IMPACT OF ASHRAE STANDARD 189.1-2009 ON BUILDING ENERGY EFFICIENCY AND PERFORMANCE

by

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Abstract

The purpose of this report is to provide an introduction to the new ASHRAE Standard 189.1-2009, Standard for the Design of High-Performance Green Buildings. The report will include an overview of the standard to detail what the purpose, scope and requirements for high-performance buildings will be. The entire standard will be overviewed, but the focus of this paper is in the areas of energy efficiency and building performance. Next, the report will examine further impacts that the standard will have on the building design and construction industry. Chapter 3 includes the impact on other standards, specification writing and coordination of the design and construction teams. A case study of an office building is performed to compare a baseline building meeting ASHRAE Standard 90.1 to a building meeting the minimum standards of ASHRAE Standard 189.1. The case study compares the total annual energy use of the two projects to determine an expected energy savings. Based on this information, recommendations about the new standard will be discussed. Universities and government entities should require ASHRAE Standard 189.1 for new construction projects, to show willingness to provide sustainability in buildings. Finally, conclusions about how the standard will change and impact industry will be addressed. These conclusions will include issues with adopting ASHRAE Standard 189.1 as code as well as discussion on the LEED rating system.

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Chapter 1 - Introduction

In the building construction industry, design is governed by codes and standards. These codes and standards dictate the way engineers design buildings. It is important for designers to understand each of the codes that they will use every day in industry. Some deal with the health, safety and welfare of the occupants, while others focus on energy use in buildings. Codes and standards can be divided into three broad groups: life safety codes, health codes and energy codes.

First and foremost are the codes and standards that deal with life safety factors. For example, the NFPA 70 (National Fire Protection Agency), also called the NEC (National Electric Code), contains requirements for electrical systems to prevent fires originating in the electrical system and injury-causing accidents from poorly designed electrical systems. The ASCE 7-05 standard (American Society of Civil Engineers), titled Minimum Design Loads for Buildings and Other Structures, dictates minimum design loads to ensure that the structural system will withstand the various loads it will be subjected to. These types of codes and standards are the basis of design, and are written to protect the lives of the building occupants. A well-designed building should keep the occupants safe; a structure should remain standing and electrical distribution equipment should not explode.

Other standards are necessary for the health of the occupants but are not as immediately apparent, because the effects of not complying develop more slowly. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) publishes ASHRAE Standard 62.1, which deals with Ventilation for Acceptable Indoor Air Quality. Rooms used to store chemicals and other harmful materials must be ventilated to keep the contaminated air from entering an occupied space. All equipment that moves air must have some sort of filtration to remove particulate from the airstream. Additionally, outdoor air must be introduced to the space at rates based on the number of people and the square footage of the area served. If these conditions are not met, it can cause health problems for the occupants. The results of failure to comply with standards like these seem less than the first codes mentioned, but are still just as important.

The last grouping of codes and standards is those that do not directly impact the health, safety and welfare of the building occupants. These include energy codes. One such standard, ASHRAE Standard 90.1, gives a guideline for a building's energy performance, which includes equipment efficiencies, lighting power densities and insulation requirements for building envelope. Another code is the International Energy Conservation Code (IECC). This is very similar to ASHRAE Standard 90.1, but is published as part of the International Code series. These three general groups of codes dictate the minimum requirements that engineers design buildings to.

Codes are constantly being examined and updated by their publishing societies as technology changes and the industry evolves. Most codes are on three year reviews, meaning that a new version of the standard is released every three years with any vital changes that come mid-cycle being issued as addendums. However, a majority of our design codes do not see sweeping changes every review cycle. When it comes to the health, safety and welfare of the occupants of a building, there are certain legal, ethical and professional requirements that must be met. Codes and standards that provide necessary design criteria do not see major changes very often.

The major exception to this trend is the area of energy codes and green design standards. Beginning in the 1970s with the United States energy crisis, the topic of energy savings has become more important to every manufacturer, building owner and engineering society. One of the first energy codes, published in 1975, was ASHRAE Standard 90.1, and it had a huge influence on the building design industry. The standard, however, only provided minimum requirements for energy efficiency for commercial buildings.

As a result of the sustainable design effort, a system to compare the "greenness" and energy savings of different buildings was developed. Thus, the LEED (Leadership in Energy and Environmental Design) green building rating system was created. The USGBC (United States Green Building Council) was formed in 1993, with the first version of LEED published in 1998. LEED greatly affected the design of energy efficient buildings as well, although it is intended to be an optional compliance system.

The latest green standard is the new ASHRAE Standard 189.1-2009, Standard for the Design of High-Performance Green Buildings, developed as a collaborative effort by ASHRAE, the USGBC, the American National Standards Institute (ANSI) and the Illuminating Engineering

Society of North America (IESNA). Some might wonder why ASHRAE Standard 189.1 was needed, when there are already energy codes in use today. The main reason is simply because ASHRAE Standard 189.1 goes beyond other energy codes in that it also provides minimums for performance for sustainable buildings. ASHRAE Standard 189.1 defines a high-performance green building as a building designed, constructed and capable of being operated in a manner that increases environmental performance and economic value over time, seeks to establish an indoor environment that supports the health of the occupants, and enhances satisfaction and productivity of occupants through integration of environmentally preferable building materials and water-efficient and energy-efficient systems (Standard 189.1, 2009). Never before has there been a code or standard in the design and construction industry that provides minimum requirements for the performance of a building. The only way for the standard to provide requirements for building operation is by requiring the development of plans for operation. These plans will allow the performance of the building to be influenced by code (Ferzacca, VanGeem, & Lawrence, 2010). This will prove to be revolutionary to the building construction industry as the standard gains support and recognition. It will also greatly impact the way that the design team looks at sustainable building. This document is written in code language, and is so worded for jurisdictions to adopt as code. If the trend of new energy or green building standards holds true, ASHRAE Standard 189.l will have as much of an impact on the building construction industry as LEED and ASHRAE Standard 90.1 have had.

The goal of this paper is to introduce the new standard and examine the potential impact that it will have on the industry. The scope of this paper is the impact of the standard on energy efficiency and building performance. While there will be impacts on other portions of the industry, the energy efficiency and performance portions of the standard will have the most substantial impacts. This paper will provide an overview of ASHRAE Standard 189.1 in order for the reader to become familiar with the requirements of the standard. The paper will then examine several impacts on the building design and construction industry and follow up with a case study discussing the energy use of a baseline building versus a high-performance green building meeting the requirements of ASHRAE Standard 189.1. These results will be used to provide recommendations for the use of the standard.

Chapter 2 - ASHRAE Standard 189.1 Overview

ASHRAE Standard 189.1 was published on January 22, 2010 (Dean, 2010). Since it has been in publication for less than a year, it will be beneficial to walk through the standard in substantial detail, to give the reader some idea of what the various sections entail. The purpose of this chapter is to examine the requirements of each chapter in ASHRAE Standard 189.1. The code is organized similarly to other ASHRAE standards, with the purpose and scope outlined at the front, definitions of terms after, and then the major sections of the standard.

The standard then breaks down into six major sections: site sustainability; water use efficiency; energy efficiency; indoor environmental quality; the building's impact on the atmosphere, materials, and resources; and construction and plans for operation. Each of these sections contains mandatory provisions which are required for all buildings and then requirements found in two compliance paths: prescriptive and performance options. In order to meet the minimum requirements of ASHRAE Standard 189.1, a building must comply with all of the mandatory provisions and then all the provisions of either the prescriptive or the performance path. This chapter will walk through each of the sections of ASHRAE Standard 189.1 in some detail so the reader has a good look at what the standard requires to better understand how it will impact the building design and construction industry. Since the scope of this paper is to examine the impact of ASHRAE Standard 189.1 on energy efficiency and building performance, this chapter will examine the sections of the standard that pertain to these topics and briefly discuss the requirements of the remaining sections of the standard.

Purpose, Scope and Definitions

The purpose of all ASHRAE standards is to define the intention of the standard. As per ASHRAE Standard 189.1, Chapter 1:

> *The purpose of this standard is to provide minimum requirements for the siting, design, construction, and plan for operation of high-performance green buildings to: balance environmental responsibility, resource efficiency, occupant comfort and well being, and community sensitivity; and support the goal of development*

that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Standard 189.1, 2009, p. 3)

Essentially, this sets up the standard to be a “green” standard. This means that ASHRAE is trying to provide a minimum baseline for high-performance buildings to be energy efficient, sustainable, and environmentally responsible.

The scope dictates what the code applies to, what projects it does not pertain to, and what it covers. Chapter 2 of ASHRAE Standard 189.1 states that the standard only applies to new buildings, and new systems, whether they are in new or existing buildings. It applies to all buildings except residential buildings that are less than three stories in height and buildings that do not use electricity, fuels or water. The standard is not intended to allow a designer to circumvent any health, safety, welfare or environmental requirements (Standard 189.1, 2009). If there is a conflict regarding the safety of the building occupants, the building design must comply with the associated code.

The definitions section contains all the terms that are specific to ASHRAE Standard 189.1, and contains a provision that definitions in codes or standards that it references shall be defined as they are in those standards. Some of the terms that are defined provide clarifications for what the standard actually expects. Others give examples and diagrams explaining various sections’ requirements.

Site Sustainability

Chapter 5 of the standard, which is titled site sustainability, deals with all aspects of a building site. A high-performance building must include provisions for making the entire project sustainable, both the building itself and the site that contains the building. This chapter of Standard 189.1 provides requirements to meet this goal. These site sustainability requirements greatly impact the design and selection of the site for high-performance buildings. The time spent selecting and laying out the site is increased in order to meet the mandatory requirements. The architect or designer doing the work on the site must carefully consider all aspects of ASHRAE Standard 189.1 before making a final decision. The site selection and development is much more complicated with requirements for a high-performance building. For example, light pollution has become a more prevalent problem, with the dark sky movement gaining more attention. The International Dark-Sky Association is the leading society on reducing light pollution. Their mission statement is to preserve and protect the nighttime environment through environmentally responsible outdoor lighting (IDA, "Mission", 2010). Light manufacturers are making it easier on designers in producing and documenting light fixtures that will meet the backlight, uplight and glare (BUG) ratings required by ASHRAE Standard 189.1.

Mandatory Provisions

There are three main sections in the mandatory requirements: site selection, mitigation of heat island effect, and reduction of light pollution.

Site Selection [5.3.1]

Site selection gives specific restrictions on where/what a building site can be, and how it can be developed (Standard 189.1, 2009). An existing building renovation, a site classified as contaminated or as "brownfield", or a site with more than 20% of the total area previously developed to be impervious ("greyfield") are not restricted. A site with 20% or less of the total area having been previously developed with impervious surfaces ("greenfield") is restricted in several ways. These include being within a half mile of developed residential land, being within a half mile of at least ten (10) basic services, and being within a half mile of a rail public transportation system. This requirement is designed to encourage pedestrian activity in the area around the site (Floyd, Lawrence, & VanGeem, 2010). The main push in site selection is to utilize a previously developed site or a site that is already in the funding or planning stage of development. Anything outside this realm must meet the more stringent requirements of a "greenfield" site. Agricultural and forest lands are specifically marked as exceptions. By ASHRAE Standard 189.1, these areas are to be avoided, unless the building's purpose is related to the use of the land. Development of the site is also limited based on FEMA's 100 year flood plain, in that no development at an elevation lower than five (5) feet above that plain is allowed.

Heat Island Effect [5.3.2]

The heat island effect is the phenomena that urban areas tend to have higher ambient temperatures than the surrounding rural areas. This is simply because concrete and metal structures hold more heat than more natural materials. Since most cityscapes are primarily paving materials and metal, they retain more heat than a rural landscape. This heat is released throughout the day and into the night, making urban areas much warmer. The second goal of the site sustainability section is to lessen the effects of this tendency (Standard 189.1, 2009). Fifty percent of the site hardscape (parking lots, roads, sidewalks) is required to be provided with some way to decrease the appearance of heat island. Options for this include: providing shade from buildings, structures or trees and vegetation; utilizing paving materials with a certain solar reflectance index value; or providing parking beneath a building.

Above-grade walls are also required to meet specific shading criteria. A percentage of the east and west walls must be shaded by trees, vegetation, buildings, hillsides, or other structures. This requirement only applies to the first twenty (20) feet of a wall above grade level, since it would be difficult to shade the upper stories of a high-rise building.

The final major part of heat island contributors is the roofs of structures. The standard here calls for a majority of the roof to have a specified solar reflectance index rating or to comply with the Environmental Protection Agency's ENERGY STAR requirements. This applies to the total area of the roof, except for renewable energy systems and green roof systems.

Light Pollution [5.3.3]

The third mandatory requirement under site sustainability is for exterior lighting systems. ASHRAE Standard 189.1 dictates that the minimum level of design for energy use in exterior lighting systems is the requirements from ASHRAE Standard 90.1. The remaining requirements are for light pollution. This light pollution relates to the backlight, uplight and glare (BUG) ratings of the specified fixtures. These ratings help eliminate light trespass from the site to adjoining properties. The definitions section includes lighting zones that identify what type of activity or on what location a building site will be. These range from undeveloped areas in rural land, LZ0, to highly active commercial centers, LZ4. The BUG rating system was introduced by the IESNA as part of Technical Memorandum TM-15-07, Luminaire Classification System for Outdoor Luminaires. The classification system replaced the previously accepted cutoff classifications (IDA, "Specifier", 2009). The actual rating relates to the amount of light allowed in the corresponding lighting zone. For example, a B1 rated fixture allows an amount of backlight that can only be used in lighting zone one (LZ1). The rating system requires manufacturers to classify their products in the three categories. Manufacturers are not required to classify all of their fixtures; which is the case for many of the current fixtures because they do not qualify due to poor performance. Because of this, they cannot be installed per ASHRAE

Standard 189.1. Tables 5.3.3.2A, 5.3.3.2B and 5.3.3.3 in the site sustainability section provide maximum BUG ratings, maximum glare ratings for building-mounted luminaires, and maximum percentages of uplight for each different lighting zone. The three tables are recreated as Table 2.1 shown below (Standard 189.1, 2009).

