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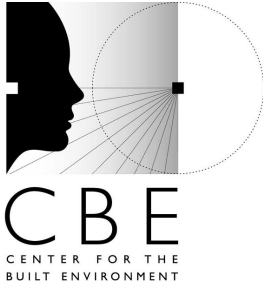
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*Excerpted from Final Report submitted to California
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CASE STUDY REPORT: DAVID BROWER CENTER

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BACKGROUND

The David Brower Center (DBC) is a 4-story 45,000-ft² office building located in downtown Berkeley, California (Figure 1). The building was completed and first occupied in May 2009. It contains lobby and public meeting space on the first floor and open plan office spaces on the 2nd-4th floors, which primarily house non-profit environmental activist organizations. Integral Group (formerly Rumsey Engineers) was the mechanical design engineer on the project and, working with the architect (Solomon E.T.C. – WRT) and other design specialists, put together a design promoting low energy consumption.

The goal of a low energy building was achieved through an integrated design process that combined thermal mass, shading, and insulation into an efficient building envelope, implemented daylighting and efficient lighting control strategies, and used a low energy HVAC system. The primary space conditioning subsystem is hydronic in-slab radiant cooling and heating, which is installed in the exposed ceiling slab of the 2nd – 4th floors of the building. Due to their larger surface area and high thermal mass, slab integrated radiant systems use relatively warmer chilled water temperatures, making them well-matched with non-compressor-based cooling, such as cooling towers. In addition to the improved efficiency of transporting thermal energy with water vs. air (about 7 times more efficient), the building cooling energy savings are attained through the utilization of a cooling tower, instead of a chiller, to make cooling supply water.

CBE selected the Brower Center as a field study site because it represents a good example of a radiant cooling system using a chilled hydronic ceiling slab design. The main goals of this case study are: 1) to assess occupant satisfaction with the building using CBE survey methods; 2) to analyze the energy consumption of this high performing building; and 3) to set up and begin a more detailed evaluation of the controls and operation of the David Brower Center and to identify strategies for improving system performance in terms of energy use and comfort.



Figure 1: David Brower Center, Berkeley, CA

OCCUPANT SATISFACTION SURVEY

CBE conducted its web-based occupant satisfaction survey at the David Brower Center during the period March 22 – April 9, 2010. Although the building was still undergoing commissioning work on the HVAC system at the time, the building owners were interested in obtaining a baseline measure of occupant satisfaction. We anticipate conducting at least one more follow-on survey in the future to track any trends over time in response to improved control and operation of the building. Of the 150 invited occupants, 74 valid responses were received, representing a response rate of nearly 50%, which is a good representative number.

Figure 2 presents the average satisfaction ratings for each of the major environmental categories addressed by the survey questions. Results from the recent David Brower Center survey are compared against the large CBE Benchmark database, containing 52,934 individual survey responses collected from over 475 buildings since 1997. The ratings are presented in terms of the 7-point satisfaction scale, ranging from -3 (very dissatisfied) to +3 (very satisfied) with 0 being neutral. Results shown for each category represent the average score for the 2-4 questions that were asked pertaining to that category (see <http://www.cbesurvey.org/survey/demos2010/> for a list of typical questions). The results indicate an extremely positive response from the occupants of the Brower Center. With one exception, the ratings from DBC are all significantly higher than the CBE benchmark. For two categories, View and Blinds/Shades, there is no benchmark data because these represent two new question categories that were added for the DBC survey.

