# Not Your Average Energy Feedback:
# Leveraging Emotion and Social Context in Feedback for the Workplace

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## ABSTRACT

Providing consumers with feedback about their energy consumption is a common strategy in the residential sector, but less common in the commercial sector. Feedback is more complicated in the commercial sector because there are typically many more building occupants to reach, most of whom have no financial incentive to use energy efficiently. Utility energy feedback programs, such as the green button initiative and energy reports, are accessed by a single proprietor or building manager as a paper- or web-based display that is not conducive to widespread dissemination to all relevant occupants. The format is also data-heavy, which many targeted consumers may not find engaging, especially when they have no financial stake in understanding the information. The present research explored the potential role of creative energy feedback displays in workplaces. We implemented a program of extremely low fidelity, ambient feedback: a ceremonial display of flags and music three times per day. Occupants participated in focus groups and surveys before and after the intervention. Results suggest that emotive, low fidelity feedback complements objective, granular feedback by capturing attention and creating motivation to learn how to reduce energy consumption. Furthermore, public feedback on collective behavior leverages social influence, creating a sense of community, group identity, norms for responsible energy consumption, and accountability. Practical implications for building these features into more conventional energy feedback programs will be discussed.


## Introduction

McCalley and Midden (1998) defined eco-feedback as "information presented during the product-user interaction which prompts the user to adopt energy saving strategies" (2). Froehlich, Findlater, and Landay (2010) later expanded the definition to "feedback on individual or group behaviors with a goal of reducing environmental impact" (1). Early eco-feedback applications focused on providing households with information about energy consumption via mailings and personal electronic devices (Fischer 2008). Applications have since expanded to other social and resource contexts, and interfaces have become more diverse and creative (Table 1).

Many innovative eco-feedback applications come out of the field of human-computer interaction (HCI). Froehlich et al. (2010) noted that HCI research has tended to focus more on innovative design and technology and less on behavioral theory and evaluation. Meanwhile, psychologists have demonstrated the reverse disposition in their eco-feedback research. As a result, most of what we know about how eco-feedback works is based on a relatively narrow range of applications (private interfaces for residential electricity consumption).

The present research expands our understanding of how innovative eco-feedback works by exploring users' response to an eco-feedback program that was unconventional along multiple dimensions. University research office occupants received public feedback on their collective behavior (social context) of electricity consumption in a planned zero-net energy (ZNE) building (resource context), via a low fidelity ambient and physical interface--specifically, a ceremonial display of flags and music (interface design). Results indicate a need for more inclusive and interdisciplinary conceptual frameworks for designing effective eco-feedback.

Table 1. Conventional and unconventional dimensions of eco-feedback

| | Social Context | Resource Context | Interface Design |
|---|---|---|---|
| Conventional Eco-feedback | Residential; individual or household behavior; private display | Electricity from grid | Scientific (numbers and graphs); computerized |
| Unconventional Eco-feedback | Commercial; community behavior; public display | Energy from renewable sources; water | Artistic, ambient, tangible; interactive |
| Eco-feedback application in this study | Commercial (office); community behavior; public display | Energy from solar PV in planned zero-net energy building | Ambient, tangible, participatory (flag and music ceremony) |

## Literature Review

The following sections review research on eco-feedback applications with the particular unconventional social, resource, and interface dimensions involved in this study. We also point out opportunities to expand these types of eco-feedback. Where applicable, we consider how findings align, or do not, with established knowledge on home energy feedback.

### Unconventional Social Contexts: Collective and Public Eco-feedback

Households have most often been the target of eco-feedback interventions. Relatively fewer interventions have targeted the commercial sector. The appropriateness of eco-feedback for employees is less convincing since they do not have a financial incentive to conserve and may lack control of consumption due to access, automation, or the communal nature of end-uses.

