

Occupant-Behavior-Driven Energy Savings at the Bullitt Center in Seattle, Washington

Michael Gilbride, Integrated Design Lab – University of Washington

Joel Loveland, Integrated Design Lab – University of Washington

Heather Burpee, Integrated Design Lab – University of Washington

Julie Kriegh, University of Washington

Chris Meek, Integrated Design Lab – University of Washington

ABSTRACT

Net-positive-energy buildings achieve performance goals through multiple integrated strategies incorporating technologies, systems, and human behavior. This paper examines the energy performance of the Bullitt Center in Seattle, WA and in particular looks at energy use that is influenced by occupant decisions. The 51,000 square foot office building is net-positive-energy and employs a series of techniques to encourage energy conserving behaviors including promoting awareness of the energy impacts of daily decisions by its occupants. This paper presents a review of the energy performance of the Bullitt Center and introduces a literature review on pro-environmental behaviors before looking closer at particular behavior influenced energy use. Specifically, how daily decisions around energy conserving actions—in this case the use of the stairs or the elevator-- in the Bullitt Center might be influenced by visual cues, building design, and social norms which in turn might influence other behaviors that promote energy efficiency.

Introduction

The Bullitt Center in Seattle, WA was designed to achieve net-zero energy through the combination of high performance building design, energy conservation by occupants, and energy production through a photo-voltaic rooftop array. Understanding how occupant behavior contributes to the overall energy performance is critical to furthering the goals of energy efficiency and conservation; however, occupant behavior is dynamic and influenced by many factors that vary from context to context. For this reason, this paper introduces a theoretical framework for encouraging pro-environmental behaviors, reviews the energy use at the Bullitt Center, and then examines exploratory research on a particular behavior – taking the stairs versus the elevator.

Understanding the motivational factors underpinning energy efficiency behavior or pro-environmental behavior in the context of the built environment is critical to fostering behaviors that positively impact building performance. In their 2014 article, An Integrated Framework for Encouraging Pro-environmental Behavior: The role of values, situational factors and goals, Steg, Bolderdijk, Keizer, and Perlaviciute, present a theoretical framework to account for variables that predict effective and enduring pro-environmental behavior. Much of the focus is centered on three influential behavioral factors: values, goals, and cues that influence behavior. Values are stable, overarching, guiding principles in life. For example, altruistic and biospheric values focus on a concern for others or the environment, respectively. Egoistic values focus on

protecting or enhancing resources for oneself, while hedonic values show a concern for feeling good right now. Goals create a framework in which day-to-day decisions are made. For example, normative goals would indicate the appropriateness of acting in a particular way based on personal or social expectations. If energy conservation was the norm, then taking the stairs over an elevator would be the goal. Egoistic goals prioritize convenience over energy conservation (e.g. taking the elevator over the stairs). Hedonic goals center more on pleasure and gratification such as status and appearance over energy conservation (e.g. taking the elevator over the stairs). Cues in the physical environment provide a catalyst to promote an alignment between values, goals and behavior. For example, a glass-enclosed stair filled with daylight offering panoramic views sparks a desire take the stair and conserve energy. Our study builds on this research to explore how physical “green” features integrated into a high performance building might act as cues to trigger motivations (values) and frame decisions (goals) around energy efficiency behaviors. By linking high performance resource efficient technologies in the built environment (net-positive energy buildings such as the Bullitt Center) with a deep understanding of pro-environmental behavior, it may be possible to enhance the performance of net-positive-energy buildings to achieve higher more enduring energy conservation goals.

The Bullitt Center offers a unique opportunity to research and evaluate the effects of multiple high performance design features and integrated efficiency strategies in relationship to occupant behavior. This is true, in large part, because the building systems are highly monitored and highly efficient (e.g. building envelope, renewable energy, waste and water treatment), but also because the building systems are highly visible in and of themselves. The visibility of the building systems has the potential to act as situational cues framing goals in daily decision making thereby stimulating a person’s environmental values and motivating environmentally friendly actions. Furthermore, as Van der Werff, Steg, & Keizer (2013) demonstrated in their research, when people are reminded of past pro-environmental actions, it is likely to strengthen their self-identity as a person who acts environmentally friendly and reinforce their core environmental values. The Bullitt Center, with its many high performance design features, offers a unique opportunity to research energy efficient behaviors that could promote environmental mindedness.

