Final Report

Behavioral strategies to bridge the gap between potential and actual savings in commercial buildings

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Abstract

Changes in operations can save 5%-30% of building energy use at low cost, yet these changes are often not implemented. Little attention has been directed to understanding why. This project focused on how building operators approach energy use and conservation in their work, viewing the building as a social system. It drew on interviews, a workshop, surveys, and case studies, learning from operators, facilities staff, researchers, policymakers and occupants.

We found two clusters of obstacles to lowered energy use. First, while building operators have the technical means to reduce energy use, social, organizational and technical constraints limit ability and motivation. These include low status, customer service practices, poor feedback on occupant environment, little energy data, and technology design shortcomings. A second cluster of obstacles rests on the fact that current combinations of buildings, management, and expectations leave many occupants dissatisfied with indoor environment.

Recommendations call for shifting the locus of energy use reduction strategies to better include building operators, who are in an ideal position to shape and vet solutions. These include (1) increasing status and visibility of building operators; (2) improving ability to see how energy is used; and (3) attending to indoor environment in coordination with energy efficiency.

Executive Summary

Introduction

The California Air Resources Board seeks to identify cost-effective options for mitigating California greenhouse gas emissions, in accordance with the California Global Warming Solutions Act of 2006 (AB 32). To support this objective, our research investigated how building operators see energy use and energy conservation in the course of their daily work, and how they can become more active players in reducing building energy use. Theory suggests that reasonable changes in operations can save 5%-30% of building energy consumption, but in many buildings these savings are not taken. Operations are not addressed in codes. Rules and guidelines for operational efficiency exist, but are often not followed. What operators do are a major "behavior" behind energy consumption in commercial buildings, and thus greenhouse gas emissions and their reduction.

Objectives and Methods

First, we sought to improve knowledge about day-to-day building operations practices and the dynamics of operations energy use in commercial buildings, and to identify opportunities for change toward lower-energy practices. Second, we wanted to illustrate the need to see building energy use as a dynamic system, rather than one in which elements (devices, behaviors, information, and indoor environmental qualities) can be satisfactorily addressed in isolation. Occupied buildings are dynamic systems of peoples, lights, energy and resource flows, walls and floors, windows and doors, roles, interactions, glitches, misunderstandings, adaptations, etc. Thus it is changes in relationships (along with changes in devices, people, etc.) that can best lead to transitions to lower energy use.

There has been very little research on these two areas. Our study is observational and analytic, but not experimental, and is not designed to prove specific strategies. Overall our goal is to outline the rich potential of the position of building operators as a means of reducing energy use and improving indoor environmental quality, and to better understand difficulties faced.

The research focused on medium and large office buildings in California, and proceeded with a layered approach. The first data collection step was a workshop of building operators, facilities staff, building energy researchers, and other building energy experts. The workshop was designed to elicit stories about building operations as a means of capturing the experiences, insights, and concerns about influencing energy use that circulate in building professions and allied communities, but are rarely written down or fully explored. The second step consisted of two series of semi-structured interviews, one with building operators, and another with energy managers, facilities staff, program experts, and other building energy professionals. The final data collection step was four building case studies, each using surveys and interviews with occupants, interviews with building operators and facilities staff, and on-site visits. We also analyzed occupant satisfaction survey data for 101 California buildings, collected and archived by the Center for the Built Environment at University of California Berkeley, to provide basic characterization of how buildings are performing from the perspective of occupants.

Results

Two principal clusters of obstacles impede lowered operational energy use. First, while building operators are technically in a position to reduce operational energy use and to address performance problems in buildings, social, technical, and organizational constraints and configurations limit ability and motivation to do so. These include limitations of status, high emphasis on particular kinds of customer service, poor feedback on occupant environment, little energy data, low staffing levels, low salience of energy and energy costs to the organization, confusion over what job skills should be required, and technology shortcomings, including those of Building Management Systems usability and training. Building operators manage energy services in their daily work, but this may rarely constitute strategic energy conservation. Often several different departments influence energy consumption, while none "owns" energy use as a core responsibility. Levels of coordination across departments are low and some steps – in particular occupant education about use of building features and coordinated expectation management – are largely omitted. Most building operators said that they did not regularly see energy bills, and other sorts of energy data available, if any, may be virtually unused for diagnosis or conservation strategies. In some buildings, these obstacles have been partly overcome, especially where LEED-certification and Energy Star status were motivators. The report highlights these examples as well as a larger need for better sharing of trustworthy information on what works.

A second cluster of obstacles relates to occupant satisfaction with the indoor environment and the ability of buildings to meet occupant expectations. Energy services provided in buildings often do not result in satisfactory indoor environments as judged by occupants, whether explained by of design, operations, facilities management, poor commissioning, insufficient education, or occupant expectations that are too high. Occupant satisfaction survey data showed surprisingly low overall levels of occupant satisfaction with temperature and air quality, both of which are directly affected by operations. Other indoor environmental factors, especially acoustics, also rated poorly. Not only is this bad for occupants and the organizations that they work for, it can also lead to higher energy use. Increased emphasis on improving the indoor environment is a promising route for reduced energy waste.

Conclusions

Reducing energy use in buildings requires more than isolated changes to technologies or attempts to "fix" operators' or others' individual behaviors. Our recommendations speak to the need to shift the locus of building energy use research toward experimentation in real buildings and toward much greater inclusion of building operators, who are in an ideal position to help shape and vet solutions. To do this, we recommend: (1) recognizing the building as a social system and using real buildings and users to experiment with solutions; (2) supporting increases in the visibility and professionalization of building operators and operations; (3) improving technical capabilities for seeing and managing energy in buildings; and (4) better coordinating indoor environmental quality with energy efficiency, also helping ensure that efficiency technologies meet their promises and that they do not lead to unnecessary deterioration of the workplace environments that occupants face.

Chapter 1: Introduction

California's Global Warming Solutions Act (AB 32) calls for California to reduce its GHG emissions to 1990 levels by 2020. Supporting this act, other state policies and plans target energy use and greenhouse gas emissions reductions from commercial buildings, which account for 36% of California electricity use and 16% of direct natural gas use (CEC 2013). The state's long term Energy Efficiency Strategic Plan specifies that 50% of existing commercial buildings should have consumption levels equivalent to zero net energy by 2030 (Engage 360 2011). California Executive Order B-18-12 ordered state agencies take action to reduce greenhouse gas emissions by at least 10% by 2015 and 20% by 2020 relative to a 2010 baseline. In short, California has set aggressive goals for reducing energy use and greenhouse gas emissions from commercial buildings.

Building operations have a major role in determining the degree to which cost-effective energy use and emissions reductions in commercial buildings will be achieved. Along with tenant practices, operations have a substantial effect on building energy use, but are not currently addressed by codes or design-centered programs (NBI 2013). Changes to building operations could save 5-15% (PECI 1999) or up to 30% of energy use in many buildings (Blumstein et al. 1980, Kolkebeck 2012). These opportunities have low investment costs and high savings relative to many technical efficiency upgrades (Lin & Hong 2013). But even organizations that are oriented to energy efficiency miss apparently simple operational savings such as weekend thermostat setbacks, despite official guidelines directing these actions (US DOE 2009).

Researchers have noted that understanding energy efficiency investments in commercial building construction and renovation requires comprehensive attention to the organizational and social relationships in commercial buildings, rather than isolated focus on technological efficiency or on individuals' knowledge or behaviors alone (Lutzenhiser et al. 2001, Janda 2013). This is also true of understanding and achieving operational energy savings.

To address operational savings potential, our research focused on how building operators approach energy use, energy efficiency, and energy conservation in their everyday work, seeing these actions in context of the buildings, devices, information, and other actors with which they interact. Building operators are the "missing link that was already there" between occupants and building energy use (Aune et al. 2009). We used interviews, a workshop, surveys, and case studies to investigate these connections, drawing from conversations with building operators, energy managers, other facilities and property staff, building energy researchers, and policymakers, as well as survey data from occupants. We analyzed this data toward identifying barriers and opportunities for achieving operational energy savings, using a perspective that complements efforts on specific technological or behavioral measures.

In centering on building operators, this perspective also provides a window into other social elements in buildings: occupant expectations, satisfaction, and behavior; representations of what building users of all sorts need, want, and do; design and systems usability; the impact of occupant and tenant complaints; and the social exchanges and coordination of many different types of actors that affect a building's energy use. The overall aim is to identify strategies, programs, and other approaches that can permit operators to achieve lower energy use and improve building operations. If modern buildings "generally fail to provide all their occupants with the safety, health, and comfort that are expected" (Levin 2003), then increased attention to building operators and operations in managing and observing these conditions is a crucial step toward healthier and more satisfying indoor environments, as well as serving governmental, business, and social interests in reducing greenhouse gas emissions. Improved recognition of the importance of building operations also supports state goals for a greener economy and a clean energy workforce.

Chapter 2: Project Objectives

The main broad objective of this project was to improve knowledge about how building operators view energy use and energy conservation in day-to-day building operations, and to identify opportunities for change toward lower-energy practices and reduced GHG emissions. In so doing, we investigated strategies for working within the multiple and often conflicting stakes that shape energy use in commercial buildings, and the low salience of energy costs for most organizations (Blumstein et al. 1980, DeCanio 1993, Lutzenhiser et al. 2001). A second broad objective was to illustrate the need to see building energy use as a dynamic system, rather than one in which elements – devices, behaviors, information, and indoor environmental qualities – can be satisfactorily addressed in isolation. Overall our aim was to highlight and investigate the rich potential of the position of building operators within this dynamic system, as a means of reducing energy use, improving indoor environmental quality, and reducing the gap between how buildings actually perform and how they could perform.

Our perspective complements efforts that target energy efficient technologies or individual actions in isolation, as well as guidelines that focus on the technical aspects of improving building operations (e.g., PECI 1999, Sullivan et al. 2010). We sought to produce practical insights and recommendation, but speak more to the research, policy, and program communities than to building operators. Data collection focused on building operators in medium and large office buildings in California.

Specific project objectives are to:

- Better understand how building operators shape energy services and see energy use and energy conservation in their daily work
- Explore relationships between occupant satisfaction with the indoor environment and energy use and operations decisions
- Understand differences between theories and actual practice of energy-related operations in medium and large office buildings
- Identify barriers and opportunities toward operations that require less energy without causing undue stress on occupants
- Complement technology-centered field assessments and behavior-oriented work on commercial building energy use and savings opportunities
- Draw attention to social organization of building operation and energy management in commercial buildings and to how this organization relates to technology-centered and individual-centered strategies to reduce energy use
- Bring the non-formalized knowledge of energy researchers and other building energy professionals to bear on the above topics
- Recommend strategies by which building operators can better achieve energy use reductions

Chapter 3: Methods and Background

We used a basic social sciences approach and a mixture of methods to address the research questions outlined in the previous chapter. There were three main phases of data collection: a workshop; interviews with building operators, energy managers, facilities managers, building energy researchers, and other experts; and four building case studies. Case studies consisted of on-site visits, surveys, and interviews, covering the perspectives of both occupants and building operators. In addition to this data collection, archived survey data on occupant satisfaction with indoor environmental quality in California commercial buildings were also analyzed. This data, collected and maintained by the Center for the Built Environment at University of California, provided a basis for understanding overall occupant experience with, and assessment of, temperature, air quality, lighting, and other aspects of the indoor environment in their workplaces. We used this occupant satisfaction data together with data on commercial building energy use and greenhouse gas (GHG) emissions (Chapter 4) to link, on an aggregate basis, energy consumption with occupant assessment of the indoor environment that this energy use helps provide.

There is an enormous variety of commercial buildings, and technologies and activities within them, ranging from malls to hospitals to office towers, and no "typical" commercial building. Data collection was not intended to be statistically representative, but rather to cover sufficient variety within practical limits, and to use the expertise of our informants for presenting a broader picture. Most data was from office buildings and our conclusions are most relevant to that sector, though we also interviewed representatives from non-office public buildings, a retail chain, and educational buildings. As we had expected when designing the research, many of our contacts were from higher-performing buildings, and we interpreted their experience in this light. A handful of interviews were with private and public sector buildings that were not high-performing. Our interpretations and recommendations do not assume that "best practices" cases – with high level of management attention to building energy use and plentiful staff and budget – can become widespread or routine. Rather we use the insights of interviewees from high-performing buildings to speak to problems and barriers that they have seen or encountered, and ways that these might be at least partially overcome.

There is little social sciences or behavioral sciences research on building operations (Aune et al. 2009), or even on the social sciences of building design, construction, and energy use (Lutzenhiser et al. 2001, Janda 2013, Schweber & Leiringer 2012). However there is a great deal of experience held by the building practitioners and building energy researchers themselves on what goes on in buildings with respect to energy use, operations, and design. Our approach draws out and builds on that knowledge, toward highlighting perspectives that better combine the technical, economic, social, cultural, and behavioral aspects of energy use, as opposed to seeing buildings as idealized technical systems that are or are not used "properly" by individual inhabitants. The remainder of this chapter provides a definition of building operator, followed by a description of methods and data background.

What is a Building Operator?

In this report, a building operator largely refers to the U.S. Bureau of Labor Statistics (BLS) job title of Stationary Engineer. According to BLS (2013), building operators:

> Operate or maintain stationary engines, boilers, or other mechanical equipment to provide utilities for buildings or industrial processes. Operate equipment, such as steam engines, generators, motors, turbines, and steam boilers.

The BLS Occupational Outlook Handbook predicts slower than average job growth for stationary engineers and boiler operators, with a median salary of $52K/year in 2010 (BLS 2013). For entry level positions, the handbook cites a high school diploma as the minimal education level, no job experience requirement, and on-the-job training. A recent Canadian study found that, in Canada, training is fragmented, there are confused definitions of what a building operator should be doing, and that labor shortages should be expected within a decade (ECO Canada 2011). The U.S. situation may be similar.

The BLS definition above refers to building operators' technical roles as system operators. In practice, building operators usually take important social and organizational roles as well. Operators are the face of the environmental services that building occupants receive. In that role, they manage expectations about the gaps between what the building can offer, what operations provides, and occupants' expectations. Operators may also have a role in influencing the business real estate functions that their managers (i.e., facilities managers) coordinate, in particular operations process and purchasing. This report presents results about technical challenges related to energy use and environmental services in their buildings. More importantly, it also describes social and organizational challenges that building operators face.

Occupant IEQ Satisfaction Survey Instrument and Data Base

Buildings, efficient or not, should presumably provide satisfactory environments for the occupants and activities within them (Cole et al. 2010, Levin 2003). As background for the data collection phase of our research, a first step was to look at how well buildings are performing from occupants' perspectives, based on a set of occupant satisfaction survey data collected and maintained by the Center for the Built Environment (CBE) at University of California Berkeley. Since 2000, CBE has administered an Occupant Indoor Environmental Quality (IEQ) Satisfaction Survey and stored the responses. The current data base includes surveys for over 600 buildings worldwide. For California, the current data base covers 101 buildings and 9261 occupant responses.

Occupants are often difficult to access in building energy research. Even building operators, facilities staff, and designers may rarely hear what the occupants in their buildings think in much of a representative manner. Occupant satisfaction surveys are not standard practice, and there are few data bases allow combining satisfaction surveys across buildings. Thus the CBE survey data base was an unusual and valuable resource for constructing a picture of building performance from occupants' perspectives.

The CBE Occupant IEQ Satisfaction Survey instrument is a standardized and sanctioned way of gathering impressions of building performance from occupants (ASHRAE 2010). It was developed with extensive testing and cognitive interviewing (Zagreus et al. 2004), ensuring good coverage of a wide range of concerns about indoor environments in commercial buildings. The standard survey contains 13 core questions and 42 supplemental questions. In the core questions, respondents are presented with a seven-point ordered-response scale for rating satisfaction on thermal comfort, air quality, lighting, acoustic quality, speech privacy, office furnishings, office layout, cleaning and maintenance, their workspace in general, and the building in general. If occupants report dissatisfaction, they are asked follow-up questions about the sources of their dissatisfaction. The survey instrument also permits occupants to offer free text comments about each area.

For many buildings, the survey instrument is customized with additional questions on other topics of interest, such as reactions to specific building features or functions. Basic data on the occupant, including sex, age in three categories, and sometimes location in the building and type of work, are also collected. Surveys are administered over the web and responses are anonymous. In addition to the occupant survey data, CBE also maintains a database of building characteristics for each surveyed building. The fields in this building database include date built, renovation date, floor area, occupancy, LEED certification level if any, and other descriptions of various characteristics and features. This allows analysts to select and compare occupant satisfaction results on the basis of building characteristics.

We completed two types of analysis with the occupant satisfaction data: analysis of satisfaction data ratings and drill-down questions, and examination of free-text responses. The former are reported in Chapter 4, and the latter are integrated into case study and interview data analysis (Chapter 5). The CBE Occupant IEQ Satisfaction survey instrument was also used as the basis for the surveys conducted in the case studies, customized (in three of the four cases) to probe on project-specific questions including adaptation, complaint processes, views on energy efficiency, and sources of building satisfaction in general.

CBE also developed an Operations and Maintenance (O&M) survey for fielding to building operators and other facilities staff. For this current research project, the survey was customized for the project and applied via a web interface for one of the case studies.

Workshop

The first phase of data collection was a Building Operations Stories Workshop, held 15 September 2011 at the Pacific Energy Center in San Francisco. The four-hour workshop was designed to guide subsequent data collection by tapping into the knowledge and experience of the building operations and building energy research communities about how day-to-day commercial building energy use is shaped in practice.

