Current Situation and Trends In Buildings and Facility Operations

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1 Executive Summary

Americans depend on commercial and institutional buildings including schools, offices, government buildings, retail stores, hotels, airports, and hospitals to provide safe and comfortable indoor environments. These buildings have a major impact on our economy and global competitiveness. They are also responsible for close to 20 percent of all energy usage and carbon dioxide (CO_2) emissions. Despite the importance of these buildings and their impact on the economy and environment, little attention is paid to proper training and professional development of the technicians, operators, and facility managers responsible for effective operation of buildings. By describing relevant trends and influencing factors, the results of the research documented within this report provide insight into the current state of building operations and facility management. The report concludes with recommendations for potential pathways from current, often reactive, methods of building operation and management to proactive methods necessary to operate and maintain high performance buildings now and in the future. This report specifically addresses the following:

1) **Current State - Where are we today?** Investigation of the current condition of buildings and their operations and maintenance, with a primary focus on how technician training is impacted by global issues of energy, emissions, sustainability, market trends, legislation and regulation, technology and systems, people and processes, and the existing buildings portfolio.
2) **Transition and Actions Required - Where do we need to go?** Market trends and industry forces influence and shape the current and future needs of buildings. New processes, skills, and technologies are needed to meet the growing list of needs. The education and training requirements for future facility managers and building control system technicians is central to these needs.

This executive summary synthesizes the findings of the primary research (survey, interviews, and focus groups) and secondary research (literature review and observations of current practices) which was completed to assess the current situations and trends in building and facility operations to support educating technicians for building automation and sustainability. The purpose of the secondary research was to review current research and trade literature, as well as reports from government and trade associations, on the topics of buildings, facility management, building operation, building control systems, and sustainability. Within the literature review, an emphasis was placed on key issues, trends, synergies, and interactions between the identified topics. The secondary research was used to inform the primary research. The primary research included an online survey, four focus groups, and 10 verbal interviews. The online survey was completed by 253 professionals, resulting in a 23 percent response rate, (calculated based on the total number of individuals who completed the survey). In total, the four focus groups included about 40 participants. The findings of both the primary and secondary research were synthesized to draw conclusions about the current gaps, form strategies to close the gaps, develop a call to action, and identify ideas for future research.

1.1 Current State of Buildings and Facility Operation

Today there are approximately five million existing commercial and institutional buildings in the United States, comprising 72 billion square feet. The buildings range from historic to newly-constructed and from small to large, spanning all geographies and climate zones. Although new buildings follow increasingly stringent energy codes and offer improved energy efficiency, few existing buildings have been retrofitted to improve energy efficiency.

Facility managers, technicians, building operators, and maintenance teams lead the daily effort to keep buildings operational, comfortable, productive, and efficient. Several major challenges confront this multidisciplinary profession and its practice:

1) **Workforce education and training:** Today there are few formal training programs available for technicians, operators, and facility managers. Many technicians enter this field with limited formal training, and instead learn through on-the-job training (OJT) provided by traditional apprenticeship programs or military experience, or through less formal training provided by senior technicians or chief engineers. The limited classroom training provided through apprenticeship programs is focused on system components and narrowly defined job skills. This historical apprenticeship model assumes that industrial skills can be mostly learned on the job, without the need to rely on extensive classroom-based education.

   Formal job training for facility managers is often indirect, as few facility management educational degree and training programs exist. This study examines this core assumption in light of technology transformation in the building industry, as well as the urgency of energy efficient building operation. Combined with a lack of well- established industry standards for facility management, operations, and maintenance practices and processes, many entering the industry find themselves unprepared for the challenges ahead. The emergence of high performance green buildings complicates matters, as the skills required to understand the systems and practices to operate and continuously optimize these buildings cannot be achieved through traditional OJT methods. Community colleges may be best-suited to provide the in-depth education and training needed for future building operators, perhaps in partnership with traditional trade union and on-the-job training methods. This is because:

   - Community colleges are structured to teach students who seek several different levels of education such as completion of one class, completion of a certificate program, or completion of an associate’s degree.
   - Association or membership with a professional association or trade union is not a prerequisite for enrollment.
   - Community colleges provide courses in math and science, which are the foundation for understanding building control systems, as well as the ability to trouble-shoot and think critically about real-world operational challenges.
   - Graduates of community colleges can be employed in either a union or non-union environment.

2) **Separation of design and construction from operation**: In most organizations, the functions of design and construction are organizationally

distinct from operations, and operate under separate budgets. The function of design and construction is typically outsourced to teams of architects and engineers. The outsourcing of design and construction greatly limits the input building operators have during the design and construction process. Limiting input from building operators during design prevents the exchange of information about the realities of maintaining and operating a building, as the design and construction community has little understanding of the needs and functions required to properly operate and maintain a building.

Construction processes, including value engineering and lack of proper commissioning, often leave the building operations team with a building that operates significantly below the original design performance specification. As a result, building performance starts low and degrades over the life of the building.

3) **Stature of the profession:** The professions of building operators, technicians, maintenance service providers and facilities managers garner relatively low status in most organizations. Dominated by a traditional blue-collar industrial organizational ethos and, in many cases, segmented union structures, facilities management and building operations and maintenance teams are mostly invisible. Seen as largely peripheral to the core mission of the organization, they find themselves low in the organizational hierarchy. The result is declining budgets, limited staffing, low clout, and a sense of powerlessness among building operators and technicians to improve building performance, all the while facing outsourcing of facilities management and building operation jobs to property management and/or maintenance management service providers.
4) **Interface:** Facilities managers, technicians, operators, and maintenance teams often find themselves serving as the de-facto interface between owners, property managers, occupants, and tenants. Caught in the middle, they must balance the conflicting needs of comfort, convenience, energy efficiency, safety, and environmental sensitivity. As a result, energy efficiency and comfort often appear to be incompatible and mutually exclusive.
5) **Mission and purpose:** Building operations groups tend to be focused on two tasks: satisfying tenants and making what is in place work reliably. While these are important areas of focus, they do not easily extend to cover additional tasks such as optimization and energy efficiency.

Major changes in building operations are needed in order for commercial buildings to be operated efficiently while meeting sustainability goals and occupant comfort requirements.

1.2 Current Transition and Trends

The buildings industry is in the midst of a gradual transition toward high performance buildings. Programs such as LEED® from the U.S. Green Building Council and ENERGY STAR from the U.S. EPA are increasingly used for both new and existing buildings. U.S. government buildings are under executive and legislative mandates to dramatically improve efficiency and reduce greenhouse gas emissions. Private industry has followed suit, including corporate sustainability goals for both owned and leased space. This is all part of a global effort to reduce CO_2 emissions, of which buildings are a major contributor.

While most of the emphasis on sustainable and high performance buildings has been in new construction, existing buildings have the greatest environmental impact. Older buildings were often built using less stringent standards and operated at sub-par performance levels. Building operations have a major impact on the delivery of efficiency and sustainability goals. To achieve required levels of building efficiency, a transition is required in building operations. Key focus areas of the transition include:

- **Re-defining the field:** The job descriptions of building operators include a wide range of job functions. Some building operators are highly trained engineers, while others have a skill set similar to a custodian. Defining sustainable building operations as a profession and providing the appropriate pay and respect is a critical first step in this transition.
- **Proper training and certification:** Like any profession, proper training and certification is necessary. The development of training programs including curriculum, laboratories, testing standards, and proficiencies, is required. If this field is to receive the needed respect and attention, professional certifications need to become an expectation.
- **Development of new tools and processes:** Improved tools and processes for building operations need to be more broadly deployed and effectively used. These include tools for evaluating and measuring building performance, scheduling maintenance, analyzing systems, and calculating return on investment (ROI). While most of these tools are commercially available today, they are rarely applied uniformly within facilities or properly integrated into well-documented processes.
- **Building performance:** Building performance must be clearly and practically defined by identifying best in class building systems and management processes. To determine what is possible and define strategies to move towards net-zero building design and operation, best in class examples from buildings in the United States should be compared to best in class examples from buildings in Europe.
- **Ongoing performance measurement:** Finally, a system for ongoing performance measurement and management is needed. Rigorously defined performance criteria should include energy efficiency, carbon footprint, comfort, uptime, and tenant satisfaction.

To successfully reach sustainability and energy efficiency goals during this transition, it is important to clearly understand current trends (Table 1).

Table 1: Summary of current trends

	Observations & Trends
People	1) *The population of facility managers and building operations staff with in-depth understanding and hands-on ability with mechanical systems is aging.* 2) *The need for facility managers and building operators competent and skilled with technology is increasing.* 3) *There is a growing understanding of the need to assign clear responsibility for energy efficiency and sustainability.* 4) *There exists a lack of clearly communicated and supported goals for energy efficiency and sustainability.* 5) *Dwindling budgets and resources present the greatest challenges to retain qualified staff.* 6) *People do not generally aspire to go into the field of building operations and facility management; instead, arriving there more indirectly.* 7) *Career pathways are not clearly defined for people in this field.* 8) *Traditional apprenticeship training is insufficient.*
Processes	1) *Facilities management, operations, and maintenance cover a broad scope of activities and responsibilities.* 2) *Today's operations, maintenance and management practice is dominated by a reactive approach.* 3) *Standard processes for operations, maintenance, and facilities management are generally not understood or applied consistently.* 4) *There is often a lack of clearly communicated and support goals for energy efficiency and sustainability.*
Technology and Systems	1) *There is increasing need for the application of high performance building systems, including building envelope, mechanical and electrical systems, and controls.* 2) *Substantial innovation and growth in lighting and lighting controls technologies has occurred in recent years, and is expected to continue.* 3) *Convergence of building systems with information technology systems and networks is a common theme in recent years, and is expected to continue to drive the evolution of building systems and technologies.* 4) *Experimentation and adaptation of wireless technologies for building system applications presents potential for lower cost implementations of controls, especially for existing buildings.* 5) *There is a growing interest in integrated systems and intelligent buildings, including the use of software for data management and decision making. Software currently used, and anticipated to be used further in the future, includes building information modeling (BIM), computerized maintenance management systems (CMMS), computer aided facility management systems (CAFM), integrated work management systems (IWMS), data depositories and energy analytics.* 6) *The application of dashboards with key performance metrics for buildings, campuses, and enterprises to facilitate operations, management, and education is growing over time.*
Buildings	1) *Existing buildings present a massive opportunity for energy efficiency and operations improvements.* 2) *There is a vast existing building stock in the United States: 4.9 million buildings.* 3) *Small buildings are numerous relative to large buildings.* 4) *The majority of gross floor space resides in buildings between 10,000 and 200,000 gross square feet.* 5) *There is a fairly even distribution of building population and size across geography and climate.* 6) *On average, energy intensity increased through and peaked in the 1980's, and has since declined.* 7) *Energy costs are often well understood, but maintenance and operating costs are not as well established, and vary significantly. Furthermore, operations budgets are decreasing over time.*

	Observations & Trends
Market and Industry	***1) Green building design and construction has gained intense interest, but the share of LEED certified buildings will tend to remain small. 2) Energy efficiency and conservation is characterized as the first priority and lowest cost energy resource, and this is expected to continue to be the case in the near term. 3) Water efficiency and conservation is also a high priority in buildings. 4) Public and private financing of energy efficiency is rising on average. 5) There is a movement towards design processes and delivery models that encompass a whole building perspective. 6) With increasing emphasis on building energy performance and indoor environmental quality, the practice of building commissioning will continue to grow. 7) Public disclosure of building energy performance will create new opportunities for market forces to determine real estate value in terms of both lease and sale. 8) Mission critical facilities such as labs and data centers present unique and special challenges for building operations and facilities management teams, and for energy efficiency and sustainability. 9) The convergence of building systems with information technology will continue to evolve the potential to deliver ever more powerful technologies and tools for O&M teams, facility managers, energy managers, and building owners. 10) There is a growing market, supported by federal legislation, to implement smart grid and demand response in buildings, with the intent to reduce peak loads and building energy consumption.***
Global Issues: Energy, Emissions and Sustainability	***1) Energy costs are projected to rise slowly but steadily over the long term. More importantly, the reliability and availability of energy may become increasingly uncertain without significant changes. 2) Load shedding, demand response, and smart metering are anticipated to become more widely used as smart grid is deployed. 3) Greenhouse gas emissions and, in particular, carbon dioxide emissions will continue to rise over the long term. The rate of increasing emissions will depend largely on the course of energy consumption and the associated actions. 4) The basic philosophy of sustainability will continue to gain momentum, and the associated practices and technologies will continue to evolve toward greater complexity.***
Oversight and Regulatory	***1) Government mandates and support for energy efficiency will continue to increase. 2) Stringency will increase in minimum energy efficiency requirements for buildings. 3) There is potential for greenhouse gas emissions reporting and controls. 4) Availability of guidance and support for energy efficient building design, construction, and operation will continue to evolve. 5) Recognition that sustainability extends well beyond construction will continue to rise, and there will be a corresponding evolution of USGBC's LEED Rating Systems to incorporate greater focus on energy efficiency, operations, and maintenance.***

1.3 Identifying the Gaps

In synthesizing the current state of buildings and facility operations with industry trends, several gaps emerged. The gaps can be classified within three broad categories: people, process, and technology. The people gap includes:

- Roles and building owner expectations
- Employment opportunities and career paths
- Education
- Trade union roles and responsibilities

The process gap encompasses a lack of standardized methods and best practices, including but not limited to:

- Goal setting
- Benchmarking and tracking of maintenance and operation costs
- Proactive energy and maintenance management techniques

The technology gap includes:

- Underutilization of software technologies currently available within the market, including but not limited to building automation systems (BAS) and computerized maintenance management systems (CMMS)
- Lack of information about new systems and equipment available to operators and technicians

Ranking the three gap classifications, the greatest needs are the people and process gaps. The technology gap presents the lesser need because:

- Many currently available technologies already exist within buildings but are underutilized. This includes building automation systems, energy benchmarking systems, and management tools such as computerized maintenance management systems (CMMS).
- To stay competitive, manufacturers and vendors must continue to develop and refine systems, equipment, and software products. As a result, the functionality and quantity of products on the market will only continue to increase. Manufacturers and vendors have a strong interest in marketing new products to stay in business and grow their customer base.

In order to more fully utilize existing technologies, and to equip professionals with the skills and processes necessary to utilize new technologies, it is necessary to focus on the people and process gaps. Although technology is important, it must be viewed through the people and process gaps.

1.3.1 People Gaps

The people gaps include roles and building owner expectations, employment opportunities and career paths, education, and trade union roles and responsibilities.

Roles and building owner expectations: The daily tasks and responsibilities of the high performance building technician and facility manager are not clearly defined. Additionally, technicians and facility managers often see their role as doing what is necessary to satisfy the tenant even if it increases energy consumption. As a result, in most organizations meeting tenant needs is at odds with energy efficient equipment operation.

There is a belief among building owners and managers known as the “super hero theory.” The theory states that some managers adopt a belief that a single technician has all the expertise necessary to solve all operational challenges. A Super Hero Technician can troubleshoot and problem solve for all system types, and also possesses excellent customer relations and business skills and an ability to adapt quickly to change.

While some technicians fit the definition of the super hero theory, it is an unreasonable expectation for most technicians because acquiring the skill set necessary to be a “super hero” technician requires many years of experience across multiple trades, as well as very strong analytical skills, the ability to communicate verbally with multiple stakeholder groups, and extensive troubleshooting and critical thinking skills. Additionally, the existence of the theory indirectly demonstrates that managers are not well informed about the complexity of mechanical, electrical, and other systems within buildings. Equating the expectations of the super hero theory to a management role would be like expecting one person to have the skills and competencies necessary to fill the roles of a human resource manager, accountant, book keeper, and administrative assistant. The existence of the super hero theory suggests that it’s necessary to educate building owners and managers about the complexity of building systems and technologies.

Employment opportunities and career paths: Career paths are often not clearly defined and many people entering facility management and building technician roles do not enter the profession intentionally. Many people do not desire to enter the building operations and facility management fields because employment opportunities are seen as invisible and largely peripheral to the core mission of an organization, and/or work performed in the field is seen as undesirable.

Education: Results of the research found that although about 75 percent of respondents had received education from a college, university, or community college, only 12 percent of respondents pursued a course of study directly related to building operations or facility management. Few higher education degree and certificate programs exist to educate facility managers within the United States. Although the International Facility Management Association (IFMA) Foundation helps community colleges and universities establish and accredit facility management degree programs, the number of students graduating from these programs is smaller than the number of professionals needed to fill future demands. Within current programs, the amount of time students spend in the field or doing lab work is often insufficient to prepare them for their careers.

Roles and Responsibilities of Unions: Although trade unions provide many benefits to their members, the structure and roles of unions may reduce the opportunities members have to help meet the needs of high performance buildings. For example, the successful operation of a high performance building starts with building operator and technician involvement during the design and construction processes. However, many unions currently have tightly defined roles, constraining how union members can participate during design and construction processes. This decreases the opportunity for integration of the design, construction, and operations processes which reduces the potential to use a systems approach.

As the number of high performance buildings continues to increase, unions, like all other educational and training providers, will need to offer training opportunities which include the skills necessary to operate and maintain high performance buildings.

1.3.2 Process Gaps

The process gaps are centered on a lack of standardization of methods and best practices, including:

- Clearly defined energy management and sustainability goals.
- Benchmarking to track energy consumption and costs, including the use of meter data.

- Tracking methods for operations and maintenance cost analysis.
- Proactive maintenance management techniques.
- Clearly defined job roles and responsibilities.
- Integration between the design, construction, and operations processes during the design phase to eliminate lost project documentation, a lack of systems perspective, and building systems not working as intended.
- Well organized and accessible building system documentation.

The lack of clearly set goals and use of benchmarking tools is supported by the survey findings, in that:

- Less than half of survey respondents use the energy use index (EUI) or ENERGY STAR Portfolio Manager available at their facilities.
- About one fourth of respondents were not aware of any set goals to reduce energy consumption.

The use of reactive maintenance management techniques is a result of the lack of standardized maintenance cost data. Finally, a lack of standardization requires facility managers and non-union technicians to often be the "jack-of-all-trades" in order to complete the variety of activities required within their job description.

1.3.3 Technology Gaps

Technology includes systems, equipment, and software. Manufacturers and vendors often educate engineers, construction contractors, and sometimes facility managers about new products, but because technicians and operators don't very often make purchasing decisions, they are often left out of the vendor education loop. Yet, technicians and operators are the ones most in need of this education.

To understand how to further utilize existing software, technicians and facility managers must have an understanding of:

- High performance building systems
- Intelligent buildings
- Middleware and enterprise systems
- Effective use of metering and meter data
- How to communicate technical information with finance, procurement, and other non-technically minded professionals

Intelligent buildings are defined as buildings that use technology and processes to provide safe, comfortable, and productive indoor environments for the building occupants. Middleware and enterprise systems include open and integrated systems, which may also include business process software.

High performance building systems include:

- Building envelope
- Mechanical, electrical, and building automation (controls) systems
- Lighting controls
- Wireless technologies
- Integrated systems
- Dashboards

Of all of the systems within buildings, controls were identified to have the largest skill gap when Comparing current skill levels against skill levels required to operate high performance buildings.

It is important to understand that the technology gap is not a lack of systems and equipment to meet the design and construction needs of high performance buildings – it is the ability to effectively use the technology and to optimize system performance. To close the technology gap will require process improvements and increased educational opportunities for operators and technicians.

1.4 Vision: How to Close the Gaps

"If you want behavior modification to occur, you need to raise awareness and then [provide] the tools [necessary] to lead to long term action." –Interview participant in response to what future educational programs must support

Meeting the goals set by building owners and managers for high performance buildings will involve further definition and elevation of the technician, operator, and facility manager. This will require identifying clear, measurable steps to close identified gaps and move building operations practices from reactive to proactive. Of the three gap categories defined, they should be prioritized as:

1) People
2) Process
3) Technology

People are needed to fill the roles of high performance building managers and operators. In order for these roles to be filled, many people will need to be educated about the processes, methods, and technologies required to efficiently operate, manage, and transform existing buildings to high performance buildings. Without properly educated professionals, energy and green house gas emissions reduction goals will not be met.

To determine what skills and processes are needed, a clear definition of a high performance building is critical. As defined by the 2007 Energy Independence and Security Act, a high performance building is:

"A building that integrates and optimizes on a life cycle basis all major high performance attributes, including energy [and water] conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations."[1]

From this definition, it is apparent that a high performance building is not just technology – it requires well developed processes and trained professionals to appropriately select, manage, operate, and repair energy efficient and sustainable technologies.

To design, build, and operate a high performance building that meets the definition stated above requires that many current industry challenges be overcome. Some of these challenges include a lack of:

[1] (Energy Independence and Security Act 2007 401 PL 110-140)

- Proactive energy, operations, and maintenance management processes.
- Support from upper management to provide proper training to complete systems-based maintenance.
- A properly skilled workforce.
- Educated owners and building managers who are willing to invest in staff training and process improvements.
- Respect of knowledgeable building operators and technicians.
- Incentives for building operators and technicians to operate buildings efficiently.
- Life cycle cost considerations.
- Systems and equipment design documentation written and presented in a format that is understood by facility managers, building operators, and engineers – not just engineers.

1.4.1 Future Building Control Technicians

The findings of this research suggest that future building control technicians will need to have the following competencies to successfully operate high performance buildings:

- Systems thinker: Understand interactions between components including controls, HVAC, and lighting.
- Basic data analysis: Understand how to use data generated by a building automation system, including how to read trend logs and how to use the data for decision making.
- How to learn: How to think independently and critically to troubleshoot and solve problems.
- Effective verbal and written communication skills, including:
    - Ability to communicate with building managers about financial decisions impacting operations and maintenance.
    - Ability to communicate with building occupants, vendors, and service providers.

Future building control technicians will be challenged by:

- Overcoming the expectation associated with the “Super Hero Theory”.
- Continually increasing pace of new, computer-based technologies.
- Learning how to communicate with managers, building occupants, and vendors.
- Approaching maintenance and operations tasks from a systems approach, as opposed to a component-based approach.
- Cultural challenges such as a belief that effective building operation is not important to high performance buildings and energy efficiency.

Overcoming these challenges to achieve the vision will require collaboration between community colleges, trade unions, product manufacturers and vendors, colleges and universities, professional associations, and many other groups. In order to foster collaboration, a national conference should be established to help share best practices and lessons learned.

1.5 Call to Action and Future Research

Achieving the vision defined by this research will require commitment of the following:

- Development of clearly focused degree programs for technicians that include:

- Field experience through labs and/or apprenticeships, communication skills, and negotiation skills to influence occupant behavior change.
    - Strategies to develop economical, portable lab modules that can be widely disseminated for use at community colleges and other training programs. The lab modules must be able to be replicated (blue printed), support multiple technologies, and be developed with support from product vendors.
    - Case studies and problem-based learning scenarios to allow students to learn from facility managers and technicians currently in the field (dealing with "real life scenarios").
    - Programs structured to be accessible to students from a wide demographic including dislocated workers, high school graduates, returning students, working professionals, and others seeking hands-on and applied training. The programs must also be structured to allow students to either earn associate degrees or certificates, or just to complete single courses.
- Identification of the roles of trade unions and professional associations, and partnerships with community colleges, universities, and other market-driven training providers to:
    - Determine if and how mentoring opportunities can be created.
    - Develop regional and / or national clearing houses to disseminate curriculum and lab blue prints, which will decrease the time and resources necessary to successfully implement more training programs.
- Determine if standards should be developed for accrediting community colleges with regard to training controls technicians, building operators, and maintainers. If so, determine the most appropriate development strategy.
- Determine how to encourage people to seek careers as building control technicians by reaching out to high schools and others seeking hands-on work opportunities.
- Education of owners to understand the value of hiring and training skilled technicians.
    - After owners understand the value of trained technicians, work with owners to develop paid apprenticeship programs for students.

1.5.1 Future Research

To achieve the call to action, the following future research is recommended:

- Compare existing training opportunities within the market with existing programs at other community colleges. This comparison should include clearly documented site visits to help share and disseminate teaching and lab development best practices for educating building control technicians.
- Interview/shadow experienced technicians to understand what skills are necessary to operate equipment efficiently and to prevent operating equipment in-hand, as well as discover preferred learning methods and topics of interest.
- Compare technician certification programs available from NATE, RSES and others to determine which one(s) brings the most benefit to the field. Then, work with these organizations to promote these programs to students, as well as to new and seasoned professionals.
- Compare facility management certifications available from IFMA, BOMA, AFE and others to determine which one(s) brings the most benefit to the field. Then work with these organizations to promote these programs to students, as well as to new and seasoned professionals.
- Develop a framework for facility management and technician apprenticeships that can be used to help community colleges, four-year colleges, and employers to build partnering relationships.
- Develop well documented processes and guidance to deploy standards and tools and for evaluating and measuring building performance, scheduling maintenance, analyzing system performance, and calculating return on investment (ROI). Various teaching methods including classroom, lab, and online should be developed to help disseminate standards and tools.
    - Determine if/how Six Sigma can be applied to develop proactive operations and maintenance standards.
    - Teaching resources should be standardized so as to be useful to multiple community college and training programs, and should include information packets, workbooks, and online materials.
    - Teaching methods must be structured for both student learning and train-the-trainer instruction.

1.6 Summary

Meeting the needs of technicians to operate and maintain high performance buildings is a large, multi-dimensional challenge. This study has classified the challenge as having three gaps: people, process, and technology. Although closing the gaps within all three classifications is important, the research suggests that the people and process gaps are the higher priority. Future research is needed to create more collaborative opportunities between community colleges, unions, professional associations, and industry members. This will help to define the criteria for developing cost effective training modules that can be widely disseminated, and educate owners about the value of training and the need for standardized operations and maintenance practices.

"We cannot purchase efficiency; we can enable it through continual training, testing, certification and encouragement" – Mark McGann
National Association of Power Engineers National (NAPE) President

2 Introduction

The National Science Foundation's Advanced Technology Education program (NSF ATE) is focused on education across technology fields. *Educating Technicians for Building Automation and Sustainability*, the NSFATE research project at Laney College, seeks to broadly inform current and future education and training needs to produce qualified technicians in building automation systems, building operations, and facility management. The lack of widely available education and training constitutes one of the greatest barriers to rapidly implementing energy efficiency, greenhouse gas reduction, and sustainability targets in commercial buildings. This research project builds on previous efforts aimed at upgrading technician education to meet today's challenges and intends to inform efforts to improve education and training in support of an industry transition to energy efficient high performance green buildings.

Building Intelligence Group was retained to complete primary and secondary research to support the NSF ATE *Educating Technicians for Building Automation and Sustainability* project at Laney College. This report presents the primary and secondary research and summarizes, analyzes, and synthesizes the findings to make recommendations in the form of a vision statement, call to action, and list of items for future research to inform subsequent stages of work. Laney intends to utilize the research findings to inform program and curriculum development in building automation and sustainability. The findings will also support professional development and regional and national project dissemination efforts. This will benefit community colleges, other training facilities, and NSF information and research centers. Improving the quality of building operations is a complex undertaking extending far beyond technological challenges. This study seeks to shed light on the many complex factors involved in building operations and the multi-faceted solutions needed to achieve best practices in high performance building operations.

2.1 Goal of the Research

The goal of research conducted by the Building Intelligence Group was to support the NSF grant for *Educating Technicians for Building Automation and Sustainability*. More specifically, to:

> ***Capture the current state of the art of building operations and facility management, describe the relevant trends and influencing factors, and envision potential pathways from the current state to the future.***

The responses to the following questions will define the efforts required to address this goal:

1. **Where are we today?**

   Framed within the broad context of controls technician education, what is the current state of buildings and their operations and maintenance in terms of global issues, market trends, legislation and regulation, technology and systems, and people and processes?

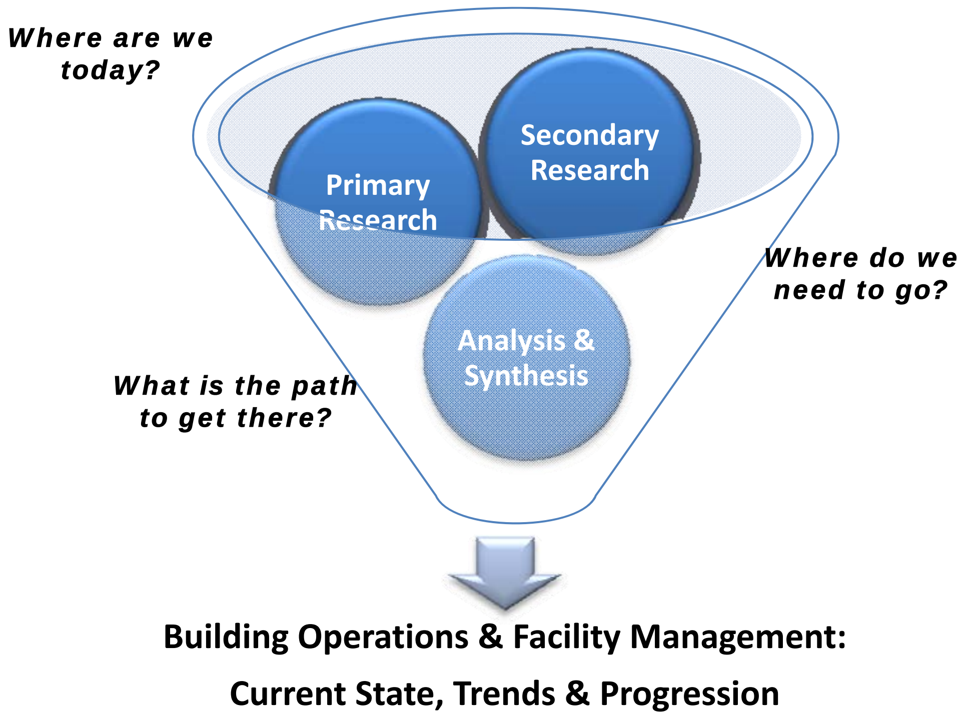
2. **Where do we need to go?**

   What market and industry forces and trends influence and shape the state and future of buildings? What transformations are required for facilities management and building operations and maintenance, and the people that work in this field?

3. What is the path to get there?
What are the potential strategies and tactics to get from today to tomorrow? How can facilities management and building operations and maintenance technicians embrace the future?

To achieve this goal, this research report responds to the first of these three questions, examines possibilities that address the second question, and speculates a direction to respond to the third question (Figure 1).

Figure 1: Project components in relation to goal



2.2 Objectives

Objectives of the research to support the achievement of the stated goal are to:

- Construct a broad picture of the current state of the art of building operations including skills, tools, roles, and responsibilities.
- Identify trends, issues, and challenges driving necessary change.
- Validate input with insight from building operations and facility management staff.
- Discover any additional needs and potential ideas for solutions.
- Develop a vision for the potential future of building operations including new roles, responsibilities, and required skills.
- Describe the potential ideas, paths, and solutions to ensure successful development and promotion of people who will perform building operations.

2.3 Hypotheses

Industry background and knowledge combined with early research results provided the opportunity to make some hypotheses regarding the operations and maintenance of buildings:

1) ***Responsibility for energy efficiency and/or sustainability is often not clear in facility management and operations teams.***
2) ***Management may be unrealistically estimating the sustainability impact (for example, in the case where a CEO establishes a goal to cut carbon emissions by 25 percent).***
3) ***There is a prevalence of "building myths" that dominate operations resulting primarily from poor documentation.***
4) ***There is a substantial disjuncture between the construction and operation processes of buildings.***
    a) ***Where applicable, unions tightly define roles. For example, unions can prevent facility managers and operators from participating in the design and construction process.***
    b) ***In many organizations, capital and construction departments are organizationally separate than, and have separate budgets from, facility management departments.***

5A) ***There is an undue reliance today on on–the-job training (OJT).***

5B) ***There is a lack of consistently available, high-quality training and certification programs.***

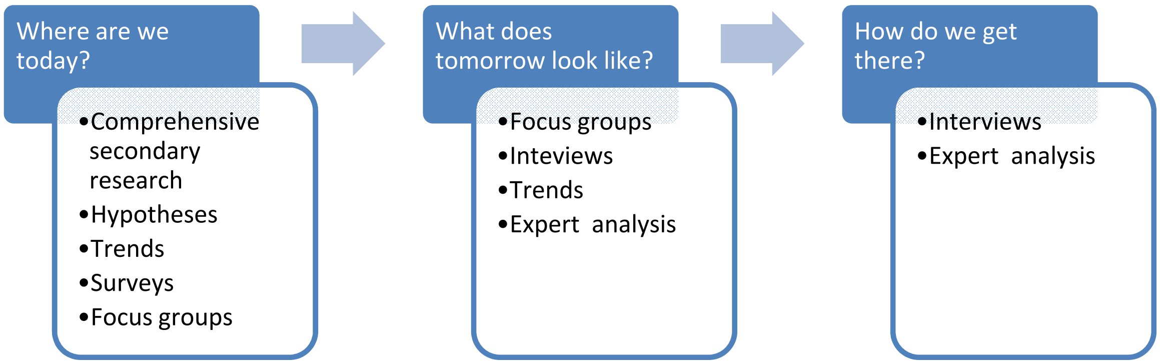
6) ***There may be misinformation and a lack of information amongst building owners and facility managers to understand that energy savings opportunities have a major impact on building performance.***
7) ***Energy efficiency is not a typically supported goal of building owners and managers.***
8) ***Lack of management support for quality O&M makes building optimization difficult to achieve, and the industry norm is minimal maintenance as necessary.***
9) ***O & M professionals may lack the technical expertise necessary to adequately operate and manage high performance systems.***
10) ***There will be a shift in functional responsibility for building operations (in policy, research, and strategic planning) from blue collar to green building professionals: there are significant implications for training, employment structure, and career advancement opportunities that would enable this shift.***

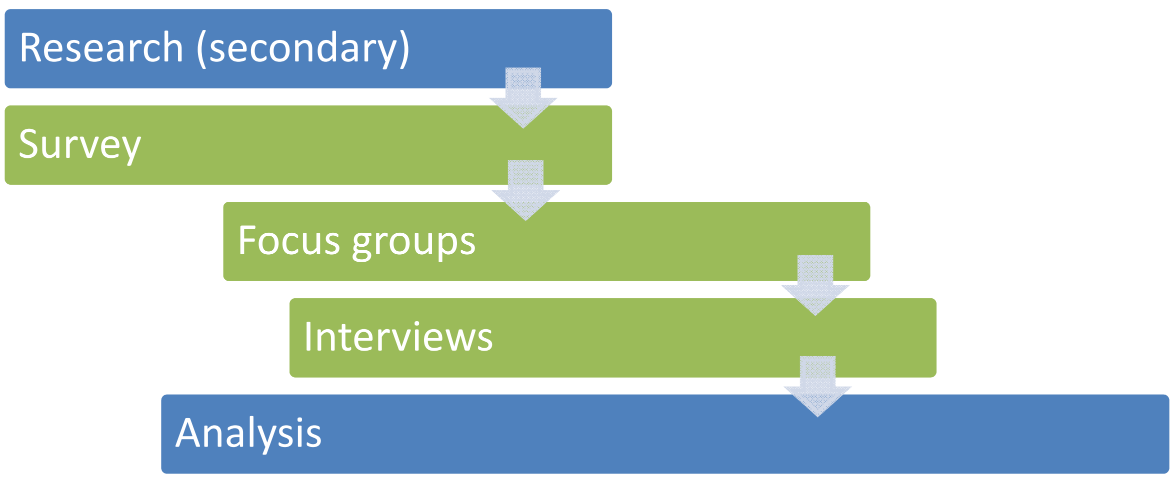
This effort returns to these hypotheses at the later stages, and the report responds to them in its conclusion.

2.4 Research Methodology and Process

The research documented within the report consisted of both primary and secondary research. Figure 2 outlines the high level approach to the overall project. The primary research consisted of an online survey, four focus groups, and ten verbal interviews. The secondary research consisted of a review of other current research and trade literature, as well as government and trade association reports. The findings of the secondary research were used to inform the primary research.

Figure 2: High Level Approach to the Research





2.4.1 Secondary Research

Secondary research consisted of review of research and trade literature, reports, and studies pertaining to buildings, facility management and operations, and related topics. The emphasis was on the key issues, factors, and trends, and their synergies and interactions.

2.4.2 Primary Research

Primary research included an online survey, four focus groups, and ten verbal interviews. The online survey was used to gather data from a national sample of the industry. In order to generalize the findings, the qualitative results from the survey were analyzed using quantitative, descriptive statistical methods.

The primary research was conducted using a phased approach of the following processes, in this order:

- National online survey
- Focus groups in Northern California
- National verbal interviews

2.4.2.1 Survey

The purpose of the online survey was to gather insight from a national audience who are directly involved with the management or operations of commercial and institutional buildings. The goal of the survey was to gain an understanding of current challenges and identify gaps and requirements for education and training associated with the operation of sustainable facilities. The survey was circulated to more than 10,000 professionals, with the intent to collect both quantitative and qualitative information from approximately 200 qualified respondents. A total of 253 responses were received, equivalent to a 23 percent response rate, calculated using the total number of completed surveys.

The specific objectives of the survey were to:

1) Obtain input from a broad geographic base across the United States.
2) Gather qualitative information directly from building operations management and staff regarding their skills, training, and challenges.
3) Identify the gaps between existing and required skills.
4) Identify where companies are in relation to implementation of sustainability goals and initiatives. Assess satisfaction with existing training and education programs.

Survey distribution methods included e-mail distribution as well as posting on web sites, blogs, and social networking sites. Specific details for each method include:

- E-mail distribution
    - BNP Media / Clear Seas Research: An e-mail distribution executed on May 19th distributed the survey to more than 7,500 people. This distribution was completed by BNP Media to subscribers of Engineered Systems and Sustainable Facilities magazines.
    - International Facility Management Association (IFMA): An e-mail was distributed by the IFMA Director of Research to the entire IFMA e-mail distribution list.
- Posting on various industry sites:
    - Today's Facility Manager (magazine web site)
    - myfacilitiesnet
    - Konstructr
- Posting on various social and professional networking sites in the appropriate groups:
    - Facebook
    - LinkedIn

Requests for posting/distribution went to the following BOMA Chapters:

- Minneapolis
- St. Paul
- Philadelphia
- Pittsburgh
- Austin
- Dallas
- Miami
- Chicago Suburbs
- Chicago
- New York City
- Boston
- Seattle
- Denver
- Cincinnati
- Cleveland
- Los Angeles
- San Francisco
- Virginia
- Kansas City
- St. Louis
- Milwaukee
- Phoenix
- Oakland
- San Francisco
- Silicon Valley

2.4.2.2 Focus Groups

The purpose of the focus groups was to build upon the results of the on the survey. The goals were to obtain further insight about the challenges faced within building operations, to discover the underlying issues, and to solicit potential solutions. While the survey provides a big picture view, focus groups allowed for further discussion of key issues, attitudes, and perhaps most important, experiences. By combining a small group of participants, it was possible to generate dialogue with the participants. This social interaction created a wealth of information which may not be revealed in one-on-one settings. Four focus groups of seven to twelve participants were completed. The makeup and focus of each group is identified in Table 2.

The objectives of the focus groups were to:

1) Obtain <u>qualitative</u> input regarding the current state of facility operations from those actively involved in these tasks.
2) Develop an understanding of best practices and challenges from industry leaders.
3) Identify where the biggest gaps exist in employee skills and gain input on how these gaps can be closed through training and education.
4) Further explore findings from the online survey.

Table 2: Focus Group Panels and Topics of Discussion

Group	Panel	Focus Group Discussion Topics
1	Laney ECT Advisory Panel members	Facility operations trends, issues and challenges
2	Laney College ECT Working Students and Alumni	Facility operations trends, issues and challenges with emphasis on training
3 **4**	Facility Operations Groups (at Laney and BOMA)	Facility operations structure, roles, responsibilities, challenges and trends

2.4.2.3 Interviews

The final phase of the research consisted of a series of in-depth interviews with industry experts to identify trends, issues, and challenges, and facilitate a vision of the future for building operations and facility management. Like the focus groups, the interviews provide qualitative data. However, while the focus groups attempted to bring like participants or groups together, the interviews included a wide range of individuals from diverse backgrounds and locations with expertise ranging from sustainability, education, technology, and commercial real estate. The placement of the interviews as the last phase of the study provided the researchers the opportunity to use the experts as a sounding board for the data previously collected, and to gain their perspective on various concepts uncovered earlier within the research. The interviews covered the topics of trends, issues, and challenges discovered and examined in the earlier phases of the research.

The objectives of the interviews were to:

1) Obtain expert opinions and insights into trends, issues, challenges, and solutions.
2) Gain the perspective of experts from various geographic locations.
3) Identify critical success factors.
4) Build a vision of the future of building operations and facility management.
5) Solicit feedback on implications of previous research phases.

2.5 Summary

This chapter has defined the goal, objectives, and methods of the research. Primary and secondary research was used to test and develop ten hypotheses. The method used to conduct the research is described. Primary research included an online survey, four focus groups, and ten interviews. The secondary research, which informed the primary research, included literature review of trade and research publications as well as reports from professional associations and government source.

3 Relevant Research and Programs

3.1 NSF Advanced Technological Education Awards

Under the National Science Foundation's Advanced Technological Education program, there are numerous awards. While these projects are focused on educational issues and programs for community colleges, there do not appear to be any projects presenting significant overlap with *Educating Technicians for Building Automation and Sustainability*. There are, however, some projects that cover related areas of education for energy distribution, renewable energy, and energy extraction (Table 3).

Table 3: Relevant NSF ATE Awards

Award	Title	Organization
0802786	Project REvamp: A Community College Electrical Technology Curriculum Model for Renewable Energy Technician Training	Kankakee Community College
0802045	Electrical Distribution Technician Training System	Pearl River Community College
0802571	Energy Technician Education Project (ETEP)	Northern Wyoming Community College District
0802456	Green Building Systems	Butte College
0602633	SEET Project: Sustainable Energy Education and Training Workshops for Future Energy Technicians	Eastern Iowa Community College
0501498	Energy Services and Technology Program	CUNY Bronx Community College
0501764	Partnerships in Educational Resources for Renewable Energy Technologies	Madison Area Technical College

3.2 Other Current Research

Other relevant research focused on building and facility operations and maintenance being conducted at the time the research for this report was being gathered is identified in Table 4.

Table 4: Current relevant work

Project	Organization or Institution	Principle(s)
A Framework for Improving Building Operating Decisions	The Pennsylvania State University	Angela Lewis
Occupant Indoor Environmental Quality (IEQ) Survey and Building Benchmarking	UC Berkeley Center for the Built Environment	John Goins Charlie Huizenga
Using Occupant Feedback to Improve Building Operations	UC Berkeley Center for the Built Environment	Edward Arens David Lehrer

3.3 Educational and Training Programs

Five different methods of education and training for controls technicians were identified:

- College and University
- Community College
- Certification
    - Typically completed by non-profit organizations such as North American Technician Excellence (NATE) or the Refrigeration Service Engineer Society (RSES)
- Apprenticeships
- Vendor/industry training
    - Controls vendors provide product specific training
    - For-profit organizations, such as MPACT and American Trainco, provide controls-focused training

Each of these education and training methods is further discussed in Chapter 5: People of this report.

3.4 Summary

This chapter provides a brief review of NSF Advanced Technological Education Awards similar to the research documented in this report. Other relevant research is then summarized. The chapter concludes with a list of five different forms of building control technician educational and training programs.

4 Background and Issues

Continued challenges with the availability of energy and the impact of global warming are pushing building owners toward a higher level of energy efficiency. The challenge is that buildings must be efficient while at the same time supporting the overall goals of any building project including architectural integrity, operational viability and efficiency, and occupant comfort. The result is the need for a high performance building with a building system that delivers greater efficiency without sacrificing function or comfort. Furthermore, high performance buildings require competent and knowledgeable managers and technicians to maintain their performance at optimum levels. At a high level, leading industry organizations and experts identify this overall trend and the workforce needs to support it:

World Business Council for Sustainable Development:	*"The three-sided demands of energy efficiency, emissions, and sustainability will be the key macro-drivers that will drive demand for highly skilled and cost effective operation and maintenance of buildings."*[2]
American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE):	*"As we are challenged to improve the performance of buildings, a skilled engineering and technical work-force is necessary to assure that buildings are properly designed, constructed and maintained."*[3]
Lawrence Berkeley National Laboratory and The Alliance to Save Energy:	*"There will be new job opportunities for people with enhanced technical skills to design, construct and operate zero energy buildings. In an era when many jobs are being lost to overseas outsourcing there is an opportunity here to create a massive number of skilled, high paying technical jobs."*[4]

Forces influencing and shaping the future of facility management and building operations range from the global issues of energy and emissions down to the people and processes that make buildings work. Influencing forces span market and industry-specific trends, the legislative and regulatory environment, and building systems and technologies. All of these forces appear to be converging on and supporting a transition to high performance green buildings. Figure 3 illustrates this convergence, while Figure 4 summarizes the key trends.

[2] (World Business Council for Sustainable Development, 2009)
[3] (ASHRAE, 2008)
[4] (Selkowitz, Granderson, Haves, Matthew, & Harris, 2008)

Figure 3: Trends Supporting the Development of High Performance Buildings

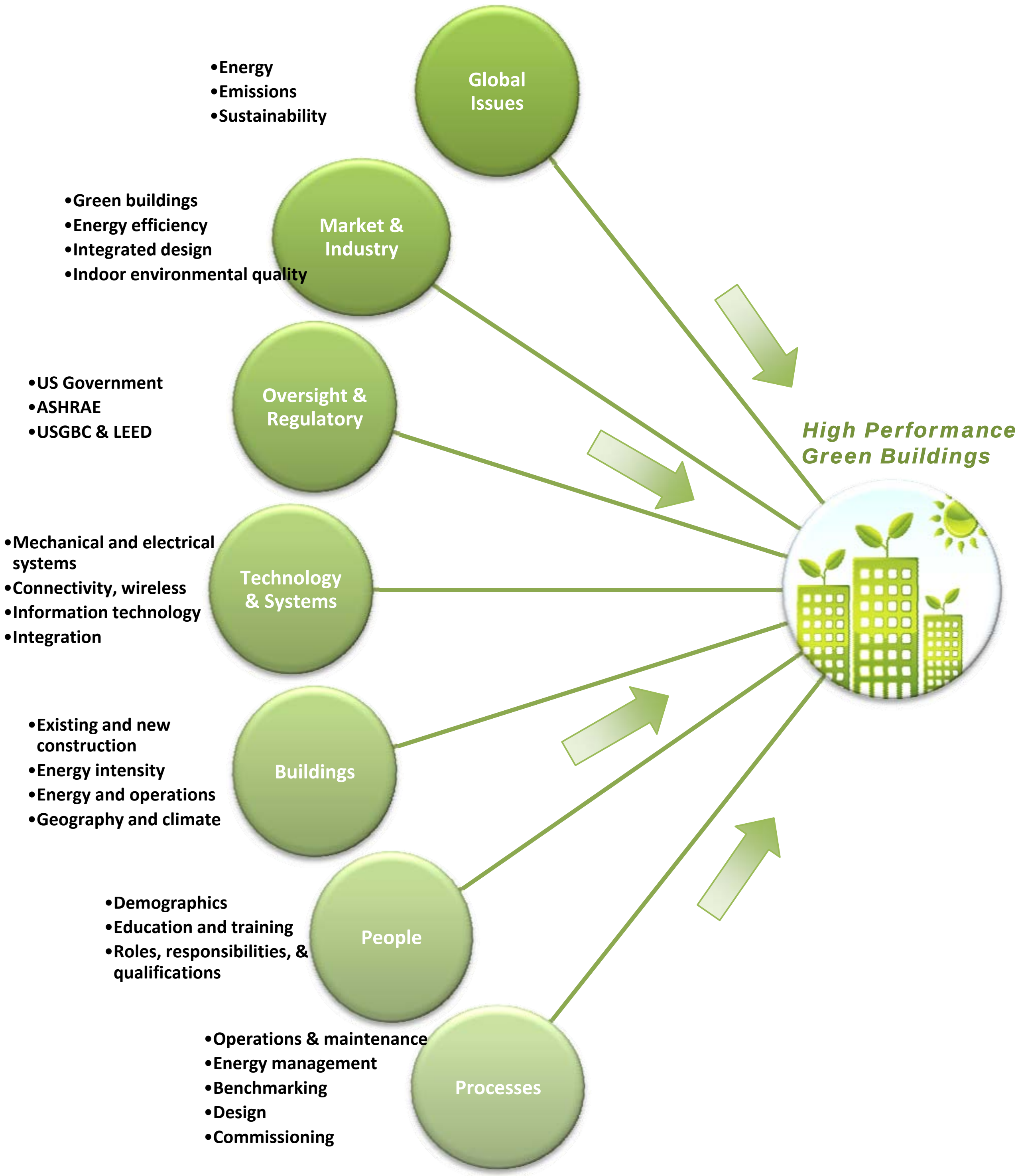


Figure 4: Summary of trends

Global Issues

- Energy: Rising costs, increasing uncertainty.
- Emissions: Climate change is underway, GHG emissions fell in 2008, but continue to increase overall.
- Sustainability: Momentum continues to build for sustainability.

Market & Industry

- Increasing demand for green buildings.
- Mounting focus on energy efficiency as the first priority.
- Increased availability of public and private financing.
- Growing recognition of financial value in green and sustainable buildings.
- Increased awareness of indoor environmental quality.

Oversight & Regulatory

- Increasing mandates and support for energy efficiency and renewable energy, including federal high performance green buildings.
- Increasingly stringent energy codes.
- Increasing emphasis on energy and O&M in LEED.

Technology & Systems

- Experimentation with new mechanical and electrical systems.
- Convergence of information technology with building systems.
- Pervasive connectivity and wireless communications.
- Emergence of middleware, enterprise applications, and dashboards.

Buildings

- Vast existing building stock presents a massive opportunity.
- Wide variation in geography and climate presents challenges.
- Wide variation in needs according to a building's principle activity.
- Shrinking budgets and resources for O&M result in decreasing performance.

People

- Changing demographics and generational transition.
- Recogntion of rapidly changing education and training needs.
- Evolving roles, responsibilities, and qualifications including direct responsiblity for energy/sustainability, and recoginition of the importance of technology and networks.

Processes

- Mounting awareness of operations and maintenance as crtical.
- Increased focus on and understanding of energy management.
- Recognition of the need and value of process-oriented and proactive approaches amidst a largely reactive practice.

4.1 Global Issues: Energy, Emissions and Sustainability

When considering the potential needs and opportunities in commercial buildings, and the needs of the people that operate and maintain buildings, three large global issues supersede all others:

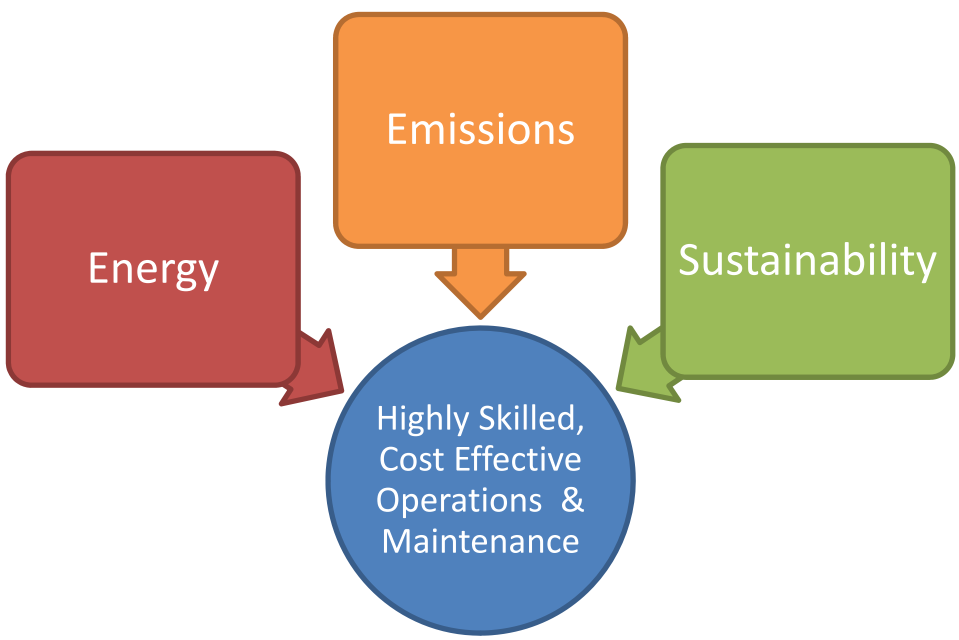
- Energy
- Emissions
- Sustainability

A continued increase in momentum is anticipated for energy efficiency, greenhouse gas emissions reduction, and sustainability. Buildings are a key confluence where these issues all come together. Key trends pertaining to these global issues are:

1) ***Energy costs are projected to rise slowly but steadily over the long term. More importantly, without significant changes the reliability and availability of energy may become increasingly uncertain.***
2) ***As smart grid is deployed load shedding, demand response, and smart metering are anticipated to become more widely used.***
3) ***Greenhouse gas emissions, and in particular, carbon dioxide emissions, will continue to rise over the long term. The rate of increasing emissions will depend largely on the course of energy consumption and the associated actions.***
4) ***The basic philosophy of sustainability will continue to gain momentum, and the associated practices and technologies will continue to evolve toward greater complexity.***

These global issues and trends are the driving forces behind the collective push to high performance green buildings, and the associated workforce needs (Figure 5).

Figure 5: Issues driving workforce needs



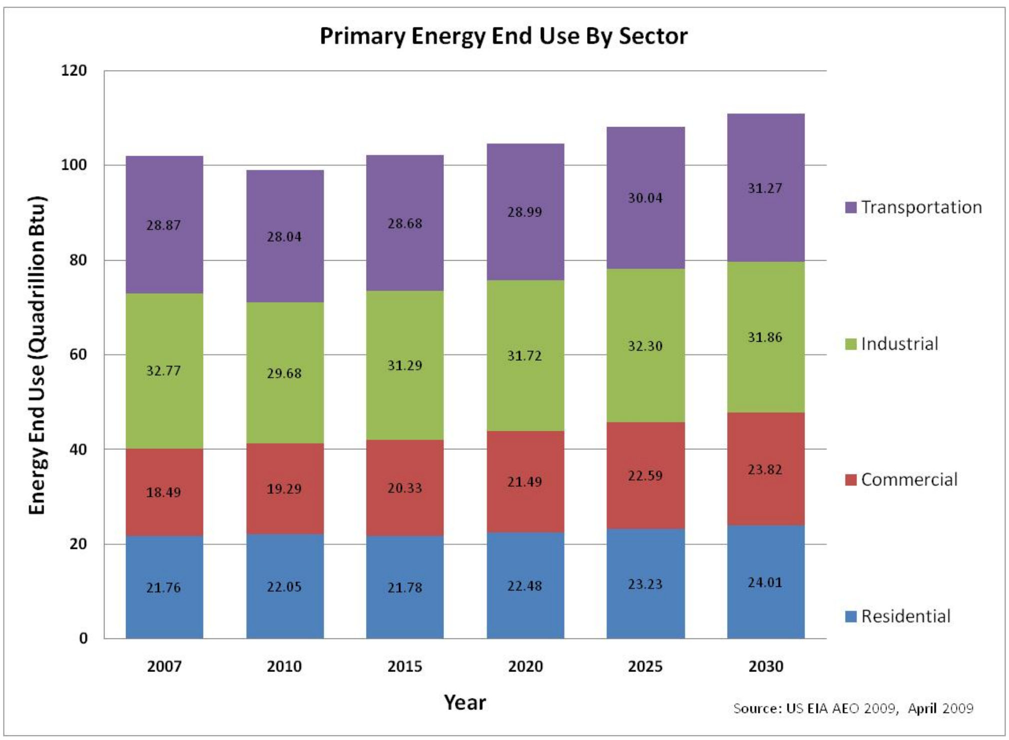
4.1.1 Energy Use Projections

With an increasing global population and the aspirations of developing nations for economic prosperity and higher standards of living, the availability and cost of energy are critical issues. Illustrating the impact of population growth on the demand for energy, New York Times columnist Thomas Friedman speculates on the hypothetical question of providing each of the next billion people with a 60-Watt light bulb: “Yikes, looks like we’ll need twenty new 500 Megawatt coal-burning plants just so the next billion people can each turn on one 60-Watt bulb 4 hours a day.”[5]

The U.S. Energy Information Administration (EIA) projections of U.S. energy consumption by the end use sector show that energy consumption in commercial buildings will experience the largest percentage growth. In Figure 6, the size of the red bars (second from the bottom) labeled as commercial increases about 5.3 quadrillion British thermal units between 2007 and 2030. Within these projections it is important to note:

- Electricity consumption will lead the way in commercial energy use.[6]
- Technology will provide energy savings, with the greatest savings contributed by improved building envelopes, improved heat exchangers, solid-state lighting, and more efficient refrigeration compressors.

