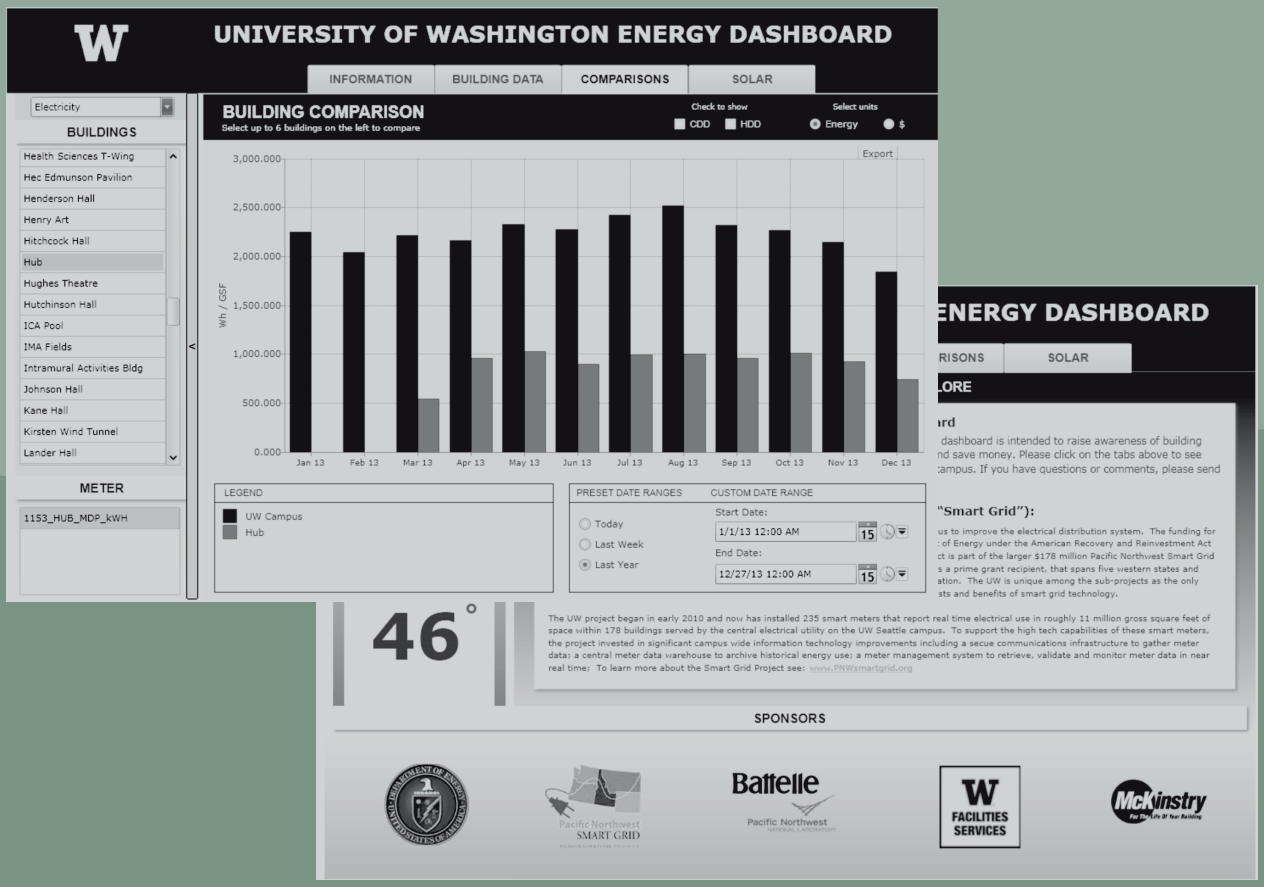

UW Energy Dashboard Study

FINAL REPORT

Funded by the U.S. Department of Energy under ARRA (American Recovery and Reinvestment Act) as part of The Pacific Northwest Smart Grid Demonstration Project

by Marilyn Ostergren

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ABSTRACT

This report summarizes the results of a research study exploring the potential for a display of whole-building electricity consumption data to inform the actions of building coordinators. The setting is a college campus where whole-building electricity meters were installed one year prior to the initiation of the study. Each campus building has a designated building coordinator whose duties include facilitating building access, coordinating evacuation procedures and acting as a liaison between building occupants and campus operations to address problems and to coordinate work that will disrupt activities of occupants. The evidence from interviews with 17 building coordinators conducted for this study suggest that the dashboard is currently having little impact, but the insights from the interview comments and from an analysis of the nature of electricity data displays provide insight to inform future designs.

BACKGROUND

The work described here represents one of six experiments/studies included in the University of Washington scope of work for The Pacific Northwest Smart Grid Demonstration Project. This study relates to another aspect of the Smart Grid project—an energy dashboard created by McKinstry Company to provide public access to data generated by the 235 smart meters installed in campus buildings. The information provided on the dashboard site describes its intention "to raise awareness of building energy consumption to inform conservation efforts that reduce energy waste and save money."

