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Beauty in Buildings: How Beauty and Inspiration Impact Building Energy Performance

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Beauty in Buildings: How Beauty and Inspiration Impact Building Energy Performance

by

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B.S., Texas A&M University, 2003

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Beauty in Buildings: How Beauty and Inspiration Impact Building Energy Performance
written by William Michael Goodrum
has been approved for the Department of Civil, Environmental, and Architectural Engineering

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The final copy of this thesis has been examined by the signatories and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Beauty in Buildings: How Beauty and Inspiration Impact Building Energy Performance

Thesis directed by Prof. Zhiqiang (John) Zhai, Ph.D.

Consideration of beauty in the built environment is growing within the building sector as the broader concept of sustainable building design replaces the more narrowly defined concepts of high performance or green building. Similarly, as building design teams become more integrated, pairing architects, engineers, construction managers, and other professionals, the concepts of beauty and energy performance are approached collectively.

In research led by ml Robles, NCARB Architect at the PatternMapping institute, characteristics representative of beautiful buildings were identified and metrics and criteria relating these beauty characteristics to building energy performance were compiled to form a qualitative evaluation tool. A sample of 35 case studies contrasting high performing with inspiring and high performing buildings were evaluated for building performance relative to both beauty and energy using the qualitative evaluation tool. Results indicated that the inspiring and high performing buildings included building systems or features that more consistently provide an experienced connection between the occupants, the built environment, and ultimately the surrounding environment.

Building energy models representing distinguishing building systems or features identified from the qualitative evaluation were developed for quantitative evaluation of energy performance through energy simulation. Relative importance to beauty and energy performance of each of the building systems or features was determined and presented as color-scaled quantitative references. The color-scaled references illustrated that building systems or features that exhibit density – combination of multiple systems – in their designs offered better performance relative to both beauty and energy.

The qualitative evaluation tool and the color-scaled quantitative references developed in this research provide useful tools for architects and engineers seeking to design built environments that are both inspiring and high performing.

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Chapter 1

Introduction

1.1 Background

Greenhouse gas emissions and availability of energy resources have become topics of ever increasing importance in society and influence various aspects of our communities. In the United States, the building sector comprises approximately 40 percent of the nation's primary energy use (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2010). With increased attention to energy resources and the large percentage of U.S. energy use attributed to buildings, building sector energy use has come into renewed focus in the past two decades as a necessary area for improvement. This renewed focus on building sector energy use resulted in the advent of building assessment and rating systems aimed at producing "high performance" or "green" buildings. Such buildings combine advanced technology and materials with efficient systems to use resources efficiently for the protection of the environment and of our energy resources, but don't necessarily provide a pleasing occupant experience. Buildings that do not provide a pleasing occupant experience may be more likely to fall into disrepair due to a lack of appreciation or concern by occupants. However, a built environment that provides an experience of beauty and inspiration may be better cared for and preserved, as occupants and visitors enjoy the building and desire to maintain it and its surroundings for continued use. Improved maintenance of buildings can also lead to better long-term energy performance by keeping equipment and systems in good repair and operating condition.

Several building rating systems exist in the U.S. to guide the building design process, such as the Environmental Protection Agency's (EPA's) Energy Star rating or the U.S. Green Building Council's

(USGBC's) Leadership in Energy and Environmental Design (LEED). New rating systems continue to be developed to address perceived gaps in the current systems, such as the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Building Energy Quotient that is in pilot status. While these building rating systems include checklist items for occupant comfort in the form of indoor environmental quality, there is a definitive focus on building science and energy performance, with little or no attention to the built environment as a pleasing or inspiring experience.

Although there are a variety of choices for building rating systems, USGBC LEED certification has become one of the most widely used and recognized rating system in the U.S. The LEED checklist format provides an organized and logical method for assessing building performance, but does not necessarily inform the building designer of relative importance of particular items in the complete design, nor of occupant perception, aside from their value in the overall score. This format may ultimately encourage the building designer to disaggregate building systems and components, fashioning a building that performs well in parts but is not a cohesive and inspiring environment.

In contrast to USGBC LEED, the recently developed Living Building Challenge from the International Living Future Institute (ILFI) requires participation in all performance areas, causing the building designer to consider all aspects of the rating system, and presumably the built environment, rather than selecting a subset necessary for achieving certification. The Living Building Challenge also includes performance areas of "Beauty" and "Equity" that draw attention to the building as a beautiful and inspiring environment as well as its place within and impact to the surrounding community. As stated in the Living Building Challenge, "the intent… is to recognize the need for beauty as a precursor to caring enough to preserve, conserve, and serve the greater good," as well as "to correlate the impacts of design and development to its ability to foster a true sense of community" (International Living Building Institute, 2009). The Living Building Challenge is pioneering the evaluation of the built environment as beautiful and inspiring, in addition to the more common building energy performance criteria, but the "beauty" evaluation criteria are relatively qualitative. These criteria are useful for seasoned architects and designers that have an appreciation and understanding of beauty and inspiration and incorporate that effectively into efficient buildings. However, being qualitative, the Living Building Challenge criteria do not offer guidance that would benefit new and learning architects and building designers in appreciating how beauty and inspiration and building energy performance may combine to achieve a pleasing experience in the built environment.

As evidenced by the Living Building Challenge, the need to consider beauty as part of building performance is growing within the building sector as the broader concept of sustainable building design replaces the more narrowly defined concepts of high performance or green building. Similarly, as building design teams become more integrated; pairing architects, engineers, construction managers, and other professionals, the concepts of beauty and energy performance are approached collectively. There is realization that beauty and energy performance are complementary for achieving an efficient and inspiring built environment – a sustainable built environment that preserves the environment and is preserved for continued use. The ILFI and the Living Building Challenge are making the first steps in addressing beauty and inspiration as part of building performance. However, further definition of the beauty characteristics important for consideration in building design as well as guidance on how they relate to building energy performance is needed to encourage the inclusion of beauty and inspiration in building rating systems. Better definition of beauty characteristics of buildings and their contributions to energy performance and occupant satisfaction will foster understanding between design team members and help lend weight to the need for the built environment to be a pleasing experience in order to truly achieve a sustainable building design. This goes beyond the design of a single building to how a building relates to its environment and how people relate to the building and the environment where it resides.

> Seen in this light, a different horizon quickly opens which goes over and beyond the individual building. One or two ecological measures here or there are not the same as ecological

> architecture; solar panels and passive use of the sun, greenhouses integrated into a house, green facades and thermal insulation are not far-reaching enough at all for real sustainable building. So far what we are seeing is more an optimizing of – albeit important – isolated aspects rather than a total concept of sustainability-oriented planning principles.
>
> (Hegger, Fuchs, Stark, & Zeumer, 2008)

This thesis builds upon the Beauty in Buildings research conducted by the PatternMapping® institute (Robles, Zhai, & Goodrum, 2012), which identified characteristics representative of beautiful buildings and developed metrics and methodology relating these beauty characteristics to building energy performance. The Beauty in Buildings research produced the BiB Matrix (Robles, Zhai, & Goodrum, 2012), which is a tool for qualitative evaluation of building performance in terms of both beauty and energy. Using the Beauty in Buildings research and the BiB Matrix, the work of this thesis aims to quantitatively analyze building energy performance of distinguishing characteristics of beautiful buildings. Development of metrics connecting beauty and inspiration to energy performance, together with analysis showing relative impacts of building systems or features on both beauty and energy performance will inform building designers for making decisions based not solely on energy use but also for making the built environment a pleasing experience.

1.2 Objective/Problem Statement

The Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research began with a question posed by ml Robles, NCARB Architect at the PatternMapping® institute, “how do beauty and inspiration impact building performance.” The goal was not to define beauty or what a beautiful building is, but to identify distinguishing building systems or features of beautiful buildings and to understand how these may impact a building’s energy performance. The Beauty in Building research considers a definition for beautiful buildings inspired by Christopher Alexander in *The Timeless Way of Building*: a building in which a person feels fully alive (Alexander, 1979). This definition includes more than just aesthetics but also an experiential quality – beautiful buildings are built environments that are pleasing and inspiring for the people in them. By exploring shared qualities of such known built environments, it was possible to develop a list of common characteristics of beautiful buildings and to then (1) develop standardized means to measure and verify those impacts, such as metrics and criteria for evaluating beauty and inspiration together with energy performance in a useable format, and (2) determine what, if any, measurable impacts beauty and inspiration may have on building energy performance.

The topic of beauty in buildings is a broad one with indistinct boundaries, which presents a great challenge. With that understanding, the Beauty in Buildings research makes initial steps toward including beauty and inspiration in the assessment of building performance. Developing an initial list of beauty characteristics and criteria for evaluating their impacts will provide a platform for further refining and articulating characteristics of beautiful buildings and their importance for building energy performance, and ultimately for designing sustainable buildings and communities. Goals of the Beauty in Buildings research include:

- Identification of shared characteristics common to beautiful buildings and building systems or features that represent these characteristics
- Development of metrics and criteria for evaluating beautiful building energy performance

For this thesis research, more specific goals include:

- Investigation of contributing factors to and identification of distinguishing building systems or features of beautiful buildings
- Evaluation of the relative importance of these distinguishing building systems or features of beautiful buildings to building energy performance

1.3 Scope/Description of Research

This thesis began with and springs from the Beauty in Buildings research led by ml Robles of the PatternMapping® institute that focused on identifying shared characteristics common to beautiful buildings and developing metrics and criteria for evaluating beautiful buildings' energy performance and ultimately produced a qualitative evaluation tool known as the BiB Matrix (Robles, Zhai, & Goodrum, 2012). Using the BiB Matrix developed by the PatternMapping® institute, a case study evaluation was completed and the potential building energy use impacts of distinguishing building systems or features of beautiful buildings were analyzed. This thesis, which includes description of Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research, is structured as follows:

1.3.1 Identify Characteristics of Beautiful Buildings

Building systems important to the energy performance of buildings are well known and well documented in building rating systems such as USGBC LEED, but clear identification of important characteristics for beauty and inspiration does not readily exist. Despite the lack of such clear information, it is known that beautiful buildings do exist and must have common shared characteristics.

This task, led by ml Robles of the PatternMapping® institute, will begin with the review of the extensive work of Christopher Alexander and his team from the Center for Environmental Structure in both *The Timeless Way of Building* and *A Pattern Language: Towns, Buildings, Construction*. *The Timeless Way of Building* addresses concepts of inspiring buildings and will be reviewed for an understanding of the broad themes common to beautiful buildings. These broad themes will be termed "Beauty Attributes" in the Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research. *A Pattern Language* articulates various building patterns that are part of the built environments that elicit the feeling of being fully alive. The patterns will be reviewed to extract those building strategies that represent the Beauty Attributes and that share a relationship with building energy use, and could therefore be expressed or evaluated relative to energy performance. These building strategies that represent the Beauty Attributes and can be evaluated for energy performance will be termed “Beauty Determinants” in the Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research. As a means of validating the selected Beauty Attributes and their representing Beauty Determinants, these beauty characteristics will be tested by evaluating a small sample of case studies representing high performing buildings and inspiring and high performing buildings. The identified Beauty Attributes and Beauty Determinants, as well as the initial case study evaluation, are documented in Chapter 3.

1.3.2 Metrics for Evaluating Beautiful Building Energy Performance

Once Beauty Attributes and Beauty Determinants have been identified, it will be possible to formulate metrics and criteria to evaluate these aspects of the built environment relative to energy performance. This task was again led by ml Robles of the PatternMapping® institute. Rather than attempting to reinvent the wheel, existing building rating systems will be used to compile metrics for evaluating energy performance of beautiful buildings. The extensive pool of metrics and criteria for energy performance evaluation contained in the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) from Japan, the Collaborative for High Performance Schools (CHPS), and USGBC LEED will be reviewed to identify those best suited to evaluate the Beauty Determinants. The selected metrics for evaluating building energy performance relative to the beauty characteristics are documented in Chapter 4.

1.3.3 Qualitative Evaluation of Building Beauty and Energy Performance

The metrics and criteria, paired with the beauty characteristics, will be used to complete evaluations of building performance for a sample case study population. An expanded population of high performing versus inspiring and high performing buildings will be evaluated and assigned project values for building performance. The results of the qualitative evaluation will be analyzed to understand potential relationships between beauty and inspiration and various factors of the built environment. Further description of the qualitative case study evaluation and analysis of the results are documented in Chapter 5.

1.3.4 Quantitative Evaluation of Building Energy Performance for Beautiful Building Features

The next step of this research aims to quantify the relative energy performance impacts of distinguishing building systems or features of beautiful buildings. Identified building systems or features will be evaluated in parametric studies using energy simulations. Results of these parametric studies will provide quantifiable evidence of the potential impact to energy performance of building systems or features identified as important to beauty and inspiration. Combined with results from the qualitative evaluation, the relative importance of the distinguishing building systems or features can be illustrated in terms of beauty and energy performance. The quantitative evaluation and results showing relative importance of building systems or features to beauty and energy performance are documented in Chapter 6.

1.3.5 Recommended Further Work

The results of the Beauty in Buildings research and this thesis work will provide useful tools and references related to the impacts of beauty and inspiration on building energy performance. Still, this research is considered to be a first step in understanding and identifying the characteristics that are representative of beautiful buildings as well as investigating how specific building systems or features representative of these characteristics may impact building performance. Next steps of this research focus on two primary areas: revision and improvement of the BiB Matrix (Robles, Zhai, & Goodrum, 2012); and further investigation and expansion of quantitative results for building systems or features representing the beauty characteristics.

Revision and improvement of the BiB Matrix (Robles, Zhai, & Goodrum, 2012) includes an expansion of the case study population to increase confidence in the identified beauty characteristics and adjustment to include beauty characteristics that may have been omitted in this body of work. The BiB Matrix can then be distributed for testing among building design professionals for clarity and ease of use in evaluating project performance. Obtaining feedback from design professionals is an important part of providing an evaluation tool that will find success and application within the building industry.

Expansion of the quantitative results involves two main focuses. First, sensitivity analyses can be pursued for each of the distinguishing building systems or features evaluated within this research. The importance of specific sizes, shapes, construction materials, and other parameters of building systems or features can be adjusted to understand and highlight the key design aspects of that building system or feature. Second, additional building systems or features that are representative of each of the Beauty Determinants can be modeled to understand their impact to energy performance. The quantitative references can be appended with results of new building systems or features to expand their application for informing design decisions.

Chapter 2

Literature Review – Current Assessment of Beauty in Buildings Research

Reviews of pertinent literature provided an understanding of previous work and laid a foundation upon which to move forward. First, a variety of building rating systems were reviewed to understand their treatment of beauty. Second, literature focused on assessment of beauty was reviewed for research identifying important or definitive characteristics shared by beautiful buildings.

2.1 Building Rating Systems

Current building rating systems, both in the U.S. and international, were reviewed to understand their assessment criteria and whether beauty and inspiration were addressed. An excellent starting point for this review came from the Whole Building Design Guide, which is a program of the National Institute of Building Sciences. One of the resources available from the Whole Building Design Guide website is a brief overview of current building rating systems. Table 2.1 outlines several of the most commonly used and respected green building rating and certification systems in the marketplace (Vierra, 2011). Reviews of these building rating systems and their treatment of beauty and inspiration follow Table 2.1.

Table 2.1: Summaries of Current Building Rating Systems

Building Rating or Certification System	**Single- or Multi-Attribute**	**Type of Standard or Certification**	**Managing Organization**	**Issues / Areas of Focus**
Domestic Programs				
Energy Star	Single-Attribute	Government certification using a benchmarking method	U.S. EPA and U.S. DOE	Building energy and water use
Leadership in Energy and Environmental Design (LEED)	Multi-Attribute	Green building rating and certification system through independent third-party verification for: • New Construction (NC) • Existing Buildings, Operations & Maintenance (EB O&M) • Commercial Interiors (CI) • Core & Shell (CS) • Schools (SCH) • Retail • Healthcare (HC) • Homes • Neighborhood Development (ND)	U.S. Green Building Council	Performance in: • Sustainable Sites • Water Efficiency • Energy & Atmosphere • Materials & Resources • Indoor Environmental Quality • Locations & Linkages • Awareness & Education • Innovation in Design • Regional Priority through a set of prerequisites and credits

Building Rating or Certification System	**Single- or Multi-Attribute**	**Type of Standard or Certification**	**Managing Organization**	**Issues / Areas of Focus**
Green Globes	Multi-Attribute	Green building guidance and assessment program for: • Existing buildings • New construction	Green Building Initiative in the U.S. BOMA Canada	Environmental assessment areas to earn credits in: • Energy • Indoor Environment • Site • Water • Resources • Emissions • Project/Environmental Management No prerequisites.
Living Building Challenge	Multi-Attribute	Performance-based standard, and certification program for: • Landscape and infrastructure projects • Partial renovations and complete building renewals • New building construction • Neighborhood, campus and community design	International Living Future Institute	Performance areas include: • Site • Water • Energy • Materials • Health • Equity • Beauty All areas are requirements.

Building Rating or Certification System	Single- or Multi-Attribute	Type of Standard or Certification	Managing Organization	Issues / Areas of Focus
International Programs				
Building Environmental Assessment Method (BEAM) (Hong Kong)	Multi-Attribute	Comprehensive standard and supporting process covering all building types, including mixed use complexes, both new and existing to assess, improve, certify, and label the environmental performance of buildings	Business Environment Council	Performance and assessment in: • Site aspects • Material aspects • Water use • Energy use • Indoor environmental quality • Innovations and additions
BRE Environmental Assessment Method (BREEAM) (UK, EU, EFTA member states, EU candidates, as well as the Persian Gulf)	Multi-Attribute	Certification system is a multi-tiered process with pre-assessment, third-party consultant guidance through an assessment organization for: • New Construction • Communities • In Use Buildings • EcoHomes	BRE Global	Assessment uses recognized measures of performance, which are set against established benchmarks in: • Energy and water use • Internal environment (health and well-being) • Pollution • Transport • Materials • Waste • Ecology • Management processes

Building Rating or Certification System	**Single- or Multi-Attribute**	**Type of Standard or Certification**	**Managing Organization**	**Issues / Areas of Focus**
Comprehensive Assessment System for Built Environment Efficiency (CASBEE) (Japan)	Multi-Attribute	Building assessment tools for: • Pre-design • New Construction • Existing Building • Renovation	JSBC (Japan Sustainable Building Consortium) and its affiliated sub-committees	Assessment areas include: • Energy efficiency • Resource efficiency • Local environment • Indoor environment
Green Mark Scheme (Singapore)	Multi-Attribute	Benchmarking scheme that aims to achieve a sustainable built environment by incorporating best practices in environmental design and construction, and the adoption of green building technologies.	Building and Construction Authority (BCA)	Rates buildings according to five key criteria: • Energy efficiency • Water efficiency • Environmental protection • Indoor environmental quality • Other green and innovative features that contribute to better building performance

Building Rating or Certification System	**Single- or Multi-Attribute**	**Type of Standard or Certification**	**Managing Organization**	**Issues / Areas of Focus**
Green Star SA (South Africa)	Multi-Attribute	Green building rating system for: • Office • Retail • Multi-unit residential	Green Building Council of South Africa administers program; Independent assessors assess and score projects	Categories assessed in: • Management • Indoor Environmental Quality • Energy • Transport • Water • Materials • Land Use & Ecology • Emissions • Innovation
Pearl Rating System for Estidama (UAE)	Multi-Attribute	Green building rating system for: • Community • Buildings • Villas • Temporary Villas and Buildings	Abu Dhabi Urban Planning Council	Assessment of performance in: • Integrated Development Process • Natural Systems • Livable Communities • Precious Water • Resourceful Energy • Stewarding Materials • Innovating Practice

2.1.1 Energy Star

Energy Star for Buildings was introduced as part of the U.S. EPA Energy Star program in 1995 with the goal of helping facility owners improve their buildings' energy performance in addition to the various pieces of equipment that had received Energy Star ratings at that point in time. Energy Star for Buildings rates buildings relative to the typical performance of a building of the same type. The rating is based on performance on a 100 point scale in areas of Energy Consumption, Thermal Comfort, Illumination, and Ventilation for Acceptable Indoor Air Quality (Office of Air and Radiation, U.S. Environmental Protection Agency, 2011).

The Energy Star rating system does not include any specific assessment of beauty and inspiration, which is not unexpected. The areas of Thermal Comfort, Illumination, and Indoor Air Quality address aspects of human comfort and focus on meeting the appropriate ASHRAE standards or achieving required light levels with electric lighting. The aim seems to be avoiding an uncomfortable environment rather than providing a pleasing one. In addition, the energy consumption is focused more on efficiency of mechanical heating and cooling systems rather than encouraging the use of passive systems that can help connect occupants to the surrounding natural environment.

2.1.2 Leadership in Energy and Environmental Design (LEED)

The USGBC was formed in 1998 and the LEED rating system introduced in March 2000. USGBC LEED differs from the rating system used by Energy Star. Though buildings receive points for performance on different credits, the total points achieved are translated into a certification level: Certified, Silver, Gold, or Platinum. The LEED system credits are organized into seven topic areas: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design, and Regional Priority (U.S. Green Building Council, 2008) with different amounts of points available for each topic area.

LEED includes credits in areas that impact human comfort and addresses access to view as part of the Indoor Environmental Quality. In addition, the USGBC has changed over time to include topic areas such as “Innovation in Design” and also encourages LEED accredited professionals to look for opportunities for “synergies” in which systems achieve credits in more than one area. The LEED system exhibits some consideration of a pleasing occupant experience and creative design; however, no credits are specifically given for beauty and inspiration.

2.1.3 Green Globes

The Green Building Initiative introduced the Green Globes environmental assessment system in the U.S. in 2004. The Green Globes program assesses environmental performance on a 1,000 point scale for seven categories: Energy, Indoor Environment, Site, Water, Resources, Emissions, and Project/Environmental Management. Similar to LEED, the total points attained by a building are translated into a certification level ranging from one (lowest) to four (highest) globes (Green Building Initiative, 2011). In 2010, the Green Building Initiative partnered with the American National Standards Institute (ANSI) to develop a green building standard; ANSI/GBI 01-2010 Standard. The standard is currently in pilot, but mimics the Green Globes ratings system in categories and scoring. It also results in achievement levels between one and four. Green Globes assessments require registration and payment to access any of the rating tools or specific criteria, so the review of Green Globes was limited to the broad categories. However, Based on information available, there is no clear evidence of assessment of beauty and inspiration in the Green Globes rating system.

2.1.4 Living Building Challenge

The Living Building Challenge was developed by the Cascadia Green Building Council in 2006 and is now overseen, together with the Cascadia Green Building Council, by the International Living Future Institute (ILFI). The Living Building Challenge is organized into seven Petals, which are further described by Imperatives. There are a total of twenty Imperatives in the Living Building Challenge. Unlike some of the other building rating systems that include separate standards or checklists for differing building types, the Living Building Challenge employs the same Imperatives and Petals regardless of the building Typology or Living Transect. The seven Petals of the Living Building Challenge are: Site, Water, Energy, Health, Materials, Equity, and Beauty (International Living Building Institute, 2009).

The Living Building Challenge is unique among building rating systems in having beauty as a requirement in a building's assessment and has begun to draw attention to this important piece. However, the Living Building Challenge recognizes the difficulty of quantifying beauty and therefore the Imperatives used to evaluate the Beauty Petal are qualitative and rather open ended. This is a step in the right direction, but a more quantitative assessment of beauty would be valuable for further consideration relative to building science.

2.1.5 Building Environmental Assessment Method (BEAM)

The BEAM is a building rating system used in Hong Kong. The BEAM Society launched Version 1 of BEAM for New Office Designs in 1996 in response to other prominent building rating systems. The BEAM rating system was based largely upon BREEAM developed in the United Kingdom. BEAM ratings are not finalized until buildings are complete and operating, to help ensure that the buildings perform as designed. BEAM is organized into five categories, each given a different weight within the overall score: Site Aspects, Material Aspects, Energy Use, Water Use, and Indoor Environmental Quality. There is also a category available for Innovations and Additions for strategies or designs that are not captured in the existing criteria (BEAM Society, Hong Kong Green Building Council, 2010). The scores in each category are translated into an overall grade of Bronze, Silver, Gold, or Platinum.

BEAM includes assessment criteria in areas that impact human comfort, similar to other rating systems, and also includes credits for natural ventilation and daylighting. Similar to BREEAM and

LEED, a credit for innovation is offered for designs that fall outside the BEAM assessment criteria. However, no specific credits or assessment criteria are given for beauty and inspiration.

2.1.6 BRE Environmental Assessment Method (BREEAM)

The BREEAM is a building rating system used in the United Kingdom and several other European Union countries. This standard is published by BRE Global. BRE has a history stretching back to 1920 when it was known as the Building Research Board. The original intent was to form an organization to research and develop building materials, but over time this organization expanded its focus to incorporate all aspects of buildings. The Building Research Establishment was formed in 1972, and the name later changed to BRE. The BRE Environmental Assessment Method was first introduced in 1990 and has been influential in the development of several other building rating systems around the world. Like many of the rating systems spawned by BREEAM, it is organized into different sections. Each section is further defined by assessment criteria, scored, and weighted to give an overall score that is translated into a rating level. BREEAM is divided into ten sections: Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution, and Innovation. These sections are scored to give a final rating of Pass, Good, Very Good, Excellent, or Outstanding (BRE Global, 2011).

Like many other systems, BREEAM includes criteria for assessing human comfort, using the title of Health and Wellbeing to describe these items. While this may appear to be a matter of semantics, it shows an approach that is broader than merely avoiding an uncomfortable environment but that incorporates a focus on promoting overall wellbeing of occupants and providing a pleasing experience of the built environment for occupants. As with the many similar rating systems, BREEAM does not establish explicit credits for beauty and inspiration.

2.1.7 Comprehensive Assessment System for Built Environment Efficiency (CASBEE)

The Japan Green Building Council and Japan Sustainable Building Consortium first developed CASBEE in 2001 in response to other building rating systems such as BREEAM and LEED. As a result, the framework of CASBEE has many similarities to BREEAM and LEED. At the same time it has unique qualities and is noticeably more detailed in its metrics and criteria as well as its scoring algorithm.

CASBEE is organized under two main categories, Environmental Quality of the Building (Q) and Environmental Load Reduction of the Building (LR), which are divided into subcategories. Environmental Quality is divided into Indoor Environment (Q1), Quality of Service (Q2), and Outdoor Environment on Site (Q3). Environmental Load Reduction is divided into Energy (LR1), Resources and Materials (LR2), and Off-Site Environment (LR3). These subcategories are further divided into various assessment criteria that are scored on Levels 1 (worst) through 5 (best). Total scores for each criterion are weighted within a subcategory, and then subcategories are weighted relative to each other in determining scores for Q and L. Scores are reported for the various subcategories and for Q and L to show the building performance in different areas. However, the overall building rating is determined based on Building Environmental Efficiency (BEE) score, which is calculated from the scores for Q and L. Based on the BEE, a building is rated as Poor (C), Fairly Poor (B-), Good (B+), Very Good (A), and Excellent (S) (Institute for Building Environment and Energy Conservation, Japan GreenBuild Council/Japan Sustainable Building Consortium, 2008).

Due to the complexity and number of metrics, CASBEE contains some criteria that are aimed at enhancing the occupants’ experience of the built environment as well as the building’s enhancement of its surroundings. Metrics such as “Perceived Spaciousness & Access to View” and “Openings by Orientation” aim to achieve an optimal use of natural resources while also connecting the building occupants to these resources. While many other rating systems offer some criteria for enhancing building sites or providing flexible spaces, CASBEE has more detailed criteria that help guide designers such as

"Attention to Local Character & Improvement of Comfort." Still, despite the extensive metrics and elaborate rating system, specific metrics for beauty and inspiration are not included.

2.1.8 Green Mark Scheme

The Green Mark Scheme is a building rating system used in Singapore. It was first launched by the Building and Construction Authority in 2005. The Green Mark Scheme framework resembles CASBEE slightly, dividing its five parts into the categories, Energy Related Requirements and Other Green Requirements. The five parts of the Green Mark Scheme are Energy Efficiency, Water Efficiency, Environmental Protection, Indoor Environmental Quality, and Other Green Features. Like several other systems, scores in these five parts are compiled to achieve an overall score and translated into a Green Mark Rating of Certified, Gold, Gold^{Plus}, or Platinum. One unique feature of the Green Mark Scheme is that specific prerequisites must be met to achieve certain levels of certification. Many other building rating systems have prerequisites that must be met to receive points in a specific category or credit, but the Green Mark Scheme identifies prerequisites on key metrics that are needed to achieve certification levels, such as Platinum. For example, a building could have a sufficiently high overall Green Mark score to achieve a Platinum rating but not receive it because a Green Mark Platinum prerequisite was not met for a specific metric (Building Construction Authority, 2010).

The Green Mark Scheme includes assessment criteria in areas that impact human comfort, though they are not as prominent as some of the other building rating systems. The Green Mark Scheme does not contain assessment criteria for beauty and inspiration.

2.1.9 Green Star (Australia)

The Green Building Council of Australia was formed in 2002. It launched the Green Star environmental rating system in 2003. Similar to other international rating systems, the Green Star program was developed in response to systems like BREEAM and LEED. The Green Star rating system is organized into nine different categories: Management, Indoor Environmental Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions, and Innovation (Green Building Council Australia, 2009).

The Green Star Australia rating system does provide a category for innovation, which allows flexibility for unique designs and addresses human comfort as part of indoor environmental air quality, but no criteria for beauty and inspiration are used in the rating.

2.1.10 Green Star (South Africa)

The Green Building Council of South Africa was formed in 2007 and introduced the Green Star rating system in 2008, which is based on the Green Star rating system from Australia. The categories and basic assessment criteria are the same as Green Star Australia, and the same rating tool is used for both. Similar to Green Star Australia, no criteria for beauty and inspiration are used for Green Star South Africa.

2.1.11 Pearl Building Rating System

The Pearl rating system was developed in the United Arab Emirates in April 2010 and is the most newly developed rating system reviewed. The Pearl rating system is organized very much like USGBC LEED. Buildings achieve credits in seven categories, with required and optional credits in each category. Pearl ratings are given for three phases of the building process: design, construction, and operation. While this research focused on reviewing the building rating system, rating systems are also offered for communities and villas (residences). Unique factors of the Pearl rating system include a focus on outdoor thermal comfort related to private outdoor spaces, an expected emphasis on water conservation, and cool building strategies (Abu Dabi Urban Planning Council, 2010).

The Pearl rating system emphasizes sustainable buildings and development and considers occupants an important part of this sustainability. Responsiveness to both occupants and the natural environment are evident in the language used for the Pearl rating system, but no specific beauty and inspiration criteria are used.

2.2 Quantification of Beauty in Buildings

The review of building rating systems revealed that while steps have been made toward the consideration of occupant comfort and experience, few systems address beauty and inspiration as part of their rating criteria. Thus, the next step in the process was to conduct a review of literature to identify what attempts have been made to evaluate beauty in buildings. The concept of beauty is a subjective one, whether in regard to people, places, or buildings. This reality means few sources provide a quantifiable discussion or review of beauty in architecture and the built environment. Even the number of sources providing more qualitative discussion of beauty in architecture or the built environment is limited.

2.2.1 Beauty as Aesthetics

A common theme among search results for evaluating beauty in architecture or the built environment was a propensity to assess beauty purely in terms of aesthetics and not in terms of the experiential quality of inspiration in a built environment. One such example was a study entitled “Quantifying Beauty: An Information System for Evaluating Universal Aesthetics” (Sudweeks & Simoff) that uses the human face to develop a model for pleasing aesthetics.