Figure 6: Projected energy end use by major sector



As shown in Figure 7, buildings are the largest consumers of energy as well as other natural resources. Furthermore, within the United States buildings account for:[7]

- 72% of electricity consumption
- 39% of energy use
- 38% of all carbon dioxide (CO_2) emissions

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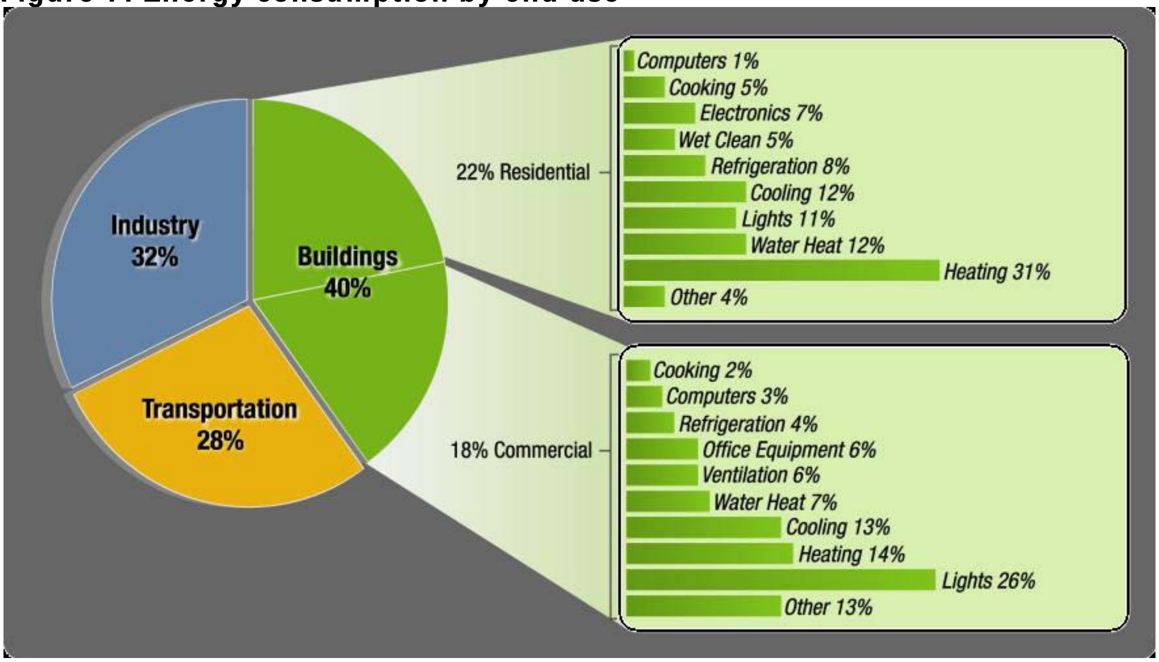
[5] (Friedman, 2009)
[6] (U.S. Energy Information Administration, 2009)
[7] (USGBC, 2009)

- 40% of raw materials use
- 30% of waste output (136 million tons annually)
- 14% of potable water consumption

Figure 7: Energy consumption by end use[8]



Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy

Multiple organizations have made projections for future energy consumption, including the United States Energy Information Administration (U.S. EIA) and the Electric Power Research Institute (EPRI). Within the U.S. EIA projection, historical data is used to predict future rates. As a result, the U.S. EIA projections are relatively flat (Figures 8 and 9) for both short-term and long-term energy price projections of commercial natural gas and electricity. It should be noted that these cost projections also account for the effects of the American Recovery and Reinvestment Act on energy consumption and efficiency. More specifically, the projections include the impacts of the following energy-specific provisions within legislation:

- Weatherization and assisted housing
- Energy efficiency and conservation block grant programs
- State energy programs
- Plug-in hybrid vehicle tax credit
- Electric vehicle tax credit
- Updated tax credits for renewable energy
- Loan guarantees for renewable energy and bio-fuels
- Support for carbon capture and storage (CCS)
- Smart grid expenditures

[8] (U.S. Department of Energy, Energy Efficiency and Renewable Energy, 2008)

Figure 8: Short-term energy price history and outlook[9]

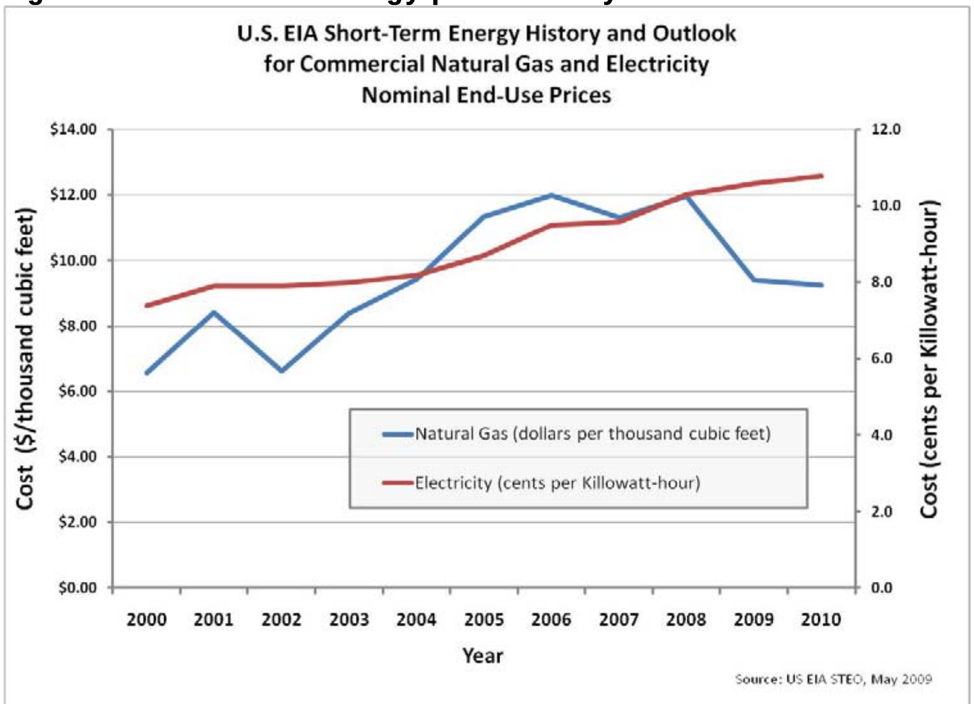
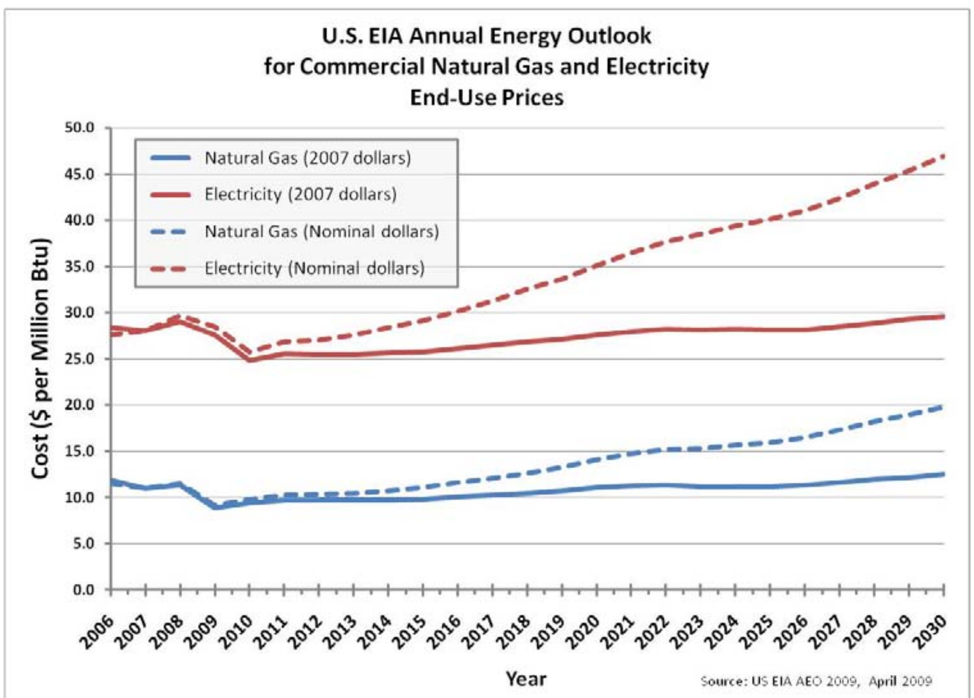


Figure 9: Long-term energy price outlook[10]

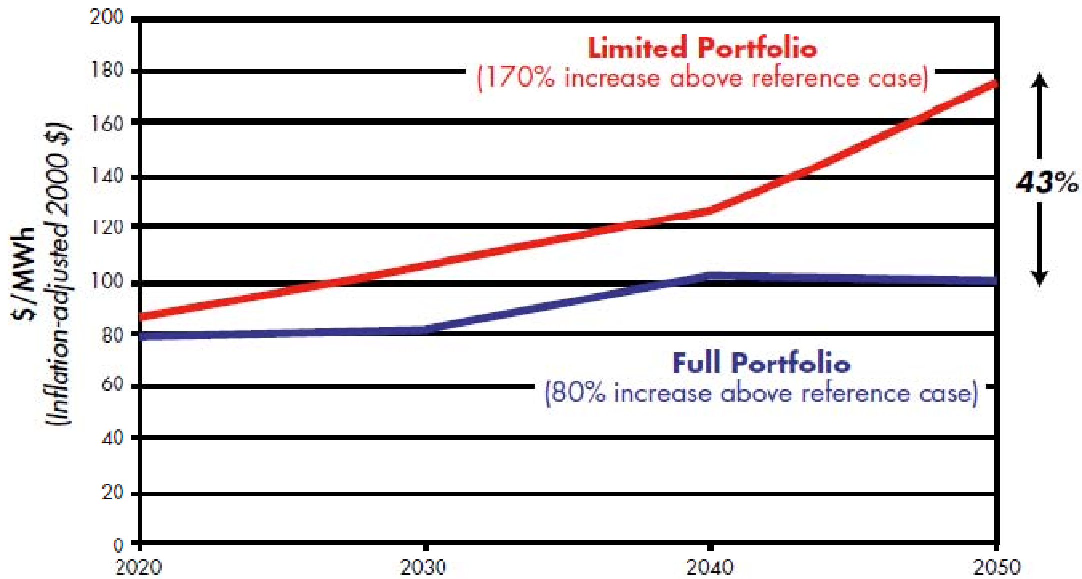


A second source of energy price projections is the EPRI Prism/MERGE Analysis. This analysis is based on projections related to the control of carbon emissions by

[9] (U.S. Energy Information Administration, 2009)
[10] (U.S. Energy Information Administration, 2009)

government through potential cap-and-trade programs. As shown by Figure 10, if carbon cap-and-trade becomes a reality, energy costs and prices are projected to rise more rapidly over time that current energy rate increases.

Figure 10: MERGE Analysis Results



The 2009 Prism analysis included a detailed assessment of potential carbon dioxide emissions reductions in eight technology areas within the electricity sector including end-use efficiency, transmission and distribution efficiency, renewable, nuclear and fossil fuel efficiency, carbon capture and storage, electric transportation, and electro-technologies. The 2009 MERGE (Model for Estimating the Regional and Global Effects of Greenhouse Gas Reductions) analysis studied the optimum economical technology portfolio of different carbon dioxide emissions limits for different policy proposals. The MERGE analysis included two technology scenarios, the limited and the full portfolio, as shown in Figure 10. The limited portfolio assumes that carbon capture and storage (CCS) is not fully deployed and the nuclear fleet has not been expanded. The full portfolio assumes availability of CCS, advanced nuclear technology, significant improvement in the costs of renewable energy technologies, availability of plug-in hybrid electric vehicles, and accelerated improvements in end-use efficiency.

From Figure 10, the MERGE analysis concludes that by 2050, wholesale electricity prices of the full portfolio are 43 percent less than the limited portfolio. However, much of the technology within the full portfolio is not currently commercially available. The study concludes that the full portfolio technologies should be further studied and developed to reduce emissions levels.[11]

[11] (EPRI 2009)

4.1.2 Emissions

Green house gas (GHG) emissions are increasingly linked to global climate change, and "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level".[12]Carbon dioxide emissions make up the largest component of GHG emissions, growing 80 percent between 1970 and 2004.[13] U.S. emissions of carbon dioxide fell slightly in 2008, decreasing by 2.8 percent from 5,967 million metric tons of carbon dioxide ($MMTCO_2$) in 2007 to 5,802 $MMTCO_2$ in 2008. This was primarily due to increased energy prices and slower economic growth. According to the U.S. EIA Annual Energy Outlook 2009, this decrease appears to be a lull amidst projections that call for carbon dioxide emissions to increase to between 5,989 and 6,886 $MMTCO_2$ by 2030.[14] As a point of comparison, prior projections in 2007 by the U.S. EIA forecasted higher levels of CO_2 emissions in 2030 by 35 percent.[15]

Table 5: Projected CO2 Emissions[13]

U.S. EIA Annual Energy Outlook	Projected CO_2 Emissions in 2030 ($MMTCO_2$)
2009	5,989 to 6,886
2008	5,802
2007	5,967

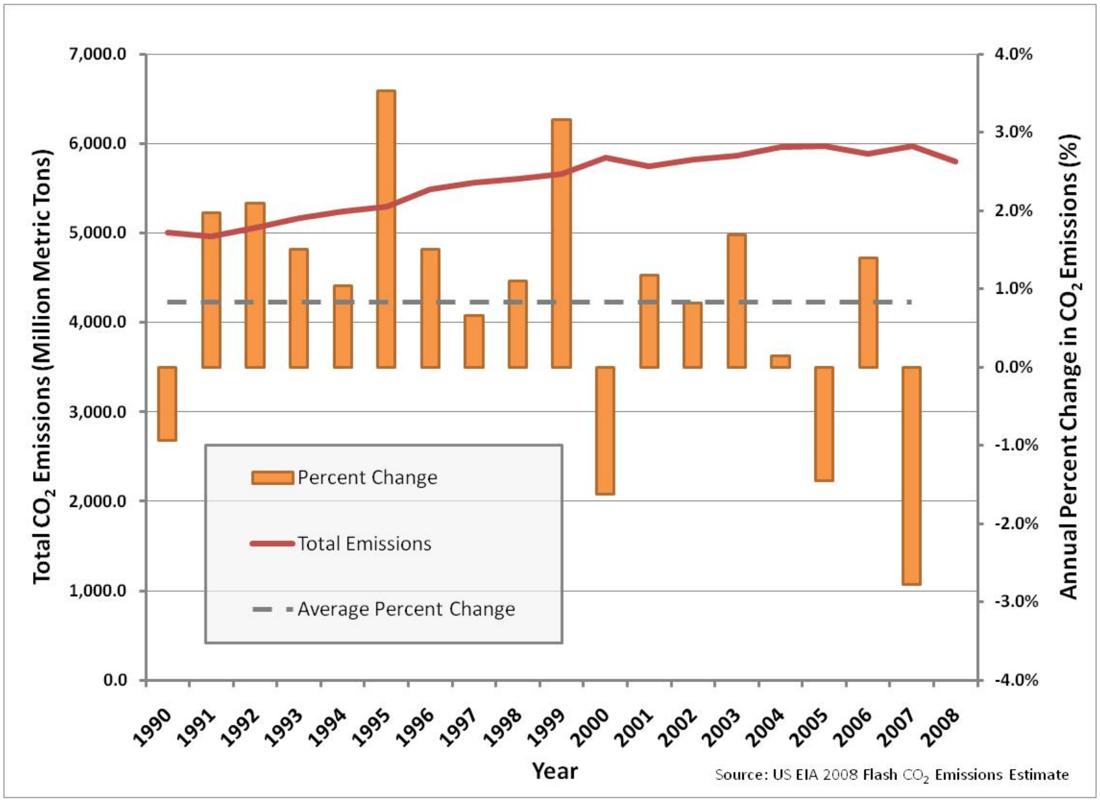
The most recent work of the U.S. Global Change Research Program calls out trends that are evident of apparent climate change, including:

- Rising temperatures
- Increasing heavy downpours
- Rising sea level
- Longer growing seasons
- Reductions in snow and ice
- Changes in the amounts and timing of river flows

The report goes on to explain that the changes and associated impacts are already underway and expected to grow over time.[16] However, there is evidence of a growing global and national political consensus that emission generation rates should be slowed, slowing any impacts of climate change and the severity of the impact.

[12] (International Panel on Climate Change, 2007)
[13] (International Panel on Climate Change, 2007)
[14] (U.S. Energy Information Administration, 2009)
[15] (U.S. Energy Information Administration., 2008)
[16] (U.S. Global Change Research Program, 2009)

Figure 11: Annual total and percent change in U.S. CO_2 emissions



As a component of mitigation efforts, GHG emissions reduction goals are ambitious, and Table 6 lists some established goals.

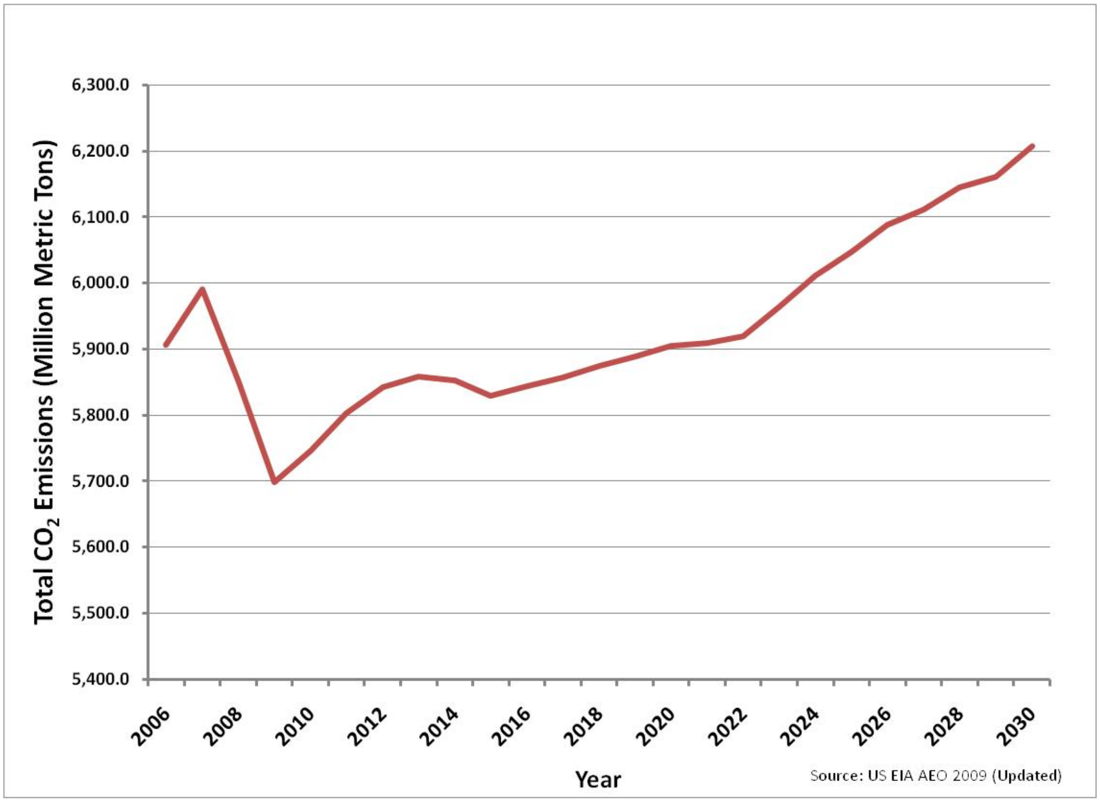
Given that buildings are one of the largest consumers of energy, they are also one of greatest sources of CO_2 emissions, contributing to 30 percent of U.S. GHG emissions. A comprehensive strategy to reduce GHG emissions and address climate change must therefore advance energy efficiency in buildings.[17]

Table 6: CO_2 emissions reduction goals

Entity / Organization	Emission Reduction Goal	By Year
IPCC	80%	2050
G8 Countries	50%	2050
California	30%	2020
Obama Administration	85%	2050

[17] (Hogan, 2009)

Figure 12: Projected U.S. CO_2 emissions



Forthcoming legislation, presently known as the American Clean Energy and Security Act of 2009, proposes carbon cap-and-trade as part of a global warming reduction plan designed to reduce economy-wide GHG emissions 17 percent by 2020. Other provisions include, but are not limited to, new renewable requirements for utilities, studies and incentives regarding new carbon capture and sequestration technologies, energy efficiency incentives for homes and buildings, and grants for green jobs. This Act passed in the House of Representatives in June of 2009 and, at the time the research was being conducted, was pending action in the Senate. Even if the Act does not pass, in a 2007 decision (Massachusetts v. EPA, 549 U.S. 497) the Supreme Court ordered the U.S. EPA to determine if carbon dioxide is a pollutant that endangers public health and welfare. An affirmative answer to this question, issued in an "Endangerment Finding" in April of 2009, set the stage for the EPA to regulate carbon dioxide under the Clean Air Act. In September 2009, the EPA announced that, beginning on January 1, 2010, large emitters of heat-trapping emissions will be required to begin collecting GHG data under a new reporting system. This new program is anticipated to cover approximately 85 percent of the nation's GHG emissions and apply to roughly 10,000 facilities.[18]

4.1.3 Sustainability

Green and sustainable are becoming market drivers for both commercial and residential buildings. In the media, sustainability has garnered a great deal of press coverage. From newspapers to industry trade journals to television and Internet, "green" is ubiquitous. This is especially true for commercial buildings.

[18] (U.S. EPA, 2009)

Sustainability is defined as "meeting the needs of the present generation without compromising the ability of future generations to meet their needs."[19] To support this definition, the triple bottom line, (the balance between environmental, economical, and social impacts), is often applied. In the building sector, sustainability is a broad topic spanning building materials, energy generation and consumption, water efficiency, indoor environmental quality, and recycling. When it comes to buildings, sustainability penetrates the processes of design, construction, operations, maintenance, and cleaning. While sustainability efforts initially focused on design and construction, there is a growing understanding that it must be applied to the whole building life cycle. To this end, owners of buildings are seeking ways in which to quantify and measure sustainability and the effectiveness of their efforts to produce more sustainable enterprises.

Although there are many definitions of what green is or is not, the term green primarily focuses on environmental stewardship and efficient resource consumption. Often, the terms sustainability and green are used interchangeably, despite differences in definition.

As we go forward in time, sustainability and green will continue to be driving forces in the commercial buildings marketplace. Similar to energy conservation, it is expected to motivate, but perhaps less directly, the adoption of new technology in commercial buildings. It will very likely become part of the mainstream practice of designing, engineering, constructing, and operating buildings. In fact, the philosophy of sustainability may ultimately drive a major global transformation, a "green revolution". New York Times columnist Thomas Friedman characterizes the transition of green to mainstream practice by describing the "green revolution":

> *"You'll know the Green Revolution is happening when companies have to change or die, and when the word 'green' disappears. You'll know the green revolution is here when in Minneapolis and St. Paul, there will be no such thing as a 'green building', there'll just be a building, and you will not be able to build it unless it's at the very highest levels of energy efficiency and sustainability. There will be no such thing as a 'green car', there'll just be a car, and you will not be able to manufacture it except at the highest levels of mileage and energy efficiency. You'll know the green revolution is here when the word 'green' disappears."* [20]

4.2 Buildings

Observations and trends regarding buildings in the United States include these seven items:

1) ***Existing buildings present a massive opportunity for energy efficiency and operations improvements.***
2) ***There is a vast existing building stock in the United States: 4.9 million buildings.***
3) ***Small buildings are numerous relative to large buildings.***
4) ***The majority of gross floor space resides in buildings between 10,000 and 200,000 gross square feet.***
5) ***There is a fairly even distribution of building population and size across geography and climate.***
6) ***On average, energy intensity increased through and peaked in the 1980's, and has since declined.***

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[19] (Brundtland 1987)
[20] (Friedman, 2009)

7) ***Energy costs are often well understood, but maintenance and operating costs are not as well established, and vary significantly. Furthermore, operations budgets are decreasing over time.***

These trends are further described in Table 7.

Table 7: Existing building portfolio – observations and trends

Characteristic	Observations & Trends
Size	• Most buildings are relatively small, with gross floor space less than 50,000 square feet.
Age	• Building age spans a wide range, with the largest segment of the building population constructed between 1970 and 2000; thus, they are between 10 and 40 years old.
Geography & Climate	• Building populations in the Midwest and South are larger than those in the Northeast and West. • However, buildings and floor space are fairly evenly distributed across climate zones in the United States.
Principle Activity	• The top three largest uses of building space by number of buildings are: 1) Office space; 2) Mercantile; 3) Warehouse/storage.
Energy Sources	• Electricity is the largest source, accounting for 45% of energy supplied to buildings. • Natural gas accounts for 35% of energy supplied to buildings. • District heat and fuel oil make up the remainder.
Energy Intensity and Expenditures	• The top three consumers of energy with the highest EUIs by principle activity are: 1) Food service; 2) Food sales; 3) Healthcare. • Both average energy intensity and expense peaked in buildings constructed between 1980 and 1990.
End Use Consumption	• The greatest end use of energy in buildings is HVAC at about 40%. • Lighting is the second largest consumer at about 20%.
Energy Management Systems	• Roughly one quarter to one third of existing buildings have energy management and control systems. • Many fewer have lighting control systems.
Operations & Maintenance Expenditures	• Between 1979 and 2005, maintenance costs have risen about 10% to 15% per year.[21]
Construction & Renovation	• The volume of new construction and renovation of existing buildings changes with economic conditions. In November 2008, Engineering News-Record reported an 8% decline in new construction in 2007, a forecasted 7.4 % decline in 2009, with a continued decline expected in 2010.[22] • Renovation of existing buildings is projected to increase, especially as funds from the American Recovery and Reinvestment Act of 2009 are distributed.

[21] (Ring 2008)
[22] (Grogan 2008)

4.2.1 Number of Buildings and Floor Space

There is a broad base of existing commercial buildings, 4.9 million in the U.S. alone, and a large volume of new facilities constructed annually (see Table 8).While most of the industry press appears to focus on the newest and greenest of buildings, the industry itself is slowly turning its attention to the existing building stock as a massive opportunity to cut energy consumption and GHG emissions. Figures 13 to 26 characterize the composition of the existing building stock and key parameters such as energy intensity and cost.

Table 8: Existing building statistics

Existing buildings:	4.9 million
Floor space:	72 billion sq. ft.
Floor space per building:	Mean: 14,700 sq. ft. Median: 5,000 sq. ft.
Energy consumed:	6.5 trillion BTU

Figure 13: Building size distribution

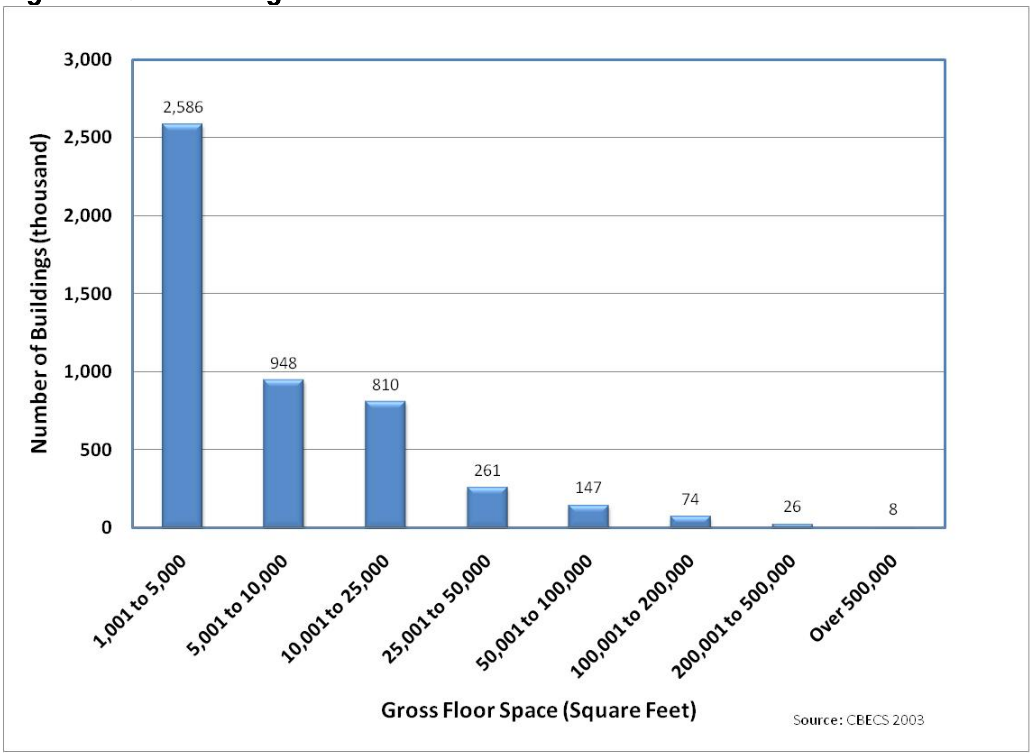
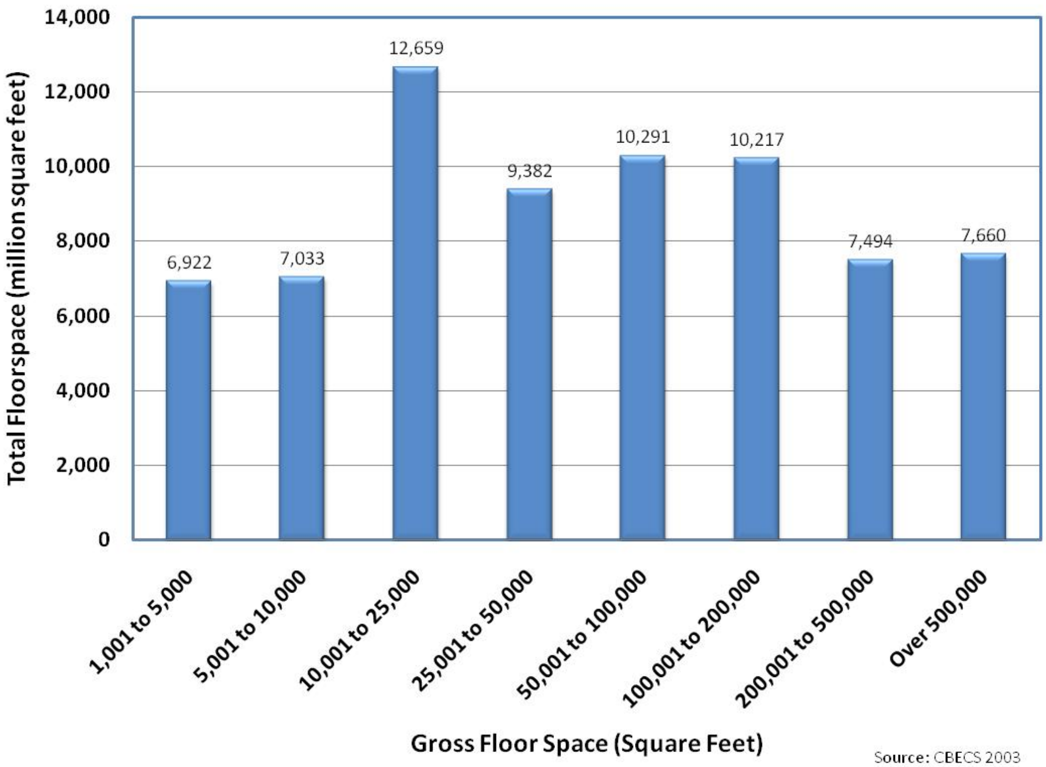


Figure 14: Floor space distribution



Figures 15 to 22 graphically summarize the number of buildings by geography and climate, age, energy sources, and principle activity. From Figures 15 and 17, calculating quantity of buildings and floor space, the southern part of the United States has the largest number of buildings. When buildings are classified by climate and quantity of buildings, the largest number of buildings is located within climates with less than 2,000 cooling degree days (CDD) and less than 4,000 heating degree days (HDD). When classified by climate and floor space, the largest category is buildings with less than 2,000 CDD and between 5,500 and 7,000 HDD.

Figure 15: Distribution of buildings by geography

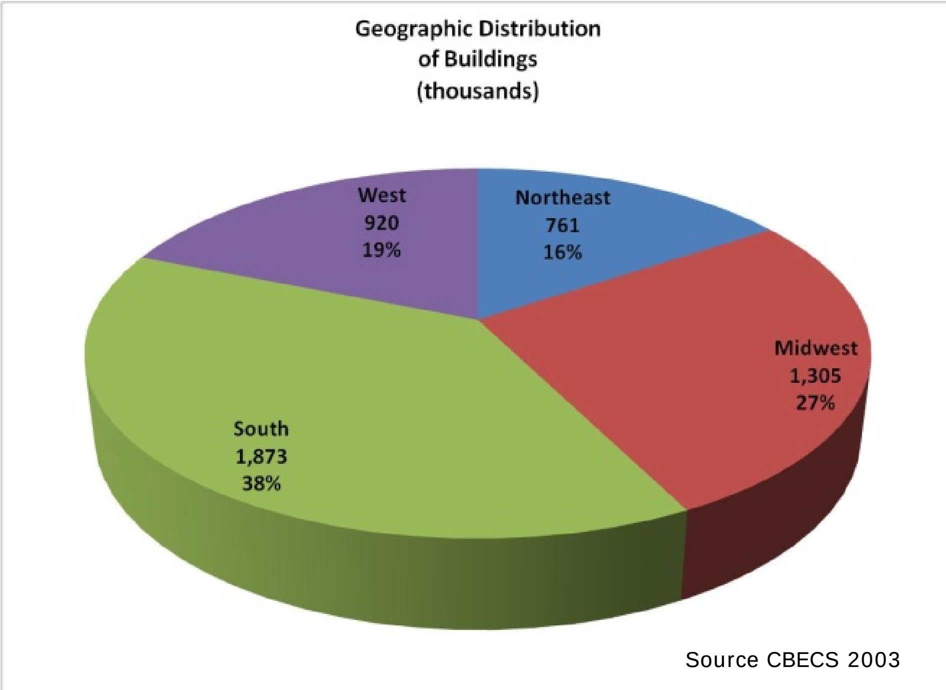


Figure 16: Distribution of buildings by climate

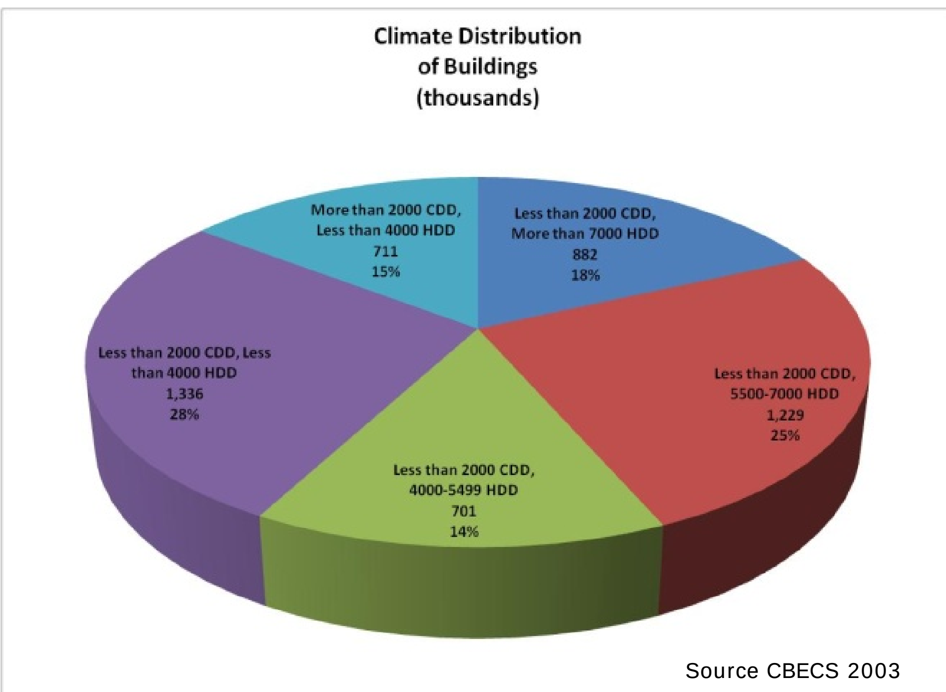


Figure 17: Distribution of floor space by geography

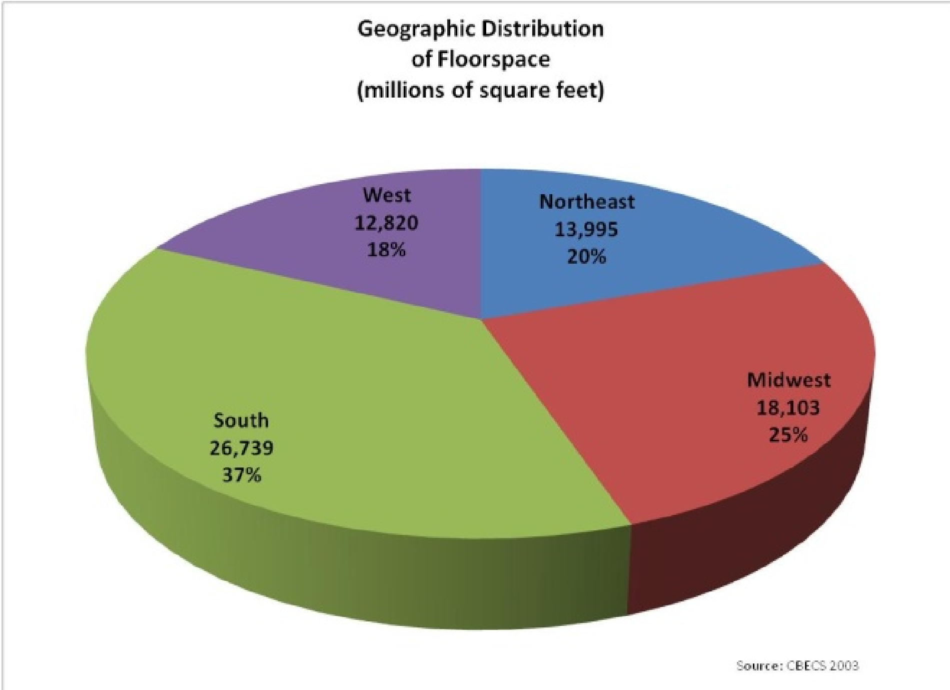


Figure 18: Distribution of floor space by climate

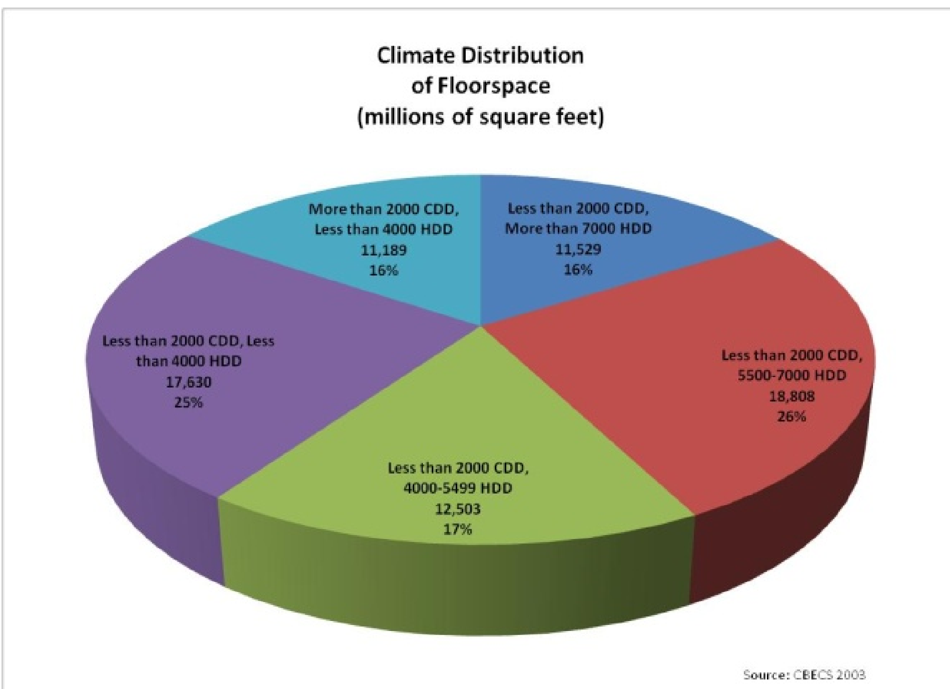
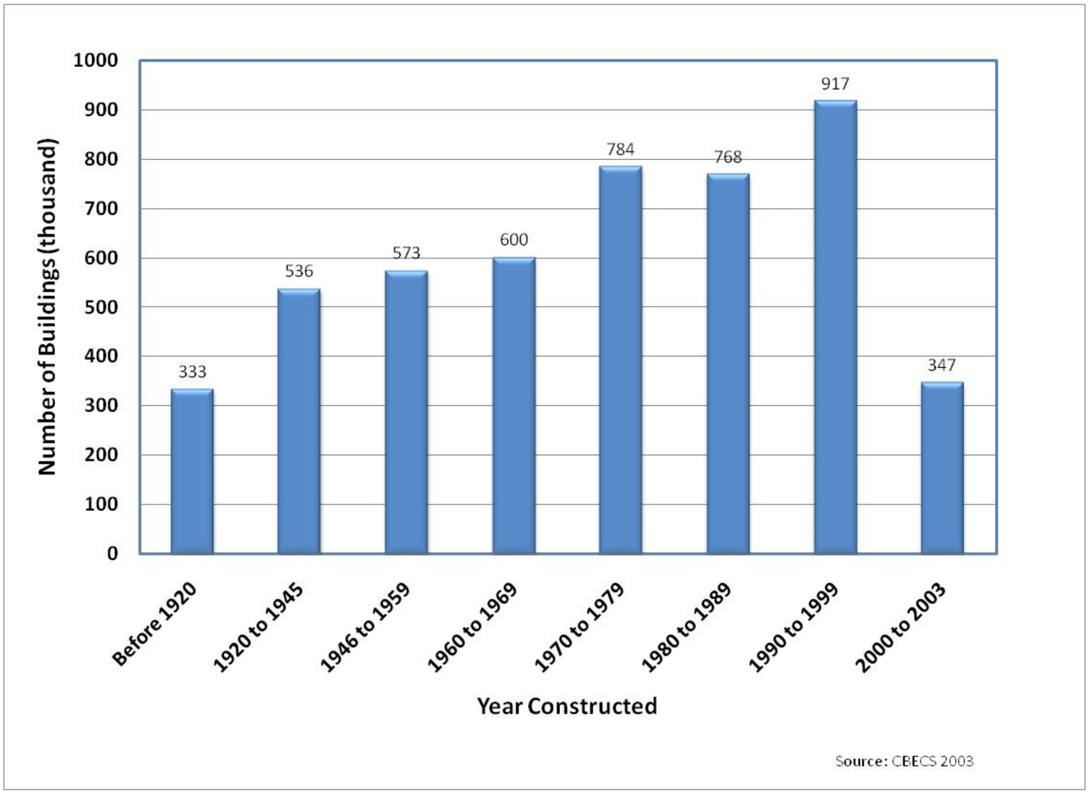
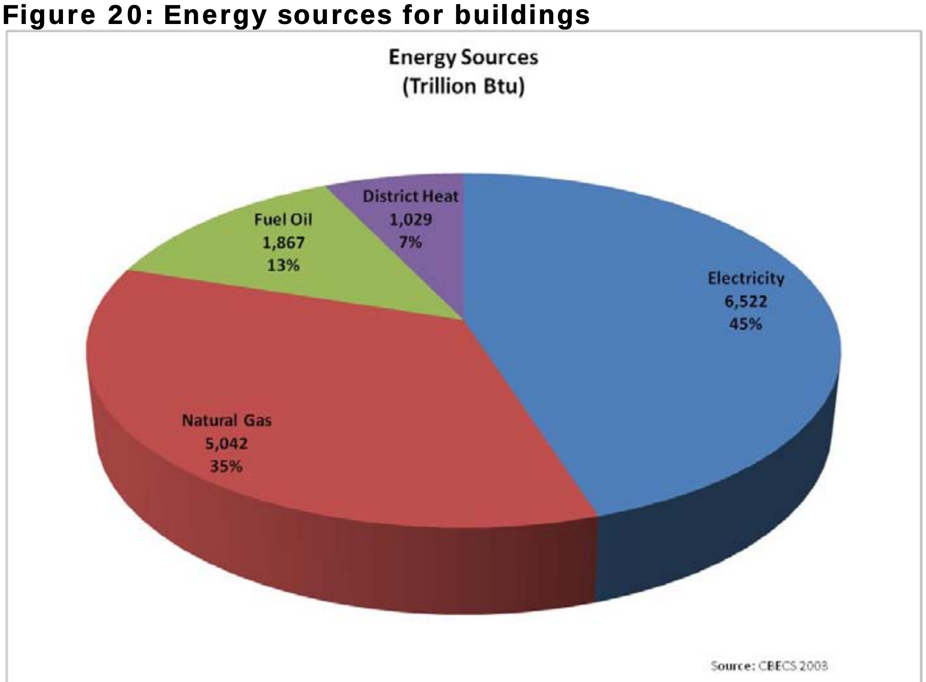


Figure 19: Distribution of buildings by age



From Figure 19, most buildings within the United States where built between 1970 and 1999, with the largest percentage between 1990 and 1999.

Figure 20: Energy sources for buildings



As shown in Figure 20, electricity and natural gas are the two largest energy sources used within buildings.

The principle activities within buildings, as identified by Figure 21, are office, mercantile, and service. When principle activities are classified by square footage, office, mercantile, and warehouse and storage make up the three largest use categories (Figure 22).

Figure 21: Principle activity by number of buildings

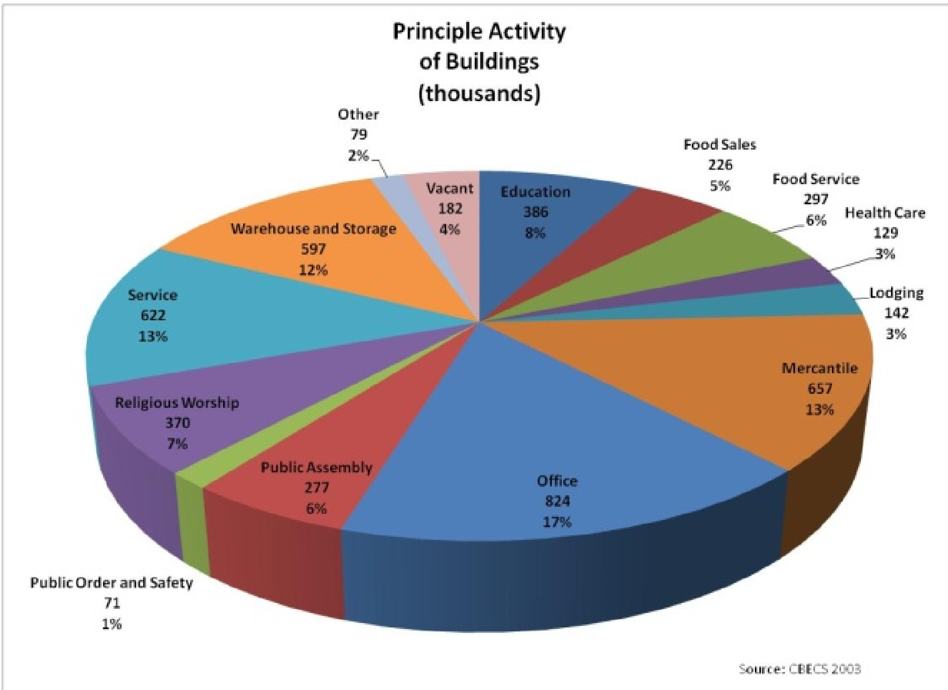
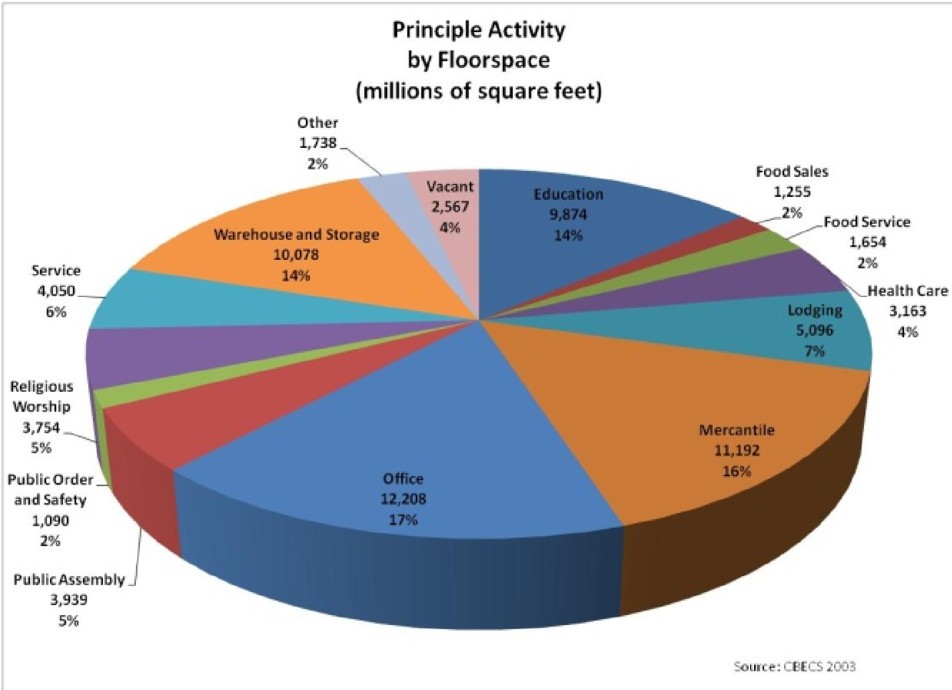


Figure 22: Principle activity by floor space



4.2.2 Energy Intensity and Expenditures

Figures 23 to 25 classify energy intensity and expenditures. Figures 23 and 24 show that the two greatest and most intensive energy expenses are food service and food sales. Figure 25 concludes that for buildings constructed before 2003, buildings built between 1980 and 1989 have both the highest energy intensity and greatest energy cost per square foot.

Figure 23: Energy intensity by principle activity

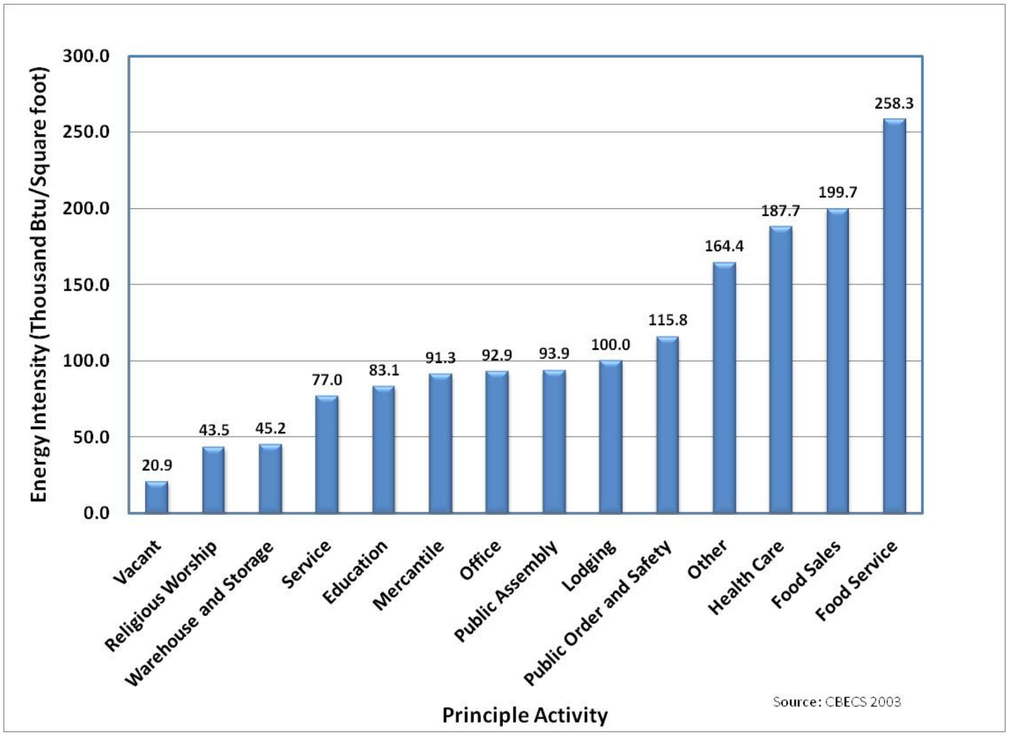


Figure 24: Energy expense by principle activity

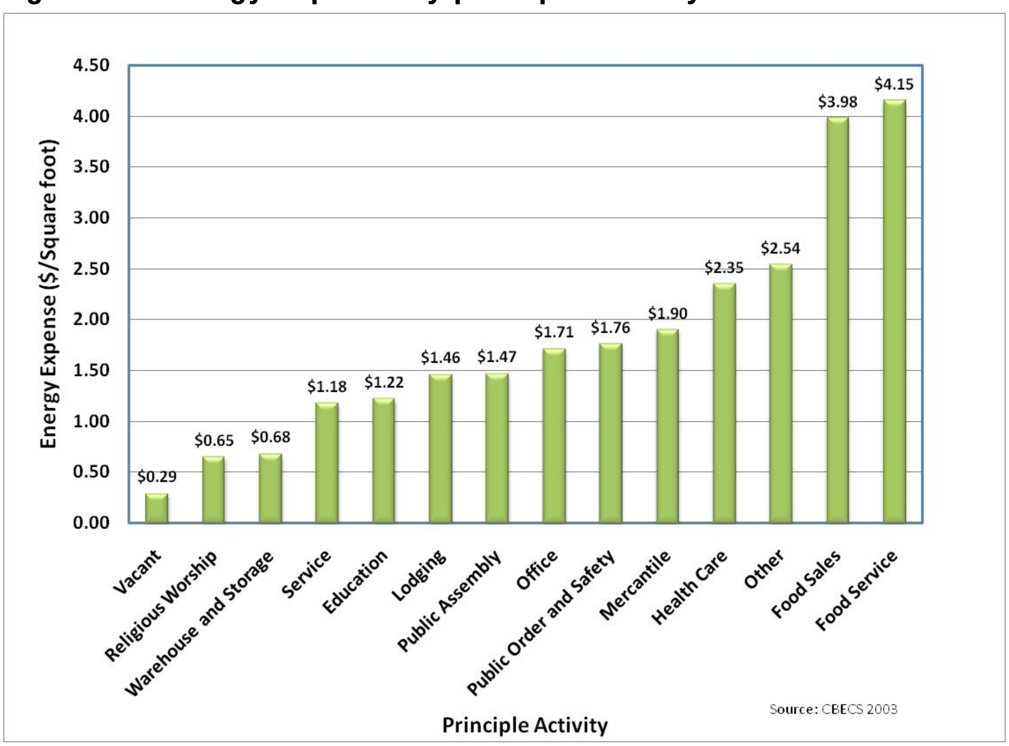
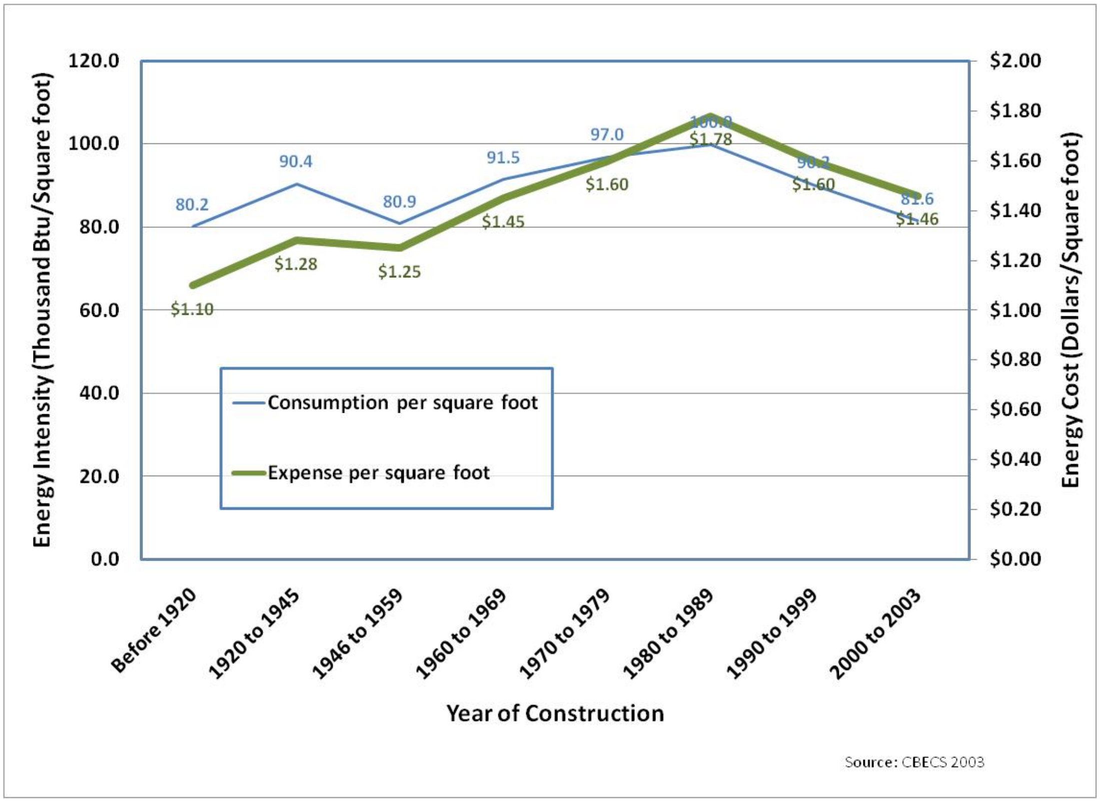


Figure 25: Energy intensity and expense by age



Synthesizing Figures 13 to 25, the following should be considered when developing building controls technician training programs:

- Building area:
  - Physical number of buildings: When tallying the quantity of all existing buildings, most are 5,000 square feet or less (Figure 13)
  - Total floor area: By floor space distribution, most buildings are 10,000 to 25,000 square feet (Figure 14)
- Geography: The south and Midwestern parts of the U.S. have the largest number of buildings by both floor space and physical number.
- Age of buildings: Building age varies widely. However, most buildings were constructed between 1970 and 1999.
- Energy use: Most buildings use electricity and/or natural gas.
- Building function:
  - By quantity: Office, mercantile, service, and warehouse and storage are the principle activities.
  - By floor area: Office, mercantile, warehouse and storage, and education are the principle activities.
- Energy intensity and expenditures:
  - Principle activity: Food service is the largest consumer of energy in units of energy intensity and cost.
  - Building age: When comparing all buildings constructed before 2003, buildings constructed between 1980 and 1989 have the highest energy intensity.

Given the above synthesis, training programs for controls technicians should focus primarily on:

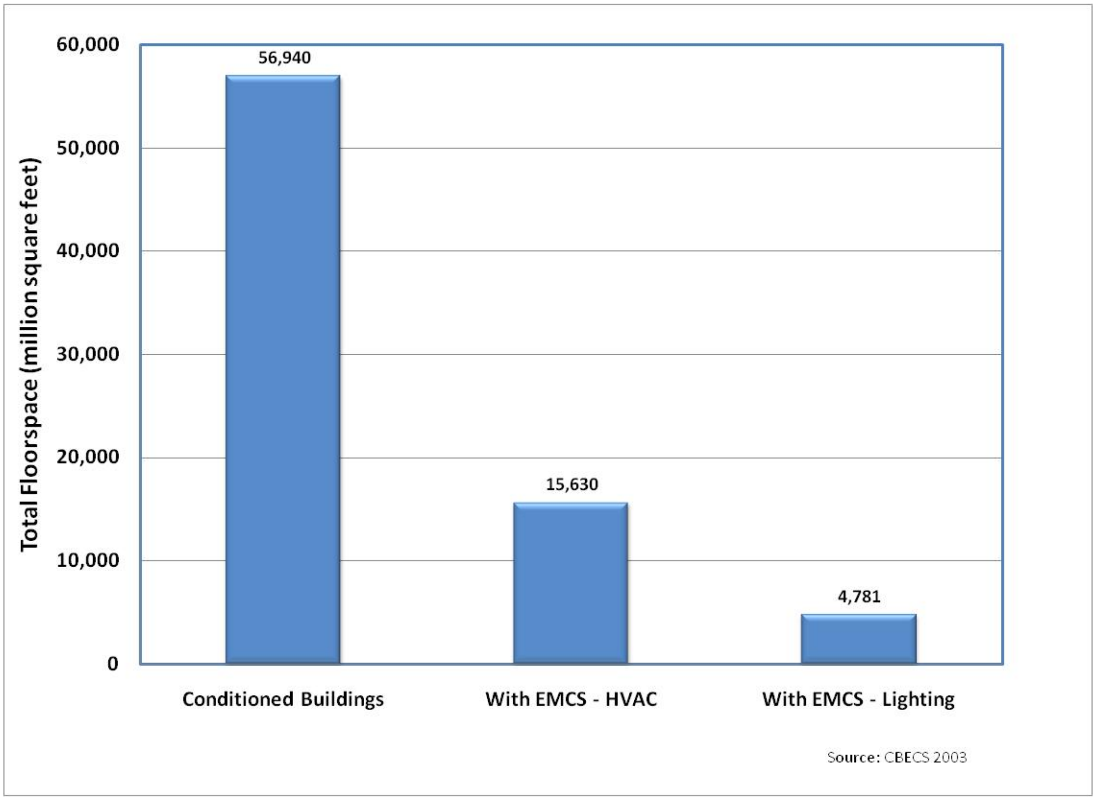
- Small buildings, both less than 5,000 square feet and between 10,000 and 25,000 square feet.
- Existing buildings and controls technologies within existing buildings, especially those installed between 1970 and 1999 that are likely to still be in use.
- Control systems and equipment typically found in offices, mercantile, warehouse and storage, educational, and food service facilities.

4.2.3 Buildings with Energy Management Systems

To provide an estimate of the overall penetration of building automation and energy management systems in commercial buildings, the research team synthesized the U.S. Energy Information Administration's CBECS (Commercial Buildings Energy Consumption Survey) data (Figure 26) in conjunction with some assumptions. According to CBECS, about one third of commercial floor space has some type of energy management and control system (EMCS) installed. In order to further characterize the population of buildings with EMCS, the following assumptions are applied:

- **Size:** Buildings with EMCS systems tend to be larger, with more than 25,000 square feet of gross floor space. Buildings smaller than 25,000 square feet are more likely to have control systems similar to residential buildings, such as programmable thermostats and light switches.
- **Age:** Buildings with EMCS systems installed are primarily newer, constructed within the last 15 years. Buildings constructed before 1995 tended to have mechanical or pneumatic control systems.

Figure 26: Building with EMCS by floor-space



Note that this data provides a fairly rough estimate of the population of buildings with EMCS, and a few additional considerations apply:

- **Large versus small commercial buildings:** While 53 percent of U.S. commercial buildings are below 5,000 square feet, these only account for 10 percent of the total floor space. In fact, roughly 35 percent of commercial floor space is in buildings smaller than 25,000 square feet (considered as small buildings) and the remaining 65 percent in buildings above 25,000 square feet (considered as large buildings).
- **Conditioned space:** CBECS data encompasses all commercial buildings, including those that are not conditioned, such as warehouses. For purposes of this study, only those buildings with conditioned space are relevant to estimating the percentage with any form of energy management.
- **Measurement criteria:** Note that CBECS defines EMCS simply as a system that provides control of temperature changes for heating and/or cooling. The researchers suspect that the survey may undercount these systems. We also believe that, due to evolution of system technology in recent years, the percentage of buildings with EMCS should be growing over time. In the 2007 CBECS data, which is not yet available, the researchers expect to see an increase in the percentage of floor space covered by EMCS.

4.2.4 Operations and Maintenance Expenditures

According to a recent research report by the International Facility Management Association (IFMA) on operations and maintenance benchmarks, operations and maintenance expenditures fluctuate based on a variety of variables. The primary factors include:

- Climate
- Location
- Building age
- Principle activity / usage

For purposes of this report, average operations and maintenance costs provided by IFMA are summarized in Table 9, and selected average staffing levels are provided in Table 10.

Table 9: Average maintenance and operations expenses[23]

Expense	$ per square foot	Includes
Maintenance	$2.22	External building, interior systems, roads and grounds, utility and central plants, and process and environmental systems.
Operations	$6.54	Includes operations, maintenance, janitorial, and utilities.

Table 10: Average staffing levels

Position	1 per X square feet, where X =
Controls & Low Voltage	450,000
HVAC and Central Plant Operators	200,000
Stationary Engineers	150,000
Group Supervisor	275,000
Operations and Maintenance Manager	234,000

The benchmarks detailed within the report provide an estimate of the current expense of operations and maintenance and the corresponding staffing levels, as well as operations and maintenance budgets. According to the survey conducted as part of this study, operations and facility management budgets are decreasing over time, with corresponding reductions in manpower and other resources. Facility managers and their staffs are increasingly asked to do more with fewer people and less money. In some cases, people are finding better and more efficient ways to do things. But in others, building performance decreases and the buildings themselves gradually fall into disrepair.

