Don’t build it, just change their operations!

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ABSTRACT

Most behavior change is focused on reducing energy use that already exists such as energy use from lighting, HVAC, water heating, and plug loads. However, there is another area of opportunity to reduce or avoid significant energy use (both embodied and operational energy use): avoiding the construction of additional square footage to support building operations that may not be needed or may not require such low square footage densities. Through building occupancy and utilization monitoring, and building asset studies, latent capacity within existing buildings can be identified to avoid constructing new buildings. Most of the latent capacity exists as time and density variables that require organizational change to capture their potential. By benchmarking an organization’s utilization and density (occupancy) rates across their building portfolios and developing building retrofit and operational programs for increasing utilization/density, these organizations can avoid new construction, in turn avoiding the energy use associated with those additional square feet.

In a study conducted earlier this year at a U.S. military base in Hawaii, occupancy rates were measured at an office building for a 2-month period. Although the building was considered mostly “full” (i.e. it could not hold more occupants), the average occupancy during operational hours was less than 60% during the study period. By increasing the occupancy rates (or density) to 80%, approximately 179,053KWH of operational energy use, and more importantly 12,003,900KWH of initial embodied energy, could be prevented in new construction by accommodating the additional people in the current building versus constructing a new building to house them. This result represents significant energy savings at little to no cost.

Introduction

Since 1970, the U.S. has saved nearly 95% of its extrapolated energy use by investing in energy efficiency measures across the economy (Alliance Commission on National Energy Efficiency Policy 2013). This investment allowed the economy to continue to expand at a rapid clip while the energy required to produce the same GDP output was cut – a phenomenon known as greater energy productivity.

Today, residential and commercial buildings account for about 41% of total U.S. energy consumption nationwide. Of that 41%, 19% comes from the 5.6 million commercial buildings spread across the country (EIA 2012). This 19% represents 8.8QUAD BTU (site) annually in 2015 (EIA 2011). That’s 105,500BTU/GSF per year.

It is well-documented that approximately 50% (EIA 2011) of commercial building energy use is for lighting, space cooling, and space heating. Thus, it is not surprising that most energy reduction strategies focus on efficiency gains in these areas. There are high-efficiency lighting programs sponsored by ENERGY STAR™. There are high performance window / envelope design guidelines. The problem is that while energy use in buildings is decreasing through these methods, and is decreasing in energy use per square foot (energy intensity), there is more energy savings potential that is not being realized through conservation programs that may actually tap into greater savings potential than efficiency programs – specifically programs that prevent the need for building more buildings.

In assessing the value of renovating existing buildings versus constructing new buildings, the concept of *avoided impacts* has been adopted as the means of measuring the value of reusing the existing building.

Once a building is built a substantial amount of energy has already been expended in the form of embodied energy. This energy comes from the extraction, manufacturing, transportation, and installation processes involved in constructing a new building. By some estimates, it can take tens of years for an energy efficient building to overcome this "sunk" energy cost. In a 2008 study, the UK-based Empty Homes Agency found that it takes 35-50 (BSHF 2008) years for a new home to recover through efficient operations all of the carbon that was expended during the initial construction process. Thus, we can't afford to waste this energy by not fully using the space that we have created with it.

In MKThink's experience, most commercial office buildings are under-occupied even when they are considered "full" or at capacity. This under-occupancy often happens when perception outweighs fact, or when organization and coordination of time and space within a building becomes too complex for an organization to manage properly. Eventually spaces become unintentional homes to activities they were not designed for originally, decreasing the usability and productivity of the space. But by reviewing the space inventory of a building and the associated personnel usage patterns, these spatial inefficiencies can be identified and corrected. However, in most energy efficiency conversations, and worse, in most energy conservation conversations, this type of optimization is not considered; it is considered as "out-of-bounds" and presumed that the organization has correctly identified its preferred and correct spatial organization for operations. This presumption needs to be challenged as more and more buildings go under-occupied and under-utilized, leading to unnecessary new buildings to accommodate a need that doesn't actually exist. This study seeks to identify the magnitude of savings both in energy and dollars that could be associated with an *avoided impacts assessment* of an existing building that is perceived as "full".