Bullitt Center Project

The University of Washington Integrated Design Lab (UW IDL) has been actively involved with the Bullitt Center since it aspired to be the highest performing green urban office building (Peña, 2014). This involvement ranges from advising on the Request for Proposals, to daylighting studies, and finally as a tenant since April of 2013 when the building opened. The UW IDL currently tracks the energy use and performance of the Bullitt Center, as well conducting tours and public outreach regarding high performance buildings, energy efficiency, and the importance of net-zero buildings to reaching environmental and energy goals.

The Bullitt Center’s energy performance, for almost 3 years of operation, has been better than predicted and has been net positive for each of the last two complete years (figure 1). During the design phase, whole-building energy simulations (Brune, 2014) projected an Energy Use Intensity (EUI) score of 16 kBtu/ft²-yr. The UW IDL has been actively documenting the performance of the building in meeting qualitative experiential objectives and quantitative energy performance goals. This includes detailed operational data collection for the daylighting system(s) and the electric lighting system(s) as part of monitoring net-zero energy performance.

For the year of 2015, whole building energy use data produced an EUI of 11.06 kBtu/ft²-yr with the building at approximately 85% occupied for the first 4 months of the year and then fully occupied after that.

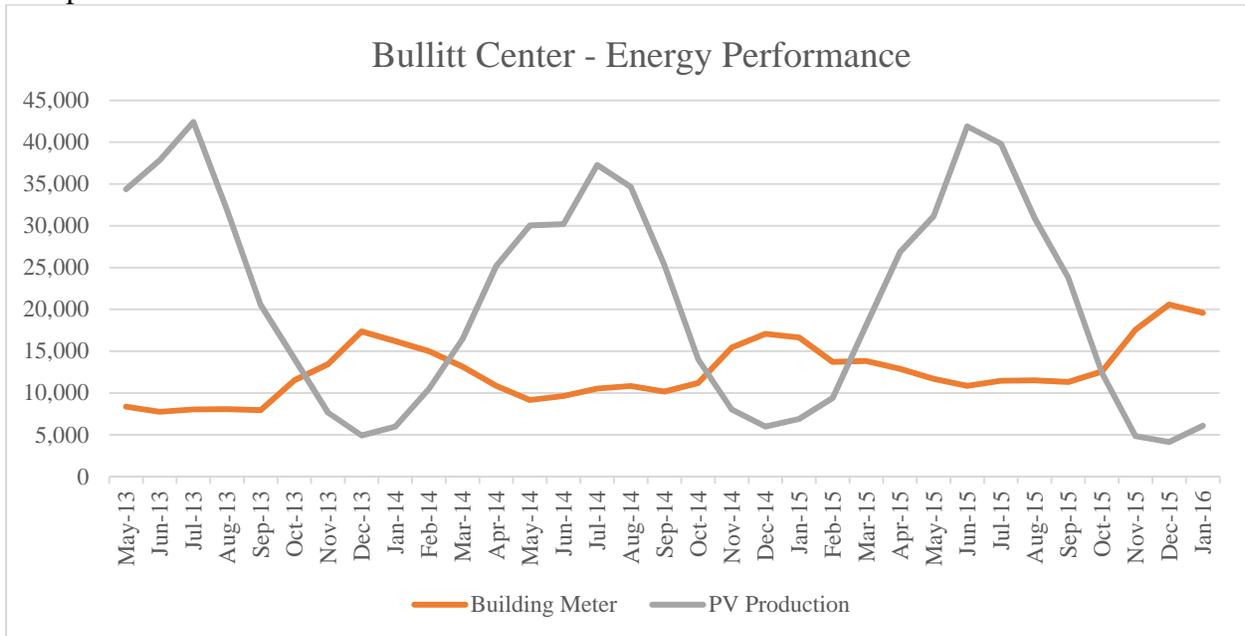


Figure 1: Bullitt Center Energy Use and Photo-Electric Cell Production

As part of the effort to understand the challenges that confront the operations and maintenance of the Bullitt Center, the Integrated Design Lab (IDL) validates and verifies the energy end use data gathered by the electrical system. The energy measurement and monitoring system was installed by Schneider Electric and each individual circuit is monitored by a current transformer (CT) that allows for the measurement and reporting of energy use. There are 382 active circuits and 149 spares set aside for future use. These circuits are placed into five categories:

1. plumbing and fire suppression
2. HVAC systems
3. IT/server.
4. lighting
5. plug loads

In addition, each circuit is designated as a building load or a tenant load, and there are 271 tenant circuits and 111 building circuits.