A work that begins to investigate representation of site beauty in quantifiable means is an extensive study conducted by the U.S. Environmental Protection Agency in 1973 (Office of Research and Development, U.S Environmental Protection Agency, 1973) titled “Aesthetics in Environmental Planning.” As indicated by the title, this study focused on economic justifications for the importance and incorporation of aesthetics into the planning of sites for all forms of civil development. Although this study focuses on aesthetics, it provides an in-depth review of methods for quantifying aesthetics that had been developed at the time of writing. The studies documented in the EPA report denote the difficulty of developing metrics and logical frameworks for pleasing environmental qualities. Regarding the difficulty of evaluating the cost/benefit of environmental aesthetics it states: “outdoor recreation emphasizes values for which the true scale is qualitative, not quantitative – a scale of pricelessness rather than a price, encouraging a policy of protection rather than consumption.” While works in the area of aesthetics, such as the EPA study, provide examples of quantification methods, we are concerned with an experiential quality that is not addressed solely by aesthetics.

2.2.2 Beauty in Architecture

Narrowing the search to works investigating beauty in architecture related to human experience provided results that are more qualitative than quantitative. An article from the Journal of Landscape Architecture, “Sustaining Beauty: The Performance of Appearance – A Manifesto in Three Parts,” provides a relatively strong case for the benefits of nature and beauty to society, but quantitative evidence is not directly provided. Similarly, two recently published books that delve into the topic of architecture and human experience are “Architecture for Happiness” (De Botton, 2006) and “Why Architecture Matters” (Goldberger, 2009). While these books demonstrate an acknowledgement of the importance of the individual and collective human experience in the built environment, both books provide very general conclusions that may be viewed more as opinion rather than an empirical evaluation.

In contrast to the general approach of the books identified above, the Committee on Architecture and the Built Environment (CABE) in the United Kingdom utilized a scientific approach to understand beauty in the built environment and its impact to society. The CABE conducted focus groups, interviews, and a national survey with the aim of answering the question “What is Beauty?” and published the results in “People and Places: Public Attitudes to Beauty.” Each research medium was used to pinpoint what people identified as beautiful in their environment. Several important conclusions were found in the study conducted by the CABE. First, people relate beauty to experience, and on the whole people relate more to emotional experiences of beauty than visual experiences of beauty (Ipsos MORI/The Commission on Architecture and the Built Environment, 2010). This conclusion supports the idea of beauty in the built environment as not purely aesthetic but as an experiential quality. Many people also expressed that they feel comfortable and at ease in nature; hence, the outdoors are a great place to experience beauty for many people (Ipsos MORI/The Commission on Architecture and the Built Environment, 2010). However, while the CABE's study used fairly rigorous research methods and extensively explored the topic of beauty in a person's environment, an investigation of how beauty may impact a building's performance was not undertaken.

2.2.2.1 Center for Environmental Structure Series

Lastly, the work of Christopher Alexander and his associates in the Center for Environmental Structure Series provides a thorough and continuing exploration into architecture that inspires people and communities. The Center for Environmental Structure Series began with Alexander's landmark work that was published in three separate books: *The Timeless Way of Building*, *A Pattern Language: Towns, Buildings, Construction*, and *The Oregon Experiment.* These works still serve as fundamental references for architecture and the built environment, especially *A Pattern Language*.

The first reference in the series, *The Timeless Way of Building*, is a qualitative assessment in a structure much like a series of essays exploring what makes buildings "alive." The book is organized into three sections with multiple chapters within each section. The first section quickly identifies what is referred to as the "quality without a name" as being central to built environments that are found pleasing and inspiring for their communities. The subsequent chapters and sections focus not on defining this quality, but proposing that it can be described using common patterns or "languages" found in communities. The idea of pattern languages is presented and discussed, but the mechanics of these pattern languages are not examined in great detail. In this way, *The Timeless Way of Building* serves to describe the fundamental nature of the task of making towns and buildings (Alexander, Ishikawa, Silverstein, Jacobson, Fiksdahl-King, & Angel, 1977).

The second book in the series, *A Pattern Language: Towns, Buildings, Construction* provides a very thorough and systematic linear categorization of building practices and strategies for achieving buildings, communities, and towns that have “the quality” and can inspire people. *A Pattern Language* is also organized into three sections, which are referenced in the title: Towns, Buildings, and Construction. Within each of these sections are patterns, which describe a particular concept or feature of the built environment. Patterns vary from qualitative concepts like “Magic of the City” (Pattern 10) to more detailed and specific items like “Six-foot Balcony” (Pattern 167). There are a total of 253 patterns documented and they are ordered in a straight linear sequence from largest to smallest in order to illustrate the connections between patterns (Alexander, Ishikawa, Silverstein, Jacobson, Fiksdahl-King, & Angel, 1977). The linear organization of the patterns and the format of each pattern’s description, which includes reference to the patterns “above” and “below” it, reinforce the idea that no pattern is isolated but is supported by smaller patterns and supports larger ones. This structure illustrates the concept that the components of a building and a community are not independent of each other.

The Oregon Experiment is the third in the series and serves as a master plan for the University of Oregon. *The Oregon Experiment* explains in full practical detail how the ideas and fundamental methods defined in *The Timeless Way of Building* and *A Pattern Language* may be implemented (Alexander, Silverstein, Angel, Ishikawa, & Abrams, 1975). Several of the subsequent publications in the Center for Environmental Structure Series were of the same format – documentation of the use and implementation of *A Pattern Language* to construct buildings in a variety of communities. These publications include *The Linz Cafe*, *The Production of Houses*, and *The Mary Rose Museum*.

Sandwiched between the publications documenting and evaluating the application and use of the methods from *A Pattern Language*, *A New Theory of Urban Design* was published as the sixth volume in the series. This work applies the principles from *The Timeless Way of Building* and *A Pattern Language* to the process of city and urban planning. While *A Pattern Language* includes some discussion of cities and towns, the focus is more on a community and individual building level. *A New Theory of Urban*

Design expands to consider the city as a whole and the idea that beautiful cities have a feeling that they are somehow “organic.” The book is a first step in the task of defining a process for the task of creating wholeness in the city (Alexander, Neis, Anninou, & King, 1987).

The Center for Environmental Structure Series has since published a series under the main title *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe.* This series currently has four parts: *Book 1 – The Phenomenon of Life*, *Book 2 – The Process of Creating Life*, *Book 3 – A Vision of a Living World*, and *Book 4 – The Luminous Ground*. These works focus on geometric and spatial properties lying “behind” the patterns from *A Pattern Language* and a single process, “the centering process,” capable of producing wholeness on a variety of scales (Alexander, Neis, Anninou, & King, 1987). While these publications present ideas that are perhaps more fundamental than those in *A Pattern Language*, they are by nature more elemental, and therefore, more difficult to translate into particular building strategies.

2.3 Summary

Review of current building rating systems reveals that, other than the relatively new Living Building Challenge, very few building rating systems include beauty and inspiration as part of their evaluation criteria. Even the Living Building Challenge provides a very high-level treatment of beauty that relies heavily on the applicant’s perception and description, and does not have quantifiable means for evaluating beauty as part of the built environment. Although few building rating systems directly address beauty and inspiration, one positive trend seen in building rating systems is the addition of recognition for building systems or features that satisfy criteria in multiple categories. This is an important step toward combating the compartmentalization of building systems that may result from the checklist format and instead viewing the building and its environment as a whole.

The review of beauty in architecture provided some valuable resources with important implications. The CABE study investigating “What is Beauty?” did not directly address what may constitute beauty in the built environment, but did reinforce the idea of beauty being an experiential and not purely aesthetic quality. The CABE also observed that nature and the outdoors played a significant role in what people deemed beautiful.

Finally, the Center for Environmental Structure Series provided substantial resources centered around an observed quality that makes spaces, buildings, and communities “alive.” Of the variety of works in this series, *The Timeless Way of Building* and *A Pattern Language* document the fundamental concepts and outline the methods for producing built environments that embody this quality to inspire and be beautiful. In addition, the linear structure of *A Pattern Language* lends itself to the identification of building strategies that may be related to building energy performance.

Chapter 3

Characteristics of Beautiful Buildings

The first task in the Beauty in Building (Robles, Zhai, & Goodrum, 2012) research process of evaluating the impacts of beauty and inspiration on building energy performance was to identify features of beautiful buildings that are related to energy performance. The goal of this task is not to define what constitutes a beautiful building. Instead, it is based on the premise that beautiful buildings are recognized to exist, and that shared qualities common to and representative of such buildings can be identified. Based on the literature review, *The Timeless Way of Building* and *A Pattern Language* were identified as primary sources for further understanding and identifying characteristics of beauty in buildings. These works focus on buildings that are "alive" and produce an experiential or inspirational feeling. This matches with the definition of beauty as an experiential quality and makes *The Timeless Way of Building* and *A Pattern Language* suitable resources for establishing characteristics of beautiful buildings. The lists of characteristics were tested against actual building case studies to evaluate their validity beyond process and theory. The identification of beauty characteristics described in this chapter was led by ml Robles of the PatternMapping® institute.

3.1 Identification of Beauty Characteristics Related to Building Performance

Shared characteristics of beautiful buildings were developed based upon an in-depth study of the work of Christopher Alexander and his team in *The Timeless Way of Building* and *A Pattern Language.* For the purpose of the Beauty in Building (Robles, Zhai, & Goodrum, 2012) research, the focus was on those shared beauty characteristics that may contribute to a building's energy performance. Therefore, not all characteristics shared by beautiful buildings as described in Alexander's work were documented for use in the Beauty in Building (Robles, Zhai, & Goodrum, 2012) research. The shared characteristics of beautiful buildings were separated into two categories: Beauty Attributes and Beauty Determinants. Beauty Attributes are broad qualities of beautiful buildings that describe fundamental concepts. Beauty Determinants are building features or systems that translate the concepts of the Beauty Attributes to a level that may be related to building energy performance. In this way, the beauty characteristics were organized in a linear fashion, similar to that of *A Pattern Language*, to make them more conducive for evaluation of their impacts to building energy performance.

3.1.1 Beauty Attributes

Beauty Attributes are broad qualities of beautiful buildings that describe fundamental concepts. These qualities were developed based on a combination of ml Robles' experience as an architect and from the qualitative treatment of patterns described in *The Timeless Way of Building* supplemented by observations from *A Pattern Language*. Three Beauty Attributes were identified to describe fundamental concepts of beautiful buildings: Local, Connectivity, and Density. Each Beauty Attribute and its definition, in words borrowed from *The Timeless Way of Building*, are listed in Table 3.1.

Table 3.1: Beauty Attributes and Definitions

Beauty Attribute	**Definition**
LOCAL	Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place are reconciled within it.
CONNECTIVITY	A true relationship, free from inner contradictions, between ourselves and our surroundings.
DENSITY	Many building patterns overlap in the same physical space, without inner contradictions; the building is very dense, it has many meanings captured in a small space, through this density it becomes profound.

The Beauty Attribute of Local essentially describes how a building connects to its unique environment. All buildings connect to their environment in some way, even if it is as simple as the building foundation, exterior walls, and roof. The Local characteristic of beautiful and inspiring buildings means that they are designed and operate in response to their surrounding environment, whereas many buildings are designed and operate to either control or isolate from their surrounding environment. This responsiveness to the environment provides a connection from the built environment to the natural environment that may be observed by the occupants and connect them to the outdoor world.

The Beauty Attribute of Connectivity builds upon the concept of Local and describes how the occupants connect to the built environment. Similar to Local, all buildings connect to their occupants in some way, such as through the entry door, observing structural forms, or walking on solid flooring. The Connectivity characteristic of beautiful and inspiring buildings is that they are designed and operate to engage their occupants and involve them in the building's function, and, ultimately, connect them to the natural environment that the building is connected to. The Local and Connectivity characteristics are interdependent and together provide the important connection between occupants within a building and the surrounding natural environment that has been identified as playing a significant role for experiencing beauty (Ipsos MORI/The Commission on Architecture and the Built Environment, 2010).

The Beauty Attribute of Density describes building systems or forms that serve multiple functions and offer modest complexity that is inspiring, rather than confusing or unclear. This may be as simple as an operable window that provides both daylight and ventilation to large windowed stairways acting as entry atriums, cross floor corridors, and thermal buffers for interior rooms. LEED and other building rating systems have started encouraging this concept of density and multi-function systems, largely for their value in design and effectiveness. This density may also translate into buildings that inspire through profound complexity.

3.1.2 Beauty Determinants

Beauty Determinants are building features or systems that translate the concepts of the Beauty Attributes to a practical level that may be tied to building energy performance. Like the Beauty Attributes, the Beauty Determinants were developed based on a combination of ml Robles' experience as an architect and from the patterns described in *A Pattern Language*. Because patterns 1 through 94 address topics for towns and communities, only patterns 95 through 253, which focus on buildings and elements of building construction, were evaluated in detail for identifying Beauty Determinants. 34 patterns were identified for consideration as Beauty Determinants from the 158 patterns evaluated in the "Buildings" and "Construction" sections of *A Pattern Language*. Patterns were chosen for further consideration based on their descriptions and definitions and the potential for energy impact. For example, patterns such as "Roof Garden" (Pattern 118) or "Indoor Sunlight" (Pattern 128) were identified for potential energy impact whereas patterns such as "”Stair Seats" (Pattern 125) or "Half-Inch Trim" (Pattern 240) were not considered. The initial list of 34 patters were evaluated a second time. Several patterns were consolidated based on the linear structure of *A Pattern Language* and some were eliminated as not possessing a strong relationship to building systems or features contributing to building energy performance. Based on the evaluation of patterns, 13 Beauty Determinants were identified to translate the Beauty Attributes to building systems or features. The Beauty Determinants and their related Beauty Attributes are listed in Table 3.2.

Table 3.2: Beauty Determinants Related to Beauty Attributes

Beauty Attributes	**Beauty Determinants**
LOCAL	Optimize passive strategies to daylight interior spaces
	Optimize passive strategies for heating interior spaces
	Optimize passive strategies for cooling interior spaces
	Optimize building figure strategies for stormwater management
	Localized geographical fit
	Locally durable material
CONNECTIVITY	Building controllability: seasonal and day-night adjusting
	Optimize passive strategies for indoor-outdoor transitions
	Self-maintaining: cycles of restoration or evolution
	No waste: everything that comes into the building goes out in a useful condition
DENSITY	Multi-use: spatial use is assigned more than one function
	Multi-functional material: material is used for more than one purpose
	Multi-functional interior wall

3.1.2.1 Local

Many of the Beauty Determinants focus on passive strategies, especially those related to the Local Beauty Attribute. Passive strategies are indicative of a building designed to respond to its natural environment as discussed in the Beauty Attributes section. The first three Beauty Determinants are focused on building lighting and heating, ventilating, and air conditioning (HVAC) systems, which together make up approximately 50 percent of commercial building consumption as illustrated in Figure 3.1 (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2010).

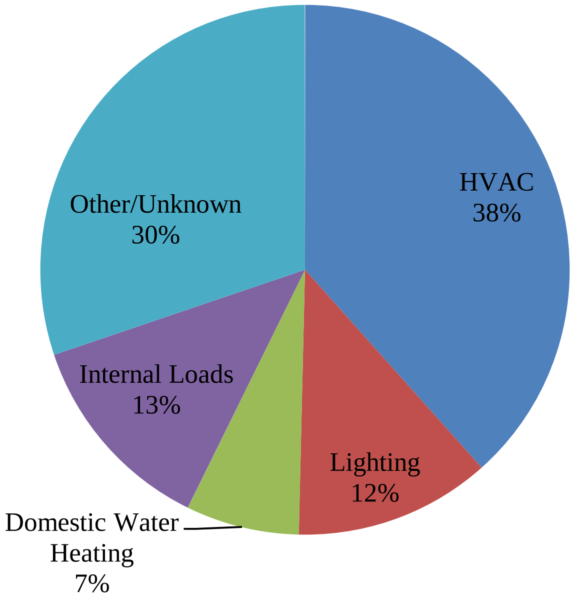

Figure 3.1: Commercial Building Energy Consumption by End Use

Given their substantial contributions to building energy consumption, reductions in the energy used for lighting and HVAC can have a significant impact on a building's energy performance. Electric lighting use is reduced by the use of daylighting, and HVAC energy use can be reduced through passive solar heating and natural ventilation strategies.

The first Beauty Determinant focuses on optimizing daylighting systems. Reductions in electric lighting resulting from the use of daylighting can provide a significant impact on building energy performance, especially considering the large percentage of building energy consumption dedicated to lighting. Passive daylighting systems typically involve windows of various forms and can also include light shelves, light tubes, or exterior slats or louvers to control and transmit daylight. Optimal strategies for daylighting may include placement and orientation of windows based on geographic location and site topography, as well as control systems designed to mitigate glare and unwanted solar gains.

The second Beauty Determinant focuses on passive heating strategies. Many of these strategies involve solar energy but the thermal mass of interior materials can also be utilized to help maintain indoor temperatures. As noted, HVAC loads represent the majority of commercial building energy consumption, so reductions in heating energy consumption can provide substantial impacts on building energy performance. Optimal passive heating strategies are often difficult to achieve in the climates where they would be most beneficial; but one example may be the use of thermal buffer zones at the building exterior designed to provide an air gap between interior spaces and the outdoors, while also taking advantage of solar energy gains on southern faces (for the northern hemisphere).

The third Beauty Determinant focuses on passive cooling strategies, which usually include ventilation. Together with the second Beauty Determinant, passive cooling stands to provide substantial savings due to the large percentage of building energy use related to HVAC. Passive cooling strategies often rely on the use of natural ventilation when appropriate, commonly in the form of operable windows but more sophisticated thermal chimney systems can also be used. Optimal strategies for cooling and ventilation are similar to daylighting and include consideration for placement and orientation of windows based on geographic location and site topography. Systems relying on operable windows may include automated window control algorithms, but this removes a level of control from occupants which they may find desirable.

The fourth Beauty Determinant focuses on management of stormwater and water runoff from a building and building site. Water runoff has several environmental impacts including flooding problems and transportation of pollutants to surface waters. In relation, water use in the building sector was estimated at 39.6 billion gallons per day, which is nearly 10% of total water use in the United States (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2010). Drawing off excessive amounts of water leads to a drop in the water table, which can have a considerable detrimental effect on local ecosystems (Hegger, Fuchs, Stark, & Zeumer, 2008). Stormwater management may help alleviate building water needs by contributing to landscape irrigation and, where rainwater capture is allowed, be used for some domestic water applications.

The fifth Beauty Determinant focuses on how a building fits within, and contributes to, its surrounding environment. This may be surrounding natural environment in a rural or even suburban setting, or surrounding social and built environment in an urban setting. The building may be integrated within the site topography or take into account specific site features, such as trees or other structures, in the building form which can have impacts on energy consumption. Items such as the conservation and restoration of habitat on a site, heat island effects, or light pollution may have impacts on the energy performance of the building as well as the energy performance of surrounding buildings.

The sixth Beauty Determinant focuses on building materials. The embodied energy, or the energy used during the entire life cycle of a product including manufacturing, transporting, and disposing (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2010), of building materials has become an important part of a building's life cycle assessment. Selecting materials that are not only manufactured nearby, but that are designed for durability and longevity in a given climate, helps reduce the embodied energy and ultimately the environmental impact of the building. In addition, local durable materials with high mass, such as concrete, may also improve the energy performance of the building as a source of thermal mass to help maintain interior temperatures. The use of reclaimed or reused materials can provide an even greater improvement to building environmental performance.

3.1.2.2 Connectivity

The seventh Beauty Determinant focuses on the ability to control building components or systems to respond to changes in the surrounding environment. These changes may be regular and sustained, such as diurnal or seasonal changes, or may be acute or periodic, such as visual or auditory distractions outdoors or storms passing through. The control mechanisms may provide full control to occupants, such as a simple operable window, or may be fully automated such as window shades or louvers that automatically adjust for the position of the sun to mitigate glare and solar gain. Adjusting to changes in the surrounding environment can allow the building to take advantage of opportunities to reduce energy consumption of electric or mechanical systems.

The eighth Beauty Determinant focuses on spaces that encourage, and perhaps blur, the transition between the built environment and the surrounding environment. These transition spaces can have a variety of forms, and can function to bring the indoors out, such as a garden courtyard providing separation between a building and a streetscape, or may bring the outdoors in, such as a space with large doors that can be opened in good weather to form a “patio” like space inside the building. Transitional outdoor spaces with vegetated landscapes have an impact on environmental performance through restoration of habitats and stormwater reductions compared to hardscape, and may help reduce the heat island effect which can impact a building’s energy performance. Transitional indoor spaces, when coupled with natural ventilation, provide seasonal opportunities for reducing building energy consumption.

The ninth Beauty Determinant focuses on the adaptability and durability of building features. The building features may include materials, producing some overlap with the sixth Beauty Determinant, but an emphasis is placed on whole features. Examples include the reuse of partial or complete building structures, flexible building spaces that can easily adapt to changing needs, or even water systems that are fed by precipitation, adapting and enduring through seasons. As building features weather or are reconfigured, they convey the passage of time to building occupants and provide a connection to the building and its history. Similar to the sixth Beauty Determinant, the reuse of existing buildings or components improves environmental performance and may impact building energy performance as well.

The tenth Beauty Determinant focuses on the reduction of waste and reuse of items or materials normally considered waste. This can be in form of reuse of materials, such as the common example where building or paving materials of an existing site are crushed and used as fill for a new building foundation. Another example is the use of building greywater for irrigation or toilet flushing, if allowed, which reduces the total water consumption of the building. The reduction of waste has an environmental impact that can be increased to the building’s benefit when items are reused or repurposed. In the case of reused or repurposed material, the tenth Beauty Determinant may overlap with the sixth and ninth Beauty Determinants.

3.1.2.3 Density

The eleventh Beauty Determinant focuses on spaces that serve multiple purposes. These spaces provide flexibility in arrangement of furniture and occupant circulation, and may serve as both private and public arenas. Multi-functional spaces may have an impact on building energy performance by reducing the building footprint through the consolidation of space types into a single area.

The twelfth Beauty Determinant focuses on materials that serve multiple purposes. Examples of such materials are structural steel, wood, or concrete members with no additional finishes, serving a function as structural materials as well as interior finishes and available thermal mass. Another example would be staircases or interior partitions that are transparent or translucent, serving as interior walls or stairs and also as “windows” to allow daylight transmission to other interior spaces. Multi-functional materials may impact building energy performance by reducing the materials used within a building and, in the example of translucent partitions, reducing energy use for lighting and heating as a result of solar energy.

The thirteenth Beauty Determinant focuses on interior walls that serve multiple purposes. The above example of transparent or translucent partitions is a good demonstration of multi-function interior walls. Other examples include movable walls within a multi-functional space that serve as bookshelves for a library, but can be moved aside to reveal a stage and transform the library into an auditorium. Similar to the other Density related Beauty Determinants, the multi-functional interior walls contribute to building energy performance through the reduction of building materials and in some cases the reduction of building footprint as a result of multiple purposes being served by one object.

3.2 Qualitative Evaluation of Beauty Characteristics

After the Beauty Attributes and Beauty Determinants were established, a qualitative analysis was performed to validate the beauty characteristics as well as to explore differences between a sample of buildings. The Beauty Attributes and Beauty Determinants were organized into a matrix to allow evaluation of building case studies. Table 3.3 shows the matrix used for qualitative case study evaluation with one blank row that would be populated with information from a building case study. Beauty Determinants are organized based on their related Beauty Attribute, with definitions of the Beauty Attributes included for reference. The BiB Matrix (Robles, Zhai, & Goodrum, 2012) development was led by ml Robles and is included with permission of the PatternMapping® institute.

Table 3.3: Beauty Characteristics Matrix

		LOCAL: Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place are reconciled within it.						DENSITY: Many building patterns overlap in the same physical space, without inner contradictions, the building is very dense, it has many meanings captured in a small space, through this density it becomes profound.			CONNECTIVITY: A true relationship, free from inner contradictions, between ourselves and our surroundings.			
BUILDING & LOCATION	RATING	Optimize passive strategies to daylight interior spaces.	Optimize passive strategies for heating.	Optimize passive strategies for cooling.	Optimize building figure strategies for stormwater management.	Localized geographical fit.	Locally durable material.	Multi-use: Spatial use is assigned more than one function.	Multi-functional material: Material is utilized for more than one purpose.	Multi-functional interior wall: Walls used for more than one function.	Building controllability: seasonal adjusting; day-night adjusting.	Optimize passive strategies for indoor-outdoor transitions.	Self-maintaining: cycles of restoration or evolution.	No waste: everything that comes into the building goes out in a useful condition.

3.2.1 Initial Case Study Comparison, Beauty in Building

To perform the qualitative analysis using the beauty characteristics matrix, a sample of building case studies was selected. Because high performing buildings are a common goal for many newly constructed buildings, case studies were selected from a population of LEED Platinum certified buildings. The population of LEED Platinum certified buildings should represent the highest performing buildings within the United States based on the wide use and acceptance of the USGBC LEED rating system. LEED Platinum buildings were chosen under the premise that if improvements in building energy performance attributable to beauty and inspiration are seen among the highest performing buildings, these improvements should also translate to other buildings and may even result in greater improvements in building energy performance.

Beautiful and inspiring buildings were represented from among the LEED Platinum certified buildings as those which have also been selected as Top Ten Projects by the American Institute of Architects (AIA) Committee on the Environment (COTE). Because architects place special importance on beauty in the built environment, the AIA COTE was considered to be a sound authority on selecting beautiful and inspiring buildings. The AIA summarizes the COTE mission as:

> The COTE works to advance, disseminate, and advocate – to the profession, the building industry, the academy, and the public – design practices that integrate built and natural systems and enhance both the design quality and environmental performance of the built environment. COTE serves as the community and voice on behalf of AIA architects regarding sustainable design and building science and performance.
>
> (The American Institute of Architects)

Case study information for each building in the sample was obtained from the USGBC LEED online project directory (U.S. Green Building Council) and AIA/COTE Top Ten Project listing online (The American Institute of Architects). Nine LEED Platinum case studies together with ten AIA COTE Top Ten selected LEED Platinum case studies were obtained, giving a total of 19 buildings for the qualitative analysis of the beauty characteristics. The case studies all follow the same format, making comparison between the sample sets simple. The case studies are organized into 12 sections: Overview, Process, Finance, Land Use, Site and Water, Energy, Materials, Indoor Environment, Images, Ratings and Awards, Lessons, and Learn More. All but the Ratings and Awards, Lessons, and Learn More sections were utilized for the case study evaluation. Brief explanations of each case study section follow.

The Overview provides a profile of the project and highlights the key design features. The Process section provides information about the design process and project team. An often noted theme among all of the projects is an integrated design approach. The Finance section provides basic cost information for the project. The Land Use section discusses how the project fits within and relates to the surrounding environment and community. The Site and Water section focuses on the specifics of the site, such as restoration of brownfield sites, landscape improvements, and water conservation and use, including stormwater management. The Energy section discusses strategies and systems designed to reduce energy consumption for the project and in most cases provides energy use data for the project. For some projects, energy use data is based on actual operation, but for many it is based upon simulated operation of building energy models. The Materials section discusses the sources and manufacture of materials used in the project and often includes discussion of waste recycling programs employed during construction. The Indoor Environment section discusses a combination of indoor air quality and ventilation as well as floor layouts and daylighting strategies. The Images section includes items ranging from simple photographs of building exteriors and interiors, to photographs of key building features, to schematics, elevations, and energy or daylight modeling graphical results.

For each project, the case study was reviewed from the Overview to the Images section, and building systems or features that represented the Beauty Determinants were recorded in the matrix shown in Table 3.3. For a given case study, building systems or features that represented a given Beauty Determinant were described in the bottom of the two rows and an “x” placed in the top row when an appropriate Beauty Determinant was present. Information for each building case study was entered in subsequent rows. The full matrix with all 19 case study evaluations is included in Appendix A.

3.2.1.1 LEED Platinum

USGBC LEED maintains an online database of LEED certified projects and case studies. The case studies were recently added and are only available for a limited number of LEED certified projects. BuildingGreen.com also maintains a similar database of project case studies that was used for a few select project case studies that were unavailable from the USGBC LEED project database. At the time of the qualitative analysis conducted for the Beauty Characteristics Matrix, only nine LEED Platinum certified buildings that were not also selected as AIA COTE Top Ten projects had available case studies. Table 3.4 outlines the basic profile for each of these nine projects.

Table 3.4: LEED Platinum Case Studies

	**Audubon Center at Debs Park** Los Angeles, CA Interpretive Center LEED NC 2.1 – Platinum

	**Blackstone Office Renovation** Cambridge, MA Commercial Office LEED NC 2.1 – Platinum
	**Chicago Center for Neighborhood Technology (CNT)** Chicago, IL Commercial Office LEED NC 2.1 – Platinum
	**Greensburg Business Incubator** Greensburg, KS Commercial Office LEED NC 2.2 – Platinum

	**Half-Moon Outfitters Distribution Center** North Charleston, SC Industrial/Commercial Office LEED NC 2.1 – Platinum
	**Home on the Range** Billings, MT Commercial Office LEED NC 2.1 – Platinum
	**Inland Empire Utilities Agency (IEUA) Headquarters** Chino, CA Commercial Office LEED NC 2.1 – Platinum

	**National Resources Defense Council (NRDC) Santa Monica Office** Santa Monica, CA Commercial Office LEED NC 2.1 – Platinum
	**NREL Science and Technology Facility** Golden, CO Laboratory/Commercial Office LEED NC 2.1 – Platinum

3.2.1.2 LEED Platinum + AIA COTE Top Ten

The AIA COTE maintains a website dedicated to the Top Ten Projects which includes case studies for nearly all of the Top Ten for each year. Ten of the AIA COTE Top Ten projects from various years that were LEED Platinum certified were selected for evaluation and comparison with the LEED Platinum only buildings. Table 3.5 outlines the basic profile for each of these ten projects.

Table 3.5: LEED Platinum + AIA COTE Top Ten Case Studies

	**Alberici Corporate Headquarters** Overland, MO Commercial Office LEED NC 2.1 – Platinum AIA COTE Top Ten – 2006
 EXHIBIT L ALDO LEOPOLD LEGACY CENTER *Overall Courtyard View*	**Aldo Leopold Legacy Center** Baraboo, WI Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2008
	**Chartwell** Seaside, CA Education LEED NC 2.1 – Platinum AIA COTE Top Ten – 2009

	**Chesapeake Bay Foundation (CBF) Phillip Merrill Environmental Center** Annapolis, MD Interpretive Center/Commercial Office LEED NC 1.0 – Platinum AIA COTE Top Ten – 2001
	**Hawaii Gateway Energy Center** Kailua-Kona, HI Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007
	**Heifer International Headquarters** Little Rock, AR Commercial Office LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007

	**Jewish Reconstructionist Congregation** Evanston, IL Assembly LEED NC 2.1 – Platinum AIA COTE Top Ten – 2009
	**Queens Botanical Garden Visitor Center** Flushing, NY Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2008
	**Sidwell Friends Middle School** Washington, D.C. Education LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007

	**Yale Sculpture Building and Gallery** New Haven, CT Higher Education LEED NC 2.1 – Platinum AIA COTE Top Ten – 2008

3.2.2 Results

For each Beauty Determinant, the number of projects with building features representing them were totaled to understand how achievable each was. Results for the LEED Platinum only and the LEED Platinum + AIA COTE Top Ten projects were compared to understand whether differences existed between the high performing and the inspiring and high performing buildings. The results of these analyses are shown in Table 3.6.