We focused our data collection on eliciting stories that participants had about their experiences in influencing or observing energy use in buildings. These stories were interpreted as “versions of reality” (Bruner 1991) that move beyond low-dimension perspectives on reducing energy use, which often rest on ideals (e.g., *if only* occupants could be convinced to care about energy use, followed instructions, operators were better-trained, particular devices or systems were installed, and so on). This focus on stories was intended to help overcome some of the normal restrictions on what can be written (or even uttered in formal circumstances) due to political or evidentiary concerns. We used these stories to build discussions about relationships among the various actors and things that shape energy use: operators, occupants, technologies, policies and guidelines, energy data, and so on. We were interested in how these interactions differ from corresponding assumptions and representations in research and policy models of building energy use, and in what participants thought was being overlooked by these representations. What's curious? What's interesting? What keeps on happening? What seems to work to reduce energy use and what doesn't?

Workshop attendees included building energy researchers, building operators and facilities management staff, and the project research team. Forty people were invited to the workshop, including building operators, facilities managers, building operations educators, and researchers. Twenty-one people attended, including members of the research team. Before the workshop, invitees were asked to gather stories from their own experiences on building operator or occupant behavior related to energy use or comfort, whether successes or failures, to share in the workshop. They were also invited to submit a favorite story before the workshop to stimulate conversation.

The workshop began with short presentations illustrating the research and the intent of the workshop. Participants were assigned to one of four working groups at separate tables, with a mixture of perspectives present in each (e.g., a building operator, an engineer, a social scientist). The participants at each table were asked to share stories and experiences about building energy use amongst themselves, and then to choose a favorite story and present it to the larger group. The entire group then discussed each table's story and contributed similar stories or counterpoint. This exercise was repeated for three rounds, after which the stories were analyzed by the group to dissect themes and expand on interpretations. Stories were recorded by scribes at each table. A graphic reporter summarized workshop output, and a workshop report was prepared (Moezzi 2013).

Interviews

For this task, we talked to ten building operators, three energy managers, and nine other building management staff (e.g., property managers, analysts) using semi-structured interviews. These interviews were designed based on the results of the stories workshop, literature and data review, the CBE Operations and Maintenance survey instrument, and consultation with building energy researchers. In addition to these interviews of practitioners, toward further developing initial findings, we also interviewed eight other experts in buildings energy, including educators, managers, and researchers. Most interviews were conducted by phone and lasted between 30-60 minutes. Several interviews were conducted on site. These usually lasted longer and allowed interviewers to better observe the context.

Building operators were identified through our professional channels. These interviews were not designed to be a representative sample of California building operators, though we made substantial efforts to reach out beyond the easiest targets. The operators and facilities staff we interviewed typically worked in buildings that were on the forefront of building operations and energy management. Most of the buildings they operated were Energy Star-rated buildings, LEED-certified buildings, or other cases where energy use or sustainability appeared to be of higher interest. We did speak to operators in a few buildings that were not Energy Star-rated and in particular conducted a series of interviews with a range of facilities management staff working with a set of public buildings throughout the state. The energy bills for these buildings were paid from a central budget, and funding for building improvements and maintenance were very limited, making for a particularly difficult set of mixed incentives. Most of the building operators we spoke to worked in northern California, though we did interview some southern California operators.

Table 1 summarizes the building operators we interviewed, as defined by their buildings. Interviews covered basic information on the operator and building background, questions on how energy use comes up in their jobs, perspectives on energy conservation, experiences in energy saving, interviews with occupants, and any recommendations they had for reducing energy use in buildings or on policies to help do so. The interviews also collected basic technical information, including the presence and type of Building Management System (BMS), as well as on building commissioning and renovation history.

Table 1. Building operators interviewed

Operator(s)	Building
A	San Francisco, Energy Star > 90, LEED EBOM[1]
B	Irvine, Energy Star 70-79
C	Encino, Energy Star > 90
D	San Francisco, Energy Star > 90, LEED EBOM
E	San Francisco, Energy Star 80-90, LEED EBOM
F	San Francisco, Energy Star > 90
G	Irvine, no Energy Star rating
H	Berkeley
I	Los Angeles, Energy Star 70-79
J	Berkeley

[1] LEED for Existing Buildings: Operations and Maintenance (LEED EBOM) is LEED's rating system for existing buildings designed to encourage operational sustainability.

Case Studies

The third phase of data collection consisted of case studies of four commercial buildings. The case studies were designed to combine, within a building, building operator experience with occupant perspectives, allowing researchers to better see the building as a social system. Table 2 summarizes the characteristics of the four buildings and the data collection processes for each. Building characteristics are blurred for anonymity.

The most challenging step in conducting these case studies was obtaining permission to survey or otherwise contact occupants. Despite the offer of a no-cost web-administered occupant satisfaction survey and analysis (e.g. offered through CBE industry meetings and newsletter), recruitment was difficult, especially since we wanted to avoid studying buildings that had already been extensively researched or that were too specific, such as buildings on university campuses. For the goal of improving the performance of future buildings, this difficulty was itself instructive. Organizations may often not see value in surveying occupants about their experiences with the indoor environment, especially compared to the potential disruption, and the risk of unnecessarily surfacing dissatisfaction or other problems. But without knowing what occupants experience, improving indoor environment and building performance are hindered by blindness about one of the most important elements of the building as an energy-conversion system.

We completed case studies for four buildings, in some cases paring down the occupant survey component so that it was acceptable to management. The process consisted of the following steps:

- Make contact and negotiate request
- Review building background material, such as LEED documentation or available design materials
- Conduct an occupant survey or interviews customized for the project (except in one case using the CBE occupant satisfaction survey that had recently been conducted instead)
- Complete interviews with building operator(s) and other facilities and property staff
- Complete one or more on-site visits
- Analyze results and prepare case study reports, sharing a report with building management in two of the four cases

Further details of each building and specifics of the research data collection steps are provided below.

Table 2. Case study buildings and data collection process

Case Study Building	Building Characteristics	Data Collection
Large Owner-Occupied Office	Single tenant, over 10 stories, more than 400,000 square feet, out-sourced building operations team; LEED-certified	Full occupant satisfaction survey with additional questions customized for the project (42% response rate) Full O&M survey with additional questions customized for the project (9 responses) On-site tour and visits Semi-structured interviews with operations teams in three groups: internal staff, operations engineering, and operations procurement (separate and in combination, 8 people in total) Interviews and further consultation with design team (7 interviews, 8 people) Energy bills Reviewed LEED-certification and design documents
Medium Local Government Office	Single-tenant LEED-certified, about 60,000 square feet, renovated in 2000s	On-site structured interviews with 22 occupants, customized for project On-site semi-structured interview with building operator Reviewed LEED-certification documentation
Large Government Office	Single tenant, over 500,000 square feet, recently renovated	Website occupant satisfaction survey for subset of 12 occupants customized for project On-site tour and interviews with two departments: building operations staff including chief engineer and department that manages and handles occupant complaints
Medium Multi-Tenant Mixed Commercial	Multiple tenants, originally constructed mid 20th century, over 200,000 square feet	Occupant satisfaction survey for major tenant, completed outside of research project Interview with property manager Interview with building operator On-site tour

Case I. Large Owner-Occupied Office

Case I is single-tenant owner-occupied building with an outsourced operations team, constructed using a design-bid-build process. It is located in the Central Valley and had been in operation about two years at the time of the case study research. The building is over ten stories, with over 400,000 square feet of office space. It is LEED-certified and includes a number of features aimed at reducing energy use while promoting occupant comfort, including under-floor air distribution (UFAD) with adjustable airflow diffusers and daylighting.

For the research project, a modified version of CBE's web-based Occupant Indoor Environmental Quality survey was administered to occupants. The modifications asked about occupant's process for resolving comfort issues and what occupants liked about the building. Slightly over 500 occupants responded, representing over half of the building's average daily occupancy. In addition to the occupant survey, we also surveyed internal and external operations staff using a modified version of CBE's web-based Operations and Maintenance (O&M) Survey. This survey was customized for the technical specifics of the building and also included questions about the operations and facilities team members' experience with and opinions about occupant behavior and energy use. Twelve responses were collected. Both the occupant and O&M surveys yielded open-ended text responses as well as closed-end responses.

In an on-site visit, we conducted semi-structured interviews with operations and facilities teams, primarily in three separate groups: internal staff, operations engineering, and operations procurement. We also conducted seven interviews with the design team, and toured the physical plant and building.

Case II. Medium Local Government Office

Case II is a LEED-certified municipal building in the San Francisco Bay Area, constructed before 1960 and renovated in the mid-2000s. The building was originally designed with operable windows and without air conditioning. During renovation, the existing windows were sealed and air conditioning was installed. As part of LEED certification and nine months after occupancy, occupants were surveyed to achieve EQc7.2 thermal comfort verification, which is a LEED credit focused on occupants' assessment of the building's thermal comfort.

Our data collection began by surveying 22 occupants. Working with Human Resources and organizational contacts from the renovation and LEED process, we surveyed occupants in person, in exchange for a free lunch. The interviews consisted of 10 questions on satisfaction with indoor environmental quality (IEQ) elements (with responses ranked on a scale of -3 to 3) and several additional open-end questions on related topics, including favorite and least favorite aspects of the building, opinion on operable windows, and ideas for improved energy management. When the interviewee replied with a "less than satisfied" rank for IEQ elements, interviewers asked for explanations. Data were recorded and analyzed.

With the results of the occupant survey in hand, we next conducted an in-depth interview with the building operator, who was one of a three-person crew managing several dozen buildings. Our questions focused on his process for handling occupant complaints, use and availability of energy information, the user-friendliness of his building management system (BMS), and his approach to operating a LEED certified building.

Case III. Large Government Office

Case III was one building within a campus located in the California central valley. It is a two-story building of over 500,000 square feet, renovated in the mid-2000s. The campus is 90+ acres consisting of about two million feet of office and support space. Two different departments managed the occupant environment. One department managed occupants and their complaints; a second department managed the building systems, maintenance, and daily operations. In lieu of surveying occupants overall, a modified version of CBE's Occupant IEQ Satisfaction Survey was conducted of the members of the first department, with twelve responses received, primarily from operations, contracts, and space planning.

In an on-site visit, we also conducted in-depth interviews with managers from both departments, including an interview with the chief building engineer. For the building engineer, our questions focused on his use of the BMS system, recommendations to designers on the selection of a lighting control system, and access to utility bills and other energy data. For the department that manages occupants and their complaints, interviews focused on the complaint process and on department member's perspectives on what makes a good building, occupant, and operations.

Case IV. Medium Multi-Tenant Mixed Commercial

Case IV was only two stories but over 200,000 square feet. It is an adaptive reuse project, built originally in the 1930s and converted several times over its history. Its current manifestation, with the original 28-foot ceilings as well as clerestory windows, make for a dramatic workplace and have likely helped attract the high profile clients occupying it. This building is known as a high-performer and has received several awards.

CBE's Occupant IEQ Satisfaction Survey was implemented for largest tenant in the building, which occupies about one-third of the space. We also completed two on-site interviews, one with the property manager and one with the building operator.

Chapter 4: Energy, Emissions, and Occupant Satisfaction

This chapter summarizes how California buildings are faring with respect to energy use and occupant satisfaction with the indoor environment, based on aggregate data sources. The first section presents greenhouse gas emissions (GHG), electricity use, and natural gas use trends for California commercial buildings. The data show an increase in California commercial building GHG emissions from natural gas use over the past decade, and increases in California's commercial building energy consumption over the past two decades.

The second section presents results on occupant satisfaction with the indoor environment of their workplaces, based on survey data for 101 California commercial buildings. Analysis of this data shows that occupants in many buildings have low satisfaction with temperature, as well as with other aspects of the indoor environment. The shortcomings identified by occupants are not always demands for more energy services, but sometimes for less.

In combination, this characterization of the current energy performance in California commercial buildings in aggregate – increasing energy use overall and evidence of low occupant satisfaction in many – point to an apparent disconnection in the efficiency of energy services viewed overall: increasing energy use does not seem to result in high occupant satisfaction, at least not in office buildings.

Emissions and Energy Use Trends

This section presents basic trends in commercial building GHG emissions and energy use for California.[2] We use a few different depictions to provide a broader understanding of how the commercial building sector is doing relative to energy and emissions reduction policy goals. In overview, emissions from commercial building energy use in California, including electricity sales-allocated emissions from electricity use, were lower in 2011 than in 2000, in part due to the variability of the annual electricity generation mix. Total electricity used in California commercial buildings increased 4.4% between 2000 and 2011, and 36.5% between 1990 and 2011. Per capita emissions from California commercial building electricity use were 8.5% higher in 2011 than in 1990. Details follow.

GHG Emissions

To estimate the contribution of commercial building energy use to California's GHG emissions, we combined estimates of emissions from direct fuel combustion in the commercial sector with estimates of the emissions attributable to electricity used in commercial buildings. This is an augmentation of the official greenhouse gas inventory accounting framework, Figure 1 presents these estimates, and their annual total, for 2000 through 2011. California's Greenhouse Gas Inventory by Sector and Activity summary (ARB 2013a) provides estimates of GHG emissions from direct fuel combustion for the commercial sector. The inventory accounts for emissions from electricity separately. To estimate GHG emissions attributable to electricity use

[2] Depending on the data source, statistics may pertain to either commercial buildings or the commercial sector; data sources could not always be coordinated as to category.

in commercial buildings, we used a sales-allocated weighting of total emissions from electricity generation as reported in the Inventory, including in-state and out-of-state generation.[3]

Emissions from direct fuel combustion from the commercial sector increased 11.7% over the 12-year period.[4] Electricity-related emissions from commercial building electricity use are two to three times the level of emissions from building direct fuel combustion. Emissions factors for electricity generation in California vary substantially from year to year, especially depending on the contribution of hydropower to the generation mix (ARB 2013b). Hydropower contributions were particularly high in 2006 and 2011, contributing to the relatively low emissions values for those years (ARB 2013b). The energy-based trends presented in the next section provide another perspective.

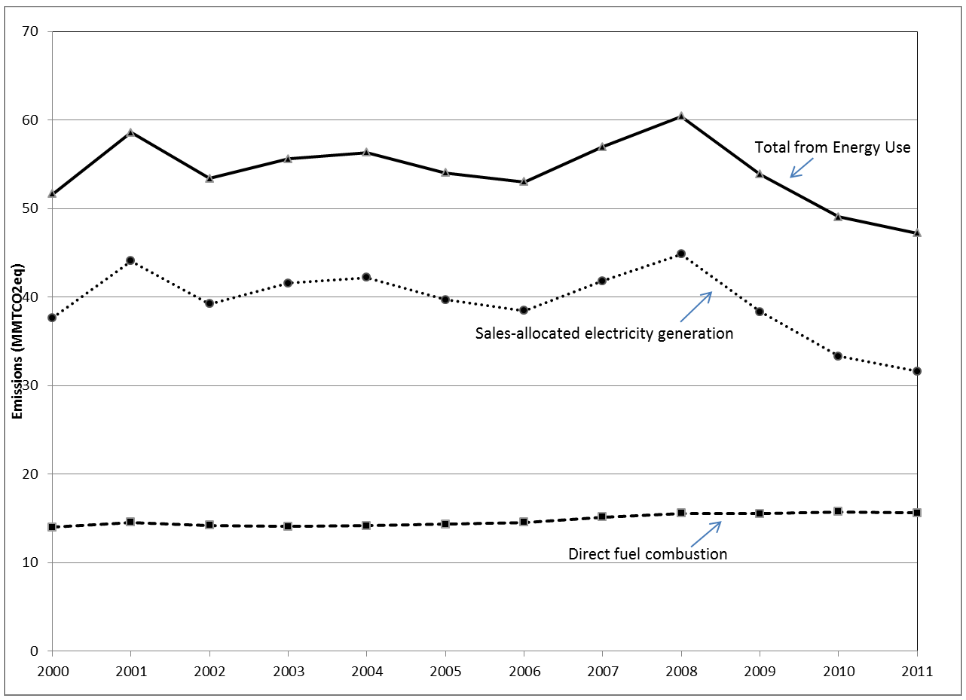

Figure 1. Trends in energy-related GHG emissions in California commercial sector

[3] Allocation was based on annual ratios of commercial building electricity use to total electricity use as reported by the California Energy Commission (CEC 2013). Actual GHG emissions from electricity use depend on details of generation mix by time of use. Our depiction does not take this into account.

[4] The GHG inventory trends summary (ARB 2013b) reports an increase in commercial fuel use emissions from 12.9 MMTCO2eq in 1990 to 14.9 MMTCO2eq in 2011, a 15.5% increase. There is a modest difference in sector definition in our analysis relative to that used in the ARB trends report, possibly due to whether Commercial CHP (a Sector Level 2 category in the Inventory) is included.

Energy Use

Figure 2 shows trends in electricity use and natural gas use for California commercial buildings based on California Energy Commission data (CEC 2013).[5] In 2011, electricity consumption in California's commercial buildings was 37% higher than in 1990, with a relatively steady pace of increase up to 2008. Between 2008 and 2011, commercial building energy use in California declined. The decline could be due to a combination of a slower economy and increased building energy efficiency. National trends are similar, with primary energy consumption in commercial buildings increasing 37% between 1990 and 2009 (US DOE 2012). Natural gas use in commercial buildings (right axis) shows much more variation from year to year, though still an upward trend. Commercial building natural gas use was 21.4% higher in 2011 than in 1990. Over the past five years, natural gas combustion in commercial buildings accounted for 15-16% of total natural gas use in the state, a higher proportion than the 11-13% in the early 1990s.

