services, including usage charges, taxes, and adjustments, along with comparison information for billing periods and average daily temperatures.
“Modern” Energy Representation
In the dorms...
Eco-Visualization

+ combining art and technology to reduce energy consumption
  + create dynamic feedback from data-driven artwork for a better understanding of resource consumption patterns
  + use visualization of a carbon footprint to increase conservation behavior in resident populations
  + identify factors that affect an individual’s ability to curtail energy usage
  + create incentives, other than monetary, that affect an individual’s commitment to conserve resources
  + develop effective visualization strategies to communicate energy consumption data
Point-of-Use/Personal Level
Collective Level:
Entire University Building

visualization as social sculpture

Installation space
NCSA lobby location
Collective Level:
Entire University Building (cont)

Kiosk with Interactive Touch Screen

Height 70" (inches)

Base Footprint 20 X 20" (inches)
Collective Level:
Entire University Building (cont)

animations show the rings spinning on and off at greater speeds with higher loads
Beyond Eco-Visualizations

* Learning within a culture of participation through
  * Art-inspired interactive exhibitions with table-top computing (e.g.: EDC, Microsoft’s Surface)
  * Eco-simulations to learn about choices and their consequences
  * Tangible information rich objects
  * Wiki-style websites to support community sharing, participation, and engagement
Designord’s Flowerpod

Collects input for all forms of energy: heat, water or electricity. If the FlowerPod is blooming, users are on the right track, but if it wilts, it points them to suggestions for improvement.
Energy Representation, an Example

- LEDs are a lot more efficient than incandescent light bulbs
- 6.8 Watt vs. 60 Watt
- 11 KWH/year vs. 109.5 KWH/year
- $1/year vs. $11/year
- 10-17 Lumens/Watt vs. 20-60 Lumens/Watt

A little demo
http://wikiresearch.cs.colorado.edu/demos/4/
Energy Representation Study
Examples

- Ford Fusion Leaves
  - http://www.youtube.com/watch?v=ioBx_kBiDBk

- Bottle Bank Arcade
  - http://www.youtube.com/watch?v=zSiHjMU-MUo -> ‘We believe that the easiest way to change people's behavior for the better is by making it fun to do.’
Psychological Ownership

- When people feel a sense of psychological ownership for something, they are likely to value it higher than what it’s worth: Ikea Effect
- On the other hand, when ideas are “pushed” unto someone, a Not-Invented-Here reaction is likely
- When people feel ownership for something, they care more and are willing to invest more -> If people become psychological owners of the energy domain, they should be more likely to learn more, make educated decisions, and tell others about it
Requirements for Ownership (Pierce et al 2002)

- Control
- Investment of Self
- Intimate Knowing (less effective)
- “Targets must be manipulable”
- “less likely to emerge under strong (e.g., highly structured) as opposed to weak situations”

Positive Effects:
- Active Involvement/Participation
- Responsibility
Requirements for Ownership in the Energy Domain

- Control -> End Users can choose what devices to use but it is often not even clear what device uses how much energy. No control over other aspects
- Investment of Self
- Intimate Knowing (less effective)
- “Targets must be manipulable”
- “less likely to emerge under strong (e.g., highly structured) as opposed to weak situations”
- Positive Effects:
  - Active Involvement/Participation
  - Responsibility
Requirements for Ownership in the Energy Domain

- **Control**
- **Investment of Self** -> Unlikely and not actively fostered by anyone
- **Intimate Knowing** (less effective)
- “Targets must be manipulable”
- “less likely to emerge under strong (e.g., highly structured) as opposed to weak situations”

- **Positive Effects:**
  - Active Involvement/Participation
  - Responsibility
Requirements for Ownership in the Energy Domain

- **Control**
- **Investment of Self**
- Intimate Knowing -> How many here can describe what a kwh is how many kwh their fridge uses? How many kwh does your stove use?
- “Targets must be manipulable”
- “less likely to emerge under strong (e.g., highly structured) as opposed to weak situations”
- **Positive Effects:**
  - Active Involvement/Participation
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Positive Effects:
- Active Involvement/Participation
- Responsibility
Specifications for Software System