Materials & Method

Study Design

A governmental naval office building at the U.S. Joint Naval Base Pearl Harbor-Hickam was installed with occupancy sensing devices from March 19, 2015 to May 18, 2015, which was selected as a feasible study window that may or may not be a representative sample of yearly occupancy rates and climatic seasonality (this is not deemed important since the primary calculation of the study uses user perception as an indicator of 'typicality' or 'representativeness"). During that period, total building occupancy was monitored 24 hours per day, 7 days per week. Occupancy rates were then compared to occupancy capacity benchmarks set by internal planning groups, internal best practice benchmarking, and external industry occupancy benchmarks. Working off of the perception by building occupants that the building was operating at "FTE (Full-Time Equivalent Person) capacity" (i.e. it felt like a full building), the study team calculated the difference between the average peak occupancy and the capacity benchmarks to determine the number of personnel that would need to be relocated if the building was indeed at capacity [the perception of "fullness" was determined informally during a postdata collection debrief with building occupants where a member of the leadership team voiced an opinion that the building felt “full”, an opinion seconded by other members of the group]. Multiplying that number of personnel by naval planning specifications for GSF (gross square footage) per FTE yielded a total GSF of “new” space required to accommodate the displaced personnel. This GSF represented the theoretical new building size for which embodied and operational energy projections were calculated to determine the additional energy consumption that would be generated by building a new building versus accommodating the personnel in the existing building. The study did not account for the marginal increases in energy use derivative of the higher personnel densities in the existing building since most of the marginal energy would be due to personal electronics (e.g. laptops, desk lamps, phones, etc.) that had not accounted for a significant portion of total building load in previous projects. The additional energy for the new building was modeled for one unit year as well as 10 years, and the cost of that energy use and the new construction cost were also modeled for reference.

Occupancy Analysis

Occupancy is defined differently across the industry. For this study, occupancy was defined as the number of building occupants present at a point in time divided by the building occupant capacity as defined by the number of desk spaces identified in the building, expressed as a percentage.

Building occupancy changes over the course of the day as people come and go. This study looked at both average occupancy during the “operating hours” and peak occupancy during a given 24-hour day from 0000-2400. Average occupancy was calculated by using a weighted average of the occupant counts during the operating hours, multiplying the occupant count by the fraction of time that a specific occupant count was measured during the entire operating period and dividing by the entire time period to get the *average occupant count*, then dividing that result by building occupancy max (BOM) to turn it into a percentage. Operating hours for which average occupancy was calculated was set from 0900-1500 during non-holiday weekdays. Peak occupancy was calculated by dividing the highest measured occupant count at a specific point in time during the operating hours for a given day by the building occupancy max.

The building occupant capacity can be set by the fire code, space-planning specifications, assigned number of people to the building, or another metric. The number of open plan desk spaces was used as the capacity limit because it represented both a pragmatic and an opportunistic threshold – the seats were already there but not filled; it wouldn’t require convincing the client that that number of people could fit in working spaces within the building.

Study Environment

The site location was chosen in coordination with client partners and determined to be at the military base located on Oahu, Hawaii. Of the 100+ buildings on the base, 4 were evaluated for study based on their use types, personnel assignments, and energy consumption characteristics (the last factor of which was relevant for a related study on energy consumption patterns). The final building selection was made based on its use as an office space and its assignment of design and construction staff (part of the study partners, allowing easier access to required data).

The building had a total of 62,614 GSF across 3 floors. The building layout was double-loaded with a main hallway breaking off to cubicle bays on either side and conference rooms mixed in at selected locations.