Table 2-1 Light Pollution Requirements

Maximum Allowable BUG Ratings						
		LZ0	LZ1	LZ2	LZ3	LZ4
Backlight Ratings	More than 2 mounting heights from property line	B0	B1	B2	B3	B4
	1 to 2 mounting heights from property line	B0	B1	B2	B3	B3
	0.5 to 1 mounting heights from property line	B0	B0	B1	B2	B2
	Less than 0.5 mounting heights from property line	B0	B0	B0	B1	B2
Allowed Uplight Rating		U0	U1	U2	U3	U4
Allowed Glare Rating		G0	G1	G2	G3	G4

Maximum Allowable Glare Ratings for Building Mounted Luminaires					
	LZ0	LZ1	LZ2	LZ3	LZ4
Within 2 mounting heights from property line	G0	G0	G1	G1	G2

Maximum Allowable Percentage of Uplight					
	LZ0	LZ1	LZ2	LZ3	LZ4
Percentage of total lumens allowed to be emitted above 90° from nadir (straight down)	0%	0%	1%	2%	5%

ASHRAE Standard for the Design of High-Performance Green Buildings, Standard 189.1-2009, Chapter 5, p. 16, 2010. © American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org. This table is based on information found in ASHRAE Standard 189.1.

Uplighting structures, facades or landscaping are allowed in some degree, depending on the light zone in question. Other exceptions include specialty lighting, such as: transportation lighting, advertising, theatrical purposes, athletic playing areas and theme elements.

Prescriptive/Performance Options

With the mandatory requirements all met, the design team must then choose either the prescriptive or the performance option and follow that path. The prescriptive option provides more criteria for site development. Per the requirements, almost half of the site must contain measures to limit the amount of runoff from the site. These measures could include vegetation, green roofing or porous walking surfaces. Further requirements for greenfield sites involve percentages of the total site area that have native or adapted vegetation. These requirements directly relate to the amount of rainwater or runoff from the site. The exceptions to the prescriptive path deal with rainwater capture and retention or the average amount of rainfall received per year.

The performance option gives strict criteria for the amount of rainfall to be managed through infiltration, reuse or evapotranspiration, depending on the type of site, whether it is a brownfield, greenfield or greyfield site. Evapotranspiration combines the movement of water from evaporation and plant transpiration (Standard 189.1, 2009).

Water Use Efficiency

Chapter 6 of ASHRAE Standard 189.1 is the water use efficiency section. It contains detailed requirements for both site and building systems that use potable or non-potable water. This section is aimed at drastically reducing the total amount of water used by the building and on the building site. Buildings account for 13% of the total water consumption in the United States (Standard 189.1, 2009). With this usage, there is great potential for reduction in use. This standard provides requirements that will greatly affect the design of buildings in the area of water-consuming fixtures and appliances. The total reduction, by following the criteria of this section, can be around 40% of the annual use compared to a baseline value. This savings is obtained from the case study in Chapter 4. The building usage reduction is detailed further in Chapter 4 of this report.

Mandatory Provisions

The mandatory requirements include site water use reduction, building water use reduction and water consumption measurement.

Site Water Use [6.3.1]

Site water use essentially deals with irrigation of landscaped areas. The first design criterion is that a majority of the developed landscape be native or adapted plant life rather than turfgrass, which is a grass that is mowed on a regular basis. Exceptions to this are athletic fields (baseball, football, golf courses and driving ranges, etc) which need to be mowed regularly.

Another requirement is in the design of the irrigation system. Sprinkler locations and the directions they are aimed have a few specific constraints in that they must be three feet from a building and they cannot spray water directly onto the building. Some level of "hydrozoning," providing different amounts of water to different areas or different types of plant life, is required. Controls for irrigation systems must also be labeled as "smart controllers" and be capable of adjusting the amount of water supplied depending on various factors. These factors include evapotranspiration rates, weather data, and soil moisture content. These are all geared toward reducing the amount of water used and the amount of water required by the site.

Building Water Use [6.3.2]

The next section is that of building water use. This is divided into four major areas where the building uses water: plumbing fixtures, appliances, HVAC systems and roofs. Almost every type of plumbing fixture or fitting is listed in this section, with limitations to the amount of water that each is allowed to consume. Most of these listed are also required to meet certain American Society of Mechanical Engineers (ASME) standards. Table 6.3.2.1 in Standard 189.1 lists various types of fixtures and fittings with the allowable amounts of water consumed (Standard 189.1, 2009). The table contains both commercial and residential fixtures.

Table 2-2 Plumbing Fixtures and Fittings Requirements

TABLE 6.3.2.1 Plumbing Fixtures and Fittings Requirements

Plumbing Fixture	Maximum
Water closets (toilets)—flushometer valve type	Single flush volume of 1.28 gal (4.8 L)
Water closets (toilets)—flushometer valve type	Effective dual flush volume of 1.28 gal (4.8 L)
Water closets (toilets)—tank-type	Single flush volume of 1.28 gal (4.8 L)
Water closets (toilets)—tank-type	Effective dual flush volume of 1.28 gal (4.8 L)
Urinals	Flush volume 0.5 gal (1.9 L)
Public lavatory faucets	Flow rate—0.5 gpm (1.9 L/min)
Public metering self-closing faucet	0.25 gal (1.0 L) per metering cycle
Residential bathroom lavatory sink faucets	Flow rate—1.5 gpm (5.7 L/min)
Residential kitchen faucets	Flow rate— 2.2 gpm (8.3 L/min)
Residential showerheads	Flow rate—2.0 gpm (7.6 L/min)
Residential shower compartment (stall) in *dwelling units* and **guest rooms**	Flow rate from all shower outlets total of 2.0 gpm (7.6 L/min)

ASHRAE Standard for the Design of High-Performance Green Buildings, Standard 189.1-2009, Chapter 6, p. 19, 2010. © American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org.

Appliances that use water, which include both residential style clothes washers and dishwashers, are required to be ENERGY STAR rated and have a maximum water factor, which is the amount of water used in a typical cycle. The ENERGY STAR rating has several ramifications that should be noted. Dishwashers use 20% less energy and minimize water use; clothes washers use 30% less energy and 50% less water use when compared to a non-ENERGY STAR rated appliance (ENERGY STAR, 2008). This can add up to significant water savings in these applications.

Other systems that use water as part of the building include heating and air-conditioning systems. In heating, ventilating and air-conditioning (HVAC) systems, once-through cooling, the process of passing potable water through a heat exchanger and discharging it to a drain, is prohibited. The water discharged in the process of once-through cooling can have severe environmental impact (Koeller & Hammack, 2010). Cooling towers and evaporative coolers have specific requirements to monitor the amount of water that they consume. This information will be used for further requirements discussed in the building operations plan section, 10.3.2.1. Air conditioning units larger than 65,000 Btu/h must have systems to reclaim the condensate from the cooling coils.

Roof spray systems used to condition the roof with potable water are also prohibited. Potable water is simply water provided from public drinking water systems or freshwater sources that meet standards for drinking water. A sustainable water system, such as a rainwater reclamation system or a grey water recycling system, can be used to provide water to a roof spray system. If a green roof is to be installed, the irrigation system cannot use potable water after the plant life has been established.

Water Consumption Management [6.3.3]

The final mandatory provision is water consumption management. This section details several requirements for a measurement system. The system must be capable of measuring the volume of potable and reclaimed water used in the building. It also must provide the ability to sub-meter the usage, if there are multiple tenant spaces in the building. The system must then store the data and be able to create reports to monitor the usage of water throughout the building. These reports will be used to ensure that the building operations plan is met.

Prescriptive Option

The prescriptive option provides requirements for three areas: site water use reduction, building water use reduction and special water features. The designer chooses between the requirements of this option and that of the performance option.

Site Water Use [6.4.1]

For site water, only one third of all other landscaped area can be irrigated with potable water; the rest must come from alternate on-site water technologies. Golf courses and driving ranges must use municipally reclaimed water, if available, or other on-site sources (rain water reclamation, grey water retention, condensate recovery, etc) for all irrigation.

Building Water Use [6.4.2]

Building water use addresses the use of cooling towers, commercial food service equipment and medical/laboratory facilities. Cooling towers have requirements based on the makeup water hardness levels. This hardness deals with the amount of calcium and other minerals present in the water. These minerals will separate from the water and deposit in the equipment and piping. This can drastically reduce the efficiency of the cooling tower. Different pieces of commercial kitchen equipment are listed with restrictions on the volume of water they consume at full operational modes. This equipment includes dishwashers, food steamers and combination ovens. Infrared or motion sensing automatic control of faucets for food preparation and washing sinks is also required. Medical and laboratory facilities have a list of several requirements, which generally require using water-efficient equipment or dry-type equipment in lieu of typical water-consuming equipment.

Special Water Features [6.4.3]

The special water features section contains requirements for ornamental fountains and pools. Fountains must use municipally reclaimed water or on-site water sources, utilize makeup water meters, have leak detection devices, and be capable of filtering and treating water to reuse in the system. Pools must have the capability to recover backwash water for use in irrigation systems or to be treated and reused for the pool. The filters must also be reusable. If a design team chooses to follow the prescriptive path, both the mandatory and all these prescriptive requirements must be met.

Performance Option

The performance option dictates how much water reduction is required. For the site, 35% water reduction of the total demand is required. The total demand is based on several factors, including the climate and the square footage of different types of vegetation. For building water use, the total annual water use must be less than or equal to the total use that would have been attained if the prescriptive option were met. Since the designer must calculate the water savings of the prescriptive option in order to meet the performance option, the question arises as to why a designer would ever choose to follow the requirements of the performance option. A situation could occur where a designer wants to use a specific water feature, but cannot use an on-site water reclamation system. Under the prescriptive path, the designer could not do this. With the performance path, this is allowed, as long as the designer makes up for the extra water consumption with savings in other areas.

Energy Efficiency

Chapter 7 of ASHRAE Standard 189.1 is titled Energy Efficiency. The purpose of this section is to provide minimum energy efficiencies, requirements for on-site renewable energy systems, and criteria for energy measuring. Buildings in the United States consume 40% of the total annual energy usage (Standard 189.1, 2009). The requirements of this section provide ways to reduce the total energy demand to attain a high-performance building.

Mandatory Provisions

The mandatory provisions are fairly straightforward. The overarching main requirement is that the building must meet the mandatory provisions of the following sections of ASHRAE Standard 90.1: building envelope, HVAC, service water heating, power, lighting and other equipment. The second mandatory provision is that the project shall make provisions for future on-site renewable energy capable of providing 3.7 W/sf, based on the total roof area. The design must provide all required space, pathways and associated rough-ins for the installation of the system. This requirement for future on-site renewable energy systems is roughly based on a typical photovoltaic panel. Most panels today provide 8 to 10 watts per square foot at peak capacity (Kennedy, VanGeem, Lawrence, & Lord, 2010). The final mandatory requirement is energy consumption management. This section details specific requirements for a measurement system for all energy sources to the building (electricity, natural gas, etc). These requirements are very similar to those for water consumption management. Energy data must be recorded and stored in order to assess building performance on at least a monthly basis.

Prescriptive Option

The prescriptive option immediately provides a clarification statement. Any requirement of the prescriptive path supersedes those in ASHRAE Standard 90.1, if the two are conflicting. The prescriptive path gives specific requirements that go above and beyond those in ASHRAE Standard 90.1.

On-Site Renewable Energy Systems [7.4.1.1]

The first requirement is for on-site renewable energy systems. Some examples of these are photovoltaic systems, wind harvesting, or solar water heating. The mandatory provision is for future expansion, but the system in the prescriptive option is to be installed during the construction process. This required system must provide a total of 6,000 Btu per square foot of conditioned space annually.

Building Envelope [7.4.2]

The next section deals with the building envelope. Appendix A of ASHRAE Standard 189.1 lists requirements for envelope and for roof insulation, which supersede the requirements of ASHRAE Standard 90.1. Criteria for windows and vestibules are also given, with specific direction on how the wording of ASHRAE Standard 90.1 is to be changed. The building is also required to be constructed with a continuous air barrier, which simply means that limits are set for air leakage rates. The rates vary based on how the measurements are taken. During design conditions (summer at ±100° or winter at ±0°), infiltrated air, which is outdoor air introduced to the space through leakage, not by design, can significantly increase the space load and the load seen by the conditioning system. Reducing the amount of infiltration can greatly reduce the amount of energy required by the mechanical system.

Systems [7.4.3-7.4.8]

ASHRAE Standard 189.1 next contains requirements for the various systems that consume energy in a building project. The first system detailed is the HVAC system. These HVAC requirements (equipment efficiencies, ventilation controls, duct leakage, economizers, fan system power, controls, energy recovery, variable speed control, duct and pipe insulation) are the same as those addressed in ASHRAE Standard 90.1. Appendix C in ASHRAE Standard 189.1 provides modifications to the requirements for equipment efficiencies given in ASHRAE Standard 90.1. The efficiency ratings in ASHRAE Standard 189.1 are higher for all types of equipment listed. Other tables in ASHRAE Standard 189.1 provide stricter requirements for the various parts of the HVAC systems.