Table 3.6: Initial Case Study Evaluation Results – Beauty Determinants

	LOCAL: Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place are reconciled within it.						DENSITY: Many building patterns overlap in the same physical space, without inner contradictions, the building is very dense, it has many meanings captured in a small space, through this density it becomes profound.			CONNECTIVITY: A true relationship, free from inner contradictions, between ourselves and our surroundings.			
	Optimize passive strategies to daylight interior spaces.	Optimize passive strategies for heating.	Optimize passive strategies for cooling.	Optimize building figure strategies for stormwater management.	Localized geographical fit.	Locally durable material.	Multi-use: Spatial use is assigned more than one function.	Multi-functional material: Material is utilized for more than one purpose.	Multi-functional interior wall: Walls used for more than one function.	Building controllability: seasonal adjusting; day-night adjusting.	Optimize passive strategies for indoor-outdoor transitions.	Self-maintaining: cycles of restoration or evolution.	No waste: everything that comes into the building goes out in a useful condition.
Total Number Representing Determinant	18	9	16	19	6	11	10	6	1	7	5	6	10
Total Number LEED Platinum + AIA COTE Top Ten Representing Determinant	10	5	10	10	5	6	7	5	1	6	4	5	4
Total Number LEED Platinum Representing Determinant	8	4	6	9	1	5	3	1	0	1	1	1	6
Total Percent Represented	95%	47%	84%	100%	32%	58%	53%	32%	5%	37%	26%	32%	53%
Total Percent LEED Platinum + AIA COTE Top Ten Represented	100%	50%	100%	100%	50%	60%	70%	50%	10%	60%	40%	50%	40%
Total Percent LEED Platinum Represented	89%	44%	67%	100%	11%	56%	33%	11%	0%	11%	11%	11%	67%
Percent of Total Represented that are LEED Platinum + AIA COTE Top Ten	56%	56%	63%	53%	83%	55%	70%	83%	100%	86%	80%	83%	40%
Percent of Total Represented that are LEED Platinum	44%	44%	38%	47%	17%	45%	30%	17%	0%	14%	20%	17%	60%

For each project, the number of Beauty Determinants represented was totaled for each Beauty Attribute. To evaluate the effectiveness of the Beauty Attributes, the number of projects having more than 80 percent of the Beauty Determinants related to a Beauty Attribute were totaled. The results of this analysis are shown in Table 3.7.

Table 3.7: Initial Case Study Evaluation Results – Beauty Attributes

	Percent of "Local" Determinants Represented	Percent of "Density" Determinants Represented	Percent of "Connectivity" Determinants Represented
Total Number Representing >80% of Attribute	6	0	3
Number LEED Platinum + AIA COTE Top Ten Representing >80% of Attribute	4	0	3
Number LEED Platinum Representing >80% of Attribute	2	0	0

3.3 Conclusions for Beauty Characteristics Case Study Evaluation

The case study analysis of the beauty characteristics was performed as an initial qualitative analysis to validate the Beauty Attributes and Beauty Determinants. A second motive of the analysis was to understand whether differences might be observed between the high performing and the inspiring and high performing buildings. The analysis was considered a scoping study and therefore the level of detail in assigning representative building features to Beauty Determinants was a cursory evaluation. It is possible that some representative features were not effectively captured in the evaluation, but the overall results are still considered representative of the individual projects and the overall building populations.

3.3.1 Building Population Comparison

The results of the initial case study evaluation reveal a difference between the high performing and the inspiring and high performing buildings. Both building populations had a majority of projects with building features that represented Beauty Determinants related to the Local Beauty Attribute, particularly for the Beauty Determinants focused on daylighting, passive cooling strategies, stormwater management, and materials. However the inspiring and high performing buildings had greater representation for the Beauty Determinants related to the Density and Connectivity Beauty Attributes, with the exception of the Beauty Determinant focused on reducing waste.

Based on the results of the initial case study evaluation and the definitions of the Beauty Attributes, it appeared that while high performing buildings are connected to their surrounding environment, that the inspiring and high performing buildings also fostered a connection to their occupants and include a density of features and systems that may not be present in the typical high performing building. These initial conclusions of differences related to beauty and inspiration required further investigation, which is the topic of the balance of this research.

3.3.2 Beauty Characteristics Validation

The results of the initial case study evaluation also revealed some differences between the Beauty Attributes and the Beauty Determinants. Because the beauty characteristics were developed to represent inspiring and high performing buildings, the results of the LEED Platinum + AIA COTE Top Ten projects were used exclusively in their validation. Results were used to refine the Beauty Attributes and Beauty Determinants and compile a list of each after they were tested against actual building projects.

3.3.2.1 Beauty Attributes

The results in Table 3.7 were used to validate the Beauty Attributes originally developed. The results indicate that the Local Beauty Attribute had the strongest representation, followed by the

Connectivity Beauty Attribute. Surprisingly, the Density Beauty Attribute had weak representation across any single project. One consideration was that while Density is a real phenomenon it may not be readily measurable in the form presented. Based on the results, the Local and Connectivity Beauty Attributes were retained and the Density Beauty Attribute subjected to further scrutiny and consideration.

3.3.2.2 Beauty Determinants

The results in Table 3.6 were used to validate the Beauty Determinants identified based on Christopher Alexander's work. All Beauty Determinants were represented by at least 40 percent of projects with the exception of the Beauty Determinant focused on multi-functional interior walls. Several Beauty Determinants even had representation of better than 50 percent of projects; these were the first, third, fourth, sixth, seventh, and tenth.

In the context of the results for the Beauty Attributes and the poor representation of the Beauty Determinant representing multi-functional interior walls, the scope of all Beauty Determinants related to the Density Beauty Attribute were reconsidered. A reasonable amount of overlap was seen between all three Beauty Determinants related to the Density Beauty Attribute, supporting a move to consolidate all three.

In addition, the Beauty Determinants related to Density were also related to the Beauty Determinant focused on the adaptability and durability of materials. Adaptability and ease of reconfiguration are necessary requirements of multi-use spaces. Multi-use spaces are often composed of adaptable and durable materials, which are multi-use materials, and frequently utilize multi-functional interior walls. For the example of multi-functional materials and walls being exposed structural elements, this relates to the display of aging and passage of time associated with durability. The Beauty Determinant for multi-functional materials was also related to the Beauty Determinant focused on materials because reclaimed and reused materials are an excellent example of multi-functional materials.

Based on these results, the Beauty Determinants related to the Density Attribute were considered to be sufficiently represented by other existing Beauty Determinants related to the Local and Connectivity Beauty Attributes and were eliminated as independent Beauty Determinants.

3.3.2.3 Beauty Filters

While the results of the initial case study evaluation indicated weak representation of the Density Beauty Attribute and supported consolidation of its related Beauty Determinants, the characteristic of density and modest complexity was considered by research members to be an important aspect of beauty and inspiration. Further review and discussion led to the development of a new category for beauty characteristics to be used in the matrix: Beauty Filters. Beauty Filters are not specific building systems or components, but features of beautiful and inspiring buildings that lie behind the systems and components. The Density Beauty Attribute was repurposed as the first Beauty Filter. The second Beauty Filter was based on physical engagement with the built environment. The two Beauty Filters are listed in and defined in Table 3.8.

Table 3.8: Beauty Filters and Definitions

Beauty Filter	**Definition**
DENSITY	Many building patterns overlap in the same physical space, without inner contradictions; the building is very dense, it has many meanings captured in a small space, through this density it becomes profound (strategy must be part of a system: multi use, multi function).
SENSE	Strategy must be experienced by a physical engagement or in a sensory accessible manner (by sight, touch, smell, and/or sound)

The Beauty Characteristics Matrix given in Table 3.3 was revised to include the Beauty Filters for use in evaluating beauty and inspiration in the built environment. The revised matrix is provided in Table 3.9. The Beauty Characteristics Matrix development was led by ml Robles and is included with permission of the PatternMapping® institute.

Table 3.9: Revised Beauty Characteristics Matrix

<table>
<tr><td colspan="2"></td><td colspan="10">**BEAUTY ATTRIBUTES: built environment qualities that make us feel fully alive**</td></tr>
<tr><td colspan="2"></td><td colspan="6">LOCAL: Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place are reconciled within it.</td><td colspan="4">CONNECTIVITY: A true relationship, free from inner contradictions, between ourselves and our surroundings.</td></tr>
<tr><td colspan="2"></td><td colspan="10">**DETERMINANTS: an element that determines the nature of something or fixes an outcome**</td></tr>
<tr><td>**PROJECT**</td><td></td><td>**1:** Optimize passive strategies to daylight interior spaces.</td><td>**2:** Optimize passive strategies for heating interior spaces.</td><td>**3:** Optimize passive strategies for cooling interior spaces.</td><td>**4:** Optimize building figure strategies for stormwater management.</td><td>**5:** Localized geographical fit.</td><td>**6:** Locally durable material.</td><td>**7:** Building controllability: seasonal adjusting; day-night adjusting.</td><td>**8:** Optimize passive strategies for indoor-outdoor transitions.</td><td>**9:** Self-maintaining: cycles of restoration or evolution.</td><td>**10:** No waste: everything that comes into the building goes out in a useful condition.</td></tr>
<tr><td rowspan="12"></td><td>fill if included</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">List building strategies used</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td rowspan="2">FILTERS: strategies must meet these 2 conditions to be considered</td><td colspan="10">SENSE: Strategy must be experienced by a physical engagement or in a sensory accessible manner (by sight, touch, smell, and/or sound)</td></tr>
<tr><td colspan="10">DENSITY: Many building patterns overlap in the same physical space, without inner contradictions, the building is very dense, it has many meanings captured in a small space, through this density it becomes profound. (strategy must be part of a system: multi use, multi function)</td></tr>
<tr><td rowspan="2">fill if meet criteria
high perf:regen pts</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">List building strategies that meet filter criteria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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Chapter 4

Metrics for Evaluating Beautiful Building Energy Performance

4.1 Development of Evaluation Metrics

The next stage of the Beauty in Building (Robles, Zhai, & Goodrum, 2012) research concentrated on developing metrics for evaluating building energy performance with respect to the Beauty Determinants. This work builds upon the final Beauty Characteristics Matrix that was developed in Chapter 3. The metrics will be incorporated into the Beauty Characteristics Matrix in Table 3.9 with the purpose of providing easily determinable means of evaluating energy performance of beautiful buildings and the building systems or features that make up the Beauty Determinants that are common to beautiful and inspiring buildings.

4.1.1 Review of Building Performance Metrics of Existing Building rating systems

Energy performance metrics are used in all of the building rating systems reviewed in Section 2.1 and these building rating systems were relied on as the primary sources for compiling a list of metrics. Due to the extensive detail of the metrics for the CASBEE assessment system from Japan, it served as a primary source for developing energy metrics. In addition to CASBEE, the USGBC LEED rating system was relied on heavily as the prominent U.S. building assessment system. The Collaborative for High Performance Schools (CHPS) was also used as a reference as a prominent assessment system in the area of education. The metrics from CASBEE were compared and contrasted with those from USGBC LEED and the CHPS to develop a working list of building energy performance metrics for evaluating beautiful and inspiring buildings.

4.1.1.1 CASBEE-NCe 2008

The structure of CASBEE for New Construction, 2008 Edition, was briefly introduced in Section 2.1.7 and the main categories and subcategories introduced. In total, there are five levels of criteria that make up the CASBEE framework, beginning with the two main categories of Environmental Quality of the Building (Q) and Environmental Load Reduction of the Building (LR). Following the main categories are six subcategories: Environmental Quality includes Indoor Environment (Q1), Quality of Service (Q2), and Outdoor Environment on Site (Q3); Environmental Load Reduction is divided into Energy (LR1), Resources and Materials (LR2), and Off-Site Environment (LR3). These subcategories are divided into a variety of criteria, and some of these criteria are further divided into even more specific criteria. In total, there are 70 criteria defined for the Environmental Quality category and 38 criteria for the Environmental Load Reduction category (Institute for Building Environment and Energy Conservation, Japan GreenBuild Council/Japan Sustainable Building Consortium, 2008). Each of these 108 criteria includes a full definition, and in many cases methodology for evaluation and scoring.

4.1.1.2 LEED 2009 for New Construction

The structure of LEED 2009 for New Construction was also discussed in Section 2.1.7. The LEED system credits are organized into seven topic areas: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design, and Regional Priority. These topic areas are defined by individual credits (and prerequisites) that include full definitions and basic methodologies for evaluation. Topic areas may have as few as one credit or as many as many as 15, not including prerequisites which must be met to achieve any points within a topic area. There are a total of eight prerequisites and 49 credits defined in LEED 2009 for New Construction (U.S. Green Building Council, 2008). As expected, the LEED credits typically have broader scopes than the

CASBEE criteria; however, CASBEE does address some items not included in LEED, such as acoustics and acoustic comfort.

4.1.1.3 Collaborative for High Performance Schools 2009 Criteria

Similar to LEED, the CHPS criteria (Colorado Collaborative for High Performance Schools, 2009) are organized into seven categories: Leadership, Education, and Innovation, Sustainable Sites, Water, Energy, Climate, Materials and Waste Management, and lastly Indoor Environmental Air Quality. Like the CASBEE criteria, each of these categories is divided into subcategories. Each subcategory includes a description of the intent, a definition of the requirements and associated points, a description of how to apply for and achieve points for the subcategory, a list of eligible project types, and a short list of useful references. There are 71 criteria spread across the subcategories and 16 of these are prerequisites for CHPS certification. Like the LEED credits, the CHPS criteria were used for comparing and contrasting with the CASBEE criteria for consistency and to identify opportunities for consolidation of metrics and criteria.

4.1.2 Compilation of Metrics Related to Beauty Determinants

The CASBEE criteria were reviewed and compared to the ten Beauty Determinants to identify any criteria that may be related to the systems represented by the Beauty Determinants. A list of 36 CASBEE criteria was developed for use as potential metrics to evaluate energy performance of building strategies representing the Beauty Determinants. These criteria were then compared and contrasted to the CHPS criteria and the LEED credits to validate their inclusion as well as to identify any areas of overlap among criteria that could present opportunities for consolidation. The list of 36 CASBEE criteria was refined to a final list of 22 metrics incorporating aspects of CASBEE, LEED, and CHPS. Table 4.1 contains the final list of 22 metrics that was compiled based on the CASBEE and CHPS criteria and LEED credits.

Table 4.1: Evaluation Metrics and Descriptions

Metric	**Description**	**Related Beauty Determinants**
Building Thermal Load	The efforts to improve the reduction of thermal gains and losses due to insolation and interior-exterior temperature gradients, and thermal load control as a means of reducing energy consumed by cooling and heating.	1, 2, 3, 5, 7, 8
Building Envelope Performance	The ability to block thermal infiltration from the surroundings: whether window systems and exterior walls have been selected to exclude outside disturbances as far as possible, in order to maintain room temperature.	2, 3, 5, 7, 8
Daylight Control	Measures against glare produced by direct sunlight: are there eaves, awnings, screens, curtains, blinds, shades, and similar elements around openings.	1, 5, 7, 8
Direct Use of Natural Forces	The unconverted use of natural forces such as sun, light, and wind as appropriate.	1, 2, 3, 5, 7, 8, 9
Daylighting	The effective use of daylight to maintain illuminance for occupants and required tasks during daytime hours. Encourages awareness of day, night and season cycles.	1, 3, 5, 7, 8, 9
Openings by Orientation	The orientation of apertures make use of daylight, solar energy, encourage ventilation, and do not contribute to building thermal load.	1, 2, 3, 5, 7, 8
Natural Ventilation	Whether indoor air temperature and ventilation can be maintained with building features.	1, 3, 5, 7, 8
Outside Air Intake/Building Air Exchange	Outside air intakes designed to take in the best outside air available (clean, temperate, no foul odor).	3, 8
Stormwater Use Directly Attributed to Building Figure	Building figure collects and directs stormwater.	4, 5

Metric	Description	Related Beauty Determinants
Stormwater Discharge	Stormwater permeation measures and temporary storage measures limit rainwater runoff flow.	4, 5, 9
Greywater Use System	The level of greywater use.	9, 10
Efforts to Enhance the Durability/Reusability	The levels of reuse of building structural elements and reducing building material waste and promote local building material reuse during construction, renovation, or disassembly.	6, 9, 10
Design for Adaptability	Provide spaces that are adaptable and flexible.	9, 10
Durability of Structural Frame Materials	The interval at which failure of structural frame materials to fulfill their functions necessitates major repair work to maintain function.	6, 9, 10
Durability of Main Interior and Exterior Finishes	The interval at which failure of interior finishes and exterior walls to fulfill their functions necessitates repair work to maintain function.	6, 9, 10
Use of Recycled Materials	Recycled, reclaimed, or reused materials for building structure and for building components.	6, 9, 10
Building Waste	Efforts to reduce the generation of waste when the building is in operation.	10
Preservation and Creation of Biotope	The efforts made for conservation and creation of habitat by the building, with a view to conserving and regenerating the natural environment and securing biodiversity.	4, 5
Attention to Local (Urban) Character	The impact of the building and site on the surrounding urban context and scenery, and what kind of contribution it makes to improving them. Evaluate efforts such as continuation of local history, contribution to city and district amenities, activities, and vitality, formation of rich intermediate spaces and a living environment with a high level of local amenity.	4, 5, 8

Metric	**Description**	**Related Beauty Determinants**
Light Pollution	Light pollution caused by buildings including exterior lights at night, light spill from the interior, lighting for advertising displays, etc.	5, 8
Improvement of the Thermal Environment on Site	Measures to assist in reducing the thermal load on areas both inside and outside the site in order to alleviate the on-site thermal environment.	3, 5
Reflected Solar Glare from Building Walls	Measures to mitigate the glare cast on the surrounding area by reflection of daylight from building walls.	5, 8

4.1.3 Discrete Criteria and Categories

In pursuit of easily determinable means for evaluation, the metrics were supplemented with simple and discrete criteria. These criteria were inspired by, and modeled after, the Society of Building Science Educators version of the Malcolm Wells Environmental Checklist shown in Figure 4.1 (Society of Building Science Educators, 2009). This checklist evaluates projects in four main categories (planet, site, building, culture) each described by multiple criteria. The criteria are scored on a between -100 and 100 in increments of 25 using a qualitative scale based on frequency of occurrence. Simple and clear definitions are provided for the lower and upper bounds of each criterion. The scoring relates to projects being classified as degenerative, sustainable, or regenerative.

Regeneration-Based Checklist for Carbon-Neutral, Zero Net Energy Design and Construction

Project:

		degeneration		sustainability					regeneration		
		-100 always	-75 usually	-50 sometimes	-25 a bit	0 balances	25 a bit	50 sometimes	75 usually	100 always	
planet	destroys the planet										regenerates the planet
	consumes energy disproportionately										consumes energy equitably
	serves few										serves many
	differentiates man-made and natural										conflates man-made and natural
	imports all its energy										exports energy from site
	emits carbon										sequesters carbon
site	pollutes air										cleans air
	pollutes water										cleans water
	wastes rainwater										harvests rainwater
	is built on a greenfield										is built on a brownfield
	consumes food										produces food
	destroys rich soil										creates rich soil
	dumps wastes unused										uses wastes as resources
	destroys wildlife habitat										provides wildlife habitat
	lacks site integration										is integral to the site
	decreases density										increases density
	promotes fuel-powered transportation										promotes pedestrian and transit access
	creates uncomfortable micro-climates										creates comfortable micro-climates
building	ignores building size issues										optimizes building size
	excludes natural light										uses natural light effectively
	uses mechanical heating and cooling										uses passive heating and cooling effectively
	is unconcerned with performance										monitors and improves performance
	discourages user control of systems										encourages user control of systems
	produces human discomfort										enhances human comfort
	uses inefficient equipment										uses highly efficient equipment
	uses non-renewable fuel-powered circulation										uses benignly powered circulation
	pollutes indoor air										enhances indoor air quality
	needs cleaning and repair										maintains itself
	uses high-carbon materials										uses carbon-sequestering materials
	is designed for demolition										is designed for disassembly
	uses materials wastefully										uses materials carefully
	cannot be recycled or reused										can be recycled or reused
culture	serves as an icon for the apocalypse										serves as an icon for regeneration
	discourages community interaction										encourages community interaction
	is socially and ecologically exclusive										is socially and ecologically inclusive
	is a bad neighbor										is a good neighbor
	is crassly ugly										is sublimely beautiful

negative score 3700 possible		positive score 3700 possible

final score:

Figure 4.1: Malcolm Wells Checklist for Design and Construction – Updated for Carbon Considerations

Based on the concept and form of the Malcolm Wells Checklist in Figure 4.1, criteria were developed for each of the 22 metrics using three categories: conventional, high performing (0), and regenerative (+). The conventional category was deemed to represent a simply code compliant building that does little or nothing to improve its surrounding environment through its presence or performance. The high performing category represents buildings such as the LEED Platinum certified buildings that are designed to have reduced impacts to their surrounding environment and may provide some benefit by their presence. The regenerative category represents buildings that do improve their surrounding environment through both their performance as well as their presence in the community. A simple and clear definition was provided in each of the three categories for each of the metrics, helping to achieve the goal of easily determinable evaluations of building performance.

4.2 Qualitative Building Evaluation Tool

The 22 metrics were combined with the discrete criteria to produce a matrix for evaluating performance of specific building strategies that represent the Beauty Determinants. The matrix is designed to assign points for building strategies that meet the criteria according to the related Beauty Determinants. Because this research focuses on high performing and inspiring and high performing buildings, only the high performing (0) and regenerative (+) categories were used for evaluation. A single point is awarded for the building strategy in the respective category for which a metric criterion is satisfied. An example of the matrix of metrics and criteria containing the first metric is shown in Table 4.2.

Table 4.2: Excerpt of Evaluation Metrics Matrix

				Related Determinants	building strategy		building strategy		building strategy	
	METRICS				HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)	
1	Building Thermal Load				0	+	0	+	0	+
	The efforts to improve the reduction of thermal gains and losses due to insolation and interior-exterior temperature gradients, and thermal load control as a means of reducing energy consumed by cooling and heating.									
	CONVENTIONAL	(0)	(+)	1						
	Requires a mechanical system	Requires a reduced mechanical system	Mechanical system is optional but not required	2						
				3						
				5						
				7						
				8						

Building strategies are first evaluated for their relation to the Beauty Attributes and Beauty Determinants in the Beauty Characteristics Matrix from Table 3.9. These strategies are then evaluated for the underlying aspects of beauty and inspiration through the Beauty Filters. Building strategies that are related to the Beauty Attributes and Beauty Determinants and that satisfy the Beauty Filters may then be evaluated for building performance using the metrics and associated criteria as seen in Table 4.2. For each of these building strategies, points are awarded in the respective category for which a metric criteria is satisfied; either high performing (0) or regenerative (+). The points are awarded to each Beauty Determinant that the building strategy represents.

Together, the Beauty Characteristics Matrix and the Evaluation Metrics Matrix form the BiB Matrix (Robles, Zhai, & Goodrum, 2012), a tool for qualitative evaluation of building performance relative to beauty and inspiration and energy performance. As buildings are evaluated in the tool, each building strategy's points are summed in each category with respect to each Beauty Determinant, as well for the category overall. Points for all building strategies are summed in each category across each Beauty Determinant and then again for the categories overall. These assessed values may then be used for comparison of performance relative to other projects and buildings.

The complete BiB Matrix (Robles, Zhai, & Goodrum, 2012) development was led by ml Robles and is included in Appendix B with permission of the PatternMapping® institute.

Chapter 5

Qualitative Evaluation of Building Beauty and Energy Performance

The BiB Matrix (Robles, Zhai, & Goodrum, 2012) described in Section 4.2, and included in Appendix B, was then used to complete a qualitative evaluation of samples of high performing and inspiring and high performing buildings. The intent of the evaluation was to identify trends separating the high performing and inspiring and high performing populations in terms of both the beauty characteristics and energy performance as assessed by the qualitative evaluation tool.

5.1 Case Study Evaluation

To complete the qualitative evaluation, case studies were again chosen from among the LEED Platinum certified buildings, including those that had also been selected as AIA COTE Top Ten Projects. The original group of 19 project case studies was expanded to include additional buildings in both the high performing and the inspiring and high performing populations. A total of 12 LEED Platinum project case studies were collected, including the nine used in the initial case study evaluation. A total of 23 AIA COTE Top Ten Projects that were LEED Platinum certified were collected, including the ten used in the initial case study evaluation. A total of 35 project case studies were evaluated in the qualitative evaluation tool.

5.1.1 LEED Platinum

Project case studies for the high performing buildings were collected from USGBC LEED online project directory and the BuildingGreen.com online database. As mentioned in Section 3.2.1.1, case studies are only available for a limited number of LEED certified projects, resulting in a smaller than desired number of high performing building case studies. Table 5.1 provides profiles for each of the 12 project case studies collected. In addition to the basic profile information that was included in Table 3.4, information on the climate, building type, cost, and energy use is included in the profiles. As mentioned in Section 3.2.1, the actual energy use data is provided for some projects, but for many it is based upon simulated operation from building energy models.

Table 5.1: LEED Platinum Case Studies

	**Audubon Center at Debs Park** Los Angeles, CA – Climate Region 3B Interpretive Center LEED NC 2.1 – Platinum 5,020 ft^2 Construction Cost: $1,096/ft^2 Energy Intensity: 17.1 kBtu/ft^2
	**Blackstone Office Renovation** Cambridge, MA – Climate Region 5 Commercial Office LEED NC 2.1 – Platinum 44,500 ft^2 Construction Cost: $236/ft^2 Energy Intensity: 39.3 kBtu/ft^2

	**Bren Hall, University of California – Santa Barbara** Santa Barbara, CA – Climate Region 3C Higher Education/Laboratory LEED NC 1.0 – Platinum 84,700 ft^2 Construction Cost: \$307/ft^2 Energy Intensity: 107 kBtu/ft^2
	**Chicago Center for Neighborhood Technology (CNT)** Chicago, IL – Climate Region 5A Commercial Office LEED NC 2.1 – Platinum 15,000 ft^2 Construction Cost: \$80/ft^2 Energy Intensity: 56.9 kBtu/ft^2

	**Eco Office** Atlanta, GA – Climate Region 3A Commercial Office LEED NC 2.1 – Platinum 10,100 ft^2 Construction Cost: \$242/ft^2 Energy Intensity: 23.5 kBtu/ft^2
	**Greensburg Business Incubator** Greensburg, KS – Climate Region 4B Commercial Office LEED NC 2.2 – Platinum 9,580 ft^2 Construction Cost: \$303/ft^2 Energy Intensity: 31.2 kBtu/ft^2

	**Half-Moon Outfitters Distribution Center** North Charleston, SC – Climate Region 3A Industrial/Commercial Office LEED NC 2.1 – Platinum 9,020 ft^2 Construction Cost: \$78/ft^2 Energy Intensity: 13.2 kBtu/ft^2
	**Heartland Consumers Power District Headquarters** Madison, SD – Climate Region 4A Commercial Office LEED NC 2.2 – Platinum 9,270 ft^2 Construction Cost: not provided Energy Intensity: 48.6 kBtu/ft^2
	**Home on the Range** Billings, MT – Climate Region 6B Commercial Office LEED NC 2.1 – Platinum 8,490 ft^2 Construction Cost: \$169/ft^2 Energy Intensity: 49.9 kBtu/ft^2

	**Inland Empire Utilities Agency (IEUA) Headquarters** Chino, CA – Climate Region 3B Commercial Office LEED NC 2.1 – Platinum 66,000 ft^2 Construction Cost: $\$114/\text{ft}^2$ Energy Intensity: 50.5 kBtu/ft^2
	**National Resources Defense Council (NRDC) Santa Monica Office** Santa Monica, CA – Climate Region 3B Commercial Office LEED NC 2.1 – Platinum 15,000 ft^2 Construction Cost: $\$340/\text{ft}^2$ Energy Intensity: not provided
	**NREL Science and Technology Facility** Golden, CO – Climate Region 5B Laboratory/Commercial Office LEED NC 2.1 – Platinum 71,300 ft^2 Construction Cost: $\$418/\text{ft}^2$ Energy Intensity: 153 kBtu/ft^2

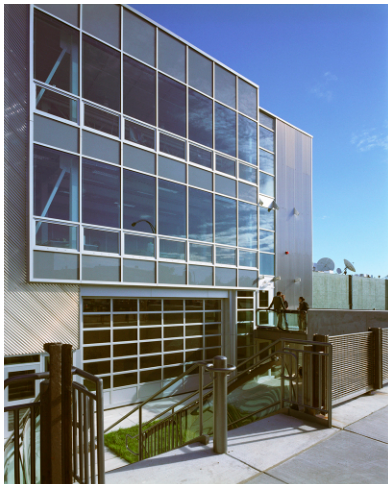
5.1.2 LEED Platinum + AIA COTE Top 10

Project case studies for the inspiring and high performing buildings were collected from AIA COTE Top Ten website as before. All of the AIA COTE Top Ten projects that were also LEED Platinum certified were collected for use in the qualitative evaluation. Table 5.2 provides profiles for each of the 23 project case studies collected. Similar to the LEED Platinum buildings, information on the climate, building type, cost, and energy use is included in the profiles. As mentioned in Section 3.2.1, the actual energy use data is provided for some projects, but for many it is based upon simulated operation from building energy models.