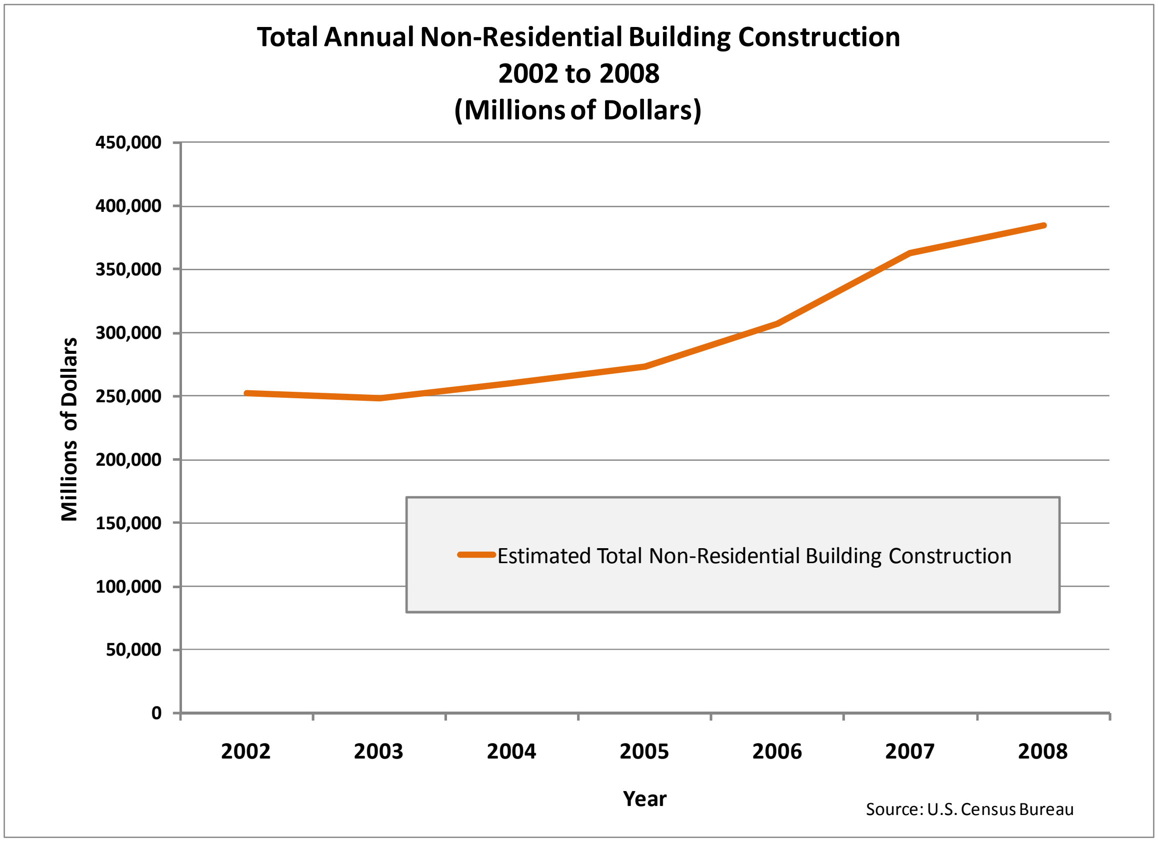
4.2.5 Construction

While buildings will likely be more demanding of their operations teams, given current construction trends opportunities will likely be focused within the existing building population. Non-residential construction grew by leaps and bounds from 2002 to 2008, but fell in 2009, dampened by changing economic conditions. Figure 27 shows annual construction value put in place from 2002 to 2008. Figure 28 shows

[23] (IFMA 2009)

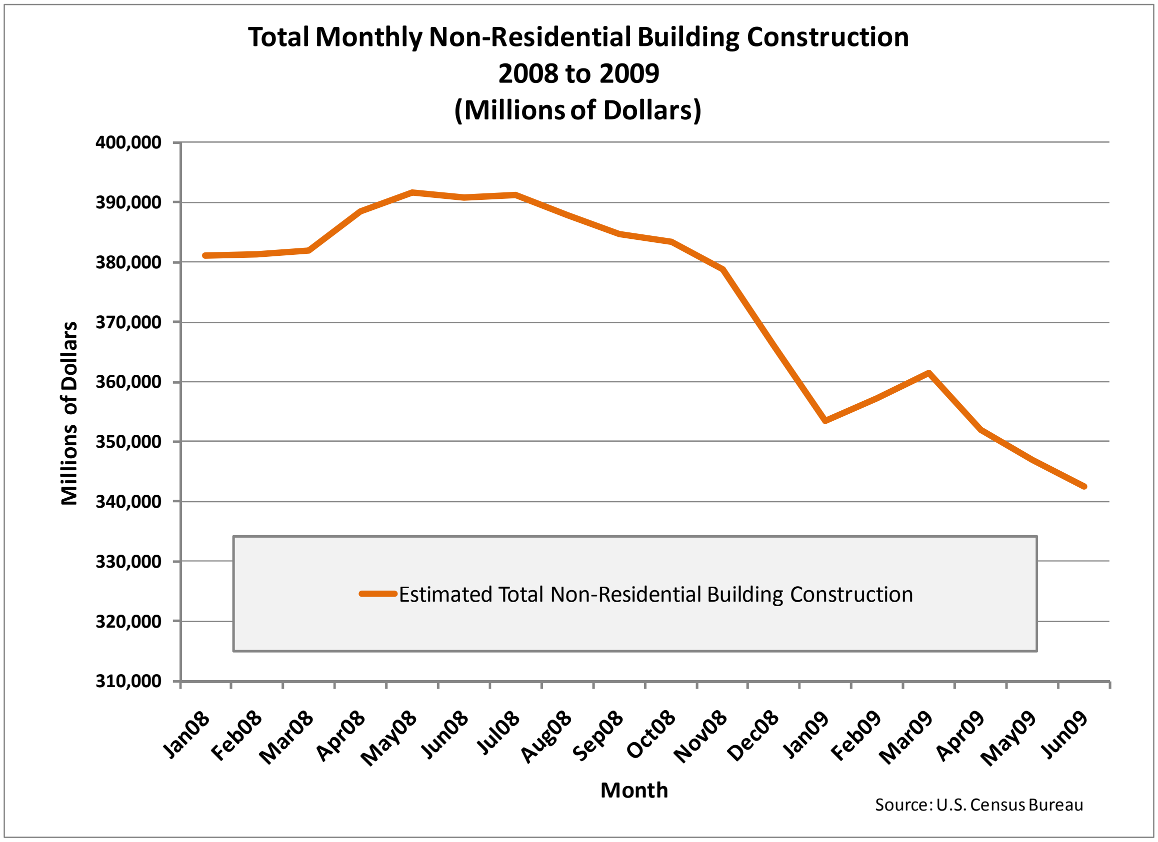
monthly construction value from January 2008 through April of 2009.[24] Construction appears to have bottomed out in January of 2009. This is fairly consistent with the AIA's Architectural Billings Index, or ABI, an index of spending on architectural design services which is typically a leading indicator for construction spending. According to the ABI, the U.S. architecture industry experienced flat or decreased billings for 16 straight months with the lowest point also in January of 2009.[25] Since January of 2009, architectural billings rose temporarily, falling again in June. July saw a slight rise in billings, and the index is expected to fluctuate for several months until the economy further stabilizes.

Figure 27: Non-Residential Construction, 2002-2008



[24] (U.S. Department of Commerce, U.S. Census Bureau, 2009)
[25] (Building Design & Construction, 2009)

Figure 28: Non-Residential Construction, 2008-2009



4.3 Market and Industry Trends

Market and industry forces are largely shaped and influenced by the three dominant global issues. This results in trends and evolving practices in commercial and institutional buildings, ranging from the growth of green buildings to increased diligence in understanding and verifying building performance. Market and industry trends can be summarized as follows:

1) ***Green building design and construction has gained intense interest, but the share of LEED certified buildings will tend to remain small.***
2) ***Energy efficiency and conservation is characterized as the first priority and lowest cost energy resource, and this is expected to continue to be the case in the near term.***
3) ***Water efficiency and conservation is also a high priority in buildings.***
4) ***Public and private financing of energy efficiency is rising on average.***
5) ***There is a movement towards design processes and delivery models that encompass a whole building perspective.***
6) ***With increasing emphasis on building energy performance and indoor environmental quality, the practice of building commissioning will continue to grow.***
7) ***Public disclosure of building energy performance will create new opportunities for market forces to determine real estate values, both in terms of lease and sale.***
8) ***Mission critical facilities, such as labs and data centers, present unique and special challenges for building operations and facilities management teams, and for energy efficiency and sustainability.***
9) ***The convergence of building systems with information technology will continue to evolve, with the potential to deliver ever more powerful technologies and tools for O&M teams as well as facility managers, energy managers, and building owners.***
10) ***There is a growing market, supported by federal legislation to implement smart grid and demand response in buildings to reduce peak loads and building energy consumption.***

4.3.1 Green Buildings

Green buildings saw very rapid growth over the last several years, and this trend is expected to continue. Green building principles and practices will be integrated into main-stream architecture and engineering communities, as well as facility operations and maintenance. This outlook on green buildings is supported by several market indicators:

- The McGraw-Hill Construction 2009 Green Outlook: Trends Driving Change Report states:

  > *"In 2005, green building was a small, burgeoning market, approximately two percent of both nonresidential (commercial and institutional) and residential construction, valued at a total of $10 billion–$3 billion for residential and $7 billion for nonresidential. Since that time, green building has expanded rapidly due to a number of factors such as growing public awareness of green practices, heavy increase in government interventions, and recognition by owners of the bottom line advantages. In fact, green building has grown in spite of the market downturn. Green seems to be one area of construction insulated by the downturn, and we expect green building will continue to grow over the next five years despite negative market conditions to be a $96-$140 billion market."* [26]

- Jerry Yudelson, a renowned expert on green buildings, projects 60 percent growth for the green building industry in 2009 despite poor economic conditions.[27] He also noted that:
    - Green building will benefit greatly from the Obama administration, "with a strong focus on green jobs in energy efficiency, new green technologies and renewable energy."[28]
    - The focus of green building will start to transition from new construction to existing buildings.

As a key element in the implementation of sustainability, the USGBC LEED Rating Systems are very popular. This voluntary program did not require energy efficiency until the latest revision issued in 2007. The program is also estimated to include up to 25 percent of all new construction projects. In addition, USGBC continues to refine the existing rating systems as well as develop new and more focused rating systems, such as the recently introduced LEED for Existing Buildings: Operations and Maintenance rating system. Section 4.4.4, focuses on USGBC and LEED, and provides additional details on green buildings, quantifying the growth of LEED registered and certified green buildings.

4.3.2 Energy Efficiency

Since the early 1970's, advances in energy efficiency in buildings have produced substantial energy savings. The Alliance to Save Energy estimates that energy efficiency efforts reduced consumption by 43 Quads since 1973, characterizing energy efficiency as "America's Greatest Energy Resource" (Figure 29).

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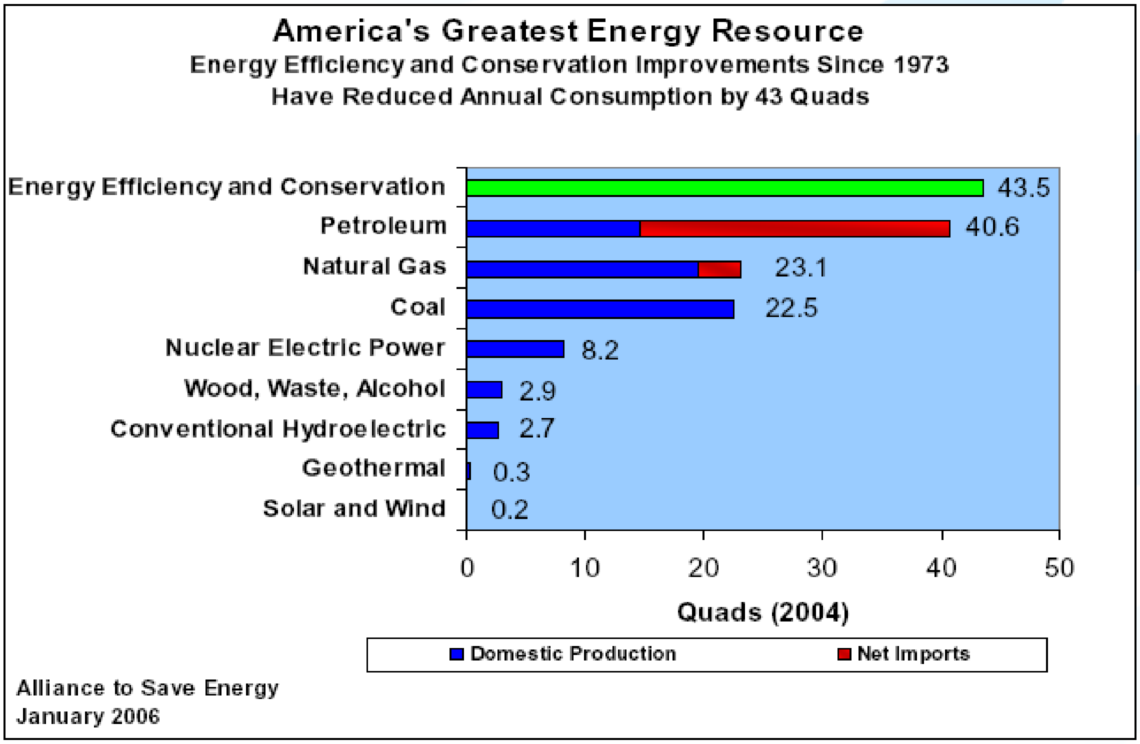
[26] (McGraw-Hill Construction, 2008)
[27] (Yudelson, 2009)
[28] (Yudelson, 2009)

Figure 29: Energy efficiency and conservation improvements

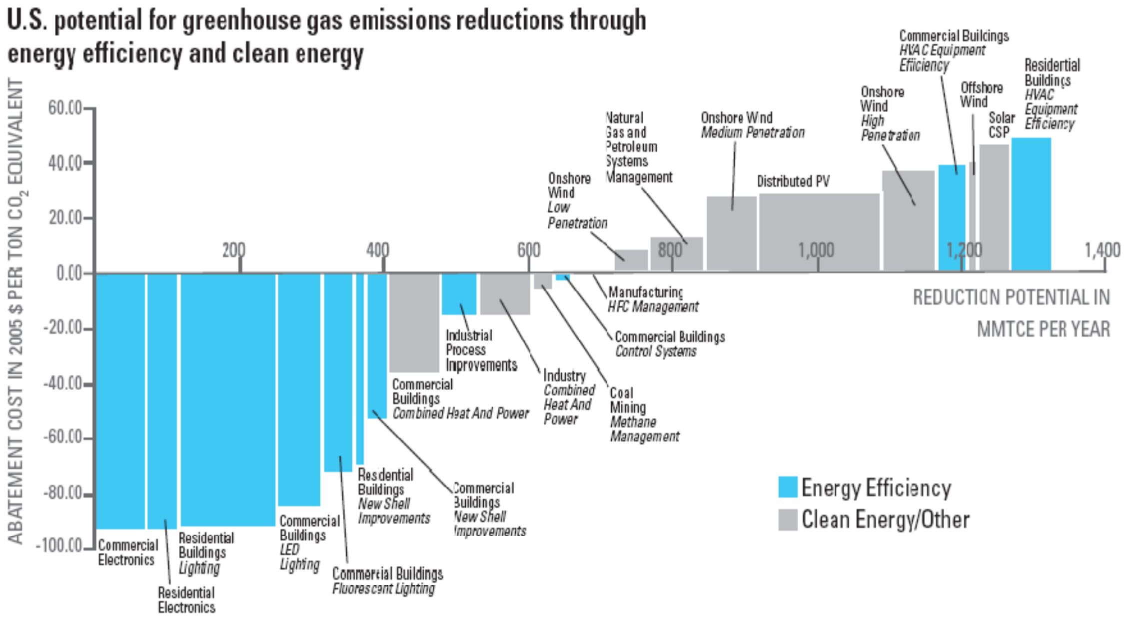


However, a vast opportunity still remains to further reduce energy consumption in the existing building stock, as noted by Secretary of Energy Steven Chu upon his confirmation. "Chu stressed the importance of energy efficiency, saying it 'remains the lowest hanging fruit for the next decade or two."[29] In fact, energy efficiency is seen as the highest priority by utilities to satisfy increasing demand, and it is also the most accessible means by which to effect near-term reductions in GHG emissions.

It is a challenge to get a handle on the cost of energy efficiency relative to its benefits in terms of GHG emissions reduction, but recent studies examine the cost-benefit relationship between energy efficiency measures and GHG emissions reductions. These cost-benefit relationships provide one perspective that may be useful in prioritizing energy efficiency methods as the market and industry act on Dr. Chu's recommendation.

[29] (Jones, 2009)

Figure 30: Energy efficiency measures and GHG emissions reduction[30]



Government financial support for energy efficiency has also seen steady growth in recent years. According to a recent report from the Consortium for Energy Efficiency (CEE), U.S. and Canadian energy efficiency budgets totaled more than $4.5 billion in 2008, increasing for the fourth year in a row, and up 21 percent from 2007.[31] Government support is further evident in recent legislation, as discussed in Section 4.4, Oversight and Regulatory.

4.3.3 Water Efficiency and Conservation

Along with energy, other natural resources are of course used and impacted by buildings, and water is of particular concern. Similar to energy, water is already a critical resource, and over the course of time its availability and quality are expected to become more critical issues. In fact, according to a recent survey of commercial property owners, contractors, architects and engineers conducted by McGraw-Hill Construction, 69 percent of respondents rated water efficiency as being extremely important, by 2013 that figure is expected to increase to 85 percent.[32]

Acknowledging this challenge, the LEED rating systems include a number of credits dedicated to efficient use of water, as well as control and reduction of storm-water runoff. Features integrated into building design to conserve and efficiently use water can reduce first costs as well as operating costs. Some of these features are listed in Table 11.

[30] (McKinsey & Company, 2007)
[31] (Jewell, 2009)
[32] (GreenerBuildings, 2009)

Table 11: Measures for water efficiency and conservation

Internal Measures	External Measures
• Dual-flush toilets • Low-flow plumbing/fixtures • Waterless urinals	• Bioswales • Native plants • On-site wastewater treatment • Porous paving • Rainwater capture and storage (for irrigation, toilets, cooling tower make-up water, etc.) • Vegetated (or green) roofs

4.3.4 Ownership and Management Recognition of Value

Recognition and quantification of financial value in energy efficiency and sustainability is necessary to the mainstream adoption and viability of high performance green buildings. Good energy and environmental practices need to make good business sense. According to a 2008 CoStar Group study, the commercial real estate world is recognizing the value of green and energy efficient buildings:[33]

- LEED certified buildings:
  - Command rent premiums of $11.33 per square foot over their non-LEED certified peers.
  - Have 4.1 percent higher occupancy.
  - Sell for a considerable premium over their non-LEED certified peers at $171 more per square foot.
- ENERGY STAR buildings:
  - Yield a $2.40 per square foot rent premium over comparable non-ENERGY SYTAR buildings.
  - Have 3.6 percent higher occupancy.
  - Sell for an average of $61 per square foot more than their peers.

Another very recent study focused on three buildings in Portland, Seattle, and Vancouver explains benefits achieved in each of the specific buildings. The benefits are consistent with those listed above and include:[34]

- Higher than average occupancy levels
- Competitive rents
- Declining operating expenditures
- Attraction of high quality tenants

Thus, the value is becoming apparent, and such statistics can help more projects overcome the obstacles presented by financial concerns.

4.3.5 Integrated Design

Historically, the process of designing and constructing a building can be characterized as fragmented, executed in distinct discipline-specific “silos” with little communication or collaboration. Today, most building projects are still conducted in this manner, but the tide may be changing. In recent years, the design and construction community recognized the importance and potential contribution of an integrated and collaborative approach to the success of a given project. The results

[33] (Miller, Spivey, & Florance, 2008)
[34] (Chappell, Corps, & Smith, 2009)

are more efficient and sustainable buildings that better meet the needs of owners, occupants, and tenants, and are more viable over the long term, both operationally and financially. A general definition of integrated building design is:

> *"… a process of design in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that permits synergistic benefits to be realized. The goal is to achieve high performance and multiple benefits at a lower cost than the total for all the components combined. This process often includes integrating green design strategies into conventional design criteria for building form, function, performance, and cost. A key to successful integrated building design is the participation of people from different specialties of design: general architecture, HVAC, lighting and electrical, interior design, and landscape design. By working together rat key points in the design process, these participants can often identify highly attractive solutions to design needs that would otherwise not be found."*[35]

The American Institute of Architects (AIA) takes the process a step further, calling it Integrated Project Delivery. The AIA uses the information in Table 12 to contrast the traditional or conventional process with Integrated Project Delivery (IPD).

[35] (BuildingGreen, Inc., 2001)

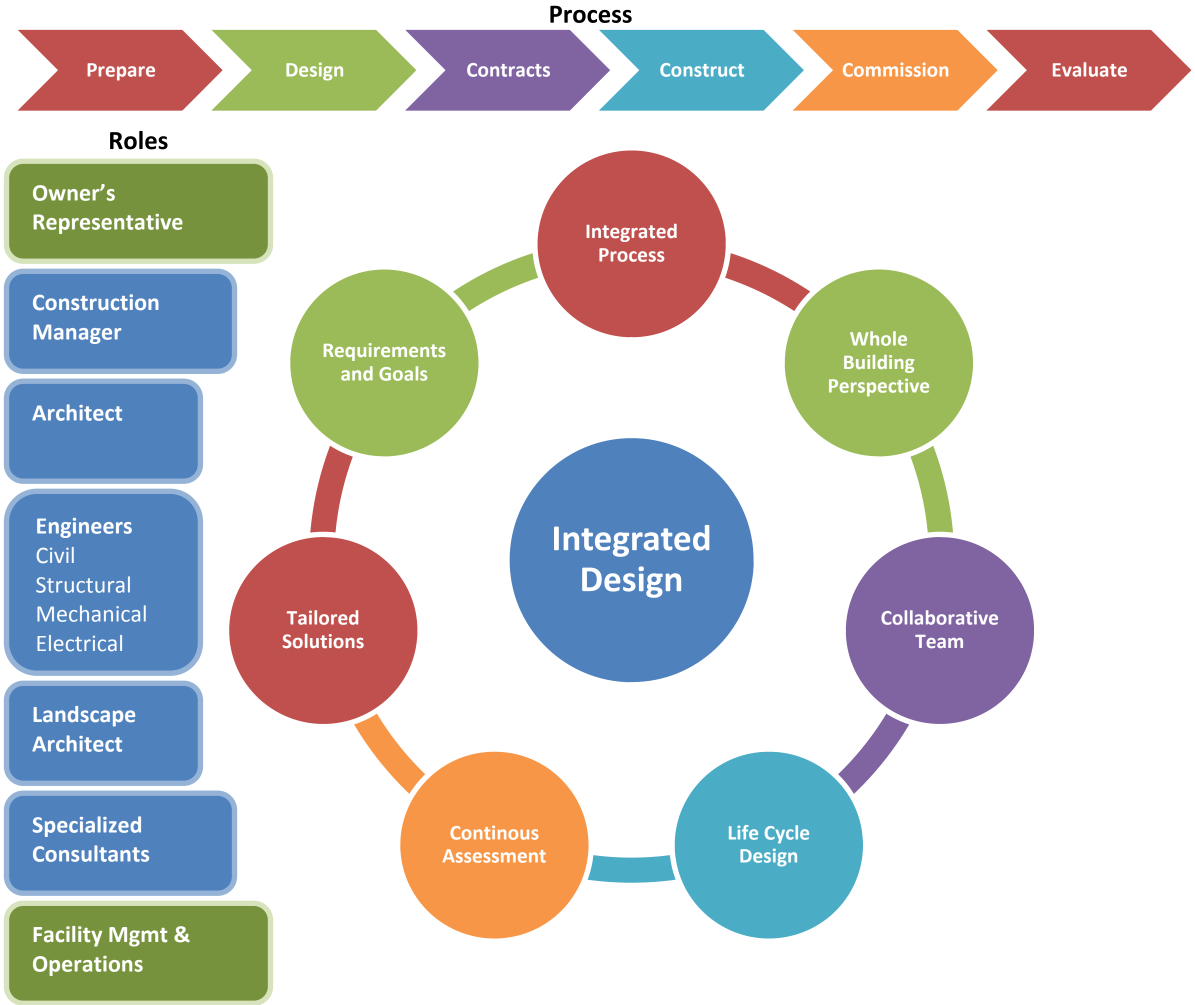
Table 12: Comparison of conventional and integrated design[36]

	Traditional Project Delivery	Integrated Project Delivery (IPD)
Teams	Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis; strongly hierarchical and controlled	Integrated team entity composed key project stakeholders, assembled early in the process; open and collaborative
Process	Linear, distinct, segregated; knowledge gathered "just-as-needed"; information hoarded; silos of knowledge and expertise	Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect
Risk	Individually managed, transferred to the greatest extent possible	Collectively managed, appropriately shared
Compensation / Reward	Individually pursued; minimum effort for maximum return; (usually) first-cost based	Team success tied to project success; value-based
Communication / Technology	Paper-based and 2 dimensional; analog	Digitally based and virtual; Building Information Modeling (3, 4 and 5 dimensional)
Agreements	Encourage unilateral effort; allocate and transfer risk; no sharing	Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing

Another important industry resource, the National Institute of Building Sciences' Whole Building Design Guide (WBDG), describes the integrated design process. The illustration in Figure 31, largely based on the WBDG's vision, attempts to synthesize the various leading definitions of integrated design.[37] It depicts the elements of the process stages and the key roles on an integrated design team. It also incorporates the role of facilities management and operations, as this is an important perspective to capture and solicit input from throughout design and construction. After all, the facilities management and operations team will inherit and assume responsibility for the end result.

[36] (The American Institute of Architects, 2007)
[37] (National Institute of Building Sciences, Whole Building Design Guide, 2009)

Figure 31: Integrated design process, roles and elements

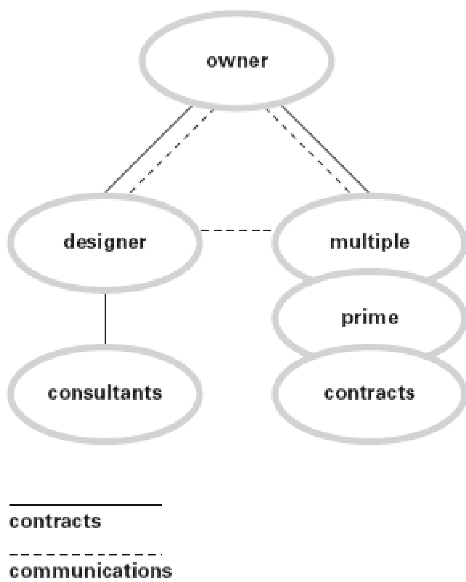
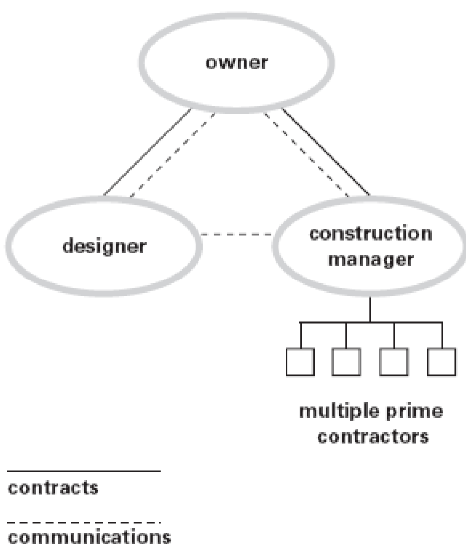


While integrated design has not yet seen widespread adoption, it is clearly recognized by many as instrumental to the realization of a more energy efficient and sustainable future for buildings.

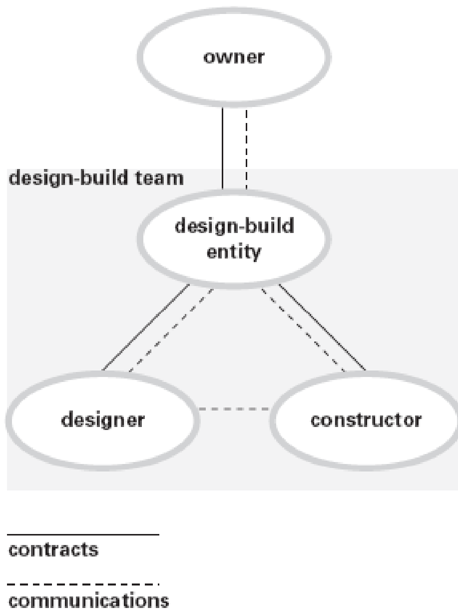
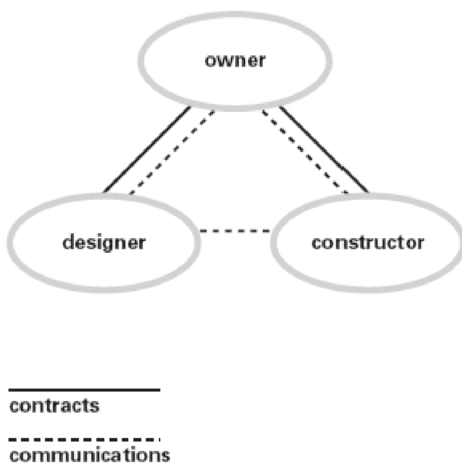
4.3.6 Project Delivery Models

There are a few prevalent models for delivery of building projects, each with its own advantages and disadvantages. Design-build and construction management models have been gaining ground in recent years, but presently design-bid-build is the most prevalent model in the United States. However, it is also the least accommodating integrated project delivery. Figure 32 summarizes the general delivery models.

Figure 32: Project delivery models[38]

Model	Characteristics / Notes
Multi-Prime 	• Commonly used in conjunction with design-bid-build. • Owner acts as construction manager and/or general contractor. • Not particularly well-suited to support integrated project delivery.
Construction Management 	• Same direct owner-architect and owner-contractor contractual relationship as design-bid-build, with the advisory benefits of a construction manager and the early cost commitment characteristic of design-build. • Design remains the responsibility of an architect, who contracts independently with the owner. • Involves the constructor prior to construction to oversee scheduling, cost control, constructability, and to bring additional expertise to project management, building technology, and bidding or negotiation of construction contracts. • Good potential to accommodate integrated project delivery.

[38] (The American Institute of Architects, 2007)

Model	Characteristics / Notes
Design-Build 	• Single point of responsibility for both design and construction activities. • Owners choose design-build in order to reduce project-based risk. • By combining design and construction under a single entity, coordination, constructability and cost-of-change is presumed to be improved. Most of the risk is borne by the design-builder. • Good potential to accommodate integrated project delivery.
Design-Bid-Build 	• Most prevalent delivery model for a construction project in the U.S. construction industry. • Offers the owner the market advantage of open competition through a regimented design phase followed by separate bid and construction phases. • Project is typically designed with little, if any, input from the parties actually constructing the project. As a result a significant amount of constructability and/or coordination issues are not discovered and resolved until construction. • Not particularly well-suited to support integrated project delivery.

Note that none of the delivery models explicitly incorporates operations and maintenance teams in any of the project phases. This is a major shortcoming of these models, as the integrated design process stops at construction and excludes the longest phase of the building. Therefore, these models should be revised.

4.3.7 Indoor Environmental Quality

Indoor environmental quality (IEQ) encompasses a number of aspects of a building that impact occupants, including:

- Indoor air quality (IAQ)
- Temperature
- Humidity
- Lighting
- Views

Note that indoor air quality by itself is rather complex. In order for the indoor environment of a building to provide satisfactory indoor air quality, the following components of indoor air must be controlled:

- Carbon dioxide
- Carbon monoxide
- Volatile organic compounds (VOCs)
- Other chemicals
- Odors, dust, and particulates
- Mold and microbes, including bacteria and viruses
- Radon
- Smoke

Methods and mechanisms for maintaining and controlling indoor environmental quality range from mechanical systems to controls. Ventilation is the primary mechanism used to maintain proper indoor air quality, and typically works in conjunction with heating and cooling systems to maintain temperature and humidity. Daylight and views, lighting controls, and shading are the primary contributors to comfort when it comes to lighting.

Over the years, the issue of indoor environmental quality has become increasingly important to building occupants and, consequently, to building owners and managers as well. It is seen as an important element in the health, safety, comfort, and productivity of occupants. This is especially true in schools and healthcare facilities, where poor indoor air quality in particular may adversely affect children's health and learning environment, and patient outcomes, respectively.

Perhaps the primary takeaway for operations and maintenance teams is that indoor environmental quality is an important health, safety, and productivity issue, and that proper management of IEQ requires both technical expertise, and a sensitivity to people's needs.

4.3.8 Mission Critical Facilities

Mission critical facilities include hospitals and healthcare facilities, data centers, laboratories, power generation and transmission control, and some manufacturing environments. Generally speaking, a mission critical facility depends on its buildings and a tightly controlled environment within them. Thus, facility management teams in these facilities have a different focus by necessity, as they simply cannot tolerate the risk of building systems not working. As a result of their unique needs, mission critical facilities are often energy intensive. For example, data centers require substantial heat rejection in order to maintain the operating environment, and healthcare facilities present substantial ventilation and filtration requirements. The primary takeaway regarding mission critical facilities is that such facilities are perhaps the most demanding of operations teams.

4.3.8.1 Data Centers

Data centers have been the focus of recent deliberations on energy, and greening of data centers is a popular topic of discussion. In any case, such facilities remain significantly more energy intensive than most buildings. According to the Alliance to Save Energy, data centers "typically consume 15 times more energy per square foot – and in some instances up to 100 times more – than a typical office building."[39] Given this large appetite for energy, the data center engineering community developed some measures of data center energy efficiency:[40]

> **PUE:** Power Usage Effectiveness is defined as the total data center facility power divided by the data center equipment power. In other words:
>
> *PUE = Total Facility Power / Data Center Equipment Power*
>
> **DCiE:** Data Center Infrastructure Efficiency is the reciprocal of PUE expressed as a percentage:
>
> *DCiE = 1/PUE X 100%*

These measures provide an at-a-glance characterization of data center efficiency, enabling operators to quickly estimate the relative energy efficiency of their data centers and take appropriate action.

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[39] (Loper & Parr, 2007)
[40] (Belady, Rawson, Pfleuger, & Cader, 2008)

4.3.8.2 Labs

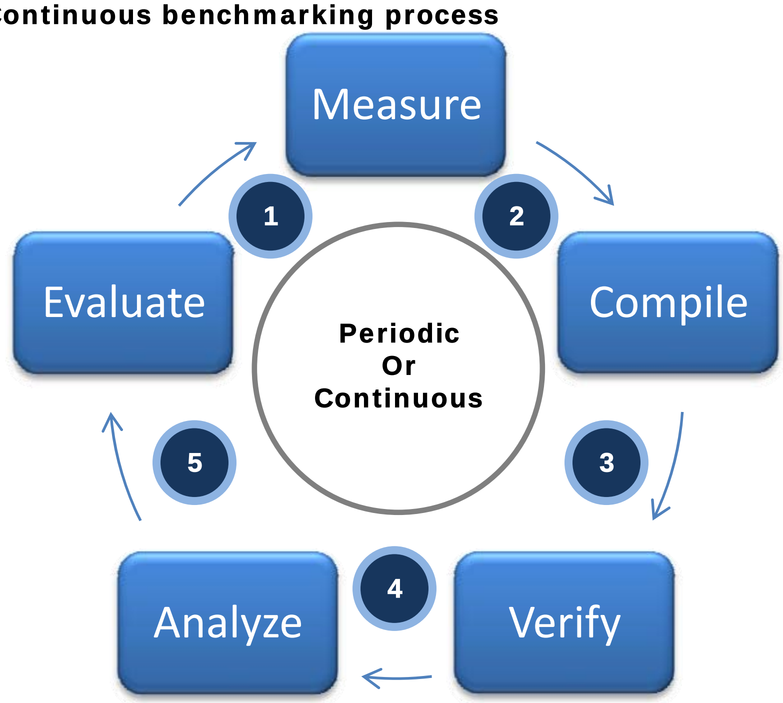
Laboratories are typically characterized by high ventilation rates. Like data centers, efforts to address and benchmark lab energy consumption are in continuous development. Labs21, a joint program of the U.S. EPA and U.S. DOE, developed two resources specifically for assessing laboratory energy and environmental performance:[41]

- An energy benchmarking tool that allows users to compare laboratories using a standard set of building and system level energy use metrics.
- The Environmental Performance Criteria (EPC), a point-based rating system that builds on the LEED™ green building rating system, designed to score overall environmental performance.

4.3.9 Benchmarking and Post-Occupancy Evaluation

How does a building perform relative to its peers and to established goals? This is often one of the first questions asked when evaluating the performance of an existing building with the intent to make improvements. Benchmarking, in various forms and depths of rigor, is a task that begins to address this question. Figure 33 outlines the steps of a continuous benchmarking process.

Figure 33: Continuous benchmarking process



There are several elements critical to the success of the benchmarking process:

- Accurate and precise documentation of building systems is absolutely critical. A large portion of the foundation for an energy benchmarking analysis is composed of information about the buildings themselves. Design and operational documentation serves as a fundamental data source. Such documentation includes as-built drawings for electrical and mechanical

[41] (Matthew, Sartor, Van Geet, & Reilly, 2009)

systems, meter and load schedules, floor plans that provide space utilization, and utility bills.

- Selection and use of appropriate benchmarks is critical to produce meaningful comparisons.
- Definition of key metrics is also critical. Furthermore, the process applied to transform raw data to key metrics must be engineered to provide accurate and reliable metrics on a consistent basis.

The tasks to implement and then administer a benchmarking program require expertise on building systems and energy, as well as a basic understanding of engineering data collection and analysis.

- Instrumentation and data acquisition elements must be specified and installed.
- Data acquisition systems must also be specified and implemented.
- Once in place, and with data collection up and running, data must be regularly verified and analyzed. Subsequent evaluation drives system improvements. This task in particular requires specialized expertise.

4.3.10 Energy Performance Labeling

If passed, the American Clean Energy and Security Act of 2009 aims to require energy performance labeling of buildings. Like nutrition labels on food products or Energy Guide labels on appliances, these labels for buildings will publicly document building performance in terms of energy efficiency and carbon emissions, opening up the opportunity for market forces to utilize and determine value based on this information. In the United Kingdom, buildings and homes are already labeled as they come up for sale or lease.[42] One example of such a label appears in Figure 34. At the time of this research, ASHRAE was conducting a pilot program for BuilidingEQ, a building label very similar to the United Kingdom energy performance label (Figure 35).

[42] (Cassidy, 2009)

Figure 34: United Kingdom energy performance label

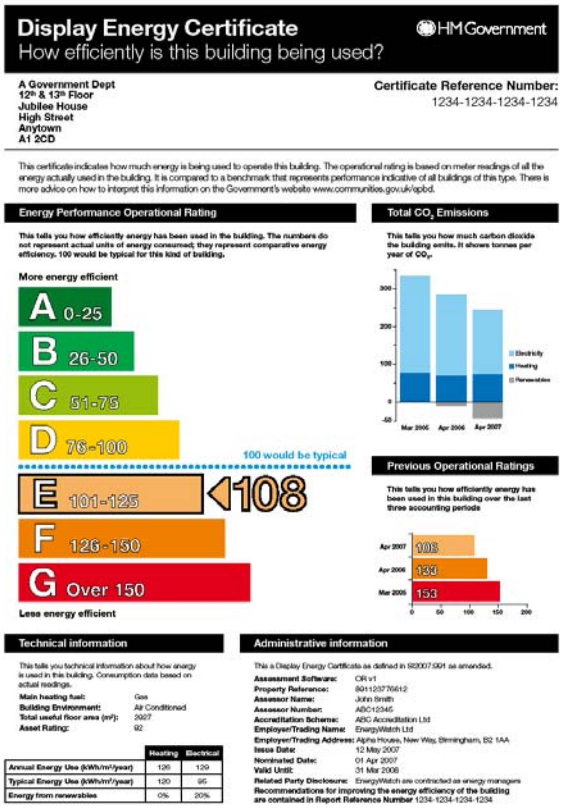
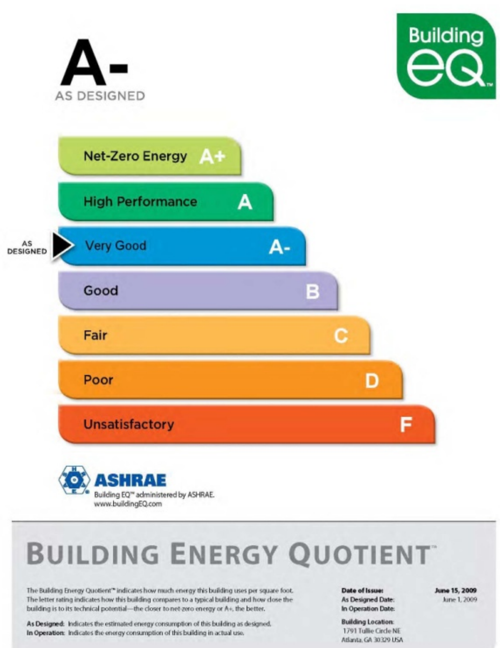


Figure 35: Proposed Building Energy Quotient (ASHRAE)[43]



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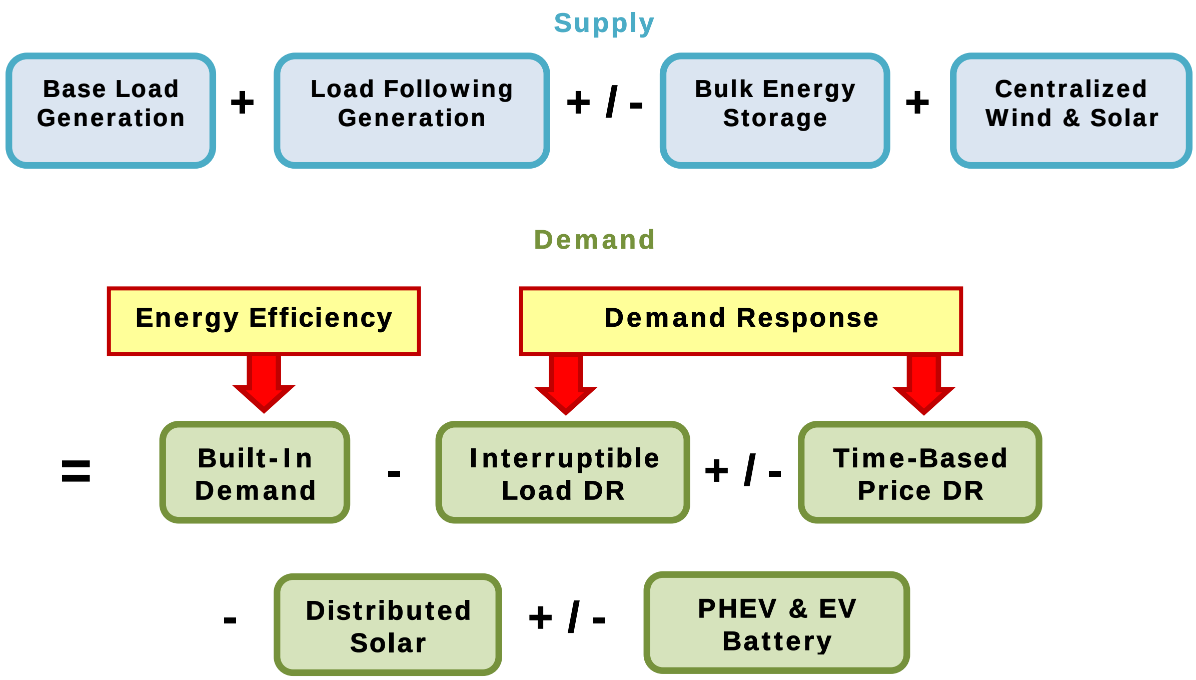
43 (ASHRAE, 2009)

4.3.11 *Demand Response and Smart Grid*

When demand response within buildings works with a smart electrical grid, there is potential to substantially reduce peak draw on the generation capacity and reduce electrical energy consumption. Demand response provides electricity consumers with choices in response to dynamic or real-time pricing and other incentives to reduce or offset consumption, particularly during peak periods. Figure 36 shows the balance of power generation and demand, and how energy efficiency and demand response contribute to the equation. For the consumer, the benefits may include reduced costs and improved reliability. For utilities, demand response improves the ability to respond to power-related emergencies and provides options during infrastructure planning, operational changes, and construction, or deferral of generating capacity. The smart grid further enables demand response through improvement of the electrical distribution infrastructure.

Figure 36: Power generation and demand equation[44]



One of the many action items within the Energy Independence and Security Act of 2007 called for the Federal Energy Regulatory Commission to report on the potential for demand response to reduce peak energy production and greenhouse gas emissions. The study found that the potential for national peak electricity demand reductions is between 38 gigawatts (GW) and 188 GW, or up to 20 percent of national peak demand, depending on how extensively demand response is applied. The report also estimates that, ten years from now, demand response programs could reduce the projected peak load by as much as 150 GW, or the equivalent of three hundred 500 megawatt power plants.

[44] Adapted from (Mansoor, 2009)

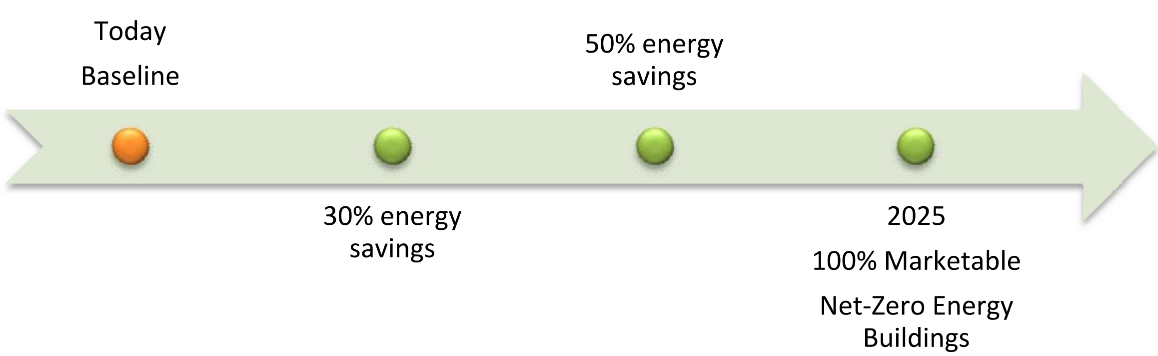
A critical key to the success of demand response is how it is actually implemented in buildings. Of greatest concern is that efforts to curtail electrical consumption result in discomfort and, consequently, loss of productivity of building occupants. Another concern is one of simplifying and automating the process of demand response to facilitate its execution and verification of the results. Both of these are topics of current research on demand response. Demand response in buildings will play a contributing role in the effort to reduce both peak demand and energy consumption, and facility managers and building engineers will need to be trained and prepared to work with yet another variable.

4.3.12 Net-Zero Energy Buildings

The ultimate end of the progression of energy efficiency and on-site power generation in buildings is to achieve economically and technologically viable net-zero energy buildings. While there are a few distinct definitions for net-zero energy buildings, the term net-zero refers to a building that produces at least as much energy as it uses in a year. Within the Energy Efficiency and Renewable Energy's Building Technologies Program, the U.S. Department of Energy's Net-Zero Commercial Buildings Initiative established a goal to achieve marketable net-zero energy buildings by 2025 (Figure 38), with a series of interim steps in substantial energy efficiency improvements as milestones on the way to this goal.[45]

Figure 37: Adam Joseph Lewis Center for Environmental Studies at Oberlin College in Ohio

Figure 38: Progression towards net-zero energy buildings



It should be noted that net-zero energy buildings are technologically possible today, and several such buildings are in operation in the United States. One notable example is the Adam Joseph Lewis Center for Environmental Studies at Oberlin

45 (U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program, 2009)

College (Figure 37). If technology is not the limitation, then one might ask what prevents the widespread implementation of NZEBs today? Many believe that the larger obstacles maybe characterized as market and economic limitations. Thus, one of the primary objectives of the Net-Zero Commercial Buildings Initiative is market transformation that will create an environment in which market forces and practical and economic conditions support high performance and, ultimately, net-zero energy buildings.

In addition to the U.S. Department of Energy, there are other organizations and consortiums supporting the movement towards high performance and, ultimately, net-zero energy buildings. These entities include:

- High Performance Green Building Partnership
- High Performance Building Congressional Caucus
- World Business Council for Sustainable Development

4.3.13 Intelligent Buildings

Another trend working in parallel with green buildings is that of intelligent buildings. In simple terms:

> *"An intelligent building uses technology and process to create a building that is safer, more comfortable and productive for its occupants, and more operationally efficient for its owners."* [46]

Intelligent buildings utilize advanced technology and improved processes for design, construction, and operations. Characteristics of intelligent buildings may include:

- Highly automated and integrated building systems.
- Common cabling and network infrastructure for building systems and, perhaps, shared with the business network infrastructure.
- Optimized control systems for mechanical and electrical systems including HVAC, lighting, metering and energy management, access control, security, fire/life safety, vertical transport, and parking.
- Cross-optimization of building systems.
- Central monitoring or control, where technology supports operations and maintenance processes.

Similar to green buildings, economics is often cited as the primary barrier to intelligent building implementation. However, as with green buildings, the drive to reduce costs and increase productivity coupled with energy efficiency mandates and the market demand for sustainability is expected to continue to increase the desire for buildings that are not only green, but intelligent as well. In fact, the convergence of green and intelligent buildings is the subject of one of the Continental Automated Building Association's (CABA) latest reports, Bright Green Buildings. Figure 39 illustrates the convergence of intelligent and green building features that comprise such a building. Within the CABA report and Figure 39, bright green is the convergence of green and intelligent. A bright green building "uses both technology and process to create a facility that is safe, healthy, and comfortable, and enables productivity and well being for its occupants".[47]

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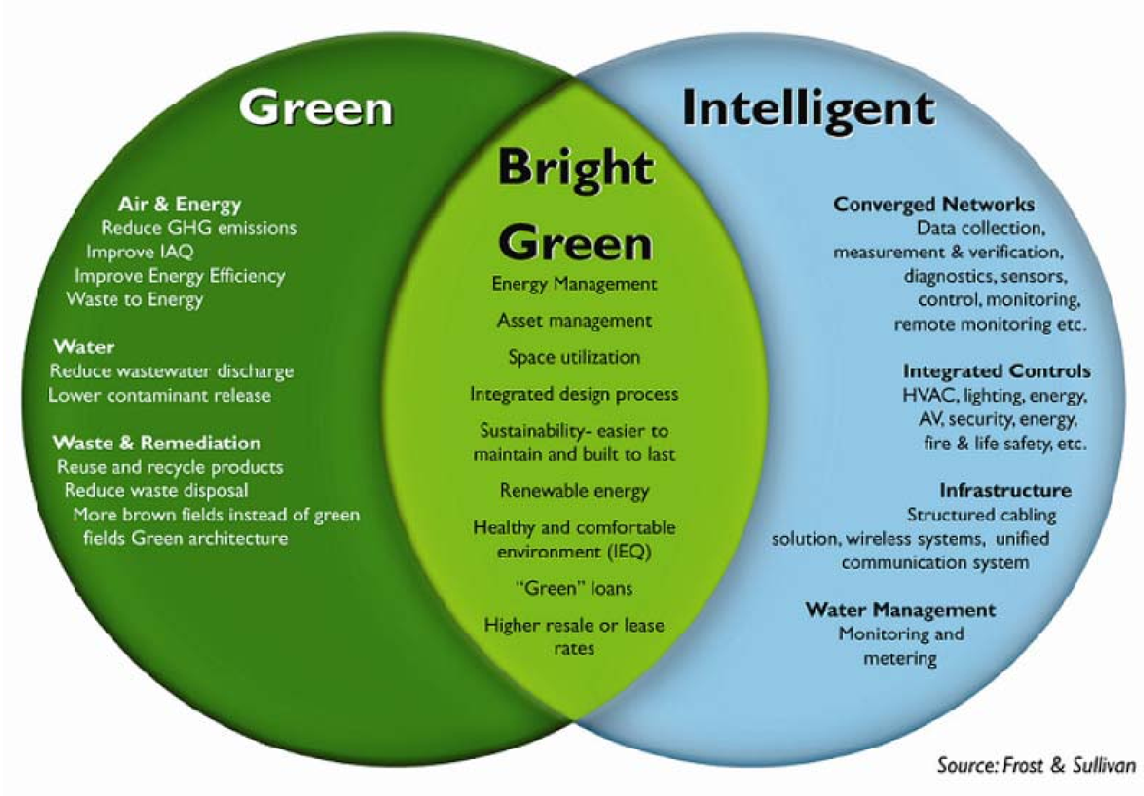
[46] (CABA, 2008)
[47] (CABA, 2008)

Figure 39: Convergence of green and intelligent buildings



4.4 Oversight and Regulatory

Key trends from an oversight and regulatory perspective include:

1) ***Increasing government mandates and support for energy efficiency.***
2) ***Increasing stringency in minimum energy efficiency requirements for buildings.***
3) ***Potential for greenhouse gas emissions reporting and controls.***
4) ***Increasing availability of guidance and support for energy efficient building design, construction, and operation.***
5) ***Recognition that sustainability extends well beyond construction, and corresponding evolution of USGBC's LEED Rating Systems to incorporate greater focus on energy efficiency, operations, and maintenance.***

4.4.1 Federal Government

In general, energy-related legislation is characterized by increasing support for energy efficiency and high performance green buildings. Table 23 lists significant federal and state legislative acts and executive orders issued since 2005, noting the most relevant provisions for commercial and institutional buildings. Figure 40 provides a timeline of this activity.

Figure 40: Timeline of acts/orders related to buildings and energy

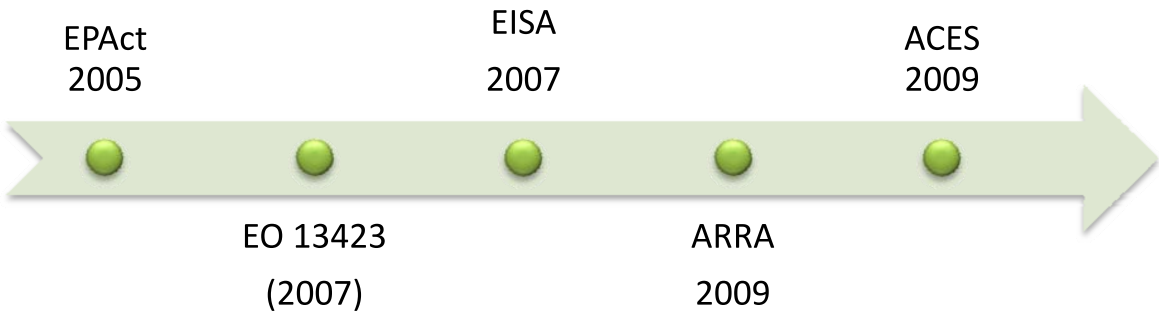


Table 23: Summary of acts/orders related to buildings and energy

Legislation or Order		Relevant Major Provisions
EPAct 2005	**Energy Policy Act of 2005[48]**	• Tax reductions: $1.3 billion for energy efficiency and conservation. • Tax credits for use of photovoltaic, solar thermal systems and microturbines. • Energy improvements to commercial buildings completed in 2006 or 2007 and exceeding 50% savings versus ASHRAE Standard 90.1-2001 are eligible for tax deductions of as much as $1.80 per square foot, with incentives focused on improvements to lighting, HVAC, and building envelope.
EO 13423	**Executive Order 13423: Strengthening Federal Environmental, Energy, and Transportation Management[49]**	• Requires Federal agencies to reduce energy intensity by 3% each year, leading to 30% by the end of fiscal year 2015 as compared to a fiscal year 2003 baseline. • Federal agencies must ensure at least half of all renewable energy required under EPAct 2005 comes from new renewable sources (developed after January 1, 1999). • To the maximum extent possible, renewable energy generation projects should be implemented on agency property for agency use. Agencies can also purchase renewable energy to help meet E.O. 13423 requirements. • Mandates that Federal agencies reduce water intensity (gallons per square foot) by 2% each year through FY 2015, for a total of 16% decrease as measured against water consumption in FY 2007. • Requires Federal agencies to ensure new construction and major renovations comply with the 2006 Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding, which was signed at the White House Summit on Federal Sustainable Buildings. It also requires that 15% of the existing Federal capital asset building inventory of each agency incorporate the sustainable practices in the Guiding Principles by the end of fiscal year 2015.

[48] (109th Congress, 2005)
[49] (U.S. Federal Government, Executive Branch, 2007)

Legislation or Order		Relevant Major Provisions
EISA 2007	**Energy Independence and Security Act of 2007**[50] [51]	• Lighting energy efficiency: Sets new standards for general service incandescent lighting in 2012 and sooner for general-service tubular fluorescent lighting and metal halide lamp fixtures. Requires roughly 25 percent greater efficiency for light bulbs, phased in from 2012 through 2014. • High Performance Commercial Buildings: Encourages development and sets goals for more energy efficient green buildings, with a national goal to achieve zero-net energy use for new commercial buildings built after 2025. • Creates an Office of Commercial High Performance Green Buildings at DOE. • Section 422 establishes a zero-energy commercial buildings initiative. • High Performance Federal Buildings: total energy use in federal buildings, relative to the 2005 level, must be reduced 30% by 2015. • For new federal buildings and major renovations, Section 433 requires that fossil-fuel energy use — relative to the 2003 level — be reduced 55% by 2010, and be eliminated (100% reduction) by 2030. • Requires GSA to establish an Office of Federal High-Performance Green Buildings to coordinate green building information and activities within GSA and with other federal agencies. The Office must also develop standards for federal facilities, establish green practices, review budget and life-cycle costing issues, and promote demonstration of innovative technologies. • Healthy High Performance Schools: Aims to encourage states, local governments, and school systems to build green schools.
ARRA 2009	**American Recovery and Reinvestment Act of 2009**[52] [53]	Calls for infrastructure renewal encompassing the following: • Energy Efficiency and Conservation Block Grants: Assists eligible entities in implementing energy efficiency and conservation strategies and programs. • State Energy Program: Public education to promote energy conservation; energy efficiency and renewable energy capital investments; commercial and industrial energy audits; initiatives to improve transportation efficiency; development of integrated energy plans; development of peak demand reduction strategies; energy efficiency training and education of building designers and contractors; pursuit of building retrofit standards and regulations; and feasibility studies for renewable energy and energy efficiency technologies, among others. • Modernization of Schools and Higher Education: May

[50] (110th Congress, 2007)
[51] (Congressional Research Service, 2007)
[52] (111th Congress, 2009)
[53] (Sissine, et al., 2009)

Legislation or Order		Relevant Major Provisions
		include modernizing, renovating, and repairing school buildings and public higher education institutions in ways that are consistent with a recognized green building rating system. • GSA High Performance Green Buildings: The General Services Administration is to convert selected federal facilities to "High-Performance Green Buildings". • DOD Modernization: The Department of Defense will modernize selected facilities, including energy efficiency retrofits. In addition, the Recovery Act also calls for research and development: • Research to develop technologies that reduce dependency on foreign oil, improve the energy efficiency of all economic sectors, and reduce GHG emissions. • The Department of Energy's Office of Energy Efficiency and Renewable Energy will pursue research on biomass, geothermal technologies, and other energy efficiency programs.
ACES 2009 [Passed in the House] **ACEL [Proposed]**	**American Clean Energy and Security Act of 2009 [House Bill]**[54] [55] **American Clean Energy Leadership Act [Senate Bill]**[56]	Among measures that support renewable energy, smart electrical grids, and cleaner and more efficient transportation in the ACES passed by the House of Representatives are some provisions that apply to buildings: • Establishes national energy efficiency building codes with independent organizations developing codes to achieve 30% and 50% higher energy efficiency targets in 2010 and 2015 respectively, with additional incremental savings every three years through 2030. • Establishes the WaterSense program at the EPA to identify and promote water efficient products, buildings, and landscapes. • Directs the EPA to develop a model building energy performance labeling program, and to apply the program in DOE and EPA facilities. • Establishes the WaterSense program at the EPA to identify and promote water efficient products, buildings and landscapes. • Instructs each federal agency to create an implementation strategy for application of energy efficient information and communications technologies and practices within agency facilities, such as advanced metering, efficient data centers, and building systems efficiency. • Documents goals for reduction of global warming pollution and establishes cap-and-trade to reduce economy-wide global warming pollution to 97% of 2005 levels by 2012, 83% by 2020, 58% by 2030,

[54] (U.S. House of Representatives, 2009)
[55] (Alliance to Save Energy, 2009)
[56] (United States Senate Committee on Energy & Natural Resources, 2009)

Legislation or Order		Relevant Major Provisions
		and 17% by 2050. • Supports workforce training, education, and resource development in clean energy, energy efficiency, climate change mitigation, and climate change adaptation.
EO	**Executive Order**	Requires federal agencies to meet a number of energy, water, and waste reduction targets, including the following provisions: • Reducing vehicle fleet petroleum use by 30% by 2020. • Recycle or divert 50% of waste by 2015. • Meet sustainability requirements in 95% of all applicable contracts. • The following measures apply specifically to federal buildings: o Beginning in 2020, all new federal buildings must be designed to achieve net-zero energy use by 2030. o Improve water efficiency by 26% by 2020. o Minimize impacts on storm water runoff.
Proposed Bill	**Federal Buildings Personnel Training Act of 2010**	Would require the General Service Administration (GSA) to identify core competencies necessary for federal personnel to maintain federal buildings at a level consistent with industry best practices. After the core competencies are determined, GSA would work with private industry and educational institutions to provide required training.