However, the limited research in this context suggests eco-feedback in the workplace can be effective in reducing energy consumption (Carrico and Riemer 2011) and waste (Siero et al. 1996; Schwartz et al. 2010), and increasing awareness and concern about energy use (Borner et al. 2012). Important features include occupant participation in interface design (Borner et al. 2012; Foster et al. 2012), community goal creation (Foster et al. 2012), peer comparison and competition (Borner et al. 2012; Peschiera and Taylor 2012; Siero et al. 1996), and department-level feedback (Foster et al. 2012). The latter runs counter to a general conclusion in home energy feedback research that greater disaggregation is optimal (Froehlich 2009). In the workplace, office occupants may be opposed to disaggregated data if it is available publicly or to supervisors as it may reveal private information about their behavior (Coleman et al. 2013). This consideration also points to the importance of the audience who can access the feedback.

Eco-feedback can have a broader (or narrower) audience than those whose behavior it reflects. For example, Moere et al. (2011) installed chalkboards on home exteriors, where they recorded individual household energy performance visible to neighbors and passers-by. This public feedback resulted in greater energy reduction and more sustained conservation behavior compared to a private feedback device. On the other hand, some utility companies provide businesses with energy reports that include feedback (Cornish et al. 2016), but these are typically sent to business owners or managers and may not reach most building occupants who use energy.

### Unconventional Resource Contexts: Eco-feedback for ZNE Buildings

Minimal literature is available on eco-feedback in the context of buildings with on-site energy generation, including ZNE buildings. This is prime territory for eco-feedback for several reasons. First, there is a unique opportunity to provide information about energy generation in addition to consumption feedback. This could help occupants connect to resource systems in a deeper way. For example, Keirstead (2007) found that households with monitors displaying PV generation information increased load-shifting and reduced consumption.

Further, research has found that solar photovoltaic (PV) adopters sometimes have misperceptions that renewable energy means free, clean, and unlimited, so there is potential for a rebound effect (Madjar and Ozawa 2006). These misperceptions may be higher among commercial building occupants that do not pay energy bills. On the other hand, some research has shown that households can become more aware and concerned about energy use after adopting PV (Caird, Roy, and Herring 2007). In either case, eco-feedback would be valuable.

Finally, microgeneration and ZNE buildings in particular suggest inherently meaningful goals (of keeping consumption within limits of local energy production) that can provide a feedback standard. Kluger and DeNisi (1996) described the feedback-standard comparison as a major mechanism behind the effects of feedback on behavior. In the absence of an intuitive, meaningful goal such as ZNE, eco-feedback applications often rely on historical and social comparisons, or arbitrary goals, to motivate consumer response.

### Unconventional Interface Designs: Eco-feedback Outside the Digital Box

Perhaps the most radical departure of the present study from conventional eco-feedback is the interface design. Early eco-feedback studies used paper reports or basic digital devices. As personal electronics and the Internet took center stage in human-information interfaces, web-based displays and mobile applications became the predominant mode of eco-feedback delivery (Froehlich et al. 2009). We are now seeing human-information interfaces embedded in our physical environments, and even on our bodies, with the growing Internet of Things and advent of wearable technologies (Ishii and Ullmer 1997). Innovations in eco-feedback displays along these lines (e.g., ambient or tangible interfaces) have generally been limited to prototypes.

The most common examples of ambient eco-feedback involve the symbolic red-yellow-green colored lights via an in-home energy monitor, to signify rate of consumption; there is support for their effectiveness in terms of demand reductions (Ham and Midden 2010), load shifting (Faruqui, Sergici, and Sharif 2010), and increased awareness of energy use (Alahmad et al. 2012). A scaled-up example of ambient eco-feedback is the Nuage Vert (green cloud) temporary art installation by artists HeHe. It reflected Helsinki’s energy savings via a green laser outline of a coal plant smokestack corresponding in size to the city’s conservation efforts (Newcombe n.d.), which resulted in significant energy savings.

Tangible interfaces are less common. One example is a project by Kuznetsov et al. (2011), who installed large glowing balloons in urban places to reflect local air quality in terms of various pollutants via red-yellow-green color changes. Similar to ambient feedback, tangible feedback embedded in the physical environment is less capable of granular data than digital interfaces. See Maze and Redstrom (2008) for other examples of tangible eco-feedback.

### Present Research

The literature surveyed above outlines the importance and feasibility of broadening applications of eco-feedback. In particular, we noted the relatively untapped potential of public, ambient, and tangible interfaces; targeting group behavior at the workplace; and designing for the context of on-site energy generation, particularly ZNE buildings. The present research explored an eco-feedback intervention with these unconventional dimensions. In the next section we overview the research setting and our participatory eco-feedback design process. We then describe the intervention and post-intervention focus group, which are the focus of this report.