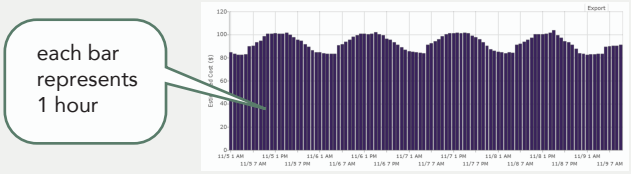
This study was proposed as a way of addressing the question "Does having access to the UW Energy Dashboard impact the behavior of building coordinators in ways that will influence energy consumption, and if so, what role(s) does it play in doing so?" Sub-questions include:

- How often and when do building coordinators find themselves viewing the displays? (Which displays are they viewing? Are they looking at the information often enough to see problems? Is the information portrayed adequate for identifying problems?)
- How are building coordinators interpreting the displays? What are they looking for? (Are they going to additional sources to better understand the displays? What or who are these additional sources? Do they lack knowledge they need to interpret the data?)
- How do building coordinators respond when they see a suspected anomaly? (What actions do they take?)
- Do building coordinators have the resources they need to follow up on questions? (Are there people they can ask? Do they know who those people are?)
- Does the dashboard give building coordinators a better understanding of their building?
- Does the dashboard prompt building coordinators to ask meaningful questions?
- Are building coordinators using the displays to communicate with others? (Other building occupants? Other building managers?)

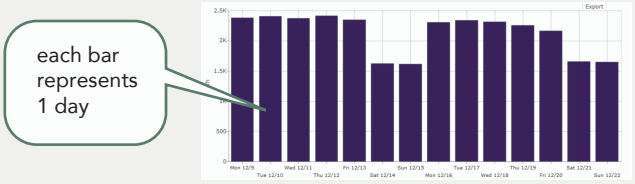
UW ENERGY DASHBOARD

The dashboard is hosted by McKinstry Company and available online: http://dashboard.mckinstry.com/uw/
It has 5 display options:

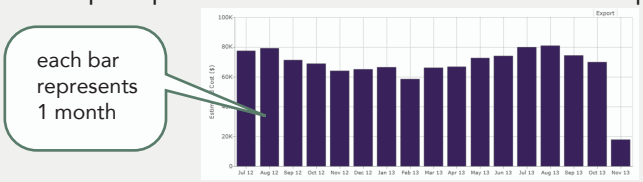
HOURLY READINGS the viewer can choose up to 5 days of consecutive hourly readings revealing the daily pattern of usage (i.e. night-time lows and midday dips).



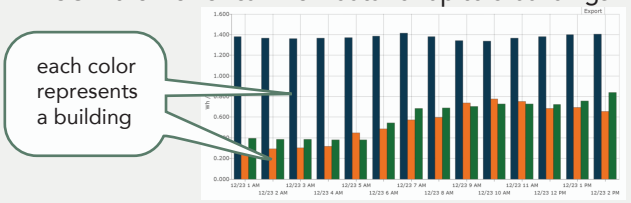
DAILY READINGS the viewer can choose up to 9 weeks of consecutive daily readings showing the average level of consumption per day in kWh. This reveals the weekday/weekend pattern of electricity usage.



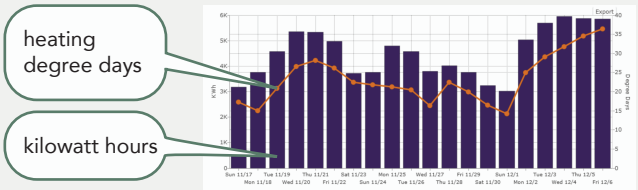
MONTHLY READINGS the viewer can choose over 1.5 years of consecutive monthly readings showing the average level of consumption per month in kWh. This reveals the seasonal pattern of electricity usage.



BUILDING COMPARISON the viewer can view data for up to 5 buildings in a single display.



WEATHER DATA COMPARISON the viewer can display heating and/or cooling degree days to see correlations between electricity consumption and outdoor air temperature



STUDY DESIGN

The study was carried out as specified in the study design approved by the University of Washington Human Subjects Review Committee (repeated here):

1. Identify 20-30 buildings to represent a range of uses, size and age.

2. Send an email message to the building coordinator for each of these buildings, inviting him/her to participate in this study.

3. If less than 20 building coordinators volunteer, identify additional buildings and send out more invitations.

4. Interview the individuals who agree to participate at a location they have chosen. Audio-record the interview (store the audio file in a password protected location).

5. Transcribe the interview, leaving out any portions the participant has asked to be excluded (as described in the consent form).

6. Five-seven months after the original interview, conduct a second interview with the subset of individuals who volunteer to participate in the second interview. Audio-record the interview (store the audio file in a password protected location).

7. Members of the study team will analyze the interview data and write a report based on the analysis. Any quotes included in the report will be identified by building use, size and age, not the name of the participant. Only quotes that pertain to the objective of the study will be included.

The interview script is included as appendix A of this report.

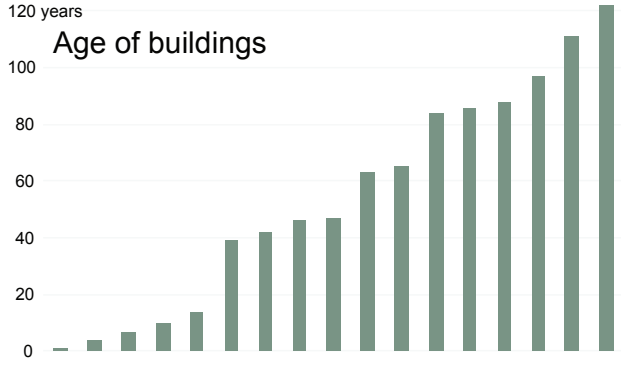
Recruitment email messages were sent to 37 building coordinators. 19 individuals responded to the email messages. 17 of those agreed to be interviewed and 16 were interviewed (the remaining participant had schedule conflicts). Follow-up interviews were sent to the building coordinators who participated in the initial interview. 6 individuals responded to these emails, 5 of whom agreed to a follow-up interview.

The interview transcripts were analyzed for themes. The results are summarized on pages 5-7.