Building Occupancy Max

Building Occupancy Max (BOM) can be based on several different capacity thresholds, including fire code, planning specifications, or other. For reference, fire code allows for 400 people. The space planning guidelines recommend 165 GSF per person equating to 379 people. There are 326 desk spaces available in the building and the naval planning department assigned 265 people to the building. We chose to use the total number of desk spaces available in the building, 326, as the BOM. This number is less than the space planning specifications but represents, from a pragmatic, physical standpoint, the actual number of desks that could be occupied immediately.

Study Population

While the individuals themselves were not studied as part of this investigation, their anonymized individual and group behaviors were observed. The teams housed in the building were all part of the naval Design and Construction teams responsible for the architecture, engineering, and construction of all naval facilities in the Asia Pacific. These teams consisted of design architects, mechanical engineers, structural engineers, civil engineers, electrical engineers, project engineers, and project managers.

This population was chosen for their commonality with traditional commercial services companies in which workers perform mostly computer-based tasks and collaborative meetings with a fixed daily schedule. This population was also known to be the best performing group with respect to energy efficiency as measured year-on-year by navy records, indicating a heightened sense of their operating behavior.

Sensors

Infrared occupancy sensors were installed at the three primary entry/exit points for the building. These sensors could detect directionality of users passing-by (i.e. detect if the user was entering or exiting), but could not distinguish between multiple people passing-by at the same time unless there was a break between people. Sensors were not installed at the two back exits, but two days of spot-checking did not indicate that any personnel used these exits for daily movement in or out of the building.

Perception of Capacity

The study population was engaged in two different meetings to discuss building usage with a primary focus related to energy use and efficiency. However, these meetings also presented an opportunity to gather perception-based information from the study population, including perception of building "fullness" or capacity. In these meetings it was established that the user perception of the building was that it was "well-used" or "felt full." Thus, this study works off of the assumption that to the users, the building is at capacity and additional personnel would need to be located elsewhere in a new or existing building.

Study Period

The study period included both weekdays and weekends. Movement in and out of buildings was measured 24 hours per day, 7 days per week.

Results

The building occupancy was studied from March 19, 2015 until May 18, 2015, approximately 2 months. Measured building occupancy during this period averaged 46% during weekday core operating hours (0900-1500), excluding holidays, based on a BOM of 326. This represents an occupant count of approximately 149 people (Figure 1). The daily maximum occupancy ranged from 124 – 204 people during the study period. Even at maximum occupancy, the building achieved only 63% capacity (Figure 2). Weekend occupancy did not register more than 10 people on any given day (Figure 1; Figure 3). We also saw that occupancy tended to reach a steady state during official operating hours (Figure 3).