Table 5.2: LEED Platinum + AIA COTE Top Ten Case Studies

	**Alberici Corporate Headquarters** Overland, MO – Climate Region 4A Commercial Office LEED NC 2.1 – Platinum AIA COTE Top Ten – 2006 109,000 ft^2 Construction Cost: \$184/ft^2 Energy Intensity: 34 kBtu/ft^2
	**Aldo Leopold Legacy Center** Baraboo, WI – Climate Region 6A Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2008 11,900 ft^2 Construction Cost: \$331/ft^2 Energy Intensity: 15.6 kBtu/ft^2

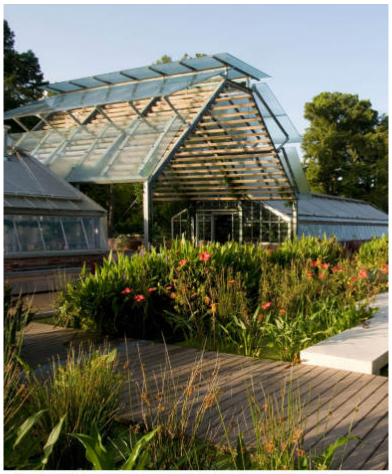
	**Chartwell** Seaside, CA – Climate Region 3B Education LEED NC 2.1 – Platinum AIA COTE Top Ten – 2009 21,200 ft^2 Construction Cost: \$434/ft^2 Energy Intensity: 27.2 kBtu/ft^2
	**Chesapeake Bay Foundation (CBF) Phillip Merrill Environmental Center** Annapolis, MD – Climate Region 4A Interpretive Center/Commercial Office LEED NC 1.0 – Platinum AIA COTE Top Ten – 2001 32,000 ft^2 Construction Cost: \$234/ft^2 Energy Intensity: 41.7 kBtu/ft^2
	**Chicago Center for Green Technology** Chicago, IL – Climate Region 5A Industrial/Commercial Office LEED NC 1.0 – Platinum AIA COTE Top Ten – 2003 40,000 ft^2 Construction Cost: \$360/ft^2 Energy Intensity: 33.3 kBtu/ft^2

	**EpiCenter, Artists for Humanity** Boston, MA – Climate Region 5 Education/Industrial LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007 23,500 ft^2 Construction Cost: \$183/ft^2 Energy Intensity: 25.6 kBtu/ft^2
	**Genzyme Center** Cambridge, MA – Climate Region 5 Commercial Office LEED NC 2.1 – Platinum AIA COTE Top Ten – 2004 344,000 ft^2 Construction Cost: not provided Energy Intensity: not provided
	**Great River Energy Headquarters** Maple Grove, MN – Climate Region 6A Commercial Office LEED NC 2.2 – Platinum AIA COTE Top Ten – 2009 166,000 ft^2 Construction Cost: \$343/ft^2 Energy Intensity: 64.2 kBtu/ft^2

	**Greensburg Schools/Kiowa County Schools** Greensburg, KS – Climate Region 4B Education LEED Schools 2.0 – Platinum AIA COTE Top Ten – 2011 132,000 ft^2 Construction Cost: \$342/ft^2 Energy Intensity: 27.8 kBtu/ft^2
	**Hawaii Gateway Energy Center** Kailua-Kona, HI – Climate Region 1A Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007 3,600 ft^2 Construction Cost: \$944/ft^2 Energy Intensity: 27.7 kBtu/ft^2
	**Heifer International Headquarters** Little Rock, AR – Climate Region 3A Commercial Office LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007 94,000 ft^2 Construction Cost: \$190/ft^2 Energy Intensity: 33.6 kBtu/ft^2

	**Jewish Reconstructionist Congregation** Evanston, IL – Climate Region 5A Assembly LEED NC 2.1 – Platinum AIA COTE Top Ten – 2009 31,600 ft^2 Construction Cost: \$316/ft^2 Energy Intensity: 50.1 kBtu/ft^2
	**Kroon Hall, Yale University** New Haven, CT – Climate Region 5A Higher Education LEED NC 2.2 – Platinum AIA COTE Top Ten – 2010 68,800 ft^2 Construction Cost: \$487/ft^2 Energy Intensity: 26.7 kBtu/ft^2
	**Lake View Terrace Library** Lake View Terrace, CA – Climate Region 3B Library LEED NC 2.1 – Platinum AIA COTE Top Ten – 2004 10,700 ft^2 Construction Cost: \$411/ft^2 Energy Intensity: not provided

	**LOTT Clean Water Alliance** Olympia, WA – Climate Region 5B Laboratory/Commercial Office LEED NC 2.2 – Platinum AIA COTE Top Ten – 2011 32,500 ft^2 Construction Cost: \$415/ft^2 Energy Intensity: 45.7 kBtu/ft^2
	**NREL Research Support Facility** Golden, CO – Climate Region 5B Laboratory/Commercial Office LEED NC 2.2 – Platinum AIA COTE Top Ten – 2011 222,000 ft^2 Construction Cost: \$288/ft^2 Energy Intensity: 31.7 kBtu/ft^2
	**Omega Center for Sustainable Living** Rhineback, NY – Climate Region 5A Interpretive Center LEED NC 2.2 – Platinum AIA COTE Top Ten – 2010 6,200 ft^2 Construction Cost: \$452/ft^2 Energy Intensity: 13.2 kBtu/ft^2

	**Portola Valley Town Center** Portola Valley, CA – Climate Region 3B Assembly LEED NC 2.2 – Platinum AIA COTE Top Ten – 2009 19,900 ft^2 Construction Cost: \$754/ft^2 Energy Intensity: 70.4 kBtu/ft^2
	**Queens Botanical Garden Visitor Center** Flushing, NY – Climate Region 4A Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2008 15,800 ft^2 Construction Cost: \$759/ft^2 Energy Intensity: 39.8 kBtu/ft^2
 The wetland purification polishing ponds complete the cleansing process and form the gateway to the historic gardens. The existing greenhouses were restored and adapted as naturally ventilated flex-use classroom/ experimental stations.	**Shangri La Botanical Gardens and Nature Center** Orange, TX – Climate Region 2A Interpretive Center LEED NC 2.1 – Platinum AIA COTE Top Ten – 2009 17,600 ft^2 Construction Cost: not provided Energy Intensity: 18 kBtu/ft^2

	**Sidwell Friends Middle School** Washington, D.C. – Climate Region 4A Education LEED NC 2.1 – Platinum AIA COTE Top Ten – 2007 72,200 ft^2 Construction Cost: \$388/ft^2 Energy Intensity: 20 kBtu/ft^2
	**Twelve West** Portland, OR – Climate Region 4C Retail/Residential/Commercial Office LEED NC 2.1 – Platinum AIA COTE Top Ten – 2010 552,000 ft^2 Construction Cost: \$250/ft^2 Energy Intensity: 26.8 kBtu/ft^2
	**Yale Sculpture Building and Gallery** New Haven, CT – Climate Region 5A Higher Education LEED NC 2.1 – Platinum AIA COTE Top Ten – 2008 62,000 ft^2 Construction Cost: \$565/ft^2 Energy Intensity: 28.3 kBtu/ft^2

5.1.3 Project Evaluation Process

This thesis research takes off from the Beauty in Building (Robles, Zhai, & Goodrum, 2012) research here with a unique case study evaluation methodology using the BiB Matrix with the intent of identifying and isolating distinguishing factors of beautiful buildings for further analysis. As in the initial case study evaluation described in Section 3.2.1, the case studies were reviewed and building features that represented the Beauty Determinants were recorded at the top of the BiB Matrix (Robles, Zhai, & Goodrum, 2012). For a given case study, building strategies or features that represented a given Beauty Determinant were listed in the top half of the BiB Matrix, above the Beauty Filters. For example, if building form and windows were oriented to take advantage of prevailing breezes for natural ventilation and windows were distributed on building faces to maximize daylighting but also mitigate solar gain and glare, this strategy would represent Beauty Determinants 1, 2, 3, and 5. If the natural ventilation were provided by operable windows that can be opened and closed to take advantage of favorable outdoor conditions, then it would also represent Beauty Determinant 7. A description of this building strategy would then be provided under Beauty Determinants 1, 2, 3, 5, and 7 and the top row labeled “fill if included” would be colored light blue to indicate that Beauty Determinant is represented. This process would be repeated for each building strategy.

Once the applicable building strategies for a project were listed, each building strategy was then “passed” through the Beauty Filters. The building strategies were evaluated to determine if they met the requirements for physical engagement and density posed by the Beauty Filters. Continuing with the example from above, the building strategy for natural ventilation and daylighting would be compared to each Beauty Filter.

First, occupants would be able to visibly engage with daylight in the space as well as observe changes in the daylight patterns depending on outdoor conditions, time of day, and season. Occupants would also be able to feel breezes allowed in through open windows and possibly smell odors carried by such breezes (which may be pleasant or unpleasant). If the windows may be controlled by the occupants themselves, they are also engaged with the physical activity of opening and closing windows based on their comfort and the outdoor conditions. Therefore, this strategy would satisfy the Sense Beauty Filter.

Second, the building strategy effectively uses building form and window placement to deliver daylight and natural ventilation, serving at least two purposes with one strategy. Operable windows also afford the opportunity for interaction between occupants and the building, providing a connection between the occupants and the built environment, as well as the outdoor environment in the form of breezes and sunlight. By representing multiple Beauty Determinants, this building strategy would satisfy the Density Beauty Filter.

If the same building also included a building strategy of increased exterior wall insulation and white membrane roof, then this strategy would also be "passed" through the Beauty Filters. First, the building envelope improvements are enclosed within exterior walls or on the roof surface, where building occupants cannot, or most likely will not, interact with these components. Although the insulation and roof membrane help maintain the indoor temperature that is felt by the occupants with the use of less HVAC energy, if the insulation or membrane were not present the HVAC system would most likely adjust to meet the load and maintain the temperature of the space. In this sense, the envelope improvements of added insulation and white roof membrane are "invisible" to building occupants. Therefore, this building strategy would not satisfy the Sense Beauty Filter.

Second, the building envelope improvements would provide passive means for reducing both heating and cooling loads and representing Beauty Determinants 2 and 3. If the wall insulation were reclaimed or composed of local repurposed materials, it may also represent Beauty Determinant 6. By representing multiple Beauty Determinants, this building strategy would satisfy the Density Beauty Filter.

If a building strategy satisfied both Beauty Filters, it was then listed in the bottom half of the BiB Matrix (Robles, Zhai, & Goodrum, 2012). From the example above, the building strategy providing daylight and natural ventilation satisfied both Beauty Filters and would then be listed in the bottom half of the BiB matrix. Like the top half, a description of this building strategy would then be provided under

Beauty Determinants 1, 2, 3, 5, and 7 and the top row labeled “fill if meet criteria” would be colored turquoise to indicate that Beauty Determinant was represented. This field also includes a summary of the points awarded in the high performing (0) and regenerative (+) categories for each of the represented Beauty Determinants after the evaluation against the metrics of the BiB Matrix is completed. Continuing the example, the building strategy providing building envelope improvements did not satisfy the Sense Beauty Filter, but did satisfy the Density Beauty Filter. Because only one Beauty Filter was satisfied, this building strategy would not be listed in the bottom half of the BiB Matrix.

For all building strategies that were representative of beauty characteristics and were listed in the bottom half of the BiB Matrix (Robles, Zhai, & Goodrum, 2012), they were then assessed against the evaluation metrics and criteria. Within a given metric, points were assigned to associated Beauty Determinants based on which Beauty Determinants were represented by the building strategy as indicated at the top of the BiB Matrix. Continuing the example, the strategy of building form and window placement to provide daylight and natural ventilation represented Beauty Determinants 1, 2, 3, 5, and 7. If this building strategy were being evaluated for metric 4, *Direct Use of Natural Forces*, points would be awarded, based on the criteria, in the appropriate category (high performing (0) or regenerative (+)) to Beauty Determinants 1, 2, 3, 5, and 7. However, no points would be awarded to Beauty Determinants 8 or 9 for this building strategy.

Building strategies were only assessed for metrics that were applicable. Based on the example, the building strategy for daylight and natural ventilation would be assessed for metrics 1, 4, 5, 6, and 7. The applicability of metrics is readily apparent for most, such as the strategy for daylight and natural ventilation not being assessed for metric 11, *Greywater Use System*. However, some metrics’ applicability may not be as clear. For example, the strategy of daylight and natural ventilation may be appropriate for metric 3, *Daylight Control*. If the case study mentioned window shades or other daylight control devices employed together with the operable windows, the building strategy would be assessed for metric 3. If the case study did not mention daylight control devices, the building strategy would not be assessed for metric 3.

For a given metric, points were assigned to criteria based on the description in the case study. In the example of the building strategy evaluated for metric 4, *Direct Use of Natural Forces*, the strategy would be awarded points in the high performing (0) category if the natural forces partially meet the building energy needs but would be awarded points in the regenerative (+) category if the natural forces replace needs for building systems. If in the example, the case study indicates that natural ventilation provided by operable windows eliminates the need for a mechanical system or allows it to be shut down seasonally (spring and autumn), then the ventilation replaces the mechanical system (during shoulder seasons in the latter case) and points for the strategy are assigned to the regenerative (+) category for the appropriate Beauty Determinants, 3, 5, and 7. If the case study indicates that daylighting is used to reduce electric lighting needs but does not specify that lighting systems are effectively replaced, then the strategy would be assigned points in the high performing category (0) for Beauty Determinant 1. If the case study mentions solar gain for winter heating but does not mention actual impacts to the heating system as a result of the daylighting and ventilation strategy, then points would be assigned in the high performance (0) category. For building strategies evaluated, if no clear indication was given in the case study with which to assess within the criteria, points were assigned in the high performing (0) category for the appropriate Beauty Determinants. Assessments defaulted to the high performing (0) category because each of the project case studies evaluated was a high performing building as determined by the LEED Platinum certification.

For a given project, each building strategy's points were summed in the BiB Matrix (Robles, Zhai, & Goodrum, 2012) in each category with respect to each Beauty Determinant, as well for the category overall. Points for all building strategies were summed in each category across each Beauty Determinant and then again for the categories overall to give assessed values for the project overall.

These assessed values were tabulated, along with other project information provided in the case studies, to compare and contrast the different case study populations.

5.2 Results

Assessed values for each project case study evaluated were summed for each project by category, overall for each Beauty Determinant, and for the project as a whole. The tabulated data and assessed values for each project case study are given in Table 5.3 through Table 5.6. Table 5.3 and Table 5.5 provide the assessed values in each category by Beauty Determinant for the LEED Platinum and the LEED Platinum + AIA COTE Top Ten projects, respectively. Table 5.4 and Table 5.6 provide the total assessed values in each category by Beauty Determinant for the LEED Platinum and the LEED Platinum + AIA COTE Top Ten projects, respectively.

Table 5.3: Case Study Evaluation Categorical Results – LEED Platinum Only

	Determinant Category Assessed Value																				**Total Category Value**	
	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**High Perfor. (0)**	**Regen. (+)**
Name	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**		
Audubon Center at Debs Park	4	1	2	1	4	1	0	0	0	2	0	0	4	1	0	0	0	0	0	0	**14**	**6**
Blackstone Station Office Renovation	4	0	0	0	0	0	1	2	6	5	4	0	0	0	4	3	4	0	4	0	**27**	**10**
Bren Hall at UC Santa Barbara	5	0	3	0	0	5	0	0	4	1	0	0	0	5	0	0	0	0	0	0	**12**	**11**
Chicago Center for Neighborhood Technology	5	0	3	0	5	0	2	1	2	1	0	0	5	0	1	0	0	0	0	0	**23**	**2**
Eco Office	3	2	4	1	5	2	2	1	7	4	0	0	0	0	0	0	1	0	0	0	**22**	**10**
Greensburg Business Incubator	5	0	3	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	**16**	**0**
Half-Moon Outfitters Distribution Center	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Heartland Consumers Power District	5	0	3	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	**18**	**0**
Home on the Range	5	0	4	0	6	0	2	1	3	1	0	0	0	0	0	0	0	0	1	0	**21**	**2**
Inland Empire Utilities Agency Headquarters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
National Resources Defense Council Robert Redford Building	6	0	0	0	5	0	0	0	6	0	0	0	6	0	0	0	0	0	0	0	**23**	**0**
NREL Science and Technology Facility	3	2	4	0	5	0	1	2	1	2	0	0	0	0	0	0	0	0	0	0	**14**	**6**

Table 5.4: Case Study Evaluation Overall Results – LEED Platinum Only

Name	**Total Determinant Assessed Value**										**Total Project Value**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Audubon Center at Debs Park	5	3	5	0	2	0	5	0	0	0	**20**
Blackstone Station Office Renovation	4	0	0	3	11	4	0	7	4	4	**37**
Bren Hall at UC Santa Barbara	5	3	5	0	5	0	5	0	0	0	**23**
Chicago Center for Neighborhood Technology	5	3	5	3	3	0	5	1	0	0	**25**
Eco Office	5	5	7	3	11	0	0	0	1	0	**32**
Greensburg Business Incubator	5	3	4	0	4	0	0	0	0	0	**16**
Half-Moon Outfitters Distribution Center	0	0	0	0	0	0	0	0	0	0	**0**
Heartland Consumers Power District	5	3	5	0	5	0	0	0	0	0	**18**
Home on the Range	5	4	6	3	4	0	0	0	0	1	**23**
Inland Empire Utilities Agency Headquarters	0	0	0	0	0	0	0	0	0	0	**0**
National Resources Defense Council Robert Redford Building	6	0	5	0	6	0	6	0	0	0	**23**
NREL Science and Technology Facility	5	4	5	3	3	0	0	0	0	0	**20**

Table 5.5: Case Study Evaluation Categorical Results – LEED Platinum + AIA COTE Top Ten

	Determinant Category Assessed Value																				**Total Category Value**	
	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**			
Name	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**0**	**+**	**High Perfor. (0)**	**Regen. (+)**
Alberici Corporate Headquarters	7	2	1	1	6	2	0	0	4	1	0	0	0	0	0	0	0	0	0	0	**18**	**6**
Aldo Leopold Legacy Center	7	3	6	1	8	2	0	0	1	2	2	0	0	0	4	1	2	0	1	0	**31**	**9**
Chartwell	7	5	0	0	2	13	0	3	2	8	1	0	3	12	3	9	1	1	1	0	**20**	**51**
CBF Phillip Merrill Environmental Center	8	0	3	0	9	0	0	0	5	0	1	1	3	0	0	0	1	1	1	1	**31**	**3**
Chicago Center for Green Technology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
EpiCenter, Artists for Humanity	10	1	2	1	4	5	1	2	3	4	1	1	6	3	3	1	4	1	1	1	**35**	**20**
Genzyme Center	11	0	4	0	11	0	1	1	0	0	0	0	5	0	4	0	2	0	0	0	**38**	**1**
Great River Energy Headquarters	4	0	3	0	6	0	1	2	7	2	0	0	0	0	4	0	0	0	0	0	**25**	**4**
Greensburg Schools/Kiowa County Schools	10	1	4	1	10	1	1	2	8	3	0	0	5	0	0	0	0	0	0	0	**38**	**8**
Hawaii Gateway Energy Center	1	4	0	0	0	8	0	0	0	4	0	0	0	2	0	2	0	0	0	0	**1**	**20**
Heifer International Headquarters	2	3	3	0	4	0	0	3	5	3	0	0	0	0	5	0	0	0	0	0	**19**	**9**
Jewish Reconstructionist Congregation	9	2	3	1	8	2	0	0	10	2	2	0	10	2	6	1	2	0	2	0	**52**	**10**
Kroon Hall (Yale)	17	3	8	2	9	6	0	4	10	8	1	1	9	2	8	3	3	2	1	1	**66**	**32**
Lake View Terrace Library	0	5	3	3	4	9	0	0	2	8	0	1	3	5	1	4	0	2	0	1	**13**	**38**
LOTT Clean Water Alliance	4	3	5	0	7	1	2	5	9	8	2	0	2	3	2	2	2	1	2	2	**37**	**25**
NREL Research Support Facility	3	3	5	2	8	1	2	1	11	2	1	0	9	1	6	1	2	0	0	0	**47**	**11**
Omega Center for Sustainable Living	2	3	4	2	6	5	0	1	6	5	1	1	4	3	4	4	1	2	1	3	**29**	**29**
Portola Valley Town Center	7	0	4	0	8	0	0	0	7	0	3	0	3	0	0	0	3	0	3	0	**38**	**0**
Queens Botanical Garden Visitor Center	10	3	7	1	9	4	0	6	11	6	0	0	4	2	7	3	0	1	0	0	**48**	**26**
Shangri La Botanical Gardens and Nature Center	5	0	2	3	5	3	0	0	3	3	4	0	5	0	1	3	4	0	4	0	**33**	**12**
Sidwell Friends Middle School	7	1	4	2	8	1	1	3	7	4	0	0	0	0	0	1	1	0	0	0	**28**	**12**
Twelve West	5	0	6	0	9	1	1	3	9	4	2	0	5	0	2	1	2	0	0	0	**41**	**9**
Yale Sculpture Building and Gallery	8	2	8	0	14	1	2	2	8	4	0	0	9	0	6	1	0	0	0	0	**55**	**10**

Table 5.6: Case Study Evaluation Overall Results – LEED Platinum + AIA COTE Top Ten

	Total Determinant Assessed Value										Total Project Value
Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Alberici Corporate Headquarters	9	2	8	0	5	0	0	0	0	0	**24**
Aldo Leopold Legacy Center	10	7	10	0	3	2	0	5	2	1	**40**
Chartwell	12	0	15	3	10	1	15	12	2	1	**71**
CBF Phillip Merrill Environmental Center	8	3	9	0	5	2	3	0	2	2	**34**
Chicago Center for Green Technology	0	0	0	0	0	0	0	0	0	0	**0**
EpiCenter, Artists for Humanity	11	3	9	3	7	2	9	4	5	2	**55**
Genzyme Center	11	4	11	2	0	0	5	4	2	0	**39**
Great River Energy Headquarters	4	3	6	3	9	0	0	4	0	0	**29**
Greensburg Schools/Kiowa County Schools	11	5	11	3	11	0	5	0	0	0	**46**
Hawaii Gateway Energy Center	5	0	8	0	4	0	2	2	0	0	**21**
Heifer International Headquarters	5	3	4	3	8	0	0	5	0	0	**28**
Jewish Reconstructionist Congregation	11	4	10	0	12	2	12	7	2	2	**62**
Kroon Hall (Yale)	20	10	15	4	18	2	11	11	5	2	**98**
Lake View Terrace Library	5	6	13	0	10	1	8	5	2	1	**51**
LOTT Clean Water Alliance	7	5	8	7	17	2	5	4	3	4	**62**
NREL Research Support Facility	6	7	9	3	13	1	10	7	2	0	**58**
Omega Center for Sustainable Living	5	6	11	1	11	2	7	8	3	4	**58**
Portola Valley Town Center	7	4	8	0	7	3	3	0	3	3	**38**
Queens Botanical Garden Visitor Center	13	8	13	6	17	0	6	10	1	0	**74**
Shangri La Botanical Gardens and Nature Center	5	5	8	0	6	4	5	4	4	4	**45**
Sidwell Friends Middle School	8	6	9	4	11	0	0	1	1	0	**40**
Twelve West	5	6	10	4	13	2	5	3	2	0	**50**
Yale Sculpture Building and Gallery	10	8	15	4	12	0	9	7	0	0	**65**

Based on the data in Table 5.4 and Table 5.6, both building populations frequently achieved points for Beauty Determinants 1 through 6, but the inspiring and high performing buildings achieved points for Beauty Determinants 7 through 10 more consistently than the high performing buildings. Figure 5.1 shows the average assessed value by Beauty Determinant for both building populations and illustrates the differences between the two building populations. The inspiring and high performing building achieved higher average values for each Beauty Determinant, and did exhibit more consistent performance for Beauty Determinants 7 through 10. This indicates that while both building populations employed strategies that connect them with their surrounding environment, the inspiring and high performing buildings include strategies that also provide a connection between the occupants, the built environment, and ultimately the surrounding environment. These results correspond to the finding that the inspiring and high performing buildings represented the Beauty Determinants and related Beauty Attributes more frequently than the high performing buildings seen in the initial case study evaluation in Section 3.3.1.

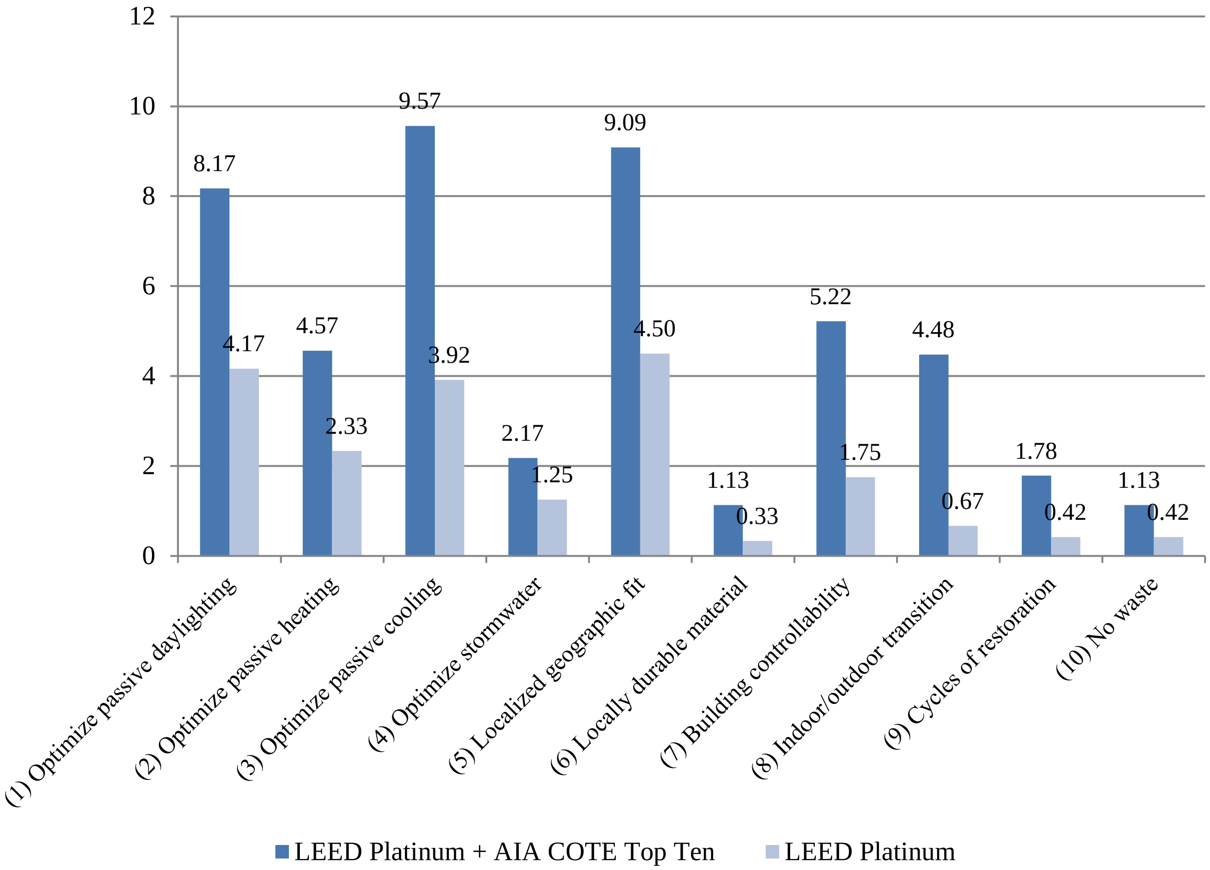


Figure 5.1: Average Beauty Determinant Assessed Value

The results of project assessed values for the high performing and the inspiring and high performing buildings are summarized in Table 5.7.

Table 5.7: Case Study Evaluation Results

	LEED Platinum Only	**LEED Platinum + AIA COTE Top Ten**
Minimum Value	0	0
Maximum Value	37	98
Average Value	20	47
Median Value	22	46

On average, the inspiring and high performing buildings had higher assessed values than the high performing buildings, which would indicate that the inspiring and high performing buildings represented the beauty characteristics more frequently than the high performing buildings.

One surprising result was that both building populations had projects which had assessed values of zero because their building strategies did not satisfy both Beauty Filters. In all three cases, the buildings employ innovative technologies that provide signinficant reductions in energy use but these systems were either isolated from occupants (SENSE) or from other building systems or features (DENSITY). The results also show that the best performing projects of the high performing population, *Blackstone Station Office Renovation* and *Eco Office*, had higher assessed values than some of the lesser performing projects of the inspiring and high performing building population, such as *Alberici Corporate Headquarters* or the *Hawaii Gateway Energy Center*. These observations highlight that there may be some exceptions within each of the building populations used for the case study evaluation. However, the overall results indicate that the case studies used to represent the high performing and the inspiring and high performing populations were reasonable representations of each.

5.2.1 Relationships of Beauty and Inspiration to Building Factors

In order to explore and understand what relationships may exist between beauty and inspiration and other factors of the building and site, the total assessed values for each project were evaluated with the project information included in the project profiles in Table 5.1 and Table 5.2. Evaluations were made for climate, building type, building setting, construction cost, and energy intensity.

5.2.1.1 Climate

The assessed values of each project were compared to the ASHRAE climate region indicated in each project case study to determine if a relationship may exist between beauty and insipiration and climate. Becausue several of the Beauty Determinants relate to passive strategies, including passive heating and cooling, mild or moderate climates may provide better locations for beautiful and inspiring buildings.

Figure 5.2 shows a plot of the ASHRAE climate region against the total project value for both building populations.

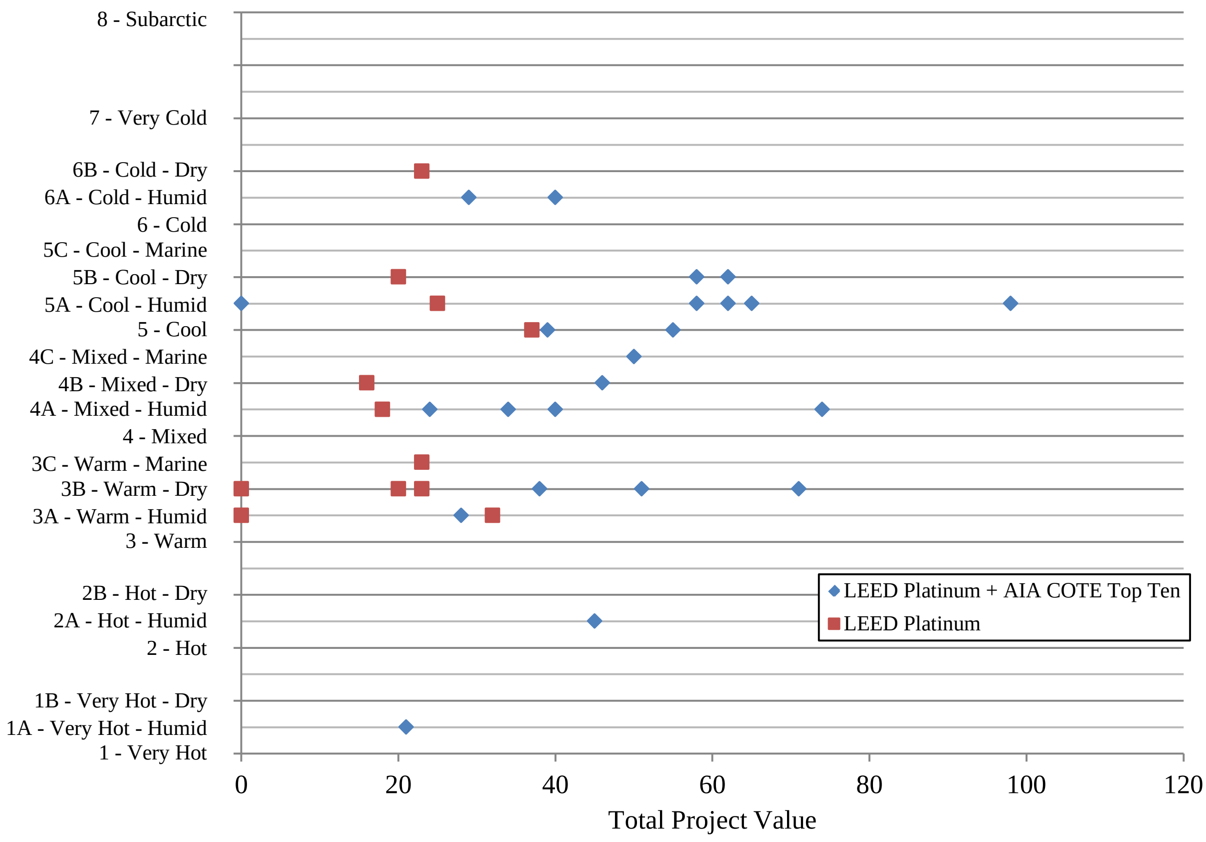


Figure 5.2: Project Assessed Value versus Climate Region

The project case studies covered a wide range of climate regions, with climate regions 7 and 8 being the only with no associated project. In the cases with multiple project case studies in a single climate region, the project assessed value varies widely across climate region. Even project values for a single building population vary widely within the same climate region. These results indicate that there is not a strong relationship between the beautiful and inspiring buildings and the climate region.

5.2.1.2 Building Type

The evaluated projects included a number of different building types. Building type was listed in each project case study, but due to the large variety in the building types indicated, similar types were consolidated and a total of 12 building types were used to represent the projects. These building types were: Assembly, Commercial Office, Education, Education/Industrial, Higher Education, Higher Education/Laboratory, Industrial/Commercial Office, Interpretive Center, Interpretive Center/Commercial Office, Laboratory/Commercial Office, Library, and Retail/Residential/Commercial Office. Figure 5.3 shows the project assessed values compared to the building type for each project case study. For clarity of presentation, no distinguishment is made between the high performing buildings and the inspiring and high performing buildings within a given building type category.