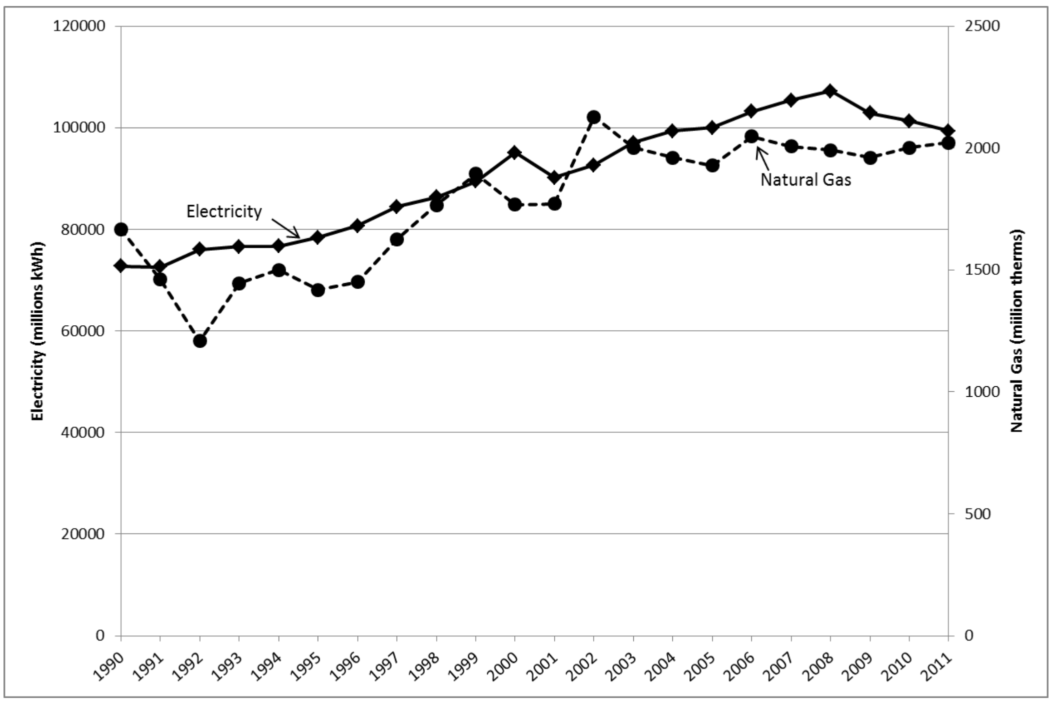

Figure 2. Electricity and natural gas use trends in California commercial buildings, 1990-2011

In summary, levels of both electricity and natural gas use in commercial buildings have increased over the past 20 years and over the past decade, with a recent flattening. In 2011, electricity and natural gas consumption were both about the level that they were in 2005-2006. Note that the scales of the natural gas and electricity usage axes on Figure 2 are not equivalent in terms of energy value. Rather, electricity contributes 4-5 times the level of primary energy use as natural gas in California commercial buildings e.g., 9149 million therms of primary electricity

[5] Between 1990 and 2011, total commercial sector natural gas energy use was 7%-17% higher each year (depending on the year) than commercial building natural gas use, and total commercial sector electricity use was 13%-17% higher each year than commercial building electricity use (CEC 2013).

use in 2011, compared to 2023 million therms of natural gas.[6] The ratio is similar for the U.S. overall, with 78% of U.S. commercial sector primary energy use in 2009 as electricity, 17% from natural gas, and the remaining few percent from other fuels (US DOE 2012).

Per Capita Energy Use

High-level climate change-related goals are often expressed in terms of absolute emissions or energy use, while efficiency is usually defined at the level of structures, devices, and sometimes intensity. Figure 3 shows electricity use and natural gas use in California commercial buildings per capita, as one type of intensity measure. Commercial building energy use per capita overall in the state is increasing, with growth in electricity use driving this increase. California's population increased 22% between 1990 and 2011. This is a slower pace than the 36.5% increase for total electricity use in commercial buildings, with per capita electricity use in California commercial buildings 8.5% higher in 2011 than in 1990. The 2011 per capita natural gas use in commercial buildings was 4% lower than in 1990.[7] Nationally, primary energy consumption per capita in commercial buildings increased 9.4% between 1990 and 2009 (US DOE 2012).

As to per floor area intensity measures, between 2000 and 2011, fuel use per floor space in California commercial buildings remained fairly steady (ARB 2013b). Nationally, commercial floor space increased at about the same rate as population between 1990 and 2011, with commercial floor area increasing 26% over the period compared to a 24% increase in population over the same period (US DOE 2012).

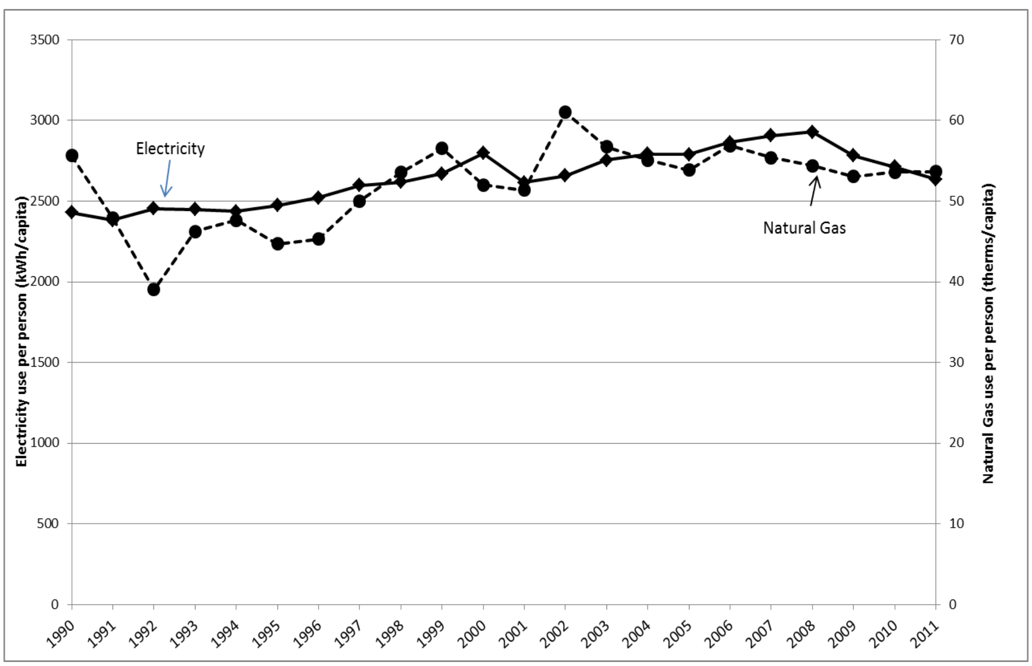

Figure 3. Per capita electricity and natural gas use trends in California commercial buildings

[6] We applied a site-to-primary conversion factor of 2.7, following Kinney and Piette (2003).

[7] The level of natural gas consumption in 1990 was particularly low: the 2011 value is 10% higher than average throughout the 1990s.

Occupant Satisfaction

Occupant satisfaction with the indoor environment is one measure of how well buildings are performing. Surveys of occupant satisfaction are not routine (Zimmerman & Martin 2001), though they are becoming more common as an option toward LEED certification. The analysis of California occupant satisfaction survey data presented below indicates that from occupants' perspectives, indoor environments are less satisfactory than might be expected. Rather, occupants often report dissatisfaction with basic elements of the temperature, air quality, lighting, acoustics, and other aspects of the buildings that they work in. This dissatisfaction speaks to disconnection between the energy services and conditions that are provided in buildings compared to occupant expectations and preferences for these conditions and services. Occupant satisfaction with indoor environment does not directly translate to physical conditions, such as air pollutant levels. There are parallels, however, in terms of the need to better integrate indoor air quality and energy consumption, and to understand the role of human behavior in determining both (Levin & Phillips2013).

Achieving high levels of occupant satisfaction is highly relevant in some buildings (e.g., Class A offices) but not a universal or even necessarily widespread goal in buildings. Minimizing dissatisfaction or expressions of dissatisfaction may often be more salient. Providing energy services to building users is the core rationale for energy use in most commercial building. Thus improving the coordination of the energy services provided in buildings with user assessment of these services is a nexus from which the efficiency of energy services can be improved. As explored in the next chapters, building operators can potentially play a major role in getting conditions and expectations to better converge, whether through changes in building operation, technology selection, improvements in technology assessment, or occupant education. Design and commissioning issues, of course, also affect how well buildings as physical systems can satisfy occupants.

Survey Data Base

Since 2000, the Center for the Built Environment (CBE) at University of California Berkeley has administered an Occupant Indoor Environmental Quality (IEQ) Satisfaction Survey and stored the responses. We obtained permission to use this data for our project, courtesy of the Center for the Built Environment. For California, the current data base covers 101 buildings and 9261 occupant responses, including only buildings with at least a 35% response rate among invited occupants. These buildings are not intended to be a statistically representative sample of California buildings. A broad range of buildings (including hospitals, offices, public buildings, educational buildings, etc.) are covered, though government-owned and government-occupied buildings predominate.

Survey Results

Table 3 summarizes occupant survey responses for major dimensions of indoor environmental quality included in the survey, aggregating individual survey responses across all California buildings in CBE Occupant IEQ Satisfaction database. Respondents rate satisfaction along a 7-point graphic "thumbs down/thumbs up" scale. The table groups responses into three categories: dissatisfied (-3, -2, -1), neutral (0), or satisfied (1, 2, 3). Across the dimensions, the percentage who stated that they were satisfied ranges from 26% (sound privacy) to 69% (amount of light, general workspace, general building, and office furnishing comfort).

Satisfaction levels for temperature and air quality, both directly influenced by building operations, are among the lowest-scoring dimensions. In response to the question “How satisfied are you with the temperature in your workspace?” less than half of survey respondents (47%) reported that they were satisfied, as discussed in more detail below. Less than two-thirds (57%) reported that they were satisfied with air quality. The stated reason for dissatisfaction was most commonly that the air is stuffy or stale, though respondents also often cited odors (especially from food, but also from printers, outside sources, etc.) or reported that the air does not seem clean.

Table 3. Occupant IEQ satisfaction ratings for 101 California buildings (n=9261)

	Average Score*	Dissatisfied	Neutral	Satisfied
		Percent of respondents		
Temperature	0.17	34%	19%	47%
Air quality	0.72	22%	21%	57%
Amount of light	1.27	17%	14%	69%
Visual comfort of light	0.97	19%	16%	65%
Noise level	0.19	37%	19%	44%
Sound privacy	-0.73	60%	14%	26%
Visual privacy	0.53	31%	15%	54%
General workspace	1.04	15%	16%	69%
General building	1.14	15%	16%	69%
Office furnishings	1.08	16%	15%	69%

*Average across ordinal-scaled variables, i.e., an arithmetic mean of ordered but non-quantitative satisfaction scores on scaled as -3 to 3 (indicative only).

Two-thirds of occupants stated that they were satisfied with each of the two core lighting variables, amount of light and the visual comfort of light. The top three reasons for dissatisfaction with lighting were “not enough daylight” (36%), “too dark” (35%), and “too bright” (24%). “Too dark” and “not enough daylight” were markedly more common in California buildings than for buildings elsewhere (13% and 15% reported these factors as problems, respectively). Survey respondents sometimes noted annoyance or inconvenience or functional problems with motion-sensed or automatic timing of lights. In our interviews and case studies, occupant resistance (whether actual or anticipated) to automatic lighting control was cited as limiting the extent to which motion-sensed lighting was installed.

The two acoustics satisfaction questions received the lowest overall satisfaction ratings of any asked on the core survey. In response to the question “How satisfied are you with the sound privacy in your workspace (ability to have conversations without neighbors overhearing and vice versa),” 26% said that they were satisfied, and 60% said that they were dissatisfied. Satisfaction with level of noise was higher, but still less than half (44%) said that they were satisfied. Satisfaction with both acoustic variables was markedly higher in private offices than in cubicles, but only one in four respondents was stationed in an enclosed private office.

Acoustics is more a matter of building and workspace design, occupancy, and activity, rather than HVAC and lighting operations, and operators do not hear complaints about acoustics nearly as much as about temperature or lighting (IFMA 2009). Given the very low performance in terms of occupant satisfaction, they may still be relevant to building operations, since they affect overall well-being and are more difficult for occupants to adapt to or cope with than lacks in thermal comfort or lighting. Both noise and lack of sound privacy can create hassles and overall an irritating environment (GSA 2012, Moezzi & Goins 2011), especially in situations where concentration or privacy are important. When survey respondents were asked whether the acoustic environment enhanced or interfered with their ability to get their job done, 41% said "interfered."

In addition to problems such as distracting acoustics, building "scripts" that do not fit users, and cannot be adequately adjusted to do so, create an additional potential layer of dissatisfaction and disengagement (Berker 2011). A script, in the parlance of social studies of technology, is a representation of expected use and users as inscribed in the physical form of a technology and its application. Buildings and the devices within them embody these scripts, and building inhabitants have to negotiate with them. Examples include how lighting automation is set, where and when cardkeys are required, working hours and energy service provision, where the chair is positioned, how controls are to be used, etc. When there are too many mismatches, occupants get irritated with the building (Berker 2011) and those who designed it. This can lead to less "engagement" with the building and lower amenability to follow its scripts, modification of scripts ("anti-programs" and "domestication"), and other forms of revolt (Berker 2011). In discussing real buildings, there are many anecdotes about users overcoming building flaws and features, such as blocking vents or redirecting air flow, taping over sensors, adding labels, etc. (see, e.g. Pritoni et al. 2012). Even in buildings that overall perform well, including some of our case study buildings, examples of user modification are not uncommon. These reactions are not necessarily a bad thing, but they do signal usability issues and can affect energy use and energy services delivery. Building operators, as well, face and modify scripts, at times disabling, modifying, or improving existing systems and conditions.

The CBE IEQ survey also asks occupants to rate their satisfaction with their workspace in general and with the building in general. Satisfaction with both of these dimensions is high relative to those of many other specific elements, with more than two-thirds of occupants stating that they are satisfied (Table 3). Our data analysis showed that respondents could easily have high satisfaction with a building despite low satisfaction with various IEQ elements. This pattern points to potential leeway in improving occupant satisfaction and well-being overall without necessarily increasing energy services or major changes in IEQ components.

Satisfaction with every IEQ dimension (not just acoustics, mentioned above) was higher in private offices than in cubicles. Respondents in enclosed private offices appeared to overall be quite content with their lot (average satisfaction score of 1.8 for "office layout," that is, quite satisfied on average, compared to an average of 0.0 for cubicle occupants).[8] Though cubicles are a fact of life for most office workers, they do not tend to make an occupant feel well-treated. Comparison of private sector versus government buildings showed higher satisfaction in private sector office buildings versus government office buildings for each IEQ dimension (e.g., 52%

[8] Since occupants in private offices are usually higher in the organizational hierarchy, the higher levels of satisfaction in private offices versus cubicles are not necessarily only due to differences in physical environment.

satisfied with temperature in 28 private office buildings, vs. 39% satisfied in 17 government office buildings). Selection bias may play a role in this difference (in that private offices buildings with comfort problems may be less likely to do a survey), but the comparison still suggests that some categories of buildings can perform considerably better than others. Still, recognizing that satisfaction is contextual, evidence suggests that LEED buildings do not necessarily provide higher levels of occupant satisfaction that non-LEED buildings (Altomonte & Shiavon 2013).

Thermal Comfort

The California Commercial End-Use Survey (CEUS) estimates that 28.5% of electricity use and 37.9% of natural gas use in California commercial buildings are used for heating, cooling, and ventilation.[9] An IFMA survey of facility professionals found that complaints of being either too hot or too cold were by far the most common complaints heard (IFMA 2009), echoed in our interviews and case studies as a dominant pull on operators' time and attention.

For our research, one of the most relevant findings in the vast thermal comfort literature is that people have widely varying preferences for the thermal conditions that they find comfortable, depending on physiology, level and type activity, clothing, culture, expectations, and so on, as discussed in both the engineering and sociology literature. Given this variability, on top of non-uniform thermal conditions within a building and complex technical systems (e.g., simultaneous heating and cooling), one of the big challenges in operating buildings is figuring out how to manage this combination of building and people, including coming to better terms with the degree to which service paradigms and HVAC design can align.

ASHRAE Standard 55 specifies that 80% of occupants in a building should find thermal conditions acceptable. Previous analysis of the CBE survey data found that only 11% of surveyed buildings had temperature satisfaction at this level (Abbaszadeh et al. 2006). We found similar results for California alone, with 15% of buildings having 80% of respondents rating temperature satisfaction as "satisfied" or "neutral." New buildings (1995 or later) did not perform much better than older ones. In short, in many buildings, it may be difficult to please most people most of the time from the perspective of this ASHRAE standard.

The occupant satisfaction survey asks respondents who report that they are dissatisfied with temperature whether the problem is that they are often too hot or often too cold, by season. Table 4 summarizes these results for all respondents. Of the 34% of respondents who reported that they were dissatisfied, being too cold in the summer (54%) was reported as the problem almost as often as being too hot in the summer (55%). So according to these survey responses, too much air conditioning ("coolth") appears to be as big a comfort problem as too little. In retail spaces, air conditioning is not just about thermal comfort but also a signal of quality or control (Cooper 1998, Kempton et al. 1992, Salkin 2005). The desire to not be judged miserly may nudge up AC levels in offices as well.

[9] Source is CA_COMM.xls (http://capabilities.itron.com/ceusweb/). Data are from 2002.

Table 4. Nature of temperature dissatisfaction by season[10]

	Often too cold	Often too hot
Summer	54%	55%
Winter	76%	32%

What about Actual Temperatures?