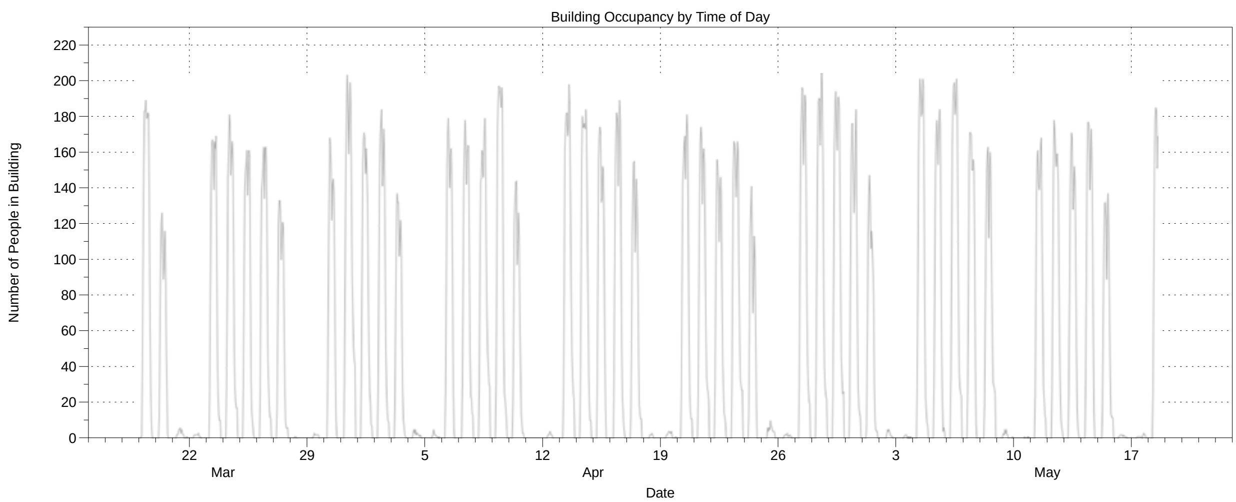

Figure 1 - Daily building occupant counts for the study period

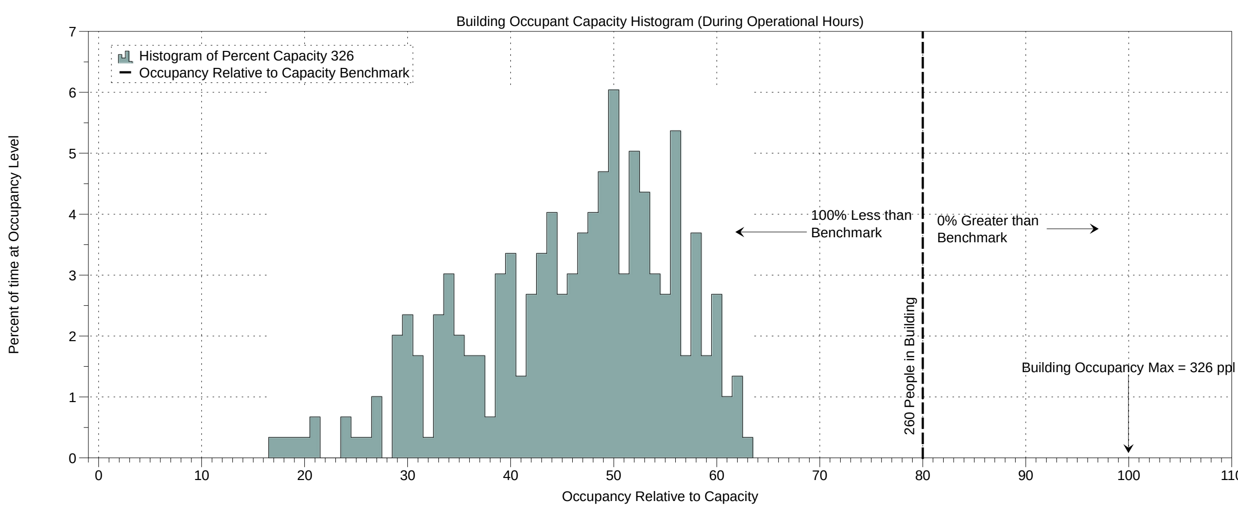

Figure 2 - Counts various occupant levels measured during the study period

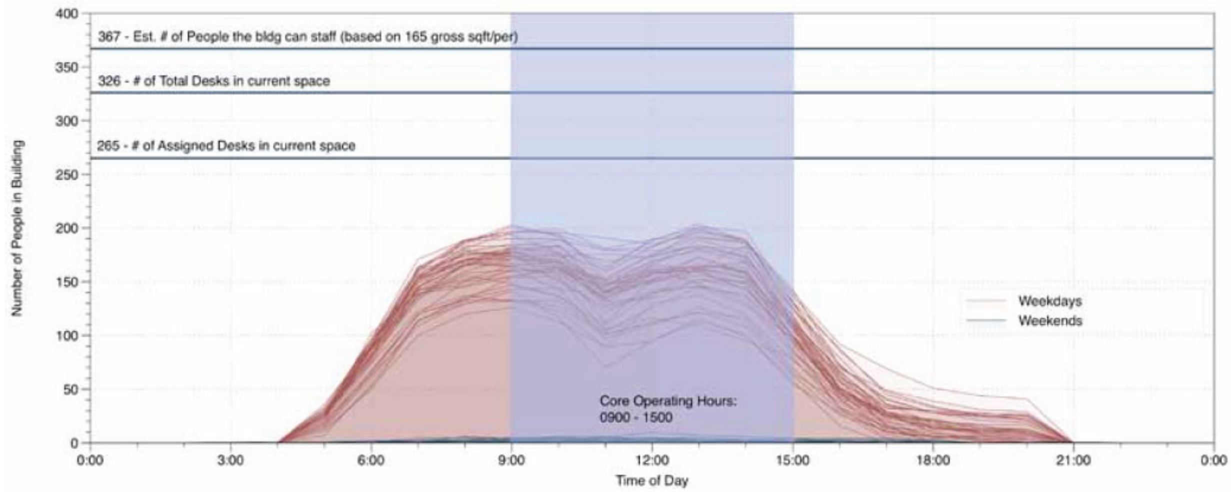

Figure 3 - Hourly occupant counts for all days during the study period compared to various building occupant capacity benchmarks

Discussion

A building average occupancy of 40-60% is not uncommon (Table 1) for a flexible work environment where workers are allowed to work remotely. However, the perception that at 56% occupancy the user group perceived that the building was “full” when in fact it was 44% vacant is alarming from a building optimization perspective. In this case study, 44% vacancy represents an additional 143 FTE (based on 326FTE max occupancy) that could be stationed within the building, again assuming occupancy based on the number of assigned desks.

Table 1: A representative sample of occupancy rates and corresponding metrics for office buildings with an open floor plan (MKThink research team internal project numbers, 2016)

	Building (gsf)	Weekly operating hours	Open Office (asf)	Open Office Seats	Density (sf/person)	Avg Observed Occ.	Max Observed Occ.
Office Building 1	36,938	55	12,816	201	64	108 (54%)	133 (66%)
Office Building 2	239,872	50	106,822	1,487	72	624 (42%)	811 (55%)
Office Building 3	15,842	60	4,296	68	63	29 (43%)	36 (53%)

Target Occupancy

The key question in occupancy of buildings – occupancy here defined as the number of people present divided by the chosen personnel capacity – is what is the ideal, or target, occupancy rate? 100% occupancy with high utilization rates of spaces – utilization here defined as the presence of at least one person in a space such that it is “utilized” – can lead to productivity