At the whole building level, the data matches the readings of Seattle City Light (SCL) to within a few percentage points. Reports were generated for the SCL reading dates and compared for the months of February through June 2014 and the results were within 5% of each other. However, when the IDL looked into the end use sub meter data, the discrepancy between the sum of the end uses and the whole building meter was 30% in warmer months to 60% in the coldest months. One of the important pieces of missing energy end use was the elevator was not properly sub-metered and so could not be tracked. This discovery led to a series of meetings between the UW IDL, the building owner, the property management company, and the electrical sub-contractor, which resulted in a recommissioning of the sub-metering system in June of 2015.

Since July of 2015 the sum of the energy end uses of the Bullitt Center has accounted for 93.5% to 95.4% of the total energy use as indicated by the whole building meter. The energy end-uses for the time period of July 2015 to December 2015 are detailed in Table 1 below:

Table 1. End-Use Energy, July through December, 2015

All units are kWh	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Totals
<u>Solar Production</u>	39,750	33,316	23,707	12,401	7,735	4,182	121,091
<u>Total Use Whole Building Meter</u>	11,458	11,498	11,310	22,574	17,577	20,583	95,000
total bldg+tenant end uses	10,785	10,878	10,692	11,751	16,633	19,630	80,369
delta	671	620	618	823	944	953	4,629
Error %	5.86%	5.39%	5.46%	6.54%	5.37%	4.63%	5.45%
Bldg HVAC	2,265	1,925	1,671	2,055	6,763	9,278	23,958
Bldg Lighting	1,294	1,313	1,391	1,575	1,530	1,684	8,788
Bldg Plug	244	237	226	229	229	226	1,396
Bldg Plumb-Fire	919	901	873	824	896	996	5,409
Bldg IT	1,136	1,185	1,148	1,207	1,276	1,315	7,267
TOTAL BLDG	5,858	5,561	5,309	5,890	10,694	13,499	46,818
Tenant Plug	3,902	4,311	4,261	4,545	4,526	4,581	26,127
Tenant Lighting	555	556	684	882	949	1,030	4,655
Tenant HVAC	406	391	376	364	400	454	2,391
Tenant Plumb-Fire	64	59	63	65	63	65	381
TOTAL TENANT	4,927	5,317	5,384	5,856	5,938	6,130	33,554