Service water heating has a few changes from the requirements of ASHRAE Standard 90.1 in both efficiency and in insulation for piping and spa pools. Tables are provided that give minimum efficiencies for different types of water heaters and maximum standby losses for storage tanks.

Lighting requirements differ from ASHRAE Standard 90.1 as well. The total lighting power allowance from ASHRAE Standard 189.1 is required to be 10% lower than the total attained from the ASHRAE Standard 90.1 calculations. Occupancy controls and daylight controls have similar requirements to ASHRAE Standard 90.1. Building security or emergency egress lighting is limited to 0.1 W/sf if those areas need to be continuously illuminated. Outdoor lighting control must be capable of reducing the power consumed by 50% during unoccupied hours, in addition to the requirements of automatic control.

The power requirements of ASHRAE Standard 90.1 remain the same in ASHRAE Standard 189.1, but one requirement is added. This requirement states that the building shall contain an automatic system to reduce the peak electrical demand by at least 10% of the projected peak demand. The Other Equipment section adds two requirements, compared to ASHRAE Standard 90.1. The electric motor requirements are nearly the same between the two standards. Supermarket heat recovery from condenser heat rejection is required by ASHRAE Standard 189.1. The other additional requirement is for ENERGY STAR rated equipment. ASHRAE Standard 189.1 includes an extensive list of all equipment that is required to be rated.

The final section of the prescriptive option simply states that the energy cost budget method from ASHRAE Standard 90.1 may not be used. To comply with the energy cost budget method in ASHRAE Standard 90.1, the designer must meet all the mandatory provisions and then use either the prescriptive path or the energy cost budget method. This method requires that the building in question prove that it will use less energy than a baseline designed building. While this method proves that a building will use less energy, it is not permitted as a compliance path for ASHRAE Standard 189.1.

Performance Option

The performance method has three main sections. The first is annual energy cost. This essentially says that the total annual energy cost for the building must be less than or equal to a building that meets all the requirements of the prescriptive option. The comparison must be made using the guidelines from Appendix D, Performance Option for Energy Efficiency. The second section is the annual carbon dioxide equivalent. This requirement states that the annual carbon dioxide equivalent (CO2e) must be less than or equal to a building meeting the requirements from the prescriptive path. The final requirement is worded the same as the first two, only the comparison must be made between the peak electric demand of the two compliance paths.

Most designers will already be trying to provide a building owner with an energy efficient and sustainable design in compliance with locally adopted codes. ASHRAE Standard 189.1 takes the design to the next level with the requirements for energy use. The envelope itself does not consume any energy, but is included in this chapter anyway. The building envelope requirements are aimed at reducing the load seen by the HVAC system. This will in turn reduce the energy consumed by the heating and cooling equipment. The increase in the design criteria for the envelope is fairly significant when compared to current industry standards. The HVAC system must be more efficient than a typical mechanical system from an efficiency rating standpoint. The requirements for energy use, from lighting to mechanical systems, are quite an increase over the norm of ASHRAE Standard 90.1. The actual lighting fixtures are not required to be more efficient; however, the design team must be more efficient in how they design the lighting system. The actual amount of savings for an ASHRAE Standard 189.1 compliant building will be examined in more detail with the case study in Chapter 4.

Indoor Environmental Quality (IEQ)

Chapter 8 of ASHRAE Standard 189.1 details requirements for all aspects of indoor environmental quality. Indoor environmental quality can have a huge impact on human health. This section of ASHRAE Standard 189.1 has less of an impact on energy efficiency, but more so in the area of high-performance. Indoor air quality, thermal comfort, and daylighting can have huge influences on worker productivity. These factors can also influence some energy use. If a building occupant is not thermally comfortable, they might adjust a thermostat or open a window and increase the load on the HVAC system. Less daylighting means that an occupant will use artificial lighting. These requirements force a designer to give more thought to how their final product will impact the owner and occupants. These include indoor air quality, outdoor air flows, thermal environmental quality and daylighting.

The indoor environmental quality section is the first main section dealing with the performance of the building. With this emphasis on performance, there is a lower stress on energy efficiency in this section. The daylighting requirements for indoor environmental quality call for more windows and skylights than a typical building. This translates into a higher load on the HVAC equipment. The increase in energy consumption by the mechanical system will not be offset by the decrease in electricity usage in the lighting system. However, it is important to remember that ASHRAE Standard 189.1 is not only an energy standard; it is a high-performance green building standard.

Mandatory Provisions

The mandatory provisions cover five broad areas, which are indoor air quality, thermal environmental conditions, acoustical control, daylighting and building isolation. To meet the indoor air quality provisions, the building is required to comply with ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality, with some modifications or additions. The design outdoor air rates in occupied spaces must be at least the value attained from ASHRAE Standard 62.1. The design outdoor air flow rate must also be monitored, with the capability to notify the operations and maintenance staff if the value for the total system falls below the minimum outdoor air rate. This section also details minimum filtration values for outside air. Restrictions are placed on where building occupants can smoke in relation to building entrances, windows and air intakes. All building entrances are required to have an entry mat system to increase the quality of the indoor air, with specific requirements detailed in the standard.

The thermal environmental conditions of the building must comply with sections 6.1, Design and 6.2, Documentation of ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy. To comply with ASHRAE Standard 55, the mechanical, control and envelope systems must be designed to maintain design space conditions within a specified range (Standard 55, 2004). These conditions include ambient temperature, humidity, air speed and other factors relating to the occupants' thermal comfort.

The next section details requirements of acoustical control, for both interior and exterior sound. If a building is near expressways, airports or areas exceeding annual averages of 65 decibels at the property line, the windows and walls of the building are required to have certain Sound Transmission Class (STC) ratings. Depending on the adjacent room occupancies, different interior walls are required to have specific STC ratings for acoustic isolation.

Daylighting by toplighting is the next section. This gives provisions for the use of skylights. Minimum areas of skylights and amount of direct sunlight from the skylights are the two major criteria that must be met. At least 50% of the floor area with a lighting power density greater than 0.5 W/sf must be in the daylight zone. Without getting into the mathematical equations used to determine what constitutes a daylight zone, the definition of a daylighting zone is the area beneath a skylight that is in direct sunlight at some point throughout the day (Standard 189.1, 2009).

The final mandatory requirement deals with the isolation of the building from pollutants in the soil. This relates back to the selection of the site with brownfield sites or areas with probable high radon content. Over time, high concentrations of pollutants in the site can work their way into the building unless proper steps are taken to isolate the foundation of the structure from the soil. This isolation is typically provided by some sort of semi-permeable barrier adjacent to the foundation wall below grade.

Prescriptive Option

The prescriptive option deals with two main topics: daylighting by sidelighting and building materials. The daylighting requirements provide minimum areas of sidelighting, depending on climate zone. Sidelighting is simply daylight introduced to the interior of the building via windows in the building walls. The next requirement deals with shading in an office space. The sidelighting must be equipped with some way to shade the building occupant from direct sunlight. This can be done with either interior or exterior shading and must be permanent. The amount of shading is given in terms of a projection factor. This factor deals with the shading from interior and exterior building projections and how they relate to one another in terms of height.

The building material section deals specifically with the interior space. All materials must be verified by a third party for volatile organic compound (VOC) content. Specific materials listed include paints, coatings, flooring materials, composite woods, office furniture, and ceiling and wall systems. Each of these is required to meet some criteria or standard. These standards include the CA/DHS/EHLB/R-174, which is commonly referred to as California Section 01350, and SCAQMD (South Coast Air Quality Management District) standards. The materials listed must be tested to be in accordance with these standards. These standards contain limits for the amounts of emissions based on tests performed on the various materials.

Performance Option

The performance option contains the same two major sections as the prescriptive path, daylighting and materials. Daylighting for the performance option requires a simulation to prove that 30 footcandles of illuminance is reached in 75% of the total daylight zones and that direct sunlight is not on a work surface for more than 20% of normally occupied hours. These can be done with a computer simulation or an accurate physical model.

The materials section requires that the emissions for a list of materials used within the building be modeled for their individual VOC concentrations. These include flooring materials, carpeting, wall coverings, rigid panels, insulation products, adhesives, sealants, paints, cabinets and office furniture systems. The amount of VOC's that are present in the building must be totaled and proven to be less than the amount that would have been obtained from the prescriptive option. This is similar to the scenario in the water efficiency section, where the designer must calculate the results of the prescriptive option, in order to meet the performance option. Deviations from the requirements of the prescriptive option must be made up in other areas, so that the total VOC concentrations in the building do not exceed a safe level.

The Building's Impact on the Atmosphere, Materials, and Resources

Chapter 9 of ASHRAE Standard 189.1 contains requirements for the whole building's impact on the atmosphere, materials, and resources. The Environmental Protection Agency (EPA) estimates that building construction debris in the United States makes up 26% of all non-industrial waste (Cross, VanGeem, & Horn, 2010). The resources that a building is constructed with can greatly affect the ability of a designer to meet the requirements of this standard, depending on how the materials are gathered and transported.

Mandatory Provisions

The requirements of the mandatory provisions include construction waste management, material manufacturing, refrigerants, collection of recyclables, and reduced impact materials. The mandatory provisions for construction waste management include diversion and total waste. The process of diversion requires that at least half of non-hazardous construction waste be diverted from disposal to recycling. The total waste section provides limitations on the amount of waste in pounds generated per building floor area. The restrictions on the amount of waste produced only apply to new construction.

The extracting, harvesting and manufacturing section requires that each of these processes follow the individual laws and regulations of the country of origin. It also dictates that, unless it is recovered or reused, wood products may not be made of endangered species of woods. The Convention on International Trade in Endangered Species of Wild Fauna and Flora

(CITES) has more information on trade regulations for certain species of wood used in building projects (Standard 189.1, 2009).

Another mandatory requirement is that CFC-based refrigerants in HVAC systems are prohibited. Ozone-depleting substances, such as CFCs and HCFCs, are also prohibited in the use of fire suppression systems.

In addition to the collection of waste to be diverted, the standard requires that there be a specific area dedicated to the collection of non-hazardous materials for recycling. Materials to be recycled include paper, glass, plastics, metals, and fluorescents and high-intensity discharge (HID) lamps and ballasts. This recycling is a requirement for the occupied building, dealing more with the performance of the building rather than the construction of the building.

Prescriptive Option

The prescriptive option provides requirements for using reduced impact materials. Reduced impact materials include recycled content materials, regional materials, biobased products, and wood construction components. The total amount of the recycled material shall be at least 10% of the total cost of the materials in the project. Part of the criteria for these reduced impact materials includes using regional materials. The regional materials section requires that at least 15% of all materials and products shall have originated within a 500 mile radius of the project site. Biobased building materials must meet the United States Department of Agriculture (USDA) standards and must compose at least 5% of the total cost of building materials used. Wood building materials must meet several requirements that prove they have been produced, shipped, and sold according to a recognized forest certification system.

Performance Option

The performance option requires that a life-cycle assessment be created with a minimum of two possible building alternatives utilizing reduced impact materials as directed in the prescriptive option. These building alternatives will be the same design, construction, and material use; with the only difference being the alternative must have a 5% improvement over the other in at least two impact categories. These impact categories include land use, resource use, climate change, ozone depletion, health effects, smog, ecotoxicity, acidification, and eutrophication. The life-cycle assessment will then follow three steps. The first step is to create a life-cycle inventory. This inventory takes into account the materials and energy (not including on-site generated) consumed and the emissions in all stages of the construction process, the operations and maintenance throughout the life of the building, and the demolition and reuse of the building at the end of its life-cycle. The second step compares the building alternatives with a third-party impact indicator. The final step includes a total review by a third-party expert. The final life-cycle assessment report is then submitted to the authority having jurisdiction.

Construction and Plans for Operation

Chapter 10 of ASHRAE Standard 189.1 is the chapter for construction and plans for operation. This section is unique compared to the other chapters of the ASHRAE Standard 189.1 in that it deals primarily with the construction and post-occupancy phases of the building project. The other sections have requirements that come into play during these stages (water and energy data collection), but the majority of those criteria deal specifically with the design and planning portions of a project. This section contains requirements for the following segments of the building project: commissioning, building acceptance testing, measurement, verification, energy use reporting, construction, and indoor air quality during construction. There are no prescriptive or performance paths to follow here. The mandatory provisions include requirements for the two broad areas of construction and plans for operation.

Construction Phase

This section deals with the requirements that the contractors and subcontractors must abide by in order to meet ASHRAE Standard 189.1. A sustainable building is not effective if the completed building is green and environmentally responsible but the construction process failed to achieve this level.

Building Acceptance Testing [10.3.1.1]

During the construction phase, a building acceptance testing process must be put into practice. The standard generally states that the plan for acceptance testing should be created during the design phase. The testing itself is to ensure that generally accepted engineering standards for the various building systems are met, and must be done to verify the installation and start-up of each building system. The systems that must be tested include HVAC, refrigeration, indoor air quality, lighting, renewable energy, water measurement, and energy measurement.

Commissioning [10.3.1.2]

In addition to the building testing, the mandatory provisions require that buildings greater than 5,000 square feet must be commissioned. The purpose of the commissioning process is to certify that the building and all systems meet the owner's project requirements. Commissioning covers the following systems: HVAC, indoor air quality (IAQ), refrigeration, building envelope, pressurization, lighting controls, irrigation, plumbing, domestic water and mixing systems, service water heating, renewable energy, and water/energy measurement. The commissioning process must be initiated during the design phase and continue at least into the first year of building occupancy.