drops since groups cannot easily schedule and improvise meetings throughout the day. 80% occupancy has been used as an accepted benchmark in space occupancy and utilization studies (MKThink research team internal project numbers). In this case, that represents an occupant count of approximately 260 people, or just 5 fewer than the actual assigned number of people to the building of 265.

Occupancy Gap

Of the target occupant count of 260 people representing 80% of the total desks in the building, only 149 people are generally present on average during the core operating hours. This represents a gap of 111 people. On extreme days, at the edge of the max daily occupancy range, this gap can change to 56 at the low and to 135 at the high.

If this occupancy gap was maintained, and occupants perceived the building as full, the additional 111 personnel would need a separate building assigned to them. This overflow would require an additional 18,315 USF (usable square feet) at a specified 165 USF per office worker[1], or 24,975 GSF (gross square feet) at an estimated 225 GSF per office worker.

Energy Use of Additional Space – New Build

During the 2-month study period from March 18 to May 19, 2015, the study building exhibited an average daily energy use of 20.4kWh/kGSF (kGSF = 1000 GSF). Breaking this energy use down further, we see that during core operating hours energy use was 1.85kWh/kGSF per hour and 0.60 kWh/kGSF per hour during non-core operating hours, including weekends and holidays. Multiplying these energy use figures by 1506 core operating hours per year and 7254 non-core hours per year, and by the estimated additional "new build" square footage, yields a total operating energy use of 179,053kwh per year (note that this calculation simplifies energy use by not adjusting for seasonality).