4.4.1.1 Federal Government Programs

Probably the two most important U.S. Federal Government programs that impact building performance and GHG emissions are administered by the Environmental Protection Agency:

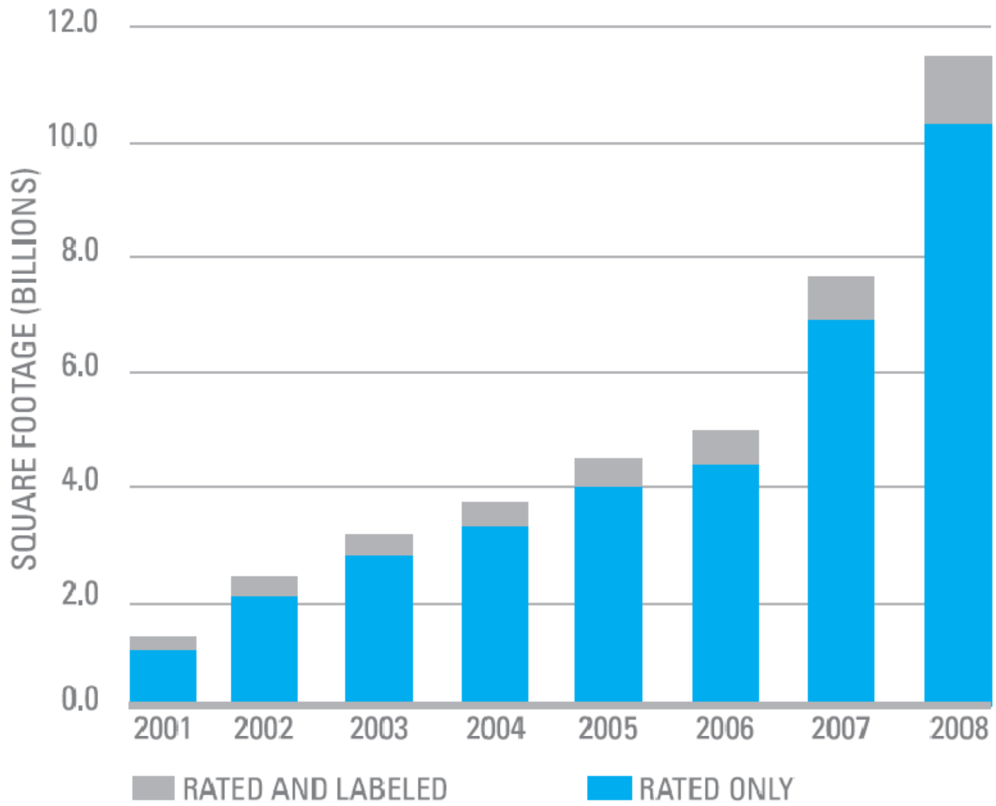
EPA ENERGY STAR

Buildings earn the EPA's ENERGY STAR by meeting established requirements for environmental conditions and achieving a score of 75 or higher on the EPA's energy performance rating system. On average, buildings that achieved the ENERGY STAR label:

- Use 35 percent less energy
- Cost $0.50 per square foot less to operate
- Produce persistent performance
- Have higher occupancy
- Yield increased asset value

Since its inception in 1999, approximately 7,300 buildings comprising more than one billion square feet earned the ENERGY STAR. Of the 7,300 buildings, more than 3,300 earned the ENERGY STAR in 2008, indicating significant increased activity in pursuit of ENERGY STAR labeling within the last 18 months. In addition to labeling, EPA's ENERGY STAR Portfolio Manager rating tool saw a substantial increase in use for energy use benchmarking in 2008, as shown in Figure 41.[57] Furthermore, commercial building design projects recognized as Designed to Earn the ENERGY STAR increased by 60 percent over the prior year.[58] All of these trends point to a substantial increase in interest and action to quantify energy efficiency and performance in buildings.

Figure 41: Growth in use of performance assessment



EPA Climate Leaders

Climate Leaders is an EPA industry-government partnership that works with companies to develop a long-term comprehensive greenhouse gas management strategy based on three components:

- Construction of corporate-wide GHG inventory
- Development of an inventory management plan (IMP)
- Establishment of aggressive corporate-wide GHG reduction goal(s)

Climate Leaders is the largest greenhouse gas emission reduction goal-setting program with over 275 corporate partners across a spectrum of business sectors. Fifty percent of partners are members of the Fortune 1000. The growth of this

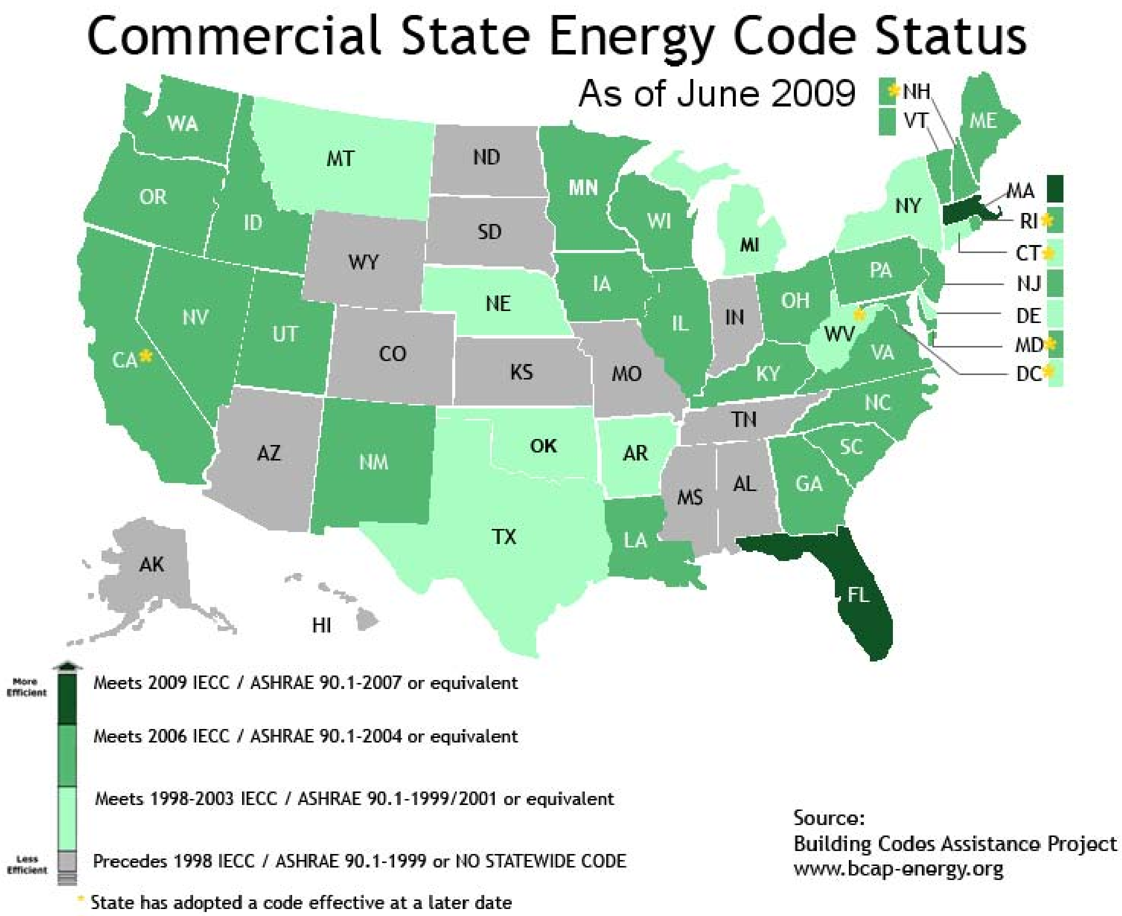
[57] (Hogan, 2009)
[58] (Environmental Leader, 2009)

program from just over 30 members initially indicates a strong corporate intent to reduce greenhouse gas emissions.

4.4.2 State Government

In general, state governments adopt standards as the basis of codes, but there is substantial variation in speed of adoption and levels of stringency. State energy codes illustrate this concept well. In general, ASHRAE Standard 90.1 serves as the basis of state energy codes, but there is considerable variation by state as to the version of ASHRAE Standard 90.1 upon which energy codes are based (Figure 42).

Figure 42: Status of state energy codes[59]



Going beyond energy codes, the American Council for an Energy Efficient-Economy provides an annual measure of states energy efficiency policy areas including: (1) utility-sector and public benefits programs and policies; (2) transportation policies; (3) building energy codes; (4) combined heat and power; (5) appliance efficiency standards; (6) "lead by example" in state facilities and fleets; (7) research, development and deployment; and (8) financial and information incentives.

[59] (Building Codes Assistance Project, 2009)

Evaluation of each state's policies results in a score and rank. In 2008, the top ten ranking states were:[60]

1) California
2) Oregon
3) Connecticut
4) Vermont
5) New York
6) Washington
7) Massachusetts
8) Minnesota
9) Wisconsin
10) New Jersey

Finally, in the economic stimulus package signed into law by President Obama in early 2009, ANSI/ASHRAE/IESNA Standard 90.1-2007 and its energy saving features are recognized through special funding measures. For states to receive additional funding from the $16.8 billion allotted to the Department of Energy, Office of Energy Efficiency and Renewable Energy, governors will be required to work toward implementation of a building energy code at least as stringent as Standard 90.1-2007 and to develop a plan for achieving 90 percent compliance with the code, including provisions for training and enforcement programs.

4.4.2.1 California

The fact that California ranks first in ACEEE's energy efficiency scorecard is no surprise. California's history includes significant and progressive leadership on environmental and energy issues. The state's energy code, Title 24, is the most stringent of any state, and the California Energy Commission clearly articulates a comprehensive and detailed vision and plan for the future in its California Long Term Energy Efficiency Strategic Plan. Some highlights of the Strategic Plan pertinent to buildings and their operation are:[61]

- Establishes California's loading order with energy efficiency as the first priority resource for utility procurement.
- Identifies workforce education and training as one of seven cross-cutting sectors critical to implementation of the Strategic Plan.
- Sets aggressive goals for energy efficiency:
  - All new residential construction in California will be zero net energy by 2020.
  - All new commercial construction in California will be zero net energy by 2030.
  - The Heating Ventilation and Air Conditioning (HVAC) industry and market will be transformed to ensure that its energy performance is optimal for California's climate.
  - All eligible low-income customers will be given the opportunity to participate in low-income energy efficiency programs by 2020.

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[60] (Eldridge, Neubauer, York, Vaidyanathan, Chittum, & Nadel, 2008)
[61] (California Public Utilities Commission, 2008)

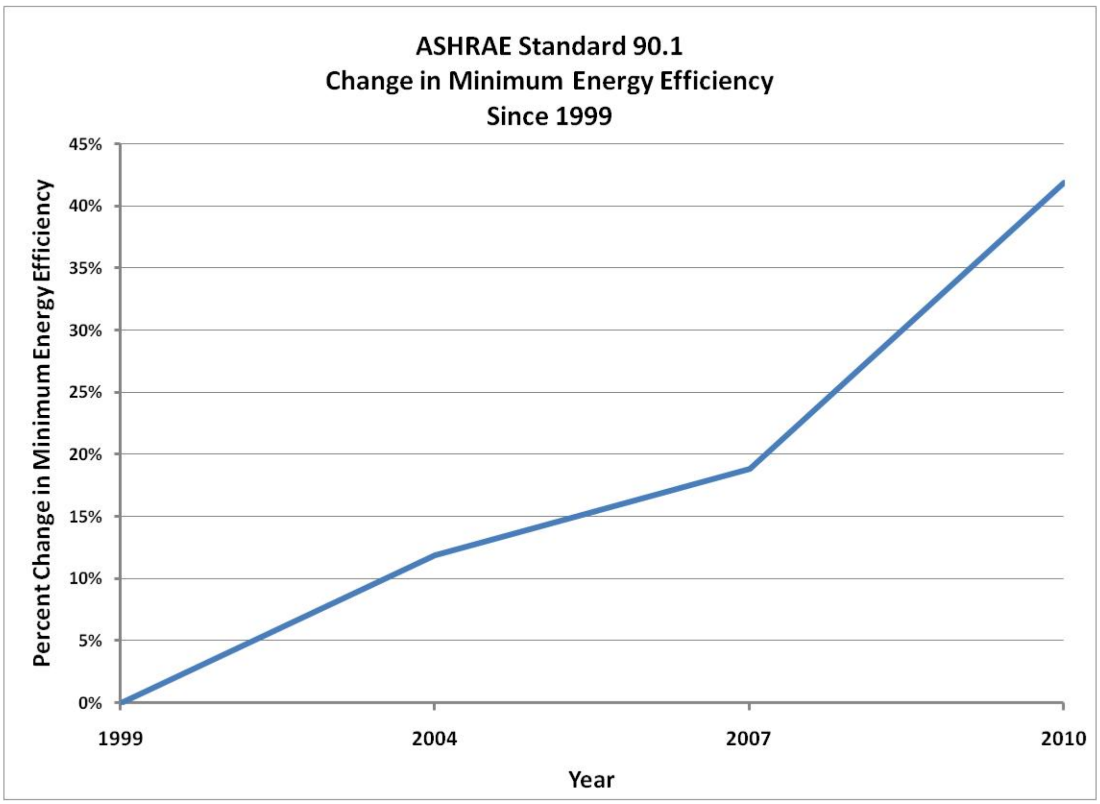
4.4.3 ASHRAE

Whether through standards and guidelines, or through education and advocacy, the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) is supporting and advocating for a progression to high performance green buildings.

4.4.3.1 Standards

ASHRAE standards serve as the basis for many state and local energy codes for energy performance and indoor air quality in buildings. These standards are also referenced in the LEED Rating System as the basis of Energy and Atmosphere credits and Indoor Environmental Quality credits. In general, ASHRAE standards have become more stringent over time, especially with regard to energy efficiency. For example, ASHRAE Standard 90.1-2007 represents a 7 percent increase over Standard 90.1-2004 in overall minimum energy efficiency standards for buildings.

Figure 43: ASHRAE 90.1 minimum energy efficiency



As ASHRAE Standards continue to evolve in a progression to net-zero energy buildings, both Standard 90.1-2010 and Standard 189.1 target a 30 percent energy efficiency improvement over Standard 90.1-2004. Table 14 lists the most relevant ASHRAE standards specific to building design, construction, and operation.

Table 14: Relevant ASHRAE Standards

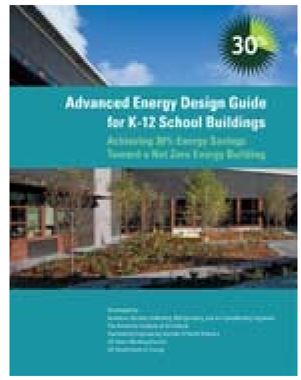
Standard	Supersedes	Title & Description
55-2004	55-1992	Thermal Environmental Conditions for Human Occupancy Specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. Environmental factors include temperature, thermal radiation, humidity, and air speed. Personal factors include activity and clothing.
62.1-2007	62.1-2004	Ventilation for Acceptable Indoor Air Quality Specifies minimum ventilation rates and indoor air quality levels that will be acceptable to human occupants, and is intended to minimize the potential for adverse health effects.
90.1-2007	90.1-2004	Energy Standard for Buildings Except Low-Rise Residential Provides minimum requirements for the energy efficient design of buildings.
100-2006	100-1995	Energy Conservation in Existing Buildings Provides criteria that will result in the conservation of energy resources in existing buildings.
105-2007	105-1984	Standard Methods of Measuring, Expressing, and Comparing Building Energy Performance Fosters commonality and consistency in reporting the energy performance of existing or proposed buildings to facilitate comparison, design and operation improvements, and development of building energy performance standards.
180-2008	N/A	Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems Establishes a minimum standard for the inspection and maintenance of HVAC equipment in commercial buildings.
189.1P	N/A	Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings Provides minimum requirements for the design of high-performance new commercial buildings and major renovation projects and addresses energy efficiency, a building's impact on the atmosphere, sustainable sites, water use efficiency, materials and resources, and indoor environmental quality.

4.4.3.2 Advanced Energy Design Guides

In recent years, ASHRAE produced a series of Advanced Energy Design Guides (AEDGs). It did so in collaboration with the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IES), and the U.S. Green Building Council (USGBC), and with support from the Department of Energy (DOE). These guides target a 30 percent energy efficiency improvement over ASHRAE Standard 90.1-1999, and are available for the following types of buildings:

- K-12 schools
- Small retail
- Small office
- Small warehouses and self-storage
- Highway lodging

Figure 2: AEDG



These guides also characterize the 30 percent improvement in energy efficiency as the first step in the progression to net-zero energy buildings.

4.4.3.3 Advocacy and Government Affairs

ASHRAE also works to promote energy efficiency in buildings through advocacy efforts at all levels of government. Most recently, ASHRAE played an active role in the establishment of two key organizational entities:

- High-Performance Commercial Green Building Partnership (HPCGBP): Works to provide guidance and technical leadership to the Department of Energy's Building Technologies Program on energy and sustainability issues.
- High Performance Building Congressional Caucus Coalition (HPBCCC): Provides guidance and support to the High Performance Building Congressional Caucus that works in turn to educate and inform policy makers.

The resulting trend is growing awareness and support for the progression to high performance buildings and energy efficiency in both the public and private sectors.[62]

[62] (Price 2006)

4.4.4 USGBC and LEED

Under the United States Green Building Council (USGBC), the Leadership in Energy and Environmental Design (LEED) rating system continues to evolve and be more broadly applied. LEED Version 3, launched in April of 2009, offers the latest advancements to the LEED Rating System (known as LEED 2009), in combination with improved online tools and a new certification model. Data available from USGBC illustrates strong continued growth in LEED registrations and certifications, as illustrated by Figure 44.[63] [64] There is also a broad geographic distribution of LEED certified projects across the United States, with the greatest number of projects in the following states:

- California
- New York
- Texas
- Florida
- Illinois
- Washington
- Pennsylvania
- Virginia

Figure 45 shows the LEED certified projects for all states.

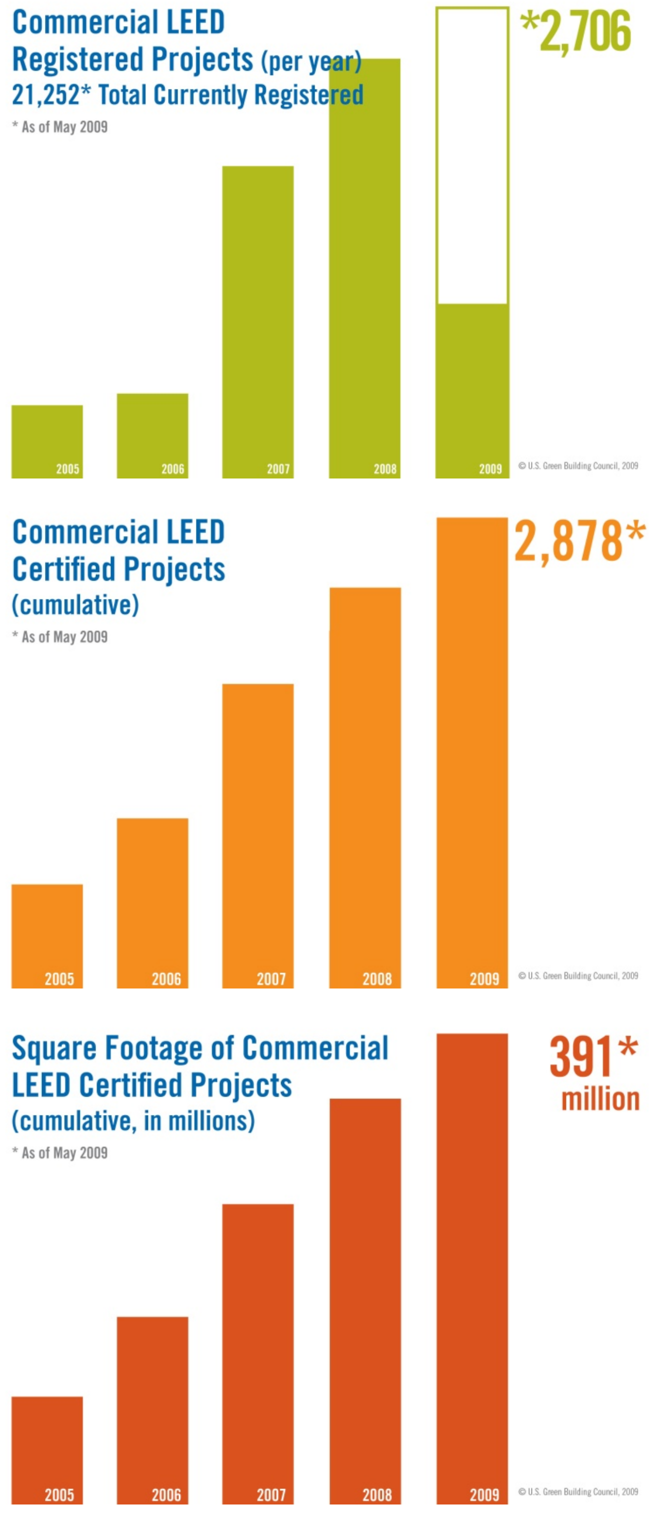
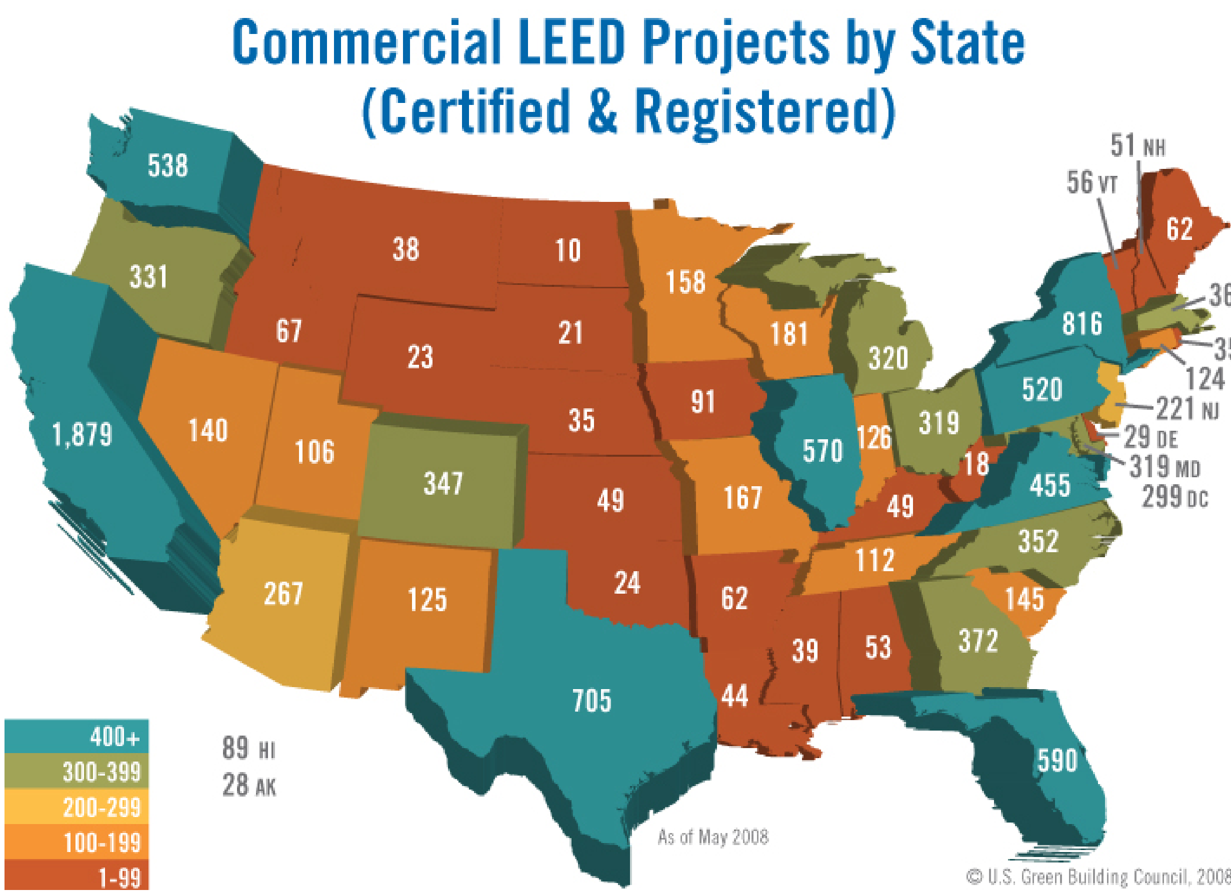


Figure 44: Trends for LEED Registration and Certification

[63] (USGBC, 2009)
[64] (USGBC, 2009)

Figure 45: LEED registered and certified projects by state



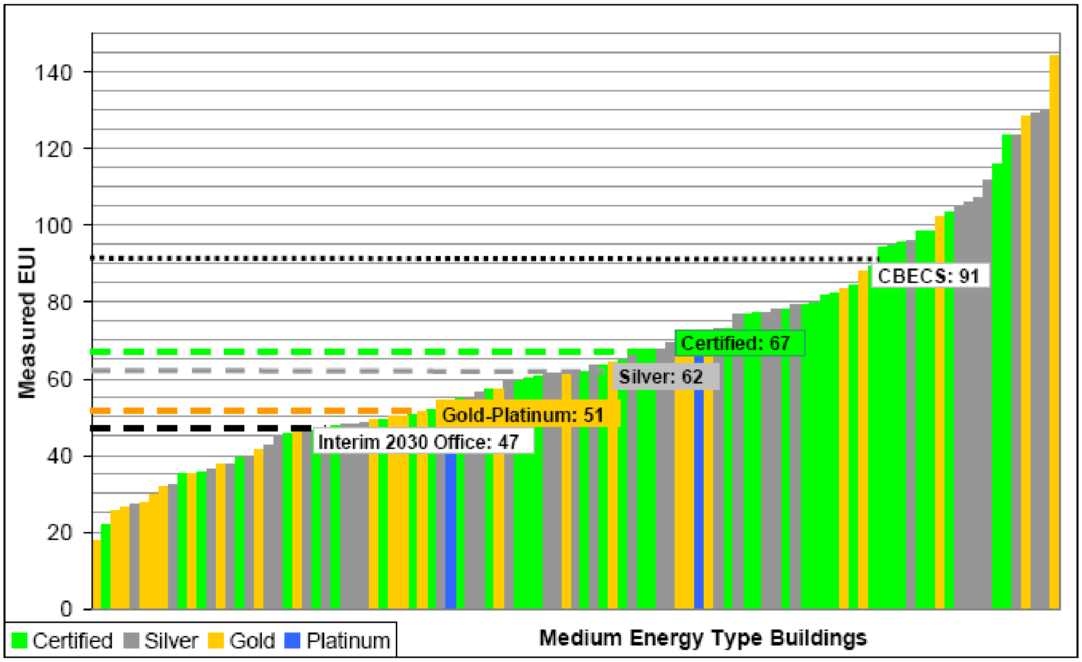
Early on, LEED offered a very strong focus on new construction. Noteworthy evolutionary trends of particular interest for LEED include a growing emphasis on the building lifecycle well beyond construction with much greater attention placed on two key aspects:

- Energy efficiency and carbon emissions impacts of buildings
- Operations and maintenance

4.4.4.1 Energy Efficiency

In addition to improved alignment of credits across rating systems, and the introduction of regional priority credits to account for region-specific environmental issues, LEED 2009 offers revised credit ratings such that it now awards more points for strategies that will have greater positive impacts on what matters most – energy efficiency and CO_2 reductions. Earlier LEED Rating Systems did not offer this emphasis on energy efficiency, and as a result, LEED certified buildings vary in energy performance across a spectrum. A study completed by the New Buildings Institute in March 2008 illustrated this phenomenon, and Figure 46 shows “median EUIs by certification level and the individual measured EUIs for each of 100 participating buildings, excluding those consisting of high energy activity types such as labs, data centers and supermarkets".[65]

Figure 46: Energy Use Intensity (kBTU/square foot) for LEED Certified Buildings[66]



The revised credit weightings address the issue of the large variation in energy consumption. A comparison of LEED-NC (for New Construction) version 3 with version 2.2 illustrates the increased emphasis on energy efficiency. While LEED-NC version 2.2 made 17 points available for Energy & Atmosphere credits out of a total of 69 points, LEED-NC 2009 (version 3) makes 35 points available for Energy & Atmosphere credits out of a total of 100 points. This is a 42 percent increase in points available for credits associated with Energy & Atmosphere.

It is also important to note that this increased emphasis on Energy & Atmosphere was previously addressed for existing buildings with the introduction of LEED for Existing Buildings: Operations and Maintenance, issued in January 2008, which made 30 out of 85 points available for Energy & Atmosphere. The proportion of points available under Energy & Atmosphere is unchanged in LEED 2009 for Existing Buildings: Operations and Maintenance, where 35 points are available out of 100 total points.

Lastly, recognizing the gap in LEED rating systems to ensure energy performance over time, USGBC announced the Building Performance Initiative to collect data from all LEED-certified buildings, with the intent to perform performance analysis and provide feedback to owners. This initiative complements the announcement made

[65] (Turner & Frankel, 2008)
[66] (Turner & Frankel, 2008)

earlier this year that will require ongoing performance data from buildings as part of their certification under the latest version of LEED.[67]

4.4.4.2 Operations and Maintenance

Again noting the introduction of LEED for Existing Buildings: Operations and Maintenance in January 2008, the LEED Rating Systems formally addressed existing buildings and the critical role of operations and maintenance:

- The opportunity for existing buildings to contribute to energy efficiency and sustainability far outweighs that of new construction.
- In order for a green building to remain green, proper and consistent operation and maintenance practices over time are vital.

These evolutions in LEED place greater emphasis on the energy performance of buildings over time, and consequently will result in greater demands on building operations and maintenance staff. Table 15 lists major provisions of LEED for Existing Buildings: Operations and Maintenance anticipated to have the greatest impact in building operations and maintenance staff.

Table 15: LEED for Existing Buildings: Operations and Maintenance

Category	Credit(s)	Title & Description
Water Efficiency	1.1	Water Performance Measurement, Whole Building Metering
	1.2	Water Performance Measurement, Sub metering
	4.1	Cooling Tower Water Mgmt, Chemical Management
Energy & Atmosphere	Prereq 1	Energy Efficiency Best Management Practices
	Prereq 2	Minimum Energy Efficiency Performance
	1	Optimize Energy Efficiency Performance
		Existing Building Commissioning:
	2.1	Investigation and Analysis
	2.2	Implementation
	2.3	Ongoing Commissioning
		Performance Measurement
	3.1	Building Automation System
	3.2/3.3	System Level Metering
	6	Emissions Reduction Reporting
Indoor Environmental Quality	Prereq 1	Outdoor Air Introduction and Exhaust Systems
		IAQ Best Management Practices
	1.1	IAQ Management Program
	1.2	Outdoor Air Delivery Monitoring
		Occupant Comfort
	2.1	Occupant Survey
	2.2	Occupant Controlled Lighting
	2.3	Thermal Comfort Monitoring

The impact and demands associated with the credits in Table 15 can be summarized by the following requirements for building operations and maintenance staff:

- Monitoring, tracking and reporting of water use, energy use, space conditions and ventilation, and emissions.
- Occupant education.

[67] (USGBC, 2009)

- Oversight and execution of re-commissioning and continuous commissioning.
- Understanding of metering, energy data acquisition, and analysis.

4.5 Summary

This chapter has provided an overview of the background and current issues necessary to understand the challenges and needs for building technician training. The chapter has provided a summary of global issues including energy, emissions, and sustainability. There was a detailed discussion of building demographics such as age, energy source, and principle activities. An overview of the market and industry trends including green buildings, project delivery methods, benchmarking, demand response, and several other topics were presented. The section concludes with a discussion about oversight and regulatory practices at the federal and state level, as well as guidance and programs by non-profit groups that are shaping the market, such as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and the United States Green Building Council (USGBC).

5 People

The knowledge and skill that building operators and facility managers possess will greatly impact the energy efficiency of a facility. In fact, a poorly designed building with good operations and maintenance practices will often outperform a well-designed building with poor operations and maintenance practices.[68]

As part of the primary research documented within this report, current trends within building controls technician training were studied through the online survey and interviews. Table 15 provides a summary of the survey results. Macro trends that emerged from research include:

1) ***Aging/decreasing population of facility managers and building operations staff with in-depth understanding and hands-on ability with mechanical systems.***
2) ***Increasing need for facility managers and building operators competent and skilled with technology.***
3) ***Growing understanding of the need to assign clear responsibility for energy efficiency and sustainability.***
4) ***Lack of clearly communicated and supported goals for energy efficiency and sustainability.***
5) ***Dwindling budgets and resources present the greatest challenges to retain qualified staff.***
6) ***People do not generally aspire to go into the field of building operations and facility management. Instead, they arrive there more indirectly.***
7) ***Career pathways are not clearly defined for people in this field.***
8) ***Traditional apprenticeship training is insufficient.***

[68] (ASHRAE 2009)

Table 16: Summary of survey results

Category	Observations & Trends
Statistics	• Total responses: 253 • 84% of respondents indicated they serve in a managerial role.
Job Titles	• Respondents provided a broad range of job titles. • One third of respondents indicated their job title as Facility Manager/Engineer.
Buildings	• More than 80% of the respondents manage multiple buildings. • More than one half of the buildings managed by respondents are greater than 100,000 square feet.
Sustainability	• The most common elements of sustainability programs are energy management and lighting.
Energy Efficiency	• Less than half of the respondents track the Energy Use Index or ENERGY STAR rating for their facilities. • About one third have energy efficiency improvement goals of 6-10%. • About one fourth are not aware of any energy efficiency goals. • The top three most commonly implemented energy efficiency measures are: 1) Lighting retrofits 2) HVAC equipment upgrades and replacement 3) Energy audits • The top three most commonly planned energy efficiency measures are: 1) HVAC equipment upgrades and replacement 2) Controls optimization or upgrades 3) Re- or retro-commissioning
Outsourcing	• The top three outsourced functions are: 1) Cleaning and janitorial 2) Landscaping and grounds-keeping 3) Engineering services
Skills Assessment	• Gaps in importance to skills are relatively small from both managers and employees, even in areas that we know are critical. This indicates that participants in this industry "don't know what they need to know". • The most significant gap is in relation to building automation. • Employees rating scores were slightly lower than the scores given by managers. This might indicate that employees are more aware that they need to know more. • The low scores for metering gives an indication of the lack of understanding of operating energy efficient facilities. Both the skills and the importance were very low, which implies that they don't feel it's important to know about.
Challenges	• The top five challenges for respondents are: 1) Not enough money 2) Not enough people 3) Not enough time 4) HVAC systems 5) Lack of management support for operations
Education & Training	• Three quarters of respondents received formal education at four-year colleges and universities or at community colleges. • Only 12% of the courses of study pursued by respondents were directly related to building operations or facility management. • Respondents cited a wide variety of certifications.

5.1 Demographics

For many years, the boiler rooms and physical plants of the United States were primarily the territory of people with backgrounds in mechanical systems and/or maintenance. In the decades following World War II, many of these people were armed forces veterans familiar with steam boilers and heavy equipment. Before widespread use of building automation and controls, issues with building systems could often be addressed by those knowledgeable about mechanical systems. However, as veterans retire and controls have evolved from pneumatic to digital, building operation and facility management become more computerized and complex.

Today, building automation and energy management systems often play a role in monitoring building systems and troubleshooting and resolving issues. The role of technology is expected to continue to grow in the daily life and work of building engineers and facility managers, creating the need for a more technologically savvy next-generation workforce. The good news is that today's students are growing up with more powerful computers, pervasive Internet, and handheld wireless devices, making them very comfortable with technology. However, the question is: Do they want to run buildings? The composition of the workforce will surely change and become more diverse, but the evolution will very much depend on the opportunities available for young aspiring building engineers and facility managers.

5.2 Culture and Competence

5.2.1 Learning Methods

Learning methods of an individual with an interest in management and an individual with an interest in how things work can be very different. Individuals with an interest in management will generally find it acceptable to read a book and listen to lectures. Individuals who are interested in how things work are generally much less motivated to read a book or listen to a lecture. Instead, hands-on practical training is often more appealing. As stated by one survey participant:

"The engineers I work with have been happy to rebuild a pump, happy to paint, happy to work on an air conditioning system – don't make me sit down with a book in front of me – do not make me sit down with a book…." – Focus group participant

To train future technicians requires an interactive, hands-on approach. Although reading is an important and necessary skill, the ability to assemble and disassemble systems and equipment is also a valuable skill. Too often, the value of assembly and disassembly of systems and equipment is deemphasized or seen to be of less value than reading or book-learning.

5.2.2 The "Super Hero Theory"

Within one of the focus groups, a theory that became known within the research efforts as the "Super Hero Theory" was discussed. The theory is the belief that managers think a single individual can have all the expertise necessary to solve operations challenges, including trouble shooting and problem solving, for all types of equipment and systems, as well as customer-relation and business skills, and an ability to quickly adapt to change.

It was concluded within the focus group that although some technicians do fit this definition, it an unreasonable expectation. Additionally, it indirectly demonstrates that managers are not well informed about the complexity of mechanical, electrical, and other systems within buildings. Equating the expectations of the Super Hero Theory to management roles would be like expecting one person to have the skills and competencies necessary to fill the roles of a human resource manager, accountant, bookkeeper, and administrative assistant. The existence of the Super Hero Theory suggests that it may be necessary to educate managers and building owners about the complexity of building systems and technologies.

5.2.3 Perceived Value of Training

Building owners and managers often underestimate the value of training.[69] Many facility managers have found that training is one of the first budget items to be cut, or in some cases, training programs are non-existent.

However, there is research evidence that investments in training are financially beneficial. For example, one study has found that increasing the training budget of a company by $680 per employee can increase total shareholder revenue of the company the following year by as much as 6 percent.[70] A recent IFMA study found that training provided by the International Facility Management Association resulted in a return on investment of nearly four to one.[71] Properly trained technicians can also reduce workplace injuries. A study completed between 1998 and 2000 found that implementing a comprehensive training program reduced recordable accidents by 63 percent.[72]

5.3 Roles and Responsibilities

Facility management is an interdisciplinary field primarily devoted to the management of commercial or institutional buildings such as hotels, resorts, schools, office complexes, government facilities, military bases, hospitals, sports arenas, and convention centers. One definition of facility management provided by the International Facility Management Association (IFMA) is:

> *"... a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology."*[73]

The interdisciplinary nature of facility management is often understated. The practice of facility management integrates the principles of business administration and architecture, as well as the behavioral and engineering sciences. Facility managers are often diplomats, psychologists, managers, and engineers. They must coordinate and oversee the safe, secure, efficient, and environmentally sound operations and maintenance of considerable assets in a cost effective manner, to maximize short-term performance and long-term preservation of the asset value. An increasing focus on energy efficiency, greenhouse gas (GHG) emissions, and water conservation

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69 (Clarke 2009)
70 (ASTD 2000)
71 (Epstein 2010)
72 (Matysiak 1998-2000)
73 (International Facility Management Association)

require facility managers to carefully evaluate the impact of their decisions and actions in light of these issues.

A facility manager must interact with all roles and all levels of responsibility within a building. These roles include, but are not limited to:

- Building owner
- Building occupants and tenants
- Members of the facility management team
  - Managers
  - Technicians
  - Engineers
  - Service providers

5.3.1 Building Owner

The role of the building owner is self-determined. The building owner decides which decisions he/she will make. The type of decisions made by the building owner can vary from high-level management decisions to property and/or facility management decisions. Depending on the structure of the organization, the building owner may have several different titles including, but not limited to: chief executive officer (CEO), property manager, business owner, developer, leasing manager, or asset manager.

5.3.2 Occupants and Tenants

Occupants and tenants are the primary reason for the existence of buildings and the reason for the building operations and facilities management teams to operate buildings. Although the purpose of the building operations team is to operate the building in a manner that meets the needs of the occupants, comfort and energy efficiency needs and other operational and occupant needs can seem at odds with each other.

Some of the challenges that surfaced during the interviews included:

- There is a tension between performance and occupant comfort. Energy and facility managers are asked to determine strategies to reduce energy consumption to control cost, while operators are asked to keep occupants happy. In many cases, processes to reduce this tension do not exist.
- Education of building occupants is becoming increasingly important.
  - Building occupants can have a large impact on energy consumption.
  - Omid Nabipoor, president of Portland's Interface Engineering has stated, "They [occupants] need to buy into strategies and understand how they can change their behavior".[74]
- Building occupants lack awareness about energy efficiency and strategies to maintain building comfort.
- Facility managers and building operators are normally viewed to have low status and prestige within an organization.

5.3.3 Members of the Facility Management Team

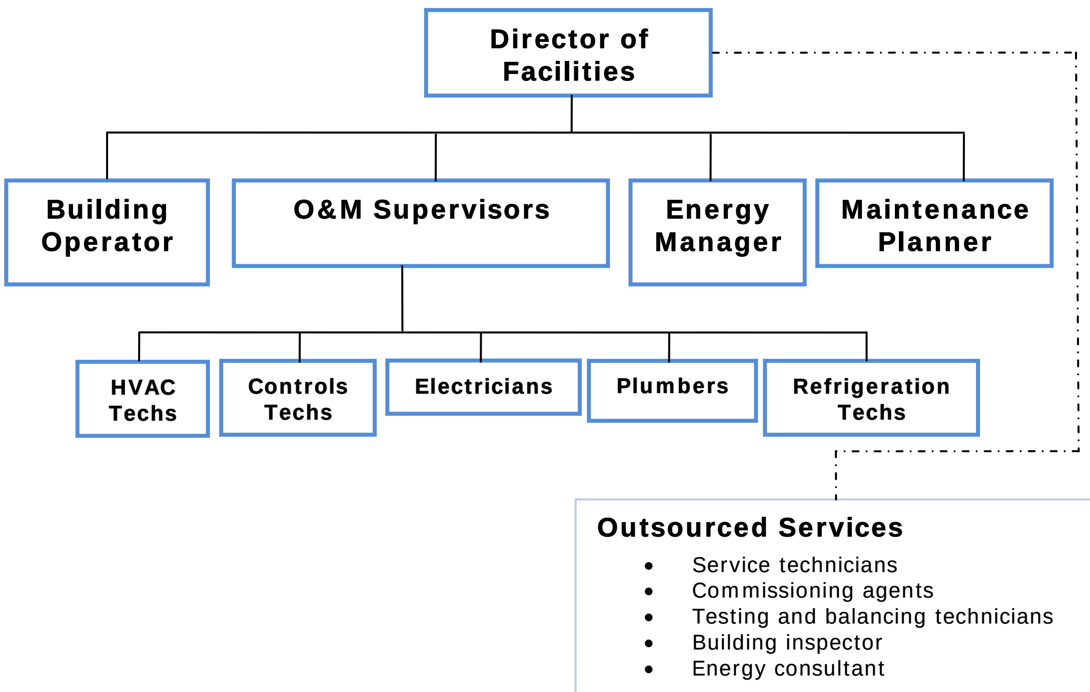
The number of members and specific roles within a facility management team varies given the type and size of the facility. However, a general example in which most organizations fit is provided within Figure 47. For simplicity, only roles directly

[74] (Reed, 2009)

related to HVAC&R, controls and lighting are included within the figure (custodial and administrative roles are not included). Question 3 of the survey also found that, in addition to organization-specific roles, job titles also vary widely. For example, a facilities coordinator may report to the building engineer. Alternately, the building engineer at one facility may be called a facility manager at another facility. In addition, the types of outsourced jobs/services and the hierarchy structure of who manages the outsourced work varies by organization.

In some facilities, the facility management team must also be able to manage office space and equipment. As the use of technology within buildings increases, facility managers will also need to be able to communicate with the IT managers and/or be able to manage IT infrastructure.

Figure 47: Facilities management team and titles



The facility management team must include team members with a wide variety of knowledge and skills. More specifically, the team must be knowledgeable of the following building systems and services:

1. Electric power
    a. Electrical substations
    b. Switchgear
2. Emergency back-up power systems
    a. Uninterruptible power supply (UPS) systems
    b. Standby generators
3. Environmental conditions
    a. Heating, ventilation, and air-conditioning (HVAC)
        i. Central boiler and chiller plants
        ii. Air conditioning equipment
        iii. Refrigeration equipment
    b. Lighting
    c. Plumbing
4. Building monitoring systems
    a. Automation and control
    b. Monitoring
    c. Metering
5. Security and access control
    a. Video surveillance
    b. Card access systems
6. Life safety systems
    a. Sprinkler and extinguishing systems
    b. Smoke/fire detection systems
7. Grounds-keeping
8. Cleaning

The North American Technician Excellence (NATE) Knowledge Areas of Technician Expertise (KATE) provides a detailed list of the areas of knowledge for installation and service of HVAC equipment, developed from a detailed job task analysis.

5.3.4 Interrelationships and Hierarchy of Roles

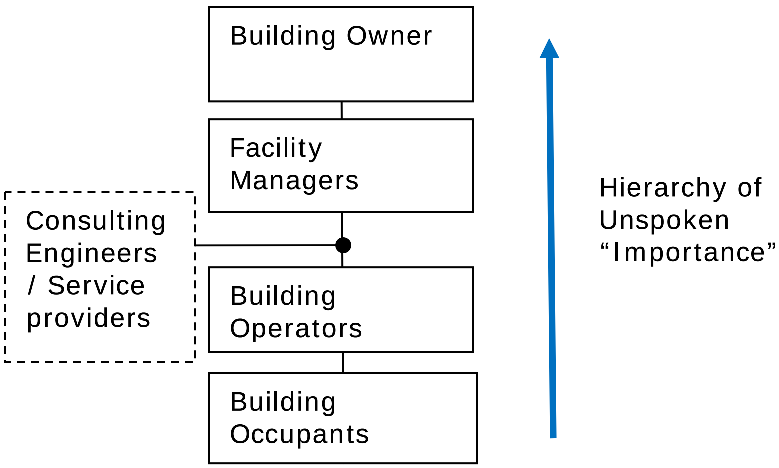
The relationships between the building owner, occupants, and facility management team are interrelated. However, the primary needs of each group are not always well aligned. As shown in Figure 48, the common relationship between the three groups is customer (building occupant) satisfaction. The owner and operators want the occupants to be satisfied, while the occupants often require certain comfort conditions to be met. Within the figure, comfort is defined to include temperature, proper lighting levels, minimal noise, and other conditions required to perform daily work functions within a building. However, how customer satisfaction is achieved and perceived by the owner and the operators is different. The owner looks at customer satisfaction through a financial lens, while the operators look at customer satisfaction through a building performance lens. The financial and performance lenses do not always align.

Figure 48: Interrelationship matrix between facility users

	Customer Satisfaction Important (Yes/No)	Lens of Customer Satisfaction
Owner	Yes	Finances
Operator	Yes	Building performance
Occupants	Yes	Comfort

There is an informal hierarchy within roles of the building owner, occupants, and operators (Figure 49). Occupants are generally viewed as the lowest in the hierarchy, followed by building operators. Operators are sandwiched between competing demands of occupants and budget constraints, staffing limitations, and policy objectives set by owners and managers. As a result, building operators often know more than they readily reveal because they lack authority to make requisite changes, upgrade systems, or make improvements.

Figure 49: Unspoken Hierarchy of Roles within Commercial Buildings



Consulting engineers and service providers are part of the hierarchy, but are not involved in daily activities, and instead enter and exit the hierarchy as needed. Consulting engineers and service providers play short-term roles as they fulfill a short-term need, such as a renovation or purchase of supplies. Consulting engineers can bring unique challenges to a facility management team because consulting engineers speak their own language, often view operators as lacking competence to keep the systems in the building operating as designed, and often lack the insight to understand the organizational structure which must be followed to keep a system properly operating.

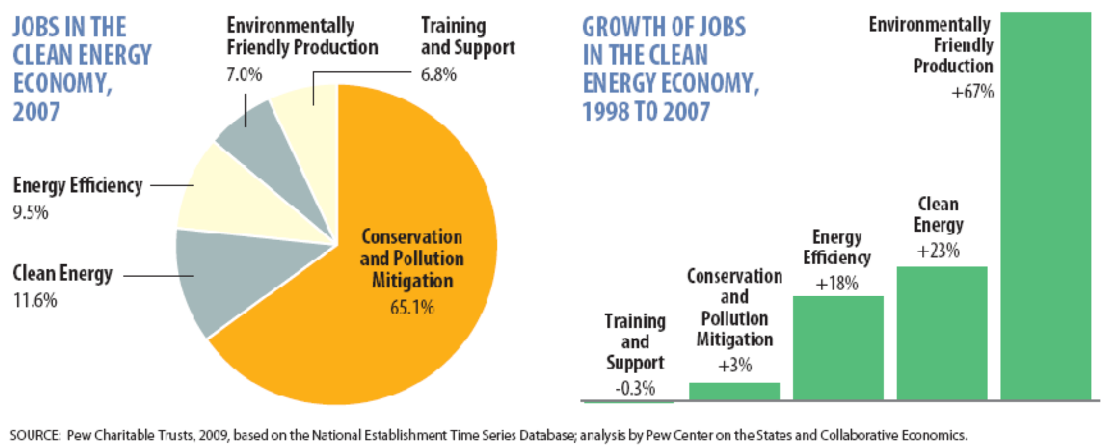
5.3.5 Employment Opportunities

Given the trend and growing focus on buildings and their role with regard to energy, emissions, and sustainability, job opportunities in the sector are anticipated to flourish as we go forward in time.

Currently, 65 percent of clean energy economy jobs are in the category of conservation and pollution mitigation. There is growing recognition among the public, policy makers, and business leaders of the need to recycle, conserve water, and work to mitigate emissions of GHG and other pollutants. As a result, jobs in the categories of environmentally friendly production, clean energy, and energy efficiency are growing at rates faster than anticipated.

Figure 50 summarizes growth trends of clean energy jobs over the last ten years, and Figure 51 illustrates the opportunities, by state, across the U.S. Goldman et al (2010) has found that energy efficiency sector jobs are likely to continue to increase over the next decade. Projected growth rates range from a factor of two to four by 2020, to as great a growth rate of about 11 percent per year. The occupations of this work force are anticipated to be about 25 percent to 35 percent professional occupations: engineers, architects, managers, program planners, and program evaluators. However, 65 to 75 percent of the work force is anticipated to be building and construction contractors and tradesmen.

Figure 50: Energy sector job trends[75]



The need for building control system technicians is anticipated to high. A study targeting the San Francisco Bay area by the Centers of Excellence found that the need for building controls system technicians is expected to grow about 40 percent in the next three years.[76] It will be more difficult to find qualified building controls system technicians compared to seven other professions in the clean energy field including HVAC mechanics, retrofit specialists, and building operators.

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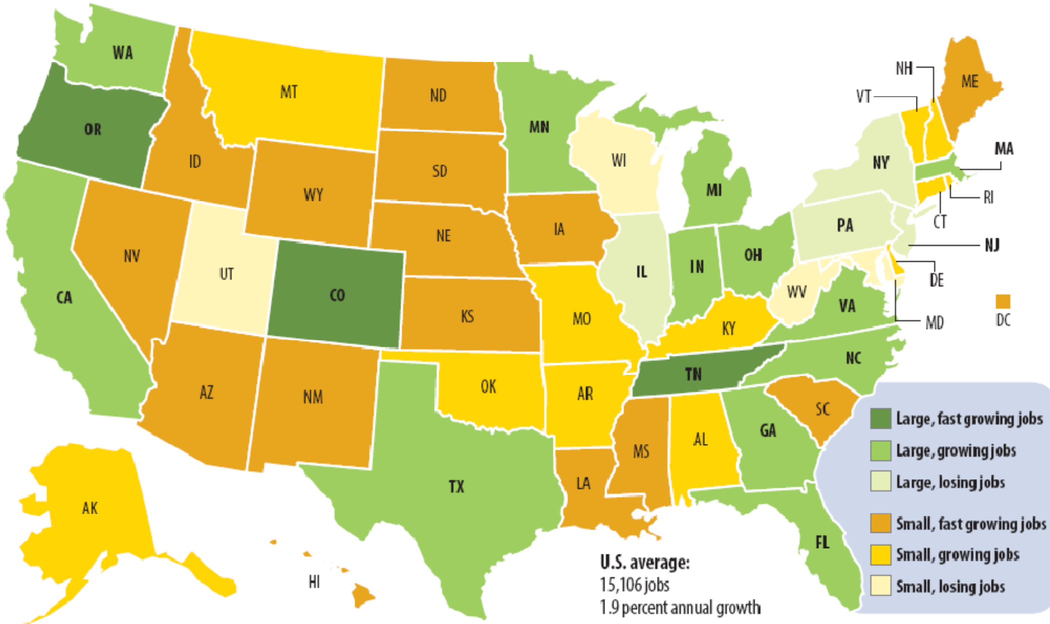
[75] (The Pew Charitable Trusts, 2009)
[76] (Carrese, 2010)

Figure 51: Energy sector job trends by state[77]



STATE	TOTAL CLEAN JOBS 2007	AVG. ANNUAL GROWTH 1998-2007	STATE	TOTAL CLEAN JOBS 2007	AVG. ANNUAL GROWTH 1998-2007	STATE	TOTAL CLEAN JOBS 2007	AVG. ANNUAL GROWTH 1998-2007
Alabama	7,849	0.31%	Kentucky	9,308	1.09%	North Dakota	2,112	3.17%
Alaska	2,140	1.14	Louisiana	10,641	2.06	Ohio	35,267	0.85
Arizona	11,578	2.19	Maine	6,000	2.34	Oklahoma	5,465	0.89
Arkansas	4,597	0.99	Maryland	12,908	–0.11	Oregon	19,340	4.77
California	125,390	0.88	Massachusetts	26,678	0.52	Pennsylvania	38,763	–0.48
Colorado	17,008	1.98	Michigan	22,674	1.20	Rhode Island	2,328	0.37
Connecticut	10,147	1.11	Minnesota	19,994	1.38	South Carolina	11,255	3.56
Delaware	2,368	0.23	Mississippi	3,200	2.57	South Dakota	1,636	7.89
District of Columbia	5,325	2.13	Missouri	11,714	0.71	Tennessee	15,507	2.14
Florida	31,122	0.90	Montana	2,155	0.15	Texas	55,646	1.70
Georgia	16,222	1.18	Nebraska	5,292	10.00	Utah	5,199	–1.31
Hawaii	2,732	4.29	Nevada	3,641	3.15	Vermont	2,161	1.69
Idaho	4,517	10.11	New Hampshire	4,029	0.44	Virginia	16,907	0.66
Illinois	28,395	–0.25	New Jersey	25,397	–1.08	Washington	17,013	0.23
Indiana	17,298	1.88	New Mexico	4,815	4.73	West Virginia	3,065	–0.36
Iowa	7,702	2.66	New York	34,363	–0.14	Wisconsin	15,089	–0.55
Kansas	8,017	4.74	North Carolina	16,997	1.62	Wyoming	1,419	5.16

SOURCE: Pew Charitable Trusts, 2009, based on the National Establishment Time Series Database; analysis by Pew Center on the States and Collaborative Economics.

5.3.6 Wages of Building Control Technicians and Facility Managers

The wages of building control technicians and facility managers will vary based on experience, region, and other organizational factors. In general, the average annual entry level salary for HVAC technician or installer is about $41,000, while an experienced technician or installer is likely to earn about $72,800 in the San Francisco Bay area.[78] The annual salary for facility managers with less than four years of experience is about $63,000. For experienced facility managers with a

[77] (The Pew Charitable Trusts, 2009)
[78] (Carrese, 2010)

bachelor degree, annual salaries are about $86,000 and as great as $96,750 annually for experienced facility managers with a master's degree.[79]

5.4 Education and Training

In many cases, people who currently work in building operations and facility management positions did not actively choose to enter the facility management or building operations field. Many people within the facility management profession will state that they "fell into the profession". The results of the survey conducted to support the research summarized within this report support this statement: only 12 percent of the survey respondents indicated that they pursued a course of study directly related to building operations or facilities management. This is very low, especially when considering that almost 50 percent of survey respondents received formal post-high school education from a four-year college or university, about 25 percent from a community college, and about 25 percent of respondents received training through certification programs or other methods. Given the indirect nature of entry into the profession, there exists extreme variation in education, training, and experience among the people working in the field. Regardless of how people arrive in the field, industry experts appear to agree on some of the most important knowledge and skills required:

- A systems perspective
- Assessment of impact on efficiency and sustainability
- Finance and economics
- Technology literacy
- Communication skills, including diplomacy
- Troubleshooting

Figures 52 and 53 summarize how individuals within the field of facility management and operations (Figure 52) and their managers (Figure 53) assessed their skills, and the importance of the same. Analysis of Figures 52 and 53 reveal that:

- The most significant gaps are in building automation.
- Gaps between importance and skill level are relatively small (both Figures 52 and 53). This indicates survey participants do not know what they need to know and sometimes may not know what they don't know.
- The rankings of the scores were slightly lower for individuals, as compared to scores provided by their managers. This may indicate that employees are more acutely aware that they need to know more.
- Low importance and skill level for metering may be an indication that there is a lack of understanding of how to operate energy efficient facilities. Although metering is required to track real-time energy performance of buildings, respondents rated both the skills and the importance low. This implies that the respondents did not feel it is important to know about building systems that manage energy consumption. This finding is inconsistent with many current trends described within other sections of this report.

[79] (IFMA Profiles 2007)

Figure 52: Individual/management skills assessment

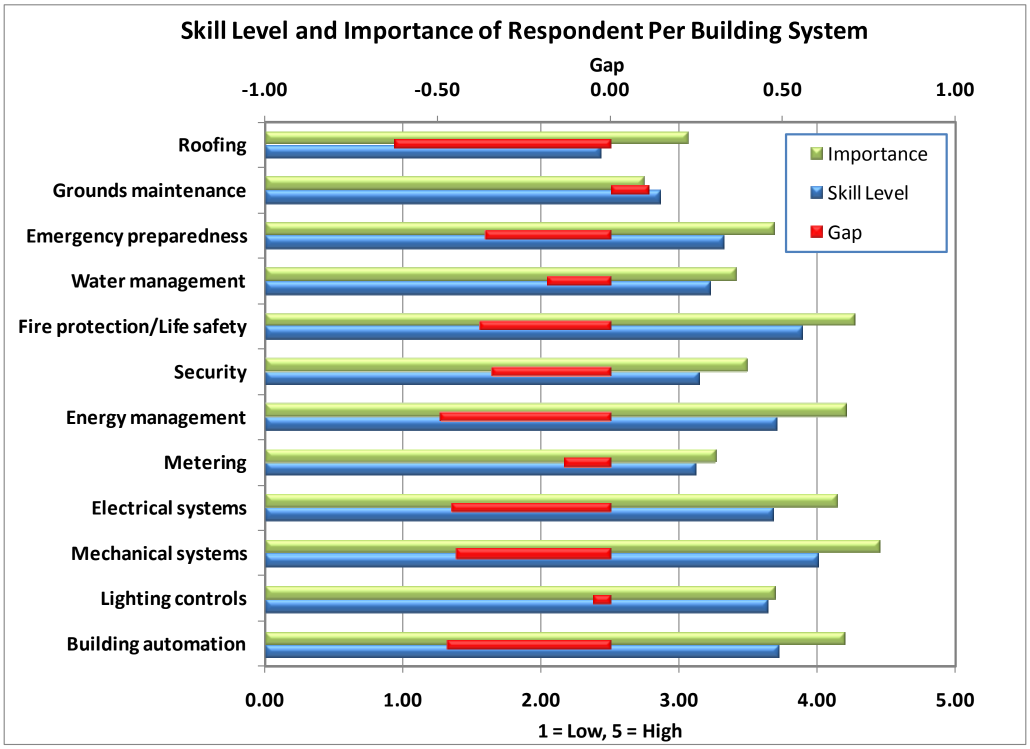
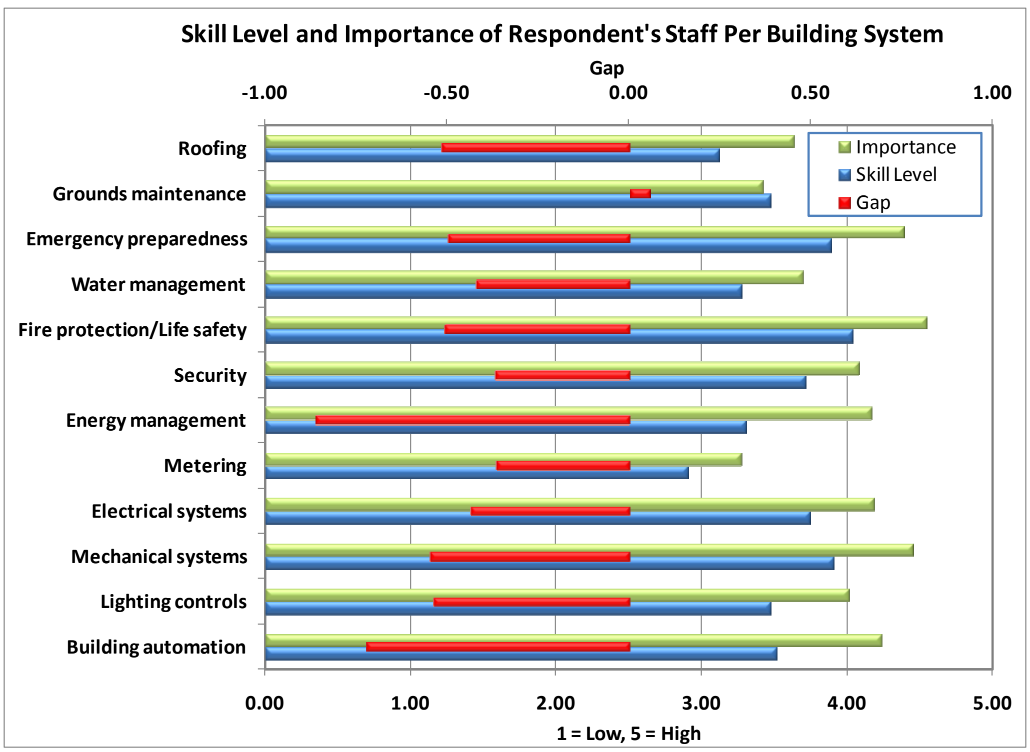
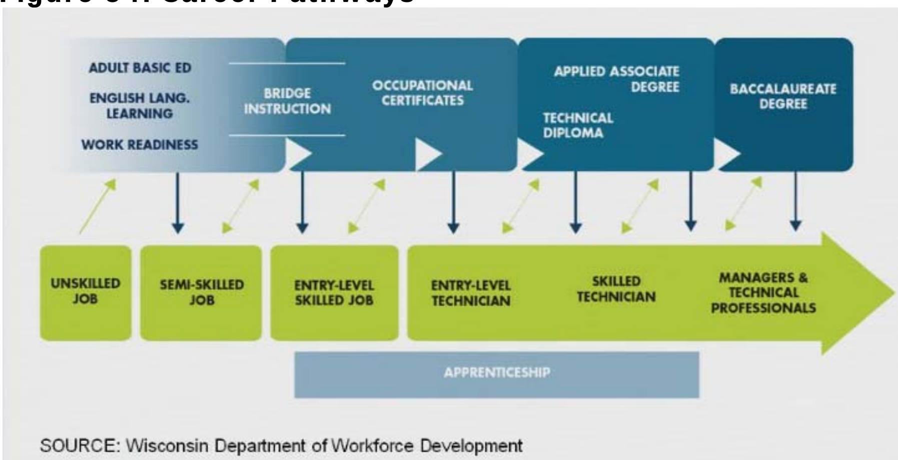


Figure 53: Staff skills assessment



As the facility management and building technician professions mature, career pathways will emerge (Figure 54).[80] As the career pathways emerge, it will be important to clearly identify different career paths for future professionals who seek to have a hands-on, field-based career versus a career that transitions from field experience to management experience.