Commissioning is divided into three major timeframes: prior to building permit, prior to building occupancy and post-occupancy. ASHRAE Standard 189.1 details several activities that must be completed during these periods. The building permit phase can be loosely defined as the design stage. Most of the planning for the commissioning process must be completed here. Before the design process even starts, the owner and design team get together and develop the owner's project requirements (OPR) and basis of design (BOD) documents. These are the basis of the commissioning plan. The commissioning authority (CxA) is essentially the one in charge of all proceedings; they review all documentation and oversee the entire process. The CxA uses the OPR and BOD to create the commissioning plan, which includes all documentation of timelines and procedures for the testing of the various systems.

The period labeled as "prior to building occupancy" includes the remainder of the construction phase. During this time, the commissioning plan is implemented, with the installation and performance of the building verified by the commissioning tests. Some of the systems cannot be fully tested due to seasonal restrictions (the heating of the HVAC system when the project is completed during the summer). For this, ASHRAE 189.1 requires that the operations and maintenance staff be trained during the construction phase. This enables the staff to test the systems when that season occurs. Part of this process includes the creation of a system manual.

After construction is completed and the owner occupies the building, the CxA must then create the final commissioning report and ensure that the commissioning plan requirements for off-season testing will be completed. The commissioning process greatly benefits the owner by guaranteeing that the project requirements are met. In the case of a high-performance building, the owner will obviously need the building to perform per the design intent, and even more so now because it is a requirement for ASHRAE 189.1.

Erosion and Sediment Control [10.3.1.3]

The next requirement of the construction phase is the planning and implementing of an erosion and sediment control plan. The plan must meet the EPA's or the local authority's minimum standard, whichever is more stringent. This plan will include all of the construction activities. It specifically targets the runoff from storm water during the construction phase of the project.

IAQ Construction Management [10.3.1.4]

Indoor air quality during construction has quite a list of requirements. A plan to manage air quality throughout the process must include a dedicated area to store air conveying materials to keep them clean. The plan must also contain a schedule for either a post-construction, pre-occupancy building flush-out or post-construction, pre-occupancy baseline IAQ monitoring. This process utilizes an equation based on the design outdoor air flow to determine a total air change value. This value is used to provide air at given conditions for an extended period of time to flush out the building. All filters and controls for the HVAC system must be in place prior to the start of the test, in order to protect the equipment.

The final mandatory requirements, relating to indoor air quality, provide information on moisture control and construction vehicle staging. The moisture control intent is to prevent mold on absorptive materials. Any construction material that has mold on it is prohibited from being installed. The final construction requirement involves staging areas for construction vehicles. These vehicles must be staged at least 100 feet from intakes, building openings, and other buildings as they wait to load or unload materials.

Plans for Operation

The second major area of mandatory requirements is plans for operation. This section deals with several types of plans for the operation of the building that will need to be documented in order to meet the conditions of the standard. There are four plans outlined in this section: high-performance building operation plan, maintenance plan, service life plan and transportation management plan.

High-Performance Building Operation Plan [10.3.2.1]

The high-performance building operation plan outlines several requirements that spill over from previous sections of ASHRAE Standard 189.1. The site sustainability portion of the plan includes procedures for the maintenance of vegetation for the shading criteria from Section 5 of the standard. There are several requirements regarding the water consumption of the building. The plan must lay out procedures for tracking and assessing the water use from the data collected under previous water efficiency requirements. Similar requirements follow for the documentation and assessment of energy use for the building. There is a six month time window, starting a year after occupancy, for the first assessment, with ongoing assessments occurring at least every three years after that. The next major topic is indoor environmental quality. The building operation plan contains requirements to monitor and verify outdoor air flows. These requirements also contain direction for testing indoor air quality and responding to issues in the HVAC system.

Maintenance Plan [10.3.2.2]

The second plan is the maintenance plan. This contains requirements for the maintenance of the mechanical, electrical, plumbing and fire protection systems. The maintenance must comply with ASHRAE Standard 180, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems, and include provisions for inspection of all the systems. Inspection and maintenance are not defined in ASHRAE Standard 189.1. In order to obtain this information, the design team must reference ASHRAE Standard 180.

Service Life Plan [10.3.2.3]

The third plan is the service life plan. This plan is created to estimate the rate of repair or replacement a building will see over its service life. The design service life is determined by the use of the building and is obtained from Table 10.3.2.3, presented below as Table 2.3. This design service life is used to help set up the timeline for maintenance for the building project.

Table 2-3 Minimum Design Service Life for Buildings

TABLE 10.3.2.3 Minimum Design Service Life for Buildings

Category	Minimum Service Life	Building Types
Temporary	Up to 10 years	Non-permanent construction buildings (sales offices, bunkhouses) Temporary exhibition buildings
Medium life	25 years	Industrial buildings Stand-alone parking structures
Long life	50 years	All buildings not temporary or medium life, including the parking structures below buildings designed for long life category

ASHRAE Standard for the Design of High-Performance Green Buildings, Standard 189.1-2009, Chapter 10, p. 42, 2010. © American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org.

All structural, envelope, and site materials and assemblies, excluding mechanical and electrical systems, are to be included in the consideration for the service life. This plan must also include the maintenance frequency for each type of assembly. The purpose of the service life plan is to provide a preventative measure for the individual systems in the building. Instead of waiting until the various systems fail, the service life plan presents a way for the design team to take care of the building systems before it comes to a breaking point. This helps to maintain a high-performance building. By preventing failure of the various systems, the plan minimizes the amount of down time when the building is not operating at design conditions. ASHRAE Standard 189.1 does not provide a document or standard to follow for the design team to reference for the service life plan.

Transportation Management Plan [10.3.2.4]

The final plan is the transportation management plan. This plan is developed in close consideration with the owner and contains requirements for how the employees of the building get to work. Preferred parking for carpools and accommodations for bicycle transportation are required for all buildings. There are several more requirements listed for the case where the owner is occupying the building, including providing incentives for employees to use mass transit, carpool matching programs and other criteria for centralizing commuter benefits.

Chapter 3 - Further Impacts

The new ASHRAE Standard 189.1 will have a large impact on the building design and construction industry. As shown in the overview of the standard in Chapter 2, every phase of the design and construction of a high-performance building is covered. Each aspect of the design of sustainable buildings will be impacted by this standard. In addition to the effect that the standard will have on design and construction, it will also greatly impact several major parts of the building design and construction industry. This chapter will detail four areas of this industry that ASHRAE Standard 189.1 will impact: standards, LEED 2009, specification writing and the design and construction teams.

Standards

The new ASHRAE Standard 189.1 will impact the use of some of the design standards that building design engineers refer to. The designer needs to be aware that ASHRAE Standard 189.1 has requirements that exceed current standards. Prior to the publication of this new standard, engineers had to be familiar with many different design standards in order to effectively work in industry. With the new standard, the use of many of these standards will be impacted. Rules of thumb that an engineer might use will have to be checked against the requirements of ASHRAE Standard 189.1.

Standards such as the IESNA Lighting Handbook provide design guidelines for illuminance levels, depending on the occupancy of the space. While these design standards are not code requirements, most lighting designers try to come close to these levels in the layout of the lighting system because it is an accepted design practice. According to ASHRAE Standard 189.1, the lighting power allowance for the entire building is to be no more than 0.9 times the value of either the space by space or building area method of ASHRAE Standard 90.1-2004 (Standard 189.1, 2009). This 10% reduction will not necessarily prevent a designer from adhering to the IESNA guidelines, but it does require a higher design level in order to strike the balance between energy efficiency and adequate illuminance levels.

Other codes will be impacted in larger degrees. The International Code Council has recently released for review its own version of a green code, the International Green

Construction Code (IGCC). This code follows the format of the other International codes, but supersedes the requirements of the International Energy Conservation Code. The IGCC lists ASHRAE Standard 189.1 as an alternate compliance path. This compliance path is available for use as long as the jurisdiction that the building project falls in allows it.

A building design engineer's use of certain standards will be affected with the adoption of ASHRAE Standard 189.1 as code. There will be increased design requirements beyond these utilized standards to achieve compliance with ASHRAE Standard 189.1. This section details three standards that ASHRAE Standard 189.1 will impact the use of: ASHRAE Standard 62.1-2007, ASHRAE Guideline 0 and ASHRAE Standard 90.1-2004. These impacts will be outlined by the differences between the standards.

ASHRAE Standard 62.1-2007

ASHRAE Standard 62.1-2007 is the standard for Ventilation for Acceptable Indoor Air Quality. The 2007 edition is the standard referenced in this report. ASHRAE Standard 189.1 requires that the building comply with Sections 4 through 7 of ASHRAE Standard 62.1 (Standard 189.1, 2009). These sections are outdoor air quality, systems and equipment, procedures and construction, and system start-up, respectively. These requirements are code in most jurisdictions anyway, either through ASHRAE Standard 62.1 or the International Mechanical Code (IMC), but there are several additional requirements that a designer should be aware of in the design of a high-performance building.

The first difference is with requirements for filtration. ASHRAE Standard 62.1 dictates that a minimum of a MERV 6 filter must be installed upstream of cooling coils and at geographical locations where the outside air is deemed to be below a certain air quality by the EPA. For these same criteria, ASHRAE Standard 189.1 requires a MERV 8 and a MERV 13, respectively. These increases in filter efficiencies will affect the sizing of any fans in the system by increasing the static pressure seen by the air handling equipment.

The ASHRAE Standard 62.1 requirements for ventilation of designated smoking areas are to be ignored by ASHRAE Standard 189.1, since smoking is to be prohibited in high-performance buildings. Minimum ventilation rates required by ASHRAE Standard 62.1 are unchanged in ASHRAE Standard 189.1.

ASHRAE Standard 189.1 uses the requirements of ASHRAE Standard 62.1 as the basis for the indoor air quality provisions in the standard. These minor modifications outlined above will impact the design of the mechanical and ventilation systems installed in buildings complying with ASHRAE Standard 189.1.

ASHRAE Guideline 0

ASHRAE Guideline 0 is a document detailing the commissioning process. Although ASHRAE Standard 189.1 does not specifically reference ASHRAE Guideline 0, most of the commissioning requirements in Section 10 of ASHRAE Standard 189.1 are outlined in the guideline. The commissioning process does not need a code to dictate exact requirements that the commissioning authority must abide by, since the process is optional for buildings not ASHRAE Standard 189.1 compliant, and not used for all building projects. ASHRAE Guideline 0 is instead used as a reference for the commissioning authority. The appendices in the guideline contain valuable information that can be used to assist in the process. Templates for different phases of the documentation provided in ASHRAE Guideline 0 can be used to streamline the commissioning procedures.

There is great potential for ASHRAE Standard 189.1 to push the industry toward commissioning as a normal project occurrence. A large part of the design industry does not fully understand the importance of the commissioning process. Granted, if the building is designed and constructed exactly as intended, the commissioning process is not necessary. Since the industry is not perfect, however, it is imperative to commission building projects. With this new standard poised to take the design and construction world into the next era, ASHRAE Standard 189.1, with ASHRAE Guideline 0, can easily become the basis for design of all projects.

ASHRAE Standard 90.1-2004

Since the emergence of the energy standard, ASHRAE Standard 90.1 has been one of the most widely accepted standards for setting requirements for building energy performance. The first version of the code was published in 1975 and has been steadily improved and refined to its current form today (Hunn, 18). The requirements in ASHRAE Standard 90.1 include almost everything that affects the energy use in a typical commercial building. This paper examines ASHRAE Standard 90.1-2007. The 2007 edition had minor changes from the 2004 edition and was not adopted as widely as the 2004 version. The 2010 version of ASHRAE Standard 90.1

was not released until after ASHRAE Standard 189.1 was published, so it will not be discussed in this paper. The standard does not list a year, so it is assumed that the 2007 version was used.

The new ASHRAE Standard 189.1 will impact the use of ASHRAE Standard 90.1, but not because of the potential for conflict between the two. The impact will come from the fact that ASHRAE Standard 189.1 uses ASHRAE Standard 90.1 as the building block for Section 7. Every chapter in ASHRAE Standard 90.1 is covered by the energy efficiency section in ASHRAE Standard 189.1. ASHRAE Standard 189.1 then builds off of the minimum requirements in ASHRAE Standard 90.1, modifying or adding to the standard to create the new design criteria for high-performance buildings.

The building envelope section is generally stricter in ASHRAE Standard 189.1. Tables providing insulation minimums for the different climate zones are organized the same, but the values are higher in ASHRAE Standard 189.1. Air leakage has several differences. ASHRAE Standard 90.1 allows higher rates overall, and lists maximum values for windows and doors. ASHRAE Standard 189.1 provides three different methods (testing materials, assemblies, or the total building) for calculating the maximum air leakage rate, outlined in Appendix B. The values given for fenestration U-factors and solar heat gain coefficients are also stricter in ASHRAE Standard 189.1. All these requirements add up to create a tighter envelope that reduces energy consumption by the mechanical system.

The HVAC section is also more stringent in ASHRAE Standard 189.1. The equipment efficiency tables change slightly in format, but each system type has a higher efficiency rating in ASHRAE Standard 189.1. The economizer requirement of ASHRAE Standard 90.1 allows designers in more climate zones to opt out of providing an economizer. Insulation values for ductwork and piping are higher in ASHRAE Standard 189.1 as well. These various sections provide an HVAC system that is more energy efficient and has fewer energy losses throughout.