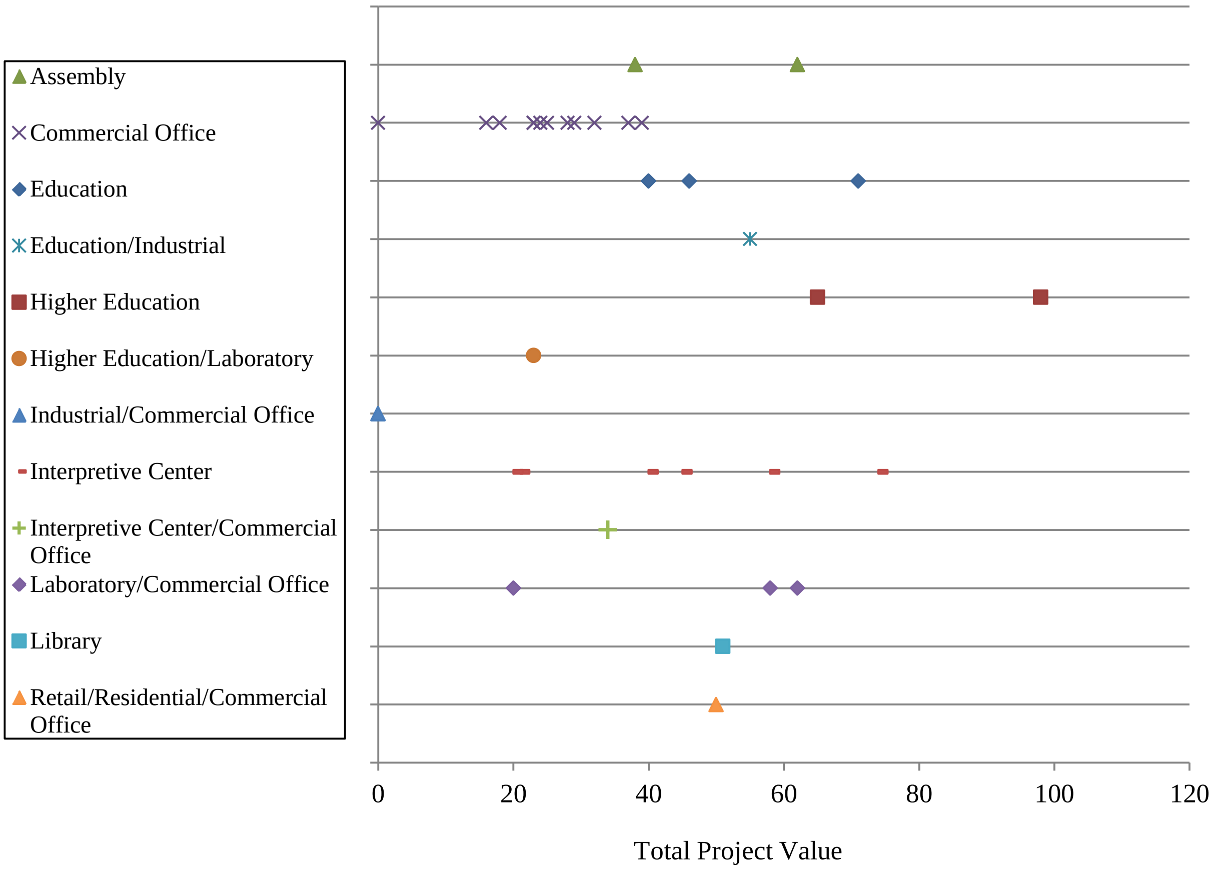


Figure 5.3: Project Assessed Value versus Building Type

The total project values for each case study demonstrate a considerable range at each building type, with the exception of the *Education/Industrial*, *Interpretive Center/Commercial Office*, *Library*, and *Retail/Residential/Commercial Office* categories which only have one representative project. The *Commercial Office* category does have lower performing projects in general, which is partially attributable to this building type being composed of several of the high performing buildings, which had lower project values on average. The *Industrial/Commercial Office* building type included two of the three projects that had project values of zero. The industrial aspect of these buildings may be a factor in the low performance, although the project *Education/Industrial* category had a project value well above zero. Further data would be needed to confirm or deny a relationship between industrial type buildings and lower performance relative to the beauty characteristics. Overall, there is not a clearly evident relationship between a high value in the qualitative evaluation and certain building types.

5.2.1.3 Building Setting

Project case studies indicated whether buildings were located in urban, suburban, or rural settings. The project assessed values were compared to the building setting to understand if buildings in a specific setting typically performed better than others. Because the connection to nature was identified as an important aspect of beauty and is fundamental to both the Local and Connectivity Beauty Attributes, buildings in a rural setting may perform better than those in an urban setting due to the composition of their surrounding environment. Figure 5.4 plots the project value for each case study relative to the project setting. Data is separated for the high performing and the inspiring and high performing buildings.

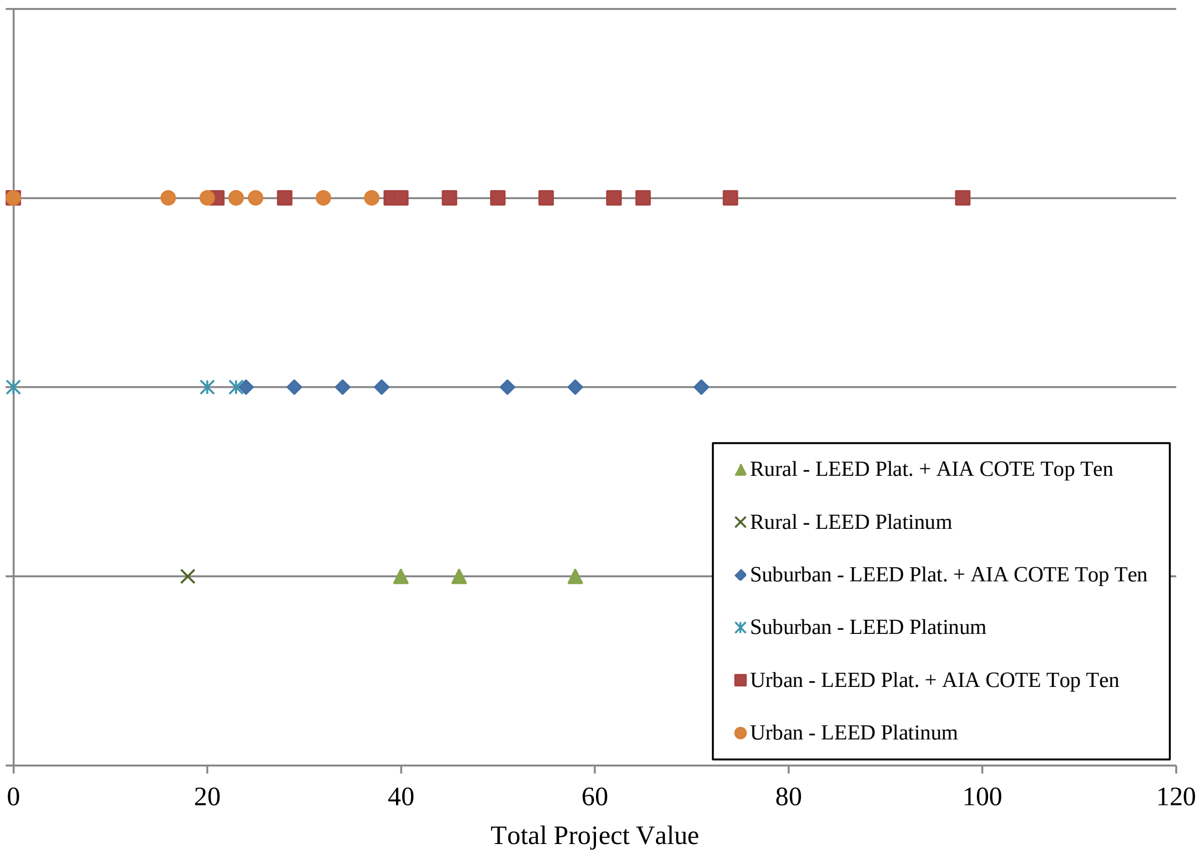


Figure 5.4: Project Assessed Value versus Building Setting

Similar to the building type comparison, the project assessed values exhibit a large range across each of the building settings. The rural setting did not provide any advantage compared to the suburban or urban settings although a rural setting typically has more natural surroundings. Again, no strong relationship is observed between beauty and inspiration and project setting.

5.2.1.4 Construction Cost

The assessed values of each project were compared to the construction cost per square foot to determine if a relationship may exist between beauty and insipiration and building cost. Figure 5.5 shows a plot of the construction cost per building area against the total project value for both building populations.

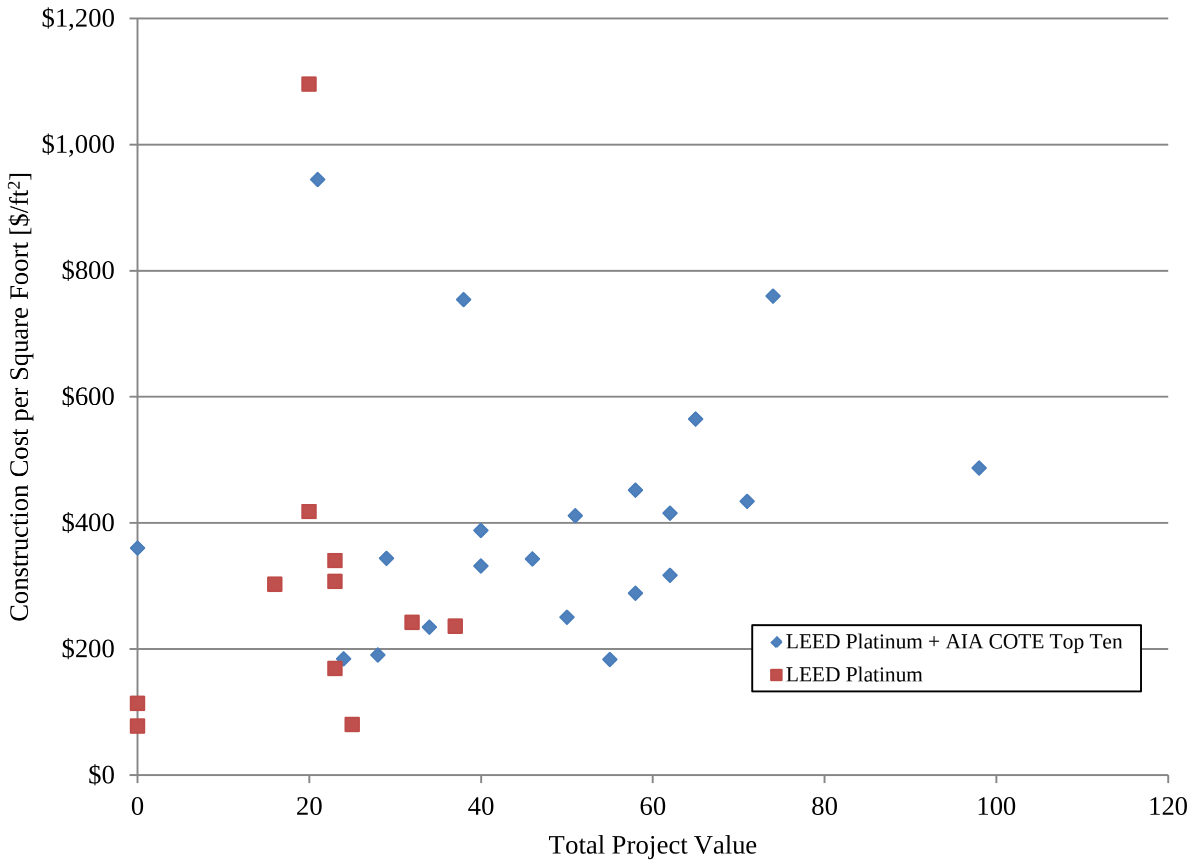


Figure 5.5: Project Assessed Value versus Construction Cost per Square Foot

The are a few outliers with high project cost and lower project values, which happen to be the highest cost building within each population group, but a general trend of higher cost for higher project values is observed among the data. To view the data in a different form, the construction cost was also evaluated respective to each building population. Table 5.8 shows the construction cost data for both case study building populations individually.

Table 5.8: Construction Cost by Case Study Group

	LEED Platinum Only	LEED Platinum + AIA COTE Top Ten
Minimum $/ft	$78	$183
Maximum $/ft	$1,096	$944
Average $/ft	$307	$411
Median $/ft	$242	$360

Based on the plot in Figure 5.5 and the data in Table 5.8, the inspiring and high performing buildings, on average, have a higher construction cost per building area. To further understand the factors that may affect the construction cost per building area, it was compared to the number of building strategies identified for potential contributions to the building construction cost. The same comparison was made for those building strategies which passed through the beauty filters in the qualitative evaluation tool.

The construction cost per building area of each project is plotted against the number of building strategies identified in Figure 5.6. The separate data points show the relationship for individual projects while the columns indicate the average construction cost per building area for all projects with that number of identified building strategies. The light red column represents the average for the high performing buildings and the light blue column represents the average for the inspiring and high performing buildings.

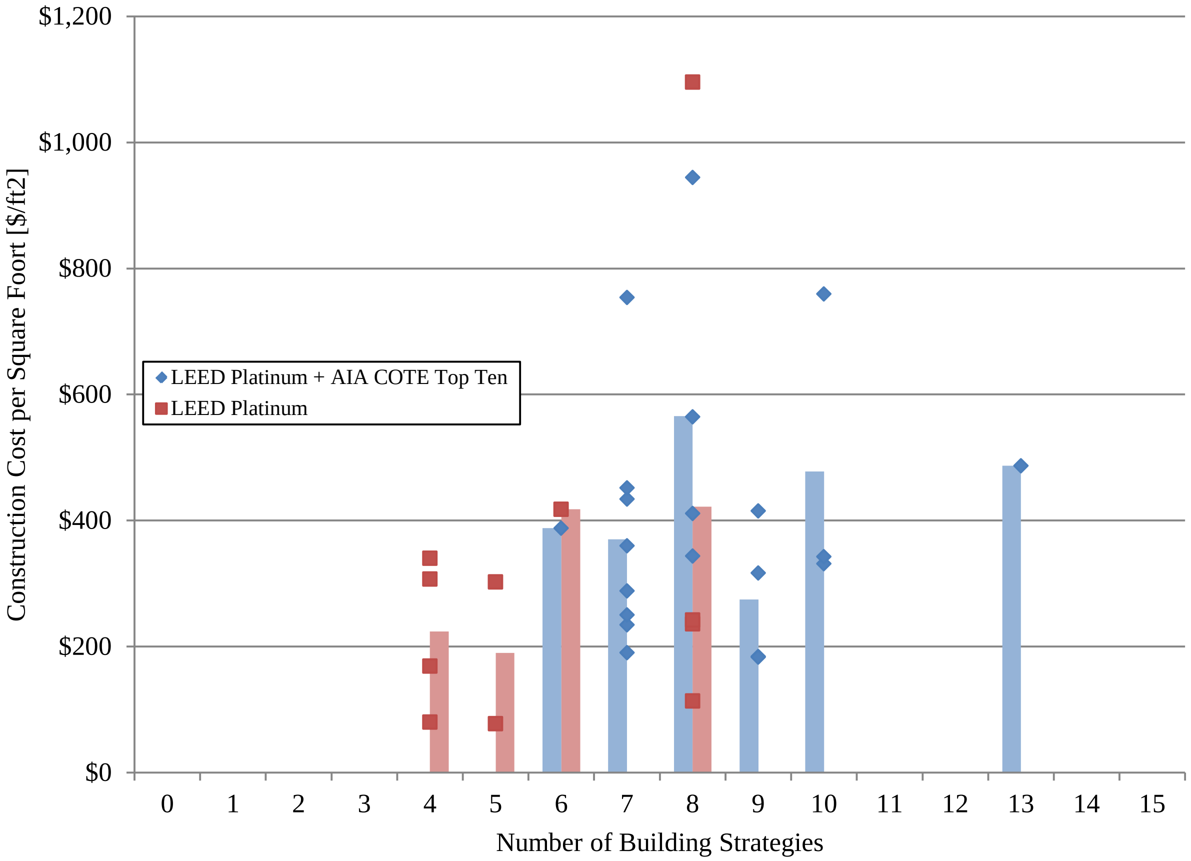


Figure 5.6: Construction Cost per Square Foot versus Number Building Strategies

The construction cost per building area exhibits a large range across each of the building strategy groups. Projects with a great number of identified building strategies did not necessarily result in higher construction cost per building area. For example, the average construction cost per building area for inspiring and high performing buildings with nine identified building strategies was approximately $275/ft^2 while it was approximately $275/ft^2 for inspiring and high performing buildings with eight identified building strategies. Based on Figure 5.6, the number of identified building strategies does not appear to have a strong relationship to construction cost per building area for the projects included in the qualitative case study evaluation.

The construction cost per building area of each project is plotted against the number of building strategies that passed the through the beauty filters in Figure 5.7. Like Figure 5.6, the separate data points show the relationship for individual projects while the columns indicate the average construction cost per building area for all projects with that number of building strategies passing the beauty filters.

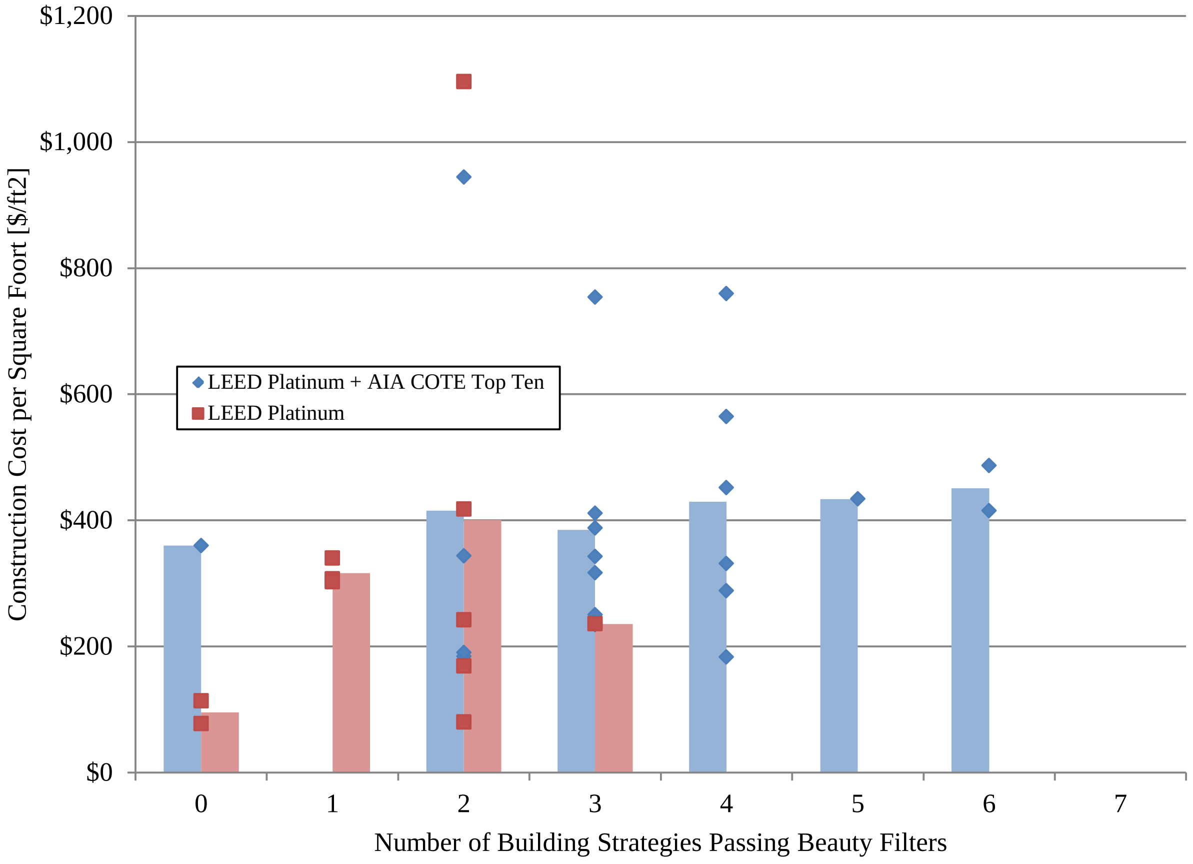


Figure 5.7: Construction Cost per Square Foot versus Number Building Strategies Passing Beauty Filters

The results for construction cost per building area compared to the number of building strategies passing the beauty filters of the qualitative evaluation tool displays a similar range as those in Figure 5.6. There is an upward trend observed in the average cost per group among the inspiring and high performing buildings, with the exception of those buildings with two strategies passing the beauty filters. This observed trend amounts to an average increase of approximately $15/ft^2 for each additional building strategy passing the beauty filters. The same upward trend may be true for the high performing buildings because the group representing three building strategies passing the beauty filters only contains a single data point. However, a larger sample of data for the high performing buildings is needed to confirm that such a trend exists. Based on Figure 5.7, there is evidence to support the conclusion that construction cost per building area is directly proportional to the number of building strategies passing the beauty filters for the projects included in the qualitative case study evaluation.

5.2.1.5 Energy Intensity

Lastly, the results of the qualitative evaluations were compared to the reported energy intensity for each project. The building energy intensity represents the grand total annual building energy consumption given in each case study. This value includes on site generation for those projects which employed on site renewable energy systems because this energy was still used to meet the energy needs of the building, although it was not purchased from a utility. Figure 5.8 plots the building energy intensity, in kBtu per square foot of building area, versus the assessed project value.

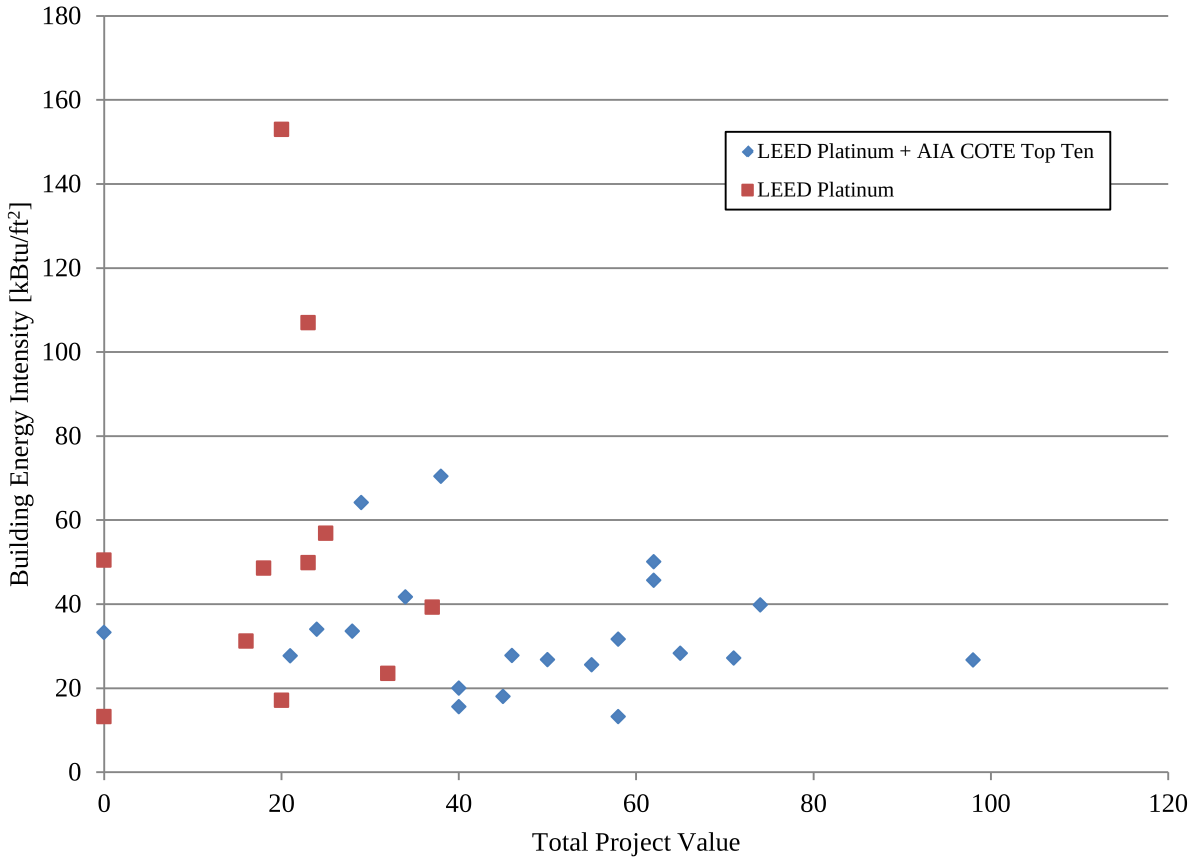


Figure 5.8: Project Assessed Value versus Building Energy Intensity

The building energy intensity does not appear to change significantly with changes in the assessed project value for either the high performing or the inspiring and high performing buildings. The project with the highest performance in the qualitative evaluation does not have the lowest building energy intensity, nor do the projects with total values of zero have the highest energy use. However, both projects with building energy intensity greater than 100 kBtu/ft^2 are from the high performing building population. Conversely, there are two projects from the high performing building population that have building energy intensities below 20 kBtu/ft^2, which are among the lowest observed between both sample populations.

As with the construction cost data, the building energy intensity was evaluated respective to each building population. Table 5.9 shows the building energy intensity data for both case study building populations individually.

Table 5.9: Building Energy Intensity by Case Study Group

	LEED Platinum Only	**LEED Platinum + AIA COTE Top Ten**
Minimum kBtu/ft^2	13.2	13.2
Maximum kBtu/ft^2	153	70.4
Average kBtu/ft^2	53.7	33.4
Median kBtu/ft^2	48.6	28.3

Based on the plot in Figure 5.8 and the data in Table 5.9, the inspiring and high performing buildings, on average, have lower building energy intensity than the high performing buildings. Given that there is a relatively large range in energy use within the case study building populations, the building energy intensity relative to climate and to building type were evaluated for potential contributions of those parameters to the building energy consumption.

The building energy intensity of each project is plotted against the climate region in Figure 5.9.

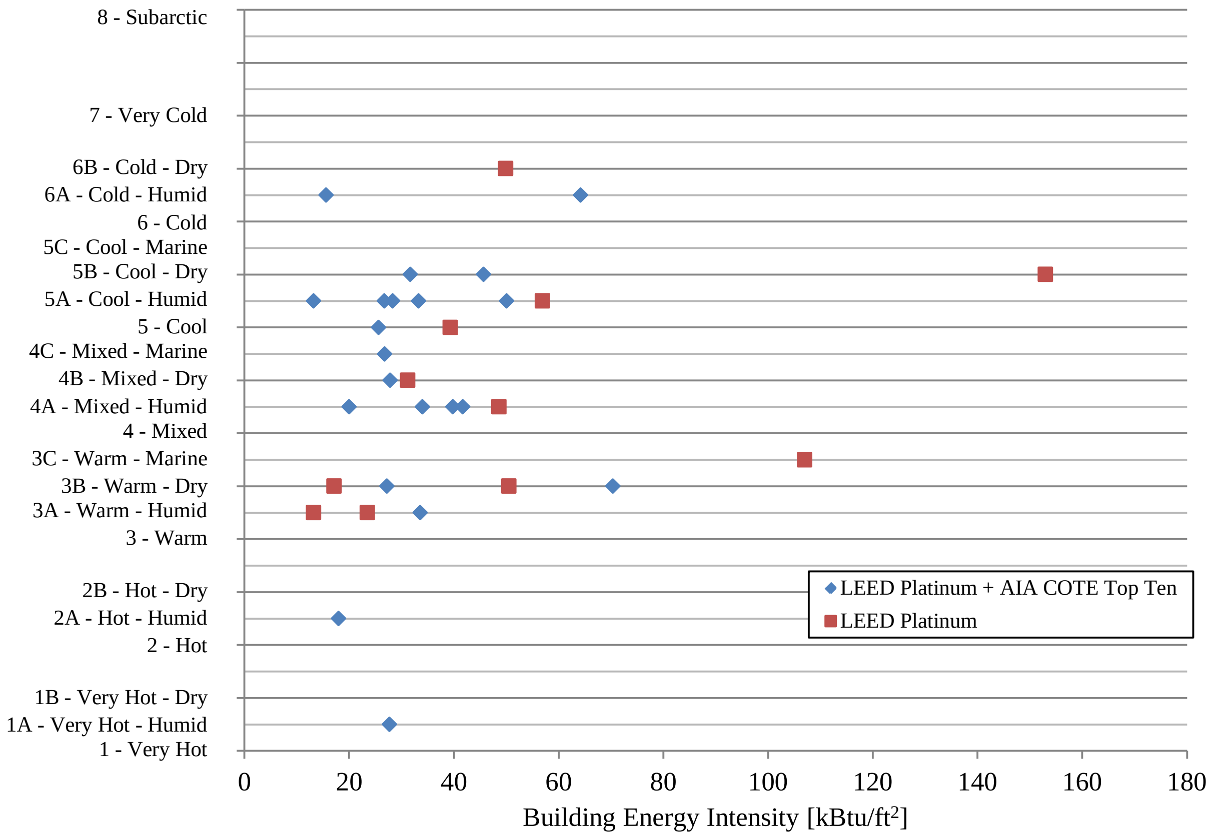


Figure 5.9: Building Energy Intensity versus Climate Region

No single climate region stands out in terms of building energy intensity, with a range of energy use in each region. Surprisingly, the buildings with the highest energy intensity actually lie within the more moderate climate regions (3C and 5A), which would be expected to have lower heating and/or cooling loads relative to the more extreme climate regions. Based on Figure 5.9, the climate region of the building does not appear to have a significant impact on building energy consumption for the projects included in the qualitative case study evaluation.

Next, the building energy intensity of each project is plotted against the building type in Figure 5.10.