Figure 54: Career Pathways[81]



5.4.1 Identified Training and Education Opportunities for Facility Managers

The variation in education and training of facility management and building operations professionals maybe due to a lack of training opportunities or a lack of awareness of available training opportunities. This section of the report seeks to identify current training opportunities.

For facility managers, the training opportunities exist at the graduate, four-year undergraduate, community college, and certification levels. The International Facility Management Association (IFMA) manages the largest facility management accredited degree program through the IFMA Foundation. The IFMA Foundation Accredited Degree Program (ADP) was developed in the 1990s to provide a recognized standard for facility management degree programs. The current standard can be found on the IFMA Foundation web page, www.ifmafoundation.org/scholarships/degree.cfm. Currently, five bachelor and two masters programs within the United States are recognized as ADP. Several more programs are anticipated to receive ADP status by the end of the 2010 calendar year. It is understood from the interviews that the development of facility management programs at the community college level has been the most challenging.

In addition to degree programs in facility management, there are also various opportunities for certification. IFMA offers the Facility Management Professional (FMP) and Certified Facility Manager (CFM) certifications. The Association for Facilities Engineering offers the Certified Plant Engineer (CPE), Certified Plant Maintenance Manager (CPMM) and Certified Plant Supervisor (CPS) certifications. ASHRAE offers the Operations and Performance Management Professional (OPMP) certification. Within the facility management profession, the CFM is the commonly

[80] (Anderson 2010)
[81] (Anderson 2010)

obtained facility management certification. Since 1992, over 3,100 professionals have been certified.[82] The ASHRAE OPMP was very recently developed, and when this report was published fewer professionals earned the OPMP than any of the other four ASHRAE certifications.

5.4.2 Identified Training and Education Opportunities for Control Technicians

For technicians, training opportunities are less structured. There does not appear to be an organization that oversees degree programs for technician training like the IFMA Foundation does for facility managers. In general, training opportunities for building technicians fit into four categories:

- Community colleges through courses and/or degrees
- Union apprentices and training
- Proprietary /vendor training
- Industry training and certifications
- Unstructured training / on-the-job training

Several community colleges across the United States have degree programs or courses related to HVAC and building control systems (Table 17). Some of these programs include a focus on energy efficient operation. It is suggested that community colleges are best suited to provide in-depth education and training because:

- Community colleges are structured to teach students who are seeking several different levels of education, including the completion of one class, completion of a certificate program, or completion of an associate degree.
- Association or membership with a professional association or trade union is not a prerequisite for enrollment.
- Community colleges provide courses in math and science, which are the foundation for understanding building control systems, as well as the ability to trouble-shoot and think critically about real-world operational challenges.
- Graduates of community colleges can be employed in either a union or non-union environment.

In order for community colleges to effectively provide in-depth education and training, a method to allow community colleges to share ideas and resources is needed. From the research completed for this report, it does not appear such a structure currently exists.

[82] (IFMA 2010)

Table 17: Summary of Identified Community College Programs Focusing on HVAC and Building Control Systems

Category	Institution or Organization	Program
Facility management	Milwaukee Area Technical College	Sustainable Operations
	UC Berkeley Extension	Engineering, Construction, and Facilities Management
Controls Technician	Laney College	Environmental Control Technology
	Pennsylvania College of Technology	Building Automation Technology
	Seneca College	Mechanical Engineering Technology – Building Sciences
	Wilbur Wright College	Building Energy Technology

Another program of interest is the Fayetteville Technical Community College. This community college has a visualization lab, The Interactive 3-D Facility, which allows students to assemble and disassemble systems and equipment virtually.

Proprietary or vendor based training is a third option. Although this type of training is very helpful to understand and troubleshoot a specific vendor solution, it may not provide general concepts or background knowledge, or encourage learning. The training may be limited to performing tasks as demonstrated by instructors.

Within the industry, there are several industry-based training programs. Each is summarized within Table 18.

Table 18: Summary of Identified Industry Based Training Programs

Industry Program	Description
American Trainco	Classroom training, HVAC controls and air distribution
Mechanical Contractors Association of America (MCAA)	HVAC green mobile classroom[83]
Metamedia Publishing	Interactive online training modules, includes controls module
MPACT Maintenance and Reliability Solutions	Multiple controls courses
National Association of Power Engineers (NAPE)	Classroom training, HVAC, controls, boilers, electricity
Wattstopper	Lighting control technician training program developed in partnership with National Joint Apprenticeship and Training Committee (NJAETC)

On-the-job training is the most common method of training. From a survey completed by the Lawrence Berkeley National Lab, on-the-job training was used by

[83] (MCAA 2010)

about 80 to 90 percent of survey participants. The report also finds that although reliance on only on-the-job training may be problematic, it is a necessary part of the work environment.

Union apprenticeship and training programs also exist (Table 19). A recent study by the National Science Foundation (NSF) has identified that thousands of apprentices and journeymen take classes at union training centers each year.[84]However, some of the current limitations of union programs identified through the focus groups, interviews, and surveys within this NSF sponsored research include:

- Due to the highly rigid divisions of labor within union structures, programs are often structured to support specific trades such as steamfitters, electricians, or plumbers.
- Apprentice programs are mainly on-the-job training programs with little formal classroom training. As a result, apprentices are less likely to learn how to learn and more likely to learn how to perform repetitive tasks.
- Unions tend to be resistant to change that could impact their scope or range of work. Thus, it may be challenging for community colleges and/or other unions to encourage change.
- Unions do not have continued education or training requirements.
- Unions can be perceived as wanting more money to complete less work. This perception may be in conflict with training, as acquiring new skills could result in more job responsibility.

When working with unions, it is very important to:

- Be highly sensitive to their needs and approach union members carefully and discretely.
- Determine how the union and those partnering with the union can emphasize the strengths each group brings to the partnering relationships. For example, unions can provide apprenticeship opportunities, while community colleges are equipped to teach math and science.

However, some more progressive unions understand that it is necessary to provide cross-skills training and that it will benefit union members.[85]

Table 19: Summary of Identified Apprenticeships

Apprenticeships	University of Virginia	Facilities Management Apprenticeship
	West Virginia University	Facility Management Apprenticeship
Union Apprenticeships	Various union programs	Steam fitters, sheet metal workers, pipefitters, operating engineers
	International Brotherhood of Electrical Workers (IBEW)	At the time of publication, a new training course for BAS technicians was in development through the IBEW, in partnership with the NJACT.

The IBEW program in development in partnership with the NJACT will use two textbooks currently in the public domain, Building Automation: Control Devices and Applications and Building Automation: System Integration with Open Protocols both developed by the NJACT. The course will include practical exercises, some paper-

[84] (Goldman et al 2010)
[85] (Goldman et al 2010)

based and some using control hardware. The program will be offered to local IBEW union members as they enter the fifth year of the apprenticeship program. As the number of students is likely to exceed the number of union trainers with the skill set required to teach this program, a train-the-trainer program is also being developed. The train-the-trainer program will be a supplement to the student learning materials for program instructors, and emphasize how to teach the topics, provide insight from experienced professionals, and discuss why the topics covered in the program are important.

Some universities, community colleges, and professional associations offer continuing education programs, as identified in Table 20.

Table 20: Summary of Identified Continuing Education Programs

Program	Website
CUNY Institute for Urban Systems	http://www.cunyurbansystems.org/pages/building-performance-lab/professional-and-continuing-education.php
De Anza College, Cupertino, California	http://www.deanza.edu/kirschcenter/[86]
National Association of Power Engineers	https://www.powerengineers.com
Penn State, Facilities Engineering Institute	https://fei.psu.edu/home2/index.aspx
University of Wisconsin Extension	http://epdweb.engr.wisc.edu

5.4.3 Identified Certification Programs for Building Control Technicians

Certifications are voluntary designations a person receives to demonstrate professional competence in an area of expertise. Controls were part of many of the certifications identified within this study, but none of the certifications focused only on controls.

[86] (Roberts and Naqvi 2010)

Table 21: Summary of Identified Building Operator Certifications

Program	Description
BOC	Building Operator Certification
BOMI	Building systems maintenance certificate
Midwest Energy Efficiency Alliance (MEEA)	Building Operator Certification
National Association of Power Engineers (NAPE)	Supervising Engineer, Air Conditioning and Refrigeration, Electrical Proficiency
North American Technician Excellence (NATE)	Technician certification, controls is part of several certifications
National Energy Management Institute (NEMI)	Testing and air balancing bureau (TABB) certification Courses: Sounds and vibration, TABB, Commissioning, HVAC Fire Life Safety Systems
Refrigeration Service Engineer Society (RSES)	Certificate Membership of 18 categories, some controls categories

5.5 Needs of Training and Education Programs

The results of survey question 22 provided insight into the continuing education needs of current facility managers and building technicians. Overall, the responses were very diverse, ranging through management, business, engineering, communication, and computer skills. The top seven most common responses are listed in Table 22.

Table 22: Most Common Skills/Certifications Desired by Survey Respondents

Rank	Skill
1	IFMA Certified Facility Manager (CFM) certification – facility management skills
2	Energy management – general knowledge
2	USGBC Leadership in Energy and Environmental Design Accredited Professional (LEED AP certification)and/or general knowledge of green/sustainable buildings
3	HVAC – general knowledge
3	Building automation systems – general knowledge
3	Business – general knowledge
3	Management – general knowledge

Given Table 22, there is a large opportunity to provide general knowledge about energy management, HVAC, building automation systems, business, and management within individual courses and degree programs. IFMA and the USGBC both have review materials and/or training courses for the certifications listed within the table. Within the focus groups conducted as part of this study, several themes specific to technician training emerged (Table 23).

Table 23: Needs for Technician Training

Theme	Comments
Delivery structure	• Offer a program, opposed to disparate classes • Include field and lab experience • Re-introduce apprenticeships • Incorporate role playing
Use of Internet	• Offer courses and training via the Internet • Create an opportunity for peer to peer sharing via the web
Program requirements	• Require continuing education
Course content	• Offer opportunities to work with a variety of systems (HVAC and IT system knowledge) • Provide a holistic perspective of how buildings operate • Promote knowledge of air systems, including the properties of air and psychometrics • Train how to collect and use trend data • Teach students how to adapt to rapidly changing technology

General comments from the focus groups about controls technician training needs also included:

- Creation of processes for high performance building operations.
- Generation awareness of the benefits of training and education.
- Promotion of awareness of the advantages and importance of energy efficient facilities.
- An understanding that "super technicians" cannot be an expected norm (see Section 5.2.2).

Meeting these needs will require the development of new tools and teaching methods. The use of computer simulation and virtual training tools,[87] as well as further development of economical hands-on labs, will be necessary.

5.6 Collaboration

Given the size of the current and future need for high performance building controls technicians, the various organizations involved with training, and current levels of training development, collaboration will be important. A framework for unions, community colleges, building owners, continuing education programs, professional associations, and product vendors is needed. Specific details of what and how collaboration should occur is beyond the scope of this report. However, some foundational ideas are shared in Chapter 10, Vision.

5.7 Summary

This section summarized the roles and interdependent relationships of the facility management team, building owner, and building occupants. It discussed employment opportunities for building control technicians, and current education and training practices and needs. Current education and training of controls technicians is addressed to some degree by community colleges, union apprenticeships,

[87] (Crabtree et al 2004)

proprietary/vendor training, and industry training. However, there are fewer trained controls technicians than are needed to meet future demands.

6 Processes

The lifecycle of a building is a continuous process (Figure 55). Over the life of a building, about 10 to 25 percent of the building lifecycle is consumed by the planning, design, and construction phase. Capital asset management consumes another 10 to 25 percent. The largest portion of the lifecycle consists of operations and maintenance, between 50 to 70 percent.

Figure 55: Building lifecycle[88]

Key observations and trends regarding operations and maintenance processes include:

1) ***Facilities management, operations, and maintenance cover a broad scope of activities and responsibilities.***
2) ***Today's operations, maintenance, and management practice is dominated by a reactive approach.***
3) ***Standard processes for operations, maintenance, and facilities management are generally not understood or consistently applied.***
4) ***There is often a lack of clearly communicated and support goals for energy efficiency and sustainability.***

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[88] (Nash, 2008)

Although the cost and amount of time spent on building operation is the greater expense, owners, engineers and researchers often spend the most time focusing on the planning, design, and construction phase. As a result, operations and maintenance practices are often reactive and unstructured. This results in several challenges:

- Systems are not properly maintained.
- Systems are designed and installed for lowest first cost, opposed to lifecycle cost.
- Maintenance activities completed are often equipment focused, as opposed to systems focused. This can result in inefficient operation and occupant discomfort.
- A perception that members of the facility management and/or building operations team are at odds with the sustainability initiatives.
- Building operators are not integral to the change management processes needed to achieve high performance buildings goals.

6.1 Largest Process Challenges

Responses to survey questions 15 and 16 provide insight into the largest challenges faced by facility managers and technicians. From question 15, the three largest needs are money, people, and time. However, nearly anyone in any profession will make this claim one or more times in their professional life. Question 16 provides further insight about why money, people and time are the largest challenges. The responses to question 16 can be classified into four repeated themes:

- Lack of shared values between team members involved in solving the challenge
- Lack of staff with required skill sets
- Lack of proactive maintenance practices
- Lack of opportunities for continued education

The lack of shared values between team members involved in solving the challenge was the most common theme. A lack of shared values was identified between:

- Building owners and lower ranking management
- Vendors and customers
- Tenants and facility managers/technicians
- Financial decision makers and technically knowledgeable operators
- Property managers and facility managers/technicians

The most common lack of shared values was between the financial decision makers and those with technical knowledge. More specifically:

- There is a lack of technical understanding of what “going green” really means.
- The value and benefits to the bottom line from upgrading equipment is not understood.
- There is unwillingness from upper management to listen to the needs of the facility manager/technician to improve process efficiency.
- Upper management lacks the understanding that proper training is needed for efficient building operation.

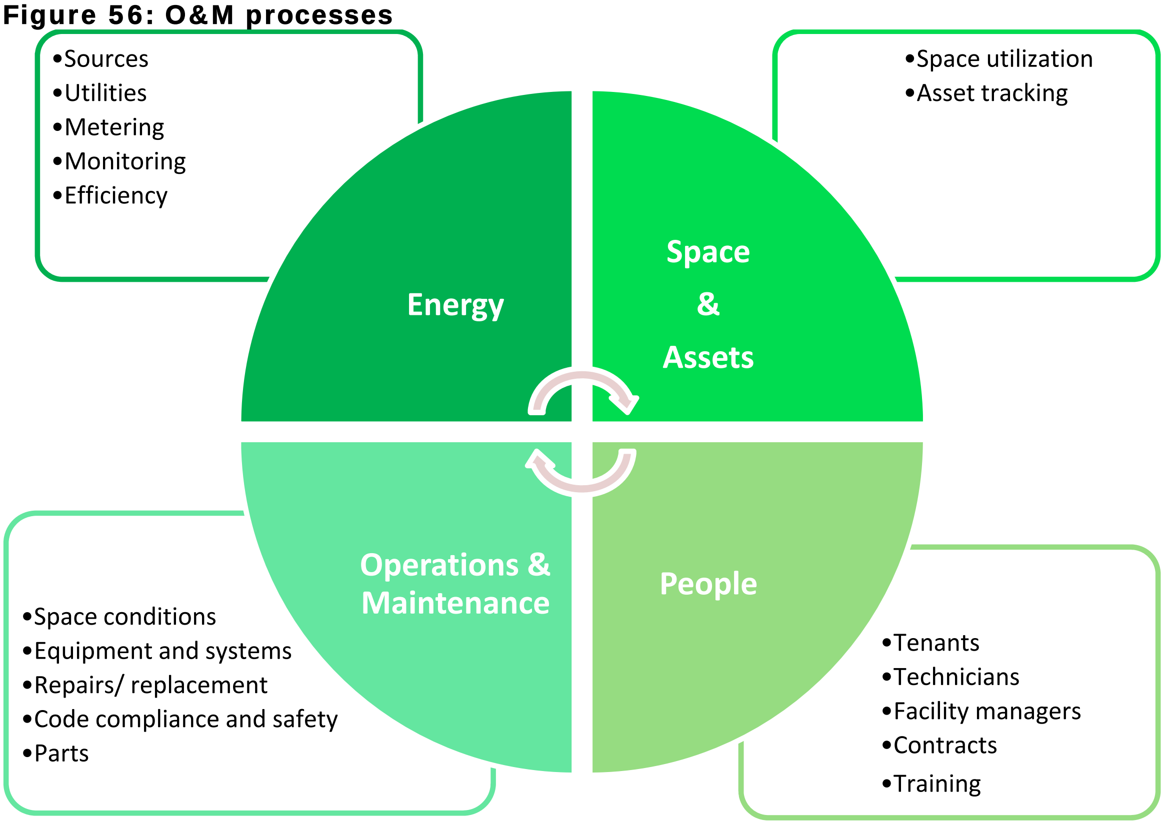
6.2 Operations & Maintenance

Operations and maintenance processes within a building are much broader and deeper than the name suggests. Operations and maintenance often encompasses a wide collection of processes, including, but not limited to:

- Space and asset management
- Energy management
- Maintenance management
- People and resource management

As shown in Figure 56, the operation of a building requires individuals with a diverse skill set. As each of the identified needs is part of the building management process, individuals must be able to communicate with other individuals with many different knowledge sets. Documentation methods and technologies used are a central part of the commutation process. Finances are also important, as the top decision makers in the process often communicate and make decisions based on financial criteria.

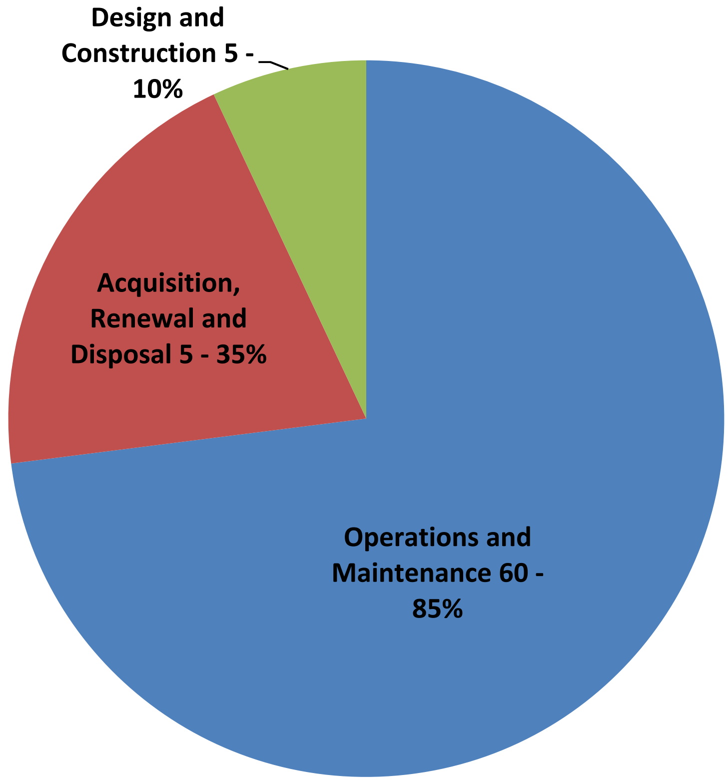
Figure 56: O&M processes



6.2.1 Financial Decision Making

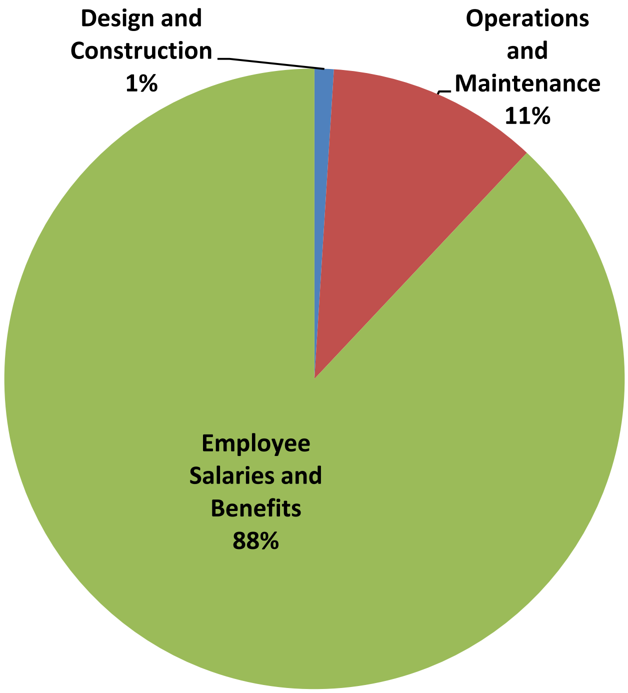
Current financial decision-making processes can negatively impact the ability of an operations and maintenance team to proactively manage and operate a high performance building. In most cases, buildings are designed and built using the lowest capital cost as a primary decision factor. Additionally, as equipment replacement decisions need to be made, return on investment (ROI) and payback are commonly used criteria. However, over the building life cycle, lowest capital costs and ROI are generally not the most economical decisions. As shown in Figures 57 and 58, the design and construction phase of a building is a much smaller percentage of the total life cycle cost than operations and maintenance.

Figure 57: Lifecycle cost for developing, operating and maintaining a non-residential building[89]



[89] (Christian and Pandeya 1997)

Figure 58: Lifecycle cost for developing, operating and maintaining a non-residential building when employee salaries and benefits are included[90]



6.2.2 Impacts of Disjointed Controls Design on Operations and Maintenance

Impacts of Disjointed Controls Design on Operations and Maintenance
Since the development of the first building automation system (BAS) in the 1970's, the level of sophistication of BAS systems has continued to increase. However, data management and processes of how to use, collect, and analyze data have not kept pace with the rate of technology development. As a result, several parts of the design process are disjointed, especially when seeking to design and operate energy efficient systems for high performance green buildings.[91] [92] [93]

The priorities of a typical building owner also create challenges for delivering energy efficient control systems. Brambley, Haves et al. (2005) state that control systems are:

- Often not purchased for potential energy savings, but for reducing maintenance or other non-energy related reasons.
- Generally considered nearly last during the design and construction process.

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90 (NIBS 1998)
91 (Hartman 2000)
92 (Brambley, Haves et al. 2005)
93 (Peterson and Sosoka 1990)

- Little attention is paid to energy expenditures and savings potential because building energy expenses account for a very small fraction of total building economic activity, about less than one percent of total office expenses.

Limited use of control theory adds to the challenges because sophisticated methods are generally not used. Even though BAS have the ability to perform applications beyond stand-alone proportional integral derivative (PID) control and single input/output proportional control, this is very commonly the design standard. Techniques such as networked control,[94] fault detection diagnostics, use of building mass as a method of thermal storage to reduce heating/cooling loads, and other advanced control strategies have been developed within research, but are very seldom applied in practice.

Current BAS procurement practices create challenges because of single sourcing and proprietary hardware. Controls hardware and software is often proprietary.[95] This creates a challenge because an "or equal" of a product may not be available. Thus, if a contractor tries to single source a control system, especially when the system is different than what was specified in the basis of the design document developed by the mechanical engineer, construction delays and/or cost increases due to coordination problems between the basis of design and the single source supplier can result.

6.2.3 Reactive and Proactive, Preventive and Predictive Approaches

Within most buildings today, although the technology exists to manage buildings proactively, operations and maintenance management practices are generally reactive. Reasons why buildings are reactively managed are process based. Although proactive building management technology exists, standard processes to use the technology do not exist across most organizations or the industry. The development of standardized processes, especially for multiple building organizations, has the potential to generate significant cost and energy savings.

There are two basic approaches to management: reactive (unplanned), or proactive (planned). Within building operations and maintenance management, proactive management is classified as preventive and predictive. Drawing upon definitions used in maintenance management, preventive maintenance is time-based. A management activity is completed after a given time interval or specified condition. Examples would include changing the filter in an air handler every six months or replacing a bearing after a fan has been in operation for 2,000 hours. Predictive maintenance is condition-based. An example of predictive maintenance would be to change the filter in an air handler after the static pressure across the filter has reached a given threshold.

Within the operations and maintenance of buildings, reactive management is the most commonly used technique. Some facility managers and technicians will describe themselves as 'fire fighters,' where the team spends all productive time responding to one emergency after the next. As a result, there is no time to plan or efficiently assign individuals to tasks, document completed work or parts used, or receive training. As a result, there is little quantitative data to support maintenance management decision-making.

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[94] (Hartman 2006)
[95] (Hartman 2003)

Energy consumption and costs are also often reactively managed. In many facilities, the primary source of energy consumption data is the utility bill. Utility bills can be helpful to benchmark past energy consumption, but are not the most effective tool for proactive, real-time energy management.

The lack of clearly defined processes is one of the major barriers to progress in the field and advancement of operations to support high performance buildings. To move from active to proactive management will require facility managers and professionals working with facility managers to document best practices to define and standardize energy and maintenance management processes.

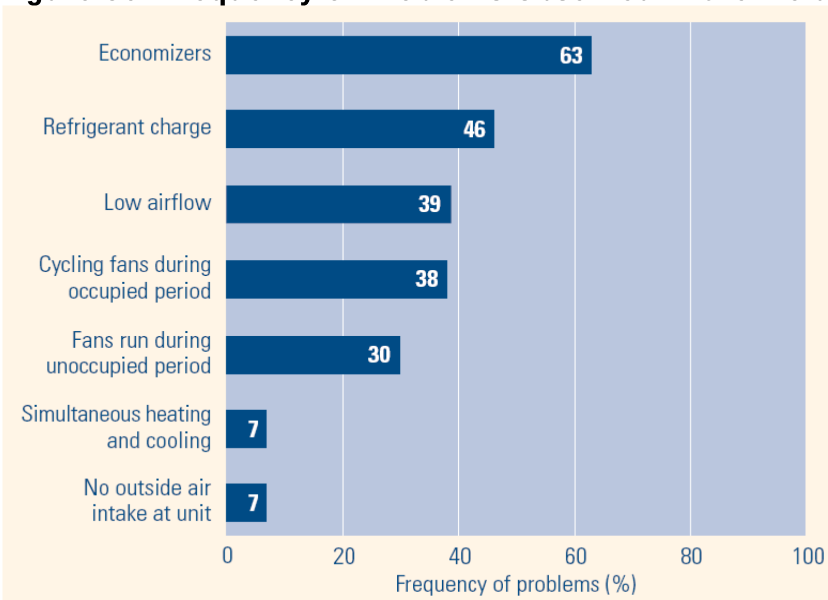
6.2.4 Focus on Energy Efficient Products

In order for a high performance building to be energy efficient, it is necessary that efficient systems and equipment be installed. However, it is even more important to ensure that the installed systems and equipment are operated efficiently. Often, owners and engineers think that high performance buildings end with design. However, a high performance building will only continue to be a high performance building during operation if practices are proactive and provide motivators for facility managers and technicians to operate buildings efficiently.

The National Association of Power Engineers (NAPE) President has stated "We cannot purchase energy efficiency; we can enable it through continual training, testing, certification, and encouragement."[96]
A study by Public Interest Energy Research (PIER) supports this challenge.[97] The study of small rooftop HVAC systems found that economizers, a control strategy that reduces energy by reducing the cooling load, were the most frequent problem observed in the field (see Figure 59). As shown in the figure, economizers were not working 63 percent of the time.

[96] (McGann 2009)
[97] (PIER nd)

Figure 59: Frequency of Problems Observed in the Field



6.2.5 Software Interoperability

Interoperability is the ability for one software program to import or export content from another software program. NIST (2004) estimates that the United States construction industry wastes $15.8 billion per year due to poor interoperability. Two thirds of this cost is from operations-related software interoperability, equating to a loss of $10.5 billion annually.[98]

Interoperability is important within facility management because multiple software programs are often required within the same organization. Further discussion of interoperability can be found in Chapter 7.

6.2.6 Centralized or Decentralized Facility Management

Ninety-two percent of survey respondents managed one or more buildings. Multiple building organizations typically operate using one of two models:

- Centralized: Buildings are managed by a central operations center and are assigned based on tasks, not buildings.
- Decentralized: Staff is assigned to specific buildings and likely performs multiple services for the building.

Within the centralized model, the central operations staff dispatches a crew out to buildings requiring service as needed. Crew members typically have specialty areas, such as tenant services, operations management, energy analysis, network support, security, or business continuity. Within the decentralized model, each building has dedicated staff and operational decisions are supported at the local level.

[98] (Gallaher, O'Connor et al. 2004)

From the survey: Current Practices, Challenges and Needs of Maintenance and Energy Management Programs,[99] the following trends for multiple-building organizations emerged:

- Maintenance plans across multi-building organizations are not standardized. Reasons for lack of standardization included:
    - Top leadership does not require a standardized plan.
    - The value of the plan is not understood by top leadership.
- Energy management plans across multi-building organizations are not standardized. Reasons for lack of standardization included:
    - Standardized plan is not required by top leadership.
    - Lack of funding to develop the plan.
    - The value of the plan is not understood by top leadership.

6.2.7 In-House versus Outsourced Facility Management

Outsourcing and out-tasking enables facility management teams to free up time and resources to focus on their core tasks and highest priorities. Out-tasking refers to the engagement of outside contractors to perform discrete services or tasks such as cleaning, landscaping, and HVAC equipment repair. Outsourcing is generally larger in scope, encompassing maintenance, building operations, or complete facility management services. Outsourcing also often includes placement of full-time staff on-site. The amount of in-house versus outsourced work, and the type of work performed by each structure, is dependent upon many factors including building function and size, public versus private sector owner, and specific service provided.

Currently, it is more common to perform facility management tasks in-house. Outsourcing of services is often considered when in-house departments have failed or appear to be incapable of keeping the facility in service, or when labor problems become too large to be internally rectified by the management team and building owners.[100]

One of the survey questions asked about outsourced work. Landscaping and cleaning/janitorial were the two most common responses where the majority of the work was outsourced.

The drivers for the use of outsourcing and out-tasking in the private sector are often based on profit/payback, market signals, and corporate responsibility. Within the public sector, policy and payback are the primary drivers. The payback within the public sector can be two or more times as compared to the private sector.

Quantitatively:

- General Services Administration (GSA) has found that outsourced service providers lack qualified, well trained people to manage buildings and equipment 97 percent of the time.[101]
- A recent International Facility Management Association report found that in-house staff members meet 60 percent of the labor needed for controls/low-voltage technicians and HVAC and central plant operations tasks. Contracted employees make up the remaining 40 percent.[102]

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[99] (Lewis 2009)
[100] (Cowley 2010)
[101] (Media Release 2010)
[102] (International Facility Management Association (IFMA), 2009)

- The market has seen an increasing shift in outsourcing of facility management tasks, including companies such as Johnson Controls Inc., Jones Lang LaSalle, Cushman & Wakefield, and CB Richard Ellis.

Table 24 provides some benefits and challenges associated with outsourcing and out-tasking. It should be noted that this table is not a list of all possible pros and cons. Depending on one's role within an organization and/or organizational specific characteristics, some of the pros may be seen as cons, and vice versa. Finally, there are many factors which impact if in-house or outsourced labor is more cost effective. Cowley (2010) states "Outsourcing is not always a less-expensive or even successful alternative."[103]

Table 24: Pros and Cons of Outsourcing and Out-tasking

Pros	Cons
Provides access to specialized skills on an as needed basis, such as absorption chiller maintenance.	Poorly established contract terms or scope may prevent intended work from being properly completed, or completed in a timely and/or economic manner.
Use of price adjustments/incentives can be used as a motivator to achieve high quality work results.	Service providers may try to 'sell' additional, unneeded services.
Frees up time of in-house staff to complete core, highest priority tasks.	Service provider may service multiple facilities and may not be able to respond as quickly as in-house staff.
Temporary workers can be hired to assist in reducing maintenance backlogs or when staff are on extended leave.	Service providers are not familiar with the facility, including where buildings and equipment are located
	Labor unions may impact decision processes about what work can be outsourced.

6.3 Process Standardization

To move from reactive to proactive building operations practices requires standardized processes. The research findings support the concept that there is a lack of standardized practices for facility managers to employ for energy and maintenance management. For example, one interview participant stated:

> *"Typically, a building operator will run their buildings to the level of their current understanding and they're in a reaction mode. If the phone doesn't ring and there aren't known problems, they're doing a good job.* ***What's missing is that they don't have written policies or standards of performance****."* - Brian Staszenski, Global Resource Efficiency Services

[103] (Cowley 2010)

This is further supported by a lack of:

- As-built documents available to facility managers.[104]
- Fully used and populated computerized maintenance management systems.[105]
- Fully used building control systems.[106 107 108]

These claims are further supported by Lewis (2009), as a lack of standardization has been found to:

- Increase project time and project costs
- Negatively impact project outcomes:
    - Unavailable and/or inaccurate building control system data
    - Lack of building performance data
    - Systems do not work correctly

In addition to a lack of management standardization within the industry, it was identified within the focus groups that there is a lack of standardization and guidelines for training and education (See Chapter 5: People for further discussion).

6.3.1 Six Sigma

Six Sigma is a problem-solving methodology to improve business and organizational performance, and has widely been used by large corporations to improve business and organizational practices. The methodology uses rigorous data collection and statistical analysis techniques to maximize profits and reduce costs while meeting the needs of the customer. Many large companies such as General Electric, Dupont, Bank of America, Honeywell, and Motorola have used Six Sigma successfully to increase profits and reduce operational costs. Some companies have used Six Sigma to improve key business outcomes or work process by as much as 70 percent.[109 110]

To date, Six Sigma is not widely applied within the design, operations, or maintenance of buildings. It is hypothesized that the use of the Six Sigma problem solving methodology could help to standardize operations and maintenance processes for commercial buildings.

6.4 Commissioning

Ask several different engineers who are involved with buildings and associated energy systems for the definition of commissioning, and you are likely to hear as many different responses. In a very general sense, commissioning is:

> *"… a systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all building facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel."*[111]

[104] (E.W. East 2009)
[105] (Berger 2009)
[106] (Rios 2005)
[107] (Piette and Nordman 1996)
[108] (Brambley, Haves et al 2005)
[109] (Gygi et al 2005)
[110] (Pende et al 2000)
[111] (Ellis, 1998)

What is likely to vary in the definitions is the breadth and depth of the process. Is it commissioning with a little "c" or a big "C"? Historically, little "c", or post-construction commissioning, was most prevalent. But the last decade saw a rise in big "C", or Design through Occupancy Commissioning, where the commissioning process parallels the planning, design, construction, and initial occupancy of a building. Adaptation of this process to existing buildings is known as re-commissioning or retro-commissioning. Figure 60 illustrates these processes. More recent variations of commissioning include processes with an element that ensures persistence of benefits, including continuous and monitoring-based commissioning. Energy savings achieved by commissioning efforts range from 5 to 20 percent in new and existing buildings. Figure 61 illustrates the relationship between commissioning and some common energy efficiency measures.

Is commissioning a worthwhile endeavor? According to recent work, including a Lawrence Berkeley National Laboratory analysis based on a dataset of more than 600 buildings of all types and sizes, the answer is overwhelmingly yes:

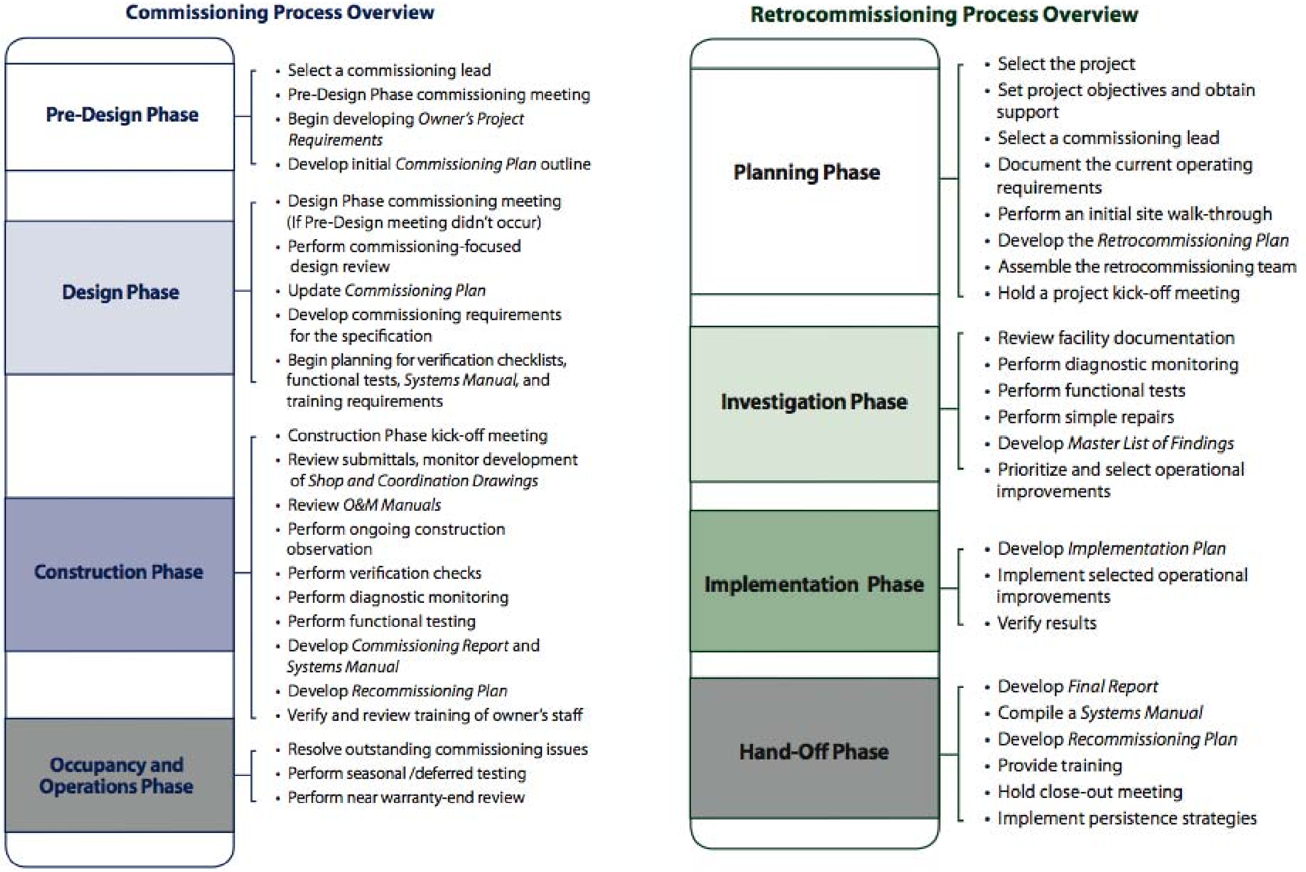
> *"The commissioning projects for which data are available revealed over 10,000 energy-related problems, resulting in 16 percent median whole-building energy savings in existing buildings and 13 percent in new construction, with payback time of 1.1 years and 4.2 years, respectively."* [112]

Such results demonstrate that commissioning is highly cost-effective. However, many challenges remain, as described by the following observations gathered in interviews and focus groups conducted as part of this study:

- Energy performance degradation all too often follows commissioning for both new and existing buildings.
- The commissioning process is often invoked too late in the project lifecycle to realize its full benefits.
- Those applying re/retro-commissioning to existing buildings are too often the same people who already practice energy management. In other words, the buildings that benefit from re/retro-commissioning are often those that need it least.
- One element of re-commissioning involves resetting all system set points per original specifications or current operational requirements. Following re-commissioning, the operations staff finds themselves responding to occupant complaints, and readjusting the set points over time. The result again is degradation in energy performance.

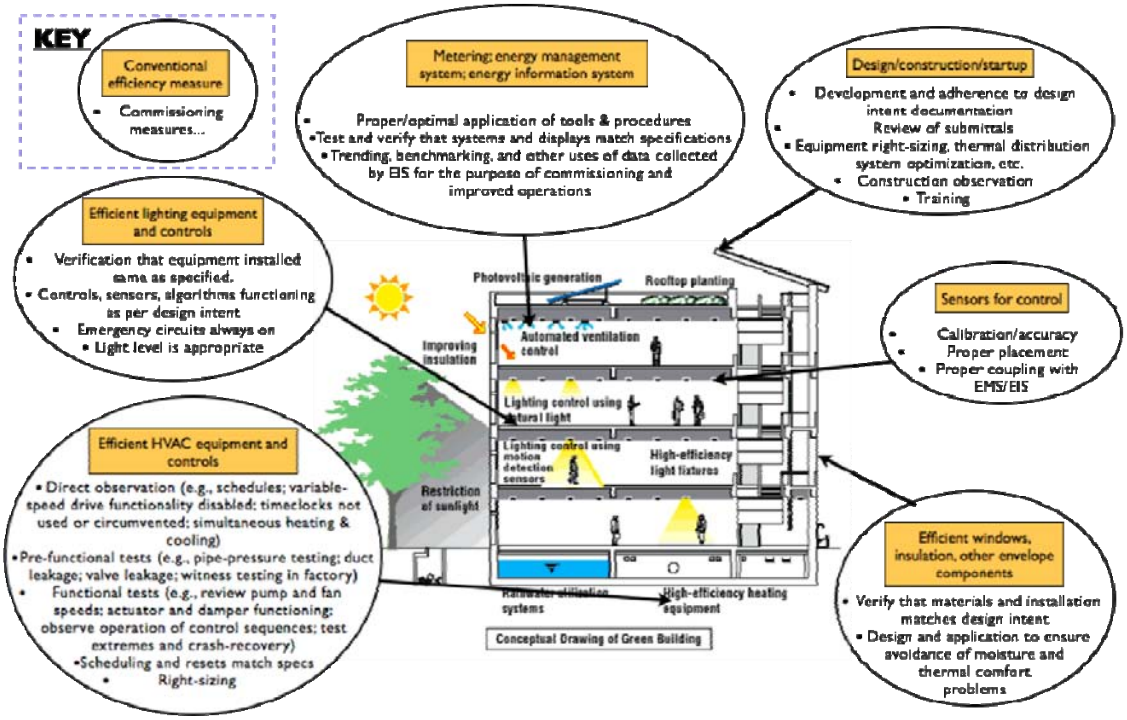
[112] (Mills, 2009)

Figure 60: Commissioning and retro-commissioning processes[113]



113 (Mills, 2009)

Figure 61: Commissioning and energy efficiency measures[114]



6.5 Summary

This chapter has defined the building lifecycle and identified the largest challenges therein. Summarizing the big picture, the largest challenges are that facility management is often reactive and there is a lack of shared values and understanding of what the high performance building operations process looks like. As a result, building operators and maintainers are often not provided with the training or educational opportunities needed to keep high performance buildings operating efficiently. Given the identified challenges, the chapter defined both reactive and proactive approaches to operations and maintenance. The practices of centralized versus decentralized facility management were discussed. The chapter closes with a discussion of why facility management process standardization is important for high performance buildings to be efficiently operated.

114 (Mills, 2009)

7 Technology

Key trends from a technology perspective include:

1) ***There is increasing need for the application of high performance building systems, including building envelope, mechanical and electrical systems, and controls.***
2) ***Substantial innovation and growth in lighting and lighting controls technologies has occurred in recent years, and is expected to continue.***
3) ***Convergence of building systems with information technology systems and networks is a common theme in recent years, and is expected to continue to drive the evolution of building systems and technologies.***
4) ***Experimentation with and adaptation of wireless technologies for building system applications presents a potential for lower cost implementations of controls, especially for existing buildings.***
5) ***There is a growing interest in integrated systems and intelligent buildings, including the use of software for data management and decision-making. Software currently used, and anticipated to be used further in the future, includes building information modeling (BIM), computerized maintenance management systems (CMMS), computer aided facility management systems (CAFM), integrated work management systems (IWMS), data depositories, and energy analytics programs.***
6) ***The application of dashboards with key performance metrics for buildings, campuses, and enterprises to facilitate operations, management, and education is growing over time.***

Demands for energy efficiency fueled by costs, codes, and sustainability programs drive the demand for improved system efficiencies and innovation of building system technologies. While the U.S. has generally used the same system types over the last several decades, the markets in other countries, especially some European countries, have widely adopted high performance building systems. Many of these high performance building systems are relatively new to the U.S. market, but are starting to gain a foothold. In addition, technologies and practices long available in the U.S. market but rarely applied are also seeing renewed interest, such as extensive integration, advanced lighting controls, and metering.

7.1 Building Envelope

7.1.1 Active facades

An active facade comprises any exterior side of a building where the optical and thermal properties may change dynamically in response to local climate, occupant preferences, ambient lighting, and/or utility request as part of a demand response program. Such changes are typically accomplished using one or more of the following mechanisms:

- Internal or external automated/motorized shades and/or blinds
- Switchable windows/glass
  - Electrochromic
  - Thermochromic
  - Photochromic

Active facades may also be adaptations of static facades or incorporate features of static facades. These static facades and their features include:

- Double facades, ventilated and unventilated
- Day-lighting, using sunlight redirection, light shelves and/or overhangs
- Solar control, using selective glass (spectral or angular)
- Integrated electrical generation using photovoltaic cells

Long overlooked in North America, the façade as a controllable and dynamic system is popular in European buildings. Active facades are just starting to be applied in the United States and Canada. As with all mechanical and electrical systems, it is necessary for the facility management team to understand the purpose of active facades, how they work, and how to properly maintain them. A few components of active facades include actuators, sensors, controllers, and other serviceable components.

7.2 HVAC

Given that heating, ventilating, and air conditioning (HVAC) accounts for about 40 percent of the energy used in most facilities, much attention should be given in the quest for efficiency and higher building performance. The sections that follow describe and illustrate trends in HVAC systems and technologies. It is important to recall that, while these new systems represent potentially dramatic energy savings, these technologies are more likely to be found in recently constructed buildings or existing buildings that have been extensively renovated. Extensively renovated buildings are very likely to include both traditional and high performance technologies and systems.

7.2.1 Shift to packaged equipment and systems

HVAC systems, especially in larger and more sophisticated facilities, have proven to be complex, unique, and costly. Historically, these systems were built up and applied in the field. In recent decades, HVAC equipment suppliers progressed towards packaged equipment, where a series of components including heat exchangers, fans, compressors, and controls are delivered as a package. This increases quality and reliability, and decreases the labor required in the field. Examples include large packaged air handlers, chillers, and large commercial unitary equipment. This progression is expected to continue with pumping systems, and even entire chiller plants will become more commonly available as packaged solutions.

7.2.2 Radiant heating and cooling

What is the most effective heat transfer medium: air or water? What is the most effective heat transfer method between an environment and its occupants: radiation or convection? These are fundamental questions at the center of HVAC practice. Radiant heating and cooling systems have approached these questions differently than conventional practice for many years.

Radiant heating and cooling systems are probably some of the most progressive of systems, with the greatest potential for energy savings. These systems are completely hydronic, employing both chilled and hot water as opposed to a distribution that uses air as the primary medium. Heat exchange methods in building spaces include radiant ceiling panels, beams, and slabs (floor or ceiling). These systems also require a means to chill and heat the water, and may employ direct or indirect evaporative coolers, chillers, and boilers, or other means such as ground and water source cooling and heating. Radiant cooling systems in particular offer some significant advantages over their conventional all-air counterparts:

- Radiation presents the most significant heat transfer mechanism between the human body and its surroundings. Other means in order of magnitude include convection, conduction, and perspiration. Therefore, radiant systems are thought to provide the best environment for human comfort.
- Radiant systems enable separation of sensible heating and cooling from ventilation, allowing for potential improvement in indoor air quality, with elimination of air recirculation.

- Radiant systems generally use less energy than forced air systems (with one reference estimating a 30 percent average savings, and a range of 17 percent to 42 potential energy savings in North American climates).[115]

While these systems present great potential for energy savings and human comfort, they are presently seldom applied in North America. They are used most often in the more relatively milder climates of Western Europe, especially in Scandinavian countries and Germany. Very recently, a small number of new projects in Canada and the United States have employed radiant cooling systems.

7.2.3 Ventilation and air distribution

Ventilation receives much attention due to its energy consumption and associated potential for efficiency. All of the outside air brought into a building must be heated and cooled, dehumidified or humidified, and filtered. This requires a tremendous amount of energy, and a variety of strategies are becoming more common in the pursuit of reduced energy consumption.

- Dedicated outdoor air systems (DOAS): One innovation that is relevant to the viability of cooling systems in North America is DOAS. These systems primarily address issues of indoor air quality, including ventilation and humidity control. The effectiveness of these systems is based on the principle of separating ventilation from sensible heating and cooling. These systems provide 100 percent conditioned outdoor air to a building, and can be used to control humidity in a building where radiant cooling is applied.
- Demand control ventilation: Many buildings are ventilated according to their design occupancy. However, alternate ventilation strategies address real-time occupancy, only providing the necessary ventilation and saving substantial energy.
- Static pressure reset: While the use of variable flow systems for both water and air have resulted in significant performance improvements in HVAC systems, they can be further optimized. Dynamically resetting the static pressure based on system demand results in substantial reduction of fan energy.
- Natural ventilation: Direct use of outdoor air for ventilation through displacement ventilation, solar chimneys, atriums, active facades, and operable windows.
- New methods of air distribution are seeing application in buildings as well, including:
  - Under-floor variable-air-volume (VAV)
  - Diffusion ventilation

7.3 Lighting

In commercial buildings, lighting accounts for approximately 28 percent of all energy usage and is second in energy intensity to building heating and cooling. Unfortunately, much of the energy used to light buildings is wasted. The waste comes from inefficient lighting technologies as well as from over-lighting certain areas and lighting areas that are not occupied. Lighting efficiency started with the movement from incandescent and low efficiency fluorescent technologies to higher efficiency fluorescent lighting. This trend is expected to continue with the advent and development of solid-state LED (light emitted diode) lighting. Lighting controls can further reduce lighting energy consumption.

[115] (Moore, Baumann, & Huizenga, 2006)

7.3.1 Lighting Controls

Commercial building owners who desire to reduce costs and comply with more stringent energy codes are also moving to the next generation of lighting control systems. These systems offer control of light levels and the ability to shut off lights when spaces are not occupied. A lighting system capable of dimming the lights when natural light is available and turning off lights when a room is unoccupied can cut energy costs for the entire building by over 20 percent. Yet remarkably, less than 1 percent of all commercial buildings currently have lighting control systems installed. The emergence of addressable lighting controls, such as systems employing communicating DALI ballasts, yields increased space flexibility and lower maintenance costs.

The movement toward improved lighting control is a trend that is expected to grow rapidly, but today can be characterized as being in a nascent stage. While the market is still relatively small, with high costs and often low user satisfaction, it is developing rapidly and is expected to grow substantially in the near term. The opportunity for growth in both new construction and retrofits to existing buildings is very large. For such growth to be realized, the value proposition needs to increase, costs need to decrease, and performance and serviceability need to improve. However, recent success stories are emerging. In one very notable building, the New York Times Building, the lighting system helped to realize energy savings of 72 percent on the floors in which it was installed.[116]

7.3.2 Automated shading

Control of glare is an aspect of lighting control that is often overlooked. For the purpose of glare control, automated shading systems are common in European buildings, and are starting to make inroads in the United States. Some lighting controls manufacturers now offer automated shading as an optional add-on.

7.4 On-Site Generation and Storage

7.4.1 Renewable Energy

There is much interest in on-site renewable energy as a method to reduce a building's power draw from the grid and to reduce its carbon footprint. The most common forms of on-site renewable generation are photovoltaic arrays and wind turbines. Often, on-site renewable energy offsets only a small portion of the energy requirements of the building, as renewable is not always a reliable source of power. The output of photovoltaic arrays drops on cloudy days, and wind turbines do not generate power on a windless day. Another challenge with renewable technologies is that they are often employed as a visible token of green, and largely due to economics, on-site renewable technologies often do not pay for themselves in timeframes acceptable to most developers. However, like many energy-related decisions, there are multiple solutions, and these technologies will continue to be part of the solution. Furthermore, as the economics improve and innovation increases, on-site renewable technologies will become more common, adding to the portfolio of equipment and systems that fall within the scope of responsibilities of operations and maintenance teams.

[116] (GreenerBuildings, 2009)

7.4.2 On-Site Power Generation

On-site generation may also take the form of micro-turbines or engine-driven generators using natural gas or diesel fuel. Commercial buildings that have critical functions, such as hospitals, data centers, and laboratories, typically have these systems installed to handle potential power outages. These systems may also be used as an alternate source of energy during periods of high energy prices or reduced energy availability.

7.4.3 Thermal Storage

There are a few ways to incorporate energy storage in buildings using methods that employ thermal storage. Thermal storage can be thought of as an energy "flywheel" that can help to meet a building's energy needs during periods of high energy prices or reduced energy availability. Table 25 summarizes the forms of thermal storage in buildings.

Table 25: Thermal storage methods

Type	Description	Advantages	Disadvantages
Ice or chilled water storage	Energy is stored during off-peak hours as ice or chilled water, and used as a source of cooling during peak hours.	May allow for consumption to occur at time of lower electrical rates. Minimal or no impact on service levels, especially thermal comfort conditions.	Substantial space required. High initial cost.
Core storage/Thermal mass	A building with significant thermal mass may be pre-cooled or pre-heated during off-peak hours such that the building core serves as the primary radiant heating or cooling source during peak hours. This is a leading edge technology used in some European buildings that employ active slabs for radiant heating and/or cooling.	May allow for consumption to occur at time of lower electrical rates. Minimal or no impact on service levels, especially thermal comfort conditions.	Concept is still in development, current work is limited to simulation, lab testing and field demonstrations. Savings are sensitive to many factors: utility rates, equipment types, occupancy schedules, building construction, climate, and control strategies. Requires complex, properly operating control strategies such as site specific control, networked digital thermostats, and communication of a global setpoint to all thermostats[117]

[117] (Braun 2003)

Other potential emerging or presently experimental methods of energy storage include thermal storage within HVAC equipment, thermal storage using phase change materials such as molten salt, storage of electrical energy in batteries, and kinetic energy storage using flywheels.

7.4.4 Cogeneration

Cogeneration combines on-site power generation with energy recovery and storage to maximize the output of a central plant. Given the large scale and expense of such systems, they are typically found on campuses, at industrial sites, or in district energy systems where they can serve many buildings on a campus or within a downtown metropolitan area. These systems are usually centered on a form of power generation, such as gas turbine or engine-driven generators. While these devices generate electrical power, the heat energy in the exhaust is recovered to drive other processes that may include heat recovery boilers for hot water or steam, or heat-driven chillers to produce chilled water. Given the scale and complexity of cogeneration systems, a dedicated operations staff is required to run and maintain them.

7.5 Net-Zero Energy Buildings (NZEB)

Over one year, a net-zero energy building generates as much energy as it uses. In order for net-zero energy consumption to occur, the building must be very energy efficient and use on-site renewable technologies. A NZEB may or may not be connected to the utility grid. However, with technologies available today, it is often very difficult to successfully operate an NZEB that is not connected to the grid. For buildings connected to the utility grid:

- If the building load is greater than the on-site power generation the building uses power from the grid.
- If the building load is less than the amount of power being generated by the on-site sources, power is exported to the grid.

There are several NZEB within the United States, including:

- The Adam Joseph Lewis Center for Environmental Studies at Oberlin College
- The Cambria Department of Environmental Protection Office Building in Ebensburg, PA
- The Science Museum of Minnesota, St. Paul, MN
- The Thermal Test Facility, National Renewable Energy Lab, Golden, CO[118]

7.6 Plug Load Controls

Every penny counts: that is the idea behind plug load controls. Plug loads comprise another opportunity to apply intelligence and realize some energy savings. Control of plug loads also provides an opportunity to control and reduce “vampire” loads. Vampire loads most often consist of desktop electronics that run continuously, even when people are away from their desk or office for extended periods of time. Plug load control solutions are available that use occupancy detection or monitoring of power usage by devices to automatically control ancillary electrical loads in office environments.

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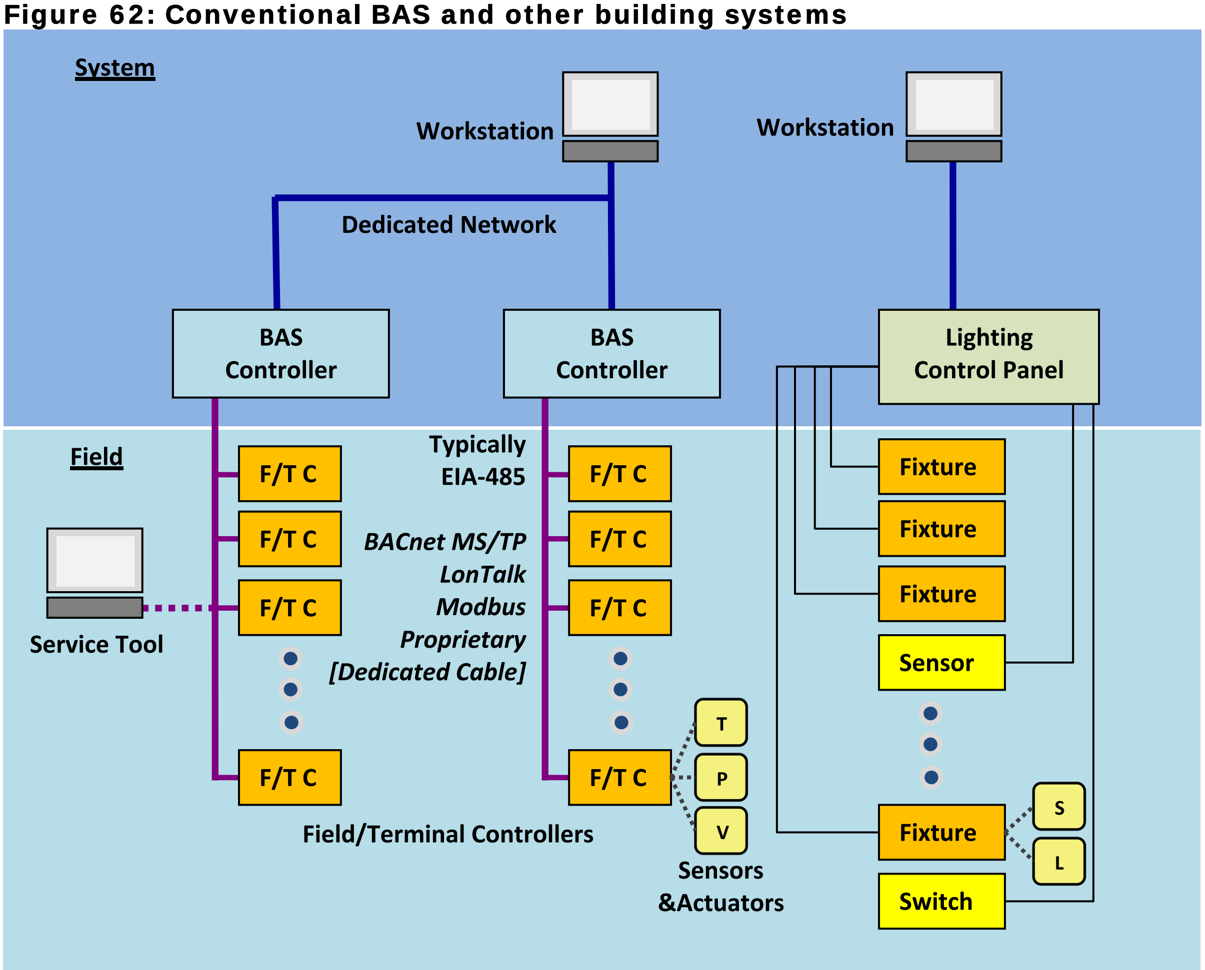
[118] (Torcellini, Pless et al 2006)

7.7 Controls, Automation and Integration

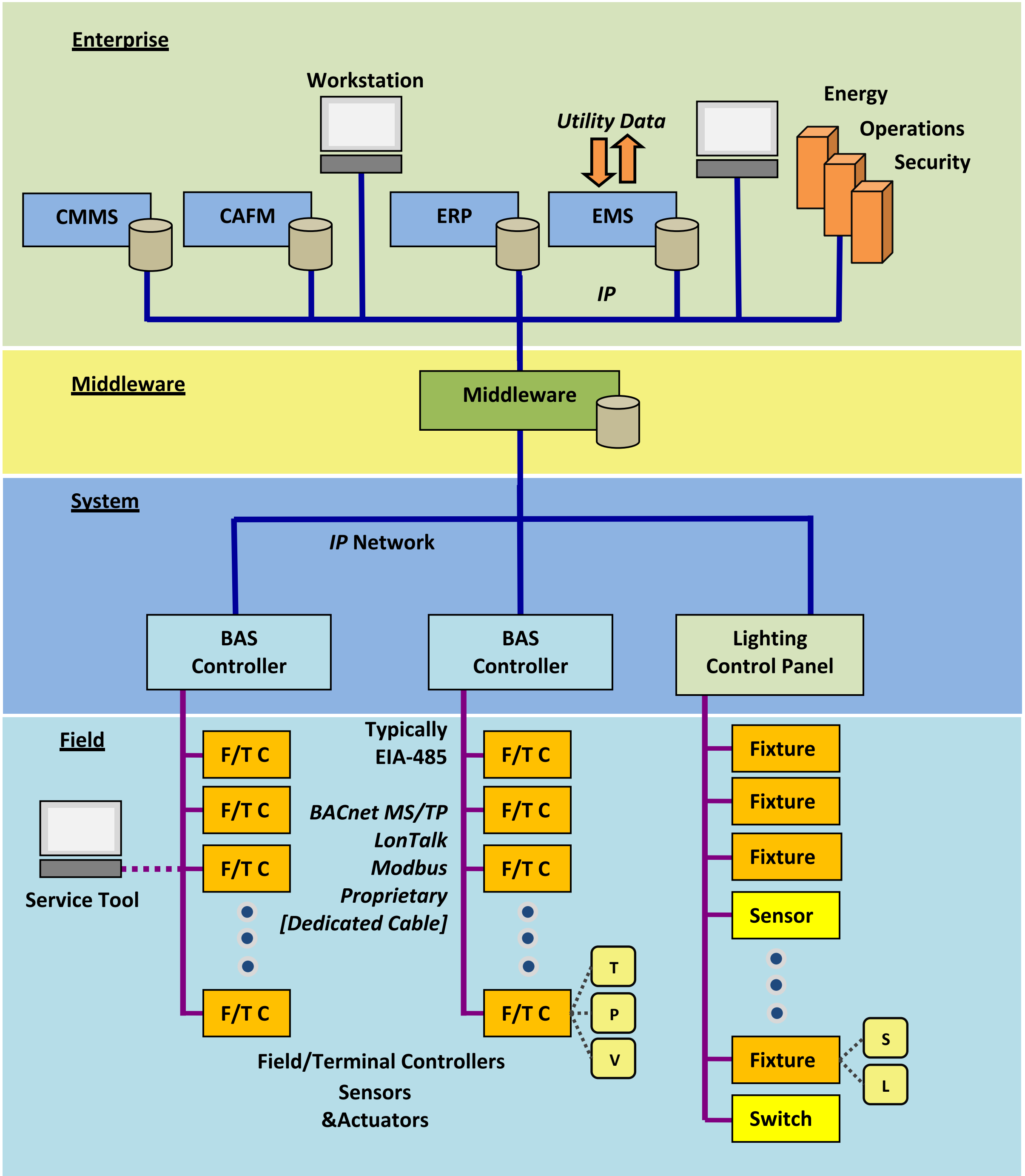
Building automation and energy management systems are widely used and accepted, especially in mid-size to large commercial buildings. However, such systems are often prone to the whims of their operators, and many systems that save energy in their original configuration are later compromised by changes or errors. It is also common that the capabilities of these systems are very rarely used in a manner that maximizes energy efficiency. Instead, they are generally employed in very basic configurations that result in minimal energy savings. Furthermore, building systems often standalone in operation and control, as illustrated by Figure 62. As shown in the figure, the building automation system is separate from the lighting control system, and each system is managed through an independent workstation on a dedicated network.