## Method

Our study took place in West Village at University of California, Davis. West Village is a mixed-use ZNE development (Hammer et al. 2014; Price et al. 2012) that has yet to meet its ZNE goal. Behavioral interventions have been highlighted as part of the solution for West Village to reach ZNE (Dakin and German 2014) and implemented with student residents (Hammer et al. 2014; Outcault et al. 2016), but not with occupants of the commercial spaces.

Most of the 60,928 sq. ft. of commercial space at West Village was intended for retail, and designated PV volume was modeled accordingly. Instead, most of this space became occupied by research labs and offices, which consume more energy than their dedicated PV panels produce. Our study is the first to address occupant behavior in these commercial spaces. We focused on a single research center located in one of four buildings that have research centers on the ground floor and apartments above. The targeted center had about 30 employees, six offices, open workspaces, a conference room, kitchen, and bathrooms.

### Eco-feedback Design

We involved office occupants in a participatory design process, deemed useful by Borner et al. (2012) and Foster et al. (2012). First, we designed a preliminary feedback system incorporating insights from our literature review--inspired by the public feedback in Moere et al. (2011), the ambient feedback in Bartram et al. (2010), the department-level feedback in Carrico and Riemer (2011), and the concept of a meaningful feedback standard per Feedback Intervention Theory (Kluger and DeNisi 1996). We then gathered data and input from employees via a survey and focus group. This design process is not the focus of the present research, but we briefly overview the methods and results as context for our eco-feedback design.

We invited all employees to take a survey regarding their energy use behaviors in the office and related attitudes. Respondents reported feeling competent they could figure out how to reduce office energy use, but admitted they did not pay much attention to energy use. We identified several specific behaviors that could be improved (in response to the feedback): unplugging devices not in use, switching off power strips before leaving, turning off lights when last to leave, using fewer lights, and turning off unnecessary lights. Occupants unanimously indicated willingness to conserve energy and reported strong personal norms for energy conservation, but social norms were relatively low (e.g., only 47% agreed with the statement "If I reduce my energy use, my supervisors and colleagues will be appreciative"). These findings suggested our feedback should focus on raising awareness of energy use and fostering workplace social norms around energy conservation. We shared the survey results with employees.

All office occupants, as well as several energy researchers from neighboring centers, were invited to participate in a two-hour focus group to envision their ideal workplace energy feedback system. Five participants attended and were given a short introduction to eco-feedback (various applications, general theories), engaged in an independent design exercise (given sheet of paper, pencil), and then a team design exercise (given butcher paper, drawing utensils). Themes among participants' designs were a desire for qualitative information and strategically timed feedback delivery when they would be most able to attend to it. One team's design resembled our preliminary design; they wanted feedback related to the ZNE goal and emphasized ideas of spectacle, community, and ceremony. They described the ceremony: "There would be somebody in charge and at the same time each day … everyone would be looking [outside] to see the result; it would be a changing of the guard – a ceremony."

We incorporated insights from the survey and focus group to arrive at our final feedback design, Flag Feedback. The cornerstone of Flag Feedback was a ceremony conducted three times per day (9am, 12pm, 4pm), beginning with a 20-second excerpt of either The Imperial March (Darth Vader theme song) or Eye of the Tiger (Rocky theme song) to indicate if the office had consumed more or less than their ZNE target, respectively, since the previous ceremony. After initiating the music, a research assistant marched outside the office periphery carrying a red or green flag (also corresponding to performance relative to ZNE) while the music played (Figure 1), before mounting the flag near the front door. Exterior walls were composed of windows, so the flag and ceremony were highly visible to all office occupants and neighboring research centers. We implemented feedback for two weeks (ten weekdays).


Figure 1. Flag Feedback ceremony.

We triangulated three sources of data to model the office-specific ZNE consumption targets: (1) the developer's modeling of estimated consumption and PV production for the space; (2) monthly utility bills for the past year reporting net consumption (consumption – production); and (3) one month of baseline data from Onset HOBO U30 data loggers. We configured the loggers to capture only lighting and plug loads because occupants had the most control over these end-uses; occupants had varied and limited control over HVAC. We excluded electric vehicle (EV) charging since it was not accounted for in the developer's modelling and no additional PV panels had been added to offset all the EV charging added after development.