Few studies report measured conditions in commercial buildings (Bennett et al. 2012), which speaks to a gap in understanding of the physical conditions that buildings actually provide, as opposed to what codes require or design predicts. One field study of ventilation rates and HVAC systems in 37 small and medium commercial buildings in California compared measurements to ASHRAE standards. Half did not meet the ASHRAE ventilation standards based on designed default occupancy.[11] Title 24 codes did not appear to be enforced, and overall ventilation control was poor. Across all buildings, the study found that temperatures were outside the established comfort zone 39% of the time in winter (14% too high, 25% too low) and 41% of the time in summer (32% too low, and 9% too high), suggesting not only discomfort but substantial energy waste. The high proportion of too-low summer temperatures found in this study syncs well with the occupant satisfaction survey results analyzed above.

Interpretation and Implications

Indoor environments of commercial buildings are largely shaped by energy use, and in turn energy use is affected by occupant and operator assessments of the indoor environment and resulting actions. Occupants and operators act in response to what others say and do, resulting in deviations from design values in new buildings, which are sometimes optimistic in terms of what they imagine future inhabitants will accept (Lenoir et al. 2011). Buildings often do not work as planned (Brown & Arens 2012, Ihnen et al. 2012, Menezes et al. 2012), but they are for people (Janda 2011), and people will adjust buildings to better suit their needs (Aune et al. 2009, Berker 2011).

Occupant demands are often assumed to drive unnecessarily high energy use in buildings. One of our policymaker interviewees noted, for example, that he had seen countless presentations where "occupant behavior" was offered as the reason that a building did not perform as well as designed. Yet as outlined above, occupants overall have low satisfaction with temperature, air quality, and other aspects of the indoor environment. Their complaints are not necessarily a request for higher levels of energy services. Given a goal of reducing energy consumption, to what degree can better coordinating these two sides of the building energy equation – the energy services that occupants want and what buildings provide – can lead to lower energy use? How misleading are complaints in terms of representing occupant needs and preferences? Or might buildings, as currently designed and built, often not be capable of doing much better (Levin 2003)?

[10] Respondents could indicate both "often too hot" and "often too cold," so the cells can add up to more than 100% across rows.

[11] Since designed occupancy was usually lower than actual occupancy, in practice, only 18% did not meet per-person ventilation standards.

Energy efficiency and sustainability concerns are now driving major changes in how buildings are constructed. The unpredictability of performance of new configurations makes it doubly important to test how well technologies are working in terms of energy use and user evaluations, both because buildings are for people (Cole et al. 2010, Janda 2011, Levin & Phillips 2013) and because designs that do not fit may not save energy at all. Building operators stand in a position to negotiate these two sides, energy use and occupant satisfaction. Energy conservation is unlikely to be of highest priority in running a building, but the promise of a better indoor environment as a result of more attention to perfecting building design and operation could deliver both energy savings and better occupant well-being in current and future buildings. Both of these largely invisible conditions, energy use and occupant well-being, need to be better seen in order to achieve this. Improving this visibility can help actual building and technology performance gain better footing with the representations of performance offered in planning, policy, and design models (e.g., building simulation models) and with aesthetic considerations.

Chapter 5: Case Studies and Interview Results

This chapter centers on the case study component of the research, drawing also from the workshop, building operator and other expert interviews, and occupant satisfaction survey data analysis. Every building, organization, and operator is different. Our selective sample notwithstanding, we highlight some of this variety as well as basic commonalities. All four of our case study buildings are relatively high-performing, judged in terms of their status on energy and sustainability benchmarks (LEED, Energy Star) and from the occupant satisfaction survey data collected. By talking to operators and others involved in these relatively high-performing buildings, and drawing on their experience with other lower-performing buildings, we learned about successful strategies that they had employed, and difficulties overcome and that remain.

For each building, data collection began with an occupant survey or interviews, based on the CBE occupant satisfaction survey. In three of the four cases, the instrument was customized for our research, probing energy use, energy conservation, managing discomfort, the complaint process, and what occupants liked best or least about the building. In one case with a large O&M crew, we also administered an O&M survey based on a CBE instrument customized for our research. We analyzed the survey data and then conducted on-site interviews with building operators as well as other members of the design, facilities, and management crews. In addition we inspected available documentation on building design and systems.

In the interviews, we asked building operators how they defined a good building, a good occupant, and good operations. Table 5 presents the results for the four case study buildings. The dominance of complaints in defining "good" and the importance of respectful and understanding occupants who appreciate the team and building are made very clear. These went hand in hand, yet in different ways in each building.

Case I: Large Owner-Occupied Office

This is a large (over 400,000 square feet) LEED-certified tower occupied by a single tenant, all state employees, and an outsourced building operations crew and relatively centralized operational decisions. There was a strong orientation to customer service, and two formalized complaint/management systems, one for specific work orders and the other for anonymous suggestions and complaints. The importance of managing complaints was especially striking in the response to the interview question: "What is good operations?" Complaints could clearly pose a threat to the reputation of the building and by implication facilities management and operations crews.

The crew described themselves as "always thinking about energy" and tweaking things to save energy, including, for example, checking weather reports and modifying the BMS settings on how many boilers to turn on, based on early morning assessment of the weather report and local understanding of the weather.

Occupant satisfaction for this building was high relative to others offices in the CBE occupant satisfaction survey data base on all components but speech privacy. This was likely in good part due to substantial post-move-in effort on the part of the crews to get the building to work well from both occupants and operations perspectives. Still, 39% of respondents said that they were less than satisfied with workspace temperature and 66% said that they were dissatisfied with speech privacy. The office used on open-space plan, in part to allow for daylighting, but this also often leads to acoustic penalties (GSA 2012). Asked what features they liked best about the building, the availability of a nice, usable outdoor area was the top answer, followed by the in-building cafeteria, windows, kitchen spaces, and a gym with showers. These results underscore the importance of well-liked and well-functioning amenities for occupant's enjoyment of a building, in general possibly compensating for shortcomings in physical conditions.

Case II: Medium Local Government

This isa LEED-certified building, originally constructed in the first half of the 20th century and renovated in the 2000s. A small operations crew serves several dozen buildings. Complaints were again a dominant issue for the crew, but in a different way than for Case I. This operator focused on maintaining the system and following the design team's intent and guidelines closely. The operator welcomes additional training on BMS in order to use the system to its fullest, but had received very little instruction. Post-renovation, senior management "owned" energy conservation and enforced policies (e.g. no space heaters). After the lead staff member's departure, energy conservation (to the extent that it was a priority) became more dispersed and was taken up by different departments in relatively uncoordinated ways. Though the operator was attentive to occupants, there seemed to be a higher level frankness in managing occupant expectations than we saw in other buildings, with occupants seeming to have learned that the building was not intended to provide customized comfort.

Case III: Large State Office

In this building, organizational matters such as split incentives on utility bills, a long procurement process, and distributed management structure, had a major effect on the types and speed at which operational decisions could be made. The chief building engineer was conscientious about his buildings, but without utility bill information he was not as informed as he wanted to be on how well the building was performing. He is one of few interviewees who is fully satisfied with his BMS, in part because he is able to program it himself and not rely on a vendor. As shown in the table, a good occupant was defined as somebody who had reasonable expectations of the building and who could even contribute to better management, consistent with the fact (as noted by some interviewees) that building occupants are state employees with a concomitant recognition as public servants.

Case IV: Medium Multi-Tenant Mixed Commercial

Building IV is an unusual configuration, as a long and low building that is only two stories, but over 200,000 square feet. It is also an adaptive reuse project, built originally in the 1930s and converted several times over its history. Its current manifestation, with the original 28-foot ceilings as well as clerestory windows, make for a dramatic workplace and have likely helped attract the high profile clients the building contains. This building too is a high-performer and has received several awards.

The building uses over 100 package roof units as its HVAC system. This approach has both challenges and benefits. One of the challenges is that there are hundreds of roof penetrations that need constant attention. One of the many benefits is that HVAC operation is very customizable. Unlike many of the other buildings studied for this project, the operator here had the freedom to turn off any and all areas that didn't need heating or cooling in real-time. Another benefit to the HVAC system was that a single broken unit was relatively inexpensive to replace in comparison to a single large unit. Additionally, when the units broke down, only a small portion of the building was impacted, rather than a large section of the building.

Each tenant paid their own energy bill. In fact, during our study, the building's largest tenant was conducting an HVAC controls retrofit for their space. On the other hand, shifting energy efficiency concerns to tenants largely severed the operator's energy efficiency efforts. When asked whether he tracked energy, the operator presented hand-written energy usage logs. This however, was the extent of his agency in the area. His role then became system maintenance, contracting and a limited amount of complaint handling.

Customer service was a dominant theme in this building, and reducing energy consumption was not at issue except to the extent that it affected attracting and satisfying tenants. This building had a single-building operator who was very attentive on setting things up to satisfy tenants and occupants, and for relatively easy maintenance, and then focused on this maintenance. The building operator cited having a "ghost crew" rather than a set of employees to manage as being a big plus for this job.

CBE's occupant satisfaction survey was implemented for the largest tenant in the building. More than half of the 200 respondents surveyed reported that they were satisfied with their space's cleanliness, lighting, air quality, furnishings and layout. Less than half were satisfied with acoustics and temperature. Noise and distraction from people talking nearby was a particular problem. In terms of temperature, occupants were often too cold in the summers and did not have access to controls to fix this problem. Complaints like these would normally be ferreted by a tenant-level facilities manager or designee. The complaint would then be entered into an online work order management system. The operator would pick up the work orders from this system rather than interact with tenants directly. Face-to-face interaction between the tenants and the operator was discouraged.

Table 5. Case study crew answers to "What is a good building? Occupant? Operations?"

What is a good ….?	I. Large Owner-Occupied Office	II. Medium Local Government	III. Large State Office	IV. Medium Multi-Tenant Mixed Commercial
Building	"A good building has no complaints"	"A good building does what it was designed to do. It maintains a good air quality, good temperature for people to do what they need to do without worrying about being too hot or too cold, and has components that won't break too often."	"A good building has creature comforts, uses energy wisely, good space planning, nice landscape, accessible and safe. It is as efficient as possible. It has occupancy sensors that turn on lights as you walk through."	"The best building is one that doesn't have a crew."
Occupant	"A good occupant is one who treats the building as if they pay the energy bill"	"Good occupants are people who understand how systems work. They are aware of the people around them and if they want the lights dimmer they know that affects their neighbor. I don't want to say, 'somebody who doesn't call me all the time.'"	"Good occupants have good manners, are respectful to janitors and don't complain too much. They are aware of all the systems (lighting, heating/cooling, etc.) within a building. A good occupant is someone who can understand limitations and even come up with new ideas."	"Somebody who doesn't call me all the time after I do initial set up. Fun tenants who appreciate what I do."
Operations	"We try to act as guardians of the building. We do not want the building to get the reputation of being a 'bad building', which is very hard to shake."	"Running the building to meet design. A good operation is less hands-on; if the system works on its own, if it doesn't require too much on our part from a personnel perspective. If it can calculate temps or need to ramp up motors or ramp down depending upon the need."	"Good operations is service-oriented and has maintenance prevention. Engineering staff have a good understanding of mechanics, fire, lighting, and run these efficiently and coordinated with BMS."	"Fixed 8-hour schedule, which is what I have. Building that is in good shape, that doesn't have many problems; files in order; workbench clean and well-organized. "

Operators' Perspectives

The rest of this chapter organizes what we heard and deduced on operators' perspectives and actions related to energy, organized by category: complaints, consequences of complaints, energy conservation, relationships with occupants and management, and technology performance. We also discuss building operations as a job, and give a brief summary of occupants' perspectives based on survey data and interviews. We draw in results from other studies when especially relevant, without intending a literature review.

COMPLAINTS AND OTHER DUTIES

- Both operators and others often described the operator's job as "fire-fighting"
- Dealing with complaints is a major draw on operators' time, effort, and attention
- Complaints that persist can be threatening to the operator's or building's reputation, or at a minimum constitute a time burden and an annoyance
- Dealing with complaints does not necessarily mean changing anything; "just showing up seems to help."
- Operators pitch explanations to help manage occupant expectations and actions
- Operators provide energy services as well as customer service
- Occupant complaints may often be considered idiosyncratic rather than indicative of a real problem, especially if control systems don't show any problem.
- Nobody wants to encourage occupants to feel too much at home
- Operators value being appreciated by occupants and tenants

Operators often described their jobs as being dominated by "putting out fires." This firefighting metaphor has a mild heroic aspect, but also implies a focus on the short-term and urgent. One facilities manager we interviewed summarized building operator duties as being dominated by work orders, complaints, and building rounds, noting that operators are trained to be conservative. This leads to risk-aversion and a lack of time, space, leeway, and attention that can be devoted to analysis, problem diagnosis, voluntary projects, or occupant education – let alone the fact that an operator or a team might possess only some of the skills required to do these tasks, and/or be discouraged or disallowed from doing them. One interviewee said:

> *Building operators respond to occupants always in reactive mode, and that is dictated by their need to solve problems as needed. They don't need to fix problems until broken, and you don't know that equipment is broken until occupants tell you. To do more than that requires teams that are managed tightly.*

If lack of pro-activity is a problem, then it has many contributing factors. Among those we heard: low staffing levels, increased automation of buildings, limited training, discontinuities in handover, lack of maintenance funds, low potential rewards for taking action, organizational boundaries, and the costs of coordinating across multiple parties and departments. Some of these factors are explored further below.

For each case study building, the importance of successfully dealing with complaints was very clear, as outlined in Table 5. How this was done differed from building to building. In the two buildings with out-sourced management teams, there was a great deal of attention to customer service in a rather corporate style. Occupants, tenants, and their organizations were clients. This does not mean doing everything that occupants asked, but it did invite specific kinds of accountability. In Case I, an owner-occupied building with outsourced management, the operations team sometimes responded to temperature complaints by using a portable electronic data logger to show whether the temperature was in range and to demonstrate responsiveness.

The property manager for the multi-tenant mixed commercial building (Case IV) stressed the importance of positive social interactions: every interaction with a tenant should produce "warm fuzzies." The purpose of the building, she said, was to make money. Energy conservation was important largely insofar as it was apparent to tenants and they did not think that their bills (which tenants themselves paid) were too high. For example, the property manager highly recommended window film since it is visible and serves its purpose in an obvious way. The building operator in this building described being very attentive to adjusting settings to occupant needs, which was made more achievable by the granularity of the technical systems in that building. He said that he responded to everything based on individual preferences and requests, noting that even if the temperature reading is in-range, the discomfort is still real:

> *It's not, it's 72[°F], you're okay. There are lots of individual differences, depending on where the thermostat is, and conditions other than temperature, like ducts, clothing, and so on.*

The occupant satisfaction survey for this building still indicated that less than half of occupants were satisfied with temperature. The challenges in dealing with this diversity in needs and conditions are both technical and social: "You've got to have the skills of Solomon," the operator said. These adjustments done, he avoided unnecessary contact with tenants.

One operator who worked in a high-tech educational building said:

> *Most of my decisions are to accommodate [occupants]. "If an occupant says, I need this to change: I do it. I don't balance that request with energy use. Maybe this is wrong. If they say it's too hot, I lower it to 70[°F] or if too cold, I increase it to 74.*

In the local government building (Case II), the approach to complaints was quite different. Here the operator deferred to design settings and to the expertise they represented.

> *If a thermal complaint is called in, we look at the BMS. If we see everything is green, then it's okay.*

The occupants we interviewed in this building seemed to keep their expectations in check. The operator was still attentive to complaints, but described his interactions in a different way than the cases above:

> *Just showing up seems to help. Often we don't fix problems because there is no problem.*

It was clear that occupant complaints often tried operations and facilities staff's patience – when the complainer persists, when the complaint seems too extravagant, invalid or trivial, or when it seems out of purview, such as odors or noise. Complaints are sometimes interpreted as a personal issue, rather than as a problem with the building. We heard several anecdotes about "other buildings, other operators" where occupants complained about building situations that had gone very awry, but the underlying problem went undiagnosed. That is, in some cases the first and even continued reaction to complaints is to manage the complainer, not necessarily determine the root of the problem.

Many of the large buildings we covered had complaint and work order management systems, but there was rarely any formal analysis of complaints (Goins & Moezzi 2013). In some cases, informal rules (e.g., wait until at least five people complain) were used to judge the legitimacy of the complaints or at least the need to react to them.

CONSEQUENCES OF COMPLAINTS

- Complaints may lead to changes in operations and increases in energy use, but it is not clear how much
- Not just complaints, but also pressures from management and others to avoid anticipated complaints, may have a major influence in increasing energy services provision
- Operations guidelines are not necessarily followed and/or they are tweaked in the name of complaints or compensate for other problems

The assumption that occupant demands generally drive energy consumption higher seems to be a near-consensus opinion in the buildings energy field. This is probably true but the process is surely more complicated than just over-demanding occupants, and the whole framing raises the question, "higher than what?." i.e., which assumptions about proper use should be privileged. Thermal complaints are a double- or triple-outlier problem, in that only some people complain and others do not – whether they do not want to be "a complainer," because it does not occur to them, or because complaining seems futile. Plus, thermal preferences vary depending upon the person, activity, etc., and conditions can vary a great deal throughout a building. Building operators obviously take these variations into account when deciding what to do, as discussed in the previous section, but "thermal votes" by complaint are not representative of the distribution of occupant experience of temperature. Similarly for lighting, service hours vs. occupancy, etc. Operators face a balancing problem but have only crude information on occupant experience, let alone limitations they face on the capabilities of the building systems.

Pressures for higher energy services do not only come from occupants. For example, one building operator said it was the express wish of the building owner to make sure that the building was fully ready for occupancy early Monday morning, which meant running HVAC at full capacity on Sunday, even if unoccupied. Combined with the engineering practice of designing for extreme days, and the non-nimbleness of buildings with respect to thermal conditions, it is not simply occupant demands, but also the importance that organizations place on avoiding complaints that shapes a basically energy-intensive operations style.