Figure 62: Conventional BAS and other building systems



While inroads on energy efficiency improvements will come through new lighting, heating, and cooling technologies, one key area will be improved and integrated controls. Controls are essential to building performance in North America, and also globally. Designing and operating high performance buildings require the implementation of controls to optimize and maximize energy efficiency and comfort. One way to optimize controls is to integrate and cross-optimize systems. Figure 63 schematically illustrates this concept. In the figure, the disparate systems shown in Figure 62 are integrated on a common network, and provide data to enterprise level applications.

Figure 63: Integrated BAS and lighting system architecture



7.7.1 *Open standard protocols*

As building automation and energy management systems proliferated in the 1970's and 1980's, the need for standardized communications methods between devices and systems became increasingly acute, and the desire to integrate systems grew. The industry responded with the development of two major open standard communications protocols: BACnet and LonTalk. In addition, an industrial de-facto standard, Modbus, was adopted by the building systems community for specific devices and applications. The motivation for building owners and developers to adopt open standard communications protocol boiled down to the following potential benefits:[119]

1) **Competitive bids:** Open protocols allow for competitive bidding for new projects, maintenance, expansions, and retrofits.
2) **Consistent installation:** Consistent installation practices and wiring topologies result in more uniformity in installations.
3) **Consistent maintenance:** For a given installation and protocol combination, common maintenance standards and practices may be applied.
4) **System integration and interoperability:** Various building systems may be integrated with one another, resulting in optimization of energy usage or comfort. For example, HVAC systems may be integrated with lighting and access control.
5) **Data acquisition:** Data logged by control systems may be shared with other applications and used for energy management.
6) **Product interchangeability:** Device interchangeability is a possibility with open standard protocols.

While these benefits all appear to be very positive outcomes, the practical reality is that the various protocol options allow for realization of these benefits to varying degrees. Open standard protocols continue to evolve, and it is expected that they will increasingly, albeit slowly, improve fulfillment of their potential. Table 26 summarizes the protocols, associated standards, and physical media.

Table 26: Prevalent building system open standard protocols

Protocol	Standard(s)	Media
BACnet	ASHRAE/ANSI Standard 135 ISO 16484-5	TCP/IP Ethernet ARCNET EIA-485 EIA-232
LonTalk	ANSI/CEA 709.1 ISO/IEC 14908-1	TCP/IP Ethernet EIA-709.1 (twisted pair) Power line
Modbus	IEC 61784-2	TCP/IP Ethernet EIA-485
DALI	NEMA Standard 243	TCP/IP Ethernet

While much industry discussion has been devoted to fractious debate pitting BACnet and LonTalk against one another, the fact of the matter is that both technologies

[119] (Strata Resource Inc., 2006)

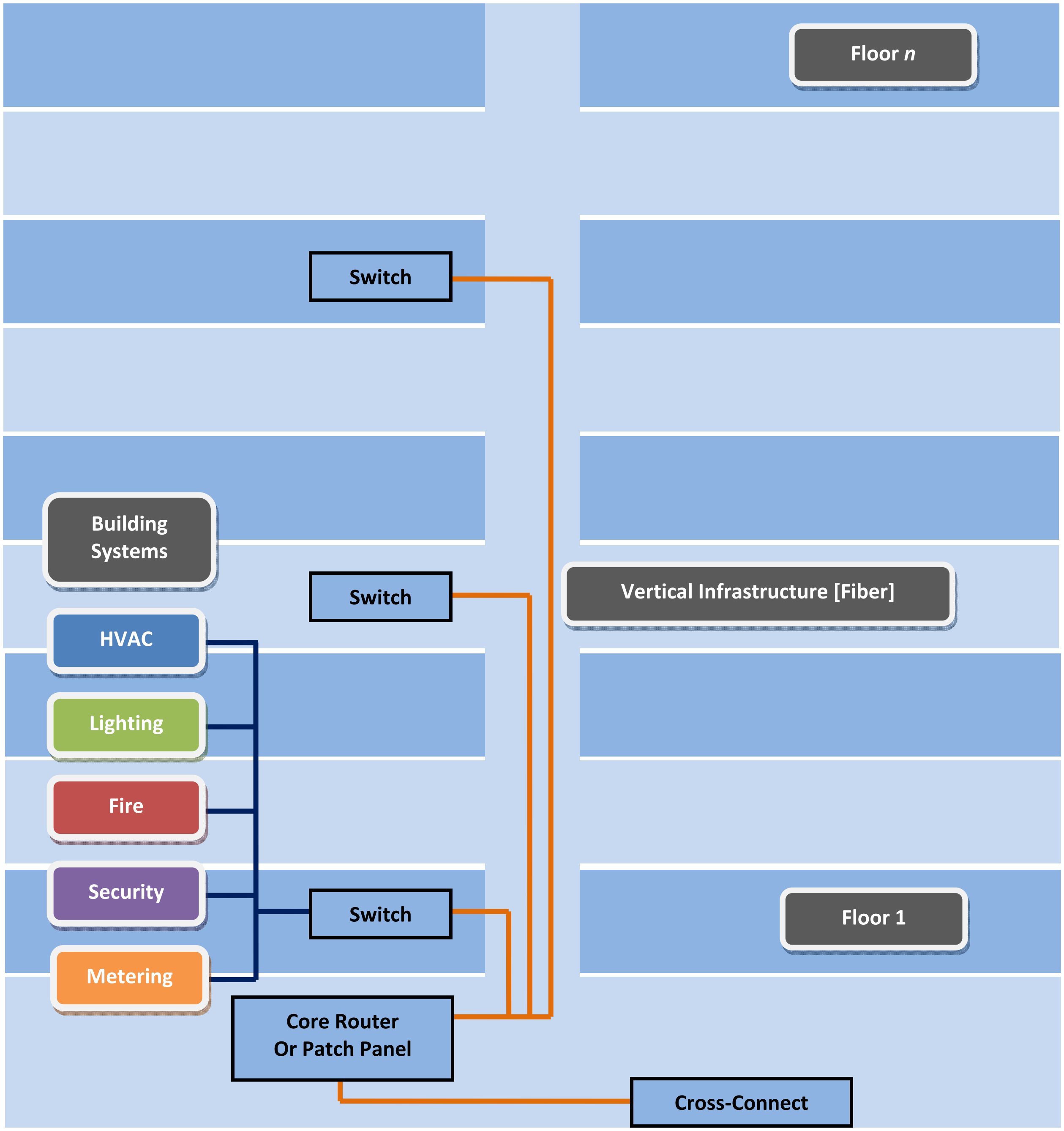
offer benefits and tradeoffs, and both possess strengths and weaknesses. The important concept to take away from the battle is that both are valid solutions, but it is important to carefully consider the needs of a given project and the solution that may be most appropriate.

Historically, open standard protocols in buildings were most commonly utilized by HVAC, building automation, and energy management systems. It is a relatively recent development from the days of pneumatic and proprietary systems. Today, other building systems, such as lighting, are also adopting the use of open standard protocols. Although slow to embrace open protocols, lighting control systems follow open standards including DALI (for addressable ballasts), or integrate to other building systems through a gateway to BACnet or LonTalk. The overall evolution of open standard protocols for building systems appears to focus on making open protocols more amenable to mainstream information technology and networks, as well as wireless communications.

7.7.2 Networking and Connectivity

Networking infrastructure is central to the ability of a building to communicate. Building systems are increasingly network-enabled, allowing them to reside on an internet protocol (IP) network. Taking this one step further, all building systems may share a common network infrastructure, and in some cases may even share the network with the voice, video, and data traffic systems within the building. Figure 64 provides one example of the network infrastructure in a building.

Figure 64: Building systems with common network infrastructure



7.7.3 Wireless Controls

Presently, the adaptation of wireless communications technology to addressable control devices and systems in commercial buildings comprises a large, and largely untapped, business opportunity. Most commercial building systems use conventional wired systems, including HVAC, building automation, lighting control, access and security, and fire and life safety (Figure 64). In a given commercial building there may be as many as 15 low-voltage communications systems serving various building systems, and in some more sophisticated facilities, such as hospitals, there are upwards of 25 such systems. Often, each system is constructed with its own dedicated wired communications infrastructure. There are three aspects of wired infrastructure that form the basis of opportunity for replacement by wireless systems:

- **Material:** Substantial low-voltage wired infrastructure supports building systems. At the time of construction, this represents a very significant cost.
- **Labor:** Along with the material investment in wired infrastructure, there is the labor to install it, combined with the labor required to setup and program the devices in the system.
- **Flexibility:** Wired systems are not very flexible, and thus changes in building space and use may incur additional costs to change the supporting infrastructure.

Wireless technologies are rapidly evolving and suppliers of building systems and controls are constantly seeking ways to leverage these technologies to produce cost-effective solutions. The most prevalent wireless technologies are listed in Table 27.

Table 27: Wireless technologies

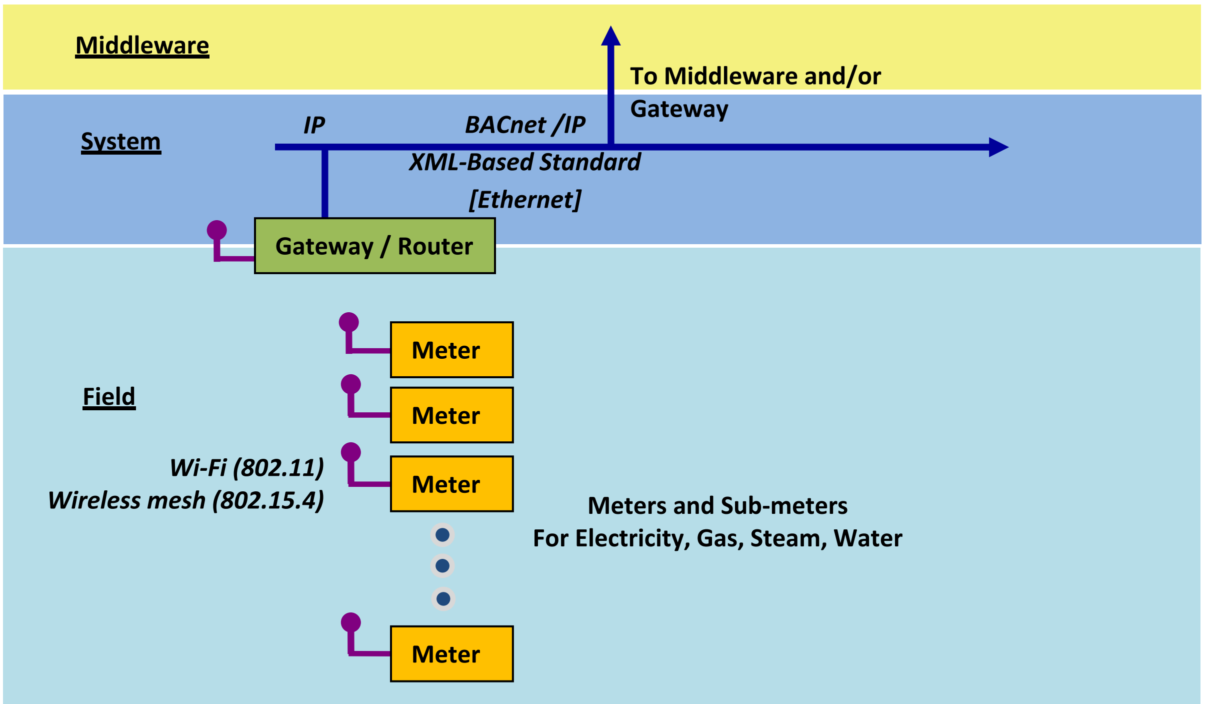
Technology	Frequency (MHz)	Data Rate (kbyte/s)	Number of Devices[1]	Notes
EnOcean	315 868	125	N/A	• Self-powered (no batteries) • Substantial momentum in Europe. • Already in use in many commercial buildings for a variety of applications.
Insteon	900	1.6 (instantaneous) 0.4 (sustained)	256	• Supports RF and Powerline. • Backward compatible with X10.
Wi-Fi				• Mainstream wireless networks.
Zigbee	868 2400	20 (@ 900 MHz) 250 (@ 2400 MHz)	65,536	• In use in limited commercial applications. • Applications appear to be largely proprietary so far.
Z-Wave	868	1.2	232	• Substantial momentum in Europe. • Already in use in a variety of residential and light commercial applications.

Notes:

1. Refers to number of devices in a single network.

Some application examples include wireless sensor networks, thermostats, meters, and lighting controls. Figure 65 provides an example of using wireless technology for a metering application. The potential for wireless devices in building systems is tremendous, especially in existing buildings, and applications of wireless technologies in this area are expected to proliferate.

Figure 65: Wireless communications in a metering application



7.7.4 Security and Access control

Security and access control systems are still often stand-alone systems due to the perceived sensitive nature of their purpose and content. However, these systems are increasingly being integrated to share network infrastructure with other building systems, voice, video and/or data networks. Transitioning video surveillance systems (CCTV) to be IP based has many benefits including lower cost, greater flexibility, and improved recording and analytics with the use of network based video recorders. Integration of access control with HVAC and lighting control provides an opportunity to optimize occupancy-based HVAC and lighting control strategies.

7.7.5 Metering

Energy meters provide an invaluable tool for monitoring and measuring energy usage, and may impact energy consumption in one of the following ways:

- **Energy measurement:** Real-time measurement of energy combined with collection of historical data enables understanding of the businesses energy consumption levels and makes it possible to determine where improvements can be made.
- **Energy savings:** Awareness of energy consumption often results in energy savings. Active energy management, enabled by measurement as noted above, can result in significant savings.

- **Allocation of energy usage and costs:** Metering enables allocation of energy costs to tenants, or to users with high energy densities such as laboratories and data centers. Allocation of energy to mechanical systems or other energy consuming systems may create opportunities for identification of problems with those systems.

Thus, while the use of metering will not necessarily result in direct energy savings, meters typically provide data for analysis, the output of which may be used as part of an energy savings program, or to improve systems performance and influence occupant or tenant behavior. Large-scale metering initiatives include:

1) **U.S. GSA:** General Services Administration's Advanced Metering Initiative is focused on providing building energy measurement for all GSA-operated facilities.
2) **State of Missouri:** The State of Missouri developed a central operations center to monitor and manage the energy usage and maintenance issues for over 800 state buildings. This project has resulted in estimated savings of $30 million per year and a simple payback of less than two years through savings in operations, service, and energy.

7.7.6 Energy Analytics and Data Depositories

Energy analytics is the process of studying, quantifying and using energy data for proactive decision making to reduce energy consumption. By using meters, sub-meters, and sensors, building control systems can collect large amounts of data. However, unless the data is analyzed and used for decision making, it is not of much value.

When using data from meters, sub-meters, and sensors for energy management decisions, it is important to determine what data should be collected. The type and time interval of the data collected for making energy management decisions may be different than the data needed for building operation. When using the data for energy management decisions, it is also important to determine strategies to normalize the data to allow for comparisons between different systems and subsystems. Standardized reports that include graphs and charts should also be developed to help quickly interpret the data and share the analysis with others who may not have energy management training.

If trend data from the building automation system will be used for periodic benchmarking, a data depository or computer server should be available to store the data. Historically, most building control systems do not have data depositories and the data is only stored for a short period of time and then deleted.

If a building automation system or multiple meters, sub-meters, and sensors are not available, whole building energy analytics tools such as ENERGY STAR Portfolio Manager can be used. ENERGY STAR Portfolio Manager is a free, publically available tool that uses utility bills to benchmark whole building energy efficiency and water consumption. Buildings that achieve an ENERGY STAR score of 75 or greater can qualify to receive an ENERGY STAR label.

7.8 Use of Software for Asset Management

Software and information technology are an essential part of facility management and building operations. Software is used to collect and store data for decision making. The type of data collected varies greatly by facility management team, but can include work order data, parts inventory, equipment and system repair histories, and key performance indicator reports. When data about the assets and management of the facility is collected, the data can be used for decision making and to support economically driven decisions. There are three general acronyms to describe facility management software used for asset management:

Computerized maintenance management system (CMMS): A CMMS is used to: plan, schedule, and track maintenance activities; store maintenance histories and inventory information; track and process work orders; generate reports to quantify maintenance team productivity.

Computer aided facility management system (CAFM): A CAFM is primarily used for space management, but may also have functionality to support condition assessments, construction and/or project management, and/or furniture management.

Integrated work management system (IWMS): Integrated work management system (IWMS): An IWMS is a system that has the functionality of both a CMMS and CAFM. In some cases, an IWMS provides similar functions to an enterprise resource planning system (ERP).

Within the asset management software market, actual functionality and which acronym is used for different products can vary. A recent benchmarking report from IFMA found that on average, 23 percent of facilities use CAFM systems and 46 percent use CMMS. Another 23 percent use spreadsheets, and eight percent rely on other methods.[120]

As the software continues to evolve, many software products can be integrated with building systems using open standards, and with IT and business systems. No matter the type of asset management system used at a facility, the data within the system must be reliable and possess a high level of integrity. If data is not entered into the system or the data is unreliable, the value of using the data for decision making is greatly reduced.

7.8.1 Building Information Modeling (BIM)

Building information modeling (BIM) is a structured database of information about a building and the systems within a building. 3D models are commonly used to link building information to the database. Currently BIM has been successfully used within the design and construction of new buildings. Successful applications include clash detection, design coordination, design authoring, and digital fabrication.[121] Within facilities management and operation, the use of BIM is in its infancy. Although BIM has not been widely used within operations and maintenance, there are many promising applications including record models, building maintenance scheduling, asset management, and building performance analysis.

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[120] (International Facility Management Association (IFMA), 2009)
[121] (BIMex 2010)

Successful use of BIM for facilities management and operations will require the adoption of open standards such as COBie and SPie. COBie, the construction operations building information exchange, is an open standard to electronically collect project information for the project handover phase, which falls between the design and operations phases. SPie, the specifiers' property information exchange, is a consistent set of definitions for materials, products, equipment, and assemblies to exchange building information between different software applications.

7.8.2 Dashboards

Similar to the use of dashboards and key performance indicators (KPIs) in the corporate world, adaptations of dashboards and KPIs are used to monitor and understand building energy performance. These dashboards, or "portals", are key elements of building systems, and can be useful from a variety of perspectives:

- **Occupants:** Kiosks for building occupants illustrate building features and performance and, in some cases, may allow for illustration of occupant impact on performance.
- **Operations:** User interface is essential for operations staff, as they interact with building systems to maintain and troubleshoot systems.
- **Management:** Reporting on building performance and corresponding financials provides facility and energy management staff with data to support decisions regarding energy resources and equipment and systems maintenance.

Portals and/or kiosks serve as points of interaction for building management and operations staff, as well as for occupants. The management portals provide a common view of all building systems and allow for operating engineers to readily view and make changes from any web-connected device. This allows the staff to be more mobile and flexible, enabling them to run the building, campus, or enterprise from a workstation, hand-held device, or laptop at home, or from another site. The occupant portals provide information on key building systems, and may include the ability for occupants to view and monitor their personal comfort. Occupant portals are also typically used to allow occupants to enter maintenance requests, and view measures of sustainability and efficiency for the building. Figures 66, 67, and 68 show three examples of portals for building occupants.

Figure 66: Oberlin College Campus Resource Monitoring System (by Lucid Design Group)

Figure 67: Broward County South Regional Library (by Green Touchscreen)

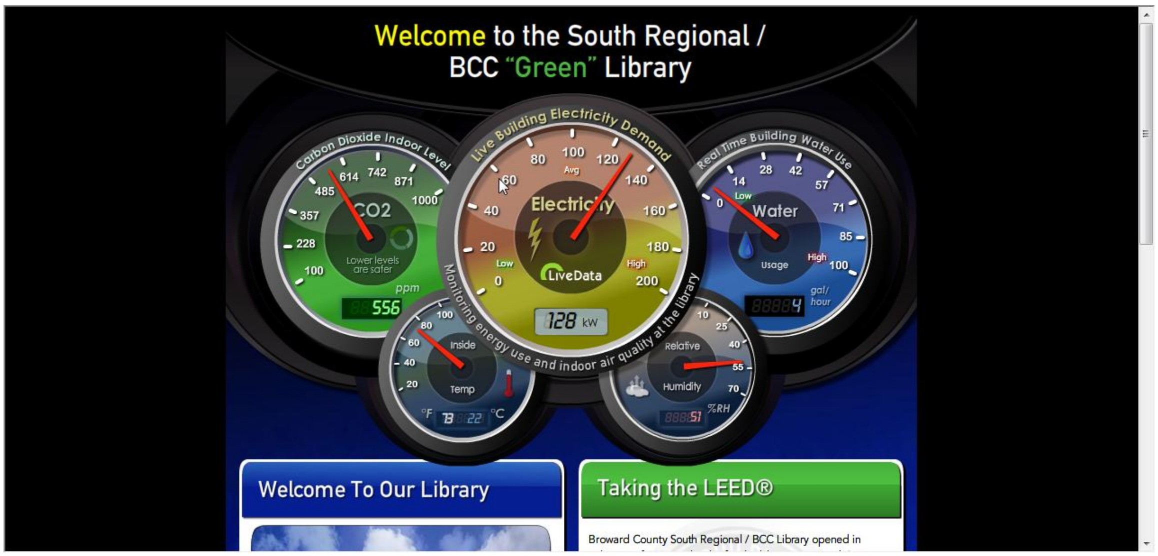
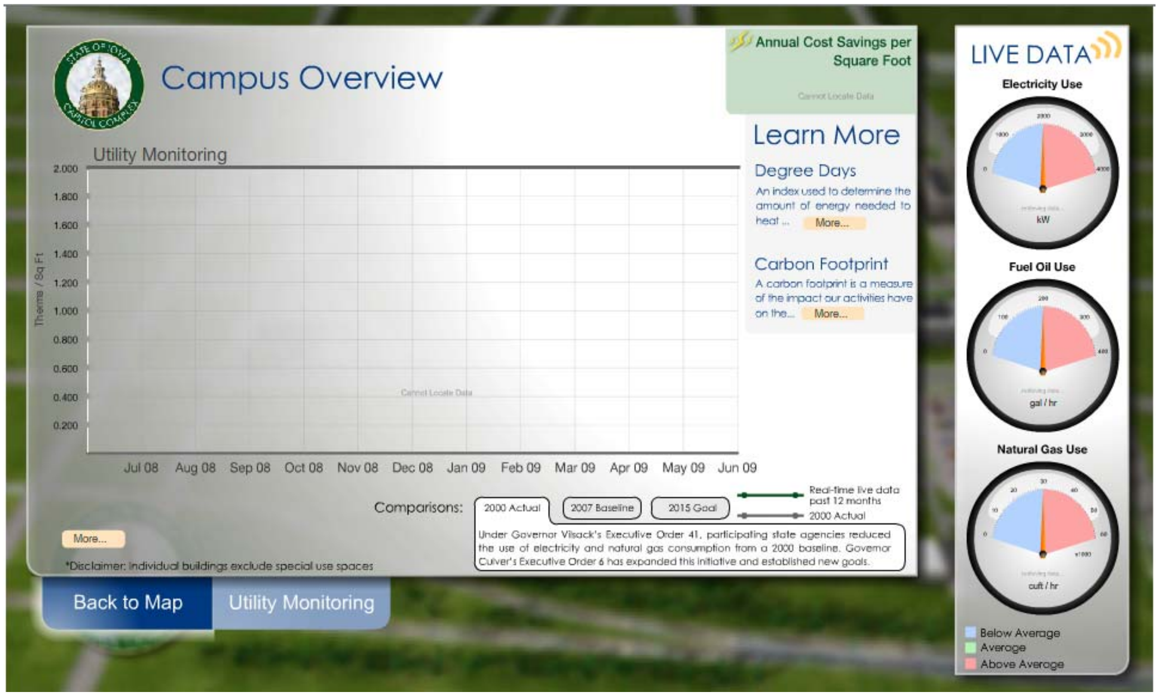


Figure 68: Iowa State Capitol Complex (by Quality Automation Graphics)



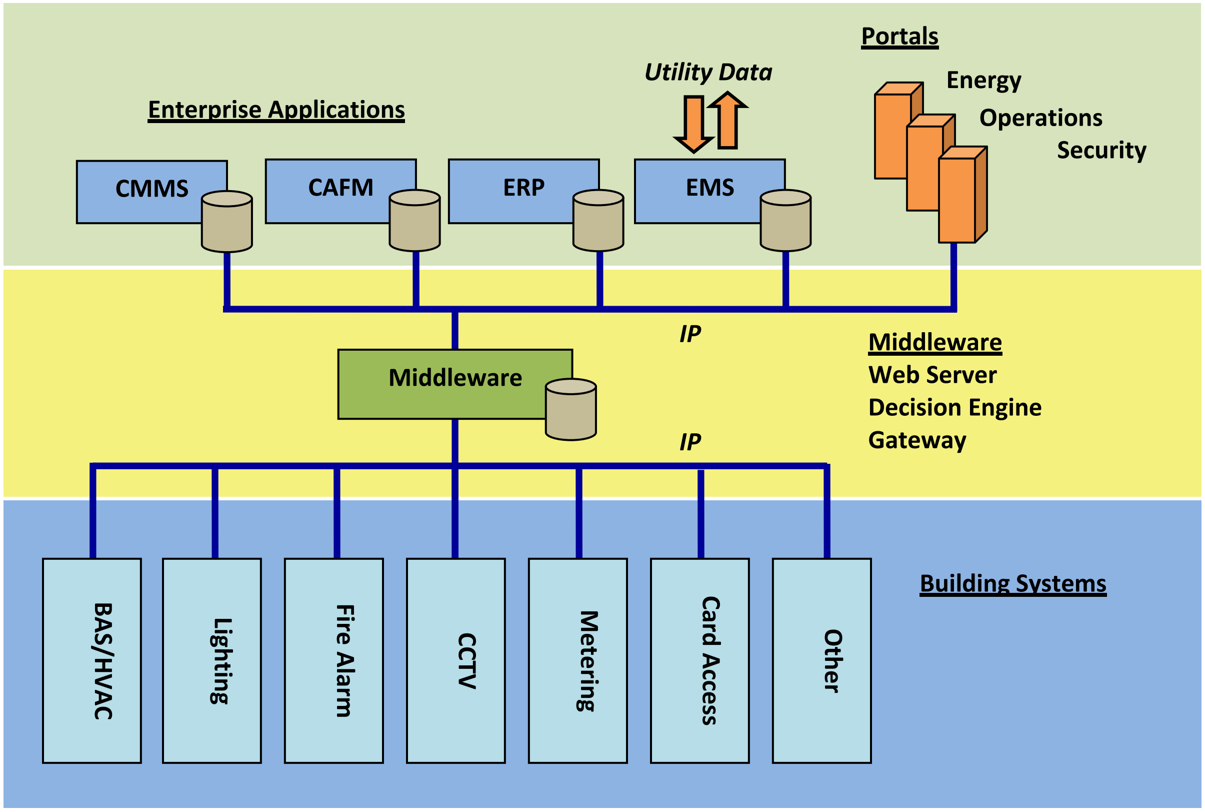
7.8.3 Middleware and enterprise systems

In the building automation and controls industry, middleware and enterprise facility management systems are a relatively recent development. The demand arose from the need for open and integrated systems, the pervasiveness of information technology, and the need for actionable information to support business processes and decisions. Prior to the onset of this technology trend, building systems were, and still are, all too often implemented in a stovepipe configuration, as discussed previously and shown in Figure 62.

Middleware is a broad term used to describe the spectrum of hardware and software components that serve to integrate and coordinate multiple building systems. Such middleware may consist of gateways, systems integration panels, building automation controllers, and/or enterprise servers and software. An example of a middleware and enterprise system is shown in Figure 69.

Middleware and enterprise systems enable integration across multiple buildings and systems, provide web based user interface for facility operations, security, management, and building occupants. They also enable the collection of data and the flow of information to other enterprise systems including asset, energy, and maintenance management. Furthermore, some enterprise systems may also provide the ability to implement high-level coordination sequences and business rules.

Figure 69: Middleware and enterprise systems



7.8 Summary

This chapter has summarized technology trends along with types of technologies and systems currently used and anticipated to be used in future high performance buildings. Technologies discussed included:

- Building envelope: Active facades
- HVAC: Radiant heating and cooling panels, dedicated outdoor air systems, demand control ventilation, and natural ventilation
- Lighting: Lighting controls and automated shading
- Controls, automation and integration: Open standard protocols, middleware and enterprise systems, networks and connectivity, wireless controls, and metering
- On-site generation and storage: Renewable energy, on-site power generation, thermal storage, cogeneration
- Information management systems, including computer aided facility management systems (CAFM) and computerized maintenance management systems (CMMS), energy management dashboards, and middleware and enterprise systems
- Building information modeling (BIM)

8 Conclusions

To close the gaps between current skill levels and actual skill levels required for technicians to efficiently operate and maintain high performance buildings requires a grounded understanding of the impact of people, facility management processes, and technology. At beginning of this report, a number of hypotheses were put forth. As a result of the research, seven of the hypotheses proved to be true, one false and two inconclusive. Each is restated below with its conclusion.

1) Responsibility for energy efficiency and/or sustainability is often not clear in facility management and operations teams.

True. Within the focus groups, it was concluded that a lack of clear goals was a larger inhibitor to energy efficiency than the cost of implementing energy efficiency projects. Within the survey:

- An energy management component was part of less than 20 percent of sustainability programs.
- Nearly half of survey participants did not know if the Energy Use Index or ENERGY STAR rating for the buildings was tracked.
- 25 percent of respondents indicated no awareness of energy efficiency improvement goals in their organization.

2) Management may be unrealistically estimating the sustainability impact (for example, in the case where a CEO establishes a goal to cut carbon emissions by 25 percent).

False. More than half of established energy efficiency improvement goals ranged from 1 to 10 percent. As the hypothesis established an unrealistic goal to be around 25 percent, the range identified by the survey is well below this value. However, one quarter of the respondents indicated no awareness of a goal.

3) There is a prevalence of "building myths" that dominate operations resulting primarily from poor documentation.

True. The focus groups, primary and secondary research, and survey support that "building myths" appear to originate not only in poor documentation, but also from the well-intentioned wishful thinking, such as the super-hero theory, and in the attempt to operate buildings reactively, without data and information.

4) There is a substantial disjuncture between the construction and operation processes of buildings.

a) Where applicable, unions tightly define roles, for example constraining operations participation in design and construction.

b) In many organizations, capital and construction departments are organizationally separate than, and have separate budgets from, facility management departments.

True. The interviews and focus groups conducted support this hypothesis. The separation of construction and operations processes is a major impediment to a transition to higher performance building operations. Adoption of integrated design (integrated project delivery) is a step in the right direction. Restructuring working relationships, both organizationally and financially, between capital projects (design and construction) and operations is required to break down the barriers to collaboration and higher performing buildings.

5) A) There is an undue reliance today on on-the-job training (OJT). B) There is lack of consistently available, high-quality training and certification programs.

A) True. From the results of the focus groups, interviews, secondary research, and survey, on-the-job training is widely used. However, it should also be acknowledged that on-the-job training is a necessary part of job development.

B) Inconclusive. The primary and secondary research identified several apprenticeships, continuing education, certifications, and degree programs available for facility managers and building control technicians. However, the research did not study or compare and contrast these programs in detail. As a result, only high-level conclusions can be drawn. It appears that there are fewer educational programs for facility managers at the community college level than the four-year degree level. The IFMA Foundation has an accreditation program for facility management degrees. For building technician training, there does not appear to be an accreditation body for the four-year or community college level.

Multiple certification programs for the facility manager and the building control technician were identified. Although it has been identified that these certifications are widely available across the United States, the scope of this research did not specifically address which ones had the largest benefit to the field or what certifications should become an expectation for professional advancement.

6) There may be misinformation and a lack of information amongst building owners and facility managers to understand that energy savings opportunities have a major impact on building performance.

True. There appears to be a lack of defined processes and a lack of understanding of the value of field data documentation. As a result, decisions are often made in the absence of data and information.

One of the major findings within the report is that the definition of building performance is multi-faceted. Depending on the organization, the definition could include energy efficiency, carbon footprint, comfort, uptime, and/or tenant satisfaction. Often, the goals of how to gather, manage, and use the data to quantitatively report these metrics are not well defined. For example, within one of the focus groups it was concluded that sustainability and other goals can appear to be in conflict between departments. An example cited was that turning up the thermostat in summer will save money and energy. What can sound like a simple energy saving strategy may not be the best decision because it may not truly save energy when looking at a decision from a systems perspective. Additionally, how building occupant productivity is impacted by energy saving strategies must also be considered.

7) *Energy efficiency is not a typically supported goal of building owners and managers.*

Inconclusive. Although the survey results found that three quarters of respondents stated their organization had established energy efficiency improvement goals, achieving the goals and/or knowing if the goals were met was not as prevalent. Several reasons for why goals were not met included money, time, and lack of properly trained staff. This lack of money, time, and trained staff indirectly supports the finding that reactive management practices for energy and maintenance management are currently generally accepted, and the benefits of proactive management (goal setting and adherence to goals) are not widely understood.

8) *Lack of management support for quality O&M makes building optimization difficult to achieve, and the industry norm is minimal maintenance as necessary.*

True. The findings of the focus groups, interviews, survey, and secondary research revealed that management support is often lacking for O&M activities because facility managers and building operators often do not have sufficient staff, training of staff is devalued, operations and maintenance budgets continue to decrease, there is a prevalence of deferred maintenance, and technicians and operators have the perspective that they do not have the authority to impact lasting change to improve building efficiency.

9) *O & M professionals may lack the technical expertise necessary to adequately operate and manage high performance systems.*

True. O&M staff will lack technical expertise when they are not provided with resources necessary to obtain required skills. As with most professions, as technology continues to penetrate job functions, it is essential to keep educational and training programs up to date.

O&M professionals need to have access to an improved and standardized toolset and processes that proactively support building operation and building management. The toolset should include tools for evaluating and measuring building performance, scheduling maintenance, analyzing systems and calculating ROI. Although many of these tools are available commercially today, they are rarely applied uniformly within facilities or properly integrated into well-documented processes.

10) *There will be a shift in functional responsibility for building operations (in policy, research, and strategic planning) from blue collar to green building professionals: there are significant implications for training, employment structure, and career advancement opportunities that would enable this shift.*

True. Currently there are few formal job descriptions for those involved in building operations. Some are highly trained engineers while others are custodians. Defining sustainable high performance building operation as a profession, and providing the appropriate pay and respect, is a critical first step in this transition. Improved educational and training programs combined with meaningful professional certifications and well-defined career pathways will facilitate the transformation to high performance building operations.

8.1 Research Summary

Conclusions draw from testing the hypotheses address many of the issues related to organizational barriers, energy efficiency, budgets, management support, and education and training needs associated with facility management and building operation. Several other important topics are summarized below for completeness.

8.1.1 Existing Buildings

The five million buildings within the United States (72 billion square feet) present an incredible opportunity for energy efficiency and sustainability. The transformation to higher performance is a daunting task that will require the contributions of many disciplines. Facility managers and operations and maintenance teams will be central to achieving high performance buildings.

8.1.2 Economics

While energy efficiency and sustainability are noble goals, in most cases, projects need to be economically viable and make business sense to move ahead. Energy costs are a primary variable in this equation. The pace at which the current building stock transitions from current practices to high performance green buildings hinges on economics.

8.1.3 Cost Effective Delivery of Technology and Solutions

While energy and sustainability are expected to drive interest in and adoption of new technology, in most cases the decision to use a technology must also make good business sense. To this end, the building design and engineering community seeks more cost effective solutions. The advanced control technologies are well accepted for many projects, but prices are too high for wide market penetration. Many owners are willing to invest in energy saving technologies, but are demanding solutions where the expenditure will be recouped in less than three years. Solutions available in the market today that utilize field wiring and/or programming typically do not provide the required payback, slowing market penetration of the technologies. Reducing the cost of wireless technologies and automated configurations presents an opportunity to reduce the overall installed cost by decreasing wiring infrastructure and labor costs, and improving installation and operations flexibility.

9 Vision

"If you want behavior modification to occur, you need to raise awareness and then [provide] the tools [necessary] to lead to long term action." –Brian Staszenski, Global Resource Efficiency Services, in response to what future educational programs must support

Meeting the goals set by building owners and managers for high performance buildings will require further definition and elevation of the technician, operator, and facility manager. This means identifying clear, measurable steps to close identified gaps to move building operations practices from reactive to proactive. Of the three gap categories defined, they should be prioritized as:

1) People
2) Process
3) Technology

People are needed to fill the roles of high performance building managers and operators. In order for these roles to be filled, many people will need to be educated about the processes, methods, and technologies required to efficiently operate, manage, and transform existing buildings to high performance buildings. Without properly educated professionals, energy and green house gas emissions reduction goals will not be met.

To determine what skills and processes are needed, a clear definition of a high performance building is critical. As defined by the 2007 Energy Independence and Security Act, a high performance building is:

"A building that integrates and optimizes on a life cycle basis all major high performance attributes, including energy [and water] conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations."[122]

From this definition, it is apparent that a high performance building is not just technology – it requires well-developed processes and trained professionals to appropriately select, manage, operate, and repair energy efficient and sustainable technologies.

To design, build, and operate a high performance building that meets the definition stated above, many current industry challenges must be overcome. Some of these challenges that must be overcome include a lack of:

- Proactive energy and operations and maintenance management processes.
- Support from upper management to provide proper training to complete systems-based maintenance.
- A properly skilled workforce.
- Educated owners and building managers who are willing to invest in staff training and process improvements.
- Respect of knowledgeable building operators and technicians.

[122] (Energy Independence and Security Act 2007 401 PL 110-140)

- Incentives for building operators and technicians to efficiently operate buildings.
- Life cycle cost considerations.
- System and equipment design documentation written and presented in a format that is understood by facility managers, building operators, and engineers -- not just engineers.

9.1 Future Building Control Technicians

The findings of this research suggest that future building control technicians will need to have the following competencies to successfully operate high performance buildings:

- Systems thinker: Understand interactions between components, including controls, HVAC, and lighting.
- Basic data analysis: Understand how to use data generated by a building automation system, including how to read trend logs and how to use the data for decision making.
- How to learn: How to think independently and critically to troubleshoot and solve problems.
- Effective verbal and written communication skills, including.
    - Ability to communicate with building managers about financial decisions impacting operations and maintenance.
    - Ability to communicate with building occupants, vendors, and service providers.

Future building control technicians will be challenged by:

- Overcoming the expectation associated with the "Super Hero Theory".
- Continually increasing pace of new, computer-based technologies.
- Learning how to communicate with managers, building occupants and vendors.
- Approaching maintenance and operations tasks from a systems approach, as opposed to a component-based approach.
- Cultural challenges such as a belief that effective building operation is not important to high performance buildings and energy efficiency.

9.2 Future Facility Managers

The findings of this research suggest that future facility managers will need to have the competencies identified in Figure 70. The items listed in this figure are very similar to the core competencies identified by the International Facility Management Association (IFMA).

Figure 70: Desired facilities management knowledge, skills, and experience[123]

Enterprise

- Mission
- Vision
- Values
- Culture / Trust
- System
- Processes
- Organization Setting
- Resource Allocation

Technical	Business	Behavioral
•Operations & Maintenance	•Strategic Planning	•Leadership
•Planning & Design	•Finance and Accounting	•Teamwork
•Building Systems	•Funding Strategies	•Mentoring
•Project Management	•Contracting/Procurement	•Coaching
•Construction	•Real Estate	•Interpersonal Relationships
•Code Compliance	•Acquisition and Leasing	•Communication
•Cost Estimating	•Business Lexicon	•Change Management
•Space Planning	•Risk Management	•Quality and Innovation
•Env. Health and Safety	•Contingency Planning	•Future Issues/Trends
•Energy Management	•Ethics / Law	•Performance Measurement
•FM Technology	•Marketing	
•Sustainability	•Human Resources	
•Life-Cycle Analyses	•Professional Development	
•Commissioning		
•Security		

Future facility managers will be faced with challenges similar to those identified for building technicians. In addition, facility managers will specifically be faced with:

- Decision making surrounding aging building stock.
- Decreasing operating budgets, especially for proactive maintenance.

To work towards the vision requires the development of a call to action to educate high performance buildings technicians. This will require community colleges to:

- Develop relationships to work alongside professional associations that certify technicians, like North American Technician Excellence (NATE) and the Refrigeration Service Engineers Society (RSES).
- Partner with other community colleges to share resources including curriculum ideas, labs, tools, and equipment.
- Partner with four-year colleges and graduate programs to help educate professors about the need for hands-on learning, facility management, and the role of technicians in building operations.
- Determine how to collaborate with unions to understand how community colleges could serve as a resource for continuing education and educational programs for journeymen.

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[123] (Nash, 2008)

- Partner with organizations and companies that develop training resources and tools, such as the National Association of Power Engineers (NAPE). Some vendors are willing to bring in demo models, or have training trailers and/or models that could be used to supplement lab demonstrations.

Community colleges, universities, professional organizations, and industry practitioners need to work together to develop a standardized program for technician training. This should include an accreditation process, and definition of appropriate lab curriculum, testing standards, and proficiencies.

As programs and partnerships are developed, facility managers and technicians will gain the skills necessary to further utilize technologies to optimize system performance, collect, track and benchmark energy performance, and help achieve sustainability and energy efficiency goals set by the organizations they work for. Achieving these goals will elevate the profession.

10 Call to Action and Future Research

To achieve the vision defined by this research will require commitment of the following:

- Development of clearly focused degree programs for technicians that include:
    - Field experience through labs and/or apprenticeships, communication skills, and negotiation skills to influence occupant behavior change.
    - Strategies to develop economical, portable lab modules that can be widely disseminated for use at community colleges and other training programs. The lab modules must be able to be replicated (blue printed), support multiple technologies, and be developed with support from product vendors.
    - Case studies and problem-based learning scenarios to help students learn from facility managers and technicians currently in the field (dealing with "real life scenarios").
    - Programs structured to be accessible to students from a wide demographic, including dislocated workers, high school graduates, returning students, working professionals, and others seeking hands-on and applied training. The programs must also be structured to allow students to earn associate degrees or certificates, or just to complete single courses.
- Identification of the roles of trade unions, professional associations and partnerships with other community colleges and universities and market-driven training providers
    - Determine if and how mentoring opportunities can be created.
    - Decrease the time and resources necessary to successfully implement more training programs through the development of regional and / or national clearing houses to disseminate curriculum and lab blue prints.
- Determine if a standard for accrediting community colleges for training of controls technicians, building operators, and maintainers. (If so, what is the most appropriate development strategy?)
- Determine how to encourage people to seek careers as building control technicians by reaching out to high schools and others seeking hands-on work opportunities.
- Education of owners to understand the value of hiring and training skilled technicians.
- After owners understand the value of trained technicians, work with owners to develop paid apprenticeship programs for students.

10.1 Future Research

To achieve the call of action, the following future research is recommended:

- Compare existing training opportunities within the market and programs at other community colleges. This comparison should include clearly documented site visits to help share and disseminate teaching and lab development best practices for educating building control technicians.
- Interview/shadow experienced technicians to understand what skills are necessary to operate equipment efficiently and to prevent operating equipment in-hand, as well as discover preferred learning methods and topics of interest.
- Compare technician certification programs available from NATE, RSES and others to determine which one(s) brings the most benefit to the field. Then,

work with these organizations to promote these programs to students, as well as new and seasoned professionals.

- Compare facility management certifications available from IFMA, BOMA, AFE and others to determine which one(s) brings the most benefit to the field. Then work with these organizations to promote these programs to students, as well as new and seasoned professionals.
- Develop of a framework for facility management and technician apprenticeships that can be used to help community colleges, four-year colleges, and employers to build partnering relationships.
- Develop well documented processes and guidance to deploy standards and tools and for evaluating and measuring building performance, scheduling maintenance, analyzing system performance, and calculating return on investment (ROI). Various teaching methods including classroom, lab, and online should be developed to help disseminate standards and tools.
    - Determine if/how Six Sigma can be applied to develop proactive operations and maintenance standards.
    - Teaching resources should be standardized so as to be useful to many community college and training programs, and should include information packets, workbooks, and online materials.
    - Teaching methods must be structured for both student learning and train-the-trainer instruction.

10.2 Summary

Meeting the needs of technicians to operate and maintain high performance buildings is a large, multi-dimensional challenge. This study has classified the challenge as having three gaps: people, process, and technology. Although closing the gaps within all three classifications is important, the research suggests that the people and process gaps are the higher priority. Future research is needed to create more collaborative opportunities between community colleges, unions, professional associations, and industry members. This will help to define the criteria for developing cost effective training modules that can be widely disseminated, and educate owners about the value of training and the need for standardized operations and maintenance practices.

"We cannot purchase efficiency; we can enable it through continual training, testing, certification and encouragement" –Mark McGann
National Association of Power Engineers National (NAPE) President

Revision History

Date	Revisions and Notes	Version
10.22.09	Review draft	A
4.21.10	Revised draft	B
5.15.10	Revised draft	C
5.27.10	Revised draft	D
7.10.10	Review draft	E
8.3.10	Final draft	F

Appendix A: Survey

Survey Questions

Introduction

Thank you for participating in this survey sponsored by the National Science Foundation. The purpose of this research is to gather insight from individuals who are directly involved with the management or operations of commercial and institutional buildings to gain insight into current challenges and identify requirements for education and training associated with the operation of sustainable facilities. This survey is designed to take no more than five minutes to complete. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. After completing the survey, you will have the option to provide your contact information if you wish to be entered into a drawing for a $100 American Express gift card. Thank you very much for your time and support. Please start with the survey now by clicking on the Continue button below.

Question 1

Are you directly involved with the daily management or operations of commercial or institutional buildings?

1) Yes
2) No

Question 2

Select the category which best describes the types of facilities you are responsible for:

1) Healthcare
2) K-12 educational
3) College and University
4) Corporate Real Estate
5) Developer / Property Management
6) Government
7) Retail
8) Hospitality/Entertainment/Restaurant
9) Other

Question 3

What is your job title? If your specific title isn't on this list, select the title that's closest to yours or type in a title in the Other box.

1) A/C Equipment Mechanic
2) Architect
3) Building Engineer
4) Building Operator
5) Building Technician
6) Electrical/Lighting Engineer
7) Energy Manager/Director

8) Environmental Manager/Director
9) Facilities Manager/Engineer
10) HVAC/R Technician building operator
11) Maintenance Engineer
12) Mechanical Engineer
13) Operating Engineer
14) Owner/Developer
15) Physical Plant Manager
16) Plumbing Engineer
17) President/VP/Director of Facilities
18) Property/Real Estate Manager
19) Space Planner/Designer
20) Stationary Engineer
21) Systems Engineer
22) Other

Question 4
How many buildings are you responsible for?

1) 1
2) 2-5
3) 6-10
4) 11-25
5) More than 25

Question 5
What is the average square footage of the buildings you're responsible for?

1) 1,001 to 5,000
2) 5,001 to 10,000
3) 10,001 to 25,000
4) 25,001 to 50,000
5) 50,001 to 100,000
6) 100,001 to 200,000
7) 200,001 to 500,000
8) Over 500,000

Question 6
Which of the following are included in your organizations energy/sustainability program? (Select all that apply)

1) Building design
2) Cleaning
3) Energy management
4) Lighting
5) Renewable energy (e.g. solar, wind, biofuels)
6) Water
7) Recycling
8) Transportation
9) Other (Please Explain)

Question 7

Do you track the Energy Usage Index (EUI) or Energy Star rating for the buildings you're responsible for?

1) Yes
2) No
3) Don't know

Question 8

What is the average EUI (kBTU per square foot) and/or Energy Star Rating (1-100) for the buildings you're responsible for?

1) EUI:
2) Energy Star Rating:

Question 9

What is your organization's annual goal for reducing energy consumption within your facilities?

1) 1-5%
2) 6-10%
3) 11-20%
4) 21-30%
5) Greater than 30%
6) We don't have a goal that I'm aware of
7) Don't know

Question 10

Select which energy reduction programs you currently have in place or are planning to implement within the next 12 to 18 months?

Program	Have implemented	Planning to implement in the next 12-18 months
Energy audits	❑	❑
Energy Star	❑	❑
LEED Certification	❑	❑
Energy benchmarking	❑	❑
Recommissioning	❑	❑
Lighting retrofits, including re-lamping and lighting controls	❑	❑
HVAC equipment upgrade/replacement	❑	❑
Controls optimization/upgrades	❑	❑
Insulation improvement	❑	❑
Windows and doors replacement/improvement	❑	❑
Roofing replacement/improvement	❑	❑
On-site renewable energy	❑	❑
Metering and sub-metering	❑	❑
Demand response	❑	❑
Training	❑	❑

Question 11

Select those items where the majority of the function is outsourced by your organization to a third party vs. handled by in-house staff.

1) Landscaping and/or grounds-keeping
2) Cleaning/janitorial
3) Equipment repair
4) Equipment maintenance
5) Plant operations (for boiler or chiller plants)
6) Building/facility operations (monitoring and oversight of building automation and energy systems)
7) Energy management
8) Engineering services
9) Facility management
10) Other

Question 12

Are you in a managerial role?

1) Yes
2) No

Question 13

The following categories are related to general building operations. Rate your abilities in each category (1 is low and 5 is high) and then rate the importance of that skill in effectively doing your job (1 is not important at all and 5 is very important).

Skill Level	1 (low)	2	3	4	5 (high)	N/A
Building automation	❏	❏	❏	❏	❏	❏
Building automation	❏	❏	❏	❏	❏	❏
Lighting controls	❏	❏	❏	❏	❏	❏
Lighting controls	❏	❏	❏	❏	❏	❏
Mechanical systems	❏	❏	❏	❏	❏	❏
Mechanical systems	❏	❏	❏	❏	❏	❏
Electrical systems	❏	❏	❏	❏	❏	❏
Electrical systems	❏	❏	❏	❏	❏	❏
Metering	❏	❏	❏	❏	❏	❏
Metering	❏	❏	❏	❏	❏	❏
Energy management (i.e. collecting, monitoring and/or acting on energy consumption data)	❏	❏	❏	❏	❏	❏
Energy management (i.e. collecting, monitoring and/or acting on energy consumption data)	❏	❏	❏	❏	❏	❏
Security	❏	❏	❏	❏	❏	❏
Security	❏	❏	❏	❏	❏	❏
Fire protection/Life safety	❏	❏	❏	❏	❏	❏
Fire protection/Life safety	❏	❏	❏	❏	❏	❏
Water management	❏	❏	❏	❏	❏	❏
Water management	❏	❏	❏	❏	❏	❏
Emergency preparedness	❏	❏	❏	❏	❏	❏
Emergency preparedness	❏	❏	❏	❏	❏	❏
Grounds maintenance	❏	❏	❏	❏	❏	❏
Grounds maintenance	❏	❏	❏	❏	❏	❏
Roofing	❏	❏	❏	❏	❏	❏
Roofing	❏	❏	❏	❏	❏	❏

Question 14

The following categories are related to general building operations. Rate the abilities of your staff in each category (1 is low and 5 is high) and then rate the importance of that skill in your staffs ability to effectively perform their current responsibilities (1 is not important at all and 5 is very important).

Skill level of employees	1 (Low)	2	3	4	5 (High)	N/A
Building automation	❑	❑	❑	❑	❑	❑
Building automation	❑	❑	❑	❑	❑	❑
Lighting controls	❑	❑	❑	❑	❑	❑
Lighting controls	❑	❑	❑	❑	❑	❑
Mechanical systems	❑	❑	❑	❑	❑	❑
Mechanical systems	❑	❑	❑	❑	❑	❑
Electrical systems	❑	❑	❑	❑	❑	❑
Electrical systems	❑	❑	❑	❑	❑	❑
Metering	❑	❑	❑	❑	❑	❑
Metering	❑	❑	❑	❑	❑	❑
Energy management (i.e. collecting, monitoring and/or acting on energy consumption data)	❑	❑	❑	❑	❑	❑
Energy management (i.e. collecting, monitoring and/or acting on energy consumption data)	❑	❑	❑	❑	❑	❑
Security	❑	❑	❑	❑	❑	❑
Security	❑	❑	❑	❑	❑	❑
Fire protection/Life safety	❑	❑	❑	❑	❑	❑
Fire protection/Life safety	❑	❑	❑	❑	❑	❑
Water management	❑	❑	❑	❑	❑	❑
Water management	❑	❑	❑	❑	❑	❑
Emergency preparedness	❑	❑	❑	❑	❑	❑
Emergency preparedness	❑	❑	❑	❑	❑	❑
Grounds maintenance	❑	❑	❑	❑	❑	❑
Grounds maintenance	❑	❑	❑	❑	❑	❑
Roofing	❑	❑	❑	❑	❑	❑
Roofing	❑	❑	❑	❑	❑	❑

Question 15

What are the top three challenges you face in your current position? (Maximum of 3 selections only)

1) Not enough money
2) Not enough people
3) Not enough time
4) Tenant satisfaction
5) Not able to find qualified staff
6) Don’t have the necessary technology or tools
7) HVAC systems
8) Building automation systems
9) Meeting energy management goals
10) Lack of management support for operations
11) Lighting systems

12) Other

Question 16
What are other challenges do you face?

Question 17
What type of formal educational training did you receive?

1) 4-year college or university
2) Community or technical college
3) Certification program
4) I had no formal educational training
5) Other (Please specify)

Question 18
What school did you attend?

Question 19
What was your course of study or degree?

Question 20
Rate your level of satisfaction with the education you received based on how well you believe it prepared you to do your job.

1) Very Dissatisfied
2) Not Satisfied
3) Neutral
4) Satisfied
5) Very Satisfied

Question 21
Which of the following professional certifications have you completed? (Select all that apply)

1) Building Operator Certification (BOC)
2) LEED AP (USGBC)
3) PE (Professional Engineer)
4) CEM (Certified Energy Manager, AEE)
5) GBE (Certified Green Building Engineer, AEE)
6) CFM (Certified Facility Manager, IFMA)
7) OPMP (Operations and Performance Management Professional, ASHRAE)
8) North American Technician Excellence (NATE)
9) Industry Competency Exam (ICE)
10) Other (Please Specify)

Question 22
What career skills are you looking to enhance in the future?

Question 23
What types of ongoing training do you participate in? (Select all that apply)

1) Manufacturer training
2) Association courses
3) Trade shows and conferences
4) Continuing education courses

5) Webinars
6) Other

Question 24
Where do you reside?

1) Alabama
2) Alaska
3) Arizona
4) Arkansas
5) California
6) Colorado
7) Connecticut
8) Delaware
9) Florida
10) Georgia
11) Hawaii
12) Idaho
13) Illinois
14) Indiana
15) Iowa
16) Kansas
17) Kentucky
18) Louisiana
19) Maine
20) Maryland
21) Massachusetts
22) Michigan
23) Minnesota
24) Mississippi
25) Missouri
26) Montana
27) Nebraska
28) Nevada
29) New Hampshire
30) New Jersey
31) New Mexico
32) New York
33) North Carolina
34) North Dakota
35) Ohio
36) Oklahoma
37) Oregon
38) Pennsylvania
39) Rhode Island
40) South Carolina
41) South Dakota
42) Tennessee
43) Texas
44) Utah
45) Vermont
46) Virginia
47) Washington
48) Washington, D.C.
49) West Virginia
50) Wisconsin
51) Wyoming
52) Canada
53) EU
54) Asia
55) Middle East
56) South America
57) Other

Question 25
How did you learn about this survey?

1) Received an email asking me to participate
2) Through a social networking site or blog (i.e. LinkedIn or Facilitiesnet)
3) Through a referral
4) Other (Please Specify)

Question 26
Please provide the following information if you would like to be entered into a drawing for a $100 American Express gift card. (Optional but required for entry)

1) Name:
2) Organization:
3) Email:
4) Phone:

Question 27
Would you be interested in participating in future research efforts?

1) Yes
2) No

Question 28
Please provide the following information so we can contact you for future research studies.

1) Name:
2) City:

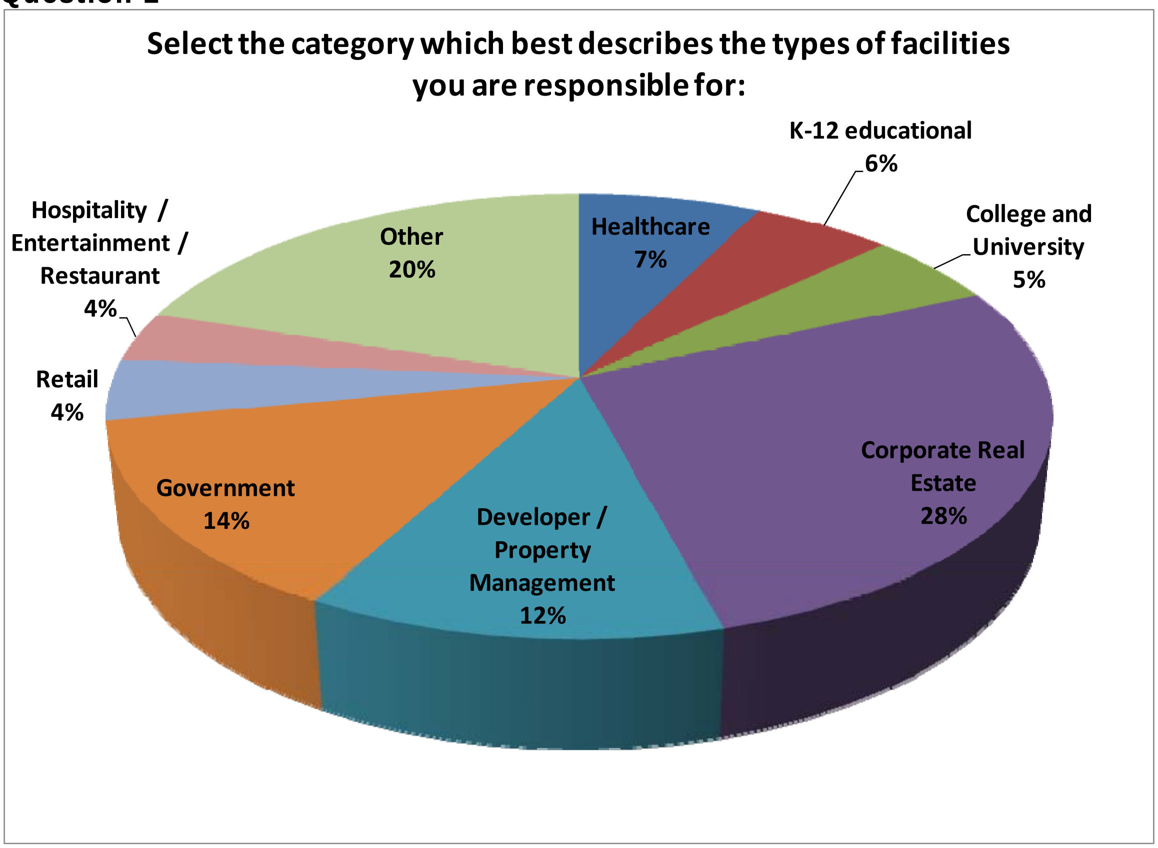
3) State:
4) Email:
5) Phone:

Survey Results

Approximately 250 people completed the survey conducted as part of this study. Given the relatively small number of responses (relative to market research surveys), it is important to note that the data presents a confidence level of 90 percent with a margin of error of five points.