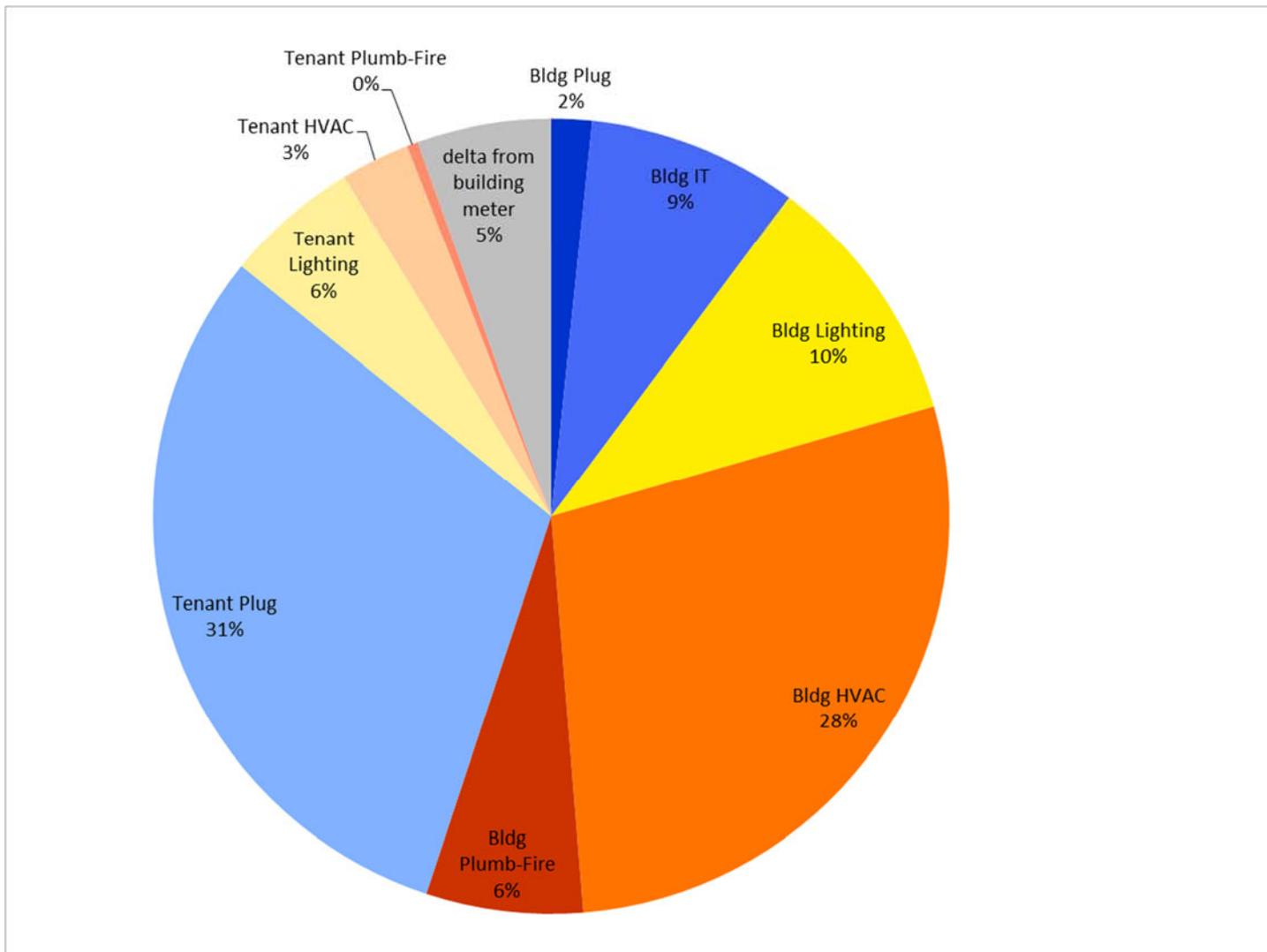


Figure 2. Bullitt Center Energy End Use – Pie Chart showing building and tenant loads for July to December 2015

As can be seen from Table 1 and Figure 2, the two largest end uses are the building HVAC systems to maintain thermal comfort and the tenant plug loads. In fact, for this time period, the tenant plug loads (31% of the total energy) were slightly larger than the HVAC systems (28%) and were the largest energy end-use. The tenant plug loads along with tenant lighting make up 37% of the building energy use and are directly impacted by the decisions made by occupants.

The Effects of Environmental Mindedness

Since the Bullitt Center’s energy performance depends to a significant degree on occupant behavior, understanding the role behavior plays in promoting energy efficiency is important. Over the past several decades, many environmental psychologists have investigated the processes underpinning environmental actions (van der Werff & Steg, 2015; Steg & de Groot, 2013; Clayton, 2013; de Groot & Steg, 2008; Stern, 2000; Dietz, 2005; Schwartz, 1992) and some believe that environmental behavior is rooted in values. Schwartz (1992) identifies core values as desirable and overarching goals that vary in importance and serve as stable

guiding principles throughout life. Value orientations that motivate environmental actions are categorized as self-transcendent values comprised of altruistic (helping others) and biospheric (helping the planet) values or self-enhancing values comprised of egoistic (enhancing self-interests such as status, time, and convenience) and hedonic values (promoting pleasure and feeling good). Though these value structures are stable and are at the core of environmental behaviors, just how they influence daily decision making is governed by multiple factors. These factors include: the availability of energy conservation cues in the built environment, the influence of goals in decision making, and the prioritization of environmental values by the individual which motivate energy conserving behaviors (Steg et al., 2014).