In two of our case studies, operators noted that they reduced the range of the proscribed deadband (e.g., to 73°F +/- 1.5°F rather than 70°F-75°F – about 23°C +/- 1°C rather than +/- 1.5°C) and/or changed the deadband based on seasonality, in order to keep occupants comfortable.[12] This was changed in the expectation that doing otherwise would cause too many complaints due to system drift. From an efficiency standpoint, the narrow deadband can have a substantial effect on energy consumption. Studies estimate about 10% savings of total HVAC use for each degree increase or degree in set-point at typical range (Hoyt et al. 2009, Pasut et al. 2013). In one case, two-thirds of the O&M survey respondents said that they considered the building to be operating efficiently, but a design engineer or commissioning agent would likely disagree.

In one interview, an energy manager on a university campus described how a directive to use a 10°F (6°C) deadband was abandoned, due to widespread operator protest. If temperature

[12] The temperature deadband in a building is the range of temperatures within which no action occurs. Temperatures below the minimum will trigger heating, and temperatures above the maximum will trigger cooling.

ranges that are more in line with adaptive comfort ranges are to be instituted, there may be a great deal resistance to be overcome stemming from the building operations point of view.. The Japanese Cool Biz (and Super Cool Biz and Warm Biz) campaigns, led by the Ministry of the Environment, targeted what we might call a "system of resistance" to expanded temperature ranges by addressing, at a national level, not only temperature range but also influencing what was considered normal office clothing (Shove et al. 2012).

Portable heaters are a classic solution to differences in thermal comfort preferences, interesting especially because they are in such common use and yet often officially disallowed or assumed to be disallowed. Fire safety is also a concern, but whether portable heaters deserve their reputation as being undesirable from an energy use standpoint is not necessarily established. Discussions in the project workshop and later in case studies and interviews yielded a number of stories about portable heaters. Many are snuck in, hidden, and usually accepted but not condoned, and operators did not seem to relish telling people that they could not have them or usually consider that kind of policing as part of their job. Having too many of them around sometimes seemed to be interpreted as an implicit critique of operations and the building. Low-power fire-safe portable heaters or other more sophisticated personalized comfort systems such as heated/cooled chairs (Zhang et al. 2012) might offer energy savings over adjustments to ambient temperature.

ENERGY CONSERVATION

- Operators manage energy services and pay attention to not wasting energy, but their definition of reduced waste is not necessarily aligned with what an outside efficiency expert might say
- Strategically reducing energy use may not often be considered part of an operator's job. LEED for Existing Buildings, however, does require attention to energy-efficient operations
- When it comes to a trading off customer service versus energy conservation, all respondents said that customer service wins, hands down, excepting only emergency power reduction requests. Innovative building operators with sufficient resources do not necessarily see a compromise between providing comfort and saving energy
- Many operators don't have much energy information, and may not even seen energy bills
- Even when operators had more detailed energy use data available via a BMS, it appeared to be used in quite limited ways, if at all
- Nobody "owns" energy. Different departments and teams may manage different aspects of energy use. Similarly, nobody "owns" indoor environmental quality.
- Energy savings from HVAC actions are difficult to predict and changes are risky with respect to complaints
- Among operators or managers who did pay close attention to energy use, energy costs rather than energy use (or sustainability and GHG emissions per se) mattered
- Where operators can see energy costs in a readily usable way, these costs may receive more attention, especially when there are social and organizational reasons to do so. For example, in some buildings, monthly meetings centered on energy bills were used as a basis for energy use discussions
- Energy conservation was a personal goal for some building operators, regardless of whether or not they were rewarded for it
- Building operators may often feel unrewarded for the jobs they do, and have more incentive not to initiate changes than to take on the effort and risk of trying to improve operations or reduce energy use
- Some operators and facilities staff suggested that financial incentives, such as salary bonuses, could be an effective way of recognizing and motivating innovation. Non-financial incentives can also be effective
- Several building operators said they wanted more information on energy efficient technologies and strategies as tested in real buildings, emphasizing the need for leaning about actual experiences on what works (or does not work) rather than marketing promises

Despite their role in managing a major proportion of building energy use, developing strategies for reducing energy use may rarely be a priority or even an official responsibility in building operator's jobs. Writing about experience in educating building operators, one researcher commented: "operators may not know about the variance (shortfall) in performance or even that they should be considered responsible for it" (Bobker et al. 2010).

Decisions about and control over energy are influenced by many parties. IT departments may manage lighting and dictate needs for server room cooling, facilities and building management may be split over several teams from different organizations, others make purchase decisions, the designer and BMS programmer have some control as embedded in the building and automation programs, while energy bills are silently paid by some other department. In two of the four case studies, the building operators interviewed made the problems of personnel clear (e.g., Case IV in Table 1, "the best building is one that doesn't have a crew").

Many of the building operators we talked to did not see energy bills regularly, or even at all. Other research has found similar results -- for example, in a sample of New York City building operators training for certification, fewer than half of building operators said that they saw energy bills regularly and very few said that they downloaded and trended BMS historical data for major equipment (Bobker et al. 2010).

In some buildings where energy efficiency was a priority, operators and facilities managers used energy bills as a focal point for strategizing, planning changes, identifying problems, and recognizing successes. One facilities manager implemented monthly meetings with building operators to discuss energy bills. Some suggested that personal financial incentives for saving energy would motivate building operators. We heard of no case where operators themselves were awarded bonuses, but a few cases where organizations were testing using energy consumption metrics as a key performance indicator. Non-financial rewards can work, as suggested in this story offered by a workshop participant (see also Diamond & du Pont 1988):

> *In New York City, the Housing Authority had a system to provide feedback to motivate their crews to lower fuel use in their buildings. Rudy Ocello from NYCHA explained: "We keep records of monthly fuel consumption and heating degree days. I monitor the fuel and the crews are allocated so much. Every month if they go over their target, they have to come in and talk to me. If they go under, they get an award seal. Some were able to get to 78% of their budget, others I had to talk to. After a while I stopped giving the seals, and they started calling me and saying, "Hey, where's our seal"? They would plaster the walls of their office with them. Feedback and motivation worked, but for some inexplicable reason, they stopped giving the seals.*

The motivation for saving energy need not come from upper management. One energy manager who used to work as a building manager stressed the importance of documenting energy savings in a way that was visible to management:

> *I had a mentor who told me a trick. He said that you make or break the energy bills, but nobody knows that and they don't pay attention. But if you can make changes, create savings, and document it all, you'll be a hero and you'll always be employed.*

In some buildings, the organizational culture is such that efforts won't be appreciated or rewarded. One building operator related his experience in a previous job, where he initiated and continued efforts to reduce energy use despite what appeared to be the tenant's almost purposeful lack of attention to energy use:

> *I was knocking them dead with energy and cost savings, but money was not an issue with them, and the green trend didn't matter. I did it because I care.*

In other buildings, careful day-to-day energy management is routine, as one of the building operators in Case I (Large Owner-Occupied Office) described:

> *We all take pride in monitoring energy use and look at the system many times per day to see if there is load we can drop. It's like driving a big ship. You don't know how it works unless you are monitoring it. We have scheduled rounds, reading meters on the hot water, water, and gas meters, and are always trying to come up with ways of saving energy.*

In cases where energy bills or investment costs were at issue, energy costs, rather than energy use or greenhouse gas emissions, were clearly what mattered, as also found in an earlier study (Levin & Wasserman 1985). So dollars may be the most useful way to communicate about energy use and potential savings from operational changes.

For GHG emissions reductions, this makes for an important disconnect, since in commercial tariffs, electricity use may scale very non-linearly with costs. Because of the demand charge component of commercial energy bills, a high proportion of a premise's electricity bill (one building operator estimated 40%) is pegged to the 15-minute peak demand period, rather than the other 43,000 15-minute periods of usage in a month. Our evidence suggested that operators may often be unaware of this demand charge, but where they were, the peak demand charge commanded a lot of attention.[13] On the one hand, as one operator noted, at least in some cases the peak demand charge was effective in directing attention to energy use, since shaving that peak could have a big effect on energy bills. On the other, the form of the tariff itself may not serve the goal of GHG emissions reduction well.

In planning energy conservation, building operators negotiate between customer service and the potential for complaints on the one hand versus potential for energy savings. This accommodation was clearest in buildings with out-sourced operations teams and in leased buildings, where operating temperature ranges are usually specified in the contract. Getting services to run without disruption, good maintenance, and perhaps even keeping operations invisible count. One building operations chief engineer with several decades of experience, operating a Class A building, commented:

> *Tenants don't care about energy costs. They want comfort. We can't compromise. Our hot/cold calls have diminished by sticking to our knitting.*

According this engineer, it was possible to reduce hot/cold calls while reducing energy use by getting equipment to operate efficiently, not by compromising comfort. Tenants in this building, he explained, bill staff out at $500/hour, wherein energy costs are insignificant even to the extent they can be seen. This explanation bypasses the "classic suspects" of technology or energy costs alone as levers to reducing energy use. Rather, attentive operations and maintenance mattered.

Several operators mentioned that they preferred adjusting lighting rather than HVAC levels as a conservation measure. The effect of service reductions for lighting are immediately visible, and savings are easy to calculate. Modest reductions in lighting service levels can yield

[13] Not all buildings face a demand charge, e.g., a campus building may rely on a central plant.

considerable energy savings but be barely noticeable to occupants, they explained. Savings from HVAC are more difficult to predict and complaints take longer to surface and rectify. One building operator commented that sometimes occupants think that when they feel there is too much air conditioning, energy is being wasted, but that this is not necessarily so. The complexity of commercial buildings is sometimes overlooked in policies directed to energy conservation. One building scientist related:

> *The Governor passed an Executive Order on temperature set points. It didn't work because it didn't put things in perspective or understand how buildings need to be operated. For example a large office building in California was in cooling mode in the interior about 360 days out of the year. The building operators followed the executive order, but that led to extra energy use, since it meant that the building interior was being cooled even more than it would have been otherwise.*

In 2009, a U.S. Department of Energy (DOE) Inspector General report found that HVAC setbacks to reduce heating and cooling during non-working hours were not used in 64% (35 out of 55) of the facilities tested (US DOE 2009). The facilities tested included both leased and owned buildings. In 20 of the buildings, setbacks were in place or deployable, but were not deployed. In 15 others, equipment had not been enabled or no longer worked, so that setbacks were not possible. Using conservative assumptions (15% savings of the 40% of energy use attributable to HVAC), setbacks would save 6% of total energy use in buildings. Despite DOE's leadership role in energy management, these apparently simple steps were not taken, whether because the systems that had been in place had been overridden or otherwise disintegrated, or because it had never been set up. So there is something organizationally that is actually not so simple about these steps.

Optimizing operating schedules and tuning start/stop strategies and temperature set-up/setback are well-known methods for reducing energy use (PECI 1999), yet reviewing these schedules regularly does not seem to be standard practice. Some building operators described success in shaving off full service hours by delaying start up and coasting at the end of the work day, but as something to test gradually to avoid complaints or big problems. There appears to usually be little impetus to undertake such tests. In few cases, accidental service disruptions lead to the discovery that reduced hours of service – and even a complete "off" during the swing season -- did not lead to any occupant complaints. Other interviews indicated that extended and/or global business hours had stretched building service hours longer. This dispersed occupancy, together with the limited ability of most buildings to provide locally specific conditions as much as desired (i.e., zoning and control), challenges current design and operations paradigms.

Some buildings had tested daytime janitorial services, with the intent of reducing lighting costs for post work-day hours, but did not always adopt them permanently. Occupant complaints about noise and disruption were clear considerations here, as we saw in reviewing survey responses as well. Some janitorial services specialize in daytime cleaning, where staff use quiet backpack vacuum cleaners and are trained to minimize disturbing occupants.

Technology performance is about more than energy and cost savings. No technology or strategy is identical to the one that is replaces, and the differences create risks of potential problems, whether stemming from the qualities of the services provided, the type of efforts required, or things going wrong. One operator managing a building in the high-tech sector noted: .

> *Tenants are looking for comfortable spaces that meet their working needs. That is always number one. You can make energy improvements but they need to be in line with their lighting, temperature, and glare needs. When you're operating a space, you need to react quickly and control damage.*

Change Management

One facilities manager with a high level of experience in strategizing about and implementing energy efficiency improvements emphasized the importance of a careful strategy for social management of technical changes in buildings.

> *Anything you do that's visible to others gets a reaction and often a complaint from others. I try to do the things that aren't visible because then you have the opportunity to tweak results before occupants know of the change.*

It is not only the resistance from occupants that has to be overcome, he noted, but also often resistance from other staff in the building organization. Building operators and facilities managers should "hang tough" with changes, and not cave in because of a few occupant complaints:

> *If you do something that affects 3000 people you might get five complaints, but you have to stand your ground. You can't let five people dictate things.*

A building operator commented that when changes were visible, it was sometimes important to talk people through it:

> *If is something obvious, you need to talk to people directly and have a physical presence with them, because so much of the issue/complaint is in their head.*

Operations teams are often stretched thin, complaints are potentially damaging, and rewards for improving energy use or building performance may be nebulous, all of which can impede experimentation. With practice, teams can develop strategies to manage these difficulties, opening opportunities for further improvements. For example, demonstrating past successes in terms of performance and energy savings can help get buy-in from other staff in the organization

Recommendations for Policy

We asked many of the building operators, facilities staff, and researchers we interviewed for their recommendations on policies that would boost the ability of building operators to improve energy use in the buildings they work in. The overall message was clear: make things easier for building operators to contribute. Building operations and facilities management are often short-staffed and risk-averse. This creates barriers to learning about and incorporating new strategies or technologies, both administratively and technically. The remainder of this section outlines some of the specific suggestions made by interviewees.

<u>Create and publicize case studies</u>

Even building operators in buildings with the highest attention to energy use called out a need for better information on real experience with energy efficient technologies. For example:

> *The industry is evolving fast. We don't know who to turn to for advice to test or vetting systems. Publish case studies on what works. Typically we want to see a technology that has a track record. We don't want to test the latest and greatest. How do we assure that what is reported will do what they say it will? We don't have that much insight in the market so we need some assurances.*
>
> *We try to stay on the cutting edge, not the bleeding edge.*

Greater availability of credible case studies could reduce the perceived risk of uptake of new technologies. In speaking about energy conservation, interviewees sometimes mentioned that they had already done everything they could. Better sharing of interesting ideas, and of experiences with technologies and strategies as applied in real-world contexts, could help overcome this inertia. These need not be only about purchasing technology, but also cover commissioning and operating systems, managing personnel or tenants, etc. Otherwise energy costs may be seen as fixed, and experimentation not worth the effort.

Doing so could help improve the likelihood that technology investments worked well, and reduce the time and effort that building operations and facilities staff need to invest in figuring out what opportunities were available. This could be especially helpful in cases where teams are short-staffed or have little buy-in from the board room or elsewhere in the organization.

Along similar lines, facility manager noted that vendors can be reluctant to recommend new technologies, and may wait until an organization has proven its ability to handle new technologies before offering them.

> *Now that we have the reputation of being green, vendors come forward with their super-efficient solution knowing that they're interested in that. Before that, vendors just offered the 70% efficient model. That approach, offering the 70% solution, is a way that vendors/contractors traditionally build trust: by appearing to add value by telling people what was "too much" for their needs. In this way vendors may talk down technologies that may actually be a more energy efficient or cost-effective choice than the option they recommend.*

Sharing experiences can help build this capacity. We also sensed that experimentation was often viewed as enjoyable and rewarding, though sometimes there were too many other problems (such as massive split incentives, unreliable or shoestring funding, staff cuts, or complete lack of appreciation) to get to that point.

Develop and maintain consistent and predictable energy policy

Some commented on energy policy in general, stressing the need to keep policies that worked well and making them easier to access:

> *There needs to be a consistent energy policy. Because they continue to change policy, people will always follow the direction of the money. It would be useful to look back at older energy policies that worked well. For example, there used to be incentives for thermal ice storage. This was a good idea because it reduces peak load.*

Improve ability to access rebates

Several interviews mentioned that rebates could be too difficult to access. This was particularly the case for organizations with limited staff and/or with low bridge funding. So provide tools and resources to support internal approval (within an organization) and facilitate easy completion of paperwork could help, as could better gap funding for cash-strapped organizations that are struggling to improve building performance. One large state organization mentioned that they faced many administrative restrictions and hurdles in accessing funding, for example, with approvals taking three years.

Expand benchmarking

While several interviewees praised Energy Star as being an important tool and motivator for reducing building energy use, only certain commercial buildings qualify for the program. One interview recommended expanding the types of buildings that qualify for Energy Star. Other sorts of benchmarking (e.g. California AB 531, discussed above) may be very useful in drawing attention to energy use.

More attention to non-star buildings

LEED and Energy Star buildings comprise only a few percent of the total building stock, one researcher interviewed noted, and not every building has the staff, resources, interest, or capability to be a star performer. A market transformation paradigm does not necessarily apply throughout the building stock, and more attention is needed toward figuring how to assist and help motivate these “other” buildings to reduce energy use and improve indoor occupant conditions.

Promote and recognize the importance of building operators to creating “green” buildings

Several interviewees called out a role for policy to help build the reputation of the building operator position, e.g., through supporting training, certification, and involvement in decisions about buildings. This recommendation is explored below in the Building Operator Job Skills and Outlook section below.