Question 1
Are you directly involved with the daily management or operations of commercial or institutional buildings?
Yes: 84%
No: 16%

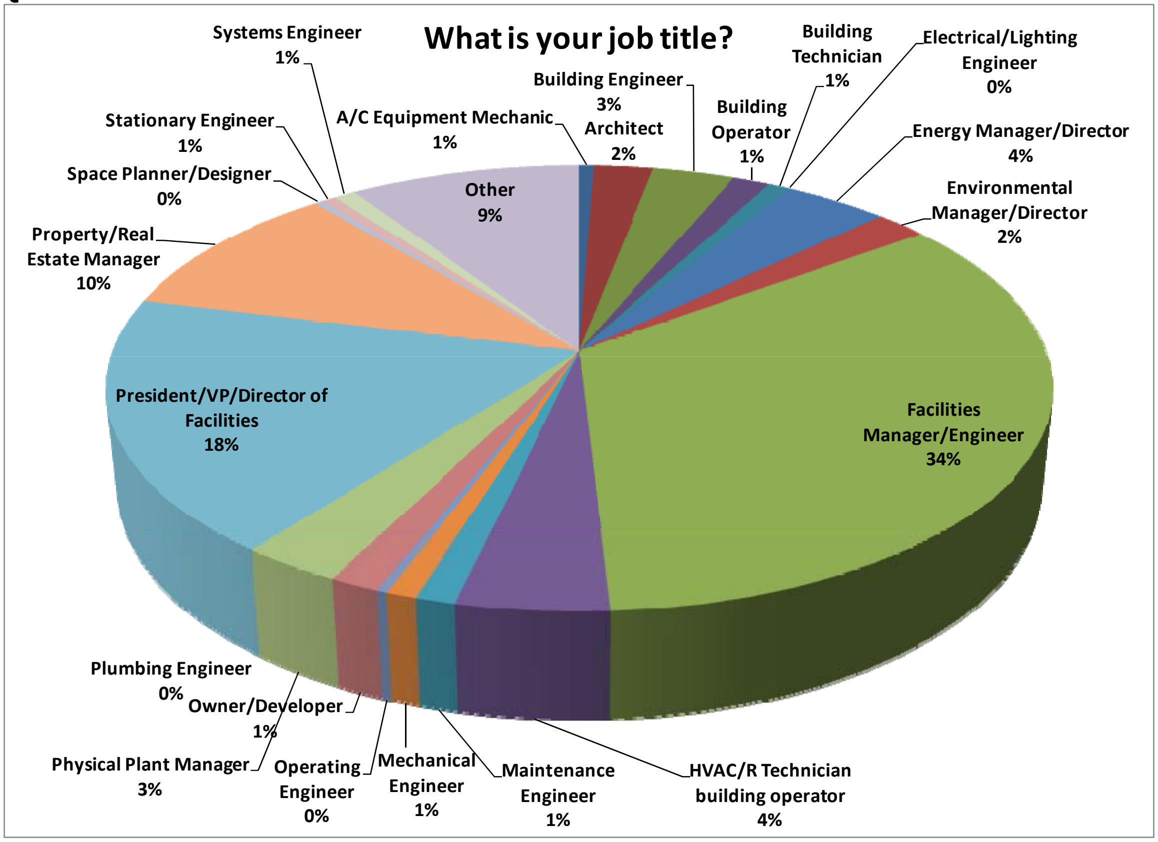
Question 2



Other responses included:

- Manufacture/ Manufacturing
- Research/Office/Manufacturing Complex
- Industrial
- Church campus
- Church headquarters
- Museum
- HVAC company that takes care of several building service contracts
- HVAC service sales
- Food plant
- High school, boys only
- All of the above
- Commercial
- Data centers
- Research
- Public Utility
- Vehicle prep center
- Office warehouse nonprofit
- Mixed use & trade show facility
- Semiconductor factories
- Bio-pharmaceutical
- Religious se
- Utility
- Semiconductor design and marketing
- Financial institutions
- Electric utility company
- Church
- Law firm
- Media
- Investments
- Corporate office/warehouse
- Office
- Private non-profit agencies program space
- Libraries
- Research labs
- Utilities
- Branch office
- Non Profit
- Corporate Headquarters
- Owner occupied business office
- Data center, office facility
- Insurance
- Non-profit religious
- Research lab
- Corp. office
- Research and Office Building
- Office
- Software
- Industrial
- Fire stations
- Commercial office
- Banking
- Commercial business
- Banking
- Capital equipment manufacturer in the high tech industry

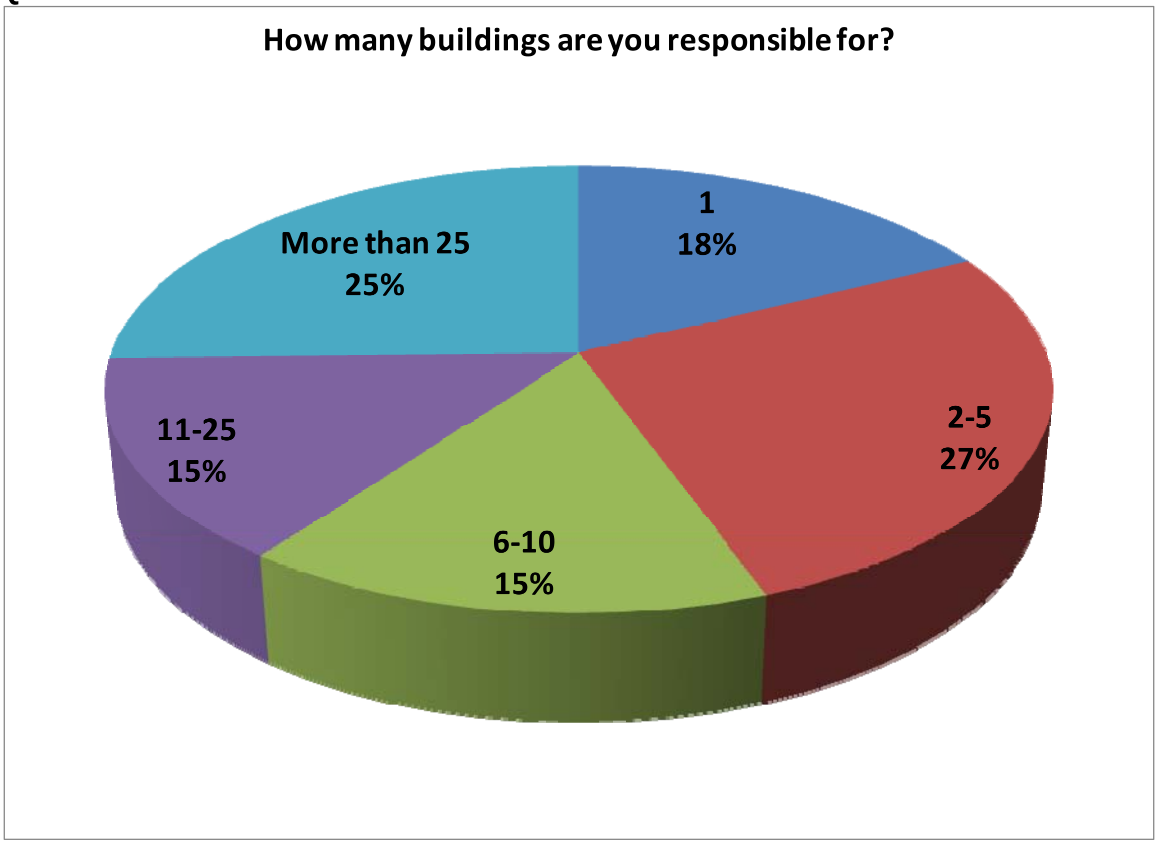
Question 3



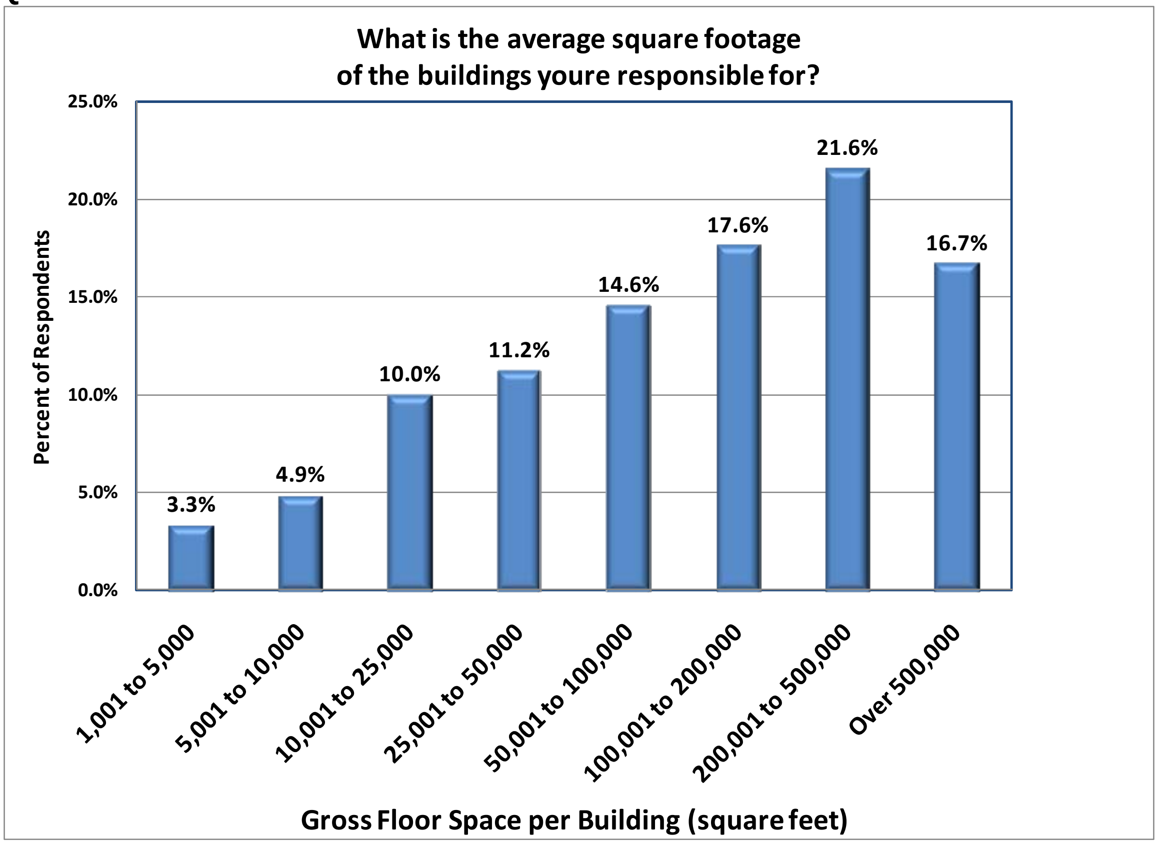
Other responses included:

- HVAC Planner
- Building Official
- Asst Chief Engineer
- Sales
- Operations Auditor
- Supply FDD
- Energy Engineer
- Business Manager
- Manager of Projects
- Facilities Coordinator
- Senior Stationary Engineer
- Manager
- FM Management Analyst
- Manager of Administration
- O & M Supervisor
- Operations Manager
- Branch Support Manager
- Dir. Operations
- Sr. Project Mgr.
- Facilities Coordinator
- District Mgr
- Facilities Project Coordinator
- Facility Management Analyst
- Director, Corporate Services
- Director, Facility & Fleet Services
- Facilities Coordinator
- Chief Engineer
- Coordinator
- Office Manager
- Electrician building operator
- Facilities Supervisor

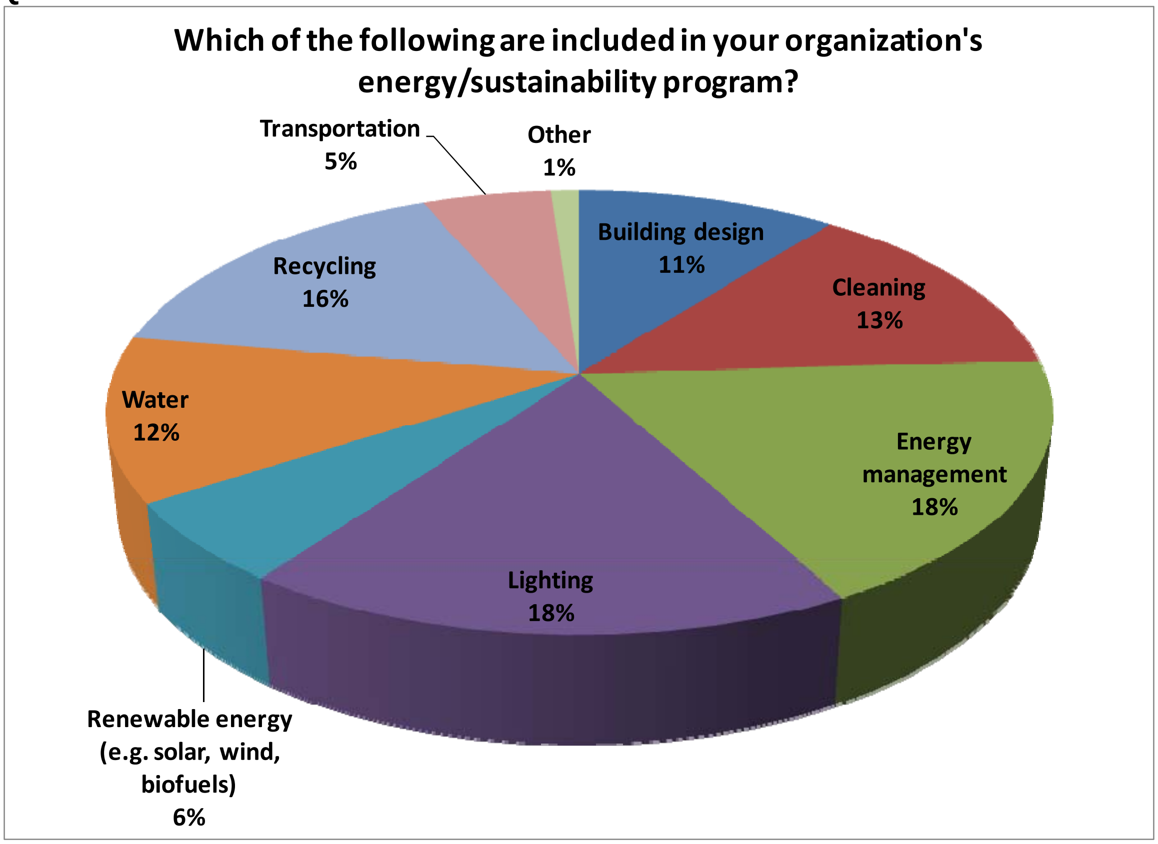
Question 4


How many buildings are you responsible for?
1
18%
2-5
27%
6-10
15%
11-25
15%
More than 25
25%

Question 5


What is the average square footage
of the buildings youre responsible for?
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Percent of Respondents
3.3%
4.9%
10.0%
11.2%
14.6%
17.6%
21.6%
16.7%
1,001 to 5,000
5,001 to 10,000
10,001 to 25,000
25,001 to 50,000
50,001 to 100,000
100,001 to 200,000
200,001 to 500,000
Over 500,000
Gross Floor Space per Building (square feet)

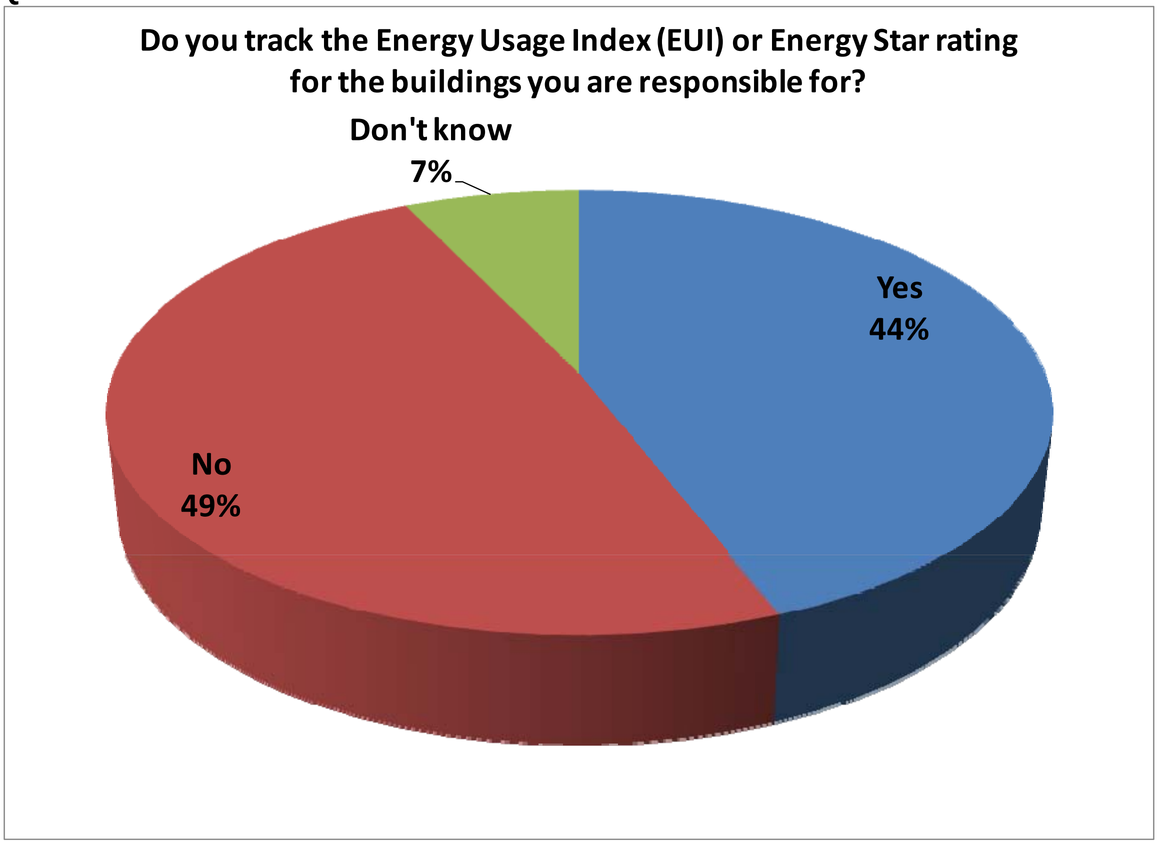
Question 6



Other responses included:

- Codes
- Daylighting
- HVAC
- HVAC service
- Window film
- All my buildings were built in 70's & 80's.
- Landfill diversion
- Co-generation
- Utilities - We have central heating and cooling plants feeding a system with chilled water, high pressure steam, power, domestic water, natural gas, compresses air, and de-mineralized water for the majority of our buildings on our main campus. We are also considered a regulated utility as we can generate our own power, and also provide these same services to adjacent non University buildings including two hospitals.
- Composting
- Education to Employees to be Green
- Purchasing
- Managed by Energy Manager
- Renewable Energy Certificates
- Retro-commissioning
- Community outreach

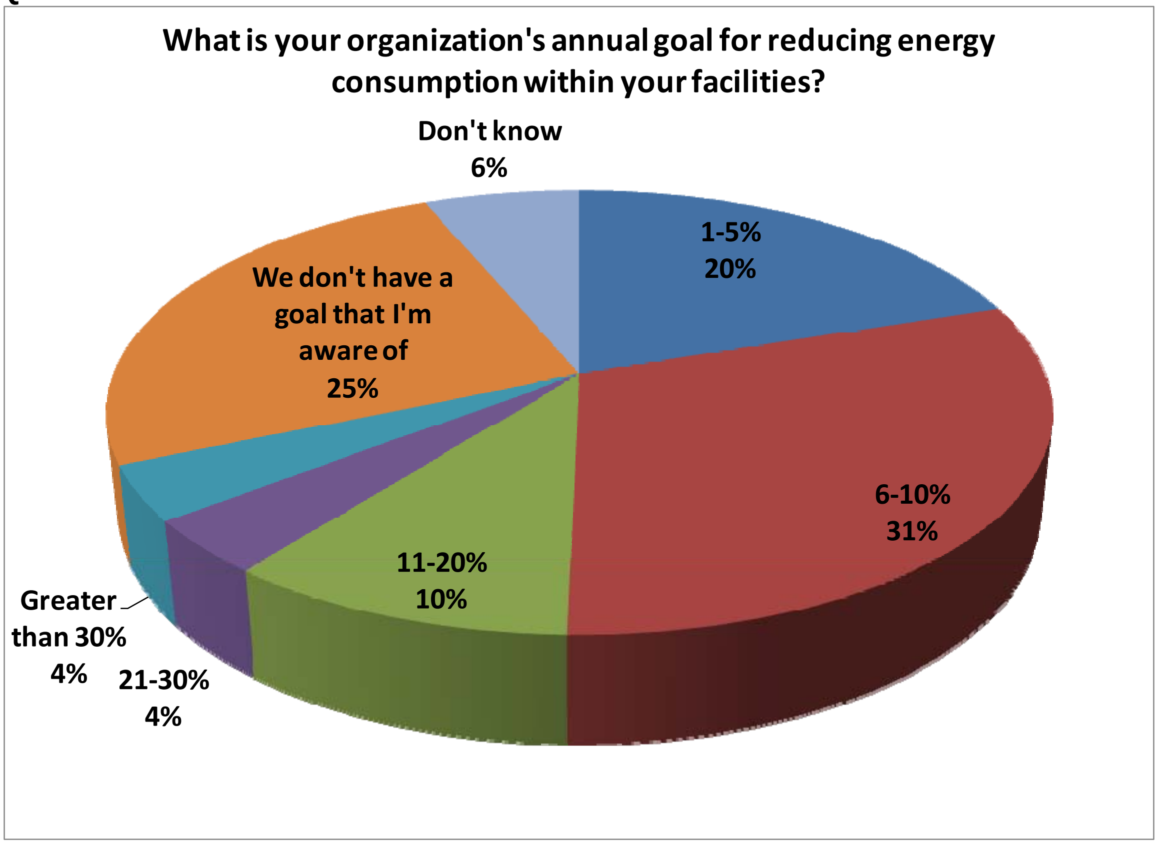
Question 7



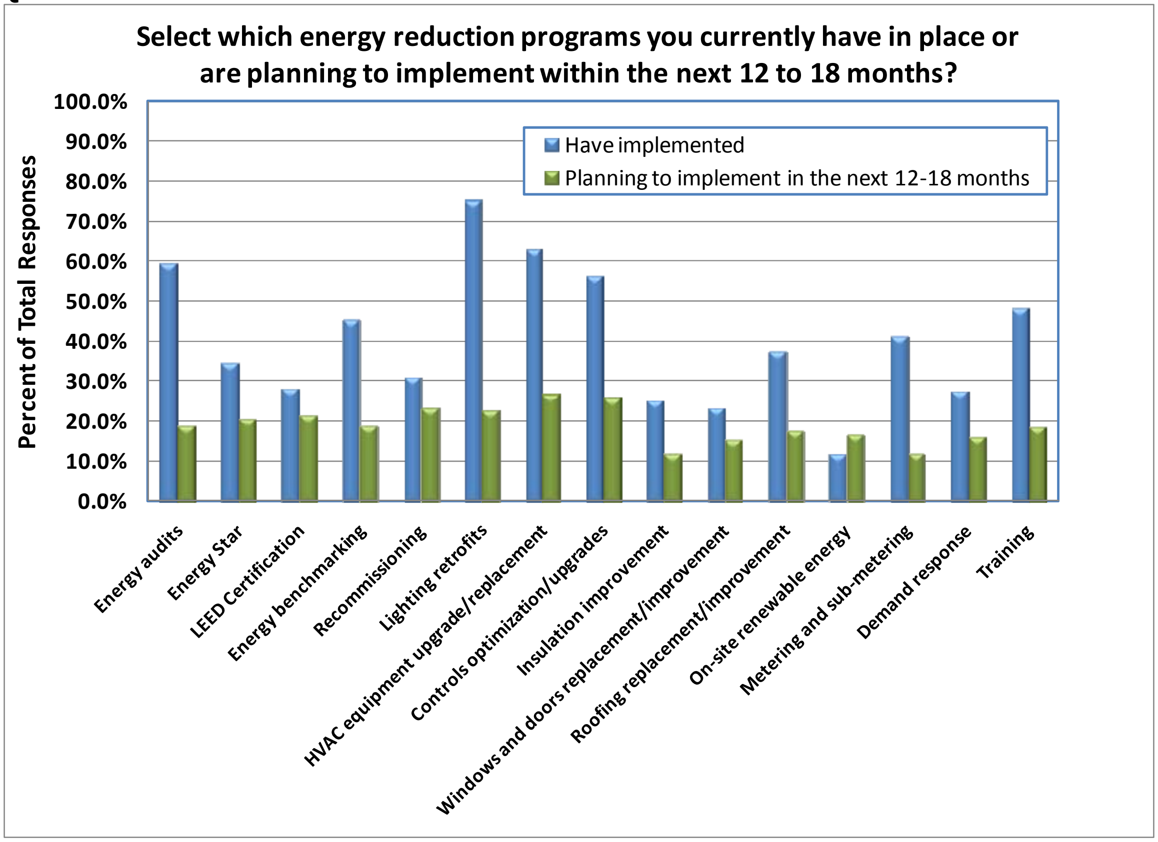
Question 8
What is the average EUI (kBTU per square foot) and/or Energy Star Rating (1-100) for the buildings you're responsible for?

EUI:	138	Respondents providing EUI:	11.9%
ENERGY STAR Rating:	71	Respondents providing Energy Star Rating:	20.9%

Question 9

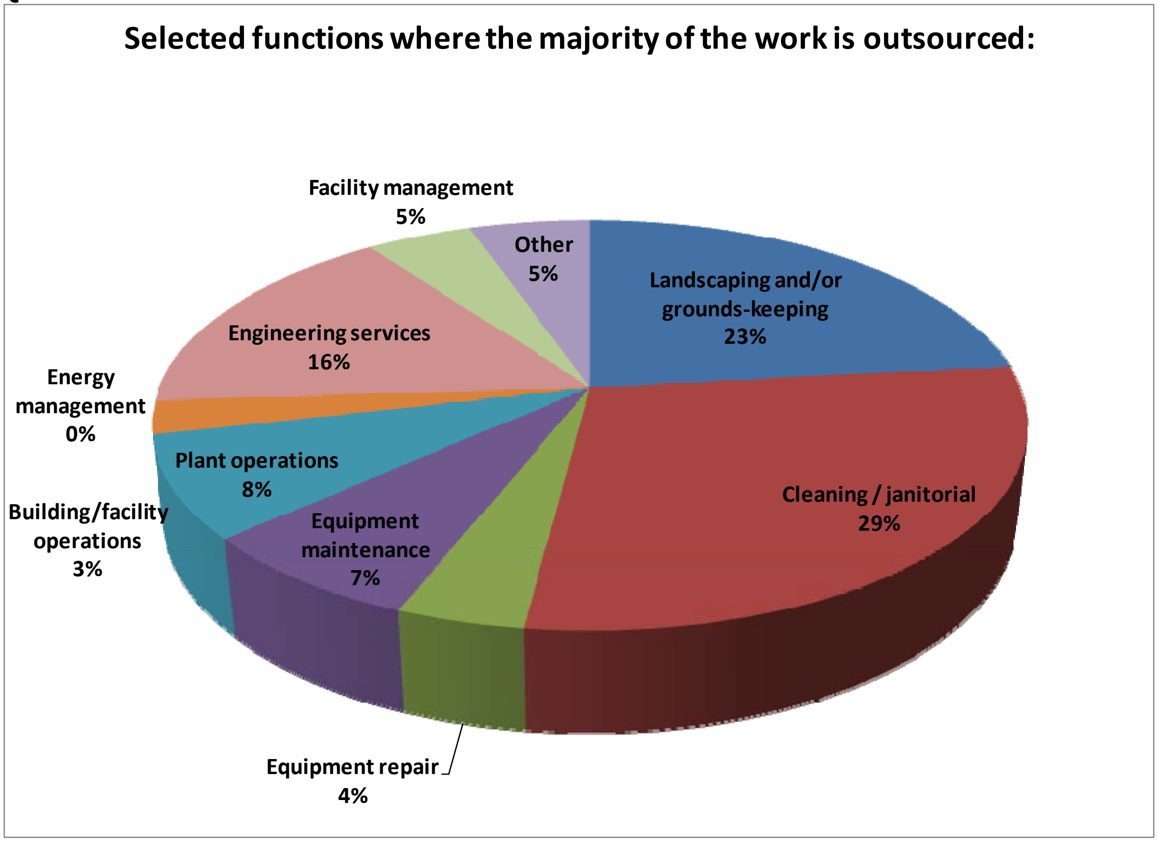

What is your organization's annual goal for reducing energy consumption within your facilities?
Don't know
6%
1-5%
20%
We don't have a goal that I'm aware of
25%
6-10%
31%
11-20%
10%
Greater than 30%
4%
21-30%
4%

Question 10



Select which energy reduction programs you currently have in place or are planning to implement within the next 12 to 18 months?
Percent of Total Responses
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Have implemented
Planning to implement in the next 12-18 months
Energy audits
Energy Star
LEED Certification
Energy benchmarking
Recommissioning
Lighting retrofits
HVAC equipment upgrade/replacement
Controls optimization/upgrades
Insulation improvement
Windows and doors replacement/improvement
Roofing replacement/improvement
On-site renewable energy
Metering and sub-metering
Demand response
Training

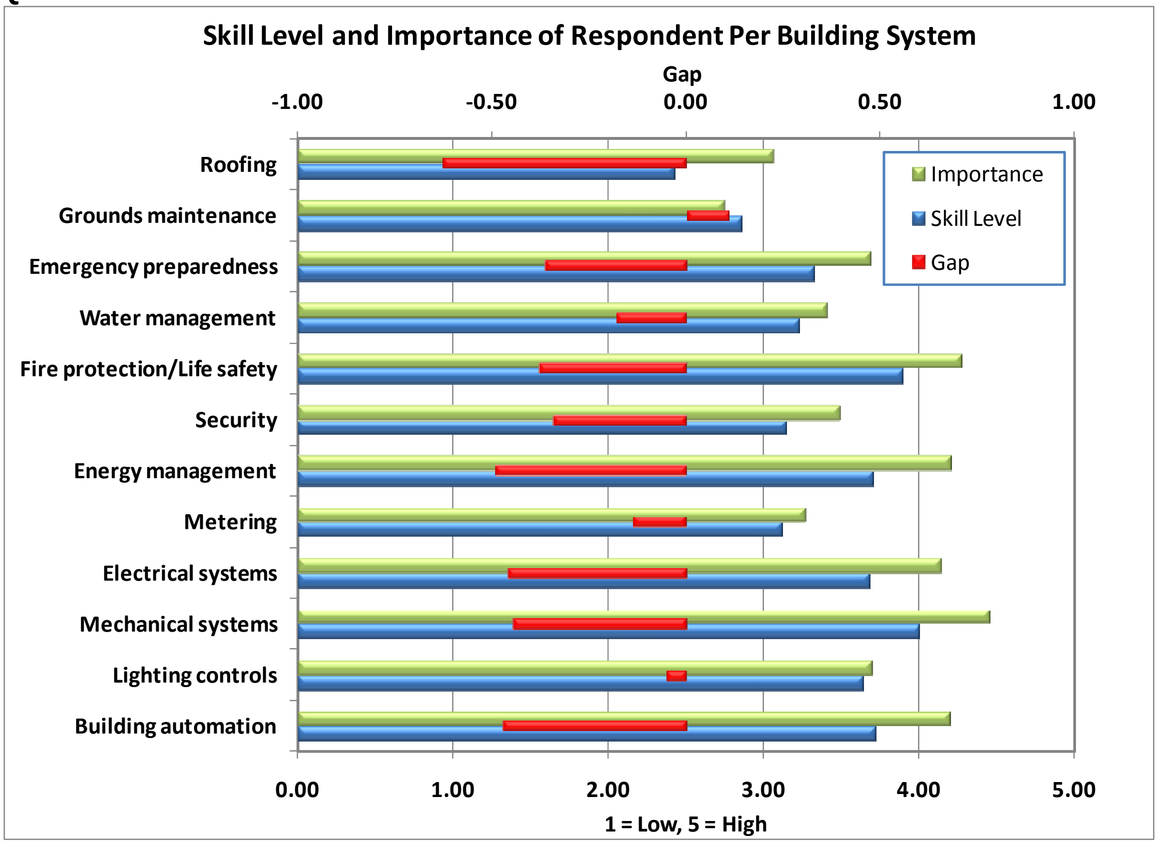
Question 11



Question 12

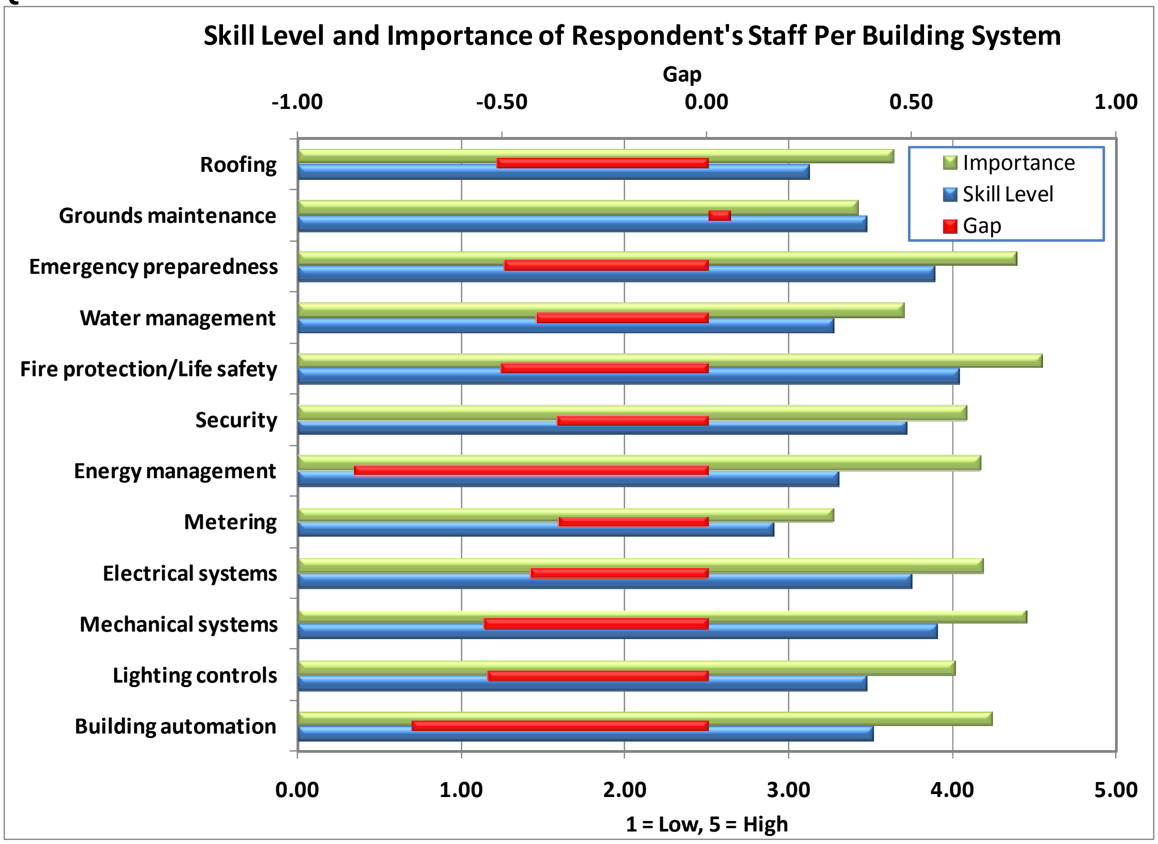
Are you in a managerial role?
Yes: 84%
No: 16%

Question 13



Skill Level and Importance of Respondent Per Building System
Gap
-1.00
-0.50
0.00
0.50
1.00
Roofing
Grounds maintenance
Emergency preparedness
Water management
Fire protection/Life safety
Security
Energy management
Metering
Electrical systems
Mechanical systems
Lighting controls
Building automation
Importance
Skill Level
Gap
0.00
1.00
2.00
3.00
4.00
5.00
1 = Low, 5 = High

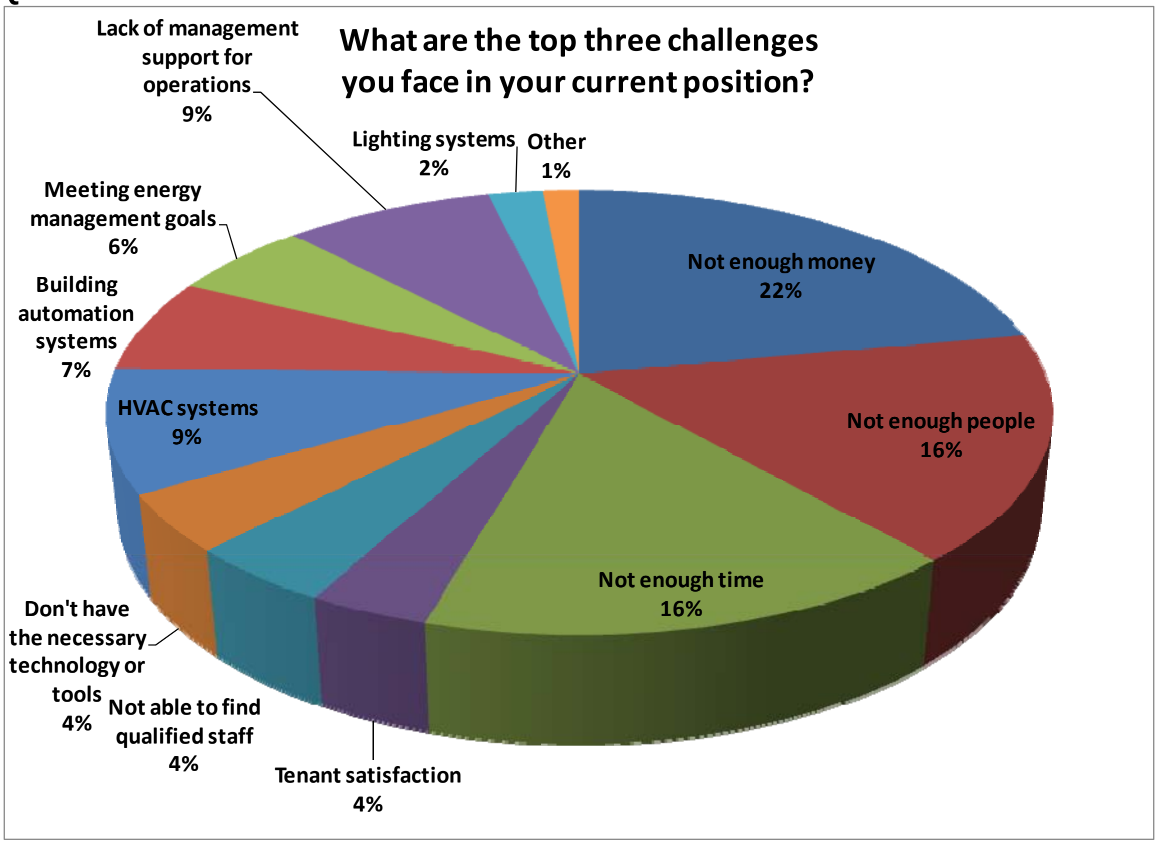
Question 14



Some observations regarding results for questions 13 and 14:

1) Gaps in importance to skills are relatively small from both managers and employees, even in areas known to be critical. This indicates that participants in this industry “don’t know what they need to know”.
2) Most significant gap is in relation to building automation
3) Employees rating scores were slightly lower than the scores given by managers. This might indicate that employees are more aware that they need to know more.
4) Metering gives an indication of the lack of understanding of operating energy efficient facilities. Both the skills and the importance were very low which implies that they don’t feel it’s important to know about.

Question 15



Other responses included:

- Not enough training
- Older buildings built in the early 1970's with bad HVAC designs.
- Affixing proper improvements to multiple strategic property strategies
- No outlook beyond three years
- Space planning
- Inability to optimize organization around functionality
- Stores may vary
- We are in a new building where most of the management systems are automated. Finding the correct timing for lighting, etc was our only challenge and is now completed.
- Unions
- Building age

Correlation of the top challenges with sector resulted in the following:

Challenge	Overall	Healthcare	K-12 Education	College and University	Corporate Real Estate	Developer / Property Mgmt	Gov't	Retail	Hospitality
Not enough money	22.00%	14.55%	21.74%	25.53%	20.64%	23.86%	17.86%	28.13%	24.24%
Not enough people	16.43%	16.36%	15.22%	23.40%	15.60%	12.50%	18.75%	9.38%	21.21%
Not enough time	15.93%	16.36%	10.87%	19.15%	18.35%	18.18%	13.39%	15.63%	15.15%
Tenant satisfaction	3.54%	3.64%	4.35%	4.26%	2.75%	6.82%	3.57%	6.25%	0.00%
Not able to find qualified staff	4.42%	3.64%	2.17%	12.77%	4.13%	4.55%	3.57%	6.25%	9.09%
Dont have the necessary technology or tools	4.17%	3.64%	6.52%	4.26%	2.75%	1.14%	6.25%	6.25%	3.03%
HVAC systems	8.72%	7.27%	17.39%	2.13%	10.09%	6.82%	7.14%	6.25%	6.06%
Building automation systems	6.57%	7.27%	4.35%	4.26%	6.42%	5.68%	11.61%	6.25%	6.06%
Meeting energy management goals	5.69%	12.73%	6.52%	0.00%	5.50%	12.50%	4.46%	3.13%	9.09%
Lack of management support for operations	8.72%	14.55%	8.70%	4.26%	8.72%	4.55%	8.04%	9.38%	3.03%
Legend	Significantly higher than Average								
	Significantly lower than average								

Question 16
What are other challenges do you face?

- Money!
- Student sense of entitlement and lack of concern for wasteful activities since they "are paying for it".
- Maintaining a complex laboratory complex with reduced lower rank supervision to carry out the mission.
- Vendor customer service is at an all time low. Significant amounts of time are spent coercing vendors to complete contractually obligated projects.
- middle of nowhere
- Education - Keeping up with all the new systems and controls
- Not enough workers to perform tasks.
- Seems to be more of reactive maintenance instead of predictive maintenance
- Not LEED qualified
- Lack of educational resources that are available at reasonable costs
- Cutting energy consumption in a 5 year old building that was built fairly efficient to begin with.
- 1. Knowing & thinking through what will work & what will not.
- 2. Distinguishing between companies that offer good/forward thinking ideas & companies that offer crappy/make fast money ideas.
- Increased regulatory requirements are unfunded mandates.
- amount of calls we respond to
- Tenant attitudes - alot of them think that everything is someone else's responsibility - even turning off their lamps or radios when they leave for the day or weekend.
- the economy and its effect on our core functions
- running small non-profit facilities that are too small to qualify for some energy usage reduction programs and running tax exempt facilities which do not qualify for tax credits for improvements
- not enough people with the proper knowledge base to perform the job.
- Do/produce more with less resources
- survival on a day-to-day basis
- lack time to research and implement conservation measures
- regulation
- Renewable energy project do not have a quick enough payback. Even with many incentives they still have long paybacks.
- No one seems to care about conservations projects that get done even though they have the quickest paybacks. Employees and others seem to only be interested in solar panels and wind.
- Doing more with less in this coming fiscal year.
- Doing more with less
- Overall decline in business presently and in the near future.
- Working in the public sector, it is difficult to get quality contractors to bid on supplies, work and projects.
- Lack of manpower
- Budget reductions
- Energy Management goals can only be accomplished with a major cultural change (to facilitate operational changes)
- Declining skilled maintenance staff available that have the necessary skill sets to operate and maintain our facilities.

- skill labor – payrate -- work ethic
- none
- Construction project that we are in the middle of.
- unknowledgeable property managers
- The declining economy causes us to do more with less
- Tough overall economy
- Lack of experience in going green economically. Technicians reluctant to change with the technical advancements. A primary source of education used to be USN, but that is changing.
- Most of the buildings we manage are new and sold within a few months of completion. It's difficult to track and although we enter the information on energy star the building we cannot get a rating due to age and occupancy.
- 1. Optimizing building systems performance and saving energy without compromising patient comfort and care in a health care facility.
- 2. Getting people to care about energy conservation.
- mostly mentioned above
- Affixing proper improvements to multiple strategic property strategies that cross the northern United States.
- All of the above
- 40 something year old building 20 to 30 year old infrastructure
- Huge deferred maintenance backlog due to years of cutbacks.
- the weather
- EGO
- power availability
- occupancy low. New spec building of 250k SF in Wash. DC on Mass Ave. Only 10% occupancy.
- Downsizing staff with no plan in place to map out how things will be in the future.
- Do more with less. Do it better and what else can you take on
- Fast-track projects at year-end based on budget under runs. Amount of space designated per person.
- management support
- Reduction of staff over the last year.
- Inability to control utility costs.
- Training of staff.
- A benchmark site assessment report
- Wearing too many hats. Responsible for a very wide assortment duties with no support staff.
- Weighing tenant perception of project importance with actual operational and upper management perception and

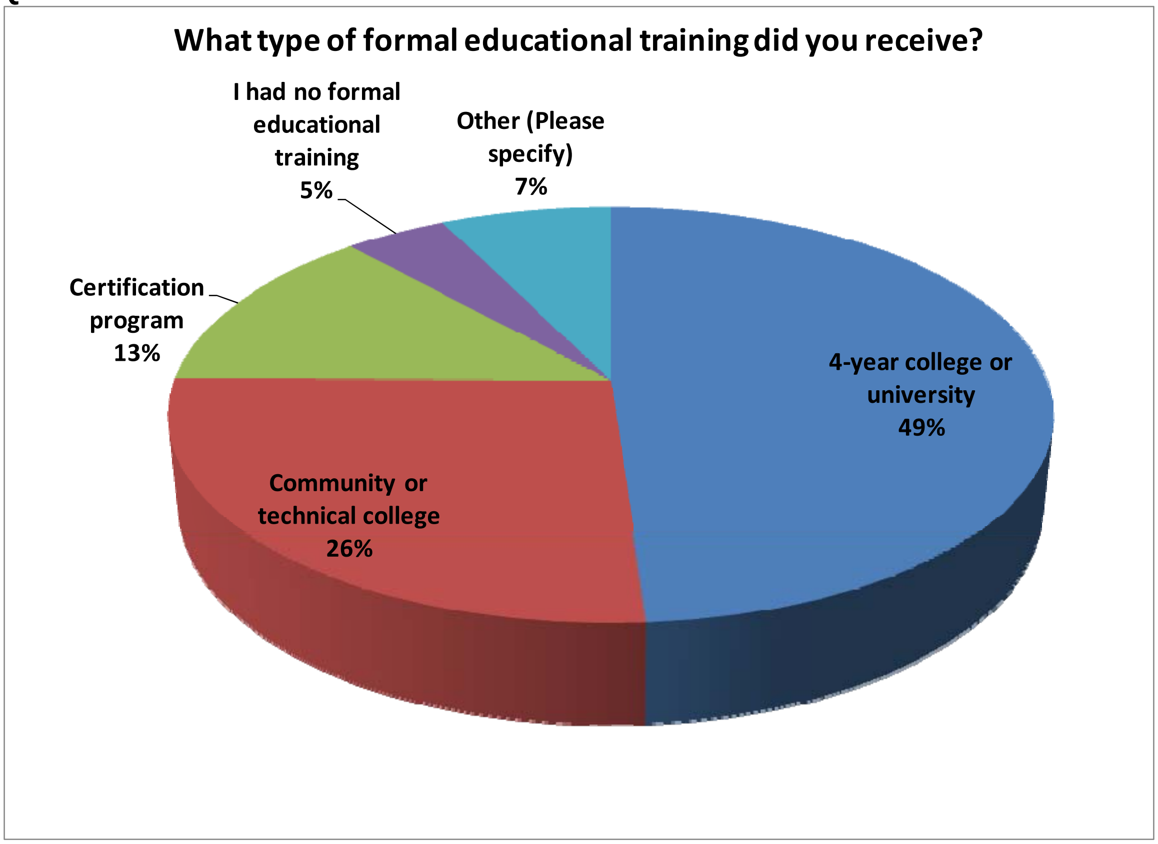
Older workforce and fewer skilled staff to take their place as they retire.

- Educating top management to where they understand the value of up grading and advancing technology be a value add to the daily business operation bottom line.
- Continuing increase of energy
- budget restraints
- BCM/Safetyand security are a top priority as this is a corporate head quarter environment
- Being a woman in this field - it's challenging for people to take you seriously. It's like you have to prove your intelligence everytime there is someone new brought into the mix
- Training
- The inability for management to understand what it costs to own and run a facility. All mechanical items are 20 years or older.
- Resistance to change underutilized positions to needed positions.
- Lack of capital improvement money has greatly reduced the payback period required to get projects approve.
- Trying to manage unrealistic expectations of organizational members.
- Upper management over values technology compared with having enough well trained staff. Also, in tight budget times sustainability initiatives seem to be the first items cut.
- Keeping tenants in our buildings.
- Have no vacancy
- Keep costs under control
- Trying to manage a facility with an outsource company.
- Skill set
- FMP
- Managing a facility with an outsourced facility management company.
- Changing the culture from the old norm of not thinking of sustainability and energy conservation.
- lack of management commitment.
- finding documented savings in a very efficient building.
- Continual initiatives to enhance operations when previous initiatives are not yet proven or stable.
- New budget cuts coming 2010 - have no clue how that will affect our operations
- Corporate support
- Lack of qualified people
- Age of work force
- Developing Policies and Procedures for Maintenance and Custodial operations

direction.

- Shrinking budgets
- Hiring freezes
- No resources to perform preventive or predictive maintenance activities
- Hardworking staff
- Reduction in budget and employees increase in responsibility and complexity of job
- Downsizing has caused some delayed maintenance and upgrades to older building systems that were planned when times were better. This has caused us to become reactive vs. proactive in our work.
- Budgets and funds for capital improvements
- Selecting the best equipment to maximize investment and sustainability
- Trying to go green 'in-between' all other day to day maintenance challenges as we own our buildings are maintain all of them, including supporting all domestic remote operations. Utilizing and optimizing the skill set of the fixed maintenance staff to constantly increase our scope and 'do more'.
- Organization always wanting to do more with less and often straying from core services. New programs, no new dollars. This often takes away funding needed for basic PM services.
- Our company is extremely progressive in the energy efficiency area,and is supportive of cost effective recommendations
- Training sessions on what to do to go green.
- Space planning
- Just not enough time
- money,skill levels,energy upgrades,board changes every 2 years new agenda,
- employee demographics/succession planning
- Interdepartmental politics interfering with the progress of projects; lack of a comprehensive strategic plan; rapid staff turnover creating gaps in institutional knowledge.
- Implementing energy savings programs meets with increasing reluctance to find money.
- Management not wanting to spend the money to upgrade vital systems and equipment.
- Same as the previous page. Money.
- communication issues
- Mostly finding qualified people that can be hired with a difficult government hiring process.
- Ergonomics, and budgeting/financing
- Too needy employee population :)
- Increased agency monitoring

Question 17



Other responses included:

- trade school
- Ph.D.
- Worked with Arch/ME for 10 years.
- Ph.D.
- Ph.D.-Eng.
- Masters Degree
- Skilled craftsman: Instrumentation & Controls
- Master Degree
- MBA
- MS in Engr Mgt
- AS degree & CFM
- MSBA
- Masters Degree
- 2-year college, associate degree
- graduate degree
- the first 3 answerers
- graduate
- Masters Degree
- Master's degree
- MBA

Correlation of the education and training with sector resulted in the following:

Educational Training	Overall	Healthcare	K-12 Education	College and University	Corporate Real Estate	Developer / Property Mgmt	Gov't	Retail	Hospitality
4-year college or university	49.12%	57.89%	23.53%	52.94%	62.82%	47.06%	42.50%	63.64%	27.27%
Community or technical college	26.86%	15.79%	52.94%	35.29%	12.82%	32.35%	25.00%	18.18%	45.45%
Certification program	12.72%	10.53%	17.65%	5.88%	12.82%	14.71%	15.00%	9.09%	9.09%
I had no formal educational training	4.24%	5.26%	5.88%	0.00%	5.13%	2.94%	2.50%	9.09%	9.09%
Other (Please specify)	7.07%	10.53%	0.00%	5.88%	6.41%	2.94%	15.00%	0.00%	9.09%
Legend	Significantly higher than Average								
	Significantly lower than average								
Notes	People in Healthcare, Retail and Corporate Real Estate are most likely to attend 4-year; K-12 and Hospitality are most likely to attend Community or Tech College)								

Question 18
What school did you attend?

- Merced College
- University of Toronto; Boston University
- US Military Academy
- Meridian Tech, BOMI class
- MVCC
- LA TRADE TECH
- Bates Technical
- University of Notre Dame
- Waterloo and McMaster
- Williamsport Community Collage
- University of Houston
- Daytona State
- Local 602 steamfitters
- Cal State Irvine
- Pima Community College
- LDS Business College
- West Virginia University
- York Catholic
- BOMA / BOMI
- Rio Salado Community College
- SUNY Maritime College
- University of Arkansas, Cal Tech
- UMD
- SUNY DELHI
- Westside Institute of Technology
- British Columbia Institution of Technology
- San Jose State & Reedley College
- Iowa State University
- Red Wing Technical College and Inver Grove Hills Community College
- Lincoln Trail College
- Ambassador University
- Laney College
- US Army Engineer School, Tarkio College
- New England Tech and R.I. College
- Renton Vocational
- Spring Garden College Phila. PA
- OSHA CAMPUS
- Kansas State University & North Dakota State University
- LDS Business College/University of Utah
- Northern Arizona University and University of Arizona
- California State Polytechnic University
- Drury University
- High school and some college
- Cardinal Stitch University
- Ccfl
- University of Southern California
- University of Illinois
- UCI
- BYU
- BYU
- University of Phoenix
- CA State Univ. of Sac.
- Lewis University
- University of Wisconsin
- Washington State & Elpaso Comm. College
- Serra High, UCSD and IFMA courses
- Colorado State University
- U of W
- San Jose City College, California
- U of AZ
- US Naval Academy
- Iona College
- San Jose State University; University of Phoenix
- Hagan School of Business @Iona College
- Ohio State University
- Cal Poly, SLO for my BS & Santa University for my MS
- West Virginia University
- University of California, Davis
- University of Washington
- Northwestern Business College

- MIT
- University of Houston
- TTC
- AFE
- Univ NC
- Ivy Tech State
- Soffolk University
- Western Montco Technical
- University of Wisconsin
- Tulsa Technology Center
- Cyprus High and BOMI Institute
- Purdue University
- Shoreline CC
- Community colleges, trade, union
- Eastern Michigan University
- GA Tech
- MSOE
- Utilities Equipment repairer course, U.S. Army
- College of DuPage
- University of Minnesota
- Cleveland State University
- John Carroll University
- BOMI
- Brandenburg University of Technology, Cottbus, Germany
- Lake Erie College
- University of Minnesota
- VA Tech
- UNL
- California Maritime Academy
- CSU
- BOMI
- Washington State University
- Tulane
- Oakland, BOMA & IREM
- Wilkes University
- University of Latvia
- several universities
- BOMI
- SUNY @ Buffalo
- VPI&SU
- Moraine valley
- University of Illinois / University of Iowa
- UCLA
- Delhi College of Engineering, New Delhi, India
- Rutgers
- Several Junior Colleges and Union Stationary Engineer
- DePaul University
- BOMI
- Saint Mary's University
- DePauw University
- esime
- ABC (Associated Builders and Contractors)
- University of Alberta, Canada
- Trinity University
- Northeastern University, Wharton School
- Madison Area Tech College
- George Mason University
- University of Tennessee
- NJIT & Kean University
- US COAST GUARD ACADEMY
- University of New Haven
- Ivy Tech
- Boston University
- University of Cincinnati
- Miami University, Oxford, OH
- University of Pittsburgh
- George Mason
- University of Utah Electrical Engineering
- SUNY
- University of California Irvine
- Pace University
- Dunwoody
- Phillips School of Business
- Calhoun College
- Albright College
- George Mason University
- SIU-C
- Wright Jr. College
- Kean University
- College of Du Page
- Minneapolis TVI
- Lehigh University
- North Carolina State University
- Long Beach State, Coastline college
- UMASS
- University of Wisconsin-Madison
- college - National College of Business
- Detroit Engineering Institute
- Wentworth Institute & Massachusetts Maritime Academy
- ITT Technical Institute
- Massachusetts Maritime Academy
- George Washington University
- Purdue University
- TUFTS
- Cerritos College, Cerritos, CA
- Pennsylvania College of Technology
- University of Phoenix
- na
- University of Colorado
- Loyola Marymount University
- University of Texas at Austin
- Linn Benton CC
- Computer Technical Institute
- Wayne State University, Michigan
- University of Colorado at Denver
- LaSalle University & Spring Garden College
- Iowa State University
- University of Illinois
- Univ. of Arizona
- SDSU and National University

- St Francis College
- AmericanRiver College
- P.S. 192
- BSc of Mechanical Engineer
- Anne Arundel Community College & various Technical
- ISU
- National Louis University
- California State University at Fullerton (CSUF)
- Oberlin College
- University of Dayton
- Texas A&M, Commerce Amberton University
- NNSAS
- SUNY Farmingdale
- Cambridge College Med in FM
- Colorado State -- USC
- Delgado College/ITT Tech
- Rider U
- TVA Power Production Training Center
- West Valley Comm College, SJS, Carpenters Apprentice Program
- Johnson County Community College
- University of Alabama
- Northeastern University / Worcester Polytechnic Institute
- University of Southern New Hampshire
- RATVI
- Gordon College
- Central Michigan University and Kennedy Western University
- IFMA
- Caldwell Collage
- Santa Rosa Junior College/ IFMA training
- University of Wisconsin-Stout
- Marywood College; University of Scranton
- Harrisburg Area Community College
- Lawrence Tech and Wayne State University
- US Air Force Academy and USC for MS
- Anoka Hennepin Tech
- Northeast Wisconsin Technical College
- Rider U.
- Northeastern Ill University
- University of Phoenix
- Eastfield College Mesquite Tx
- Consumnes River College
- Indiana University Northwest
- Purdue University Calumet

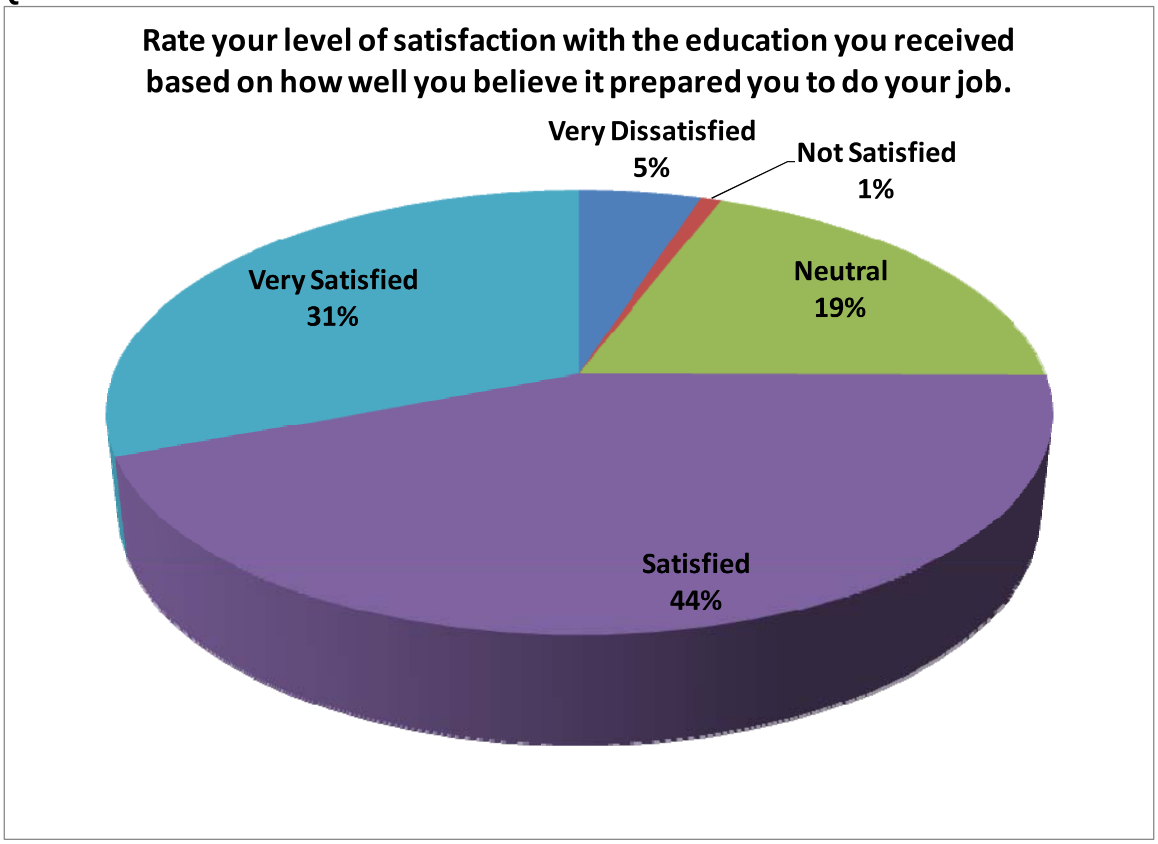
Question 19
What was your course of study or degree?

Of the courses of study listed, 12% are directly related to building operations and facilities management.