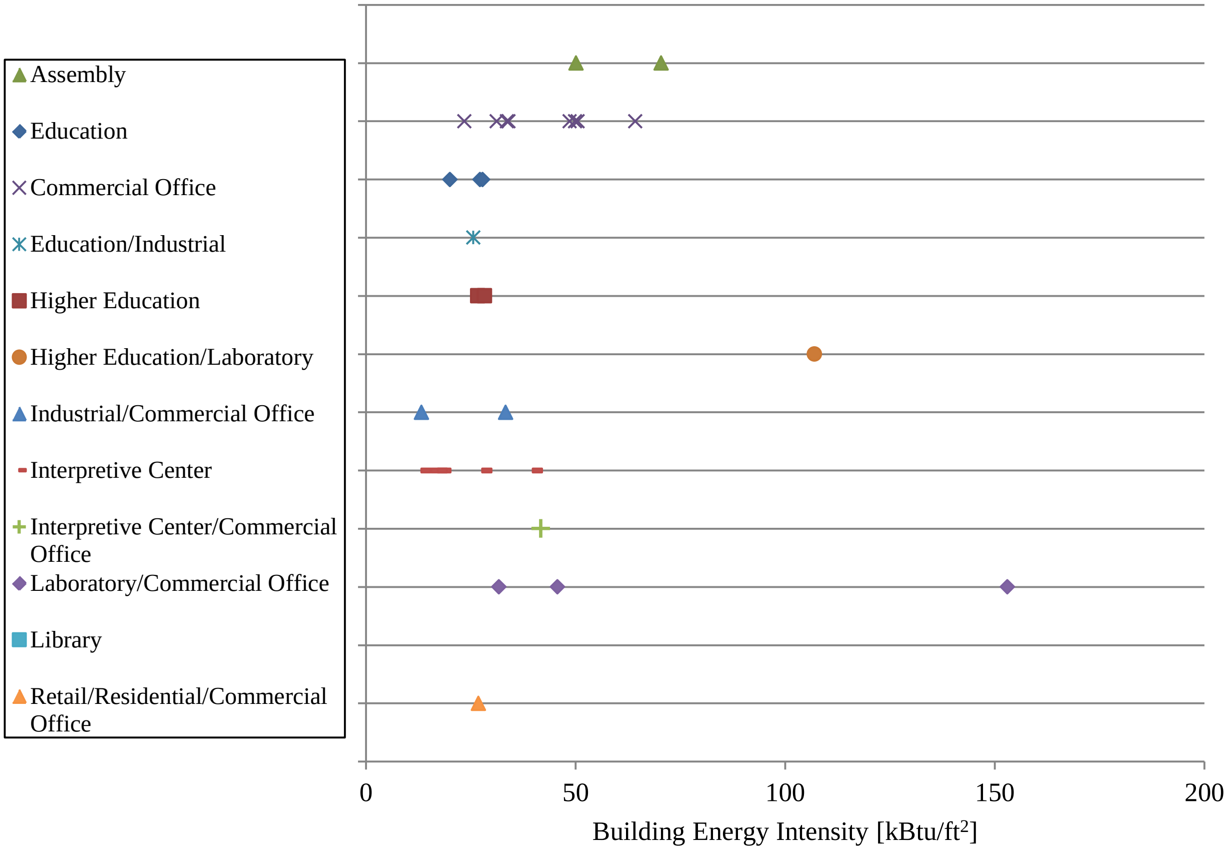


Figure 5.10: Building Energy Intensity versus Building Type

Simlar to the climate region, no single building type clearly stands out for either higher or lower building energy intensity relative to the other types. It is noted that the projects with the highest building energy intensity are associated with building types involving laboratory space. Because laboratory spaces usually incorporate large amounts of electronic or mechanical equipment, higher energy use in these building types is not surprising. The two projects with high building energy intensity are from the high performing building population and correspond to the two high energy users identified in Figure 5.8. Therefore, the remaining two projects in the *Laboratory/Commercial Office* category that have much lower building energy intensities are from the inspiring and high performing building population. However, without understanding the division of office and laboratory space within these buildings, it is difficult to draw any significant conclusions relative to performance of laboratory type buildings in terms of beauty and energy.

5.3 Conclusions for Qualitative Evaluation of Building Performance

Based on the results presented in Section 5.2, the inspiring and high performing buildings better represent the beauty characteristics than the high performing buildings. This was in part due to the inspiring and high performing buildings achieving points related to the Connectivity Beauty Attribute more consistently than the high performing buildings, indicating that the inspiring and high performing buildings include systems or features that may provide a more readily experienced connection between the occupants, the built environment, and ultimately the surrounding environment.

Comparisons of the assessed values for each project to various building factors revealed that for the evaluated case study population the inspiring and high performing buildings on average had higher construction cost per building area than the projects that were high performing. Further investigation reveals that this increase in construction cost per building area may be related to the number of building strategies passing the beauty filters in the qualitative evaluation. While the inspiring and high performing buildings exhibited higher average construction cost per building area, they also had lower annual building energy consumption per building area than the high performing buildings. It should be noted for both the constuction cost and building energy intensity data, that there is a relatively large range observed within the case study building populations, so there may be factors that influence the cost and energy use besides performance relative to the beauty characteristics.

Chapter 6

Quantitative Evaluation of Building Energy Performance for Beautiful Building Features

The qualitative evaluation presented in Chapter 5 indicated that the inspiring and high performing buildings had lower annual energy use per building area, on average, than the high performing buildings. While there may be several factors that contribute to reduced energy use among the inspiring and high performing buildings, some of this reduction may be attributable to performance of specific building systems or features of the inspiring and high performing buildings. The next step in this research was to understand the building systems or features that may distinguish the inspiring and high performing buildings from other high performing buildings and to determine what potential impact these buildings systems or features may have on overall building energy use.

6.1 Isolation of Best Performing Beautiful Building Features

6.1.1 Analysis of Qualitative Evaluation Results

The results of the qualitative evaluation presented in Section 5.2 were used to identify and isolate building systems or features of the best performing projects. Projects were compared based upon the total project value assessed in the qualitative evaluation to identify the best performing projects. Table 6.1 organizes the projects by assessed project value, in order from highest value to lowest value.

Table 6.1: Case Study Projects by Total Project Value

Name	Building Population	Total Project Value
Kroon Hall (Yale)	LEED Platinum + AIA COTE Top Ten	98
Queens Botanical Garden Visitor Center	LEED Platinum + AIA COTE Top Ten	74
Chartwell	LEED Platinum + AIA COTE Top Ten	71
Yale Sculpture Building and Gallery	LEED Platinum + AIA COTE Top Ten	65
Jewish Reconstructionist Congregation	LEED Platinum + AIA COTE Top Ten	62
LOTT Clean Water Alliance	LEED Platinum + AIA COTE Top Ten	62
NREL Research Support Facility	LEED Platinum + AIA COTE Top Ten	58
Omega Center for Sustainable Living	LEED Platinum + AIA COTE Top Ten	58
EpiCenter, Artists for Humanity	LEED Platinum + AIA COTE Top Ten	55
Lake View Terrace Library	LEED Platinum + AIA COTE Top Ten	51
Twelve West	LEED Platinum + AIA COTE Top Ten	50
Greensburg Schools/Kiowa County Schools	LEED Platinum + AIA COTE Top Ten	46
Shangri La Botanical Gardens and Nature Center	LEED Platinum + AIA COTE Top Ten	45
Aldo Leopold Legacy Center	LEED Platinum + AIA COTE Top Ten	40
Sidwell Friends Middle School	LEED Platinum + AIA COTE Top Ten	40
Genzyme Center	LEED Platinum + AIA COTE Top Ten	39
Portola Valley Town Center	LEED Platinum + AIA COTE Top Ten	38
Blackstone Station Office Renovation	LEED Platinum	37
CBF Phillip Merrill Environmental Center	LEED Platinum + AIA COTE Top Ten	34
Eco Office	LEED Platinum	32
Great River Energy Headquarters	LEED Platinum + AIA COTE Top Ten	29
Heifer International Headquarters	LEED Platinum + AIA COTE Top Ten	28
Chicago Center for Neighborhood Technology	LEED Platinum	25
Alberici Corporate Headquarters	LEED Platinum + AIA COTE Top Ten	24
Bren Hall at UC Santa Barbara	LEED Platinum	23
Home on the Range	LEED Platinum	23
National Resources Defense Council Robert Redford Building	LEED Platinum	23
Hawaii Gateway Energy Center	LEED Platinum + AIA COTE Top Ten	21
Audubon Center at Debs Park	LEED Platinum	20
NREL Science and Technology Facility	LEED Platinum	20
Heartland Consumers Power District	LEED Platinum	18
Greensburg Business Incubator	LEED Platinum	16
Chicago Center for Green Technology	LEED Platinum + AIA COTE Top Ten	0
Half-Moon Outfitters Distribution Center	LEED Platinum	0
Inland Empire Utilities Agency Headquarters	LEED Platinum	0

The three projects with the highest assessed values were Kroon Hall, Queens Botanical Garden Visitor Center, and Chartwell, which all had assessed project values greater than 70. In addition to the three projects with the highest values, the projects with assessed project values greater than the inspiring and high performing building average of 47 were identified for comparison. These projects were divided into three total tiers: the top three projects already identified; a second tier with values between 60 and 70; and a third tier with values between 50 and 60. Table 6.2 lists the projects identified for use in isolating building systems or features distinguishing beautiful and inspiring buildings.

Table 6.2: Groups for Building Feature Comparison

Name	**Building Population**	**Total Project Value**	**Comparison Group**
Kroon Hall (Yale)	LEED Platinum + AIA COTE Top Ten	98	Top Three
Queens Botanical Garden Visitor Center	LEED Platinum + AIA COTE Top Ten	74	Top Three
Chartwell	LEED Platinum + AIA COTE Top Ten	71	Top Three
Yale Sculpture Building and Gallery	LEED Platinum + AIA COTE Top Ten	65	Second Tier
Jewish Reconstructionist Congregation	LEED Platinum + AIA COTE Top Ten	62	Second Tier
LOTT Clean Water Alliance	LEED Platinum + AIA COTE Top Ten	62	Second Tier
NREL Research Support Facility	LEED Platinum + AIA COTE Top Ten	58	Third Tier
Omega Center for Sustainable Living	LEED Platinum + AIA COTE Top Ten	58	Third Tier
EpiCenter, Artists for Humanity	LEED Platinum + AIA COTE Top Ten	55	Third Tier
Lake View Terrace Library	LEED Platinum + AIA COTE Top Ten	51	Third Tier
Twelve West	LEED Platinum + AIA COTE Top Ten	50	Third Tier

The average assessed values per Beauty Determinant, which make up the total project values for each of the top three tiers, are shown for each Beauty Determinant in Figure 6.1.

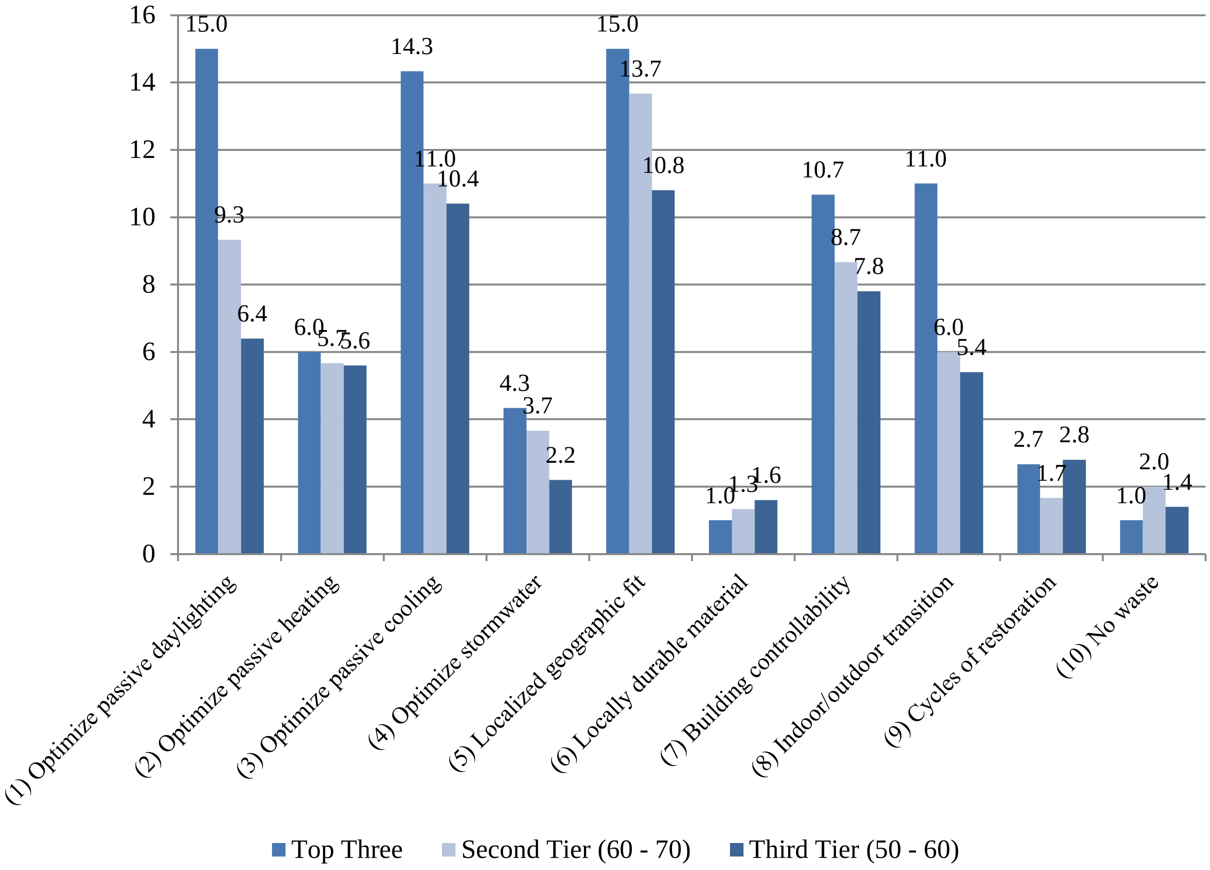


Figure 6.1: Average Beauty Determinant Assessed Value – Top Three Tiers

The results in Figure 6.1 display the expected profile for the majority of the Beauty Determinants, with the top three having the highest average value, followed by the second tier, and lastly the third tier. Some Beauty Determinants have greater disparity than others, and Beauty Determinants 6, 9, and 10 do not follow the expected profile for assessed value.

To identify which building systems or features distinguished the inspiring and high performing buildings from the high performing buildings, the average assessed value of each Beauty Determinant was compared to the remaining case study population for each of the top three tiers. For a Beauty Determinant, comparisons were made by determining the difference between the average assessed value for the tier group and the average assessed value for project case studies below that tier. The difference was then divided by the average assessed value of the project case studies below the tier to give a fractional difference between the tier group and the rest of the population. The fractional difference was calculated for each tier group relative to the other inspiring and high performing buildings as well as relative to the entire project case study population. Based on this comparison, if a tier group performed better than the remaining population on a particular Beauty Determinant by a fractional difference of one, the average Beauty Determinant assessed value for that tier was double the average assessed value of the remaining population. Therefore, a value of one was used as the critical value for identifying the Beauty Determinants that distinguished the top three tiers from the balance of the high performing projects in the case study population. Figure 6.2, Figure 6.3, and Figure 6.4 show the fractional difference of the average Beauty Determinant assessed value for the top three, second tier, and third tier, respectively.

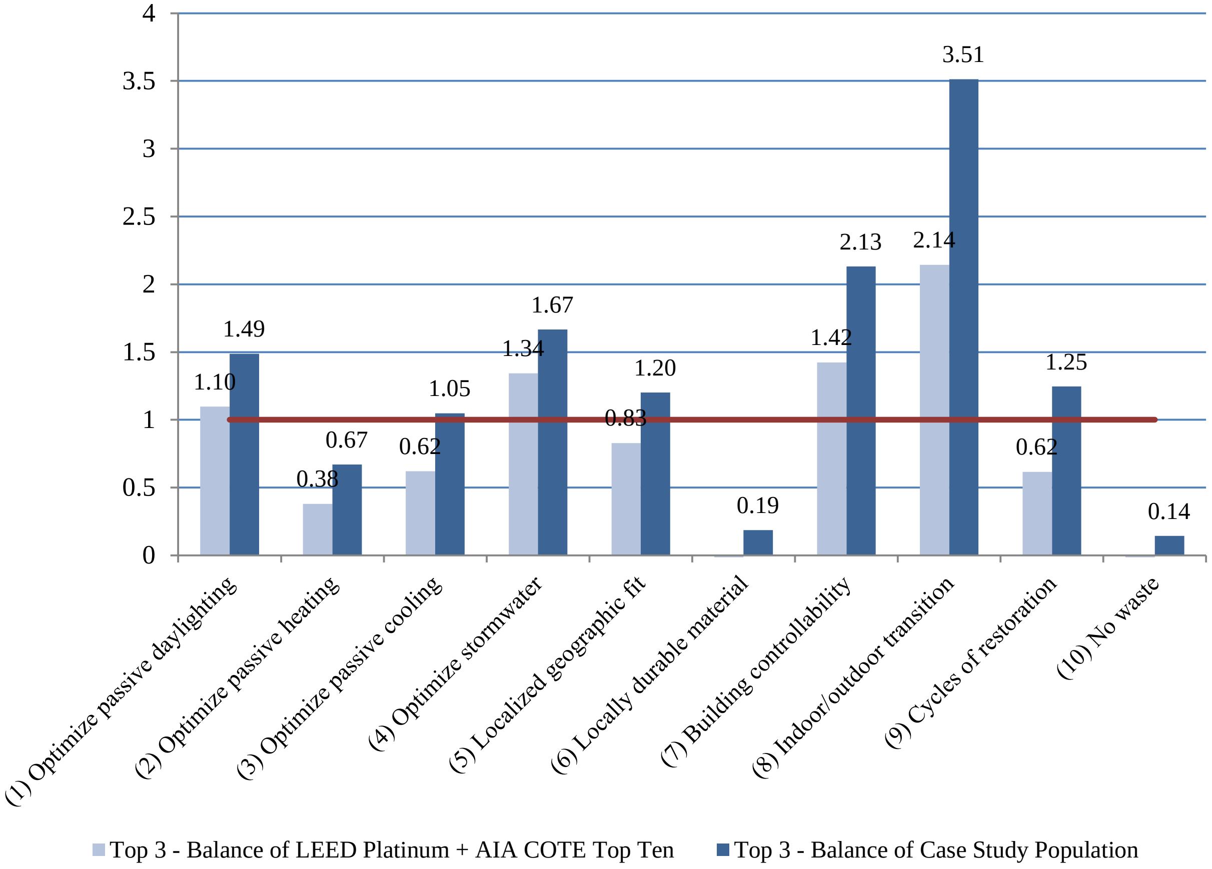


Figure 6.2: Fractional Difference in Beauty Determinant Average Assessed Value – Top Three

For the top three projects, Beauty Determinants 1, 4, 7, and 8 clearly stood out as having better performance relative to the inspiring and high performing buildings as well as the entire project case study population. Beauty Determinants 3, 5, and 9 displayed better performance than the project case study population as a whole, but did not exceed the critical value of one when compared to the inspiring and high performing buildings only.

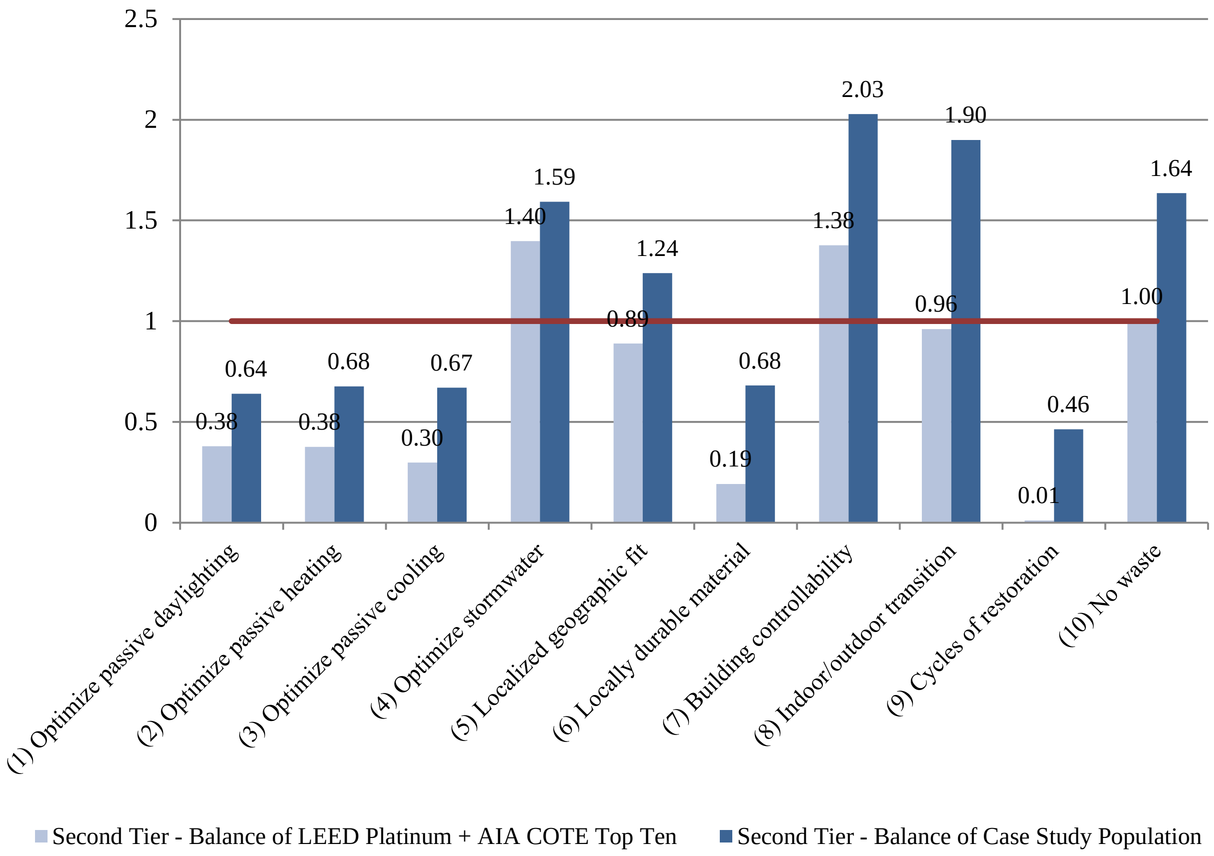


Figure 6.3: Fractional Difference in Beauty Determinant Average Assessed Value – Second Tier

For the second tier projects, Beauty Determinants 4, 7, and 10 stood out as having better performance relative to the inspiring and high performing buildings as well as the entire project case study population. Beauty Determinants 5 and 8 displayed better performance than the project case study population as a whole, but did not exceed the critical value of one when compared to the inspiring and high performing buildings only.

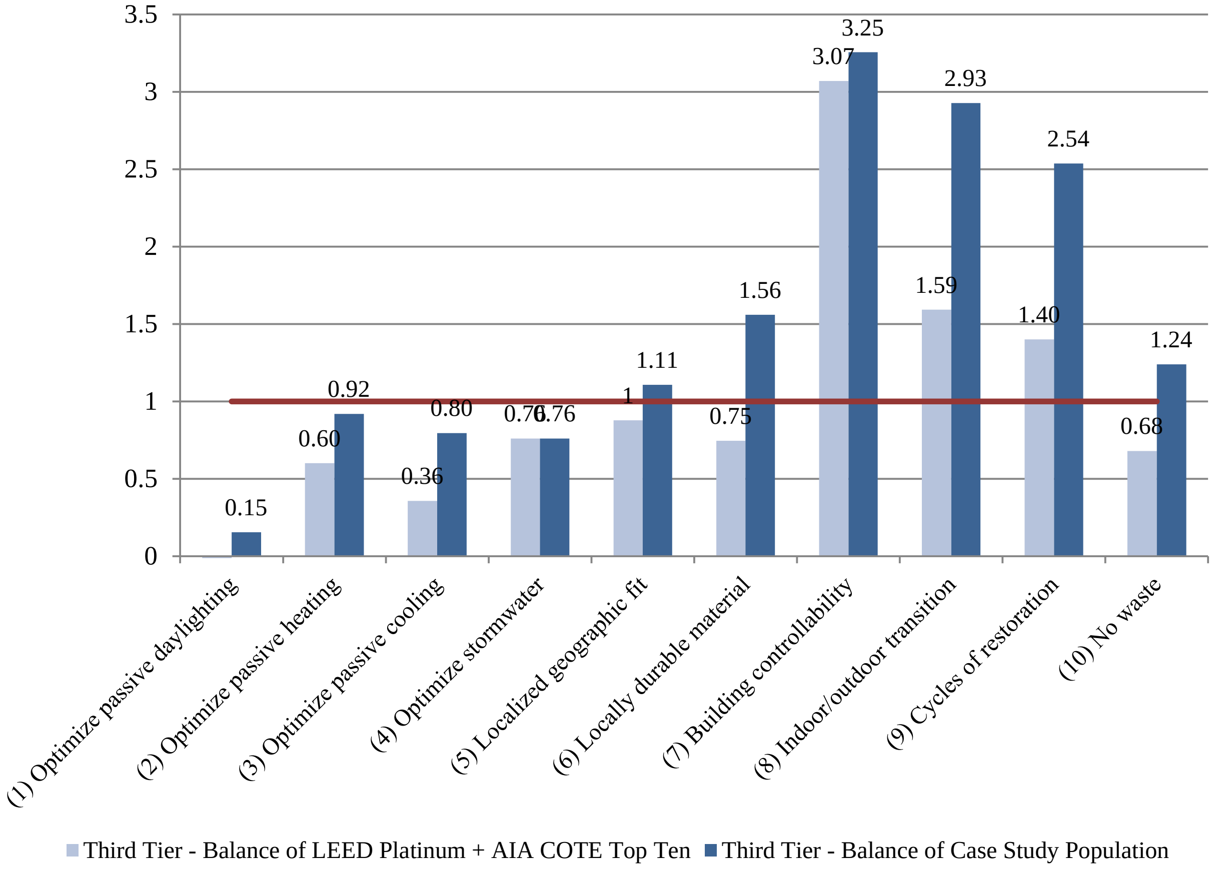


Figure 6.4: Fractional Difference in Beauty Determinant Average Assessed Value – Third Tier

For the third tier projects, Beauty Determinants 7, 8, and 9 stood out as having better performance relative to the inspiring and high performing buildings as well as the entire project case study population. Beauty Determinants 5, 6, and 10 displayed better performance than the project case study population as a whole, but did not exceed the critical value of one when compared to the inspiring and high performing buildings only.

6.1.2 Identified Beautiful Building Features

The results of the comparison in Beauty Determinant average assessed value are summarized for all three tiers in Table 6.3. Beauty Determinants with fractional differences greater than the critical value relative to both the inspiring and high performing buildings and the entire case study population were labeled as first level. Beauty Determinants with fractional differences greater than the critical value relative to the entire case study population, but not relative to the remaining inspiring and high performing buildings were labeled as second level.

Table 6.3: Beauty Determinant Summary for Building Feature Comparison

Tier Group	**First Level Beauty Determinants**	**Second Level Beauty Determinants**
Top Three	1, 4, 7, 8	3, 5, 9
Second Tier	4, 7, 10	5, 8
Third Tier	7, 8, 9	5, 6, 10
Overall (Present in more than one Tier)	4, 7, 8	5

Based on the results of the comparison of Beauty Determinant average assessed value, the Beauty Determinants 4, 5, 7, and 8 were identified as areas that most distinguished the inspiring and high performing buildings from the remainder of the case study population.

To develop a list of building systems or features distinguishing the beautiful and inspiring buildings from the other high performing buildings, the project case studies for the tier groups were reviewed and the building strategies associated with the Beauty Determinants identified from the tier group comparison were listed. The building strategies were consolidated into a single list with representative descriptions. Many building strategies represent more than one Beauty Determinant, leading to a list of building strategies that encompass more Beauty Determinants than just 4, 5, 7, and 8. For example, many of the building strategies representing Beauty Determinants 5 and 7 include operable windows and daylight control, resulting in a building system representative of Beauty Determinants 1, 2, and 3 as well. Because density is an important feature in beautiful and inspiring buildings, as identified in Chapter 3, this is an expected consequence. A total of seven building systems or features were identified from this analysis. These building systems or features are listed in Table 6.4, and discussed in detail below, including their importance to human performance and occupant satisfaction. Accompanying examples from the top three tier groups are provided for each building system or feature.

Table 6.4: Building Systems or Features Distinguishing Beautiful Buildings

Building System or Feature
Operable window placement and size to optimize daylight, views, and ventilation (prevailing breezes) and foster connection to outdoors
Building form designed for daylight penetration and natural ventilation (stack or cross-flow) and to keep outdoor access close
Building integrated with landscape providing insulation (and mass) for cooling and heating, and opportunities for vegetated roofs in some cases
Vegetated roof accessible to occupants and aids in rainwater collection and building insulation
Rainwater catchment system prominent and visible; designed for interaction with participants
Large opening doors to blur demarcation between indoors and outdoors and provide seasonal opportunities for ventilation and cooling as well as daylight
Transitional space (thermal buffer/patio/arcade/courtyard) between indoors and outdoors

- Operable window placement and size to optimize daylight, views, and ventilation (prevailing breezes) and foster connection to outdoors

- Building form designed for daylight penetration and natural ventilation (stack or cross-flow) and to keep outdoor access close

The first two building strategies are complementary, and Kroon Hall is used as an example to illustrate both. The building has a long and narrow footprint to improve daylight penetration and also encourage airflow with natural ventilation. Kroon Hall has a moderate amount of windows on the north and south facades (the long faces), but uses good window placement combined with the long and narrow form and interior floor layout to provide good light and air movement to the building interior. The north and south windows are recessed to provide control of glare and solar gain during summer months. The east and west facades are nearly all glazing, with external wooden louvers to provide shade and glare control while preserving views from within the building. The building’s central stairway helps physically and visually connect occupants to other parts of the building as well as to the outdoors via the views through the east and west facades. The placement of windows, central stairwell, and use of skylights atop help increase daylight penetration as seen in Figure 6.5. The central stairway also allows for stack-effect ventilation to complement the cross ventilation from the operable windows, which is illustrated in Figure 6.6. Window operation is controlled by occupants but Kroon Hall employs a system that alerts occupants when windows should be opened or closed to best take advantage of outdoor conditions.

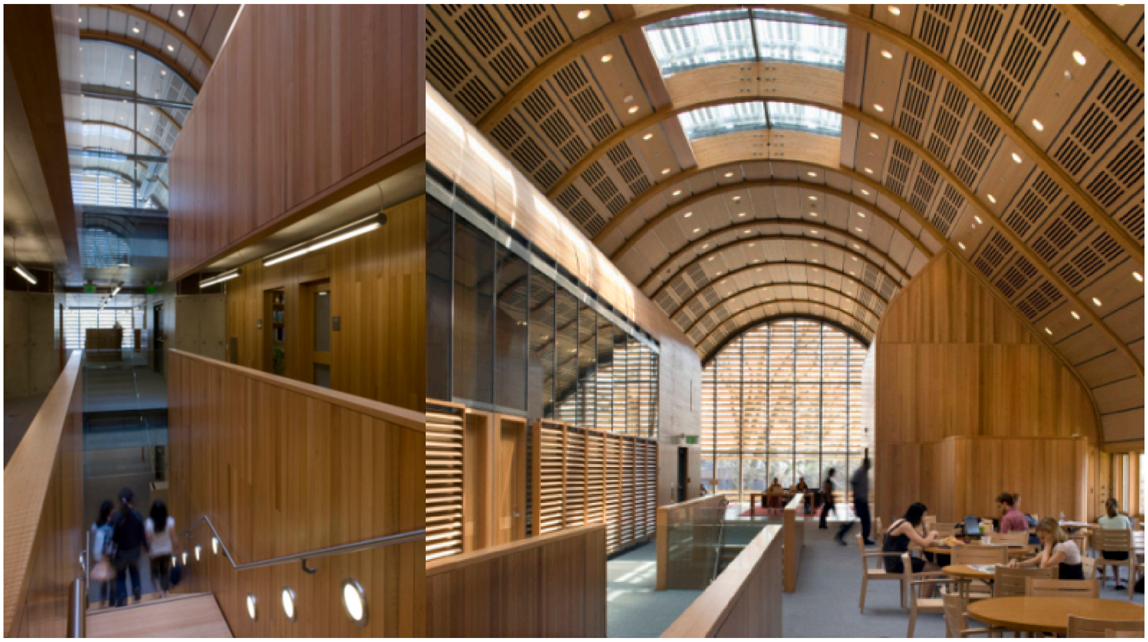


Figure 6.5: Central Stairwell, Window Placement, and Building Layout for Daylighting – Kroon Hall

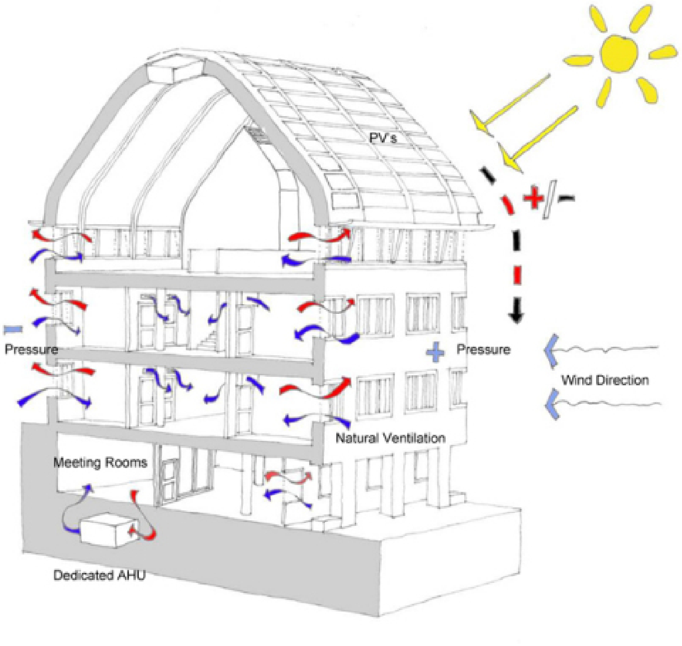


Figure 6.6: Natural Ventilation Schematic – Kroon Hall

- Building integrated with landscape providing insulation (and mass) for cooling and heating, and opportunities for vegetated roofs in some cases

Queens Botanical Garden Visitor Center was chosen to illustrate the integration of the building, or part of the building, within the landscape. The visitor center is divided into two parts, a reception building that includes offices spaces for staff, and an auditorium space for various public events. The auditorium space is partially underground and is covered by a vegetated roof that integrates with the surrounding gardens and landscape, including a foot path that meanders up to the crest of the auditorium roof. Figure 6.7 provides an elevation view of the visitor center showing the sloping roof of the partially underground auditorium.