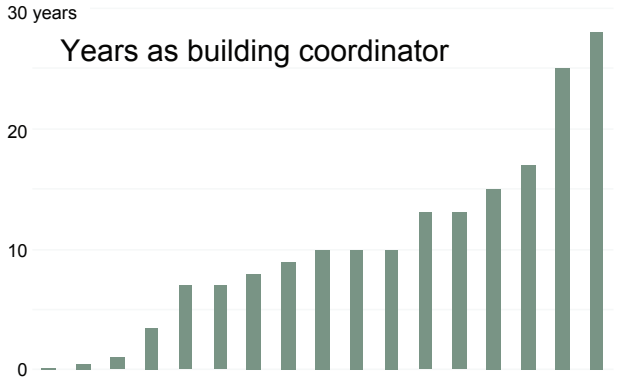
PARTICIPANTS & INTERVIEW RESULTS

University of Washington Building Coordinators
The various roles played by building coordinators at the University of Washington are defined in UW Administrative Policy documents (http://www.washington.edu/admin/rules/policies/APS/13.04.html). They relate to several aspects of building function: security and general management; health and safety; utility shutdowns, building renovations remodeling; building hours; building keys and locks and building use permits.

Building Coordinators who participated in this study
17 building coordinators participated in this study. The buildings they were responsible for ranged in age from under 10 years old to over 100 years old. They included research buildings with science and engineering labs, classroom buildings, administrative buildings and buildings which housed performance halls.



The length of time the participants had served in the capacity of building coordinator ranged from 1 week to over 25 years.



When asked to characterize their building coordinator work, the interview participants gave responses that were closely aligned with what is written in the policy documents. There was, however, a great deal of variation in the level of involvement in these activities and the time spent on building coordinator duties. For some it was an almost negligibly small part of their job while for others—typically those in science and engineering buildings—it was a full- or half-time position.

Interview questions
The interview questions were designed to elicit responses that would generate insight into the potential value of giving building coordinators access to electricity displays. They included direct questions such as "Did the displays give you information about your building that you didn't know before?" as well as questions designed to provide relevant contextual information such as "To your knowledge, are there known problems with your building's energy consumption performance?" The responses are summarized on the following 3 pages.

The following questions were asked to get a sense of the participants' knowledge of their buildings' performance.

• How did you learn about your building's operation?

From experience on the job

15/16

From involvement with the building renovation

4/16

A common theme was that the participants received no formal training for this position but learned more about their building each time they interacted with maintenance and operation staff. Four of the participants had been involved in major renovations and learned a great deal about their building from that experience.

• Are there problems with your building's energy performance?

Room temperature control issues

9/16

Limited electricity capacity

3/16

Air pressure balance issues

3/16

The most common response to this question was that occupants complained about being too cold or too warm. A few mentioned difficulties with balancing air pressure which led to problems with doors not latching or ventilation equipment making noises. A few mentioned that the building had limited capacity resulting in blown fuses when circuits were overloaded.

• Are there opportunities to improve your building's energy performance or reduce energy consumption?

No

2/16

There are some things I could do...remind occupants to keep fume hoods closed, ...defrost freezers, ...turn off lights

4/16

I have no influence or control over this/I don't see it as part of my job

7/16

It's hard to get people to change their behavior…and hard to ask them to when they're wearing gloves to stay warm

2/16

Yes, but I'm told it would be too expensive

6/16

This question was written with the expectation that answers would adress building issues like poor insulation or overheating. But as the results shown above indicate, the common responses related to changing occupant behaviors or reflected a sense that this was not feasible and/or not relevant to their work. The question also triggered comments about why improving energy performance conflicted with other priorities such as meeting safety regulations or needs related to teaching and research.

The following questions were asked to explore the potential or perceived potential for access to electricity data to inform behavior.

• Do you have access to information about your building's energy consumption?

No (I don't think so)

16/17

I did in the past, but the meter stopped working

1/17

The original goal of this question was to learn whether the participants had pre-existing knowledge of their building's energy consumption, but what came up was that none of them were aware of the dashboard, though one had known about a previous metering effort.

• Responses related to the usefulness of having access to electricity data:

I don't think this would have an impact on my work as building coordinator

3/17

It would be useful to have data to help occupants understand the need for changes

3/17

Participants had a hard time imagining how they would use the dashboard though three suggested that it could be a useful to show occupants as evidence for why building modifications were being made.

• Response to the dashboard

Surprise at the pattern (e.g. energy use did not rise during events or dip significantly on weekends)

4/17

Surprise that newer buildings were not more efficient

4/17

The participants were generally interested in seeing how much electricity their building consumed and were particularly interested in seeing how they compared to other buildings, though identifying comparable buildings was a challenge. Several noted that new buidings did not appear to use less energy than older buildings.

• Changes they would like to see

Submetering by floor or lab

3/17

Integration with scheduling system

1/17

A handful of participants had ideas for improvements to the dashboard. Three said they would like to see data for individual floors or labs and one wanted to be able to integrate the information with a calendar of scheduled events in the building.

- Would building occupants be interested in the dashboard?

Yes, occupants care about the environment

9/17

Yes, it's relevant to them

2/17

9 participants felt that building occupants would be interested in learning about how much energy the building consumes because of concern for the environment. Two more felt that occupants would be interested for other reasons (it was relevant to their research or they were concerned about exceeding the building's capacity.