RELATIONSHIPS WITH OCCUPANTS AND OTHERS

- In communicating with occupants, operators actively shape occupant expectations and can impart information about using the building and its features
- Operators report that occupants typically comply with behavior change requests when they are made personally and provided along with explanations; social exchange and courtesy matter
- Face-to-face interactions also permit occupants to impart information about the building to operators, i.e., occupants are also "eyes and ears" on building performance (though not sensors)
- Operators often have a great deal of knowledge about building performance but may lack platforms to communicate this expertise to higher management and/or the status to influence them
- Operations and operators may be relatively invisible to occupants and organizational management, with movement through secret passageways and offices located behind unmarked doors
- Separation of operators and occupants is probably exacerbated by perceived status differentials, by the circumscription of the operator's roles, and the expectation that buildings are self-running
- Increasing the visibility of operations and other opportunities for exchanges with management and occupants can increase the salience of energy/resources use and increase the knowledge of building user

Building operators are sometimes considered "tinkerers," but in practice, operators often have to be masters of communications to be effective. Soft functions may be carried out with little formal training, guidance, even without the expectation of success. It is a part of the job that is often hidden from upper management and those outside the building operations milieu, but still a critical responsibility of building operators.

The building operators we spoke with described efforts to educate and influence occupants while handling occupant complaints and work orders. Operators used these face-to-face encounters to explain the reasons for requests (e.g., why a portable heater was not allowed) or to show how to use certain building features (e.g., user-adjustable vents). Operators admitted to sometimes bending the truth. For example, they sometimes cited rules and requirements as being imposed by others, e.g. "we can't increase the partition heights because of LEED requirements." Supplying a reason for action or inaction was seen as decreasing further complaints and/or increasing compliance while maintaining or building positive relationships.

These interactions between operators and occupants can be important in shaping occupant expectations about the building as well as educating them about how to best use building features. Besides this sort of coincidental interaction, there may be little outlet for discussing how well the building is working from an occupant's perspective or how to improve how well it works, whether through changes in occupant actions or in operations. Occupants sometimes get written information about building features and their proper use. While reference guides may be useful, is may take concerted effort to get these written communications right: they are one-way, difficult to customize to context, take initiative to read and engage with, and not necessarily distinguishable from all the other rules that employees face that may or may not be taken seriously. Writing about experiences with encouraging behavior-related energy savings in federal agencies, Malone et al. (2013) note that rules about sustainability that are disseminated only by email or mailbox inserts are unlikely to work.

Face-to-face or otherwise personalized operator-occupant interaction holds potential as an avenue to increasing occupant satisfaction with indoor environmental conditions, and maybe to decreasing energy use. However, in at least some of our case study buildings, that level of interaction may often be discouraged, in that transcends operation's technical silo or a customer service silo that is responsive rather than interactive, i.e. "the customer is always right." The second limitation here is that operations teams may be too short-staffed to support much of this kind of interaction. While increased levels of automation reduce the strict need for personnel on the ground, there is a cost in terms of operations team ability to coordinate and interact with occupants. In some buildings there is relatively little that an occupant can adjust. This was the case in one of our case study buildings (Case II) which had a small operations staff; the operations team's interactions with occupants were more to identify big problems or manage expectations than to drive changes.

Physically, building operations staff are often isolated from occupants, even to the extent of secret passageways and unmarked doors in hidden corners of the building. There are likely a few different rationales for this isolation, including a reticence to expose the crew to more requests, a perception that buildings are self-running, and possibly status differentials and concerns that operators do not have the communication skills or the proper status for full interactions with tenants and clients. There are downsides to this isolation. Building operators can be important educators about how to use the building and its features. However their interactions with occupants are often too limited to exploit this capacity much, or to get feedback or questions that may not be reported through official work orders or complaint systems. For occupants, buildings may be becoming increasingly opaque, with more and more unmarked controls, mysterious features, or automated decisions for which no override is available. This can also contribute to a sense of alienation (as opposed to engagement) with a building.

In discussing the use of daytime janitorial staff, some interviewees mentioned a side benefit, in that the interaction between occupants and the janitorial staff seemed to help humanize the janitorial staff in the eyes of the occupants. In turn this seemed to lead to more considerate behavior toward the crew. Something similar could take place if operations staff and operations were also more visible. Whole building energy use displays, e.g., energy usage feedback monitors posted in lobbies or on websites, may be useful in increasing the visibility of energy use but do not humanize operations.

The invisibility of operations also pertains to interactions with management:

> *Building maintenance is perceived as second class … and no one wants to know about it until there's a problem.*

Status, lack of appreciation, and lack of respect were also noted as barriers:

Operators often get the feeling that they aren't worth much from bosses.

As discussed above, in many buildings, energy use on its own is not considered a problem, even by the people who pay the bills. This may not change. However, there are bigger-ticket items – especially occupant satisfaction and well-being and maintenance costs – that operations staff can also speak to. One program developer described how formally recognizing a particular building operator for his special contributions to building sustainability encouraged the building operator to go even further.

It's important to compliment building operators and others. They can start to think of themselves as environmentalists; it becomes who they are. Awards [such as BOMA recognition] matter.

TECHNOLOGY PERFORMANCE AND LIMITATIONS

- Operators reported using BMS at different capacities, but it seemed clear that with complex BMS, capabilities are often unused
- Operators may receive very little training with a BMS when it is introduced in their building
- Some operators pointed out that building controls often mean fewer jobs for operators, and more jobs for controls engineers
- Industry hierarchies may impede usability critiques of building controls systems
- Other technical problems, such as bad systems, problems with serviceability, low granularity of technology (e.g., to fit part-occupancy or smaller loads), were also reported as leading to energy waste
- One operator said, "It takes 15 years for a new technology to work."
- Heroic, persistent efforts by building operators could sometimes make or break the performance of an advanced technology building
- Building maintenance can be a form of energy conservation too. In some cases (a set of government buildings in particular), lack of funds for maintenance and upgrades made attention to energy efficiency and even modest investments very difficult
- LEED certification and Energy Star benchmarking were clearly motivators for attention to energy use in many cases, but do not cover all situations or opportunities

Building Management Systems (BMS), also known as Building Automation Systems (BAS) are present in more than half of US buildings larger than 100,000 square feet.[14] BMS offer the possibility of reducing the degree of manual intervention required to operate a building and a means of increasing operational efficiency, potentially reducing energy use. However there are many questions about how well they work in practice (Granderson et al. 2011, Webster 2005).

We asked building operators who used a BMS (present in nearly all cases in our sample) about how they used their BMS. Everybody we talked to basically "liked" their BMS. It made their jobs easier, and reduced the need for (and hassles of) large crews. However detailed discussions also revealed that in a number of cases building operators felt limited in the extent to which they could use BMS capacities. For example, in Case II (medium government building), the operator reported closely following design guidelines, aiming to keep panel lights green, but said they received only about 15 minutes of training. Even basics such as programming schedule changes would require a contractor:

> *I like what we have, it's awesome, but on BMS, I wish it were more user-friendly. We have to call the service contractor back to do certain things. We can do basics, but were never taught to work with the system. The service contractor is trying to protect his job, understandably so. We know how to go into the system and see trouble areas, how to*

[14] According to Business Energy Advisor (http://bea.fpl.esource.com/BEA1/PA/PA_BuildingAutomationSystems/PA-36) accessed November 2013.

reset, but we can't change CFMs.[15] *We have to get the consultant to come in to program the changes we need.*

The operator hesitated to make changes, because he said lacked a sufficiently broad understanding of the system. Similarly for the lighting system, training was insufficient for learning out to program off lighting in one areas of the building. For Case I, the operations crew was more willing to override the BMS, but still reported having received very little training, again a short session soon after the system was installed and before the building was fully occupied.

More detailed studies of how BMS are used in practice have reported similar findings: BMS are used to manage operations and occupant complaints, but there is substantial mismatch between the capabilities of the BMS and operators' ability, time, and training to exploit these capabilities, compounded by lack of documentation for the system (Webster 2005, PECI 1999). The financial interests of the many players in the industry hierarchy for BMS deployment can also inhibit the degree to which systems meet their promises (Webster 2005).

Beyond the question of the degree to which BMS capabilities are fully used, the Stories Workshop surfaced another concern about disabling and overriding BMS setting, as narrated by a researcher:

Operators reduce the complexity of the BMS to their level of understanding. They'll often put things under manual control. This can lead to cascading inefficiencies. There used to be pneumatic controls that would work on their schedule: a room with HAND, OFF, AUTO (HOA) switch(es) – "motor control system." So back in the day, an outside observer could walk into that room and see how the building was being operated. Now, with all the automation, settings are more hidden, buried somewhere in the BMS. A lot of the deviations from programmed settings are a result of handling occupant complaints. Operators are really sensitive to these complaints and may change settings based on very few complaints. Then there are cascading problems. The BMS loses the ability to appropriately control at system level — and things usually don't get set back right. There are also elements of "man vs. machine" in wrestling for control and establishing legitimacy.

Other reports have also noted the prevalence of disabling and overriding (PECI 1999, Webster 2005). Our research was not designed to examine BMS use and usability in detail, but it did seem clear that more attention to BMS as used in real buildings is required.

In response to the problem of unused BMS capabilities, a usual proposal is that building operators need more education, training, and motivation. Improved training could surely be useful, but the problems are not necessarily of operator's knowledge and skills but also of more systematic limitations of BMS design and usability. Some BMS are relatively usable, some operators have the motivation, time, and mindset to learn to exploit BMS capabilities beyond the surface, and some organizations have the resources to hire programmers for complex needs, but in many cases the promises of the BMS did not appear to be fulfilled.

[15] CFM is ventilation rate, i.e., cubic feet per minute.

One major efficiency problem that the engineers in a large office building (Case I) pointed to was the inability to tailor energy use to parts of the building. In particular, if a particular group was working on Saturdays, they could not efficiently provide heating and cooling to just this group, but rather had to serve almost half of the floors. All designs may be compromise, but here and in a few other cases, building operators pointed to low granularity as leading to waste (see also Ihnen et al. 2012).

LEED certification was a clear motivator for many buildings. Interviewees noted that LEED (and Energy Star) called attention to sustainability, created value in the real estate market, and mobilized teams, at least for some types of buildings. It was clear that LEED certification could take a great deal of effort. We observed some tendencies to consider "LEED as enough." That is, once the building has been certified as having been designed with energy efficient systems, designs, and protocols, that little more need be done. This was clearest in one case study building (Case II) with a minimal crew, where as noted above, the building operator was explicit about deferring to original design parameters rather than modifying them, citing the fact that We cannot speak to the effects of this mode of operation in terms of building performance, which may change over the long term. What is interesting from the perspective of operations, however, is the extent to which LEED may symbolize, rather than necessarily lead to, particular levels of performance (Brown 2010).

BULDING OPERATOR JOB SKILLS AND OUTLOOK

- The Bureau of Labor Statistics foresees lower-than-average growth for building operator jobs, and outlines low educational requirements and on-the-job training for entry-level jobs (see Chapter 3)
- Building automation systems are changing rapidly, often with complex definitions of what they should do, but what building operators should know or do is under-defined
- Some interviewees stressed the importance of professionalizing building operations, toward improving the status of operators and helping other parties recognize the contribution of building operations to IEQ, sustainability, and building performance in general
- Professionalization could also increase operator knowledge and expertise on energy use
- Building operators could also contribute to the design process for new buildings. Their in-depth knowledge on system operations, manufacturers, schedules, controls, maintenance, and access to systems would also create more effective handoff from design to operations.
- Building operations has a potentially great fit with being viewed as a green job, if training and compensation develop to support this aspect

Among the building operators we asked, many had come into the profession accidentally, recruited for or attracted by a well-matching skill set. As to the question of what skills a building operator should have, that depends on the building, but often requires technical (including both mechanical and engineering aspects), administrative, and management skills, as well as good ability to deal with the non-routine. One building operator we spoke to called operating a building “an art, not a science.” Many of the operators we interviewed had a maritime background. One interviewee mentioned: “Ships and building are the same stuff, just the building doesn’t float.”

Despite increasingly elaborate specifications of what building systems and automation should do to create energy-efficient well-functioning buildings, “what building operators need to know remains under-defined” (Bobker et al. 2010). Practices and roles are often bundled with technologies; “practices emerge, persist, and disappear as links between their defining elements are made and broken” (Shove et al. 2012). In the case of BMS, one can ask what happens to building operations, or the roles (and lives) of building operators as a new technology, one that makes part promises to run the building correctly without human intervention, enters.

This raises an important question about expectations for future buildings, what they achieve, and how they do it. Researchers have pointed out that high-technology highly-instrument buildings may not work well out of the box, or even if well-commissioned, maintain that balance (Brown & Arens 2012, Ihnen et al. 2012). One building scientist we spoke to credited a building operator “working 24/7” to turn a state-of-the-art building from a potential disaster to a well-functioning building, in a way that an outside consultant could probably not have accomplished. Smart people, with sufficient leeway to effectively advise and act, are needed to manage smart technology, if this technology is to work.

Several interviewees discussed the importance of professionalizing the building operator position, moving it from being viewed as a technical trade for “tinkerers” to one that more fully recognizes the complexity (or potential complexity) of the position. While the amount of commercial floor space is growing (Chapter 4), if anything, we heard of attrition in workforce, with previously large crews dwindling to only a few operators for several dozen buildings. Education, certificates, and other means of promoting the importance of building operators can help here, even beyond any knowledge gains. This is not just a matter of training on technical matters, but also of building a wider recognition and appreciation of building operators as a bigger contributor to buildings that work well. One interviewee, an educator, recommended:

> *Professionalize the technicians and their role. You need to get boiler room people into the board room.*

The same interviewee commented that different communication styles sometimes impeded the degree to which building operators' insights could be adequately heard. Furthermore, this interviewee mentioned, the roles of experts working on building performance can be too siloed for the necessarily interconnected nature of the building systems. For example, an electrician called in for a problem may look only at the wiring, not the motor. In certain cases, union rules may limit what parts of the system an expert can intervene with.

California does not have a certificate program, and not all building operations curricula give good coverage of energy use. Making energy use and sustainability part of the operator job and recompensing the position accordingly, may "get people in and get them in action," one interviewee suggested. The career motivation is probably less saving a bit of energy on the margin, but rather getting buildings to work better and being rewarded for doing so. Professionalization and greening would likely require the collaboration of many actors, including partners in industry, trade organizations, educational institutions, and governments, but could inject real power for improving how buildings work exactly where needed: in the building.

Occupants' Perspectives

Conversations with building operators made it clear that a great deal of attention is devoted to managing occupant complaints. Toward assessing how well this complaint management is working, this research project collected or used occupant reports in three different ways: analysis of CBE's archived occupant satisfaction survey data, surveys and interviews with occupants in the case study buildings, and through stories collected for and in the workshop. The next section interprets this data in light of what we learned about operations.

The energy efficiency industry's attention to behavior in commercial buildings has focused almost entirely on occupant behavior, rather than on operator behavior. Most of this attention has been in the last ten years; otherwise "occupant behavior" has been about what people do in homes (Moezzi & Janda 2013). In recognizing occupants as active creators of commercial building energy use, building energy simulation studies have studied how to better model the variability of occupant behavior, such as under what conditions or with what stochastic pattern an occupant may open a window (e.g., Azar & Menassa 2012, Hoes et al. 2009). This is a big advance on previous work which largely modeled occupants as passive objects, e.g., generating heat, requiring certain building conditions, and acting in fairly regular ways. It does not go far in explaining "why" or in predicting what occupants will do, but it can help in understanding and planning for uncertainty including potentially design that is more risk-conscious with respect to behavior. The second major topic on behavior in buildings has been on methods to get occupants to change their behavior, as a source of behavioral energy savings in buildings or a key to achieving zero net energy performance or meeting other energy use benchmarks. Results are mixed (Malone et al. 2013, Shui 2012, Shove et al. 2012).

- In many buildings, occupants report low satisfaction with temperature, air quality, and other aspects of the indoor environment that are directly affected by operations (Chapter 4)
- Buildings with high levels of customer service to occupants often have higher levels of occupant satisfaction, but even in such cases, the percentage of occupants who say that they are satisfied with temperature in the building is rarely better than 60%. Satisfaction with acoustics is often far lower.(Chapter 4)
- Dissatisfied occupants often call out being too cold in the summer as a major cause of their dissatisfaction with temperature. (Chapter 4)
- Representations of occupant needs and demands, in addition to (and sometimes more so than) what occupants themselves say or do, shape energy service levels
- Complaints are unlikely to be a representative indicator of occupant experience; the nuances of complaint response ("squeakiest/biggest wheel gets the grease") adds another layer of distance
- Occupants learn what to expect in a building through experience, including interactions with buildings staff
- Occupants adapt to and cope with building shortcomings, sometimes in ways that are discouraged or officially disallowed

- They often receive little education about how the building is supposed to work or how to use various components, and/or the education that they receive may often not be absorbed or otherwise useful
- Satisfaction with workspace and buildings is not just about the indoor environment; social exchanges and reciprocity matter

We want to begin with a sympathetic view of occupants. Most presumably value "comfort, cleanliness, and convenience" (Shove 2003) as well as control and perhaps most importantly, an environment where they feel they can work productively. But many people work in buildings that make them want to flee (Leaman 2009). Occupants cope and adapt to the physical conditions of the workplace (Heerwagen & Diamond 1992) via clothing adjustments, portable heaters, opening windows, disabling power management, etc. Many may hesitate or avoid intervening in communally-managed components of the building, such as adjusting shades or lighting levels. In Case IV, the original building had operable windows which were sealed during renovation. Some liked this, others did not, but one noted relief is that it had eliminated arguments about whether the window should be open or not. This comment underscores the fact that a building is a communal environment. Opening or not opening windows, being present, complaining or not complaining, etc., are social actions with social implications, as well as environmental ones.