Service water heating equipment has similar differences. The operating efficiencies of the equipment must be better per the requirements of ASHRAE Standard 189.1. Allowed standby losses for storage tanks and heaters do not change as drastically as some of the other sections' requirements. The service water heating system complying with ASHRAE Standard 189.1 will be more efficient than an ASHRAE Standard 90.1 system.

Lighting systems in ASHRAE Standard 189.1 are at least 10% more energy efficient than those in ASHRAE Standard 90.1. The requirements for control strategies and exterior lighting are the same between the two standards. Interior lighting for either standard can be met by following the building area method or the space-by-space method. To meet the requirements of ASHRAE Standard 189.1, however, the total watts allowed must be reduced by 10% to attain the actual maximum.

In the Other Equipment sections, the only topic covered is motor efficiencies. Both standards provide the same table, but the requirements of ASHRAE Standard 189.1 are a small percentage more efficient than those in ASHRAE Standard 90.1.

The overall difference between the two standards will be outlined further in the case study in Chapter 4. Table 3-1 details the requirements of ASHRAE Standard 90.1 compared to those of ASHRAE Standard 189.1. The table allows a much easier look at the overlapping requirements of the two standards, with references to where the information came from.

Table 3-1 Comparative Matrix for Standards 90.1 and 189.1

	ASHRAE Standard 90.1-2004	ASHRAE Standard 189.1-2009	Comments
Building Envelope			
Insulation	Tables 5.5-5.8	Tables A-1-A-9	189.1 has higher values
Air Leakage	Doors: 1.0 cfm/sf Other: 0.4 cfm/sf	Appendix B 0.04 cfm/sf	189.1 describes a continuous air barrier
Fenestrations	U-factor: T5.5-5.8 SHGC: T5.5-5.8	U-factor: TA-1-A-9 SHGC: TA-1-A-9	189.1 typically has better values
Heating, Ventilating, and Air Conditioning			
Equipment Efficiencies	Tables 6.8.1A-J	Tables C-1-C-8	189.1 typically higher
Economizers	Table 6.5.1	Table 7.4.3.4A	189.1 more stringent
Duct Insulation	Tables 6.8.2A-B	Tables C-9 & C-10	189.1 requires more
Pipe Insulation	Table 6.8.3	Table C-11	189.1 requires more
Service Water Heating			
Equipment Efficiency	Table 7.8	Table C-12	189.1 typically better
Lighting			
Building Area Method	Section 9.5	90% of allowed	either method is permissible
Space-By-Space	Section 9.6	90% of allowed	
Other Equipment			
Motor Efficiencies	Table 10.8	Table C-13	189.1 0.5%-3% higher
Energy Cost Budget Method			
Energy Cost Budget	Chapter 11	not allowed	189.1 Appendix D

LEED 2009

The USGBC is one of the collaborating members of the development of ASHRAE Standard 189.1. The USGBC is also the society that created the first green rating system with LEED. The first version of the green rating system was released in 1998. LEED v2.2 was released in 2005 and was a widely recognized version that became the basis for green building design. This version was modified to give a higher precedence to features that have a larger environmental impact in the latest version, LEED 2009. Based on a perfect score of 100, the amount of points available, buildings receive a total score for a combined green rating. These levels in LEED 2009 are: accredited – 40, silver – 50, gold – 60 and platinum – 80 (USGBC, 2009).

Since the USGBC was such a large contributor to the initial development, ASHRAE Standard 189.1 and LEED 2009 have a lot of the same requirements. Each document has its own requirements that the other does not have, but there are far more overlapping topics between the two. This section will examine some of those criteria that have different constraints, to break down the impact that the code-based ASHRAE Standard 189.1 will have on the implementation of the voluntary rating system LEED 2009.

Under site sustainability, one of the differences is that of light pollution reduction. In ASHRAE Standard 189.1, there are five (5) lighting zones that a building site can fall into, compared to the four (4) zones that LEED 2009 has. The requirements of LEED give maximum values for illuminance levels at certain points relative to the property line of the site. Also listed are cutoff angles with percentages of light allowed above nadir. The ASHRAE requirements deal solely with the BUG ratings, along with the percentage of lumens allowed to be emitted above 90 degrees or more from nadir. The percentages for uplight are much more stringent in ASHRAE Standard 189.1: LZ1 at 0% for both, LZ2 at 1% vs. 2%, LZ3 at 2% vs. 5%, and LZ4 at 5% vs. 10%. The BUG ratings of fixtures from ASHRAE Standard 189.1 may attain similar values to the fractions of footcandles allowed at the property line from LEED, but it is difficult to provide proof that illuminance values match up with the LEED requirements.

In the water use efficiency section, LEED states that the building water use must be 20% less than a baseline calculated value from tables provided in LEED 2009, while ASHRAE Standard 189.1 lists allowed values for water consumption for specific fixtures. The requirements in ASHRAE Standard 189.1 are very straightforward; water consuming fixtures and fittings are given specific amounts of water they are allowed to use. LEED 2009 does not have specific fixture requirements. All that must be shown is that the building uses at least 20% less water compared to a baseline level. As long as this is proven, any combination of fixtures or fittings can be installed. LEED does not include requirements for laundry or commercial kitchen facilities, unlike ASHRAE Standard 189.1. The requirements in each are similar in terms of the decrease in water consumption.

One of the interesting impacts in the area of energy efficiency is the use of on-site renewable energy systems. It does not necessarily outline a potential problem between the two, but it does raise an important point. In ASHRAE Standard 189.1, some level of renewable energy is required with provisions for future addition of renewable energy systems. On the other hand, LEED 2009 does not have on-site renewable energy as a prerequisite, and is instead only listed as an option to achieve a certain number of points, depending on the level of energy produced.

For indoor environmental quality, LEED does allow dedicated smoking rooms that meet certain ventilation requirements, compared to the requirements of ASHRAE Standard 189.1 where this is prohibited. An ASHRAE Standard 189.1 requirement and a LEED prerequisite dictate that ASHRAE Standard 62.1 ventilation rates must be met. One of the LEED credits, IEQ Credit 2, gives a point for providing 30% more ventilation than the baseline set by ASHRAE Standard 62.1. Providing more ventilation than is required to improve the IAQ of a space also requires that the HVAC equipment be larger. By bringing in more outside air at summer or winter design conditions, the heating and cooling coils must be able to condition a more extreme mixed air temperature. This in turn raises the amount of energy used by the system.

The above discussion is not an exhaustive list of the differences between ASHRAE Standard 189.1 and LEED 2009. There are many more differences between the two, but many of those differences are too minor to matter or are the change between a mandatory requirement and an option for LEED credit. These two documents are difficult to compare, despite their similarities. Some of the requirements of ASHRAE Standard 189.1 are not mandatory in the LEED rating system. However, just because it is not required in LEED does not mean that a designer will not include it in a LEED design. The following table, Table 3-2, is a tool to compare some of the requirements of LEED 2009 and ASHRAE Standard 189.1.

Table 3-2 Comparative Matrix for LEED 2009 and ASHRAE 189.1

	LEED 2009	ASHRAE 189.1
Site Sustainability		
Lighting Zones	4	5
Light Pollution	max illuminance	BUG ratings
Site Selection	available for points	limited
Heat Island Mitigation	available for points	required
Energy Efficiency		
On-Site Renewable Energy Systems	not required but can attain points	required plus future addition allowances
Monitoring Energy Use	available for points	required
Water Use Efficiency		
Water Consumption	save 20% over baseline	max value for fixtures/fittings
Irrigation Systems	50% less	use strategies
Wastewater Reduction	50% less	not covered
Materials and Resources		
Recyclable Collection	required	required
Waste Management	available for points	required
Use of Recycled Content	available for points	required
Regional Materials Use	available for points	required
Indoor Environmental Quality		
Smoking	dedicated areas	prohibited
Ventilation	points for bringing in more than 62.1	must have at least 62.1
Outdoor Air Monitoring	available for points	required
Refrigerant	no CFCs	no CFCs
Acoustical Control	required	required
Materials VOC Control	available for points	required
Thermal Comfort	meet Standard 55	meet Standard 55
Daylighting	25 fc at 75%	30 fc at 75%
Plans for Operation		
Erosion and Sediment Control Plan	required	required
Transportation Plan	available for points	required
Commissioning (enhanced)	min level required, points for next level	required

Specification Writing

Another important part of the building design industry is specification writing. Most people immediately associate building design and construction with a set of building plans, documents that dictate to a contractor how the structure is built and how the systems are installed. This is only half the job that a designer must do to have a complete set of construction documents. The specifications dictate exactly what needs to be done in order to meet codes, standards and the owner's project requirements. The specifications are the set of documents that the designer uses to provide the information to make the building "high-performance." In order to provide all the requirements for compliance with ASHRAE Standard 189.1, the specifications will include details to meet the operations plan requirements detailed in Chapter 10 of the standard.

The main impact of ASHRAE Standard 189.1 on the specification writing process will be the addition of several new sections. Typical specs include separate divisions for the various components that go into a building. Some of the various spec sections are as follows: general requirements go to Division 1, site construction to Division 2, building materials like concrete, steel and wood to Divisions 3-6, and mechanical and electrical are Divisions 15 and 16. These sections are usually included in every project. However, with the requirements of ASHRAE Standard 189.1, sections for commissioning, building operations plans and materials requirements will need to be included. The contractor will need to be made aware of these, so that they can include the added requirements in the bid.

There will need to be a section for the commissioning process. The contractor will need to know that a commissioning agent will be involved throughout the construction process and what responsibilities for the commissioning process the company is responsible for. Commissioning will require specifically documented procedures for the testing and start-up of the various systems. The schedules of the different members of the construction team will need to be coordinated for the commissioning agent to effectively set up the required portions of the commissioning process.

There are various indoor environmental quality requirements that will need to be detailed in the specifications as well. The construction phase requirements for building flush-outs will be included in a separate specification section. Requirements for smoking at the job site and the staging of construction vehicles will be outlined in the specifications. The design team should bring these new requirements to the contractors' attention to ensure adherence to the requirements.

Each of the plans for operation contained in Chapter 10 of ASHRAE Standard 189.1 will be detailed in a section of the specifications. The high-performance building operations plan, maintenance plan, service life plan and transportation management plan should each have a separate section in the specifications. These sections should include all the requirements as well as templates for the requisite documentation. The parties responsible for providing information to meet these requirements of ASHRAE Standard 189.1 should be informed about the new information in the specifications.

The design team will need to include all these requirements as added sections in the specifications, so that the contractor can allow for them in the bid and schedule them during the construction process. New sections in the specifications will be necessary in order to meet all the performance requirements for sustainable building projects. The building construction plans can hold all the information that a contractor needs to make the building energy efficient, from equipment schedules to on-site renewable energy systems layouts, but the specifications will contain the majority of the information required for a building to be "high-performance." The specification writing process will be greatly affected by the new ASHRAE Standard 189.1-2009.

Design and Construction Teams

Another impact will be to the organization and operation of the design and construction teams. This has already been noticed with the increasing number of LEED building projects, but the effect will be more pronounced with ASHRAE Standard 189.1. This section will cover the collaboration of the design team and the communication between the design and construction teams.

In order for the high-performance building design process to run smoothly and efficiently, the design team will have to work together much more closely than on most projects. One typical project scenario is outlined as follows. An owner hires an architect, who provides plans and leads discussions about the project. After agreeing on a design, the architect selects an engineer for the system design work. The engineers provide building systems construction documents to the architect, and the project goes to bid. In many circumstances, the engineer has minimal contact with the owner during the design phase. In order to meet the requirements of

ASHRAE Standard 189.1, the owner must be more involved in the process. This is mainly due to the commissioning process. The commissioning agent must bring the owner in to discuss the owner's project requirements and the basis of design. In order for the building project to meet the requirements of commissioning, this process must be started before the architect and engineers begin design. Then, for the process to continue running smoothly, the design team must discuss the commissioning requirements throughout the design phase. This closer collaboration is not all that different than normal, but can still be a challenge that must be overcome.

The next impact is the communication between the design team and the construction team. Since ASHRAE Standard 189.1 has many requirements for the construction process, the design team must communicate this to all the contractors and sub-contractors. The indoor environmental quality requirements for smoking apply to the construction phase as well. The start-up and testing procedures will be different than for a typical building. The schedules for commissioning tests are part of the specifications. The contractor's team will have to communicate their schedule for commissioning, systems testing, and building flush-out procedures. Any delays in these tests and processes will need to be accounted for to determine how they will affect the plans for operation.

The design and construction teams will have a higher level of accountability between each other and among themselves in order to meet the requirements of ASHRAE Standard 189.1. The higher level of communication and collaboration has already been seen in the design and construction of LEED projects. The process for designing high-performance green buildings is different from LEED in that ASHRAE Standard 189.1 provides requirements for the performance of the building. These added requirements will increase the level of communication involved among both the design and construction teams.

Chapter 4 - Case Study

In order to comprehend the impact of the new ASHRAE Standard 189.1 on the energy efficiency of buildings, this chapter will compare a high-performance building meeting the requirements of ASHRAE Standard 189.1 to a typical building meeting the minimum requirements of ASHRAE Standard 90.1-2004. This comparison will be done using version 3.64 of the Department of Energy's eQUEST software. According to Kent Peterson, the chairman of the Standard Project Committee for 189.1, Standard 189.1 will attain a weighted average of 30% energy savings when compared to the minimum requirements of ASHRAE Standard 90.1 (Peterson & MacCracken, 2010). This case study will examine the energy use of an ASHRAE Standard 189.1 compliant building to determine the overall annual energy use compared to the minimum standard.