There were some inconsistencies in electrical panel labeling and lack of access to some spaces associated with the electrical panel, so we were unable to identify all circuits with certainty. For example, we believe we included one or two ceiling lights in a neighboring office space (which our participants could not control). Due to this imprecision, analysis of consumption data is not a rigorous way to evaluate the feedback intervention; however, we provide these data in Figure 2 as context. An engineer was hired to complete more accurate circuit mapping for subsequent projects. As previously mentioned, our focus was on user experience with this innovative eco-feedback, assessed in the post-intervention focus group.

Our calculations of ZNE consumption targets proceeded as follows. First, we determined an annual target by multiplying the estimated annual PV production for the building by the proportion of actual electricity consumption the office lighting and plug loads represented out of total building consumption. Then, we calculated a weighted average target for the month based on actual consumption of that month in the previous year relative to annual consumption. Following the same pattern, we calculated two weighted average daily targets--one for work days (235/year) and another for weekend days and holidays (130/year), based on actual consumption for the past month. Finally, using baseline data from HOBO loggers, we calculated three weighted average hourly targets: one for workday morning hours (9:00 a.m. - 12:00 p.m.); one for workday afternoon hours (12:00 p.m. - 4:00 p.m.); and one for night and weekend hours (4:00 p.m. - 8:00 a.m. on weekdays and all weekend hours). Multiplying these hourly targets by the number of hours in each period (weekday mornings, weekday afternoons, nights, and weekends) we arrived at the four consumption targets used in the flag experiment.

The HOBO logger web portal, HOBOlink, was programmed to send an email to a member of the research team at the end of each of the periods described in (5) above with the consumption data for that period. This person then quickly processed the data (summed and compared to the respective ZNE target), to determine the valence of the feedback (i.e., which flag and music), then implemented the ceremony (or emailed someone else who implemented).

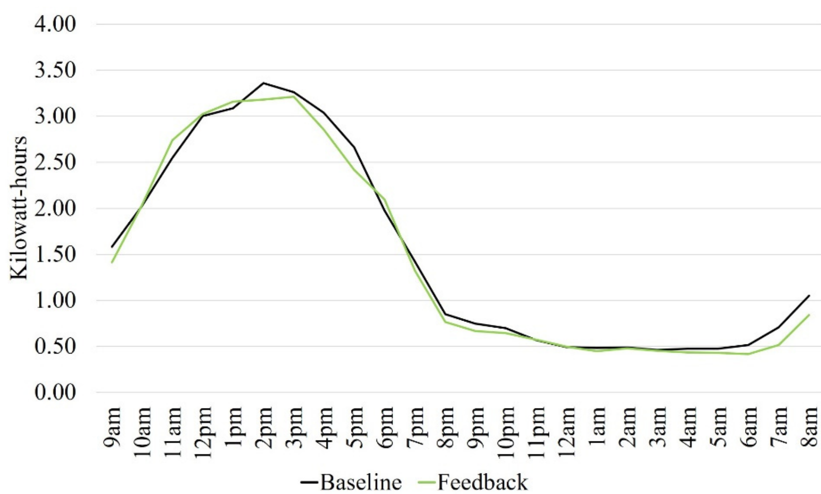


Figure 2. Comparing average hourly weekday consumption in baseline and feedback phases.

## Post-Intervention Focus Group

A one-hour focus group was designed to assess office occupants' experience and opinions regarding Flag Feedback. We recruited all office occupants via email, and provided food as a participation incentive. Six attended, including a staff computer programmer, two staff transportation researchers, an administrator with a background in mechanical engineering, and two student research assistants with backgrounds in mechanical engineering and transportation.

We framed the focus group as a discussion for a next iteration of the feedback system, rather than as an evaluation of the system, in order to encourage critical feedback. Before opening the discussion, we reviewed important characteristics of eco-feedback that support behavior change per Sanguinetti, Dombrovski, and Sikand (2018), concerning feedback information (e.g., granularity, feedback standards), timing (e.g., frequency), and display (e.g., location, medium, modality, style). Our aim was to prompt consideration of all aspects and experiences of Flag Feedback and other possibilities. We then asked participants what features they wished to retain, change, omit, or add to the system, and why.