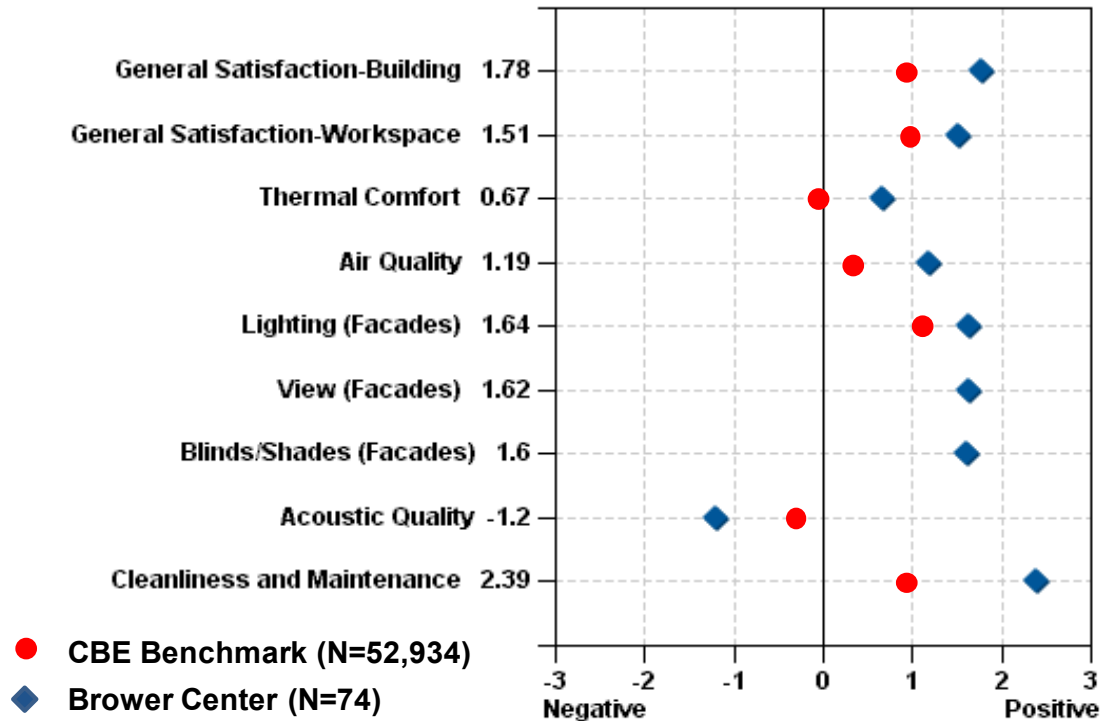


Figure 2: Average satisfaction ratings by category – Brower Center vs. CBE Benchmark. Survey conducted March 22 – April 9, 2010.

Acoustic quality represents the one category that scored lower (-1.2) than the CBE benchmark (-0.3). The tenant office space in the Brower Center is primarily open plan with many exposed concrete (hard) surfaces, especially the radiant slab ceiling used for cooling and heating. Under these conditions, it is not surprising that occupants expressed dissatisfaction with noise privacy. Figure 3 shows a breakdown of the reported causes collected from survey respondents who expressed dissatisfaction with acoustic quality. The results confirm the expected performance with a large percentage (> 80%) identifying noise and distractions from other people in the neighboring area, as well as a majority (60%) citing echoing of voices and sounds (presumably from the hard building surfaces). The David Brower Center is investigating possible mitigation measures to improve acoustic quality. If interior design improvements are made (such as installation of more sound absorbing surfaces) a future survey and acoustic measurements could be used to quantify the amount of improvement.

In conclusion, despite the reported dissatisfaction with acoustic quality in the building, overall, the occupants were very satisfied. Figure 4 shows the overall satisfaction rankings for the two questions about “general satisfaction with the building” and “general satisfaction with the workspace.” For the general satisfaction with the building, the mean response (1.78) was greater than 82% of all buildings in the CBE benchmark database. For the general satisfaction with the workspace, the mean response (1.51) was greater than 78% of all buildings in the database.