SECOND ROUND OF INTERVIEWS

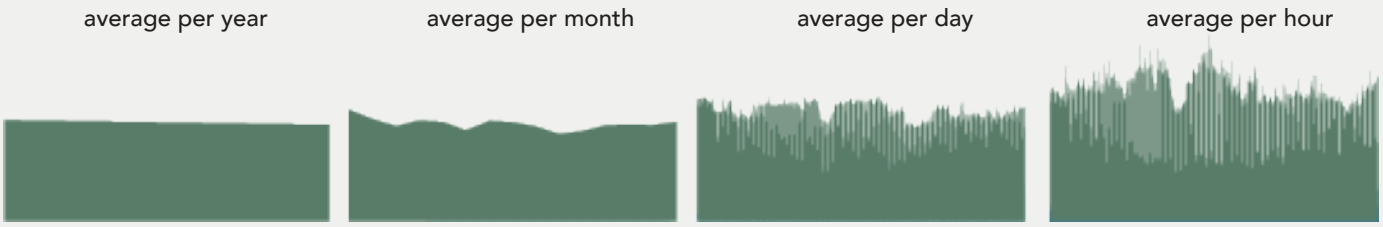
When the experimental design was set up and approved, the second round of interviews was intended to be an opportunity to learn how the participants had used the dashboard during the intervening months. However response to the follow-up email was low (only 6 of the 16 participants responded), and of those who responded, only one had looked at the dashboard during the intervening period. This meant that the follow-up interviews were limited as an opportunity to learn how the dashboard had been used apart from hearing why it had not been used (most had simply forgotten, one had been too busy). I took advantage of the opportunity to present participants with additional displays of their data to explore the possibility that an enhanced dashboard could be more useful. Comments about responses to these additional displays are incorporated in the presentation of display options on pages 8-11.

DISPLAYS OF THE ELECTRICITY DATA

During the course of this study I explored alternative presentations of the data. I've grouped these into 5 clusters which I refer to as "display parameters." They are listed below and described in more detail on the following pages:

1. Level of Aggregation (hourly, daily, monthly, etc)
2. Non-consecutive aggregation (e.g. average of all readings taken at noon)
3. Presentation strategy (bar chart, line chart etc.)
4: Comparison (with other buildings, with weather data etc.)
5. Adding dimensions (reveal more data parameters in a single display)

display parameter: LEVEL OF AGGREGATION



GUGGENHEIM HALL (AERONAUTICS & ASTRONAUTICS)

Value of consecutive aggregation displays

Large scale aggregation (e.g by month or year) makes it easier to see trends that can be obscured by short-term variation and to answer questions such as "has our overall rate of consumption changed?" Small scale aggregation (e.g. by day or hour) makes it possible to see fine-scale patterns and reveals the magnitude of difference between the highest and lowest readings (apparent in the displays above). It facilitates questions such as "Have there been changes in the hourly pattern of consumption change over the past months? Are there unusual periods of consumption that might be worth looking at more closely to correlate with change in building use or rennovation and repairs?"

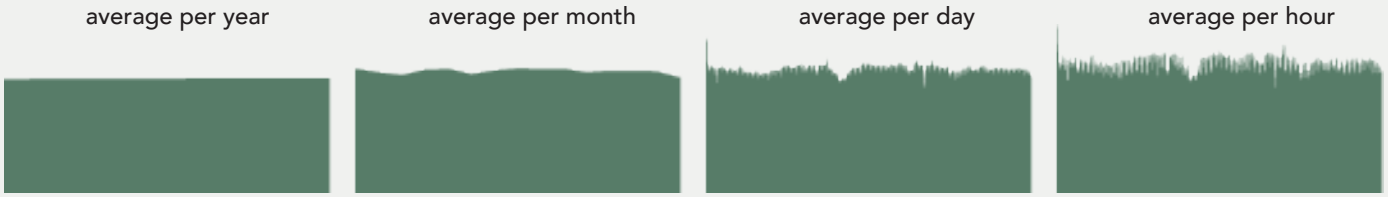
Current dashboard and user responses to these displays

The current energy dashboard presents hourly, daily and monthly levels of aggregation, though the timespan over which data can be viewed at each level is limited (e.g. you can view hourly data for up to 5 consecutive days, but you can't see what hourly data looks like over the course of a year as is shown in the displays on this page).

During the second round of interviews, I showed participants displays of their data at these different levels of aggregation. The displays seemed to be easy to understand and led to further exploration (e.g. to zoom in on an area that was anomalous and attempt to understand why).

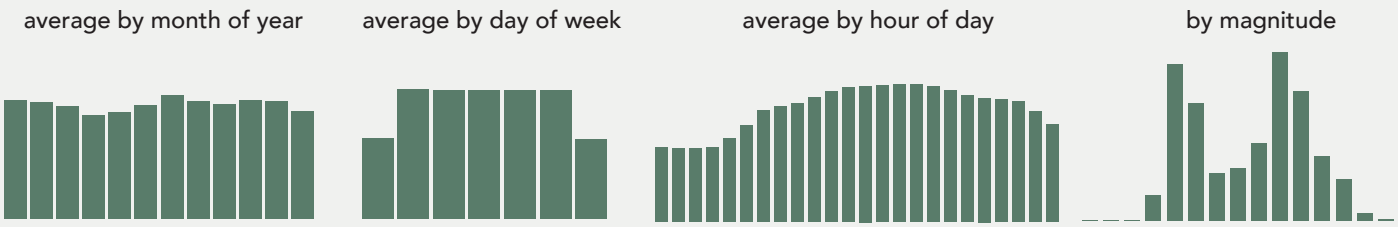
Notes on the displays shown here

The displays above are from Guggenheim hall, a building that shows dramatic differences in consumption between weekdays/weekends and between day-time/nightime. The displays below are from the Computer Science and Engineering building, which shows much less variation (the visible dip corresponds to winter break, 2012.)