Occupant actions go beyond adjusting the official controls in proscribed ways. They modify and overcome stuff that they do not like. In some of the case study buildings, we saw examples of hand-made cardboard glare blockers, vent baffles, and other similarly ingenious or simple responses to design elements that "don't work" or un-vetted operational decisions. In a vignette collected for the workshop, one building occupant wrote:

> *Most employees are in tiny cubicles, like 8 feet square. One cube neighbor who sits about three feet away wears his jacket all morning because a vent blasts him with cold air. It switches off at 2 p.m. Then my vent starts blasting, so I have to put on my coat. Another nearby occupant in an enclosed office has wildly varying temperatures every day. Her desk is positioned so that the right side of it is parallel to the window. She has to wear a mitten on that hand, and has to endure endless teasing about it. When we first moved into this building we did complain about the temperatures, but were always told that that when they were hot, someone on the other side of the building was cold, and so nothing could be changed. The compromise seems to be that we are all uncomfortable, all the time.*

As shown in the aggregate analysis of occupant IEQ satisfaction data, occupant satisfaction with temperature and with other aspects of the indoor environment are low overall, and still not very good in the best-performing buildings. To most accounts, occupant complaints or the threat of complaints may push levels of energy services to higher levels and longer hours. The provision of these services is imprecise relative to what occupants want or at least will tolerate. Despite the high salience of complaints to building operations, occupants may often remain silent about the problems they encounter. In one case study building (Case I), the organization had implemented two systems for occupant requests and feedback on the building. One was a routine work order/complaint system. The second was an anonymous suggestion/feedback system to organizational management. The anonymous system was quite popular. Occupants submitted comments on odors, ideas for improvements, or parts of the building that were not working correctly, but did not to want their name attached.

Complaints and the risk of complaints are major forces in shaping energy services, their levels, and their schedules. Rather than seeing this as a matter of occupants per se driving the need for energy services, it may be more useful to see this as a matter of representations of occupant demands and needs. One story from the workshop helped illustrate this:

> *In the existing building [a research building in Southern California], there was no air conditioning. They polled occupants on whether they would prefer air conditioning or natural ventilation. Occupants said that they preferred natural ventilation, noting that they got free ice cream on hot days. But they put in air conditioning anyway.*

The idea that "occupants want air conditioning" was stronger than the occupants' vote.

Automation can also provide more services than wanted and with less control. Motion-sensed and other automated lighting systems impose when lights are on, and at what level. Occupants sometimes want less light (Chapter 4) but may be unable to do much about it, or doing something about it might be a hassle. Several interviewees spoke to the occupant/tenant politics of automatic lighting and a hesitation to use them too widely. There appears to be need for better fine-tuning of what automated systems do relative to what occupants want or will tolerate.

Education

Our evidence suggested that occupants are often not very educated about how to use building features. There may rarely be a person or department assigned to the role of an educator, which requires technical knowledge as well as good communications skills to do well. At the same time, what occupants do affects energy use and indoor environment for the building as a whole. Building simulation models specify elements as detailed as dirt on windows, ands, differences as small as not fully latching a window affect the envelope and interior temperature. Occupants are likely oblivious to this level of detail, not knowing, for example, that they have not "correctly" close the window. Building science recommendations on operation may be counterintuitive to what an occupant might expect based (Ackerly & Brager 2012). Even when controls are obvious, there may be little or no information on what they do and how they should be used (Pritoni et al. 2012).

One building energy researcher commented:

> *There's a simple solution to office discomfort: give occupants control by labeling manual switches. But a facility manager's response is typically NO; they put in automatic controls because they don't trust occupants and won't educate them on how to operate the building better.*

In some cases, facilities staff were frustrated that occupants did not read or absorb instructions about proper use as disseminated in e-mails or in user manuals. This does not mean that written information cannot be useful, but rather, that information on its own can have limited effect. Operators, as noted above, often said that they got positive results from face-to-face communications with occupants. In explaining how the building was supposed to work, occupants seem to come to a closer understanding of the operations point of view, even if it meant that the occupant's complaint could not be addressed by technical changes. At the least, these explanations may change occupant expectations of the building and thus the relevance of further complaints. More feet on the ground, whether through more building staff, well-trained peer "energy champions," or even building orientations for new employees, could be more useful than manuals. It also seems clear that compliance will be better if there is something in it for occupants rather than a top-down directive.

In several buildings, we heard of occupant engagement programs designed to encourage occupants to change energy use behaviors. Operators and energy managers were not necessarily very aware of these programs when they did exist. While sometimes successful (Shui 2012), one program manager we interviewed observed:

> *What we have in many cases is a desire [on the part of management or the energy efficiency industry] to do something. People act on what they can observe: they observe that people use computers, have lights, etc., and assume that occupant engagement means that people should turn these things off: a focus on people's fingers and switches.*
>
> *If I were going to design a building (or occupant engagement program), I would engage occupants: tell them that we are looking to save energy, look at plug loads, are they necessary, are there ways to improve efficiency while maintaining amenity? That, as opposed to writing a list of things and banning them. That will alienate employees and create resentment.*

This holds even for devices that seem as simple as a smart power strip. Occupants can be skeptical of new devices that are designed to save energy or otherwise automate control, especially when there is no introduction to these devices, hassles associated with using them (Vischer 2007), and no perceived value to the occupant. In talking with occupants, the importance of a sense of fairness and respectful give-and-take came through. The overall impression is that humane adult conversations (e.g., between occupants and operators or other facilities staff) may be more effective in engaging occupants than more manufactured campaigns.

Chapter 6: Summary and Discussion

Project Rationale

Our research focused on how building operators see energy use and energy conservation in the course of their daily work. What operators do a major "behavior" behind energy consumption in commercial buildings but one that research has barely investigated. Operational rules and guidelines for energy efficiency exist but may often not be followed (US DOE 2009, Malone et al. 2013). Studies estimate that 5-30% savings are possible through feasible changes to how commercial buildings are operated (Blumstein et al. 1980, Kolkebeck 2012, PECI 2012). These changes are often at low investment cost relative to efficiency upgrades (Lin & Hong 2012).

Meeting California's aggressive GHG emissions and energy use reductions goals, including those for commercial buildings, will require all hands on deck. Over the past 10 years, energy consumption in California commercial buildings has increased overall and per capita (Chapter 4) despite improved energy efficiency in buildings and devices. Evaluations of new buildings often point to a gap between design and performance, with actual energy use higher than predicted (Menezes et al. 2012) and indoor environments less satisfactory than what occupants expect or wish (Levin 2003, Leaman 2009, and Chapter 4). Through their position in controlling a high proportion of total building energy use, and interacting with the systems and people that control other aspects of energy use and indoor conditions, building operators are in an extraordinary position to see energy use and to help change it.

Reducing commercial building energy use through operational changes is not simply a matter of targeting improved behavior. A basic challenge is that different roles, rewards, responsibilities, priorities, resources, abilities, mindsets, technical possibilities, systems interactions, communications and scopes for action often do not align with energy across (or even necessarily within) actors. In addition, energy is invisible, while energy services are usually visible or palpable. Providing them is a fundamental reason for the building anyway.

This complex of relationships is an elaboration on the basic "barriers" framing for energy conservation in commercial buildings identified long ago. From an economics perspective, commercial buildings are characterized by massive split or misaligned incentives with respect to design, construction, and operation (Lutzenhiser et al. 2001, Zimmerman & Martin 2001) and to investing in energy efficient technology (DeCanio 1993, Blumstein et al. 1980). The fact that even individuals do not invest in apparently cost-effective energy efficiency has been one of the major struggles of the energy efficiency policy industry (Shove 1998), and organizations do not behave like individuals (DeCanio 1993).

Compared to investing in technologies, changing energy using behaviors within buildings poses additional challenges because changed actions have to persist to yield energy savings. These actions are relational, evolving in a building as people, organizations, and technologies re-synchronize with each other via changing expectations, settings, compensations, and practices. For persistent savings, something about the way energy use is organized, the social system of energy use, needs to change, whether in concert with or independently of technology changes.

Operators actions clearly depend on what occupants, tenants, managers, owners, bosses, machines, design, electronic "intelligence," guidelines, leases, laws, etc. allow or invite, as well as on how these various expectations, needs, and wants are interpreted and represented, and on the resources, technologies, and information available to undertake these actions. Given this complicated network, rather than look at what operators do as a matter of individual behavior, our research was designed to help put operator actions in social context, toward understanding the system of relationships that shape their actions and how this system might be reshaped to patterns that do better at reducing energy waste. In so doing, we complement guidelines on recommended operations practices (e.g., PECI 1999, Sullivan et al. 2010) as well as emerging social science work on building design professionals and other "building communities" (Axon et al. 2012, Janda 2013).

The remainder of this chapter summarizes findings from this project. Commercial buildings are immensely diverse, both technically and organizationally, while our sample was small and exploratory with respect to specifics. The results from this study should be interpreted in that light, and as a means to seed discussion and to contribute to building better bridges between the vast pool of experience and expertise in real buildings and the research, policy, and technology development efforts that aim to improve how energy efficiently these buildings function.

Synopsis

Two principal clusters of obstacles impede lowered operational energy use. First, while building operators are technically in a position to reduce operational energy use and to address performance problems in buildings, social, technical, and organizational constraints limit ability and motivation to do so. These include limitations of status, high emphasis on particular kinds of customer service, poor feedback on occupant environment, little energy data, low staffing levels, low salience of energy and energy costs to the organization, confusion over what job skills should be required, and technology shortcomings, including those of Building Management Systems usability and training. Building operators manage energy services in their daily work, but this only rarely constitutes strategic energy conservation. Often several different departments influence energy consumption, while none "owns" energy use as a core responsibility. Levels of coordination across departments are low and some steps – in particular occupant education about use of building features and coordinated expectation management – are largely omitted. Most building operators said that they did not regularly see energy bills, and other sorts of energy data available, if any, may be virtually unused for diagnosis or conservation strategies. In some buildings, these obstacles have been partly overcome, especially where LEED-certification and Energy Star status were motivators.

A second cluster of obstacles relates to occupant satisfaction with the indoor environment and the ability of buildings to me*et* occupant expectations. Our analysis of occupant satisfaction survey data for 101 California commercial buildings showed surprisingly low overall levels of occupant satisfaction with temperature and air quality, both of which are directly affected by operations. Despite the high level of apparent attention given to customer satisfaction, in the occupant survey data we analyzed, less than half of surveyed occupants in these buildings stated that they were satisfied with temperature in the workplace. Even in the highest-performing buildings, some 20% of occupants rated temperature as less than satisfactory. Other IEQ factors, especially acoustics, also rated poorly in the view of occupants. These results suggest that the current combination of building design, operations, facilities management, and occupant expectations are destined to leave a considerable proportion of occupants uncomfortable. Not only is this bad for occupants and the organizations that they work for, it can also lead to higher energy use. In short, energy services are not efficient relative to occupant assessment of the indoor environment, whether because of design, operations, feedback that is biased or absent, insufficient commissioning, inadequate training, or occupant expectations that are too high. The latter are not independently generated, but depend on past experience, knowledge, social and technical cues, and so on. . Improving the indoor environment, through better feedback and appreciation of its importance in design and operation stages, are a promising route for reduced energy waste.

Table 6 sketches building-level findings and recommendations from our research, categorized along four dimensions: comfort, energy, technology, and social/organizational factors. The "What we found" column summarizes results on the current state of building operations in most buildings. The "Recommendations" column summarizes our assessment as to how these situations might be improved toward lower energy use and better provisioning of IEQ, based on some of the practices we saw in the highest-performing buildings, insights from interviews, and our analysis of the data in concert. The remainder of this chapter elaborates on these results.

Discussion

The importance of customer service and typical non-salience of energy use

Avoiding complaints, and managing them when they arise, is a defining element of the job for most building operators. Especially in buildings that are not owner-occupied or when the operations team is outsourced, there is no question that avoiding complaints almost always comes before deliberate energy conservation. The question instead comes to how occupant complaints and the risk of them are balanced relative to energy use. With sufficient staff, training, data, team management, and attention to maintenance, the balance may work relatively well, both leaving occupants relatively satisfied and reducing energy waste. Such coordination can create a form of precision energy management.

However operations may often be short-staffed, be dealing with a compromised building, or lack important training and information about the building. It is difficult to provide good customer service with a faulty product. There is also a lack of tools, such as occupant satisfaction surveys and energy information even as basic as energy bills, to assess conditions and measure the outcomes that building operators are implicitly charged with managing.

Table 6. Overview of building-level findings and recommendations

	What we found	Recommendations
Comfort/IEQ		
Comfort provision	Usually as much as possible, given technical constraints	More informed via enhanced complaint, comfort, and energy monitoring Quality education for occupants
Comfort monitoring	Largely none – complaints only	More regular occupant feedback and interaction
Energy		
Energy monitoring	Largely none – energy bills were often not seen	Regular reporting and analysis in concert with IEQ
Technical		
System diagnosis and maintenance	Often know what's wrong, but limited technical and monetary resources to deal with it	More sharing of actual experiences and best practices; gap funding for rebate access; easier rebates
Systems optimization	Largely none	Make easier via better BMS interface and infrastructure
Social/organizational		
Complaint handling	Completed or ignored, little formal analysis	Regular analysis of complaints
Customer Service	Crucial, but hands off	Crucial, but with more occupant interaction, toward education and mutual understanding
Managing up	Little strategic input in IEQ, energy or systems development	Greater visibility for operators in strategic energy management efforts, design, and research
Rewards	Energy savings are difficult to notice, often with little extrinsic reward for procuring them	Build strategies to make energy savings and operational improvements easier to track
Change	Making changes is risky and can take a great deal of effort	Formally recognize and manage resistance

These deficiencies lead to a fire-fighting mode rather than more strategic management, problem diagnosis, or necessarily following operating guidelines on recommended energy and service practices. Problems can cascade. Overall the consequence of non-synchronized management is likely to be higher levels of energy services (e.g., lower set-points for air conditioning, narrower temperature deadband, and extended hours of operation), conservatism against short-term risk, and accretion of services provided. This is the nature of customer service, where treating and avoiding complaints are an earmark of performance. This may be accomplished by changing the services provided, sufficiently changing the expectations of the complainer or potential complainer, or even just be impeding complaints.

Avoiding customer service problems can be so important that owners and property managers may directly discourage even investigating reducing energy use, given the non-salience of energy costs. Giving the appearance of saving energy is important at times, such as during emergencies (Lutzenhiser et al. 2002), but here building activities are considered high-stakes (such as lawyers, judges, international finance, etc.) or otherwise integral to the experience of the building (Cooper 1998, Kempton et al. 1992, Salkin 2005) saving energy may be antithetical. In some buildings, saving energy is absolutely not important, whether for costs or green reputation. In other cases, owners or tenants may consider energy costs as fixed since they usually change so little and often ledger so invisibly.

Many of the building operators we spoke to did not see energy bills or do much, if any, analysis, with other forms of energy data. Building operators who were most attentive to energy use still said that they spent no more than 10% of their time actively thinking on energy. No one person or group in a building has oversight over energy use. Occupant requests and complaints may be managed by more than one group, IT departments can control lighting, data servers, and security, other groups decide purchasing, and an occupant engagement program may be conducted by yet another group. Levels of coordination among these disparate efforts to reduce energy use are often low. Even energy managers have influence or authority over only certain arenas and aspects of energy use, e.g., investments rather than operations.

Building operators manage energy services, but in a different form than a kWh/btu or cost-optimized form might. Strategic reduction of energy use, whether for cost saving or environmental performance, was sometimes of virtually no importance to those who evaluated building operations as a service. Even where a building operator might be intrinsically motivated to find ways to reduce energy use, he or she could face many countervailing forces, including the need to coordinate or get approvals with other departments or actors who may be reticent, lack of time, lack of discretionary funding, insufficient training and documentation, lack of data on energy consumption, and the invisibility of savings or of other forms of success.

This does not make progress impossible. Interviewees described ways that they had successfully navigated these challenges and achieved energy savings. Some emphasized the need to manage resistance to change, whether by careful testing before fully launching or announcing, or by exchanging information with management or occupants. Documenting and presenting the benefits of past operational changes in terms of associated monetary savings can help build organizational buy-in to continued efforts, some mentioned.

Toward making energy a more visible part of building operations, several interviewees described processes for energy discussions based on review of monthly energy bills. Monetary rewards for energy use reductions (e.g., as reflected in Key Performance Indicators) were being tested in some situations, though at least in one case the building operator was not enthusiastic. Other interviewees pointed to the importance of recognizing and encouraging building operator efforts to reduce energy use, which otherwise may be unrewarded and unremarked.

Our interviews and case studies underscored the fact buildings are social organizations. There are reasons for "waste." Attending to these reasons has a better chance of effecting actual change than do trying to correct individual behaviors.

> *Employees' behaviors, actions, and possibility for action are couched within the guidelines and limits of their jobs, which are set by the organizations for which they work, and are further conscribed by the premises in which they perform their duties. These premises may seem static, but they are punctuated by periodic changes which are often invisible in studies of individual behaviors (Janda 2013).*

The same thing may be said about building operators.

Operators' status and tools may often limit scope of action

Several interviewees commented strongly on the invisibility of building operations and on perceived status differentials, wherein building operators are seen as "tradesmen," basically performing a simple technical job. In many cases, these interviewees suggested, operator contributions were routinely undervalued and innovation discouraged. Isolation is another issue, since building operations are often hidden from others in the building, including both occupants and organizational management. Operators may work behind unmarked doors or not even be located in the building at all. Building operators may often be left out of board room and other strategic design, facilities, and energy conversations, even while in theory they could make substantial contributions to improving building and organizational performance and to reducing energy costs.