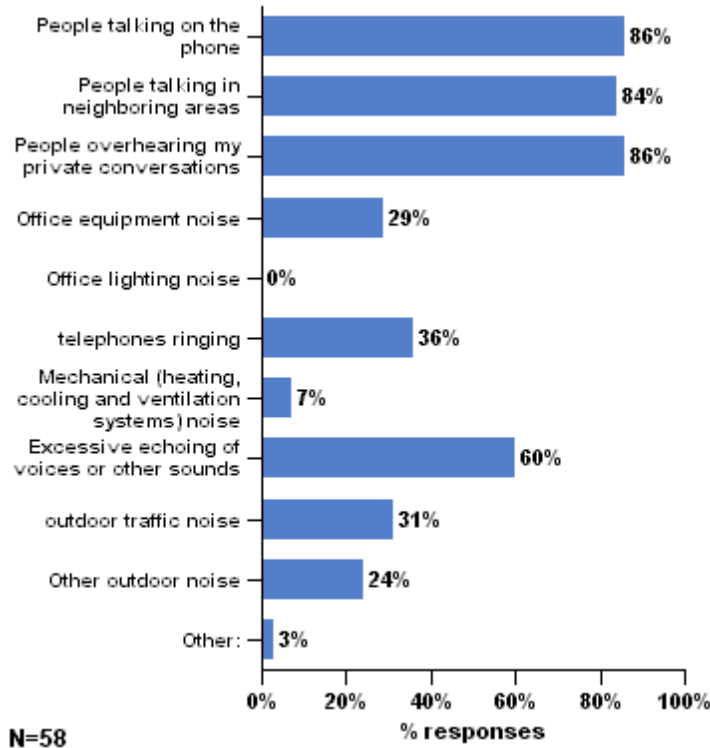
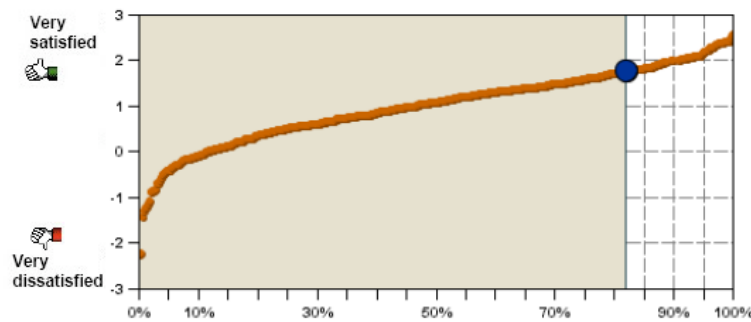


Figure 3: Reported causes of dissatisfaction with acoustic quality

General Satisfaction-Building

82%
Percentile

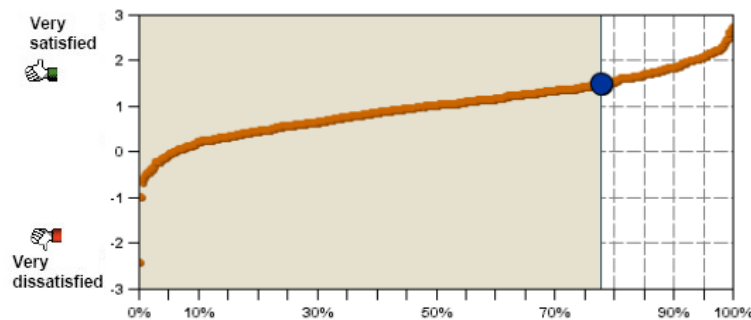


1.78
Mean Response

87%
Satisfied

General Satisfaction-Workspace

78%
Percentile



1.51
Mean Response

84%
Satisfied

Figure 4: David Brower Center overall satisfaction rankings

ENERGY PERFORMANCE

ENERGY STAR. The Energy Star program was first developed in the 1990's by the U.S. Environmental Protection Agency in an attempt to reduce energy consumption and greenhouse gas emissions from power plants. The Energy Star program has also developed energy performance rating systems for several commercial and institutional building types and manufacturing facilities. This rating system for buildings was developed using statistical analysis of the Department of Energy's Commercial Building Energy Consumption Survey (CBECS) database comparing certain key building characteristics with source energy use. A building is rated by inputting key independent variables (e.g., gross area, number of occupants) and the monthly energy (and water) use for the past year. After weather normalizing, this data is passed through the EPA regression models to arrive at a percentile ranking relative to the comparison population. These ratings, on a scale from 1 to 100, provide a means of benchmarking the energy efficiency of specific buildings against the energy performance of similar facilities.