Manhattan, Kansas Office Building

The building to be modeled is a two story office building located in Manhattan, Kansas. The total building dimensions are 125 feet by 160 feet, giving each floor 20,000 square feet. The floor to floor height is 12 feet. The floor plan of the office building is attached as Appendix A. The Manhattan, Kansas location was chosen for this case study for two reasons. First, the location is fairly average in terms of design standards. California is generally considered to be very progressive from an energy code perspective. Title 24 is the accepted standard for the state of California and is much more stringent than any version of ASHRAE Standard 90.1. States like Wyoming and South Dakota have no commercial energy codes (DOE, 2010). Secondly, the location is also ideal from a climate outlook. Kansas sees extreme design conditions in both summer and winter. Further south, summers can be much warmer, but the winter months are much milder. In northern climates, the opposite is true with harsher winters and milder summers. The design conditions for Manhattan, Kansas find a good middle ground to show the difference in both heating and cooling. An office building was chosen for similar reasons. The loads and equipment seen in an office are fairly average when compared to other occupancies. The office was also chosen for simplicity. A hospital could easily have been modeled as the comparison for the case study, but a health care building contains much more equipment that would not be considered typical. Additionally, the largest percentage of design work in the United States is office buildings. This means that a case study involving an office building will be fairly indicative of the building design industry.

The building will be modeled first with all the requirements of ASHRAE 90.1. This will be denoted as the baseline building. The same building will then be modeled with all the requirements of an ASHRAE 189.1 building. These requirements will be limited to the building envelope, systems (HVAC, lighting, service water heating), and water efficiency criteria. In order to meet the requirements of Standard 189.1, the remaining mandatory provisions (site selection, operations plans, etc) will be assumed to have been completed for the modeled high-performance building. The utility rate for electricity is assumed to be $0.07 per kilowatt-hour and the rate for natural gas will be $0.20 per therm. These are purely averages for the Manhattan area and are used for comparative purposes, not for modeling an actual annual utility bill.

ASHRAE 90.1 Baseline Building

The baseline building is assumed to have been designed and constructed with all current industry standards. This baseline will give an average level for energy consumption for a typical office building in Manhattan, Kansas. Following are the standards and minimums used for the baseline calculation in the areas of building envelope, energy efficiency, and water use efficiency. The input values used in eQUEST can be referenced in Appendix B.

Building Envelope

ASHRAE Standard 90.1 has several requirements for the building envelope. The first is in the area of air leakage. The infiltration of outside air can be a huge problem from an energy standpoint, since the HVAC equipment has to work harder to condition air that is not at room conditions. Standard 90.1 provides a maximum value of 1.0 cfm/sf for glazed swinging entrance doors and 0.4 cfm/sf for all other fenestrations and windows. The office building meets the requirement that less than 50% of the gross wall area and less than 5% of the gross roof area contain fenestrations. The windows are typically 4 feet wide by 6 feet high and the skylights are typically 4 feet by 8 feet. These values are used to determine a maximum cfm for the infiltration area. The eQUEST software asks for an input of cfm/sf of wall area and a cfm/sf of floor area, which are calculated as 0.153 cfm/sf of wall area for windows and 0.012 cfm/sf of floor area for skylights. These infiltration values are calculated by taking the maximum rates allowed by

ASHRAE Standard 90.1 and multiplying by the total area of fenestrations. This gives an allowed cfm of infiltration air. This cfm is then related back to the total wall and roof area to input into eQUEST.

The next building envelope requirement is heat transfer ratings of walls, roofs, and slab-on-grade floors. Tables list the requirements for different areas of the United States. Manhattan, Kansas falls into climate zone 4A. For a roof with insulation entirely above deck, the minimum R-value is 15, continuous. For this building, above grade walls are CMU with brick facing, which is under the category of mass wall. The R-value must be at least 5.7, continuous. Unheated slab-on-grade floors have no insulation requirements. In some cases, the minimum value was not available in the eQUEST software, so a slightly higher value was used. For example, eQUEST does not allow the input of R-5.7, so the insulation was set at R-6 to meet the minimum value. Since the required insulation in ASHRAE Standard 90.1 is listed as a minimum, the next highest value must be used for consistency. In the cases where an insulation value was not available, the next highest value is typically not significantly higher. This will not result in a considerable change in the final results.

The final set of envelope requirements is with the fenestrations. Maximum U-factors and solar heat gain coefficients (SHGC) are given for the different climate zones. The SHGC is permitted to be greater on north facing fenestrations for climate zone 4A. The percentage of vertical glazing for the building is between 40 and 50%, so the maximum U-factor for all windows and doors is 0.46. The maximum solar heat gain coefficient for northern facing fenestrations is 0.36, and the SHGC for the remaining exposures is 0.25. For this case study, the skylights are glass, and are to be installed with curbs. The table then gives maximums for U-factor as 1.17 and for solar heat gain coefficient as 0.39.

Building Energy Use

The first baseline building requirement for the energy use of systems in the project is in lighting systems. ASHRAE Standard 90.1 has specific requirements for the lighting power density for different types of spaces. The eQUEST software utilizes the space-by-space method for lighting in W/sf values. These values are as follows: conference rooms and lobbies at 1.3, offices (open and private) at 1.1, corridors at 0.5, restrooms at 0.9, storage rooms at 0.8 and mechanical/electrical rooms at 1.5 W/sf. Task lighting is added to the open offices, private offices and lobbies. The values used are the defaults from eQUEST, given as watts per square foot of area. The lobbies and open offices utilize 0.4 W/sf and the private offices use 0.3 W/sf.

While there are no requirements given for remaining electrical loads in Standard 90.1, this is still an important part of an energy simulation. The modeling software gives a place to input plug loads for these spaces. The eQUEST program provides default values based on industry standards. These default numbers were kept for the baseline building.

Service water heating can be a significant source of energy use in a building, depending on the number of fixtures requiring hot water in the project. For the office building given, the water heater is a gas-fired storage type heater. ASHRAE Standard 90.1 requires that the storage tank be insulated with a minimum of R-12.5. There is also a requirement for standby loss, which is calculated to be 0.63%/hr. The heater itself must have a thermal efficiency of 80%.

The final major area of energy use is HVAC equipment. This case study modeled a typical system an office building would use. This system consists of an estimated four (4) 20 ton air handling units with variable air volume (VAV) hot water reheat, DX cooling coils with roof mounted condensing units, and a natural gas boiler to provide hot water for heating. ASHRAE Standard 90.1 has several tables with requirements for efficiencies of mechanical equipment, based on the size of the equipment. Simplified calculations for the load on the building place the equipment in the range of 240 to 760 kBtuh. The air-cooled condensing units for the DX coils are required to have an EER of 9.3. The natural gas-fired boiler must have a minimum thermal efficiency of 75%.

Building Water Use

The final comparison point is in the area of water usage. ASHRAE Standard 90.1 does not include any requirements for plumbing fixtures. The baseline values instead are taken from LEED 2009. The Water Efficiency Prerequisite 1 requires that buildings use 20% less water than a baseline building. It then gives a table outlining the current industry baselines based on fixture type (LEED, 2009). This table is used to attain the standard for this office building. The design of this office contains the following numbers of fixtures: thirty-two (32) lavatories, twenty-eight (28) water closets, and fourteen (14) urinals. Baseline requirements are given for lavatories as 0.5 gpm, water closets as 1.6 gpf, and urinals as 1.0 gpf.

ASHRAE 189.1 Building

The second part of the case study was to look at a high-performance building. This building was designed to meet the minimum requirements of ASHRAE Standard 189.1. Most building projects trying to meet the high-performance standard would go above and beyond the requirements of ASHRAE Standard 189.1, but this case study is examining the minimum energy savings of a green building versus the baseline building. The design parameters of this building for the scope of this study are the building envelope, energy use and water use. Appendix B provides a table detailing the input values used for the high-performance building.

Building Envelope

ASHRAE Standard 189.1 covers the same areas that ASHRAE Standard 90.1 does, but the requirements are much more stringent. For infiltration, the standard requires that there be a continuous air barrier to minimize all unwanted outside air coming in. The requirements for the air barrier are detailed in Appendix B of ASHRAE Standard 189.1. After meeting certain requirements for materials used in the construction of the building, the entire envelope must have an air leakage rate of no more than 0.4 cfm/sf. Also, the total vertical fenestration area can be no more than 40% of the gross wall area, which compares to the 50% allowed from ASHRAE Standard 90.1.

Insulation ratings of roofs, walls and floors are also stricter in ASHRAE Standard 189.1. The roof insulation must be at least R-25, continuous. Mass walls are designed at R-11.4, continuous. Slab-on-grade floors are required to be insulated with a minimum R-value of 10 for 24 inches horizontally. These higher R-values will correspond into a greater resistance to heat transfer through the envelope, effectively reducing the load seen by the space.

The final part of the building envelope requirements pertains to the fenestrations in the envelope. ASHRAE Standard 189.1 does not differentiate between exposures. All windows and doors have a maximum U-factor of 0.45 and a maximum solar heat gain coefficient of 0.35. However, the standard also provides another requirement to further reduce load from solar gain from the east and west exposures. Based on the case study location being climate zone 4A, an equation is given to essentially reduce the weighted gains from the east and west exposures by 10% of the north and south exposures. The total gain is attained by multiplying the respective fenestration areas by the solar heat gain coefficient for that exposure. With this calculation, it is determined that the solar heat gain coefficient for the east and west exposures must be further reduced, from the maximum of 0.35 to a new value of 0.25, for both windows and doors. The skylight U-factor is set at a maximum of 0.69 and the solar heat gain coefficient is 0.32. The total skylight area is unchanged from ASHRAE Standard 189.1 to the baseline building.

Building Energy Use

The allowable building energy use in high-performance buildings is also greatly affected, compared to that of a baseline building. The first area is in lighting systems. ASHRAE Standard 189.1 dictates that the lighting power allowance will be equal to the value obtained by either the building area or space-by-space method multiplied by 0.9. Each of those values for the different types of spaces in this office building were factored this way and input into the eQUEST program. This effectively saves 10% on energy use from lighting alone. The modeling program also applies this to the HVAC system. Less energy consumed by the lights translates into a slightly decreased load on the mechanical equipment. Task lighting is left unchanged for the minimum high-performance building.

The other electrical loads are modified somewhat from the baseline building values. ASHRAE Standard 189.1 provides an extensive list of equipment that must be ENERGY STAR rated. Some of these items (refrigerators, computers, copiers, printers, monitors, etc.) will be present in an office setting. The plug load values for conference rooms, office spaces and open office layouts are slightly lowered in anticipation of the savings from this equipment. There is no real way of providing an exact percentage of power use in these, since most of this equipment is owner furnished. Most ENERGY STAR rated equipment is estimated to reduce energy consumption by about 20% (ENERGY STAR, 2008). Taking into account that not all equipment in the office will be required to have the rating, the plug load value was decreased by about 10% as an estimate of the energy savings.

In service water heating equipment, there are no differences in the requirements for gas storage water heaters. The thermal efficiency is still required to be 80%, and the standby loss equation is the same.

The final area of comparison is that of HVAC equipment. The same heating and cooling systems were modeled for the high-performance building. Although most high-performance building designers would likely choose a more energy efficient HVAC system (i.e. geothermal heat pumps, etc), the same VAV with hot water heating coils, DX cooling system, and boiler for hot water heating is modeled. This is to ensure that the case study is unbiased, and is only comparing a minimum, industry standard building to a minimum high-performance project. The same types of tables for equipment efficiencies are provided in Standard 189.1, but the values are typically more stringent. The EER for an air-cooled condensing unit supplying the cooling system becomes 9.8. The thermal efficiency for the boiler is 89% per ASHRAE Standard 189.1.

Building Water Use

The water use for each type of fixture listed in ASHRAE Standard 189.1 is typically more stringent than the baseline values from LEED 2009. Water closets are limited to 1.28 gpf, urinals are 0.5 gpf, and lavatories have the same 0.5 gpm requirement. Lavatories that use self-closing faucets are limited to 0.25 gallons per cycle. For the purposes of this case study, faucets with automatic shutoff were considered to be the fixtures installed.

Comparison and Results

With the outlined requirements for the baseline building and the high-performance building, the models were run through the eQUEST program. The output charts for monthly energy consumption are attached as Appendix C. The total annual electricity use for the baseline building was just under 640,000 kWh, and the total gas consumption was about 530,000 MBtu. This compares to a total electricity use of about 480,000 kWh, and a total annual gas use of around 430,000 MBtu for the Standard 189.1 building. The total electricity savings adds up to about 25% annually. The natural gas savings is right at 19% annually. Combining all energy use by the costs of electricity and natural gas gives a total cost savings of about 25% for an office building in Manhattan, KS.

This comparison, however, does not include the requirements for on-site renewable energy forms. Providing a system capable of annually producing 6.0 KBtu/sf will provide approximately 74,000 kWh of energy to the building. This will further increase the energy savings of the project.

This case study also does not include the peak load reduction requirement of ASHRAE Standard 189.1. This can be accomplished by load shifting or demand limiting, and will provide more energy use reduction. This requirement in the standard stipulates that the peak electric demand must be reduced by at least 10%. This does not translate into an added 10% energy savings with the given results from the case study, since the building does not operate at peak load all the time. The amount of savings will vary based on the total amount of the peak demand, so it is difficult to convert the peak reduction into a total amount of savings. The energy savings provided by the required on-site renewable energy systems and the peak load reduction will add to the total savings of 25% to attain a value close to the 30% that ASHRAE predicts (Peterson & MacCracken, 2010).