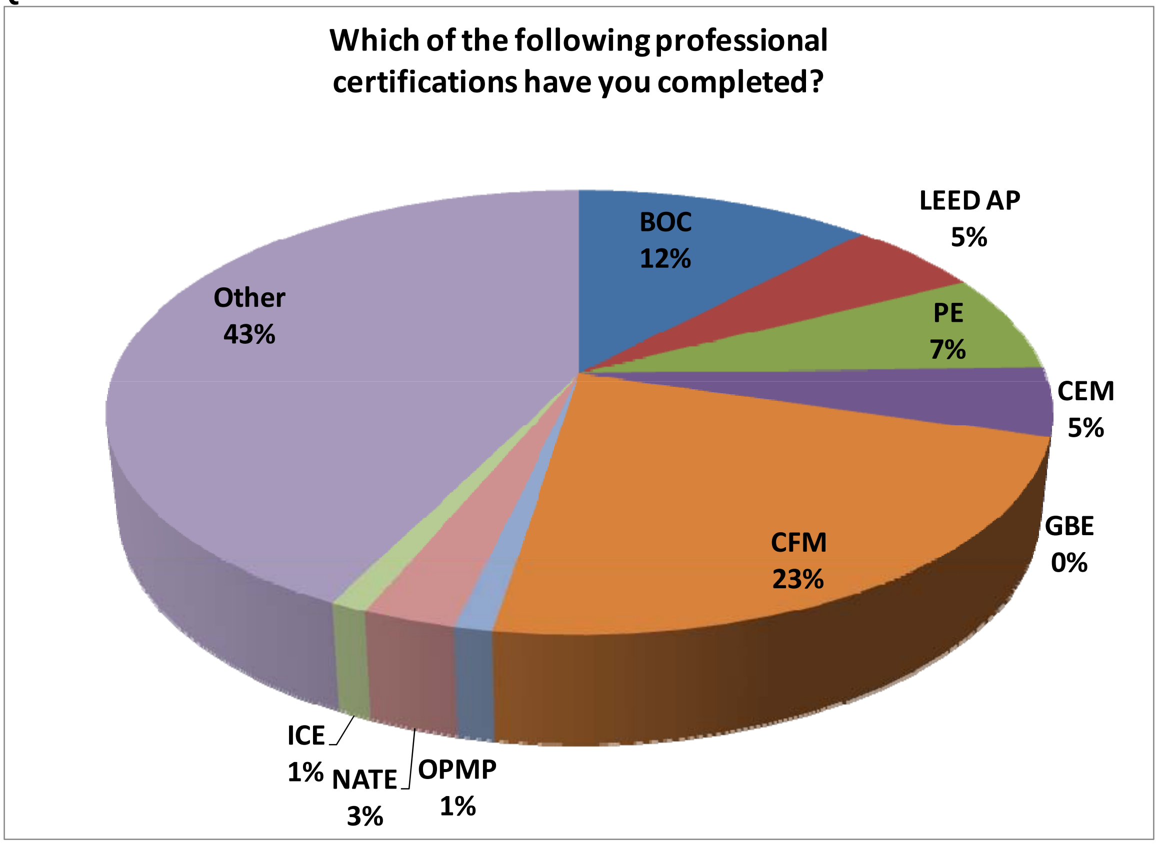
- Mechanical Engineering
- Business
- Business
- architecture
- Bachelor Degree
- Real Estate Appraisal
- Business - Marketing
- Management
- Psychology
- Religious Studies
- Mechanical Engineering Technology
- Industrial Education Human Relations and business
- engineering
- Communications
- construction Management
- Business
- Masters Facilities Management-No longer available
- facilities management
- Business Management/ Electronics
- Business Communications
- Instrumentation & Controls
- Real Estate and Const. Management
- Business
- B.S. Business Administration
- Industrial Electricity
- B.S. General Business
- Public Administration
- CFM Certification
- Electrical Engineering
- Certificate Program for Facility Design and Management
- communications
- Business and c
- Facilities operations
- HVAC
- Business Administration
- Facility Management
- Business Administration
- Industrial Technology
- HVAC
- Aircraft Technician
- Civil Engineering & Architecture
- BA Business Management
- Finance, project management, building inspection
- Business Administration/Psychology

- Retail, Marketing
- Business & Pre Law
- Architecture and Construction Management/ Urban and Regional Planning
- Assoc.
- Public Management and Engineering
- Industrial Technology
- Business Administration and Architecture
- Business Administration and Public Administration
- Management
- Horticulture
- Master of Science in Systems Management
- Psychology
- Facilities Management
- Business Admin
- Business
- BS Business Management
- BA in Fine arts and Teaching Credential
- Finance/Accounting
- Business Mgmt - Org Development
- Forestry
- FMP
- B.S. Applied Human Science
- HVAC & R, Mechanical Systems
- Arch & nConstr. Mgmt
- BS
- Business BBA
- Business Management; Organizational Management
- General Management
- Civil Engineering
- Industrial Engr & Engr Management
- B.S. Forestry
- Animal Science
- Facilities Management
- business administration
- Psychology and Sociology
- Associate in Supervisory Management
- Facilities Management
- Mechanical Engineering
- electrical engineering/business management
- BS ENGINEERING/MANAGEMENT
- Mechanical Engineering Technology
- HVAC/Plumbing
- Chemistry, History & Philosophy
- Business
- Mechanical Engineering
- BSBA
- AA business and art & design
- Facilities Management
- Engineering
- BSCE
- Interior Design
- Business Management
- Electrical Technology
- Business Administration
- BSME
- Civil Engineering
- Journalism
- business
- Computer Technician
- Business
- Bachelor of Science in Management
- Accounting & Engineering
- Industrial Technology
- Civil Engineering
- Lab Sciences
- Sociology and Human Resources
- BSME / MBA
- Community Economic Development
- Building UTILITIES Mechanic
- Business Admin
- BS in Business Administration
- Facilities Management Professional
- Management
- industrial education / CFM
- BS Industrial Technology...Plant Engineering
- Public Administration and English
- Business Administration
- Industrial Management
- Engineering Mechanics
- Building Utilities Tech
- Associate degree In Architectural Model Building
- BS Economics
- BS ED
- Business Management
- General studies
- Agriculture - engineering
- Business
- Construction Tech

Question 20


Rate your level of satisfaction with the education you received based on how well you believe it prepared you to do your job.
Very Dissatisfied
5%
Not Satisfied
1%
Neutral
19%
Very Satisfied
31%
Satisfied
44%

Question 21



Question 22
What career skills are you looking to enhance in the future?

- CEM
- Energy
- NONE
- LEED
- Building Automation knowledge
- I haven't given the matter any thought until now.
- Obtain Business degree
- Management Degree
- Mechanical or structural engineer degree
- Computer Skills
- Communication
- Sales training
- Project Costing, Life Cycle and ROI
- NATE CERTIFICATION
- Building commissioning
- Overall building knowledge
- LEED AP Certified & more building automation controls training.
- LEED Certification, BIM, fenestration, On-Site Renewable energy
- LEED and Six Sigma
- Planning and project management
- Energy Management.
- HVAC
- Basic knowledge on industry trends
- Global exposure and involvement
- Mechanical and HVAC
- PhD
- CEM CFM certifications
- CAD, Excel, Microsoft Project
- Trends for the industry
- Nearing retirement
- LEED certification and Indoor Air Quality
- Lean Manufacturing expertise
- Looking to be a LEED AP
- Environmental- air, land, water, energy, safety
- None
- Public Speaking and public relations skills to better tell others about all the good work we've done already.
- All
- CFM& LEED certification
- Real Estate
- Energy Management, engineering

- management
- Safety & Environmental
- None - I know too much already
- CEM
- More computer skills
- Energy and green
- Facilities Management certification
- Energy Related Accounting
- HVAC and building automation
- All of them
- Energy management and a professional property management or real estate designation
- HVAC Controls
- Completing my RPA
- LEED certification
- LEED / Energy Star
- More conversant on the LSC, NFPA 99, and other codes. Go after the AFE CPE certification
- Basic HVAC and Energy Management for the Property Manager
- LEED AP
- 1. LEED AP
- 2. Energy management/conservation training.
- Energy Audits, Commissioning (Cx)
- Facility Management
- Leadership
- Professional certification
- Continuing education & improvement
- Currently enrolled in University of Phoenix BA program for Hospital Administrator
- Looking to complete RPA (Real Property Administrator) and FM (Facility Manager)designations in 2010
- LEED
- BOMA
- Management Skills
- Energy efficiency
- Analytical skills as they relate to energy
- I am at a good point right now.
- Trading money futures, i.e. FX
- CPM Designation
- LEED Certified
- Get my CFM
- Real Estate and computer/software skills
- Facility Certification
- CFM
- Industry best practices, leaders in energy management for like companies, employee training to be Green at home and carry that to work
- Master -- MBA will complete 2011
- would like to find the time to obtain CFM cert
- FMP & CFM
- My knowledge of Energy savings and data
- Education
- Communication
- BOC Certification
- None
- CME and LEED AP+O&M
- Facilities Management
- Building automation
- I am working on BOMI Systems Maintenance Administrator Certification
- More to business and accounting. (sadly, this is what seems to be driving the industry)
- Retirement
- Obtain Certified Facility Manager from IFMA
- facility certification
- Management and Design
- what every class's that help in being green
- Energy Saving
- Leasing
- Any and all.
- Business skills, never enough
- knowledge of latest trends in energy and water management
- Property management, technology
- Going to retire within 18 months
- Masters of Business
- All that leads to CFM
- CMMS training
- Education related to the design, construction, and operations of high performance buildings.
- Not at the moment
- Would like to complete the IFMA training as soon as corp. funds are available again for education.
- IFMA Cert
- Sculpture
- Obtain My CFM
- Sustainability
- Organizational and Systems
- Facility Management
- Project Management and
- None right now
- IFMA Certification - CFM
- I am hoping to expound as a director of medical and research institutions.
- CFM
- Certifications ,education, IFMA contacts
- CFM certification
- Illinois Master electrician certification
- CFM
- Better HVAC knowledge.
- Obtain the CFM
- CFM - OSHPOD class A inspector
- Technical writing and presentations
- Organizational, Technological and

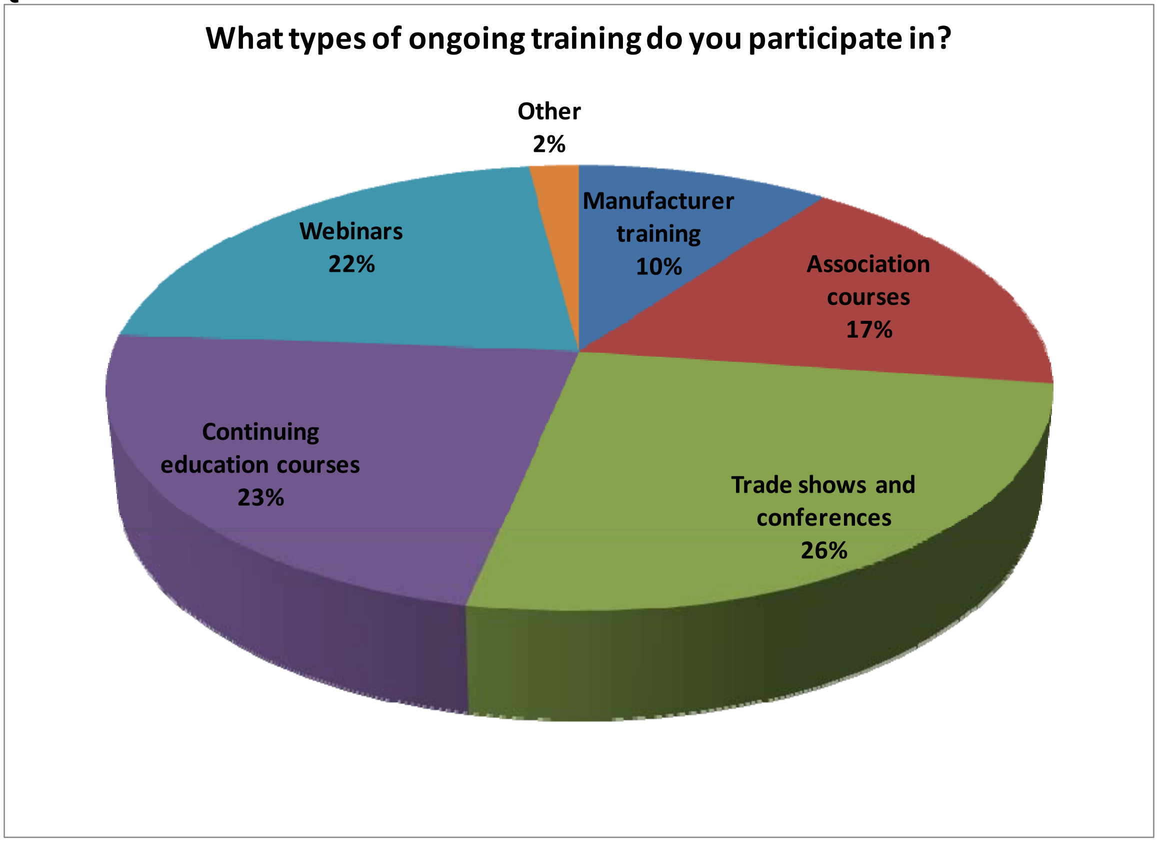
collection.

- Environmental and energy efficiency
- LEED Certification
- Management Skills
- General knowledge of HVAC systems
- Public Administration and Business Administration
- Technical. Management
- Technical Knowledge in HVAC, Electrical
- Ability to maintain employment until I retire in 2 years. I am involved in a PEER group of our IFMA Chapter for LEED and learning about LEED.

Financial

- Every skill could always be enhanced.
- Keep up-to-date with technology changes
- Project Management Professional
- SMA
- LEED AP
- Business side of energy management
- LEED Accreditation
- Facilities Management

Question 23



Other responses included:

- trade school
- union, AFE
- RPA
- Management Seminars
- On-site training
- IFMA programs; City Utilities info sessions
- UW classes in engineering
- IFMA MTGS
- IFMA sponsored programs
- College
- club won't support, pay
- In-house Mgmt training
- IFMA Chapter Meetings
- CFC Universal & BOC Level 2
- CPMM
- CHFM
- OSHA 30 Hr
- Ph.D.
- RPA
- QCxP
- SMA
- BOMI Master Facility Executive
- HVAC Journeyman
- CPM
- IFMA FMP
- RPA (BOMI)
- RPA
- RPA
- RPA
- RPA, FMA
- Co electrical License
- CPM
- RPA
- RPA
- BOMA RPA
- cpmm
- Master FacilityExecutive
- RPA,FMA --BOMI
- none
- FMP
- FMP
- SMA
- FMP
- FMP, IFMA
- RPA/BOMI
- RPA
- MPPM
- CERT, FEMA
- working on FMP
- IFMA
- CFMS, RPA, FMA, ACoM
- N/A

- FMA
- RPA, FMA
- BOMA RPA, FMA, SMA
- RPA
- AIA
- 1st Grade Engineer
- BOMI - RPA
- CPM(IREM)
- CHFM, Ashe
- RPA, FMA
- AIA, NCARB
- CPM & RPA
- CHFM
- SMT
- RPA, FMA, SMA
- cpm,rpa
- LDS Church FM Cert.
- RPA & FMA from BOMI
- LEED GA
- FMA
- Boiler Operations and Maintenance Level I (MTAA)
- FMA
- Master Facility Executive Certificate
- Working on CFM certification at the present time.
- FMP
- FMP
- CPE
- FMA,FMP,RPA
- FMA

Question 24
Where do you reside?

The survey covered a broad geographic distribution with a strong focus in North America. Approximately 96% of the people responded as residing in the United States, and 2% as residing in Canada. The top five states with the most respondents are as follows:

1) California
2) Illinois
3) Minnesota
4) Pennsylvania
5) Texas

The remaining 2% responded as residing in South America, Europe, Asia, or Australia.

Questions 25-28
For purposes of keeping survey respondents identities confidential, results for questions 25 through 28 are not included in this report.

Appendix B: Focus Groups

The focus groups were conducted in the San Francisco area to obtain additional insights on the data collected from the secondary and survey research. The focus groups allowed for delving into the issues, attitudes, and perhaps most important, experiences of individuals associated with building operations. They also allowed for discussion about the gaps and requirements for achieving high performance facilities, with the specific emphasis on energy efficiency. Objectives included:

- Obtain qualitative input regarding the current state of facility operations from those actively involved in these tasks.
- Develop an understanding of best practices and challenges from industry leaders.
- Identify where the biggest gaps exist in employee skills and gain input on how these gaps can be closed through training and education.
- Further explore findings from the online survey.

A total of four groups were conducted with participants gathered through professional recruiters and lists provided by Laney and BOMA. Each group lasted 90 minutes, with a total of 30 participants over the four groups.

Group	Location	Participants	Recruitment Method
1	BOMA Silicon Valley office	Combination of FM management and operators	BOMA members and recruits from the Silicon Valley area
2	Laney College	FM management and operators	Participants recruited through Laney contacts and recruiting
3	Laney College	Members of the Laney College ECT Advisory Committee	Participants invited by Laney College
4	Laney College	Current and former students at Laney ECT who work in facilities operations	Participants invited by Laney College

The focus groups represented a mix of small, mid-sized, and large organizations from a diverse cross section of industries, including:

A/C Heating and Cooling
ABM
Adobe Systems
Alameda County
Berkeley Repertory Theatre
CBRE
CPUC
Dionex Corporation
Ebay
Equity Office
Full Circle Architecture
Laney
Lawrence Livermore Lab
LBNL
Merilease Leasing Mgmt.
Nexant, Inc.
Penta Data Systems
Peralta
PG & E
Saratoga Management
Sartorius Stedim Biotech.
SBRGI
SF Bay COE
Summit Medical Center
Trane
UC-CIEE
University of CA-Berkeley

Focus Group Conclusions

- A number of myths exist in relation to building operations:
    - "Super Hero Theory" i.e. the belief by managers that a single individual with expertise in all types of building systems and technologies, business, and customer relations, is the answer to all their woes.
    - A perception by some within building operations that their department is at odds with sustainability initiatives.
    - Building operation isn't integral to achieving high performance buildings.
    - Building operators are unable to affect real change.
- No real standards or definition of what constitutes a "high performance building".
- Without any formal guidelines or education and training standards, many in this industry have no way of knowing whether they know what they need to know to operate high performance buildings.
- Belief that energy efficiency is all about the systems and not about what I do (i.e. "if only we had the money to buy new systems, our buildings would all be energy efficient").
- The addition of role playing, apprenticeships and online courses would enhance current educational programs.
- Very few, especially in the smaller organizations, have any formal training for FM and the majority fell into it by chance vs. design (participant backgrounds included writer, welder, woodworker, purchasing manager, petrochemical engineer, military, and accountant).
- Representatives of larger organizations are more likely to have training but it's as likely to be hands on vs. classroom.
- Money is perceived as the major inhibitor to achieving greater energy efficiency but comments indicate that lack of clear goals are as much or more to blame.
- Those with more sophisticated facilities feel they lack enough (or in some cases any) qualified personnel to operate them.
- Unions provide an outlet for training for their members but it's not easily accessible nor does it necessarily relate to the skills required for operating high performance buildings.
- Organizations that are deeply involved with sustainability such as Adobe and Ebay recognize the PR value it holds, while the smaller companies or those involved with leasing space (vs. owner-operators) are less able to realize or find a way to capitalize on these benefits.
- Lack of time and money are seen as the greatest barriers to energy efficiency but training also plays a critical role.
- It's becoming increasingly important for facilities operations personnel at all levels to have at least a basic proficiency or understanding of the following:
    - How buildings operate from a systems perspective
    - Impact of their individual actions on energy performance and sustainability initiatives
    - ROI/Economics
    - Basic computer literacy
    - Communications/Diplomacy
    - Troubleshooting

Key Findings

Note: quotations from participants are included where available to support the findings.

What Defines a High Performance Facility (in relation specifically to energy efficiency)?

Clear and measurable criteria is in place for defining what constitutes high performance for that facility and for assessing how well the building is performing against those criteria.

- *"Right now, we know our baseline from year to year-we use Energy Star—we have our own custom design real time monitoring system –similar -and Adobe has the same thing-called IVIS –it allows us to monitor our energy profile and demand and then also set baselines and determine the benefits of specific projects—and energy conservation projects based on the data—real time data"*

Continuous improvement through ongoing review of performance, preventive maintenance and constant attention to how well the building is performing

- *"We actually went out and hired an energy service that monitors all our energy –it is called MOCK energy –and so we get a report every day of our energy consumption."*

Integration of demand response, LEED with energy efficiency initiative such as demand response

- *"One of the things that all kinds of people have been saying is that there is LEED and then there's energy efficiency-and they are not necessarily the same thing, to me EE and LEED should line up."*

Integration of stakeholders (Architects and Engineers/IT/Operations/Occupants)

Zero net energy for some situations within a window of 10-20 years depending on location and other factors

- *"I think we should be shooting for no waste generation-I think this goes back to the zero net energy -we should not think of an infrastructure draw—we should think of it as an infrastructure surplus-these buildings should be supporting themselves—and generating more energy."*

Clear policies tied with incentives related to energy performance

- *"Carrots and sticks basically—incentives, and then regulations."*

Contributes to various aspects of the business, be it financial or otherwise

- *"I think all owners, CFOs, and presidents-every project-every sustainability project has to make financial sense. The ROI has to work; there are some small exceptions-if it makes good PR sense, marketing sense—but the bottom* *line, we are all here representing owners or shareholders or somebody who has an investment in the property."*

Buy-in from the top, often a result of their understanding of the marketing and PR benefits

- *"all the way to the top at ebay –they have a directive out through their troops, if you will, towards the sustainability mindset-and ideas and I think what they found is that it has a lot of great marketing impact for their shareholders and other investors in sustainable companies-and it is basically –it is a main focus."*

Feedback from prior experiences incorporated into design of new buildings

Impediments to Achieving High Performance Facilities

Not enough focus on the long term—necessity dictates that "putting out fires" takes up the bulk of time for organizations with limited resources.

- *"…With projects on energy management, unfortunately, they all looked good on paper—but in reality, they all drifted- I should not say all-maybe half of them drifted back to their original conditions over a period of five to ten years—because people would complain-and the technicians would go out with subtle little changes over a long period of time-and would get it back to where they would not get complaints and then you are not saving the energy."*

- *"We don't have time to really work on equipment like you should and that is where most of the bad conditions happen. everybody does everything and so you are responding to the emergencies, cold calls, water leaks—room is too hot-lights are out—a number of things."*

- *"It is more of an issue of put out the fire by the front door-that people see as they come in."*

Lack of knowledge among FM staff of the terminology, programs (i.e. several of the participants didn't know about Energy Star or LEED Existing Buildings) resources, tools, etc. that could be applied to reduce energy usage.

- *"and the biggest gap that I see right now being in conservation and operation-and now I am getting back in the conservation, is really having the real talent to maintain all of this now energy efficient high tech buildings-that is our biggest problem".*

Finding qualified personnel can be a challenge and some managers have lofty visions of the ideal employee (the "Superman Theory").

- *"we are having trouble recruiting the level of technical staff that we need in any event and I think that's a very common problem in this area—I have a lot of staff that have a lot of these skills, but don't necessarily have the combination (of skills)."*

- *"See, there are people who understand the engineering management system but not necessarily the mechanical system…or the chiller plant or the heating system –and so I won't need an expert in building automation-I want an expert in energy management system. I don't need a mechanical engineer. Can I have a combination of all of them? A little bit about everything but more than anything else –understands how this whole big system works together and also is a great communicator, has good people skills…"*

Operations personnel don't feel empowered.

- *"… often they (building operations personnel) just say-if anyone would listen to me-I could do it…and when you talk to them, they do know how their buildings work and they are just not given the resources or the ear to control things -and I know there is a lot of ignorance out there and I won't deny that but I think it's broader than that-that there is no ability for them to actually have an impact because there could be people making financial decisions above them who disregard their recommendations."*
- *"I think bureaucracy is such a huge thing trying to get through it, and so for me, as a stationary engineer where I am –to get to the person who is going to make a decision, is about five levels up and so…. I have to pull out it every so often and read the back-and it says nobody cares what you think—so put it away and continue on—just—continue fixing whatever is broken and go from there."*

What's in it for me?: without incentives or motivational programs in place, both employees and tenants may not be as involved as they could be in reducing energy usage.

- *"We have a lot of buildings-they are older and have been in the area and it is going to cost us billions of dollars to try to retrofit them and bring them up to the standards –but without the demand from the people who rent them…."*

Unions can be a disincentive to a systems approach.

- *"…there is no financial benefit for them to take five different guys who are learning five different trades and getting union dues from each of them and put them into one job-do you know what I am saying?"*

Not enough benchmarking or establishment of a baseline and for what constitutes "high performance" and for establishing organization-wide energy reduction goals. (This also ties in with the ability to reward or motivate employees and tenants.)

- *"I have questions-the first was this question of high performance-do the operators know what a high performance building is? Do people have any reason to feel that they should have high performance buildings-the words would be incentives, recognition, reward…"*

Especially in smaller organizations, outside vendors are responsible for many of the functions that directly impact energy performance, some more successfully than others.

- *"You get some of the maintenance contracts—the contractor might bid the maintenance for less time than it actually takes—hoping that when they get out there that they would make it up on the job."*

There's a lack of focus on continuing education and learning to accommodate changing requirements and technologies.

- *"I am from a union shop and our opportunities are very limited-we do not have a requirement for ongoing training and so it is kind of a different picture than what you are painting—if we want to go to San Francisco at 6 in the evening and take a class, we are welcome to do it—but there is nothing available locally and the main point I wanted to bring up is the engineers I work with –in probably the last 5 years have been happy to rebuild a pump, happy to paint, happy to work on an air conditioning system-don't make me sit down with a book in front of me-do not make me sit down with a book…."*

Systems aren't maintained or optimized.

- *"I am seeing the issue that stuff gets put in and then it doesn't get maintained—due to the cost of having a person qualified to work on it and so they are really trying to kill the maintenance—not kill it but slow it down and just get by with whatever is needed…"*

Different ownership models exist with their own unique issues and requirements making it difficult to prescribe a systematic approach for operations.

- *"a lot of times if you are –leasing out a whole building-to a single tenant –you don't have that same initiative because they are going to pay the energy bill-whereas if you have a full-service multi-tenant building where you are actually paying the energy bill, then you have some stake in it-so you have two different people looking at the same issue".*

Special types of buildings such as data centers, which use a tremendous amount of energy, are especially challenging.

- *"We have a data center-but we should be motivated to improve efficiency because we have a fixed amount of power and if we are using that for lighting and cooling then we can't plug in more servers-the more servers we have plugged in –the more money we make—so we should be motivated to improve efficiency and there are several ways to do that in our infrastructure but the return on investment and the projected profits—for the full data center-it keeps us from doing it-not only that-we have to be up for 24/7 –we can't be off for an hour or a day or any amount of time at all."*

- *"All the energy efficiency programs are all geared towards office buildings and with industrial buildings even though we have buildings that are 300,000 square feet—large huge expansive buildings that are still using the old lights that buzz and, you know, there is nothing that is really geared towards industrial."*

Buildings are often not being commissioned and systems aren't being maintained.

- *"I am seeing the issue that stuff gets put in and then it doesn't get maintained—due to the cost of having a person qualified to work on it and so* *they are really trying to kill the maintenance—not kill it but slow it down and just get by with whatever is needed-and being a nonprofit, they work for today and not for the long term."*

Fear of displacement and/or different perceptions.

- *"I have heard from a lot of operations people that they are concerned that they are going to be obsolete if they actually do high performance buildings because what do you need them for?"*

Perceptions of conflicting goals between departments.

- *"Operations and Sustainability-I see-frequently that those two are in direct conflict because the sustainability group or the energy people -their entire job is to save energy. And so the easy way to save energy is to crank your thermostat up to 78 in the summer-but the 10,000 people that work in my buildings will lynch me-you know-and you need someone at the top with the political will and the oomph- to say, okay, we are going to set those thermostats at 76 and make it stick and I don't care who you are and how important you are…"*

Old technology hampers efficiency efforts and lack of funds makes it difficult to invest in new technology.

- *"I think with some of the newer companies that build these buildings, they have a greater chance of implementing new programs and policies and building infrastructure it helps them out and they can get some money back from the city-it is a platform for them to use to talk about their company name and so it is a great benefit for newer people –we have a lot of buildings-they are older and have been in the area and it is going to cost us billions of dollars to try to retrofit them and bring them up to the standards…"*

Traditional ROI models aren't in sync with the longer term paybacks associated with certain technologies.

- *"As part of the economic collapse, we have seen –as a direct-mandate and probably everyone in this room has seen-hey let's do green-let's save some money-let's be energy efficient but we have no specific guidelines and we went to our ___ section and said, hey, let's –let's improve the cooling-let's increase the efficiency of the chillers-let's get more reliability, more reliable equipment in—and –after all these exercises….they said let's investigate this—and let's investigate that-we have specific groups-energy efficiency gurus-and they come out and they do the analysis and project the return on investment…and if we don't have a 2 ½ year payback we are not going to do it."*

Lack of financial or business awareness creates situations in which solutions are presented that don't make good business sense and/or aren't being presented to management in a way that demonstrates the positive impact they can have on the bottom line.

- *"A building operator might not talk in the same language as a CFO because the CFO only sees the financials."*

Lack of understanding of how one system affects another, and how each of them impact energy performance.

- *"There is a lack of a holistic picture of the building because there is no continuity between the design of the building and the program it is being used for and the way it is being maintained"*

Skills Required to Achieve High Performance Facilities

Because high performance buildings rely on a systemic approach to operations (e.g. what happens with one system affects another) it's critical that building operations personnel have an understanding of how these systems work together.

- *"It is finding that right character-that right person ---that has the technical background, that has the understanding that you can –not so much –having a mechanical engineering background, or electrical engineering background, but being able to understand building operations-not just to be so focused on one piece of the –or one aspect.."*

Building diagnostics.

- *"You can have the ability-not to have all the information on the performance units-but you can have training on some problems and by doing that you can check almost everything –that is going on the buildings—sensors and air flow…"*

Energy efficiency.

- *"We need a lot more about that-energy efficiency, not only on HVAC but involves construction, lighting, windows…"*

Knowledge of state and federal incentives and rebate programs.

Understanding of energy codes.

Data visualization capabilities (understand graphs, charts, etc…).

Basic knowledge of general architecture (baseline should be able to read drawings).

Networking and computer skills.

- *"The thing that I find myself doing more often than not is to sit down and train them on how to use Excel—one of the most important programs that I ever used-and with all the energy stuff—and anything—forms, Excel is one of the keys."*

Energy simulation tools and modeling (analysis and actions to take).

Knowledge acquisition skills: learning how to learn.

Know how to educate and communicate with occupants and management.

How to communicate with different entities (managers, tenants, vendors).

Customer service and listening skills.

PLC.

Retro-commissioning.

How to sell up.

Analysis of data including charts and graphs.

Problem solving and troubleshooting skills.

- *"Troubleshooting skills-and what I mean by that is have a person who has done a lot of critical thinking—and all of that –some individuals when it comes to-like Debbie said earlier-sometimes they know how to pull wire and all that but when there is a problem-they don't know how to –well, not only troubleshoot it but narrow it down."*

Financial language and thought processes, ROI.

A full understanding of how their actions impact energy performance.

- *"I will give you a data center example-where somebody the other day said that we want to wall off this data center and it will drop our energy use dramatically-and we said well it will –it will drop your energy use- but not as much as you think because you are not going to change your heat extract from your data center-you are going to move less air around it-that's all. They don't understand the fundamental concept."*

Recommendations for Education and Training Programs

Participants were given the opportunity to design their idea training and education program for building operations personnel, which revolved around the following:

- Course of study vs. disparate classes
- Include a Fieldwork component (vs. classroom only)
- Re-introduce apprenticeships
- Offer courses over the Internet
- Incorporate role playing for interacting with management and tenants (charm school)
- Offer opportunities to monitor different makes and models of systems
- Continuing education as a requirement
- Create an opportunity for peer to peer sharing via the web
- Provide a holistic perspective of how buildings operate
- Create a process that's shared with employees and employers for how to operate a high performance building
- Generate awareness of the benefits of training and education along with the advantages and importance of achieving energy efficient facilities

    - *"I have it as a course of study as well-on line portion and hands on training-I started with a preliminary energy efficiency understanding—how all these mechanical and automated pieces of equipment and overall building –how they work together-HVAC, plumbing, water treatment, for me specifically, particulate and humidity control how they all interact—and how to review them –how to get a full understanding of the building needs and then options for improvement and understanding within –as they relate to the upper level—you know –bringing in solar power, lighting, fire/safety and emergency preparedness and then lastly, very in depth course study on the mechanical and electrical requirements with respect to equipment"*

    - *I think the old fashion apprenticeship format actually works very well because you are taking the classes and the labs at night, but you are actually doing the actual work in real circumstances and I found that it was very different in the best lab in the world."*

    - *"I prefer-since I don't have time to traditionally walk into a class, I am going to jump on line and I am going to do it and there may be some real world stuff to follow up with - a lot of us smart people can really do it really quickly and really fast on the Internet."*

    - *"I think each of these courses should also have labs because I am more of a visual person and it helps me understand it better once I see it instead of just reading about it-and, of course, an internship would be the key-and, of course, the financial aspect..."*

Moderator's Guide

Building Operations Focus Group: Managers and Operators
Discussion Guide

Primary Objectives

1) Obtain qualitative input regarding the current state of facility operations from those actively involved in these tasks.
2) Identify where the biggest gaps exist in employee skills and gain input on how these gaps can be closed through training and education.

A. Introduction — 3 - 5 minutes

1) Thank you for coming in today (moderator introduces herself along with the others from Laney and BIG, and explains the role they'll play during the group).
2) Purpose of this session is to gather insight from individuals who are involved with the management or operations of commercial and institutional buildings to gain insight into current challenges and identify requirements for education and training associated with the operation of sustainable facilities. The input provided in this discussion will be combined with other research being conducted through a National Science Foundation grant to develop recommendations for improving education and training for future generations of building and facility operations technicians and professionals in order to achieve higher performing, more sustainable buildings.
3) We are interested in your opinions and experiences; there are no right or wrong answers. It's not just a discussion with me—you can talk to the entire group and get and give feedback from one another.
4) Equipment
5) We're audio taping the discussion so we have a good record of our conversation, but your individual comments will remain confidential
6) Tell me a little about yourself
   a) Name
   b) Where you work
   c) What your job is: # of facilities they maintain, # square feet,
   d) Something you like to do in your spare time

B. Viewpoints on Energy and Sustainability — 10 minutes

- As we all know, over the past couple of years, there has been lots of discussion and activity in government and industry regarding sustainability of commercial and institutional facilities. I want each of you to take a moment and write down what comes to mind when you he about this topic. Specifically, what are the emotions or feelings that first enter your brain when we talk about sustainability?
- What do you include under the heading of sustainability?
- Do you believe that commercial/institutional facilities play an important role in relation to this issue? Why or why not?

C. Sustainability within their organizations 25 minutes

- How big of a priority is sustainability in your organization?
    a. Why do you think it is or is not/what's driving this?
- Do you have specific goals for energy reduction or other sustainability measures and if so, what are they?
- Who is responsible for sustainability within your organization?
- For the remainder of the discussion, we're going to focus specifically on energy efficiency and carbon reduction. Who's responsible specifically for energy, carbon reduction, etc.
- Hand out list below: After it's completed, ask for show of hands of which are in place today and which are planned in the next 1-3 years for a few of the major ones.
    - Energy audits
    - Energy Star
    - LEED Certification
    - Energy benchmarking
    - Re-commissioning
    - Lighting retrofits, including re-lamping and lighting controls
    - HVAC equipment upgrade/replacement
    - Controls optimization/upgrades
    - Insulation improvement
    - Windows and doors replacement/improvement
    - Roofing replacement/improvement
    - On-site renewable energy
    - Metering and sub-metering
    - Demand response
        - How are each of these handled and by whom (position, outsourced, etc.)
        - How comfortable are you with each of these?
- (Ask them to turn over their sheet). In front of you is what we're going to call the "sustainability curve". Put an x where you feel you are today and an O where you feel you need to be.
    - For those of you with a gap: What are the main causes for this gap? (write on the white board)
    - For those of you with a narrow gap: Tell us how you got to where you are today?
- How satisfied are you with the energy efficiency of your buildings? What works well and what doesn't?
- How do you monitor and measure energy efficiency? Who's responsible for this?
- What are impediments to achieving more efficient facilities? (probe for the role employees play)

D. Employee Skills 15 minutes

Similar to the disclaimer associated with a car's EPA Rating, i.e. "*your fuel economy may vary,*" building performance varies tremendously depending on the skills, training, and tools available to the building engineer or operator.

- How well do the skills of you/your employees match up with the requirements of operating a sustainable facility?
- Put up list and ask for input on capabilities of employees in performing these functions and discuss gaps.

    - Building automation
    - Lighting controls
    - Mechanical systems
    - Electrical systems
    - Metering
    - Energy management (i.e. collecting, monitoring and/or acting on energy consumption data)
    - Security
    - Fire protection/Life safety
    - Water management
    - Emergency preparedness
    - Grounds maintenance
    - Roofing

F. Staffing and Training 15 minutes

- What are the credentials of you/your employees? (Schooling, training programs, certifications). Do you have specific hiring requirements in terms of credentials?
- What's your assessment of how well current educational programs prepare operations personnel for the workplace? (Probe for specific examples of what works and what doesn't. What should they know when they get out of school?)
- What types of issues do you face in recruiting or hiring operations employees? (look for demographic, retirement, recruiting, skills issues)
- As our last exercise, we're going to give you a new job title: Curriculum Designer. Tell us what the ideal building operations educational program would look like in order to operate sustainable facilities. What would be included as required courses that might not be there today, how would it be structured in terms of on the job training, etc. What skills will future employees have? Write down your ideas on the sheet in front of you. (go around room and ask for their ideas).

G. Conclusion 3 - 5 minutes

Thank you and goodbye.

Appendix C: Interviews

In-depth Interviews were conducted with representatives of organizations that are actively involved in education and training initiatives or are successfully managing or serving high performance facilities. Objectives of the interviews included:

- Obtain expert opinions and insights in trends, issues, challenges and solutions.
- Gain the perspective of experts from various geographic locations.
- Identify critical success factors.
- Solicit feedback on implications of previous research phases.

The following chart lists the interview participants and their organizations along with a synopsis of the major theme from each interview.

Interview Name	Organization	Major Theme
Brian Staszenski	Global Resource Efficiency Services	Need to raise awareness and provide tools if you want change to occur.
Charles Claar	IFMA Foundation	There's a great need at the technician and supervisory level for more training, and much of it can be done at 2-year programs.
Chuck Frost	UC Berkeley	Expertise requires going out into the field and getting experience with different systems and Equipment.
Angela Lewis	Penn State Center for Sustainability	You have to have buy-in from employees and involvement of FM at the design stage to achieve high performance facilities.
Jim Whalen	Boston Properties	The key to success is in tying all of the disciplines together: Asset management, FM, IT, PM/FM and Engineering--all have to work together.
Kathy Roper	Georgia Tech	Education and training programs combined with research of FM are critical in moving this industry forward.
Mark Levi	U.S. GSA	Technician skill sets in installing and running systems will need to increase as systems become more complex.
Paul Quinn	Duke Realty	Building occupants have more of an impact on energy savings than operations personnel.
Rob Pawliuk	University of Alberta	Today's technicians need to be technologically savvy. And, hands-on experience is essential.
Rebecca Ellis	Questions & Solutions Engineering	Organizations engaging in re-commissioning are generally those that already run buildings well.

Interview Summaries

Brian Staszenski
General Manager
Global Resource Efficiency Services

Brian is charged with overseeing the contract in place between Peralta Colleges and Chevron to institute energy management initiatives throughout the facilities. One of the main focuses of his organization is building occupant behavior modification: training staff, occupants, faculty and, especially, building operators. They would like to find opportunities to work with Laney (and other colleges) to incorporate aspects of their process for behavior modification into courses for building operations personnel.

Gaps he sees today with building operations include:

1. Typically, a building operator will run their buildings to the level of their current understanding and they're in a reaction mode. If the phone doesn't ring and there aren't known problems, they're doing a good job. What's missing is that they don't have written policies and standards of performance.
2. Proper documentation: Just finished the City of Vancouver and two of their connected buildings, and they didn't have any documentation. Also finished College of the Rockies. When they cost out the work, asked if they had CAD plans but found out that they only had open files for CAD plans not the actual plans.
3. For the hands on operator: Take a BAS system, they'll often go manual and tinker with the systems. Part of the documentation is to make sure they understand the standards. They should be able to understand the basic foundation and how set points work.
4. Must be able to read a CAD plan.
5. Always uses the paradigm: "If you want behavior modification to occur, you need to raise awareness and then [provide] the tools [necessary] to lead to long term action.

Charles Claar
Director of Academic Affairs
IFMA Foundation

Charlie is in the process of helping to rebuild a program initiated by IFMA in the 90's for accrediting facilities management programs at the college level. The accreditation requires a program to teach 6 or 7 of the competencies IFMA has identified (see www.ifmafoundation.org for list of competencies and of accredited organizations).

According to Charlie, they're really in their infancy with the community colleges. They're currently in the process of writing a standard for community colleges that will be done in the first quarter of 2010. There has been a struggle to get the academicians to accept that there's a need for community colleges to be doing the training. 25 to 33 percent of the people who get out of 4-year schools have non-technical degrees.

He believes that there's a great need at the technical and supervisory level for more education and much of it can be done at the 2-year level. Has had discussions with people from the National Energy Management Institute, which is funded by the unions, and they have a training center in Philadelphia thathas a great lab. They have some relationships with the community colleges but need more. He wants to work with them and get the community colleges into their standards. They think they need nine more credits so they can give people their associate degree. Would be mostly union people right now but perhaps that will change.

They haven't gotten to the skills piece yet. Feedback that they're getting is that all of the grads in the 4-year programs get hired and that all of the companies are happy. A weakness is the financial training. To be accredited, would expect them to be able to do simple payback and management and financial accounting.

Chuck Frost
Senior Facility Engineer ***Instructor***
UC Berkeley **Laney College**

The primary reason for interviewing Chuck was to follow up on our focus group discussion, which Chuck was a part of along with his boss at UC Berkeley, Sarah Shirazi. At the focus group, there was extensive discussion of the need for training individuals to be almost like superheroes who are experts at technology, interpersonal skills, finance, and more. Sarah pointed to Chuck as an example of such an individual, so we wanted to follow up with him and learn more about what makes him unique and how these traits might be replicated in others.

Chuck attributes much of his distinction as anüberFM to both number of years in the field and the type of training he received. Chuck started his career at Lawrence Livermore, which is very focused on training and sent him through a 2 year program at Laney that got him a job as an apprentice. He was an apprentice for 4 years, which equated to 8,000 hours of hands-on experience during which time he was paid 50% of journeyman scale. In Livermore, the belief was that it took 10 years to get a technician to the point where they're well rounded. In relation to his communication skills, these were acquired in a job he had which required him to work with both the facility designers and maintenance.

Chuck believes that obtaining expertise is a result of going out into the field and getting experience with the different systems and equipment and that what Laney is doing with its equipment lab might cut in half the time that it typically takes. A major benefit of the Lab is the hands on experience and the ability for the instructors to build in bugs that the students have to fix which simulate real life experiences.

Recommendations for Education and Training Programs:

- Consider an apprenticeship program for incoming students. Because of the low pay, this would most likely apply to younger students who are not yet in the workforce.
- There are different roles associated withoperating a building. You might have a maintenance worker who only needs to change the lights and that's good for them. Perhaps you can move them up and perhaps not, but if you teach everyone the information, then some of the students will utilize it.
- Understand forensics and how to utilize trend data (trying to focus on that more in his classes, and its benefits to you if you're an HVAC or a controls technician). It's critical to be able to sort through the trend data vs. just collecting it.
- Interpersonal communication course: learn about different personalities and how you have to not take things personally
    - Always dealing with customers and you need to keep them in the loop
    - Need to have good communication overall and with specific types of individuals

Angela Lewis
PhD Candidate, Architectural Engineering
Penn State Center for Sustainability

Description of Angela's Area of Study from the Penn State Website: *As energy costs rise and budgets tighten, reducing building operating costs become an increasing interest of facility managers and building owners. However, often organizational structure, time and corporate culture does not exist to allow facility managers and building owners to develop new theories, models and tools for the operation and maintenance of mechanical and control systems. The goal of the research is to develop a Building Operations and Performance Framework to guide and assist facility managers and building owners in planning, implementing and refining building performance and maintenance programs.*

Angela's research is focused on increasing building efficiency by providing facility operations personnel with the right tools to effectively utilize technology. Angela believes that we have very effective tools for maintenance and energy management but that these tools aren't being effectively used. There is interdependency between energy management and maintenance management. If you don't ensure that the operators maintain and know how to operate a system, it won't work. She was recently talking to a very experienced tech about variable speed drives who said that the operators are using them as "expensive disconnects to turn things on and off."

She believes that hands-on experience is critical. "You need a team of people and the team needs a skill set that understands mechanical and control systems and has had some hands on experience with the systems vs. just sitting in the classroom learning about theory, which is what's missing in the 4-year college."

Structure to Achieve High Performance Buildings:
It starts with having a good plan for energy and maintenance during renovation or building or before making improvements. You need to have real buy-in from employees and involvement of FM at the design stage.

Required Skills

- How to turn data into information.
- Variable speed drives.
- Maintenance management.
- Writing good control sequences (design engineers and controls contractors).
- Good understanding of mechanical systems with at least some hands-on knowledge.
- Basic understanding of Excel, generating bar and pie charts.
- General understanding of the types of meters and sensors available—new ASHRAE president talked about the role of existing buildings in reducing energy. To do this, you need a basic understanding of the importance of calibration.
- Understand how to set up a BAS system, i.e. need to look at how it will be used first, and then decide how to measure it.

Jim Whalen
Sr. VP, CIO
Boston Properties

In addition to being associated with one of the nation's largest offices -- REITs (Real Estate Investment Trust), with 36 million square feet and 1,500 tenants -- Jim is considered unique in this industry based on his dual focus on building operations and IT. Under Jim's leadership, the company has been very aggressive in instituting energy efficiency initiatives. Boston Properties is an example of a company that is applying both technology and process to achieve high performance buildings, and is enabling their operations personnel to play an important role in their success.

Boston Properties has hundreds of meters that are pushing out 3-5 minute increments on 70 percent of their buildings (main meters and sub-meters for the most part). They're using the data to be proactive-- to help change tenant behavior and understand how they're using their air, electricity, etc. The two critical issues are changing behaviors and changing components. The PM's and engineers are responsible for the data for each of the buildings.

They're very focused on Energy Star with their best buildings being in the upper 70's (started out in the 50's). They're currently going after best practices for example in data centers. One of their future plans is to have a targeted reduction goal on energy consumption. They are also highly committed to preventive maintenance, with an automated system that's created 90,000 orders. In 2003, the company invested in a network for the operations needs of the company which consists of hubs at the property tied in together.

Jim believes the key to success is in tying all of the disciplines together: Asset management, FM, IT, PM (their title for FM's), and engineering all have to be at the table, which many of their peers have been unable to do. The requirement is to get IT people working with and speaking the same vocabulary as engineers.

The COO is critical. Real estate has such a focus on the deal and operations and facilities plays second fiddle. So, being able to build solid business cases is essential. They're also fortunate to have many large single tenanted buildings where they can partner with the tenant to reduce energy usage. Having data to share is critical in these partnerships.

Required Skills

- Engineering and PM's need to know IT and networking concepts and vocabulary (more extensive for engineering but PM's need the understanding as well).
- Operational analysis—being able to manage buildings from an operational analysis standpoint will be key for facilities personnel. Today, only 10-20 percent of their employees are prepared when they enter the organization.
- Engaging and marketing skills are critical--there's a tension between service and response and the education piece.

Kathy Roper
Associate Professor
Georgia Tech

Kathy is an industry expert in the area of FM education. By her own account, prior to joining the faculty at Georgia Tech, she exemplified many of the FM's from a prior era. Her background was in Journalism, but she fell into FM. Her most recent job was with Sprint, where she was in charge of all of their facilities in the Southeast. Through her involvement with IFMA, she was working on a project with Georgia Tech to develop a new graduate level degree program -- an MS in Science in Integrated Facilities and Property Management -- when she decided to join their faculty.
Since she's been at Georgia Tech, she's been trying to instill that research and education are important parts of this industry. She's gotten to know a lot of people in the U.K., and they're more advanced in researching FM and putting together education and training programs to move the industry forward. In contrast, in this country people have come to it from a number of different areas: architecture, engineering, building mechanics, etc. As a result, she believe that "we've all been learning on the job and, at this point in the maturity of the industry, it's good we're looking at the progression of high school to technical school to fieldwork. The education isn't cohesive at this point…"

In the past, FM's have been the ones who advocated for more maintenance, and financial people didn't see the payback. Now, they're seeing that the payback is faster as energy costs go up, or it's a green initiative. Energy is the big ticket and is catching on. Thinks it's small now, but will become more prevalent in 3-5 years as they recognize that the energy savings come from how the facilities are operated. "As the questions are asked, we're becoming more recognized -- now people are caring."

Required Skills

- Computer skills—how to operate the automated and integrated systems.
- Communications: FM people have to have customer service skills so that the tech that replaces an air valve also needs to be able to relate to the tenants.
- Even for technicians, it would be helpful to understand that everything has a cost tradeoff. Need to understand simple costing.
- Thinks it will be critical that low level people have a complete understanding of the systems. Education at all levels is critical, not just at the top. You can have the smartest person design the system, but then the junior people go in and make changes that don't maximize the systems. Even the users need training.
- Apprenticeships are essential but there isn't a lot of this going on. Catch 22 because a lot of their students are working already. At the undergraduate level, it would be great. Industry doesn't understand how to link back and many organizations don't understand the value. If there were a framework for what an FM apprentice would do, a lot of companies could benefit from it. Has had a great program with GSA with their management trainees.
- Finding qualified personnel is a problem. They're going to ASHRAE and the few community colleges that they have. There's a huge gap at the technician level. Don't have a program that teaches an integrated level.

Mark Levi
Energy Program Manager
GSA Pacific Rim Region

GSA is one of the largest real estate organizations in the world, with management of over 8,300 public and private buildings. As part of GSA's Energy and Water Conservation Program, Mark serves as a resource for GSA facilities in the Pacific Coast to provide information and recommend programs that reduce utility costs and energy and water usage. The majority of their buildings qualify for Energy Star and LEED has become a requirement for new facilities.

Mark has seen many issues in relation to the capabilities of the personnel for building controls contractors. Many of the control systems require programming and this is beyond the capabilities of many of their technicians. Another issue is systems integration. Controls companies can handle putting in their own system but once you start sharing the systems, they don't have the networking skills they need. Because the installation isn't right, you end up with problems with operations where systems are un-programmed.

Ironically, Mark has found that the newer buildings in his region are performing worse than the old buildings. This has to do with bad controls and the fact that the envelopes on the new buildings now have a lot of glazing. As a result, the older ones tend to perform better. Once the buildings are built, they are doing retro-commissioning and get improvements, but they contract out maintenance and he feels many of the people doing the work aren't very good. A lot of them override the controls.

GSA is currently in the process of instituting an advanced metering program which will provide much needed data on the buildings. They've also seen success with workstation-specific lighting. Mark believes the key to high performance buildings includes:

- Utility type services on demand: Lighting sensors, workstation lighting.
- Envelope issue will have to be addressed.
- Technician skill sets will have to increase both to run and install systems as they become more complex.
- Will need strong facilities engineering organizations that can manage the process (even if you outsource you need internal people).
- Need to make decisions on what to standardize on and what not to standardize on.
- Require a monitoring system and then need someone to look at the data from a central location – either a good technician or an engineer.

Required Skills:

- IT skills need to go up to keep the controls working (both from installation and operations—at all levels).
- More conceptual knowledge of HVAC. For example, need to not only understand how to do maintenance or repair of a motor but also how the system works so that if you change the pressure setpoint, you know the impact.
- Ultimately will need to get to the point where they're running diagnostics and tying them to maintenance.

Paul Quinn

Strategic Execution Officer
Duke Realty

Duke Realty is one of the largest commercial real estate companies in the U.S. with 750 buildings in their portfolio and 250 building technicians in their employment. Duke has three sub-groups related to sustainability: New Construction, Operations (of the buildings they manage) and Corporate Operations (corporate headquarters). As the Strategic Execution Officer, he essentially owns all issues related to sustainability, including energy efficiency. They've embarked on a plan to figure out, from a maintenance standpoint, whether they're doing everything they can to save energy. They're looking at how the maintenance group is organized as well as how it dispatches work in addition to other factors.

Duke has come up with an Energy Star score for every building. They have broken that population into 4 groups based on the scores: Group 1 is 75 or higher; 70-75 had maintenance folks go in and see how they could get there through minor changes; 20 points or below (energy dogs) sent out the maintenance folks to see what was going on from a data center, or a 24-hour call center etc.; the last group is 20—70 and they're not doing anything with that group yet. It's tough to raise the scores. In the newer buildings (within 3 years) they have metering so they publish on a quarterly basis and publish it to property mgmt and maintenance to see if the building is running efficiently. They also put together a training program to teach simple things like looking for where the peak is vs. where it should be. They did find a few brand new buildings with a peak at 7 am in the morning because they were starting it up too early.

In terms of technology, they've standardized on Tridium's Niagra and now have 40 buildings on that system. They haven't implemented much in the area of renewable energy due to the cost, and are only sub-metering on buildings built in the past 2-3 years. They're also saving energy indirectly since they know that the least energy sustainable thing to do is to put someone in a truck for an alarm, and with the Niagra system, all 40 of the alarms go to the central location and they dispatch it with a priority so they're rolling fewer trucks. HVAC is the low-hanging fruit. They've had a hard time justifying any cost savings on an existing building for lighting. Have a living lab in his office where they've tried all sorts of things, LED, Occupancy controlled, etc. but it's been tough to prove the savings. "If you have a really old building, you can justify it. But under 10, it's difficult."

For the calendar year 2008, calculated the company's carbon footprint so they could see where they were. On the energy side, reduced it down to tons of carbon, and on the corporate side, reduced it down to tons of carbon per employee. They hired a consultant to do it the first time but don't see value in doing it again. Better to focus on Energy Star since it has marketing value and it can demonstrate operating costs.

They rely on the senior operations managers who have 15+ years in operations and came up from a technical level to interact with tenants and management, analyze call histories, do budgeting and work hand with the property managers to reduce energy usage. "One of the challenges in (investor-owned) office buildings is that the investor doesn't reap the rewards. If the tenant is willing to help finance the costs, we're happy to do it. The occupant has more of an impact then the operator. If they run their building 18 hours, it costs more to run. We try to do the research and then talk to the tenants. My experience is that tenants aren't going to be open to this discussion unless it's obvious that there are savings."

One thing he'd love to see from the industry, not from the vendors, are case studies for putting in, for example, LED lights and breaking it down by hours, operations, etc. It could be: here's an ROI, here's how it's succeeded. Students could even get involved with this.

In terms of skills, ROI is critical. "We had an operations manager in DC who said he was going to replace MR16 bulbs and said the payback was less than a year while the bulb was $40 so obviously their methodology wasn't rigorous enough. They must know how to do the ROI calculation."

Robert Pawliuk
Operations Manager
University of Alberta

University of Alberta is one of the top research universities in the world, with over 37,000 students and nearly a million square feet of buildings. Rob is responsible for managing a staff of 20 employees who handle the day-to-day operations of the school. He has been actively involved with both design and operations for over 20 years.

Because they both own and operate their facilities, Rob feels they're more conscientious and accountable for how their buildings operate, although funding is definitely an issue. They currently have over $1 billion of deferred maintenance on their buildings, so they could be operating better. Five years ago, they made a decision to switch from proprietary to commercial systems and have 5 preferred vendors that are allowed to provide controls in the building. They have recently begun using Tridium to monitor those buildings.

In 1975, they started an energy management program, recognizing that energy was an issue. Over the last several years, have had an energy avoidance of over $200 million, tracked based on the original metrics (heating, cooling, lighting retrofits). In terms of structure, if Capital Projects are involved in a new project, he is in all of the meetings. However, once projects are underway, there are not enough people in his department go around to make sure that they're representing the energy efficiency viewpoint. His senior building operators are involved during construction to do the commissioning of construction so they learn how the building functions. They have an energy management group in their engineering department, which is becoming the Office of Sustainability. As they get more into metering, the sustainability office will look at the data and then will pass it along to him. In the future, he would like to be able to see the data on a real-time basis.

Currently, they hire a lot of their operations staff from the Northern Alberta School of Technology and they're coming with a refrigeration background or HVAC technicians, while some have a design background.

Required Skills:

- Need more qualified workers (shortage in their area).
- The new technician today, if he gets a call that someone is too hot or too cold, he should be getting on the laptop.
- The older guys are electricians, plumbers, HVAC techs. They're hiring the same types today but they need to understand IT. Ideally, should be training them more on building control systems. They're learning the basics of a DDC system: basic programming—either graphic or line; more of an operational training—some sort of practicum, almost a crossover into the power engineering training.
- Need an apprenticeship program—he would train and then hire them. The program that's closest is called the Building Environmental Technology Systems program. "They have a lab set up and they give them exposure. It's not enough though. They need real-life experience of having an occupant hot and needing to solve their problem."
- How to deal with occupants.

Rebecca Ellis, PE, LEED AP, CCP, CxA
President
Questions & Solutions Engineering

Ms. Ellis is a nationally recognized leader in the commissioning industry. She has helped define mainstream commissioning services and is a much sought-after speaker, author, and trainer. Ms. Ellis has written a monthly column about commissioning for Engineered Systems magazine for more than nine years. Prior to founding Questions & Solutions Engineering, she developed and led the largest commissioning service group in the country.

Ms. Ellis has 20 years of experience engineering and managing a variety of HVAC system projects. Ms. Ellis is a specialist in the design, analysis, and commissioning of intricate temperature and humidity control systems, with a particular strength in direct digital controls. She has extensive experience in the design and analysis of museum, laboratory, and animal research facility HVAC systems. She has also been active in performing energy conservation studies, proposals, and designs, and applies that expertise to all new and renovation HVAC design projects.

The majority of Ms. Ellis' HVAC engineering has been for renovations, often in occupied buildings, where the confines of existing and often unknown conditions constrain the design and installation of new systems. This experience has resulted in a keen appreciation of the need for close coordination between all parties involved in a design and construction project.

Based on her extensive commissioning experience, Ms. Ellis makes the following observations:

- Energy savings generally range from 5to 20 percent for both new and existing buildings.
- Savings on new buildings that are not commissioned in the first place can be very high.
- The most frequent causes of degradation of system performance are the following:
    - Sensors are out of calibration.
    - Outside air dampers do not properly function.
    - They are often stuck in an open position or shut off.
    - Air-flow measuring stations for outdoor air and/or supply/return do not operate properly and/or are out of calibration.
    - Lack of training of operations staff combined with discomfort with controls results in manual override of items that are not well understood.
- People engaging in re-commissioning are those that manage buildings well to begin with, resulting in relatively smaller savings.
    - In Ms. Ellis' experience, well-managed buildings where re-commissioning is performed have been exclusively managed by outside property management firms.

Appendix D: Notable Buildings Exhibiting System and Technology Trends

Building	Systems or Technologies	Radiant h/c	Chilled beams	Evaporative cooling	DOAS	Natural ventilation	Lighting controls	Active façade	On-site renewable	Cogeneration	Integrated systems	Notes
New York Times ***New York, New York***	 						●	●		●		Achieves significant energy savings with advanced dimming lighting controls.
Manitoba Hydro ***Winnipeg, Manitoba, Canada***		●				●		●				Incorporates natural ventilation, radiant cooling, and a double active facade in a large-scale building.

Building	Systems or Technologies	Radiant h/c	Chilled beams	Evaporative cooling	DOAS	Natural ventilation	Lighting controls	Active façade	On-site renewable	Cogeneration	Integrated systems	Notes
Loyola University Klarchek Information Commons ***Chicago, Illinois***		●				●	●	●			●	Incorporates radiant cooling as well as natural ventilation, and the active double façade utilizes automatic shading.
250 South Wacker ***Chicago, Illinois***			●		●							Substantial retrofit to an existing building incorporated active chilled beams, upgraded building envelope, and converted existing AHUs to DOAS units. Same staff runs the building-post renovation.

Building	Systems or Technologies	Radiant h/c	Chilled beams	Evaporative cooling	DOAS	Natural ventilation	Lighting controls	Active façade	On-site renewable	Cogeneration	Integrated systems	Notes
Great River Energy ***Maple Grove, Minnesota***							●		●			Applies dimming (daylight harvesting) lighting controls, limited LED lighting, on-site wind power.
Wal-Mart Supercenter ***Las Vegas, Nevada***		●		●	●		●				●	Uses 45% less energy than the baseline Supercenter, employing LED lighting, advanced lighting controls and daylight harvesting, indirect evaporative cooling, heat recovery, and radiant cooling.

Appendix E: Cogeneration System Examples

Project (with Link)	System Information And Additional Links
District Energy Saint Paul	Success Stories
Duquesne University	Energy & Operations
EPA Region 9 Laboratory	Cogeneration at Work
New York Times Building	Environmentally Sustainable Towers in Manhattan Gather Heat from Power Generators
University of New Mexico	UNM Utilities UNM Cuts Energy Usage 13.4%, Reduces Utility Spending by $2.4 Million

Appendix F: Key Resources

Resource (with Link)	Additional Links
AIA The American Institute of Architects	Integrated Practice / Integrated Project Delivery
ASE Alliance to Save Energy	Energy Policy
ASHRAE American Society of Heating, Ventilation, Air-Conditioning and Refrigeration Engineers	
BOMA Building Owners and Managers Association International	
BOMI Building Owners and Managers Institute International	
California Energy Commission	Research, Development, and Demonstration
DRRC Demand Response Research Center	
EPRI Electric Power Research Institute	
FacilitiesNet	
FERC Federal Energy Regulatory Commission	
IFMA International Facility Management Association	
LBNL Lawrence Berkeley National Laboratory	
OASIS Organization for the Advancement of Structured Information Standards	
NSF National Science Foundation	Advanced Technological Education (ATE)
NIST National Institute of Standards and Technology	Smart Grid
NREL	
NYSERDA New York State Energy Research and Development Authority	
CBE UC Berkeley Center for the Built Environment	
U.S. DOE U.S. Department of Energy	
U.S. EIA U.S. Energy Information Administration	Annual Energy Outlook CBECS
U.S. EPA U.S. Environmental Protection Agency	Energy Star
USGBC U.S. Green Building Council	
WBCSD World Business Council for Sustainable Development	
WBDG Whole Building Design Guide	

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