If we include initial embodied energy for the 24,975 GSF building, we add a one-time energy expenditure of approximately 12,003,900kWh (M. Watts 2016) to the total additional energy use of the new building. For reference, if the new building was 50% more energy efficient than the current building, it would still take ~134 years to save back the energy sunk in the embodied cost of extracting, manufacturing, transporting, and installing the new building. For simplicity, we did not include recurring embodied energy use from operations and maintenance in these calculations.

Cost for Additional Space – New Build

If constructing a new building from the ground up to accommodate the additional workers is required, the cost would vary based on the location of construction and the current cost of materials worldwide and locally. For Hawaii, in 2015, the average construction cost was $300 per constructed square foot (Mortgage News Daily). This equates to a new building cost of $7.49 million.

Operating costs for office buildings in Hawaii were estimated at $6 per GSF in 2011 (IREM 2011). This equates to an additional $149,850 per year. Of this, it is estimated that energy accounts for $65,720 annually based on average electricity rates on Oahu of $0.34/kWh (Electricity Local 2016).

10-year Impact Over the course of 10 years, the total cost for a new building, including operations, would be $8.99 million and would account for an additional 13.9 million KWH consumed (12mil KWH embodied, 1.93mil KWH operating).

[1] Provided by client.

Avoiding New Build - Comparison to Other Energy Efficiency Measures

Traditional office building energy efficiency interventions include: lighting retrofits, window retrofits, HVAC retrofits, and so forth, focusing on the high energy use areas of lighting, space cooling, and space heating. Many of these energy efficiency and deep retrofits have 15-30% reductions in site energy use (PNNL 2011). However, simply avoiding the operational energy use associated with the "new building" for the 111 personnel would have reduced site operational energy use by 28.5% based on a composite energy use of the existing building (448,897kWh/yr) and the new building (179,053kWh). Adding in the embodied energy use by amortizing it over a 50-year building life brings that annual energy savings up to 48.3%.

Conclusion

By taking an approach to energy efficiency and conservation that incorporates building occupancy rates from a potential new construction point of view (i.e. having to build a new building for the additional occupants), and not just a building system utilization point of view (i.e. occupancy as a means to determine when lights should be on or off), we can realize large savings in buildings that don't need to be built. But typically this type of analysis is not included in building energy efficiency/conservation intervention or retrofit measures. Instead, it is assumed that the building occupants and the organization they work for, or the management company operating the building, are keeping track of the proper space usage and occupancy of the building. However, this does not appear to be the case in many situations and frequently office spaces are under-occupied from a capacity perspective and under-utilized from a time of day perspective, leading to missed opportunities to maximize the use of the already-existing building portfolio.

Looking at the entire U.S. commercial building sector, there are 5.7 million buildings comprising 87.4 million GSF (EIA 2012). Considering that on average commercial buildings are 60% occupied at any given time in the new economy (flexible work, sick absences, travel, etc.), and with a target occupancy of 80%, that means that 17.4 billion GSF of commercial space is either unoccupied or under-occupied. That's 8.3 trillion KWH (EIA 2012; M. Watts 2016) of embodied energy being wasted if these buildings are perceived as "full" and new space is constructed to accommodate more workers. And/or that's 114 billion kWh (E Source 2002) of annual energy waste to light, heat, cool and otherwise operate that space.

Traditional energy efficiency measures are excellent steps for saving 10-30% of building operating energy use (EPA 2016), but the greatest savings will be those derived from both the operating energy and the embodied energy savings of preventing new build. These savings can be orders of magnitude greater than traditional energy efficiency/conservation measures, even exceeding the annual operating energy use of the building by orders of magnitude. Thus, we hope that this type of analysis will become increasingly used in the energy efficiency/conservation industries moving forward, combining traditional building and real estate space planning/management with energy consumption management.

Acknowledgments

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