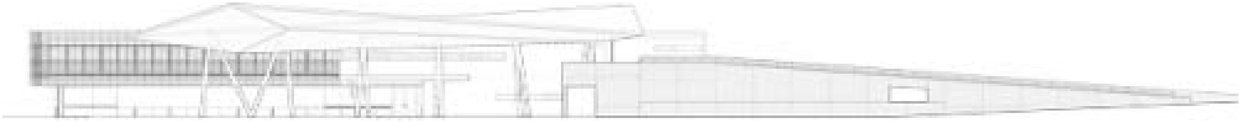


Figure 6.7: Building Elevation Illustrating Partially Underground Auditorium – Queens Botanical Garden Visitor Center

The vegetated roof and foot path are shown in Figure 6.8. Also shown is another prominent feature of the visitor center, a water channel that begins at a large pool near the reception building and flows between the reception building and the auditorium. A frog’s eye window looks across the water channel, and together with skylights in the vegetated roof, provides daylight to the partially underground auditorium.

Figure 6.8: Auditorium Vegetated Roof and Separating Water Channel – Queens Botanical Garden Visitor Center

- Vegetated roof accessible to occupants and aids in rainwater collection and building insulation

While vegetated roofs are not an uncommon feature of high performing buildings and are known for their insulative and stormwater management benefits, the distinguishing feature of the inspiring and high performing buildings is making vegetated roofs accessible to occupants and encouraging them to experience a micro natural environment. The Queens Botanical Garden Visitor Center auditorium shown in Figure 6.8 provides an excellent example of a vegetated roof that is accessible to occupants. The foot path from the main walkway in the garden encourages visitors to explore the rooftop area. Another example of a vegetated roof that is made accessible to occupants is seen at the LOTT Clean Water Alliance Regional Service Center. Vegetated roofs situated atop lower levels of the building are accessible to occupants on upper floors. The presence of the vegetated roof area may also help reduce glare from sunlight that might reflect off typical roof membranes.

Figure 6.9: Vegetated Roof Accessible for Occupants – LOTT Clean Water Alliance

- Rainwater catchment system prominent and visible; designed for interaction with participants

Similar to the vegetated roof building feature previously described, it is not unusual for rainwater catchment systems or pervious pavement to be present in high performing buildings. However, the distinguishing feature of the inspiring and high performing buildings is making these systems accessible to occupants and engaging them, visibly, audibly, or by touch. Again, the Queens Botanical Garden Visitor Center provides an excellent example with the water channel shown in Figure 6.8. The water begins in a main biotope pool by the building entrance, flows through the channel into a series of biotope pools on the site and emerges in a fountain at the garden entry. The water feature responds in level and flow to weather and season. Figure 6.10 shows a schematic of the building grounds with the main pool, water channel, and flow path through the site to the entry fountain visible.

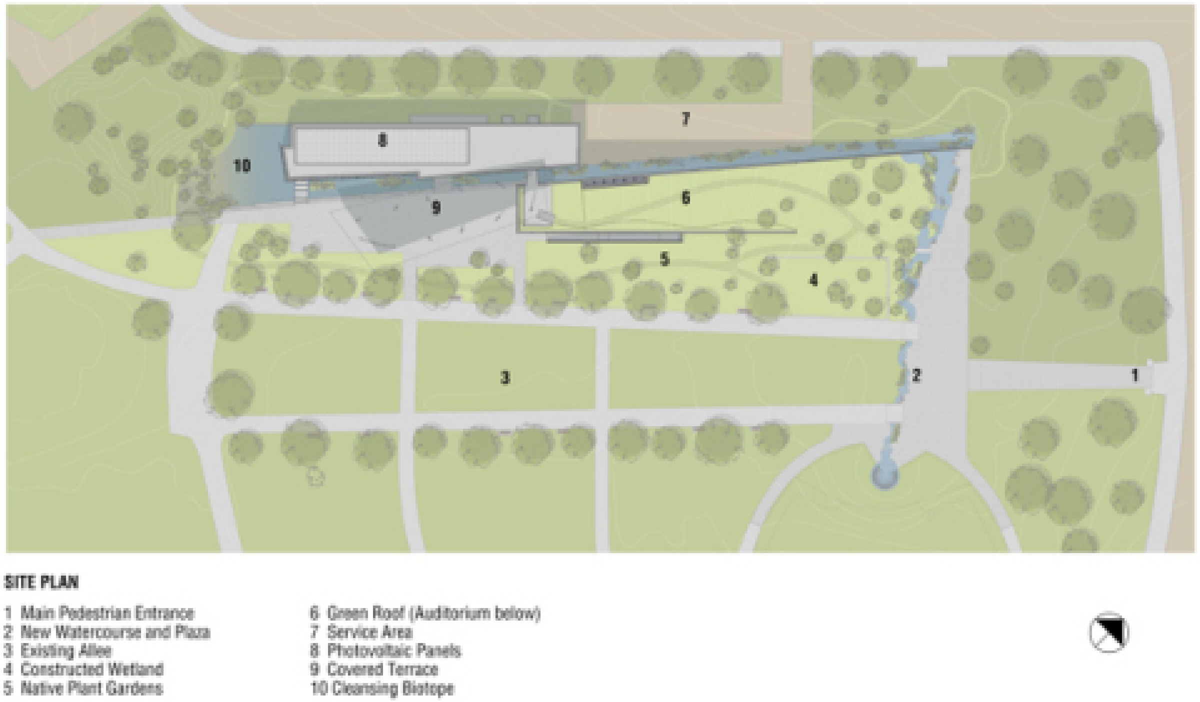


Figure 6.10: Rainwater Collection System Prominence on Site Grounds – Queens Botanical Garden Visitor Center

Another good example of a rainwater collection system accessible to occupants is the rainwater cistern at the Chartwell school. Water is collected in a large cistern and flows through a series of channels in the plaza. The water channels serve as a source of play and for teaching for the students at Chartwell. Figure 6.11 shows the cistern and water channels. Several additional examples of water features engaging to occupants can be found at other top tier group projects, such as LOTT Clean Water Alliance, the Omega Center for Sustainable Living, and EpiCenter, Artists for Humanity.

Figure 6.11: Student Interaction with Rainwater Collection System – Chartwell

- Large opening doors to blur demarcation between indoors and outdoors and provide seasonal opportunities for ventilation and cooling as well as daylight

Several projects in the top tier groups included spaces with large opening doors, such as sliding, folding, large roll top, or garage style doors, which could be opened during favorable weather. The doors allow for natural ventilation of the spaces, taking advantage of breezes to cool the space. They effectively "bring the outdoors in" by removing the barrier between the indoor space and the outdoor space. These spaces can aid or improve the transition between indoors and outdoors, and encourage movement between the two. Examples of spaces with large opening doors are shown for Chartwell, the Yale Sculpture Building and Gallery, and EpiCenter, Artists for Humanity in Figure 6.12, Figure 6.13, and Figure 6.14, respectively.

Figure 6.12: Large Opening Doors in Multi-Use Area – Chartwell

The multi-use area at Chartwell include four large, garage style doors that may be opened when weather permits. As seen in the view from outside the building, opening all four doors effectively removes the lower half of the exterior wall for the multi-use area and expands this space into the adjacent courtyard.

Figure 6.13: Large Opening Doors for Gallery Entry – Yale Sculpture Building and Gallery

The entry to the gallery includes large, folding doors that may be opened when weather permits. Opening these doors contributes to natural ventilation within the gallery and removes the barrier between the gallery and the street, which may encourage passers by to visit the gallery.

Figure 6.14: Large Opening Doors for Main Gallery – EpiCenter, Artists for Humanity

The main floor of the EpiCenter includes a large, garage style door that may be opened when weather permits. A small, landscaped courtyard was built outside the doorway to provide a gathering space and natural environment amidst the urban and industrial setting of the EpiCenter.

- Transitional space (thermal buffer/patio/arcade/courtyard) between indoors and outdoors

Several of the projects in the top tier groups included some form of transitional spaces to promote movement between the indoor built environment and the surrounding environment. Examples of these transitional spaces include thermal buffer corridor spaces, such as included in the Aldo Leopold Legacy Center or the Jewish Reconstructionist Congregation; patio and plaza spaces, such as Chartwell or the

Queens Botanical Garden Visitor Center; and courtyard spaces, such as EpiCenter, Artists for Humanity or Kroon Hall. Examples of each of these types of transition spaces are shown for the Jewish Reconstructionist Congregation, the Queens Botanical Garden Visitor Center, and Kroon Hall in Figure 6.15, Figure 6.16, and Figure 6.17, respectively.

Figure 6.15: Stairwell as Thermal Buffer Space – Jewish Reconstructionist Congregation

The stairways of the Jewish Reconstructionist Congregation are placed on the north and south sides of the building, forming thermal buffer zones between the building exterior and the building core. The south stairway begins at the main entrance and functions as the main corridor of the building. The large windows along the stairway allow the space to take advantage of solar heating. They also provide a transition between the indoor built environment and outdoor natural environment, as occupants can easily see either inward or outward as they ascend or descend the stairs entering and exiting the building.

Figure 6.16: Covered Entry Patio Space – Queens Botanical Garden Visitor Center

The main entry to the visitor center at the Queens Botanical Garden Visitor Center employs a large canopy that functions as a solar shade for the reception building, angled to prevent glare in summer and allow solar gain in winter. It also forms a covered patio and public gathering space for the building. This covered space serves as an extension of the building to the outdoors and provides a transition between the indoor built environment and outdoor natural environment. Visitors and occupants can easily congregate in either space depending upon weather conditions. The covered patio also affords a view of the main biotope pool and water channel described previously.

Figure 6.17: Ground Floor Cloister Space – Kroon Hall

The ground floor of Kroon Hall opens to large lawn where classes and students gather during favorable weather. An arcade between the lawn and the ground floor forms a cloister that provides a space of transition from the building interior to the outdoor space, and encourages students to take advantage of the courtyards constructed as part of the project. Other spaces within the building are also designed with close access to courtyards, which include seating to foster outdoor gatherings. The lawn pictured also serves as a vegetated roof for an underground parking area for university service vehicles.

6.1.2.1 Importance to Occupants

Section 5.2 observed that inspiring and high performing buildings were more consistent in achieving points related to the Connectivity Beauty Attribute. This connection between building and occupants is a primary theme among the building features identified as distinguishing for the inspiring and high performing buildings and presented in Section 6.1.2. Past and present research supports these findings in key areas relating to the building features and Beauty Determinants identified.

Beauty Determinant 4 concerns stormwater management, but an important part of the water collection systems identified was their proximity and accessibility to occupants. Addressing this connection to water, the importance of water in the landscape was studied for adults and children in a rural setting in Japan. Findings indicated that water is especially attractive for children and that designers should ensure close proximity of water features to allow interaction (Yamashita, 2002), such as the example given of the rainwater collection cistern at Chartwell.

Beauty Determinant 7 relates to occupant control and the ability of the built environment to respond to changes in conditions. The importance of occupant control was identified as a key factor for occupant comfort in a study conducted by ASHRAE, which focused on how operable windows affect the indoor thermal environment and occupant comfort. The study continuously measured subjects' microclimate and used a repetitive survey taken multiple times per day to collect information on occupant comfort. The research supported the relaxed operative temperatures for naturally conditioned spaces provided in ASHRAE 55-2004, but only if the occupants have access for personal control of their environmental conditions, such as control of operable windows (Brager, Paliaga, & de Dear, 2004). Personal control of the environment was also identified as a primary variable affecting human productivity – or the ability to enhance their work output through increases in quantity and/or quality – by research conducted on multiple European office buildings (Leaman & Bordass, 1999). Increased ventilation rates, which can be a result of natural ventilation through operable windows, have also been shown to reduce the prevalence of sick building syndrome symptoms (Fisk, Mirer, & Mendell, 2009).

Beauty Determinant 8 relates to the transition between the indoor built environment and the surrounding outdoor environment. This may be experienced through the presence of views to the outdoors or close proximity to outdoor access from the building. Numerous studies have documented the importance of views and access to nature for occupant satisfaction. One such study specifically investigated how the content in the view from a window impacted occupant satisfaction and well-being. The research suggested that views with components of nature contributed substantially to occupant satisfaction and sense of well-being, where views of built elements had lesser impacts on satisfaction (Kaplan R. , 2001). The restorative effects of access to and time spent in nature have also been studied extensively. Research has shown that time spent in the natural environment has more restorative effects than a simulated natural environment consisting of images and videos (Kjellgren & Buhrkall, 2010), making buildings with close access to nature important and potentially more beneficial to occupants than simply having a view from a window. Roger Ulrich has conducted numerous studies on the health benefits of nature and gardens in hospital environments (Ulrich, 2002).

Overall, the ability to control one’s environment and presence of or access to nature play significant roles in occupant satisfaction with the built environment. These factors have also been shown to impact the performance and health of occupants, which can have significant value beyond the energy impacts of the building systems or features identified as distinguishing factors for beautiful and inspiring buildings.

6.2 Building Energy Simulation of Beautiful Building Features

Section 6.1.2 identified the building systems or features that distinguished the inspiring and high performing buildings from other high performing buildings. The next step of this research used building energy simulation to determine the potential impact these building systems or features may have on overall building energy use. The identified building systems or features were translated into building features that could be explored using energy models, and grouped based on the building systems or features given in Section 6.1.2. The building features were organized into a total of four main groups with specific modeling parameters listed for each of the various building features as outlined in Table 6.5.

Table 6.5: Building Energy Simulation Outline

Model Group	**Building Feature**		**Modeling Parameters**	**Number of Cases**
Window + Form	Operable window placement and size to optimize daylight, views, and ventilation (prevailing breezes) and foster connection to outdoors		Daylighting only vs. daylighting + hybrid ventilation (via operable windows)	2
			Windows concentrated on south and north, with minimal apertures on east and west vs. equal concentration vs. use of shading devices (louvers)	3
	Building form designed for daylight penetration and natural ventilation (stack or cross-flow) and to keep outdoor access close		Square building vs. reference (rectangle) vs. long and narrow (depth of 40 ft. across)	3
Transition Spaces	Transitional space fostering connection between indoors and outdoors	Landscape	Compare different landscape surfaces – asphalt, concrete, vegetation	3
		Large doors to blur demarcation between indoors and outdoors (used with hybrid ventilation)	Orientation of space with doors – N, S, E, W	4
			Doors with vegetated landscape	4
			Doors with covered patio	4
			Doors with covered patio and vegetated landscape	4
		Thermal buffer zones	With and without daylighting + hybrid ventilation, and with and without vegetated landscape	3
		Covered Patio	Orientation of shade – N, S, E, W	16
			Angle of shade – 0°, 15°, 30°, 45°	
			With daylighting+hybrid ventilation	16
			With vegetated landscape	16
Integrated with Landscape	Building integrated with landscape (Walls with ground contact)		Number (1, 2, 3) and orientation (N, S, E, W) of building walls embedded in landscape	12
			With vegetated landscape	12
Vegetated Roof	Vegetated roof accessible to occupants (on a lower level of a multi-level building) and aids in rainwater collection and building insulation		Compare mid level vegetated roof, top level vegetated roof, and both mid and top level	3

Based on the modeling parameters identified in Table 6.5, EnergyPlus was selected as the energy simulation software for investigating the energy performance of the building systems or features.

Although eQUEST is more commonly used in the U.S. building industry for energy simulation, particularly within the LEED certification process, EnergyPlus was better suited for modeling the hybrid ventilation strategy. EnergyPlus Version 6.0.0.023 was used to perform energy simulations of building models as outlined in Table 6.5. Descriptions of the building energy models are given below.

6.2.1 EnergyPlus Building Models

Energy impacts of each building system or feature were measured against the energy performance of a base building model. Changes were applied to the base building model and the resulting energy use compared to the energy use of the unaltered building model. To capture potential effects of climate on energy use for the investigated building systems or features, building energy simulations of each modeling parameter were also performed for multiple climate regions representative of the climate regions of the tier group buildings.

6.2.2 Multiple Climate Regions

The three tier groups included projects located in climate regions 3B, 4A, 5, 5A, and 5B; as a result energy simulations were completed in locations representing each of these climate regions. The building envelope construction of the building models was adjusted based on ASHRAE Standard 90.1-2004 to be appropriate for each climate region. The Commercial Buildings Initiative of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy provides a reference table and EnergyPlus building models for DOE Reference Buildings in each of the climate regions (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2010). Table 6.6 outlines the climate regions, locations, and associated major building envelope parameters used to simulate the performance of the building systems or features in the selected climate regions.

Table 6.6: Building Model Information by Location

Location	Los Angeles	Washington, D.C.	Boston	Chicago	Golden
ASHRAE 90.1-2004 Climate Zone	3B-CA	4A	5	5A	5B
Exterior walls					
Construction Type	Steel frame	Steel frame	Steel frame	Steel frame	Steel frame
R-value ($m^2 \cdot K$ / W)	1.42	1.42	2.10	2.10	2.10
Roof					
Construction Type	IEAD	IEAD	IEAD	IEAD	IEAD
R-value ($m^2 \cdot K$ / W)	2.79	2.79	2.85	2.85	2.85
Window					
U-Factor (W / $m^2 \cdot K$)	3.24	3.24	3.24	3.24	3.24
SHGC	0.25	0.39	0.39	0.39	0.39
Visible transmittance	0.16	0.31	0.31	0.31	0.31
Foundation					
Foundation Type	Mass Floor	Mass Floor	Mass Floor	Mass Floor	Mass Floor
Construction	4 in slab w/carpet	4 in slab w/carpet	4 in slab w/carpet	4 in slab w/carpet	4 in slab w/carpet
R-value ($m^2 \cdot K$ / W)	0.54	0.54	0.54	0.54	0.54

6.2.2.1 Base Building

The base building model for energy simulation was based upon the DOE Reference Building for a medium office. This building was chosen because the commercial office building type is representative of a large number of the buildings from the case study population. The building is based on ASHRAE Standard 90.1-2004 and ASHRAE Standard 62-1999. Building envelope construction may be adjusted for the climate region based on ASHRAE 90.1-2004, and the window to wall ratio is approximately 33 percent. The office is a three-story rectangular building with four perimeter zones and a core zone on each floor for a total of fifteen zones. The building is approximately 164 feet long and 109 feet wide, with a total floor area of approximately 53,628 ft^2. Figure 6.18 shows a basic image of the base building model.

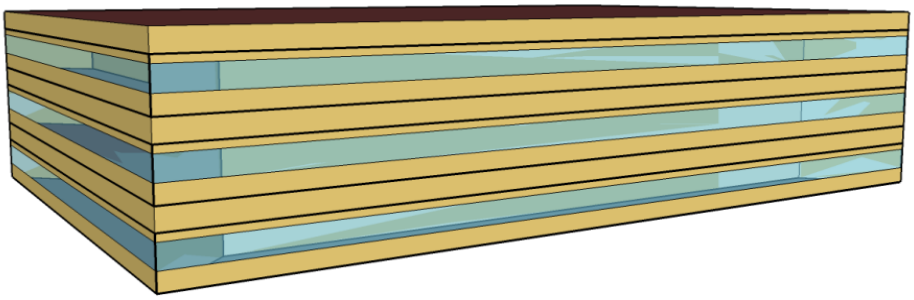


Figure 6.18: EnergyPlus Base Building Model – DOE Medium Office Reference Building

The building utilizes a variable air volume (VAV) HVAC system with terminal reheat at each zone. The main heating coil for the air handling unit (AHU) uses natural gas as the heating source, while the reheat coils at each VAV box use electricity as the heating source. Cooling is provided by a direct expansion (DX) coil. The building assumes infiltration at perimeter zones of 0.4 cfm/ft^2, with only 25 percent of this value when the VAV system is operating. Sizing of the HVAC system was automatically performed by EnergyPlus based on the heating and cooling design days for the location modeled.

Internal loads for the building are given in Table 6.7. The base building does not include daylight control, external shading, or the use of natural ventilation.

Table 6.7: EnergyPlus Base Building Internal Loads

Internal Load	**Value**
Lighting	1.0 W/ft^2
Plug Loads	1.0 W/ft^2
People	5 people/1,000 ft^2
Elevators	2 @ 20 HP each, 91% motor efficiency

6.2.2.2 Window + Form

A series of adjustments were made to the base building model to represent the building features for operable window placement and to represent building form designed for daylight, views and ventilation that also fosters connection to the outdoors. Each of the building model adjustments made in the Window + Form category are described below.

6.2.2.2.1 Daylighting

To begin, the base building was modeled with and without daylighting control. Although daylighting was not listed as an overall first or second level Beauty Determinant in Table 6.3, it is an integral part of many of the building systems or features being investigated. To help illustrate the impact of the Density aspect, daylight control was modeled individually and then together with hybrid ventilation to show the benefit of designing window systems for both daylight and natural ventilation purposes. The daylighting feature of EnergyPlus was previously tested and shown to be sufficiently accurate for predicting reductions in electric lighting power and VAV reheat coil power, providing results within approximately 17% of representative test conditions (Loutzenhiser, Maxwell, & Manz, 2007).

6.2.2.2.2 Daylight + Hybrid Ventilation

To illustrate the benefits of Density, a building model combining daylighting control with natural ventilation through operable windows was developed. Natural ventilation was added to the base building model with daylight control. The Zone Ventilation model within EnergyPlus was used to simulate natural ventilation through operable windows based on the wind and stack effect. The Zone Ventilation model utilizes information on the window opening area and opening schedule together with wind speed and temperature data from the EnergyPlus weather file to determine the ventilation airflow within the building. The user may input a temperature schedule to determine the bounds for natural ventilation and provide indoor and outdoor temperature cutoff ranges, outside of which windows are closed and natural ventilation is not used. A maximum wind speed is also specified as a cutoff for natural ventilation. Parameters used to define the Zone Ventilation model are listed in Table 6.8.

Table 6.8: EnergyPlus Zone Ventilation Model Inputs

Parameter	**Value**
Window Opening Fraction	0.3
Minimum Indoor Temperature	65°F
Maximum Indoor Temperature	80°F
Delta Temperature	0°F
Minimum Outdoor Temperature	50°F
Maximum Outdoor Temperature	86°F
Maximum Wind Speed	89 mph

The building model for this research assumed that windows were typically operated by building occupants rather than an automated system, although projects like Kroon Hall employ systems to alert occupants when to open and close windows. To represent windows that were occupant controlled, only 30 percent of windows were assumed to be open at any time when natural ventilation was in use. Because the base building model represents windows as one area of glazing for the given building façade, operation of individual windows was not modeled. The window opening fraction was set to 0.3 during ventilation periods, simulating all windows as 30 percent open, rather than modeling 30 percent of individual windows open. Since the Zone Ventilation model bases airflow on the area of the opening and not the position, this should achieve the same effect within the model as if 30 percent of individual windows were fully open.

ASHRAE Standard 55-2004 provides indoor temperatures for occupant comfort specific to buildings utilizing natural ventilation in Section 5.3 of the Standard. These temperatures are more relaxed than the comfort standards for mechanically ventilated buildings and are presented in Figure 6.19 (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2004). The maximum and minimum indoor temperatures specified for the Zone Ventilation model are based on the temperatures provided by ASHRAE Standard 55-2004 at minimum and maximum outdoor temperatures of 50°F and 86°F, respectively. The maximum wind speed cutoff was based on the default value provided by EnergyPlus.

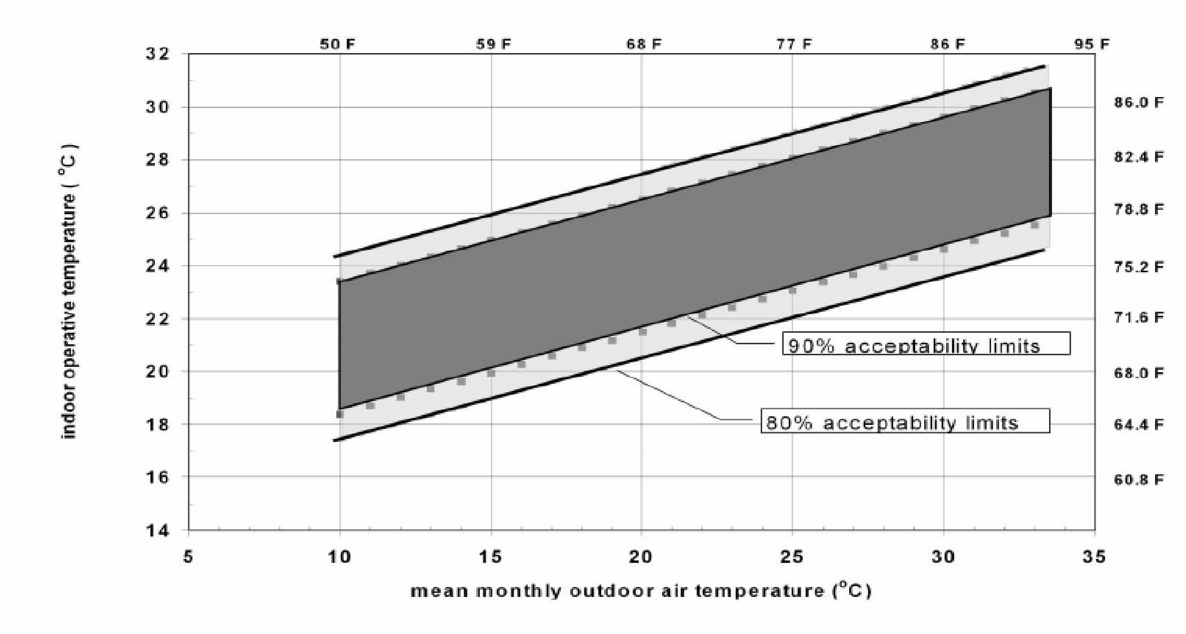


Figure 6.19: Operative Temperature Ranges for Naturally Conditioned Spaces – ASHRAE 55-2004

The heating and cooling setpoint schedules for the base building model were adjusted to follow heating, cooling, and natural ventilation seasons shown in Table 6.9.

Zone mixing during natural ventilation was modeled by placing “doors” on the interior surfaces between the perimeter zones and the core zone on each floor. The “ZoneMixing” command of the Zone Ventilation model was used to specify the number of air changes per hour between the core and perimeter zones. An air change rate of 2 air changes per hour was used to represent mixing between the core and the north and south perimeter zones, and a rate of 1.2 air changes per hour was used to represent mixing between the core and the smaller east and west perimeter zones.

The majority of projects in the case study population relied on a combination of natural and mechanical ventilation based upon season. Therefore, a hybrid ventilation approach was used for the building model. To model hybrid ventilation for the building, a seasonal schedule was developed to control the use of natural ventilation versus the operation of the mechanical system. The seasonal schedule was developed for each location based on the operative temperature of the interior spaces. A simulation was first performed using natural ventilation only. The daytime operative temperature was recorded on an hourly basis for an entire year of operation. Three “seasons” were defined to describe system operation: heating, cooling, and natural ventilation. The heating season consisted of times when the indoor operative temperature was typically below 68°F. The cooling season consisted of times when the indoor operative temperature was typically above 77°F. The natural ventilation season consisted of times when the indoor operative temperature was between 68°F and 77°F. This approach for determining the seasonal schedule for hybrid ventilation follows the method used by previous research conducted for low energy cooling systems in a mild climate (Olsen & Chen, 2003). Table 6.9 shows the heating, cooling, and natural ventilation seasons defined for each location based upon inspection of the indoor operative temperature.

Table 6.9: Hybrid Ventilation Seasons by Location

Season	**Los Angeles**		**Washington D.C.**		**Boston**		**Chicago**		**Golden**	
	Begin	End	Begin	End	Begin	End	Begin	End	Begin	End
Heating	NA	NA	Dec.21	Jan.31	Nov.16	Feb.28	Nov.30	Mar.31	Dec.16	Feb.15
Cooling	Jul.1	Oct.15	May21	Sep.30	Jun.21	Sep.30	Jun.1	Sep.30	Jun.21	Sep.30
Natural Ventilation	Oct.16	Jun.30	Feb.1	May20	Mar.1	Jun.20	Apr.1	May31	Feb.16	Jun.20
			Oct.1	Dec.20	Oct.1	Nov.15	Oct.1	Nov.30	Oct.1	Dec.15

Seasonal schedules were implemented within EnergyPlus using the “AvailabilityManager:HybridVentilation” command. This command serves to maximize natural ventilation and turn off the HVAC system when the specified control conditions are met. The user inputs a control type schedule used to determine when conditions are favorable for natural ventilation. A control type of 0 represents no ventilation control, control type 1 is temperature based control, control type 2 is enthalpy based control, control type 3 is dew point based control, and control type 4 is outdoor air ventilation based control. Temperature based control was used for the hybrid ventilation model, which required the user to input the outdoor cutoff temperatures and wind speed for using natural ventilation. The cutoff temperatures used for the hybrid ventilation availability manager were the same as shown in Table 6.8.

Results for the hybrid ventilation model were compared to the results for the hybrid ventilation system modeled by Olsen and Chen to validate the model operation. Olsen and Chen modeled a commercial office building in the United Kingdom using a similar hybrid ventilation system in EnergyPlus. The mechanical system was a VAV system and ventilation was provided by operable windows. The seasons defined by Olsen and Chen were heating between November 1 and March 31, cooling between June 15 and August 31, and natural ventilation in between the heating and cooling seasons. These seasons were similar to those for Chicago, so that location was used for validation against Olsen and Chen's model. Olsen and Chen achieved energy reductions of approximately 22 percent compared to the base building and VAV system. The hybrid ventilation model for the medium office building in Chicago achieved energy reductions of approximately 23 percent for heating and 19 percent for cooling compared to the base building. The energy reductions observed for Chicago were in reasonable agreement with Olsen and Chen.

6.2.2.2.3 Building Footprint

Changes in building model footprint were made to the model incorporating daylight control and hybrid ventilation. The Geometry Transform command in EnergyPlus was used to develop a building model with a square footprint and a building model with a long and narrow rectangular footprint. The Geometry Transform command allows the user to adjust the building footprint by changing the building's aspect ratio. The user provides the current aspect ratio of the building and the desired aspect ratio and EnergyPlus automatically adjusts zoning and surfaces to match the desired aspect ratio. The DOE

Reference Building has a rectangular footprint with an aspect ratio of approximately 1.5, meaning that the building is 1.5 times as long as it is wide. The square building was modeled by entering a new aspect ratio of 1.0.