Table 1 summarizes the Energy Star rating report obtained from the Energy Star Portfolio Manager website [EPA 2010]. The results are based on one year's worth of utility bill data (including PV generation) for the period ending June 30, 2010. The David Brower Center achieved an Energy Star rating of 99, demonstrating exceptional energy performance and well above the threshold of 75 to qualify for an "Energy Star Label." The weather normalized site energy utilization intensity (EUI) was 47 kBtu-sf/yr.¹

Performance Metrics	Current (Ending 6/30/2010)	ENERGY STAR Label	National Average
ENERGY STAR Rating	99	75	50
Energy Use Intensity			
Site (kBtu/ft ²)	47	109	147
Source (kBtu/ft ²)	68	157	212

Table 1: Energy Star Rating Report for David Brower Center (August 2010)

POWER MONITORING. During the past year, CBE completed an installation of power monitoring equipment that allows a detailed end use breakdown of energy by HVAC system components (e.g., air handlers, cooling tower, water pumps, water source heat pumps), and building loads (e.g., lighting, plug loads, auxiliaries). The power monitoring instrumentation includes power meters installed on all major electrical panels, and by utilizing the power reporting capabilities of the variable frequency drives (vfd) that control each of the HVAC system components, we are also able to record the power usage of each individual component. All metered panels and vfd outputs are being trended through the building management system (BMS).

Power data have been collected and analyzed for the month of January 2011. Figure 5 shows average weekday power consumption profiles for the major panels and meters based on all non-holiday weekdays during January. The results show that on average, the BLDG_POWER (which does not include the tenant power) is selling power back to PG&E for a few mid-day hours due to

¹ Based on total PV generation, once over-generation is determined, the EUI will be even lower.

the PV generation. The total building power usage is still positive at all hours because it also includes the two tenant meters (their sum is shown as “tenant power”). The non-tenant power profile is shown as the sum of the bi-directional BLDG_POWER meter and the PV generation.

Figure 6 presents average weekday power consumption profiles for all sub-metered panels underneath the BLDG_POWER (or BC PG&E Meter) meter. The highest profile (non-tenant power) is identical to that shown in Figure 5. The four sub-panels (VND-1, BC-MMHF1, BC-M, and BC-MHR) all exhibit fairly typical and steady day-time use profiles that never exceed 8.6 kW on any given hour. The sum of these four sub-panels is shown as the dotted blue profile. The difference between the non-tenant power and the total for these four sub-panels is shown as the green profile, which represents a variety of miscellaneous loads. Surprisingly, this miscellaneous profile reaches a maximum value around 20 kW (considerably higher than all individual sub-meters shown) during the morning hours before gradually decreasing to around zero by late afternoon. We are investigating the possible causes of this use profile. It seems likely to include lighting because the profile increases again in the evening, coinciding with nighttime hours during January.

Figure 7 presents average weekday power consumption profiles for all HVAC equipment underneath the BC-MHR meter. With the exception of the AHUs (dashed dark blue line), all pumps and the cooling tower fan show low power usage for all hours of the day (mostly less than 1 kW). During January the cooling tower fan is turned off most of the time. The top two dotted profiles represent a comparison between the power measured at the HVAC panel (BC-MHR) and the sum of all HVAC components. We are investigating the cause of the difference.