Underscoring this narrow view of the role of building operators, occupational data indicates that compensation is modest, expected growth in job opportunities is lower than average, possibilities for career advancement are limited with a low top-out salary, and no training is required for entry-level positions (BLS 2013). Yet building operator positions clearly require or at least benefit from multiple (technical, engineering, administrative, communications, etc.) and complex skills.

The low visibility of building operators in managing building energy use carries over to research and policy as well, for example, in the fact that building operations is often forgotten as a set of "behaviors" with potentially huge impact on actual energy use. The relative under-attention to the role of building operators in running buildings, in shaping the indoor environment, in determining energy use, and in otherwise managing building performance contrasts with the amount of attention paid to the role of technology and automation for these same roles. Rather, the roles, desired skill sets, and responsibilities of building operators can be decidedly under-defined relative to that of the BMS (Bobker et al. 2010, ECO Canada 2011). Although BMS, building automation, and advanced technology are often promoted as the best route to reduced energy use in existing and future buildings, there has been relatively little formal thought to the role of the people running (or even working) in the building to managing and evolving or domesticating this technology. Rather, futuristic scenarios seem to assume that "smart buildings" will run themselves with little need for human intervention and that this is the best, most efficient, course – despite the evidence to date (Aune et al. 2009). Building energy researchers who work in or with actual buildings have pointed to the poor feedback mechanisms currently in place (Brown & Arens 2012, Goins & Moezzi 2013). Better recognition of the importance of interplay between people and technology can foster more constructive development of building technologies in use.

Lack of training for using BMS illustrates the under-definition of desirable building operator duties and skills. In two of our case study buildings where BMS had recently been installed, operators had been trained very minimally on the system. In one case, training was reported as lasting 15 minutes. This operator felt ill-equipped to make changes to the BMS default programs, even when there was call to do so, and there was little time or resources available to learn. Service contractors can provide support, but at costs that may be administratively awkward or cost-prohibitive. Several of our contacts suggested that the difficulty of using BMS can lead to extra energy use, such as things left on or maladjusted because they are too difficult to change or it seems too risky to do so. Results on lack of full facility with BMS that we uncovered in this study are similar to those found by other researchers (Granderson et al. 2011, PECI 1999, Webster 2005). A good deal of the complexity and thus promise of BMS may be left unused, possibly adding to, rather than subtracting from, energy use.

While additional training would help, this problem can only be partly ascribed to lack of training on the part of building operators. Much of the difficulty lies with a systematic lack of attention to usability, overlooked in transitions from development to sales to acquisition to maintenance (Webster 2005). In some buildings, however, there did not seem to be major problems with BMS usability. In one case, the building operator was very satisfied with the BMS and his ability to use it. In another building, the operator felt moderately proficient with the BMS and successfully called on university students to do additional programming using an open-source communications protocol.

Taking steps to professionalize building operations can improve the status of building operators, enhance their ability to influence others, and provide motivation and leeway for building operators to become more active players in the strategic management of energy use. The Federal Building Personnel Training Act, passed in 2010, identifies core competencies and addresses training opportunities for building operations and other facilities personnel working in federal buildings. The results of this legislation can also be useful for California.

Occupant satisfaction is out of sync with building performance

Despite the high degree of attention paid to complaint avoidance and management, only 47% of surveyed occupants for the 101 California buildings for which we had occupant satisfaction survey data stated that they were satisfied with temperature in the workplace. Only 57% said that they were satisfied with air quality. Temperature and air quality are both determined, in large part, by building operations. In other words, while responding to and avoiding occupant complaints appears to command a great deal of an operators' attention, and shape energy use to higher rather than lower levels of energy services, these operational choices do not result in very high levels of occupant satisfaction. For those dissatisfied with temperature in the summer season, the source of dissatisfaction was as likely feeling too cold as it was feeling too hot (Chapter 4). That is, many occupants say that they would prefer less cooling in the summer rather than more.

Operators and other building management staff may not be aware of low levels of satisfaction, since occupants are rarely consulted about their assessment with and experience of the indoor environments they inhabit. In fact there may often be reluctance to know, since expressions of dissatisfaction can be costly in a number of ways.. The situation raises an important series of questions about relationships between energy use and the indoor environment. Energy use and indoor environment are often treated as separate topics (Levin and Phillips 2013), with buildings assumed to be adequate to provide satisfactory indoor environments. If indoor environmental quality is to be partly judged by occupant satisfaction, this does not appear to be the case. The dissatisfaction is not only with temperature and air quality, but with very low levels of acoustic satisfaction as well (Chapter 4).

If building energy use is to be substantially lowered, this mismatch of occupant satisfaction, the design of the indoor environment, and operations will have to be better addressed. Mismatches are often attributed to occupants expecting or demanding too much. This explanation is convenient but does not take account of actual building performance, how this performance relates to design, how occupant expectations are developed, or how the system of provision and expectation can be shifted to one in which what buildings can and do provide better match what occupants want. Occupants are often barely educated about how to use the building, and overall occupant engagement programs may focus more on "fingers and switches" than on addressing more fundamental concerns about how occupants can contribute to reductions while serving their own purposes, such as comfort, convenience, well-being and productivity.

Better performance here could be achieved from a variety of steps, including improved feedback from occupants, such as in surveys or other techniques (Bordass and Leaman 2005) as compared to the hot/cold complaint process, better education of occupants, and reconsideration of common assumptions about the conditions that buildings actually provide compared what they are designed to provide. One of the responses to the difficulty of coordinating the performance and low nuance of centralized management of energy use with the varied preferences of occupants has been to propose personalized controls of thermal, lighting, and other environmental factors. While the idea is promising, some early work suggests that usability, and perhaps other issues as well, can leave these controls often unused (Jelsma et al. 2003, Karjalainen & Koistenen 2007).

Furthermore, though educating building occupants about building features is likely a good thing, higher knowledge about features does not necessarily lead to higher stated comfort (Brown and Cole 2009), and occupants are not necessarily ready to be conscripted by a building's instructions (Ackerley & Brager 2012).

Technology performance may often fall short of promises

The data collection for this study did not focus on technology performance, though our discussions with building operators and others seconded others' doubts on how well certain building technologies perform relative to design expectations and the process by which they are, or are not, improved (Brown & Arens 2012, Ihnen et al. 2012, Menezes et al. 2012). This is especially pertinent to efforts that increase the role of building automation and "intelligence" in order to improve building energy efficiency. Ihnen et al. (2012) comment:

Today's digital controls make it much easier for building codes to require complex control algorithms than it is for building operators to implement them and realize the purported energy savings. As an energy efficiency industry and HVAC design industry, we cannot continue to fool ourselves that designers, engineers, controls contractors, commissioning agents and end uses will become experts with these complex systems when the market demands the cheapest, fastest construction humanly possible.

In talking to one highly experienced building operator about his experience with testing new technology, the operator commented

It takes 15 years for a new technology to work.

Several informants commented on how important building operators can be to getting innovative technologies to "work." Building operators may usually not be formally integrated into this domestication process. Our recommendation, which is aligned with increasing the professional status of building operations, is to more regularly call on building operators in design, technology acquisition, and other building management planning.

Reducing the Gap

California is grappling with how to fairly credit energy utilities for energy savings from behavioral programs. Most of the debate has focused on the residential sector. The idealized types of statistical criteria that might be applied in certain residential programs (Todd et al. 2012) are more difficult to apply in commercial buildings.

In commercial buildings, occupant engagement programs have sometimes shown modest successes in influencing the behavior of individual occupants (Shui 2012). These programs take concerted effort that organizations and individuals may currently often be unwilling to accept, as some of our interviews suggested. Such programs also face a basic challenge in terms of how well they can acknowledge the details of building users' experiences and create value for individuals, especially given the rather poor current performance of buildings from the perspective of occupants. These challenges can likely be at least partly overcome, but more attention to systems of energy use (including design, usability, operations, behaviors, and rewards) seems required.

Recent social science work has highlighted the importance of "building communities" as key to creatively instituting energy savings practices in buildings, successfully cutting across the organizational difficulties and mixed incentives that are central to the problem of commercial building energy use (Axon et al. 2012, Janda 2013). As also noted by Junghans (2012), facilities personnel and building operators are parts of these communities and of potentially critical importance in leading and contributing to innovative improvements in actual buildings, especially given their roles in balancing technology selection, indoor environment, and energy use. As is, these contributions may be too often discouraged or inhibited, or at least not actively sought out. Training and education programs can improve the capabilities of building operators, but these capabilities need also to be valued in action to have wide impact. In many of the buildings covered in our research, some of this value had been recognized, but overall much more of this recognition seems required.

LEED and Energy Star have been clear motivators for attention to energy-efficient design and energy use in some buildings. Improvements in building operations can support operations-phase elements of LEED (e.g., LEED-EBOM), helping draw attention to the importance of building operations in shaping energy performance. As some interviewees noted (see Chapter 5), these programs are not motivating or even relevant for all buildings or organizations. Building energy disclosure laws could help draw more attention to the actual energy use of commercial buildings, as distinct from asset or design ratings of efficiency which are sometimes an end in themselves (Brown 2010). California's Assembly Bill 1103 (Saldana 2007) and Assembly Bill 531 (Saldana 2009) will require certain commercial buildings being offered for sale or lease to disclose building energy use, with initial compliance currently expected to begin January 2014. Other commercial building energy use disclosure regulations are in effect in New York City and elsewhere. Such programs promise to build more emphasis on the operations phase of buildings and on the importance of operators and facilities staff. Comparative benchmarking relies on distributions, so by definition there will always be low performers, and difficult questions on assessing what any building is actually providing (around-the-clock services? retail? satisfied occupants and good air quality?) are inescapable.

The final chapter summarizes our recommendations for research and policy to help reduce energy use in commercial buildings. Our overall suggestion, applicable to building, research, and policy levels, is that enabling and encouraging building operators to better address building energy use is a key to better-performing, lower-energy buildings. Rather than simply trying to change an operator's individual behavior, this requires a closer look at all the pieces and a movement toward shifting the main locus of "solutions" toward operators and building occupants rather than primacy on technology. Operators and occupants are the ones with the biggest stakes in helping buildings work better and are also in the best position to help shape and vet the means to do so.

Chapter 7: Recommendations

Our recommendations for research and policy fall into four categories: recognizing buildings as social systems; supporting the visibility and professionalization of building operators and operations; improving technical support for seeing and affecting energy in building operations; better integration of indoor environmental quality and energy efficiency; and improving building functionality from occupants' points of view.

I. Recognize buildings as social systems

Occupied buildings are dynamic system of peoples, lights, energy and resource flows, walls and floors, windows and doors, roles, interactions, glitches, misunderstandings, adaptations, etc.   Attempts to intervene with specific physical or information components of this system, including better training, technologies, and information, may get lost, overthrown, be rendered redundant or irrelevant, or otherwise not work as planned.

For researching and intervening in building energy use, the above system of interactions, and the associated choices, tensions, risks, uncertainties, unintended consequences, knowledge gaps, missed opportunities, and various other forms of ignorance, is where the most important problems can be found and where solutions can best be tested. Our overall recommendation is that research and policy learn to better observe, recognize, and act within the building as social system, where components interact and things do not work as planned. The more specific recommendations below take this systems view into account.

II. Support visibility and professionalization of building operators and operations

Operators have tremendous potential to influence energy consumption in commercial buildings. Our interviews indicated that they have often have limited power, leeway, resources, and motivation to reduce energy consumption. Rewards may come instead from providing certain kinds of customer service and solving short-term problems. Current occupational outlook is poor, and operators and operations can be isolated from both occupants and management. Low visibility and low power limit the degree to which operators' existing skills, knowledge, and potential can affect positive change, the motivation to make changes toward more efficient energy use, and the value of increased knowledge. Professional associations such as the Building Operators and Management Association (BOMA) and educational programs such at Laney College (Oakland) already address some of these problems.

Our general recommendation, applicable to buildings, research, and policy, is to increase the visibility, status, and ability of building operators expanding on positive associations (e.g., green, naval). Doing so can promote the position of building operator to being better recognized as having a crucial role in developing and delivering high quality indoor environments energy efficiently. More specifically:

Support training, and consider supporting certification as a means to professionalization. California does not require certification for building operators. Whether through a state requirement or not, the certificate can play role in professionalization. Curricula should include good coverage of energy use and energy efficiency.

Recognize and promote building operations as a green job. Building operators can have a major effect on the indoor environment and indoor air quality as well as on building energy use and sustainability. These potential contributions to environmental sustainability can help make building operations an attractive career.

Include operations and operators as true partners in energy efficiency programs, policy, and research. Operators see how buildings work first hand and can be key in helping local and state governments, as well as industry, meet performance goals associated with climate change and environmental policies. Technology alone is unlikely to suffice and in any case, needs to be vetted in real buildings to help ensure satisfactory performance.

Include operators in design charrettes and the design process. Building operators have among the best first-hand knowledge of technology performance, serviceability, potential problems, and the degree to which equipment and design fit operating needs, but are not regularly included in the design process. Incorporating them early in the design process creates more effective handoffs from design to operations, and more energy efficient buildings as well.

Help define the building operations profession. The building operator's job is under-defined especially with the emphasis on building intelligence and automation. Better definitions of what building operators are supposed to do, know, and be rewarded for could help grow the profession into its full potential

III. Improve technical support for seeing energy and managing in building operations

The invisibility of energy, the fact that it is influenced by many different people, organizations, situations, and things, mixed incentives, and the fact that adequate energy services are a priority for most businesses, combine to create a basic challenge for energy conservation. The levels of energy use reduction required to meet state emissions and energy use reduction goals in commercial buildings requires a major change in how things are done. Building operations will be a key part of such changes, and better ways of seeing and influencing energy will be required to support them. Based on our interviews and literature review, the current tool set is often not up to the challenge. Possible improvements include:

Help develop better energy use data and use of energy data. From our interviews and case studies, we learned that the data available on building energy consumption may often be put to little or no use. The data is either not considered applicable, usable or user-friendly, or relevant to the tasks at hand. Some organizations and individuals, however, were very successful at creating and/or using energy data. They had developed strategies for increasing the salience of energy use in building operations, including monthly meetings about energy bills, policies, recognizing and praising success, incorporating goals into job descriptions, incorporating monetary incentives (e.g. compensation linked to an energy consumption Key Performance Indicator) into operations contracts, or documenting savings to share with boardrooms.

Realistic sharing of experience on what works. Even organizations on the cutting edge of building energy efficiency expressed a need for more and better information on real world experience with energy-savings technologies were needed. The right forum (possibly peer-to-peer) could also cover management strategies, such as strategies to overcome resistance to change, effective presentations of financial information, educate occupants, etc. We saw that certain "bad" systems, once installed, created years of trouble and frustration

Building Management Systems. Our research suggested that Building Management Systems (BMS) are often used in very partial capacities, seconding the findings of other researchers. While operators generally "liked" their BMS, training is often surprisingly poor or even non-existent, programming can be difficult, and proprietary systems limit how much operators can do on their own. This may sometimes lead to more, rather than less, energy consumption than would manual control. Improving the usability and applicability of BMS may be at least as important as improving training.

Make rebates more usable. Make rebates for building energy efficiency investments easier to apply for and more broadly available. They currently often require a lot of paperwork, which is difficult for organizations without much administrative capacity, and more financial contribution from the applicant than available for organizations that are cash-poor.

IV. Better integrate indoor environmental quality with energy efficiency, using evidence from real buildings to do so

Our analysis of occupant satisfaction survey data showed that occupant satisfaction with many aspects of the building indoor environment was often low. Interviews and case studies showed that dealing with occupant complaints dominates the time and energy of operations teams, while an emphasis on avoiding complaints appears to drive energy use and service levels higher and creates an inertia that impedes change. In turn occupant demands are often cast as the culprit for unnecessarily high building energy use, even while most occupants think the indoor environment could be considerably better.

If lower energy use is to be achieved without harming occupant well-being, productivity, or physical health, then much more attention to the dynamic links between energy use, design, operations, indoor environment, and occupant satisfaction will be required to better synchronize these elements and to define what good building performance means. This includes questions about how well systems work in practice, improved assessment of occupant satisfaction and actual conditions in the building, better understanding of occupant and operator behaviors, improving occupant education about the building, better understanding of how comfort expectations are established and how they are influenced, and even more humanized consideration of entire building philosophies (e.g., highly controlled intelligent buildings) based on experiences in actual buildings rather than the necessarily-idealized representations of models. Building operators and other buildings management staff can contribute their first-hand knowledge on how things work, what goes wrong, and strategies for improvement.

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Glossary

BMS	Building Management System
CBE	Center for the Built Environment, University of California Berkeley
CBECS	Commercial Building Energy Consumption Survey
GHG	Greenhouse gas
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LEED	Leadership in Energy & Environmental Design
O&M	Operations and Maintenance
MMTCO2eq	Million metric tonne (Tg) of CO2 equivalence, based on IPCC Second Assessment Report's Global Warming Potentials

Definitions

BMS: Building Management System, also called a Building Automation System or an Energy Management and Control System.

CBE: The Center for the Built Environment, founded in 1997, is an industry/university research collaboration with a mission of improving building environmental quality and energy efficiency. It is operated at the University of California Berkeley.

CBECS: CBECS is a commercial building characteristics and energy use survey collected periodically by the Energy Information Administration of the U.S. Department of Energy. The most recent published survey is from 2003. The 2007 survey was abandoned due to technical problems. A 2012 edition is in preparation.

LEED: LEED is a non-governmental building rating and third-party verification system managed by the U.S. Green Buildings Council.

IEQ: As used in this report, Indoor Environmental Quality is a broader term than indoor air quality, and refers to occupant assessment of various aspects of building physical environment (e.g., thermal conditions, visual quality, acoustics, air quality, and specific building features).