COMPUTER SCIENCE & ENGINEERING

display parameter: NON-CONSECUTIVE AGGREGATION



GUGGENHEIM HALL (AERONAUTICS & ASTRONAUTICS)

Value of non-consecutive aggregation displays

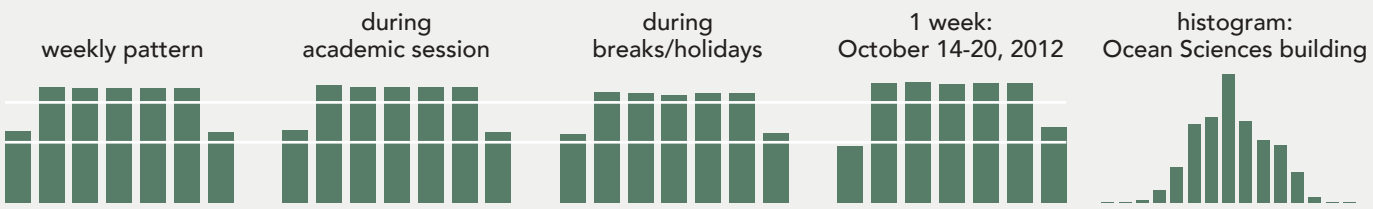
I refer to this category of displays as *non-consecutive* aggregation because they average readings taken at different times (e.g. they were all taken at the same hour of the day, but on different days). This shows generalized patterns that can be used to address questions such as "how does this week's readings compare to the overall average?" Units of aggregation can also be made more specific to address questions such as "how do average daily readings taken when the temperature is above a certain level compare with those taken when the temperature is below a certain level?" Aggregation can also be done based on the magnitude of the readings to produce a histogram like the one on the right which shows that electricity consumption in Guggenheim Hall tends to be at one of two levels (a higher and lower kWh level). These displays act as succinct profiles for a building's energy consumption patterns that can be easily compared with other buildings.

Current dashboard and user responses to these displays

The current UW Energy Dashboard does not include non-consecutive aggregation.
When I showed participants displays of their data at these different levels of aggregation they found the monthly, weekly and hourly displays to be intuitive, but several struggled to understand the histograms.

Notes on the displays shown here

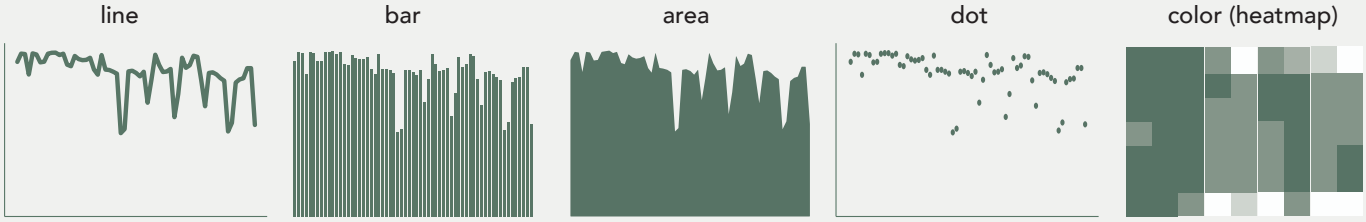
The displays above are from Guggenheim Hall. As mentioned above, the histogram on the right shows Guggenheim's distinctive two-hump pattern reflecting the substantial differences between readings taken during night-time or on weekends and those taken during the day on weekdays. In contrast, the histogram for the Ocean Sciences building shown below on the far right has a single hump reflecting less distinct differences between weekends/night-time day-time weekday readings. The first four displays below show 3 aggregations of daily averages by weekday for Guggenheim Hall. The first was created from all of the available data. The second was created from readings on days when the academic quarter was in session. The third was created from readings on holidays and academic breaks. The fourth shows the values for a single week (October 14-20, 2012) and reveals that on Sunday, October 14, consumption was lower than average while on Monday-Saturday consumption was slightly higher than average.



GUGGENHEIM HALL (AERONAUTICS & ASTRONAUTICS)

OCEAN SCIENCES

display parameter: PRESENTATION STRATEGY



GUGGENHEIM HALL (AERONAUTICS & ASTRONAUTICS)

Value of different presentation strategies

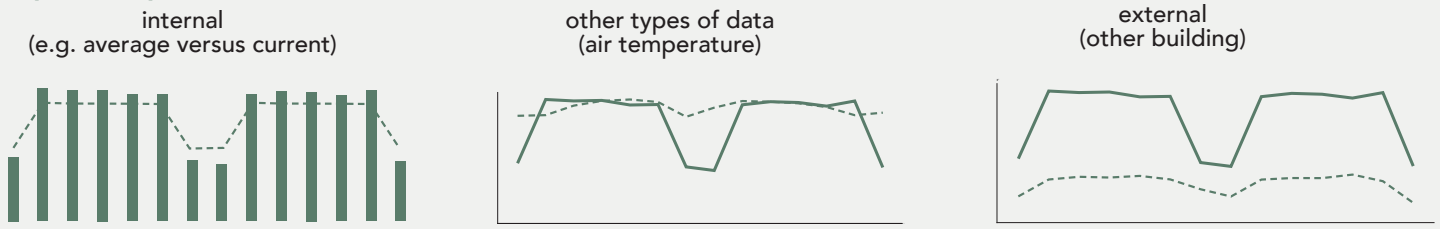
The 5 displays above all show the same data values—daily readings from July 1 through September 1, 2012. Different display strategies make different aspects of the data more salient. For example, the dot display (fourth from the left) makes it easier to focus on the lower readings that began appearing in August. The heatmap on the right makes it immediately apparent that those values occur on weekends (in this display, each column represents a week and each row represents a day of the week). This set of display options is by no means comprehensive, but is intended to demonstrate the value of providing multiple display options to help the viewers choose the one that fits their needs.