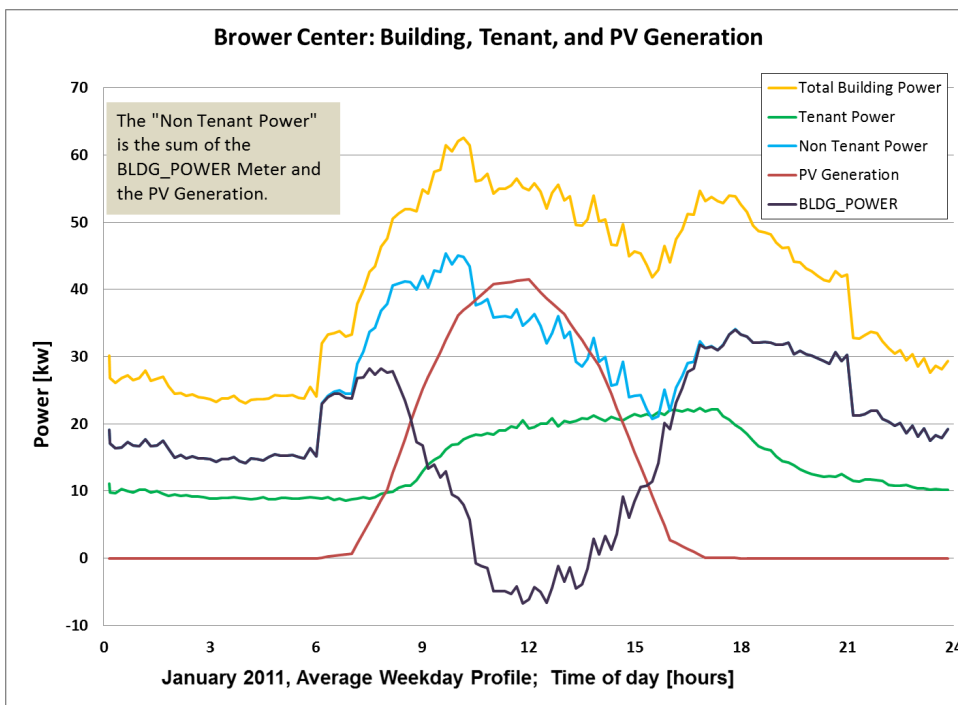


Figure 5: Average weekday power profiles, main panels, David Brower Center

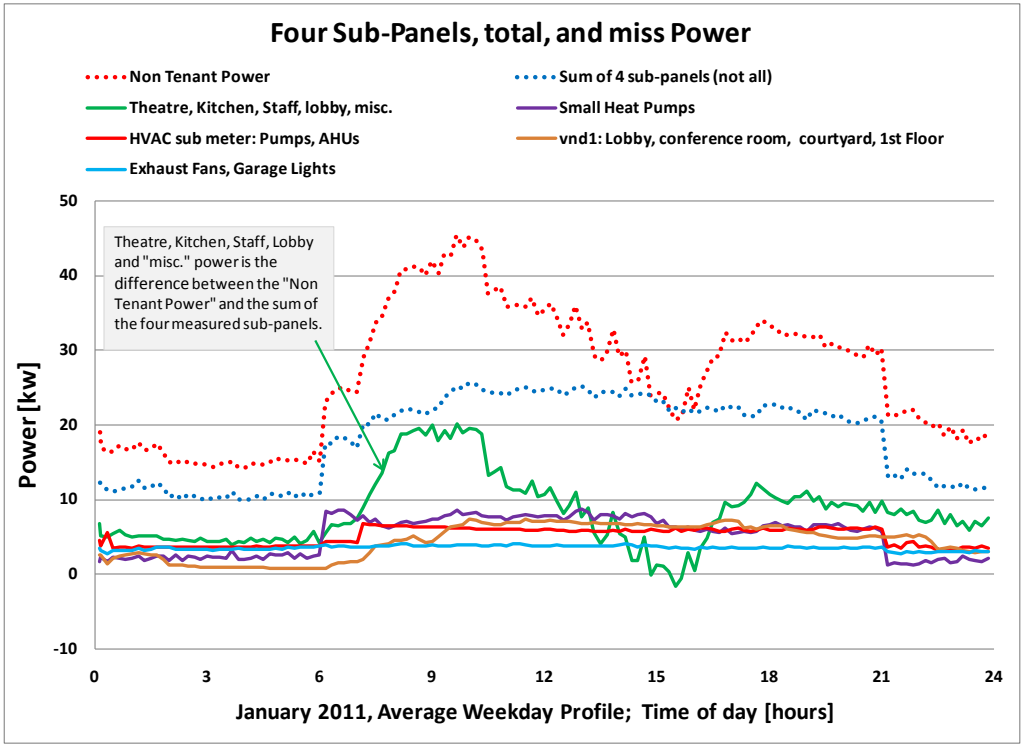


Figure 6: Average weekday power profiles, sub-panels, David Brower Center

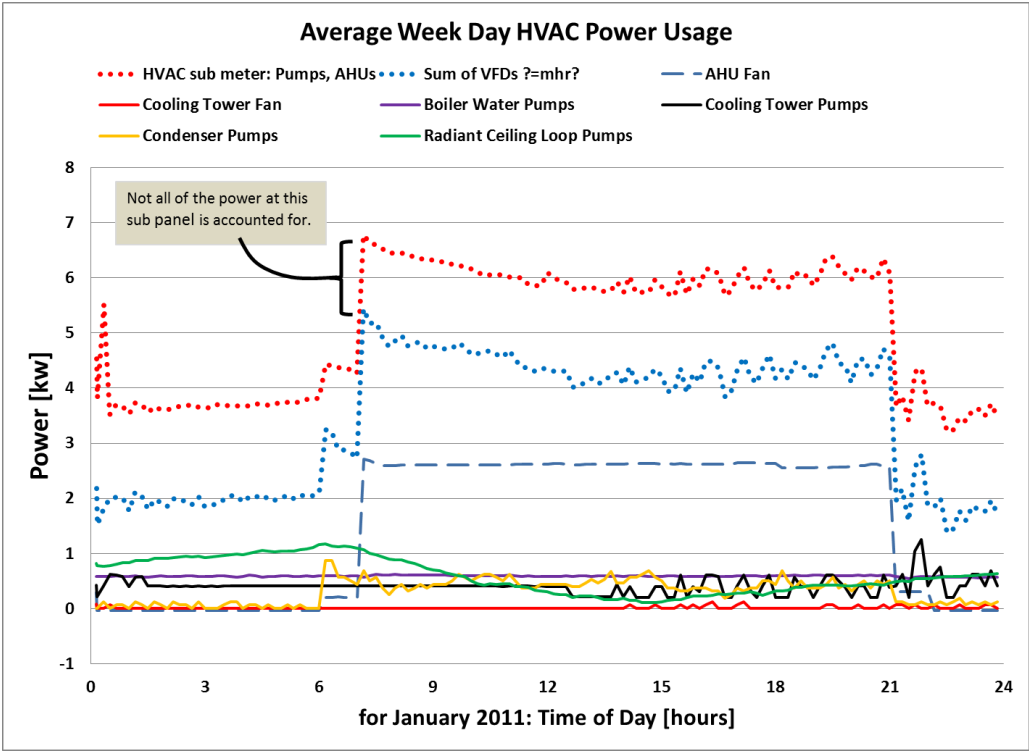


Figure 7: Average weekday HVAC equipment power profiles, David Brower Center

NEXT STEPS

CBE's field study of the David Brower Center is continuing under funding from CEC/PIER (Contract 500-08-044) and CBE Industry Partners. Although the completion of the power monitoring installation was delayed due to circumstances beyond our control, we now have an excellent sub-metering capability moving forward. CBE will be studying the controls and operation of the David Brower Center and identifying strategies for improving system performance in terms of energy use and comfort. The upcoming work will focus on key elements of the advanced system design of the building, including slab-integrated radiant cooling and heating, and underfloor air distribution. Heating operation will be studied over the next few months before switching to cooling performance during the spring and summer months.

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