The water efficiency of a high-performance building that meets ASHRAE Standard 189.1 is demonstrated by the water use in the building model. Comparing the values of a baseline domestic water system to the requirements of ASHRAE Standard 189.1 results in about a 40% savings in total water use. Water closets have 20% savings, urinals have 50% savings and lavatories have the capability to provide something around a 40% savings, based on average use for a self-closing faucet cycle.

The initial cost of a high-performance building will obviously be higher, due to the higher requirements for the building envelope, the more energy-efficient equipment and the on-site renewable energy systems. However, these costs will be offset by lower energy bills and maintenance costs. This information can be used to calculate a simple payback period. Values were taken from the RS Means Construction Cost Data book to give the rough total construction costs. The median value for a low-rise office building is $99.50 per square foot (Waier, 2006). With the 40,000 sf building in the case study, the baseline building is nearly $4 million. Adding 10% for the ASHRAE Standard 189.1 building puts the initial cost at just under $4.4 million. With the baseline building at 5,300 therms of natural gas and 640,000 kWh of electricity, this adds up to $45,860 per year for a total energy bill. The high-performance building consumes 4,300 therms of natural gas and 480,000 kWh of electricity per year. The on-site renewable energy system capable of producing 65,000 kWh annually is taken out, to result in 415,000 kWh of purchased electricity. This produces an annual energy bill of $29,910. Another recurring cost is maintenance and repair. Data from the Whitestone Research Group puts buildings in northeast Kansas at around $2.90 per square foot per year for maintenance and repair costs (Lufkin, Turner, & Miller, 2007). With the maintenance and service life plans, these costs are assumed to be 10% lower annually for the ASHRAE Standard 189.1 building, which gives the maintenance costs at $2.60 per square foot annually. These values are used in a simple payback equation to determine the expected payback period. This period is just over 14 years, which means that the owner can expect to make back their initial investment in cost savings in that time frame. This payback period does not include any provisions for the peak demand limiting or load shifting, since this depends on the utility company. It also does not contain the water consumption savings, which can be very fluid, depending on the local jurisdiction. Each of these will serve to decrease the payback period.

Chapter 5 - Recommendations

The new ASHRAE Standard 189.1 has great potential to be a major part of a building design engineer's design criteria. At this time, the standard is less than a year old, and consequently, is still generally unknown. But as its presence continues to grow in the industry, it will become a viable option for building owners who want to build a high-performance structure. With all this incredible potential, my recommendations for ASHRAE Standard 189.1 are threefold: continue to develop the standard, utilize the standard for Kansas State University projects, and adopt the energy standard for all new federal government projects.

The first recommendation is for continued development. ASHRAE Standard 189.1 has the ability to impact the building design and construction industry to the same level that ASHRAE Standard 90.1 did in the 1970s. The industry is constantly looking for ways to save energy in commercial buildings, since buildings in the United States account for 40% of all the energy use (Standard 189.1, 2009). If trends continue this way, high-performance buildings, and consequently this standard, if enforced by code, could quite possibly become the norm for the commercial sector. With this potential looming on the horizon, it is imperative for ASHRAE, the USGBC, and the other collaborating members to update and refine the standard regularly. The typical three-year review that most codes are subjected to would be adequate for the continued advancement of the standard. As new technologies enter the industry, ASHRAE Standard 189.1 must adapt to keep current.

The next recommendation is for Kansas State University to require all new construction projects and all remodel work to adhere to ASHRAE Standard 189.1. The university has shown a commitment to sustainability in recent projects on campus. The brand new Leadership Studies building is a LEED silver structure. The Justin Hall addition is also expected to garner a LEED-certified rating. With projects like these already completed or almost to the construction phase, university officials have proven themselves willing to go green. The university can become one of the first entities to get on board with ASHRAE Standard 189.1 and essentially adopt this for all new projects. With a large number of renovations and additions scheduled, it would be a perfect time to showcase the standard. Universities are capable of capturing the national spotlight by employing sweeping changes to campus policies, not the least of which is in building projects. With the help of alumni and some state funding, universities can begin to lead the rest of the nation into the next generation of high-performance buildings.

The final recommendation is for the Department of Energy to adopt ASHRAE Standard 189.1 as the standard for all new government projects (Scott, 2010). According to an eSociety article published by ASHRAE, the DOE is considering adopting the International Green Construction Code as the requirement for all federal jobs. On July 27th, 2010, the DOE held a set of hearings for debate on the idea. ASHRAE Vice President Ross Montgomery spoke at the hearings, urging the committee to reference the ASHRAE Standard 189.1 alternate compliance path of the IGCC as a means to meet the code. With so many government buildings throughout the country, it makes sense that they be as energy efficient as possible. Additionally, many state governments would see the success that the federal government has had and adopt the standard for state government projects as well.

Chapter 6 - Conclusions

The new Standard for the Design of High-Performance Green Buildings will have a huge impact on the design industry. With requirements for buildings including site sustainability, water use efficiency, energy efficiency, indoor environmental quality, construction plans, and the building's impact on atmosphere, materials and resources, ASHRAE Standard 189.1 provides a code-based standard for green buildings. It builds on ideas established by the USGBC with LEED and minimums established by ASHRAE Standard 90.1 to create a complete design for high-performance buildings.

In order to give an unbiased view of the standard, it is important to look at the issues that might arise from adopting ASHRAE Standard 189.1 as a code. One issue is in implementation. With life safety codes, it is simple for an authority having jurisdiction to examine calculations to determine if the systems meet code. Several of the requirements in ASHRAE Standard 189.1 have no quantifiable means to determine if they are being met. The on-site renewable energy systems must meet certain criteria for the amount of energy they can supply. The difference between what a photovoltaic system can produce and what it actually does produce can be substantial. Additionally, the plans for building operation might be difficult to enforce as code. The adoption of ASHRAE Standard 189.1 will also greatly increase the demand on code enforcing agencies and building departments by requiring the certification and training of additional staff to deal with the new requirements of ASHRAE Standard 189.1. Energy and water consumption assessments are required to be examined every three years. It will be difficult for the authority having jurisdiction to enforce this part of the standard.

A second issue is in the extra costs associated with meeting the requirements of the standard. The first cost of a high-performance building is significantly higher than that of an industry standard building. Many building owners who want to provide a green building are prepared to deal with this cost. Adopting ASHRAE Standard 189.1 as code essentially forces an owner to pay for a much more expensive building, from an initial cost perspective. Two examples that can increase initial cost are on-site renewable energy systems and commissioning. Part of the reason that renewable energy systems have not yet become common on most new construction projects is simply the high cost to install and maintain the systems. Providing systems that meet the requirements of ASHRAE Standard 189.1 will add significant cost to the building project. Commissioning also poses an added cost for building owners. The commissioning process can add anything from 5-10% of construction costs to the overall building project. These issues can make the implementation of ASHRAE Standard 189.1 as code quite a problem.

Even with the issues shown, there is still a huge potential for buildings to save on annual energy costs with this standard. Based on the case study performed for this report, the standard will provide building owners with 25% annual energy savings from the industry baseline building. This savings will translate into a sustainable building with minimal impact on the environment. The 14-year payback period will also be of great interest to the building owner. Whether it is the impact on the design itself, the use of other standards in the industry, LEED, or the design and construction teams, ASHRAE Standard 189.1 will greatly affect the building design and construction industry.

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Appendix A - Case Study Office Floor Plans