Current dashboard and user responses to these displays

The current UW Energy Dashboard uses bar charts for all of the electricity data and line charts for the heating- and cooling-degree day data.

I showed participants all of these displays with the exception of the dot display. They seemed to find the various displays easy to interpret. They were particularly interested in heatmap displays showing weekly patterns for the entire data set (in which quarter breaks and holidays were easy to recognize as strings of pale squares).

display parameter: COMPARISON



Value of comparison displays

The ability to make comparisons is perhaps one of the most important ways to increase the effectivenss of the displays becuase it creates context. They help to address questions like "Is this pattern normal?" "Are these readings unreasonably high?" "Is this dip the result of occupant behaviors or weather?" The diagram above shows three major types of comparison: comparison between readings for a single building, comparison with other types of data that may impact electricity consumption, and comparison with readings from a different building.

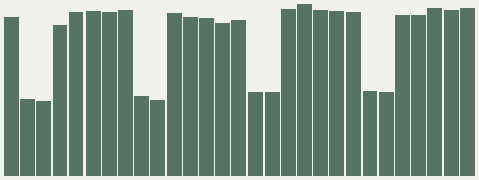
Current dashboard and user responses to these displays

The current UW Energy Dashboard allows viewers to compare data between buildings and to compare electricity data with cooling- and heating-degree data (see diagrams on page 2).

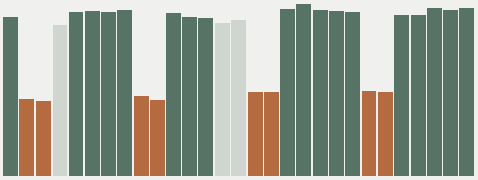
I showed a few additional comparison displays to interview participants. One that generated interest was a bar chart showing average consumption for 10 buildings. Another that generated interest was a scatterplot showing the correlation between electricity consumption and outdoor air temperature for a building that used electricity for cooling. Scatterplots are an excellent way to show correlations, but they are relatively challenging to understand and I found that viewers needed assistance to appreciate what they were seeing.

display parameter: ADDING DIMENSIONS

2 dimensions (height and position)



4 dimensions (height, position, color, shade)



Value of adding dimensions

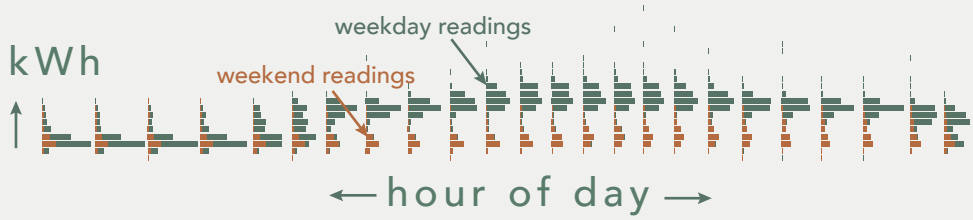
Adding dimensions refers to using additional visual strategies to display additional data parameters. For example the bar chart above on the left shows 2 data parameters - the size of the reading (represented by the height of the bar), and the day of the reading (represented by the horizontal position of the bar). The bar chart on the right shows 2 additional parameters, day of the week (represented by color, green = weekday and brownish orange = weekend day), and type of day (represented by the shade of color, dark = regular working day, pale = holiday - in this case Veteran's Day and Thanksgiving Day). These additional dimensions facilitate interpretation of the data (i.e. help explain why some readings were relatively).

Current dashboard and user responses to these displays

The current UW Energy Dashboard displays are limited to 2 dimensions.
I showed participants displays in which I had added additional dimensions and they responded well, though I was there to explain each dimension. It would require more design and testing work to ensure that these displays would be properly interpreted without narration.

Notes on the displays shown here

Below is a more challenging example of a multi-dimensional display. It shows histogram data (which many people find challenging). The vertical position of the bars indicates the size of the reading in kWh and the length of the bars indicates the number of readings at that kWh level. The color (a 3rd dimension) indicates whether the readings were taken during a weekend or on a weekday. A 4th dimension is created by splitting the histogram into 24 parallel histograms, each showing the readings taken during one time segment of the day (e.g. the first shows all the readings taken between midnight and 1:00 AM). This display allows you to see that the readings in the early hours of the morning are similar on weekends and week-days, but that the weekend daytime readings look more like early morning readings than weekday day-time readings.



DISCUSSION

The central question this study aims to address is "Does having access to the UW Energy Dashboard impact the behavior of building coordinators in ways that will influence energy consumption?" Assuming that the 17 participants are somewhat representative of the 200+ building coordinators at the UW, the answer is quite clearly "no." Setting aside the evidence that most of them are unaware that the dashboard is available, the responses to the interview questions suggest that they do not see the information as relevant to their work as a building coordinator and the displays do not give them information they able to take advantage of.

Below I address the sub-questions this study was designed to address.

• How often and when do building coordinators find themselves viewing the displays? (Which displays are they viewing? Are they looking at the information often enough to see problems? Is the information portrayed adequate for identifying problems?)