Taken together, situational cues and goals influence the prioritization of values that promote or deter environmental mindedness and behaviors. Complicating the value – behavior relationship, people may find that choices in daily situations involve conflicts between self-transcendent (altruistic/biospheric) and self-enhancing (egoistic/hedonic) values (van der Werff & Steg, 2015). For example, in the Bullitt Center, people may have the option to save time (egoistic value) by taking the elevator to the floor of their office or save building energy (biospheric value) by taking the stair. Researchers have found that when multiple values can be leveraged in a situation the likelihood of pro-environmental behaviors occurring is enhanced because environmental values are prioritized and conflict is reduced (Steg, et al., 2014). Again, using the Bullitt Center example, taking the stair engenders benefits for mind and body (beautiful views and healthy exercise) as well as conserving energy (reduced elevator use). In this scenario, there are multiple values that come into play: biospheric (saving energy), egoistic (healthy body and status), hedonic (pleasurable views), altruistic (saving energy use for a more significant need).

Is it possible to strengthen environmental mindedness such that environmental values are prioritized in support of pro-environmental actions even when it might not be convenient? In 2013, Van der Werff et al. found that by reminding people of their past environmental behaviors it strengthened their environmental self-concept (thinking of oneself as an environmentally friendly person) and this frame of reference helps to prioritize values that motivate environmentally friendly behavior (Van der Werff et al., (2013).

The Bullitt Center offers a unique opportunity for exploratory research on the effects of multiple situational cues and environmental triggers found in high performance building design. Notably, not only are the building systems highly monitored and highly efficient (e.g. high performance building envelope, net-positive energy and water treatment), they are highly visible (e.g. stairs, rain gardens, roof-top wetland, solar array, automated windows and shades, composting toilets, etc.). These situational cues frame daily decision making (goals) for building occupants and are likely to help prioritize core values upon which environmentally friendly actions are taken. While it is beyond the scope of this paper to examine the relative weight and effectiveness of each of these elements, we are suggesting that Bullitt Center provides an example that is consistent with the literature on pro-environment behaviors.

For example upon approaching the building it is immediately clear that the building is comprised of a set of unique features that have been designed with energy efficiency in mind (figure 3).



Figure 3. The Bullitt Center – note the prominent roof top solar array and the “Irresistible Stair” in the light filled stairwell (left). Photo by John Stamets

The net-positive energy producing solar array topping the six story building juts out over the public right-of-way as a visible and durable sign of energy production and conservation through renewable energy sources. There is an implied shared social responsibility to be mindful of energy conservation promoting altruistic values. The building itself has automated windows and blinds that adjust to the elements--sun, wind, and rain-- reinforcing the connection to nature and biospheric values. Healthy exercise is supported with ample secure bike storage facilities, zero car parking and multiple stairwells with views. Walking through and past rain gardens prior to entering the center, the building users witness on a daily basis, the collection and treatment of site storm water to achieve net positive water. The conservation of water is further reinforced through grey water composting toilets. Both interior lobbies feature daylight staircases to create a convenient, desirable stair climbing experience rather than using the elevator (less conveniently tucked out of site). Educational displays (Figure 4) are prominently located in the Discovery Commons lobby, in the “Irresistible Stair” and throughout building. These displays highlight and explain the systems at work in the building reminding people about their values and the importance of the environmental qualities of the building, which in turn are likely to promote

pro-environmental behaviors of the building occupants.



Figure 4. Interior building signage for the Bullitt Center.

Finally, the social and personal norm expectations associated with working in a widely documented sustainable high performance building establishes an overarching goal frame, reinforced by situational cues throughout the building to access both self-transcendent and self-enhancing value orientations. As the Bullitt Center’s tenants change and the building’s status becomes less prominent, the enduring nature of the behaviors can be verified or not, and this will indicate how central is this overarching goal frame.

Furthermore, as Van der Werff and colleagues (2013) demonstrated in their research that when people are reminded of past pro-environmental actions, it is likely to strengthen their environmental self-identity as a person who acts environmentally friendly and prioritize their core environmental values. The architectural systems, building systems and signage design of the

Bullitt Center function as constant reminders of past pro-environmental behaviors and future performance expectations and, as such, offers a rich opportunity to research how these multiple techniques encourage energy conserving behaviors and promote environmental mindedness.