- Offer Control
- Motivate and Reward Investment of Self
- Enable an Intimate Understanding of the Domain and the System
- Create manipulable software and artifacts
- Create flexible and weakly structured usage scenarios and curricula around this
Proposed System: EMPIRE

- **Empowering People in Reducing Energy Consumption**
- A meta-design environment in which users can create simulations and visualizations of their own (and others) energy consumption
- Simulation consists of device-agents; their energy profile can be based on smart meter readings or manually entered specs; every agent has an associated schedule with the option to use default schedules or create custom ones (e.g. use TV for two hours in the morning, two hours at night, standby all other times)
System Organization
Proposed Infrastructure

Current Smart Meters
Current Consumption in Abstract Units or Visualization as Graphs in Proprietary Systems.

EMPIRE SYSTEM
Raw Data
Energy Data
Raw Data
Processed Data
Collab
Sim
Warehouse
Access Own Data
Offer Control: A Meta-Design System to Simulate and Visualize Energy Usage

- Offer a meta-design environment that end-users can modify and use to create artifacts that are also meta-design artifacts

- We are work as a meta-designers to the energy domain, offering toolsets to create energy calculations and represent energy. Domain experts and interested users create simulators and visualizations of energy usage. End-Users use and extend simulators and visualizations with their own data to understand their own usage
Motivate and Reward Investment of Self

- The Meta-Design Environment is augmented by a social website in which users can upload, share, rate their creations.
- Personal attribution and explicit ownership for ideas and artifacts.
- Social standing/reward infrastructure through friendly competition and rankings.
- Awareness tools to let users know that there is an audience.
Enable an Intimate Understanding of the Domain and the System

- The system itself is a meta-design object that allows all interested users to modify and extend the system; not just open-source, but documented source

- The very purpose of the system, with its simulator module and extensive information on the website, is to create and understanding of the energy domain

- In addition, people can become experts on very specific topics where only few people have an intimate understanding, e.g., how to create a simulation of an entertainment center
Create flexible and weakly structured usage scenarios and curricula around this

- For use in school and after-school environments:
  - Open ended goals with unlimited possible solutions
    - Simulate your room and try to identify a way to save 10% or more
    - Compare your room’s energy consumption with that of your friends; what do they differently, where do you use more energy?
Prototype Demos

- http://wikiresearch.cs.colorado.edu/demos/1/
- http://wikiresearch.cs.colorado.edu/demos/2/
Takeaway Message

- To be effective in creating a feeling of ownership, a system has to fulfill requirements that are not common to current software systems and are very rare in the energy domain.

- A meta-design approach offers itself to a system that aims to create a feeling of ownership.

- It is not enough to create the technical solution; they have to be used in novel, weakly structured, curricula and situations.

- More evaluation is necessary to evaluate if it does in fact increase a feeling of ownership and whether a feeling of ownership results in long term energy savings.
The Ethics of Motivating Behavior Change

- Is it ethically correct to make use of unconscious reactions to motivate behavior change?

- The goal is to increase educated decision making – but it’s using methods that prevent exactly this

- Should a system that aims to educate be transparent about the ‘tricks’ it’s playing on the users mind?

- If these methods and systems can be used to foster ‘good’ behaviors like energy saving, they could probably also be used to foster ‘bad’ behaviors
Supportive Social Environment

- People like to be ‘normal’
  - People want to use as much energy as their neighbors
- People trust decisions/actions by other
  - Social proof can make everything funny
How to Create/Support a Supportive Social Environment

- Create a Social Proof
  - make ‘good’ behavior visible
  - make others aware of ‘good’ actions

- Annotate information about the norms
  - Example: add smiley faces

- Create a supportive environment
  - Highlight supportive views and users
  - ‘Hide’ unsupportive, or opposing views
The social environment is never completely determined by external factors.

Social and technical interventions can help shape an environment in different ways.

The implicit shaping of social environments should not be ignored or treated as a side-aspect of Web 2.0 developments.

More studies are necessary to completely understand the impact – and the limits – of designer-decisions on a social environment.