These questions were written with the expectation that building coordinators might be in a position to use these displays to monitor building performance and report anomalies to Facilities Services. Having spent time interviewing building coordinators, exploring the data, and learning more about building management and maintenance, this initial expectation feels somewhat misplaced or naive. On the other hand, this could be the direction we head toward as building technologies evolve. The role of building coordinator might evolve as well to include using building data to help occupants achieve their goals (staying comfortable and doing their jobs) while minimizing energy demands.

• How are building coordinators interpreting the displays? Do they lack knowledge they need to interpret the data?

As I viewed the dashboard with building coordinators I saw them work to align the patterns they saw in the data with their knowledge of how the building was used (which was often considerable) along with their knowledge of what consumes electricity in their building (which, with some exceptions was limited). The displays triggered more questions than answers (is electricity used for cooling in this building? do server rooms consume a significant amount of energy? are the dips at night a result of occupants leaving or building systems being shut down?) As the small body of literature relating to processing and presenting electricity meter data makes clear, sorting through the factors that influence electricity consumption to accurately interpret this data is complex and requires access to information about building systems and settings, occupancy levels, weather conditions and sources of electrical load (e.g. Liu, Chen, Mori, & Kida, 2010; Mathieu, Price, Kiliccote, & Piette, 2011; O'Neill et al., 2011; Smith et al., 2011). Though building coordinators do not have an engineer's need for precision in their interpretations, they do need some ability to incorporate additional information in order to make sense of the patterns they see.

What are they looking for?

The building coordinators were generally curious to see how much energy their building consumed, and how they compared with other buildings, but otherwise seemed to have few expectations about what the displays would show them.

Are they going to additional sources to better understand the displays? What or who are these additional sources?

In buildings where performance events took place, the building coordinators turned to their calendars to see how those events corresponded to changes in electricity consumption.

• How do building coordinators respond when they see a suspected anomaly? (What actions do they take?)
In this initial exposure to the dashboards, most building coordinators simply attempted to interpret the anomaly based upon their own experience and understanding and were left confused if the two were not aligned. They didn't seem to feel it was their place to take action or inform someone else about what they saw.

• Do building coordinators have the resources they need to follow up on questions? (Are there people they can ask? Do they know who those people are?)
Given that the participants had spent little or no time on their own with the dashboard I didn't get feedback to address these questions. The URL, "http://dashboard.mckinstry.com/uw/), created some confusion about whether the dashboard came from the UW or McKinstry. There was also confusion about the intended audience (e.g. several suggested that this dashboard would be of more interest to UW engineers).

• Does the dashboard give building coordinators a better understanding of their building?
Again, the lack of time the interview participants spent with the dashboard meant there was little evidence to use as a basis for answering this question. However, having spent considerable time exploring the data myself and watching participants learn from new displays during the second round of interviews, I see good potential for an updated version of the dashboard to achieve this goal. By exploring carefully-designed displays and by comparing displays across buildings, it is possible to develop a sense for the uniqueness energy consumption patterns of each building.

• Does the dashboard prompt building coordinators to ask meaningful questions?
Within the context of the interview, the dashboard provoked questions about whether the amount of energy the building consumed was reasonable or excessive as well as questions about how electricity is used in the building.

• Are building coordinators using the displays to communicate with others? (Other building occupants? Other building coordinators?)
Several participants saw the potential for the dashboard to be used as a communication tool when explaining the need for potentially disruptive building modifications, but only one participant reported having shared the dashboard with someone else (a supervisor).

Despite the limited use of the dashboard, the results of this study provide a number of insights upon which I have based recommendations for actions to take to increase the likelihood that the dashboard will be used as a tool for better understanding electricity consumption in UW buildings.

REFERENCES

Liu, D., Chen, Q., Mori, K., & Kida, Y. (2010). A method for detecting abnormal electricity energy consumption in buildings. Journal Of Computational Information Systems, 14, 4887-4895.

Mathieu, J. L., Price, P. N., Kiliccote, S., & Piette, M. A. (2011). Quantifying Changes in Building Electricity Use, With Application to Demand Response. Smart Grid, IEEE Transactions on(99), 1-1.

O'Neill, Z., Shashanka, M., Pang, X., Bhattacharya, P., Bailey, T., & Haves, P. (2011). Real Time Model-based Energy Diagnostics in Buildings. Proc. Building Simulation'11.

Smith, D., Henretig, J., Pittenger, J., Bernard, R., Kofmehl, A., Levine, A., . . . Piette, M. A. (2011). Energy-smart buildings: Demonstrating how information technology can cut energy use and costs of real estate portfolios: Accenture.

RECOMMENDATIONS

The following recommendations are based on insights gained from this study.

Raise awareness

The fact that none of the building coordinators knew about the dashboard is clearly a major barrier. I offer the following recommendations with appreciation for the fact that similar efforts may have been made to disseminate this information, but lack of interest and/or lack of time may have prevented this information from being heard.

- Consider making a link to the dashboard available on the Campus Engineering & Operations page
- Consider sending an announcement to building coordinators and encouraging them to forward the announcement to building occupants
-Consider using marketing experts on campus to make a more concerted effort to raise awareness about the dashboard (ideally after other recommendations have been put in place to improve the likelihood of a positive reception).

Consider expanding the role of the building coordinator

Many of the building coordinators interviewed for this study pointed out that facilitating energy conservation or monitoring building performance is not one of the designated roles for building coordinators. Yet they are in the unique position of being the person most familiar with both the uses of the building by occupants and with the work done in the building by maintenance staff and others. This makes them a valuable ally in facilitating conservation efforts by communicating opportunities for reducing waste from building occupants, and helping occupants accomodate changes that will improve efficiency in the building.