To further explore how the Bullitt Center's design and signage impacted pro-environmental behaviors and mindedness, it is important to establish clear distinctions between baseline energy needed to operationalize building systems and direct energy used by occupants such as miscellaneous electrical loads. According to Kwatra, Amann, and Sachs, (2013) as building energy loads decline with the improvement of high performance building envelopes and systems, then direct electric loads take on increasing importance. The next section of this report elucidates the impact of a single electrical load impacted by behavior, the elevator, in the Bullitt Center. The decision to use the stairs versus the elevator has impacts on the energy use of the building and the health of the occupant.

Decisions to Use the Elevator and Stair

Background

As part of a Bullitt Foundation funded research effort, The Integrated Design Lab examined the health impacts of the building design using both qualitative and quantitative measures (Burpee 2015). A design objective of the Bullitt Center design is to promote stair use for both health and environmental benefits. Using this case study and looking closely at the decision to use the stairs or elevator and the situational cues integrated into the design, the signage (Figure 5), and other triggers in this particular decision, we can explore how these strategies may influence this behavior. The stair use was measured using people counters to assess the efficacy of the Bullitt Center's "Irresistible Stair," which is designed to encourage stair usage over elevator usage. This is not intended to prove a causal relationship or tease out the relative impacts of the multiple strategies, but rather is closer look at a particular pro-environmental behavior and how the design and daily interaction with the building shape that behavior.



Figure 5. Building design signage that encourages physical activity to reduce energy use and improve health.

The decision to take the stair or elevator may be influenced by environmental factors. A general strategy to encourage stair usage includes designing the stairs to be more prominent than the elevator. The Bullitt Center embraced this framework by emphasizing the importance of stair usage in its design, both to increase physical activity health benefits and to decrease energy consumption by elevators, which typically account for 10% of a building’s energy (Sachs 2015). As a result, prominent stairs are a major design feature of the Bullitt Center (figure 5). Deemed the “Irresistible Stair,” this central stair is located directly adjacent to the main entrance, while the elevator is tucked away in a less conspicuous location. Use of the stairs is further encouraged through aesthetic design: constructed out of steel, glass and Douglas fir lumber. With continuous glazing on three sides, the stairs provide views to downtown Seattle and beyond to the Puget Sound and Olympic Mountains.



Figure 6. Image of the “Irresistible Stair.”

Data Collection and Analysis Methodology

Tracking Stair Usage.

Bi-Directional People Counters (PRx20D1) were placed at the base of the staircase on the 2nd floor and at the top of the stairs on the 6th floor, as well as at the 2nd- and 6th-floor entries to the elevator. These battery-powered devices tallied a total number of people moving past the counter in both directions. Weekly readings from May 7th, 2013 to March 4th, 2014 were taken from the devices, with each data point indicating that someone had passed the threshold of the reader, and was counted as a “trip” either up the elevator or up the stairs.

Results

Data results show that 75% of trips initiated at the 2nd floor entry are travelled by stair, revealing a strong trend to choose the stairs over the elevator. In addition, data indicate that the “Irresistible Stair” is used for 68% of full ascents from the 2nd floor to the 6th floor, showing a persistent usage of stairs even for multiple flights. The weekly breakdown of elevator trips versus stair trips can be seen in Figure 6 while the monthly number of entries and exits are

indicated in Table 2. The relative high elevator use in May of 2013, may be influenced by the fact that many occupants were still moving into the Bullitt Center during that month. Figure 7 includes the monthly number of trips using either the elevator or stair and indicates if the trip was to the top floor or terminated earlier.