One author led the focus groups while two research assistants took detailed notes, including quotes when possible, which were later combined and content-analyzed. We sorted responses by relevance to social context, resource context, and interface design, and then by more specific dimensions, e.g., granularity, frequency, and modality. We also identified themes inductively from users' discussions, e.g., about qualities and effects of the feedback.

## Results and Discussion

Themes emerged from the post-intervention focus group regarding the unique impacts of the unconventional characteristics of our feedback system, including users' affinity for the flag ceremony, which became part of the office routine and strengthened community identity. However, participants expressed a desire for more frequent and detailed data with historical and social comparisons. We discuss findings in terms of the unconventional eco-feedback social context, resource context, and interface design dimensions that characterized Flag Feedback.

### Social Context

Flag Feedback represented several unconventional social context dimensions, including that it targeted collective behavior in the workplace and was accessible to a public audience. Themes related to the collective and public nature of the feedback that emerged in analysis of the focus group discussion included: identity, accountability, community, and social sharing. One participant noted, "It gave our office character...made us different...unique." Another noted, "A public flag display could keep you accountable to your neighbors." Thus, the collective and public feedback reinforced group identity in the office; and there were indications that publicness increased motivation to conserve, which is consistent with Moere et al. (2001).

Opportunities the feedback provided for socializing and creating a sense of community were featured in participants' discussions. They enjoyed the students parading around with the flag and noted that people outside the office were interested. Participants also asked for the addition of social comparisons so they could compete with other research centers. These findings are consistent with other eco-feedback research that recommends social-sharing and competitions (Peschiera and Taylor 2012; Siero et al. 1996).

### Resource Context

Flag Feedback was unique in that it conveyed information about renewable energy sources. Feedback relative to the ZNE goal provided information not only about electricity consumption, but also inherently about on-site generation. Our interest in studying this context was the hypothesis that a ZNE goal would be a particularly motivating feedback standard.

The ZNE goal did resonate with participants as part of the identity of West Village and they wished to retain it in any continuation or new iteration of office feedback. However, they also wanted other types of feedbacks standards, including social comparisons and historical comparisons so they could "get trends" in performance. One suggestion was to keep a chart in the office with a record of red and green flags over time. Other suggestions involved the provision of averages or moving averages. These findings are consistent with previous findings that multiple eco-feedback standards are useful (Fischer 2008).

Another theme related to resource context was an interest in end-use disaggregation of consumption information, specifically lighting, vehicle charging, and HVAC. They also discussed the possibility of disaggregating by space (conference room, offices, student space). This desire for greater detail was tempered by concerns for privacy, similar to other workplace energy feedback research (Coleman et al. 2013). Participants' general consensus was that individual energy use data publicized at the office was not desirable. A more popular idea was to communicate consumption per capita since office occupancy fluctuates widely.

### Interface Design

The Flag Feedback design was unconventional in a variety of ways. It was extremely low fidelity (two information levels) and low frequency (updating three times per day). It was also ambient (music), tangible (flags), and delivered by a person (participatory). The literature on residential energy feedback suggest feedback should be as granular and frequent as possible, and that computerized feedback is more effective than other mediums (e.g., Fischer 2008). Our findings do not negate that granular, frequent, computerized feedback has its benefits. Rather, they suggest a trade-off between these dimensions that make eco-feedback precise--thus supportive of learning, and opposite qualities that make eco-feedback salient and meaningful--promoting awareness and motivation (see Sanguinetti et al. 2018).

Participants appreciated the multimodal design for making the feedback salient. Some said the music alerted them and they did not need the parade, whereas others said they would not have noticed the feedback if not for the parade because they wore headphones. One participant summed up the ambient nature of the feedback, "The thing about the flags… they're just there."