Figure A-1 First Floor Plan

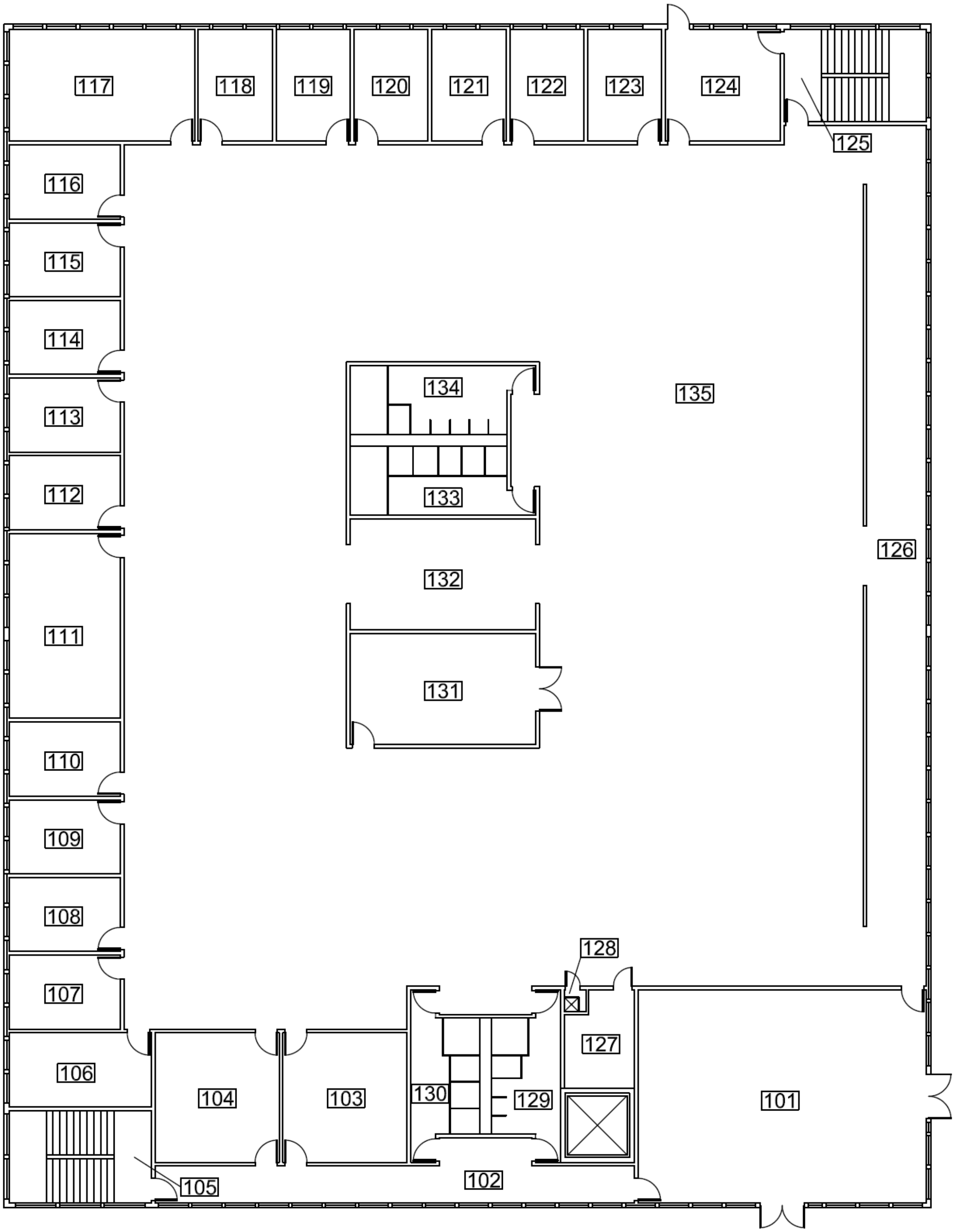


Figure A-2 Second Floor Plan

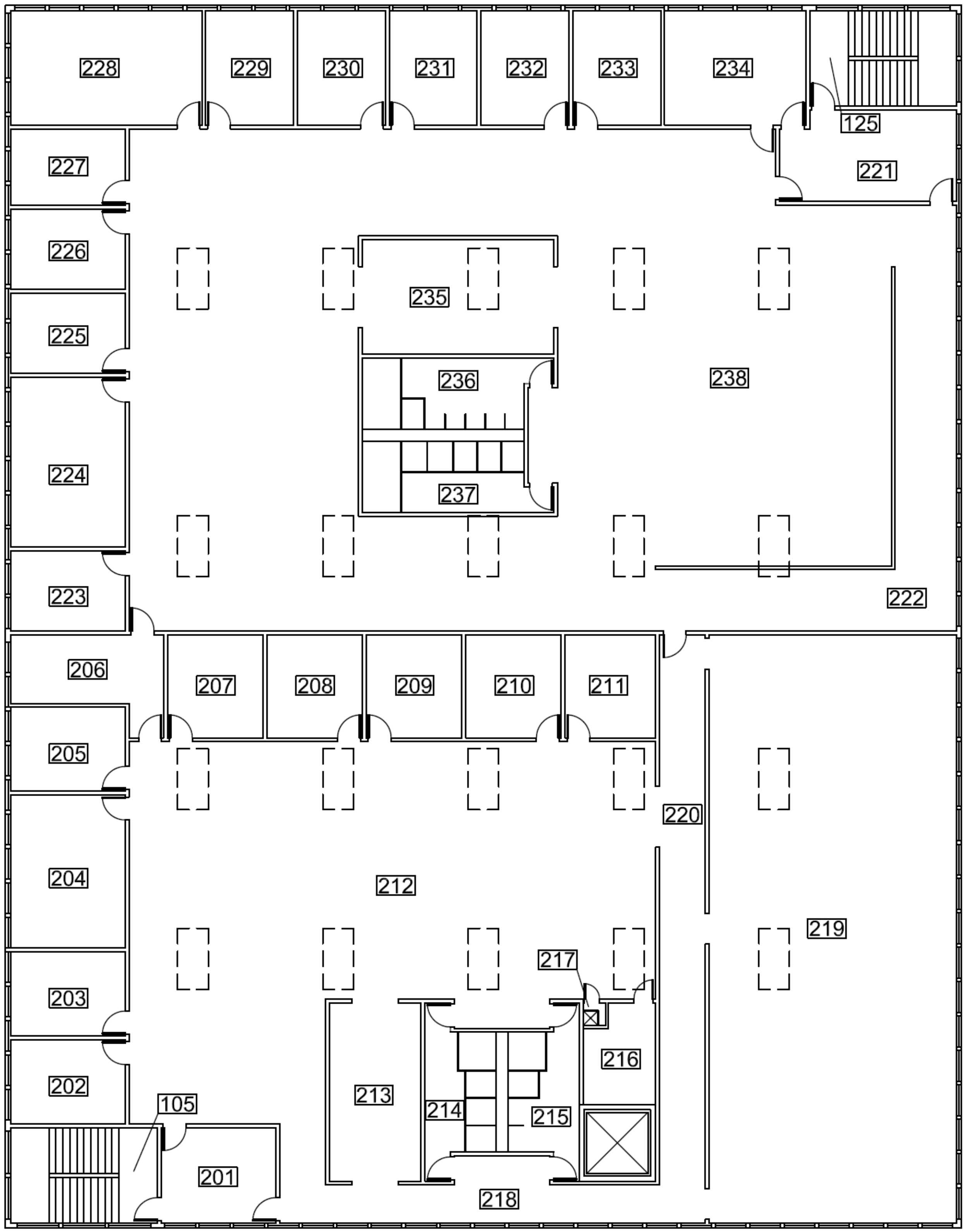


Table A-1 Case Study Building Room Data

Room #	Room Name	Area (SF)
101	Lobby	1,120
102	Corridor	371
103	Mail/Copy Room	293
104	Storage Room	293
105	Stairwell	240
106	Mechanical Room	192
107	Office	150
108	Office	150
109	Office	150
110	Office	150
111	Conference Room	375
112	Office	150
113	Office	150
114	Office	150
115	Office	150
116	Office	150
117	Conference Room	379
118	Office	152
119	Office	152
120	Office	152
121	Office	152
122	Office	152
123	Office	152
124	Lobby	235
125	Stairwell	240
126	Corridor	928
127	Mechanical Room	116
128	Janitor's Closet	9
129	Men's	172
130	Women's	172
131	Conference Room	375
132	Break Room	375
133	Women's	210
134	Men's	210
135	Open Office	10,319

105	Stairwell	240
125	Stairwell	240

Room #	Room Name	Area (SF)
201	Lobby	188
202	Office	165
203	Office	165
204	Conference Room	300
205	Office	165
206	Mechanical Room	200
207	Office	169
208	Office	169
209	Office	169
210	Office	169
211	Office	160
212	Open Office	2,785
213	Break Room	280
214	Women's	172
215	Men's	172
216	Mechanical Room	116
217	Janitor's Closet	9
218	Corridor	344
219	Open Office	2,490
220	Corridor	462
221	Lobby	268
222	Corridor	696
223	Office	158
224	Conference Room	333
225	Office	158
226	Office	158
227	Office	150
228	Conference Room	375
229	Office	173
230	Office	173
231	Office	173
232	Office	173
233	Office	173
234	Mail Room	278
235	Break Room	375
236	Men's	210
237	Women's	210
238	Open Office	5,226

Appendix B - Case Study Input Data

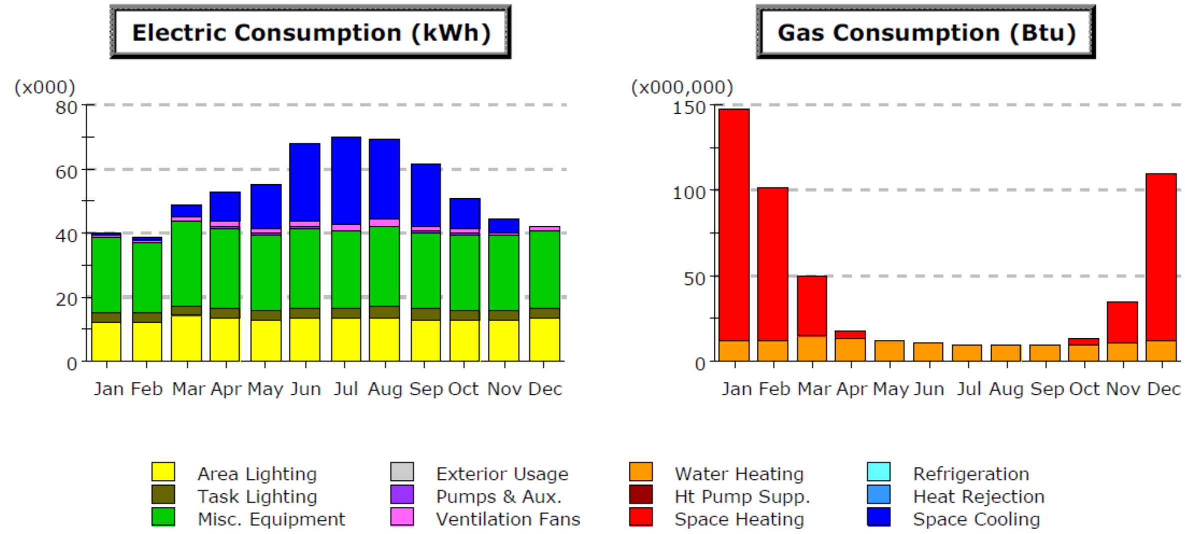
Table B-1 Case Study Input Data

	ASHRAE 90.1 Baseline	ASHRAE 189.1 Building
Roof Insulation	R-18	R-25
Wall Insulation	R-6	R-13
Floor Insulation	none	R-10 -2 ft
Window U-Factor	0.47	0.45
Window SHGC (exposure)	N: 0.36	N&S: 0.35
	all: 0.25	E&W: 0.25
Skylight U-Factor	1.17	0.69
Skylight SHGC	0.39	0.32
Lighting (W/SF)		
• Conference	1.3	1.17
• Private Office	1.1	0.99
• Lobby	1.4	1.17
• Corridor	0.5	0.45
• Open Office	1.1	0.99
• Restrooms	0.9	0.81
• Mech/Elect	1.5	1.35
• Storage	0.8	0.72

	ASHRAE 90.1 Baseline	ASHRAE 189.1 Building
Task Lighting		
• Private Office	0.3	0.3
• Lobby	0.4	0.4
• Open Office	0.4	0.4
Plug Loads		
• Conference	1.0	0.95
• Private Office	1.5	1.4
• Lobby	0.5	0.5
• Corridor	0.2	0.2
• Open Office	3.0	2.2
• Restrooms	0.2	0.2
• Mech/Elect	0.2	0.2
• Storage	0.2	0.2
Cooling Efficiency	9.3 EER	9.8 EER
Economizer	none	yes
Boiler Efficiency	75%	89%
Storage Tank Insul	R-12.5	R-12.5

Appendix C - Case Study Output Results

Figure C-1 ASHRAE 90.1 Baseline Building Monthly Enduse Data



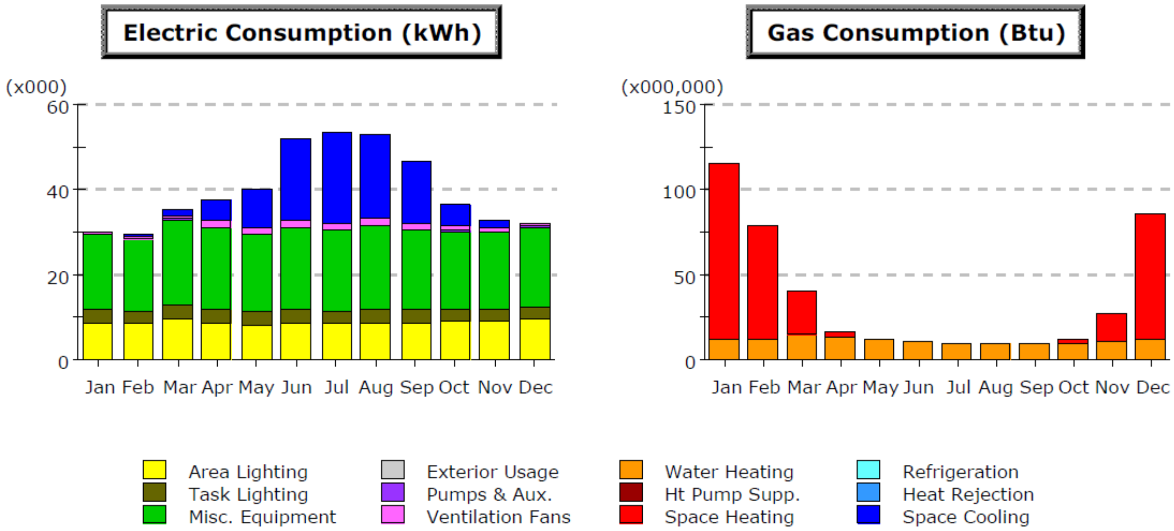
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.36	0.68	4.03	9.49	13.30	24.16	26.58	24.76	18.85	9.30	3.83	0.53	135.88
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.89	0.82	1.15	1.54	1.67	1.92	2.12	1.98	1.85	1.49	1.05	0.91	17.39
Pumps & Aux.	0.24	0.21	0.23	0.19	0.18	0.17	0.18	0.18	0.18	0.19	0.21	0.24	2.40
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	23.03	22.17	26.00	24.97	23.78	24.97	24.52	25.26	24.23	23.78	23.49	24.52	290.72
Task Lights	2.85	2.78	3.31	3.17	2.96	3.17	3.08	3.19	3.06	2.96	2.94	3.08	36.55
Area Lights	12.39	11.95	14.04	13.48	12.80	13.48	13.22	13.63	13.07	12.80	12.66	13.22	156.73
Total	39.76	38.62	48.76	52.84	54.69	67.88	69.68	69.00	61.23	50.52	44.17	42.49	639.66

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	135.73	89.46	35.64	4.52	0.69	-	-	-	0.44	3.69	24.31	98.22	392.70
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.84	11.96	14.14	13.27	11.49	11.18	10.02	9.82	9.37	9.59	10.34	11.82	134.86
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	147.57	101.42	49.78	17.79	12.18	11.18	10.02	9.82	9.82	13.29	34.65	110.04	527.57

Figure C-2 ASHRAE 189.1 High-Performance Green Building Monthly Enduse Data



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	0.23	1.47	5.22	9.16	19.48	21.40	19.95	14.51	4.86	1.81	-	98.08
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.71	0.64	0.87	1.17	1.28	1.53	1.68	1.59	1.48	1.16	0.79	0.70	13.61
Pumps & Aux.	0.21	0.19	0.20	0.16	0.15	0.14	0.14	0.14	0.14	0.16	0.18	0.21	2.02
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	17.66	17.00	19.94	19.15	18.23	19.15	18.80	19.37	18.58	18.23	18.01	18.80	222.92
Task Lights	2.85	2.78	3.31	3.17	2.96	3.17	3.08	3.19	3.06	2.96	2.94	3.08	36.55
Area Lights	8.81	8.43	9.59	8.83	8.19	8.49	8.40	8.79	8.75	8.97	9.01	9.41	105.66
Total	30.24	29.27	35.37	37.70	39.97	51.96	53.50	53.04	46.51	36.34	32.75	32.20	478.85

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	103.72	67.70	25.89	2.71	0.41	-	-	-	-	1.87	16.53	74.51	293.35
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	11.84	11.96	14.14	13.27	11.50	11.18	10.03	9.82	9.38	9.60	10.34	11.82	134.89
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	115.56	79.66	40.03	15.98	11.91	11.18	10.03	9.82	9.38	11.47	26.87	86.34	428.24

Appendix D - Permission Release

Harr, Julie <JHarr@ashrae.org> Wed, Nov 10, 2010 at 11:27 AM

To: Aaron Blush <aaron.blush@gmail.com>

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Julie Harr

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---

Aaron Blush <aaron.blush@gmail.com> Tue, Nov 9, 2010 at 10:56 AM

To: "Harr, Julie" <JHarr@ashrae.org>

Ms. Carr,

As of right now, I have recreated Tables 5.3.3.2A, 5.3.3.2B, and 5.3.3.3 (the light pollution reduction tables) as one larger table summarizing the three. I have also decided to use Table 6.3.2.1 (the plumbing fixtures and fittings table) and Table 10.3.2.3 (design service life) in the paper as well.

Aaron Blush

c: (785) 640-0198

e: aaron.blush@gmail.com

Harr, Julie <JHarr@ashrae.org> Tue, Nov 9, 2010 at 9:44 AM
To: Aaron Blush <aaron.blush@gmail.com>

Dear Mr. Blush:

If you will identify the tables you wish to use and as long as the material you wish to use does not represent more than 33% of the entire Standard, then I will be glad to send you permission in an email response.

Best regards,

Julie Harr

Aaron Blush <aaron.blush@gmail.com> Mon, Nov 8, 2010 at 9:44 AM

To: "jharr@ashrae.org" <jharr@ashrae.org>

Ms. Carr,

My name is Aaron Blush, and I am a graduate student in architectural engineering at Kansas State University. I am doing my masters report on the impact of the new ASHRAE Standard 189.1. I had e-mailed Stephanie Reinichie about reproducing tables from the standard in the report and she directed me to you. What is the proper procedure for pulling tables directly from the standard?

Thanks for your help.

Aaron Blush

c: (785) 640-0198

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