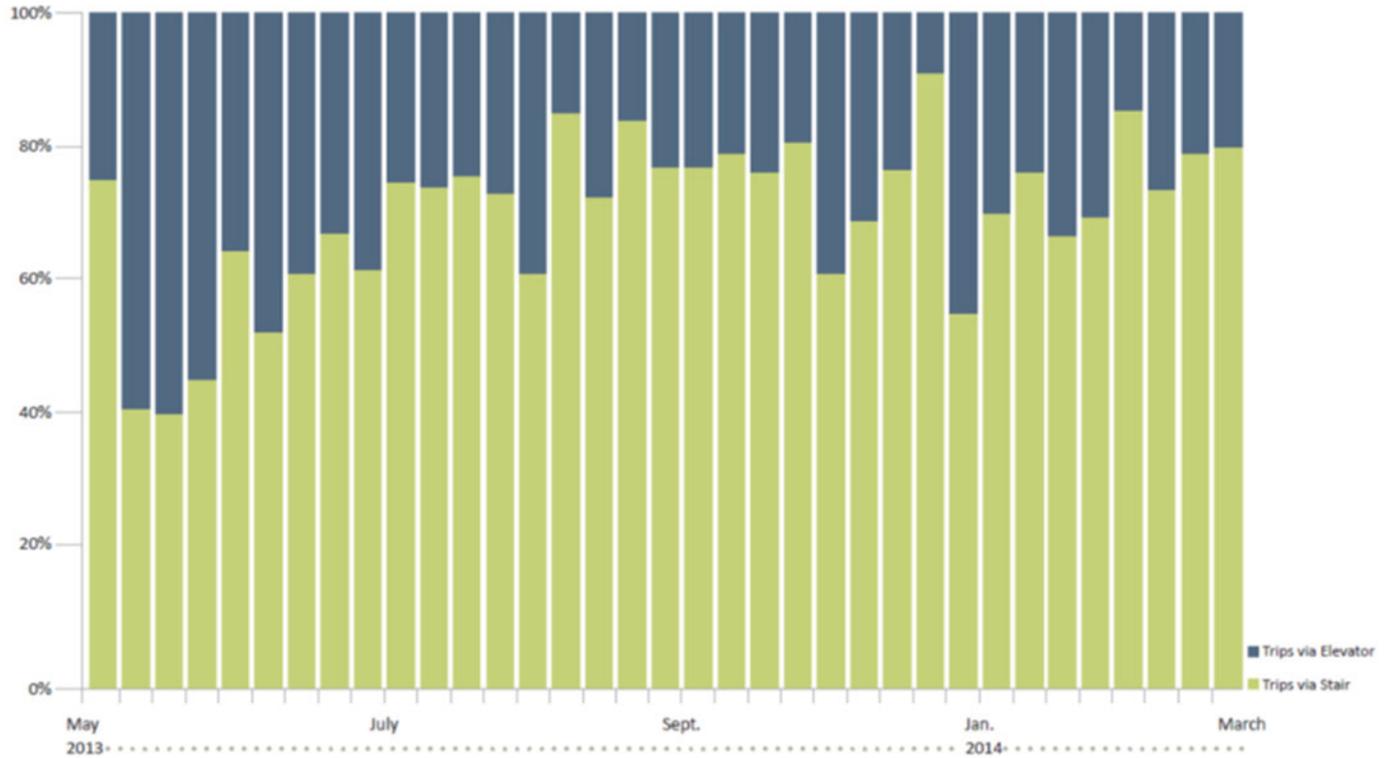


Figure 6. Weekly percentage of trips to the 6th floor by elevator and stair from May 2013 to March of 2014

Table 2. Monthly totals from the people counters located at the 2nd- and 6th-floor entrances and exits to the staircase and the elevator. Colors indicate connection, for example someone entering the 2nd floor elevator (dark gray) may exit on the 6th floor (dark gray).

		May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Entry	2nd Floor Elevator	2168	1762	975	836	775	698	637	842	1015	630
	2nd Floor Stair	2524	3959	3000	2994	3056	2931	3037	1554	3131	2473
	6th Floor Elevator	690	732	386	338	221	232	295	268	503	237
	6th Floor Stair	1073	650	650	902	858	809	776	602	917	843
Exit	2nd Floor Elevator	1646	1365	681	595	565	516	399	423	692	463
	2nd Floor Stair	2372	2750	2882	2691	2960	2794	2770	1477	2993	2383
	6th Floor Elevator	726	751	381	281	222	192	234	304	238	206
	6th Floor Stair	1252	786	812	1074	1069	1025	995	720	1249	1121