Consider adding to the training provided to building coordinators

As one building coordinator pointed out, the role of building coordinator in most buildings is assigned to an individual whose main job has nothing to do with building function and may have no experience with interpreting data displays. In addition to providing information about the electricity loads in their building (something addressed below), they may benefit from training to interpret and use the energy dashboard. (This applies to other building occupants as well and could consist of a combination of brief tutorial videos and annotations within the dashboard displays to explain, for example, what heating degree days are and why they may or may not correlate with electricity consumption patterns).

Consider providing more guidance to viewers

The introductory page on the dashboard site specifies that the dashboard is intended to raise awarenss of building energy consumption to inform conservation efforts, and suggests that viewers can send an email message if they have questions or comments. As mentioned in the discussion of the interview results, there was some confusion about the source of the dashboard (UW or McKinstry) and the audience (engineers or occupants). Viewers, including building coordinators might feel more empowered to use the dashboard if they felt convinced that the dashboard is directed to them and provided with guidance about how they can use it to help the University.

Consider the following enhancements to the energy dashboard

Add information about the validity of the data. When viewers see information that is difficult to make sense of (e.g. surprisingly high or anomalous values) they may lose confidence in the accuracy of the data. This could be addressed by adding the ability to display notes explaining anomalies (e.g. "an electrical outtage occured here") and also a general note to indicate whether or not the data for a given building has been viewed and vetted by an engineer.

To ensure that they first display a viewer sees is easily to interpret and interesting, change the default display to a line graph showing at least 2.5 days of hourly readings (to reveal the 24-hour pattern) or at least 2.5 weeks of daily readings (to show the weekly pattern).

Allow for all levels of aggregation (yearly, monthly, daily, hourly and 15-minute) at any span of time the viewer chooses rather than switching to a higher level of aggregation for longer time spans.

Allow the viewer to view non-consecutive aggregations—i.e. the average 24-hour pattern for weekdays, the average 24-hour pattern for weekends, and the average weekly pattern and to use these to compare with current values.

Allow the viewer to switch between bar charts, line charts, area charts, dot charts and heatmaps as appropriate.

Include academic calendar year data and enable the viewer to add color to indicate weekend/weekday readings, academic breaks and holidays. Ideally allow the viewer to add custom calendar data for their building.

For each building, provide information about the building use - perhaps in the form of a pie chart showing percentage of classroom, office, lab, computer space, food service etc.

For each building, indicate whether heating and cooling are done with electricity along with other major electricity-consuming facilities (e.g. server rooms or food services).

For building comparison displays, don't restrict the number of buildings that can be displayed. Use a line chart as the default display and give an option of side-by-side mini-charts.

Appendix A: Interview Script

[Note: The only questions that will be asked and recorded, other than those written below, will be requests for clarification of answers to the original question]

Thank you very much for participating.

We're conducting these interviews with building managers at the UW to find out how useful the new UW Energy Dashboard is. I realize you may not have seen it yet, which is fine – if that's case I'll show you the dashboard and ask you questions about whether you expect to find it useful.

I'll be recording the interview so I can keep track of your answers. I may end up quoting you in a written report to explain to others why the Dashboard is or isn't useful. I won't use your name with the quotes – just the type, size and age of the building. But if you happen to say anything you'd rather not have quoted, just let me know and I won't include it. Also feel free to pass on any of the questions I ask and I'll just move on to the next one.

I'm going to start the recorder now. [Start recording]

Questions to ask in the first interview only:

• How long have you had the role of building manager for this building? Have you had other building manager positions at the UW?
• What does the building manager job entail, generally?

Pre-existing knowledge of building performance
• What information about how your building's energy consumption is currently available to you?
• What information (if any) about the building's operation were you given when took this position? Where/how have you learned about your building's operation since you took this position (if any)?
• To your knowledge, are there known problems with your building's energy consump tion performance (e.g. are there known problems with the ventilation fans)? If yes, what are those problems?
• To your knowledge, are there opportunities to reduce the building's energy consump tion? If yes, what are those opportunities?
• Are there plans to make changes that would alter the building's energy consumption (e.g. retrofits/remodeling/additions/changes in function)? If yes, what are those plans?
• Who has control over changes that would improve the building's efficiency? Is that someone you communicate with?
• What would you find it useful to know about how your building performs?

Questions for both interviews (first and follow-up):

Anticipated response to provision of meter data (if they haven't already seen it)

- Have you had access to electricity and other energy consumption data for your building in the past? Would you find it useful to have access to electricity and other energy consumption data for your building?
- Do you anticipate that building occupants will be interested in this information? If yes, describe that.
- Are there particular people/particular roles that will be interested? If yes, who are they?

Response to provision of meter data (if they have already seen it)

- Describe your experience with the UW Energy Dashboard – it's useful to hear negative as well as positive experiences. (NOTE: the display will be present during this discussion).
- Which views have you looked at? (Follow-up questions if they haven't already answered them) Have you looked at other buildings' consumption? Was that helpful? What level of granularity did you find helpful - daily, weekly, yearly?
- How often did you feel it would be useful to look at the dashboard?
- Have you shown this information to others either to inform them or to consult with them? Do you foresee a situation in which you might do so?
- Have you discovered anything unusual in the data?
- Did the displays give you new information about your building that you didn't know before?
- Do you have ideas for reducing electricity consumption triggered by these displays? Do you have a way of making that happen or influencing it in your role as building manager?
- What changes would you like to see in the display of the current information?
- What additional information would you like to have in the Dashboard?