The infrequency and strategic timing of the feedback also contributed to its salience. Participants compared it to cuckoo clocks and church bells, because it kept them aware of the time. One participant compared it favorably to continuous feedback by noting that continuous feedback can be distracting. Another participant said of the Flag Feedback, "It had us very well trained." They were particularly attuned to the noon flag ceremony, noting that it prompted the thought, "I should be hungry" or "Instead of thinking it's lunchtime, I think, 'It's flag time!'"

The flag ceremony also elicited a strong, positive affective response and participants became quite attached to it. A common sentiment was that the feedback was "fun." The music played a large role in this, one participant noting it "added an emotional element." They liked the positive and negative associations of the particular songs (i.e., Rocky and Darth Vader). When discussing elements of the feedback system to retain, participants strongly advocated for the music. They also expressed attachment to the flags and noted that outsiders had asked why the flags stopped. There were no reports that occupants found the ceremony disruptive to their work.

"Data!," one participant exclaimed, "Gimme the numbers!" Although the flag feedback was quite popular, there was a consensus that quantitative information was lacking. One participant explained the “flags were unsatisfying” because they did not tell those watching the ceremony anything useful. Participants lacked perceived control with respect to the feedback because they had trouble drawing specific implications for their own behavior. As a solution, participants suggested computerized displays, disaggregated data, and more frequent feedback.

One participant suggested that quantitative computerized feedback could accompany the flag ceremony: “I’d also like a screen with graphs and numbers that turns on around the same time the flag ceremony starts” because “even if the flag is still red, at least you could see the effect you had if you changed your behavior.” Participants wanted this granular feedback to be “big and obvious” like the flag ceremony, but also noted the irony in using a large monitor.

In terms of increasing feedback frequency, participants discussed adding a notification, e.g., audio alert, midway between flag intervals or if consumption goes above a certain threshold as a prompt or warning before it is “too late.” They also thought continuous feedback would be empowering by showing immediate impacts of behavior. One participant argued that more frequent data would only be empowering if occupants had sufficient control over consumption.

One participant summed up the consensus of the focus group, “Keep the music. Keep the flags. Add the numbers.” This is consistent with previous research suggesting that iconic and scientific data visualizations in eco-feedback complement each other (Froehlich et al. 2009; Kim, Hong, and Magerko 2009). For example, Kim et al. found that a bar chart visualization supported retrospection whereas imagery of a coral reef promoted emotional attachment.

Scientific and iconic data visualizations fall into the broader categories of pragmatic and artistic eco-visualizations, respectively (Holmes, 2007; Pierce, Odom, and Blevis 2008). Pierce et al. (2008) defined informative art as a type of eco-visualization in between pragmatic and artistic, which “may be just what is needed to allow [eco-visualizations] to become an accepted and valued part of everyday life” (7). Flag Feedback fits best in this category of informative art.

### Limitations

Researchers worked at the intervention site and were known to participants, which could have contributed to biases in focus group participants’ comments. Results could also be strengthened by increasing the intervention period, increasing the focus group sample size, measuring actual energy-related behaviors as in Siero et al. (1996), and tracking accurate consumption data; an engineer has been hired to more accurately track consumption on subsequent projects. Furthermore, the study setting’s university and research office characteristics limit the generalizability of findings. Despite limitations, this study supports important theoretical developments for the subject of eco-feedback.

## Conclusion

This research explored the potential of eco-feedback applications with unconventional dimensions, some of which are contraindicated by previous research concerning residential electricity feedback. The eco-feedback provided in this study was infrequent, low fidelity, and reflected collective behavior. Consistent with prior research, these dimensions, all related to eco-feedback precision with respect to target behaviors, did not support users in learning much about the relationships between their behavior and resource consumption or environmental impact. However, interrelated dimensions, such as modality, strategic timing, and audience, led to other benefits. Specifically, the multi-modal (music, flags, human delivery), ceremonial, and public eco-feedback was highly salient and meaningful to participants in this exploratory study.

There is a need for new conceptual frameworks that are inclusive of all behavioral mechanisms that contribute to eco-feedback effectiveness, including learning, attention, and motivation (see Sanguinetti et al. 2018). Such frameworks highlight the value of unconventional eco-feedback dimensions, including new possibilities for interface design. They also enable systematic investigations into how to balance incompatible dimensions of eco-feedback to optimize, or maximize, learning, attention, and motivation functions.

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