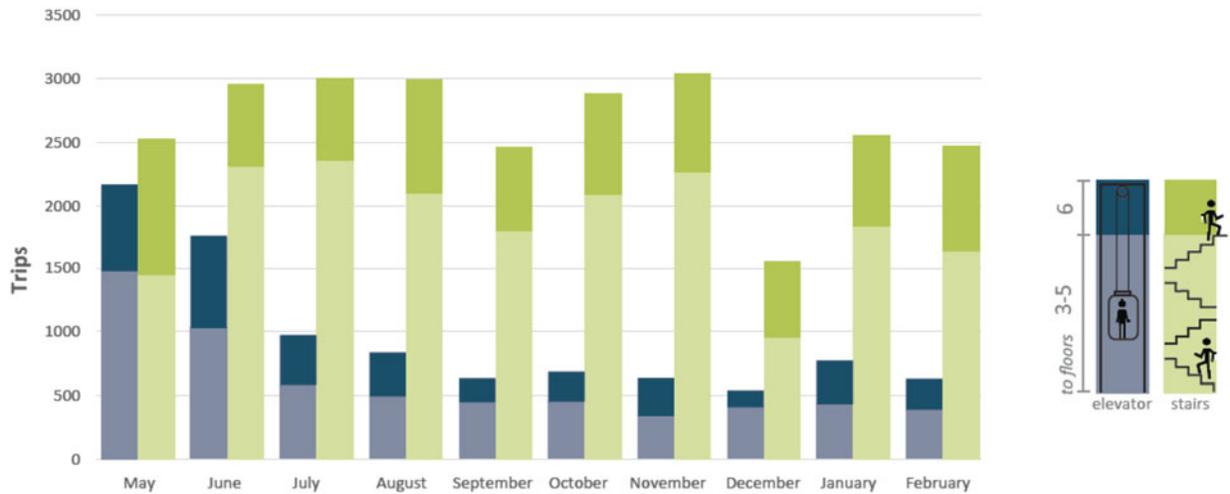


Figure 7. Monthly number of trips up using either the elevator or the stairs. The darker color represents trips to the 6th floor, while all other trips are assumed to have terminated between floors 3 and 5

Discussion

Data generated by the people counter, shown in the table in Figure 2, provide a general assessment of the proportion of trips taken by stair versus elevator, but the limited number of people counters did not account for an alternate fire stair that provides access to and egress from the Bullitt Center. Therefore, occupants that enter on the second floor “Irresistible Stair” and exit using a different staircase—and vice-versa—are only counted once by the people counter. In addition, regular group tours of the Bullitt Center often follow such a pattern, leading to a higher number of total entries than exits. The tours are offered two days a week, Tuesdays and Saturdays comprising a maximum of 20 individuals. Over a month, this equals approximately 160 trips for the second floor, which is roughly 5% of the total entries on average.

The stated design intent for the Bullitt Center’s prominent central staircase was to promote the use of the stairs for both occupant health and energy savings. These data, showing that 68% of trips were taken via stairs, indicate a very favorable outcome when compared to a study that reports that, on average, ascents via the stairs account for only 23-27% of total trips during a typical day in a commercial office building (Olander 2011). In contrast, the Bullitt Center has achieved the goal of having an “Irresistible Stair,” with stairs providing the principal means of vertical circulation. The persistence of the preference for using the stairs over the 10-month measurement period indicates that this stair usage was not due to the novelty of the stair but rather a habitual preference.

Emerging Conclusions

While many factors may contribute to the decision to take the stairs over the elevator, it is clear that the Bullitt Center occupants demonstrate that this preference can be sustained. This behavior is reinforced by the design of the building. The Bullitt Center’s unique features, designed with energy efficiency in mind, are visible and also explained through signage. These features and their visibility may help building occupants prioritize environmental values, reinforce environmental goals and promote environmental behaviors.

A potential limitation of the study is that tenants of the building may self-select to work in a sustainable office building and therefore be more apt to engage in pro-environmental behaviors and to accept this as the appropriate (normative) behavior for the building. Longitudinal studies over time will help mitigate this potential limitation. Future areas of research would include the development of an experimental research project to capture before and after effects of treatments designed to test distinct design features, pro-environmental behaviors, energy reductions, and resultant impacts on EUI over the next several years.

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