The long and narrow rectangular building was modeled to have a building width of approximately 40 feet, resulting in a desired aspect ratio of 11.2 for the building. The width of 40 feet was based on research conducted for multiple European office buildings documenting that a width of 40 feet is optimal for human performance when considering daylight penetration and natural ventilation effectiveness (Leaman & Bordass, 1999).

6.2.2.2.4 Window Placement

Three models were developed to investigate different approaches to window placement for daylighting and ventilation performance. In the United States, daylight considerations typically focus on north and south facades for sun and skylight while taking measures to control sunlight and glare on east and west facades. These measures can include eliminating windows on the east and west facades, reducing window area on the east and west facades, or using shading devices to control glare and solar gains on the east and west facades. To model each of these scenarios, changes were made to windows on the east and west facades for the model incorporating daylight control and hybrid ventilation. No changes were made to any other building components or systems.

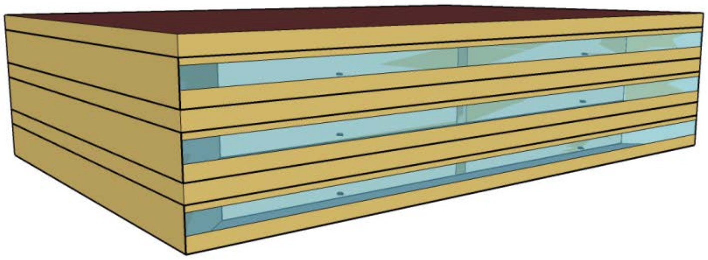


Figure 6.20: EnergyPlus Building Model Eliminating East and West Windows

Figure 6.20 shows the building model with windows on the east and west facades removed. This scenario presents an extreme case for controlling glare and solar gain. However, removal of windows eliminates views to the outdoors which are important for occupants.

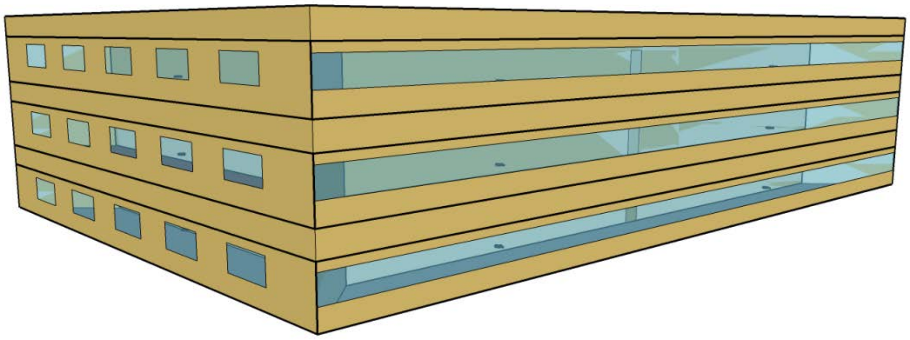


Figure 6.21: EnergyPlus Building Model Reducing East and West Windows

Figure 6.21 shows the building model with the east and west windows reduced to half of the area in the base building. This provides a better alternative than removing the windows entirely because it preserves some views to the surrounding environment; however, views may be limited by this reduction.

Figure 6.22: EnergyPlus Building Model with Louvers on East and West Windows

Figure 6.22 shows the building model using shading devices to control glare and solar gains on the east and west facades. The louvers were modeled as shading devices that were six inches wide and extended the entire width of the window. Louvers were spaced six inches apart over the entire window face. These were modeled to represent shading louvers such as those used at Kroon Hall or LOTT Clean Water Alliance. The louvers help control solar gain and glare with minimal interference with the view for occupants in the building.

6.2.2.3 Transition Spaces

Transition spaces for the indoor/outdoor transition were identified as first level Beauty Determinants in Table 6.3, but these spaces may take several different forms as presented in Section 6.1.2, including courtyards, large opening doors, thermal buffer spaces, or covered patios. Building models were developed to represent these types of transition spaces as best as possible.

6.2.2.3.1 Landscape

EnergyPlus does not include a feature or field to represent landscaped courtyards or garden areas. However, such spaces can provide reductions in the local ambient temperature and research has been conducted documenting these changes in temperature. Much of the current research focuses on daytime temperature reductions of urban green spaces during summer months, which does not account for diurnal or seasonal affects of these green spaces. However, a recent study conducted in Japan investigated these diurnal and seasonal effects of urban green spaces and measured the difference in temperature between the green spaces and the surrounding urban environment. Reported results are shown in Figure 6.23 (Hamada & Ohta, 2010).

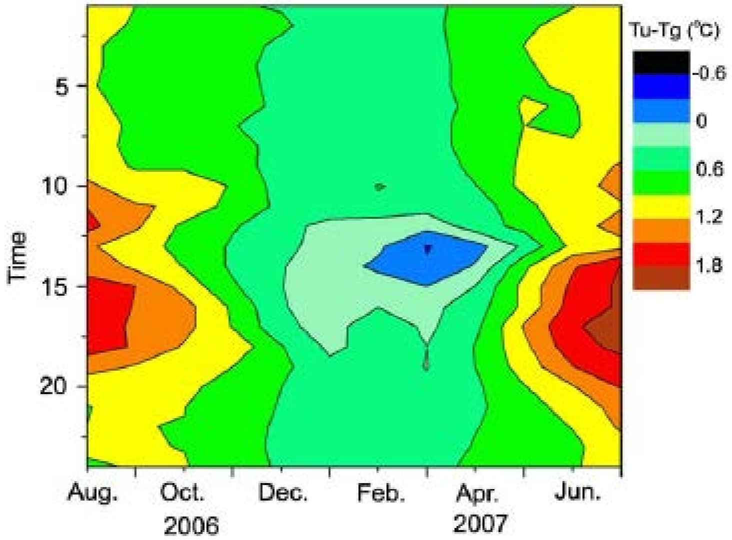


Figure 6.23: Diurnal and Seasonal Variations in Urban (T_u) and Green Area (T_g) Temperatures

The results from Figure 6.23 were tabulated for reduction in temperature due to green areas (T_u – T_g). The reductions are shown for each season, differentiating between day and night, in Table 6.10.

Table 6.10: Urban Temperature Reduction from Green Areas

Season	**Day**	**Night**
Spring	0.9°C	0.9°C
Summer	1.9°C	1.2°C
Autumn	0.9°C	0.9°C
Winter	-0.3°C	0.6°C

The table indicates that green areas provide reductions in daytime temperature during spring, summer, and autumn, but result in a slight increase in ambient temperature during winter months. Temperature reductions remain constant at night during spring and autumn, are slightly less than daytime reductions in summer, and reductions are seen in winter where a temperature increase was observed in the daytime.

Given this point of reference, landscaped courtyards were modeled in EnergyPlus by adjusting the ambient temperature within the weather file for each location based on Table 6.10. Seasons were defined for each location based upon Table 6.9. In addition to the adjustments to ambient temperature, the ground reflectance was adjusted. A ground reflectance of 0.22 was used to represent a landscaped courtyard, which is the same as the default reflectance used for a vegetated roof in EnergyPlus. This reflectance is very close to the default ground reflectance of 0.2 used by EnergyPlus.

To provide comparison for potential temperature reductions of landscaped courtyards, building models were developed to represent possible hardscape surfaces of asphalt and concrete. These surfaces were modeled simply by changes in ground reflectance. The model did not account for potential thermal mass implications of these surface types. Reflectance modeled for asphalt and concrete are shown in Table 6.11. These values were based upon research conducted by Lawrence Berkeley National Laboratory (Pomerantz, Akbari, Chen, Taha, & Rosenfeld, 1997).

Table 6.11: Surface Reflectance for Landscape and Hardscape Models

Paving Material	**Reflectance**
Asphalt	0.1
Concrete	0.4
Vegetated Landscape	0.22
EnergyPlus Default	0.2

6.2.2.3.2 Large Doors

Building models representing the large opening doors were developed from the model incorporating daylight control and hybrid ventilation because these are key aspects of the benefit of the large doors for building spaces. The large doors were modeled as a single glazed door on one of the perimeter bottom floor zones of the medium office building. The zone dimensions were adjusted slightly to extend the zone horizontally to the exterior walls at either side, as opposed to the zone intersections of 45° employed in the base building model. In addition, the air exchange rate between the zone with the large door and the core zone was increased to twice the rate of the hybrid ventilation model described in 6.2.2.2.2. The building model for the large opening doors is illustrated in Figure 6.24.

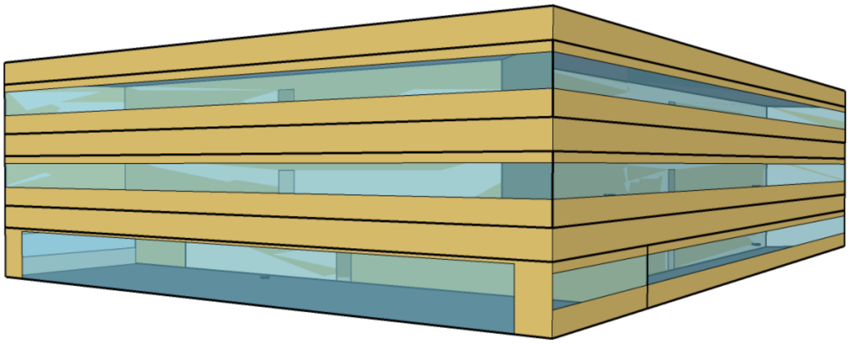


Figure 6.24: EnergyPlus Building Model for Large Doors

Control of the doors was based on the hybrid ventilation schedule and Zone Ventilation model inputs described in Section 6.2.2.2.2.

6.2.2.3.3 Thermal Buffer

Three scenarios of building models representing thermal buffer zones were developed. First, thermal buffer zones were added to the base building model, with no other changes. Second, thermal buffer zones were added to the daylight control and hybrid ventilation model. For this model, the thermal buffer spaces were modeled as having operable windows at the ground level only, because occupants would not have access to windows at higher stories. Lastly, the thermal buffer and daylight control and hybrid ventilation model was adjusted to include a vegetated landscape as described in Section 6.2.2.3.1.

The thermal buffer spaces in the models were developed based on the example of the north and south main stairways of the Jewish Reconstructionist Congregation. Similar to the Jewish Reconstructionist Congregation, the north thermal buffer space was designed with the original amount of window area as the base building, to allow daylight in the space. The north face of the building model for the thermal buffer spaces is illustrated in Figure 6.25.

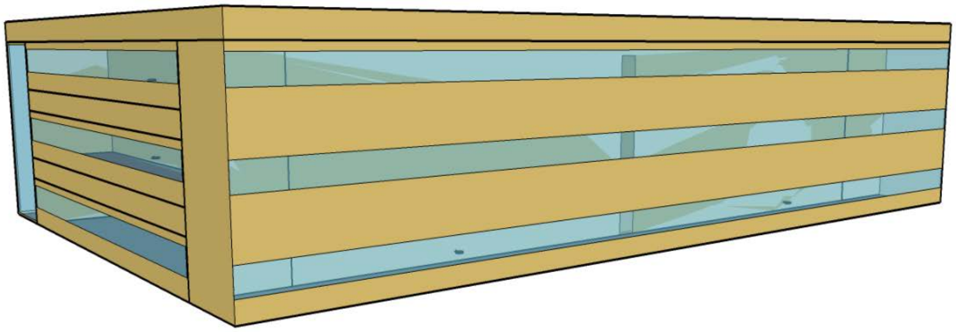


Figure 6.25: EnergyPlus Building Model for Thermal Buffer – North Façade

The south thermal buffer space was composed almost entirely of glass to take advantage of solar resources and provide views to the outdoors to aid in the transition between indoor and outdoor space. The south face of the building model for the thermal buffer spaces is illustrated in Figure 6.26.

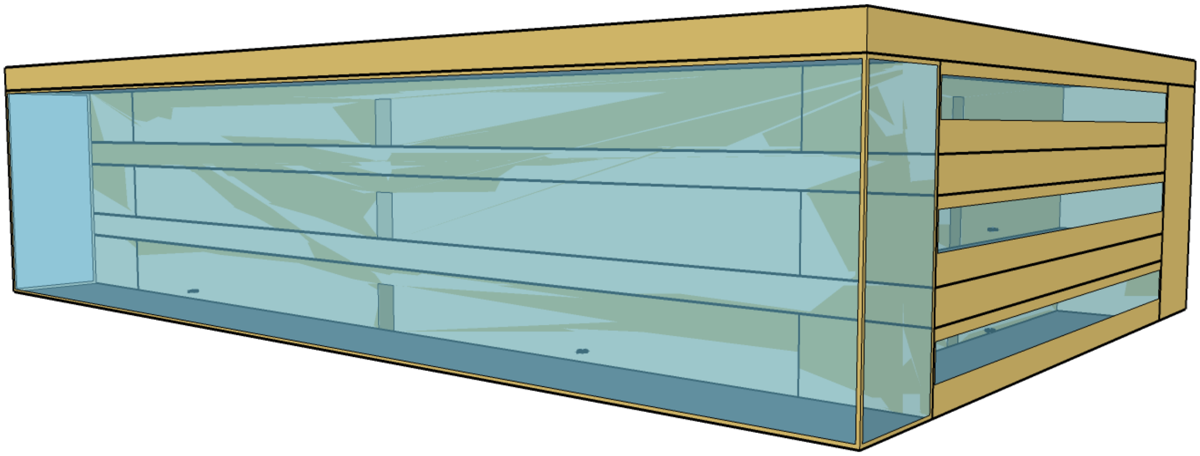


Figure 6.26: EnergyPlus Building Model for Thermal Buffer – South Facade

Similar to the building models for the large doors, the zoning of the base building was adjusted to represent the thermal buffer spaces. Perimeter zones were combined and extended the full width of the building on both the north and the south sides. The total building floor area was not changed. Adjustments were made for some of the internal loads in the thermal buffer spaces as listed in Table 6.12 to represent more of an entry lobby/corridor space compared to traditional office space based on ASHRAE Standard 62.1-2004.

Table 6.12: EnergyPlus Thermal Buffer Building Internal Loads

Internal Load	**Value**
Lighting	1.0 W/ft^2
Plug Loads	0.333 W/ft^2 (1/3 of typical office)
People	2.5 people/1,000 ft^2
Elevators	2 @ 20 HP each, 91% motor efficiency

6.2.2.3.4 Covered Patio

Similar to the thermal buffer spaces, building models representing the covered patio were developed for three scenarios: the base building, the daylight control and hybrid ventilation model, and the daylight control and hybrid ventilation model with vegetated landscape. The covered patio was simulated by including an external shading device the width of the building and 50 feet deep. To understand potential impacts from variations due to site restrictions, simulations were conducted for the covered patio space on each of the north, south, east, and west sides of the building. In addition, the covered patio was simulated with the external shade adjusted between horizontal and 45° from horizontal in 15° degree increments. Figure 6.27 shows the building model with a covered patio on the south side at an angle of 15° from horizontal, providing an example of the model used.

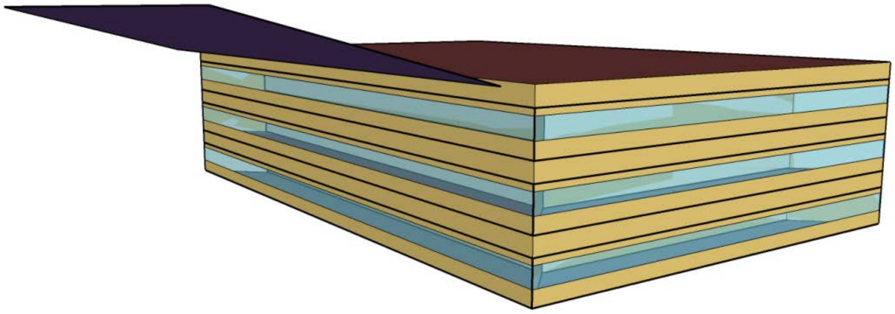


Figure 6.27: EnergyPlus Building Model for Covered Patio at 15°

To further investigate impacts of combination building features highlighted in the Density Beauty Filter, the covered patio model was combined with the building models for the large opening doors as a potential variation of transition space. Only the horizontal building shade was used in combination with the large doors building models to moderate the number of simulations performed. An example of this combination of building features for transition space is shown in Figure 6.28.

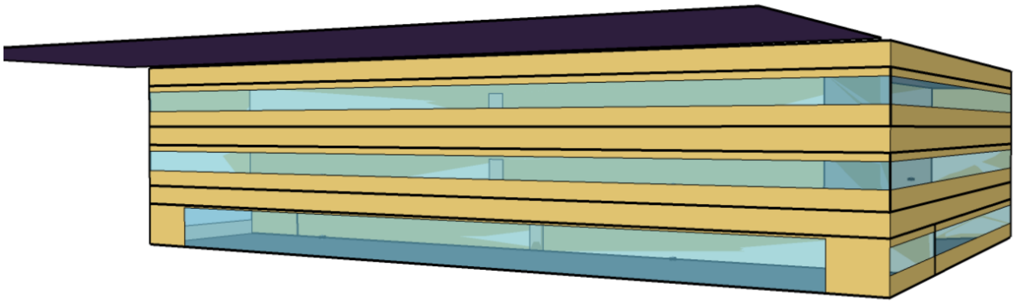


Figure 6.28: EnergyPlus Building Model for Covered Patio and Large Door Combination

6.2.2.4 Integrated with Landscape

Integration with the landscape was identified as a building feature important for beauty and inspiration, such as the example of Queens Botanical Garden Visitor Center in Section 6.1.2. In order to model building integration with the landscape, a simpler approach was taken: one that is similar to the integration with the landscape featured at Kroon Hall. The ground floor of Kroon Hall is partially embedded within the landscape on one side and open to the courtyard space on the other. This is illustrated in the schematic in Figure 6.29.

Figure 6.29: Schematic of Building Integration with Landscape – Kroon Hall

Building models representing integration with the landscape were developed from the base building model by having ground floor exterior walls with ground contact based on the example of Kroon Hall. Models were developed for one, two, or three walls with ground contact. The walls with ground contact were varied for north, south, east, and west, or combinations of directions for the models with more than one exterior wall with ground contact. Simulations of the building integrated within the landscape were also performed with a vegetated landscape, such as the courtyard at Kroon Hall.

For the building models of integration with the landscape, the construction of exterior walls with ground contact were adjusted to utilize eight inch concrete rather than the steel frame construction of the base building. Other ground floor walls that were exposed to air were left as steel frame construction.

6.2.2.5 Vegetated Roof

Vegetated roofs are included in many high performance buildings and can provide thermal and water collection benefits for buildings. As discussed in Section 6.1.2, the key aspect related to beauty and inspiration for vegetated roofs is access to nature for building occupants, which can be achieved by having the vegetated roof on the lower level of a tiered building so that occupants of upper floors may access this green space. Therefore, energy simulations for the vegetated roof focused on identifying possible differences in performance for a vegetated roof on a lower roof level where it may be accessed by occupants of upper floors, versus a vegetated roof on the top level where access is likely restricted or limited for building occupants. For this model, the base building model was adjusted to form a bi-level roof. This adjustment was made by removing half of the third floor from the office building, exposing the roof of the second floor to third floor occupants. However, this change reduced the total floor area of the base building, making energy use comparisons to the base building uninformative. Results for energy use of the vegetated roof models were therefore compared to the bi-level roof building developed from the base building. The bi-level roof building is shown in Figure 6.30.

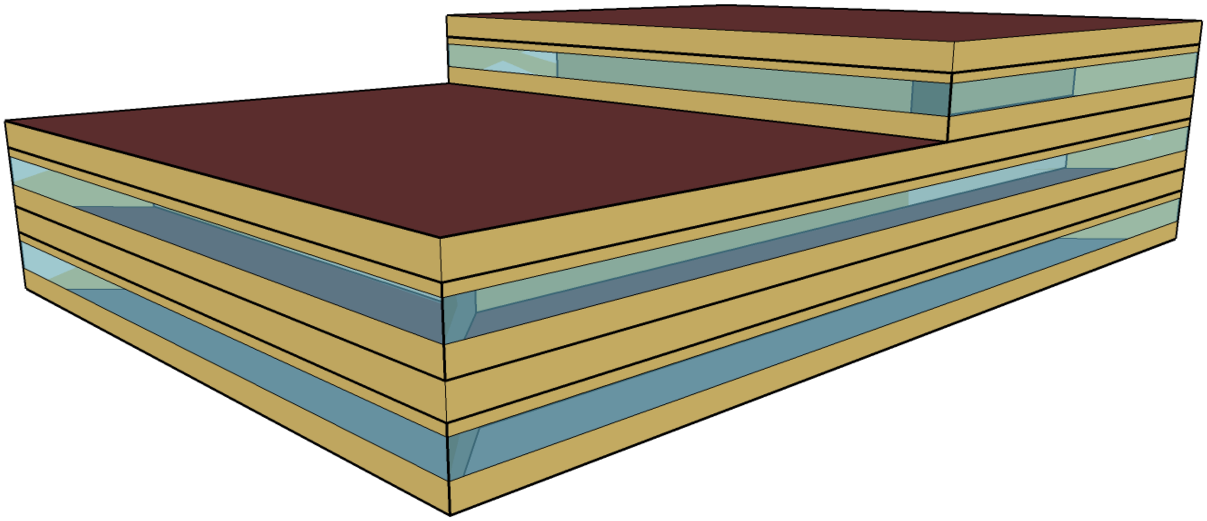


Figure 6.30: EnergyPlus Building Model with Bi-Level Roof Used for Vegetated Roof Simulation

The vegetated roof model for EnergyPlus allows users to define the vegetated roof as a construction layer that replaces the typical roof membrane like that used for the base building. The vegetated roof model accounts for solar impacts due to reflectance of plant leaves, thermal insulation of the soil layer, and thermal effects from evapotranspiration based on the stomatal resistance of the roof plants. This model was developed by D.J. Sailor at Portland State University and tested against measured temperatures of a vegetated roof on an existing building in Florida (Sailor, 2008). Sensitivity studies of various vegetated roof model parameters were conducted and compared to base vegetated roof models in Chicago and Houston. The base vegetated roof model for Chicago was used for comparison and validation of initial results for the vegetated roof model used in this research. However, Sailor’s work utilized EnergyPlus Version 3, which used a conduction transfer function for the thermal model. Sailor noted that the model would be modified to take advantage of the finite difference model employed in newer versions of EnergyPlus (Sailor, 2008). Therefore, the base vegetated roof model from Sailor’s work was reproduced in EnergyPlus Version 6.0.0.023 for validation.

To replicate the base vegetated roof model from Sailor’s work, the EnergyPlus example file generator (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy) was used. Sailor used the example file generator to develop a model for a basic building with the inputs listed in Table 6.13. The EnergyPlus example file generator was used to develop an updated building model in EnergyPlus Version 6.0. Inputs for the updated vegetated roof model are listed in Table 6.13.

Table 6.13: Vegetated Roof Model Validation

Example File Generator Input Parameter	**Sailor Base Vegetated Roof Model**	**Sailor Base Vegetated Roof Model – EnergyPlus Version 6.0**
Model	Simple	Simple
Standard	ASHRAE 90.1-2004	ASHRAE 90.1-2004
Location	Chicago, IL	Chicago, IL
Building Type	Office/Professional	Office/Professional
Number of Floors	2	2
Total Floor Area	4,000 m^2	4,000 m^2
Roof Construction	Default (Membrane with solar reflectivity = 0.3, insulation 0.125m thick with conductivity of 0.049 W/m K)	Default (Membrane with solar reflectivity = 0.3, insulation 0.125m thick with conductivity of 0.049 W/m K)
Wall Type	Not specified (assumed default)	Not specified (assumed default)
People Density	3.91/100 m^2	3.91/100 m^2
Electrical Plug Intensity	8.07 W/m^2	8.07 W/m^2
Gas Appliance Intensity	Not specified (assumed default)	Not specified (assumed default)
Vegetated Roof Parameters		
Soil Depth	0.2 m	0.2 m
Dry Soil Thermal Conductivity	0.4 W/m K	0.4 W/m K
Dry Soil Density	500 kg/m^3	500 kg/m^3
Dry Soil Specific Heat Capacity	1,000 J/kg K	1,000 J/kg K
Leaf Area Index	2.0	2.0
Irrigation Schedule	1 cm/week (June – August)	1 cm/week (June – August)

To validate the vegetated roof model used in this research, a vegetated roof layer was modeled on the base building in Chicago using the same vegetated roof parameters as shown in Table 6.13 and the results for energy reduction compared to the results for energy reduction from Sailor’s base vegetated roof model in Chicago updated to EnergyPlus Version 6.0. The updated version of Sailor’s model provided reductions in energy use of approximately 0.3 percent for electricity and approximately 13.7 percent for natural gas. The base building with vegetated roof in Chicago used in this research provided reductions in energy use of approximately 0.6 percent for electricity and approximately 3.6 percent for natural gas. The results show reasonable agreement for electricity, but a somewhat greater difference for natural gas, which may result from differences in the HVAC system design between the models. Sailor’s updated model used gas as the primary heating source while the base building used electric reheat. Overall, the vegetated roof model was considered to be valid for the purposes of this research.

Once the vegetated roof model was validated for the base building, the bi-level building model was adjusted to include vegetated roof layers. The model was simulated for four scenarios to provide a comparison of potential energy impacts: the bi-level building with no vegetated roof layers, the bi-level building with a vegetated roof on the lower level, the bi-level building with a vegetated roof on the upper level, and the bi-level building with vegetated roofs on both the lower and upper levels.

6.2.2.6 Rainwater Collection System

Building rainwater collection systems that are designed for prominence and interaction with occupants were identified as an overall first level Beauty Determinant in in Table 6.3. While it is difficult to model the prominence of these systems, EnergyPlus does include optional fields for water tank storage and rainwater collection systems that can provide measure of potential water savings available. Unfortunately, although these fields are included in EnergyPlus Version 6.0.0.023, there is an internal error with the water storage calculation that prevents this model from being utilized in the current version.

6.3 Results

A total of 535 energy simulations were performed for this research given the various building systems or features modeled and the different climate regions. The percent change in energy use relative to the base building, or to the bi-level building in the case of the vegetated roof models, was calculated for each simulation. However, the large number of simulations made it impractical to show results for each and every model and scenario. A more effective means for communicating the results was to provide a range of percent change in energy use from the base case for each model group and each of the transition spaces listed in Table 6.5. This presentation aligns with the aim of the energy simulation portion of this research, which was to establish the potential impact on energy use for each building system or feature identified as a distinguishing aspect of beautiful and inspiring buildings. Based on the results for performance range of the building systems or features, the relative importance of each feature to the building energy use was determined. This relative importance was then combined with the results of the qualitative evaluation to develop a building design decision reference for inspiring and high performing buildings.

6.3.1 Performance Range for Beautiful Building Features

The percent change in energy use relative to the base building, or to the bi-level building in the case of the vegetated roof models, was calculated for each simulation at each location listed in Table 6.6. These results were compiled and analyzed to determine the scenario with the least reduction in energy and the scenario with the greatest reduction in energy. For some building features, certain scenarios even produced increases in energy consumption. Based on this analysis, a range of percent change in energy use from the base case was determined for each model group and each of the transition spaces in Table 6.5.

6.3.1.1 Location Specific Performance

Figure 6.31 through Figure 6.33 show comparisons of the least and greatest reduction in energy use for each case at each location. The figures illustrate the changes in relative impact by climate region for reductions in building energy intensity, heating energy, and cooling energy. The name of each location is labeled for each bar in the plot. The bars in light blue represent cases with the least percent reduction, or greatest percent increase, in energy use relative to the base case. The bars in maroon represent cases with the greatest percent reduction in energy use relative to the base case. Data supporting these figures is included in Appendix C.

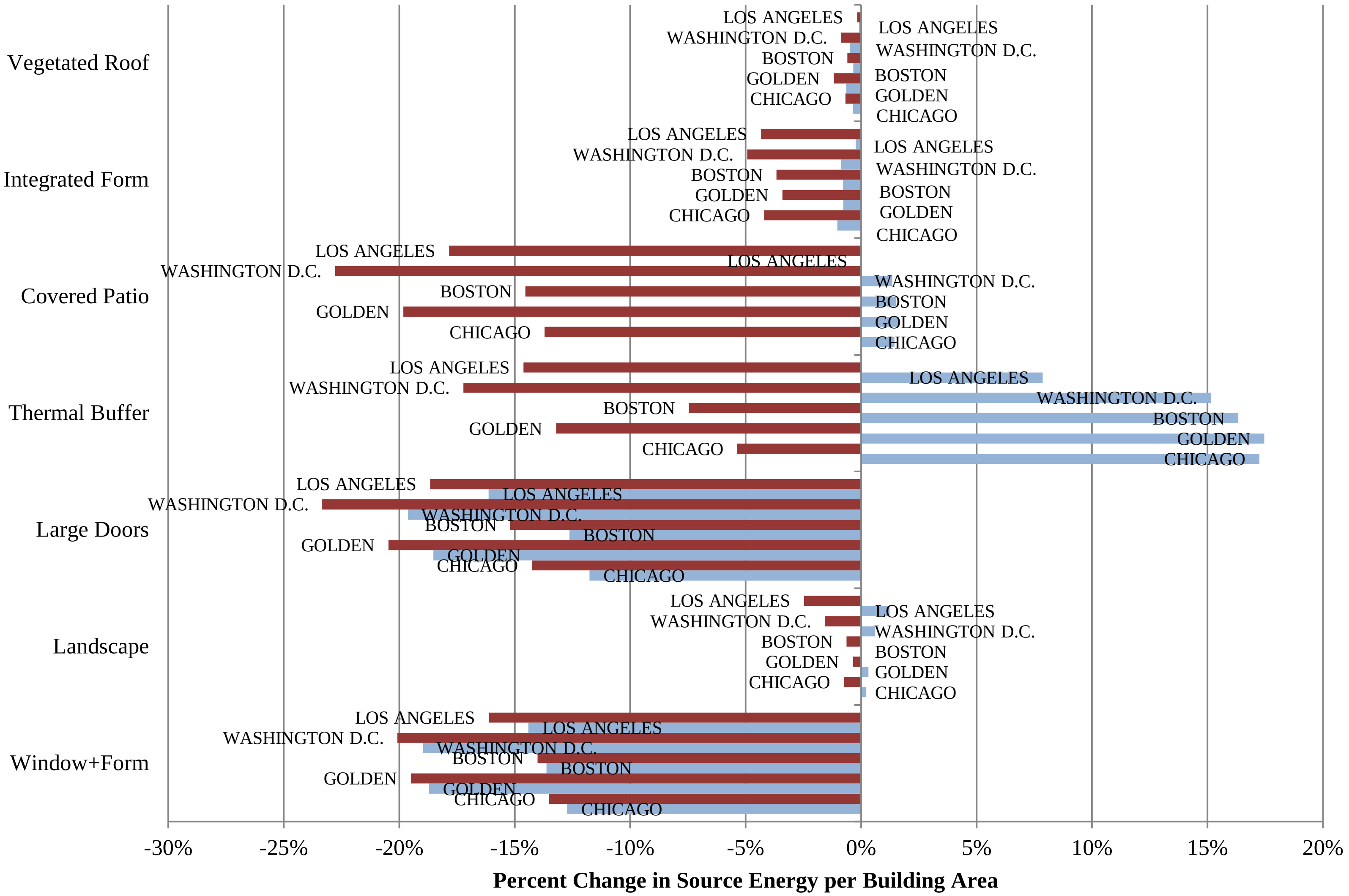


Figure 6.31: Performance Range of Building Features by Location – Building Energy Intensity

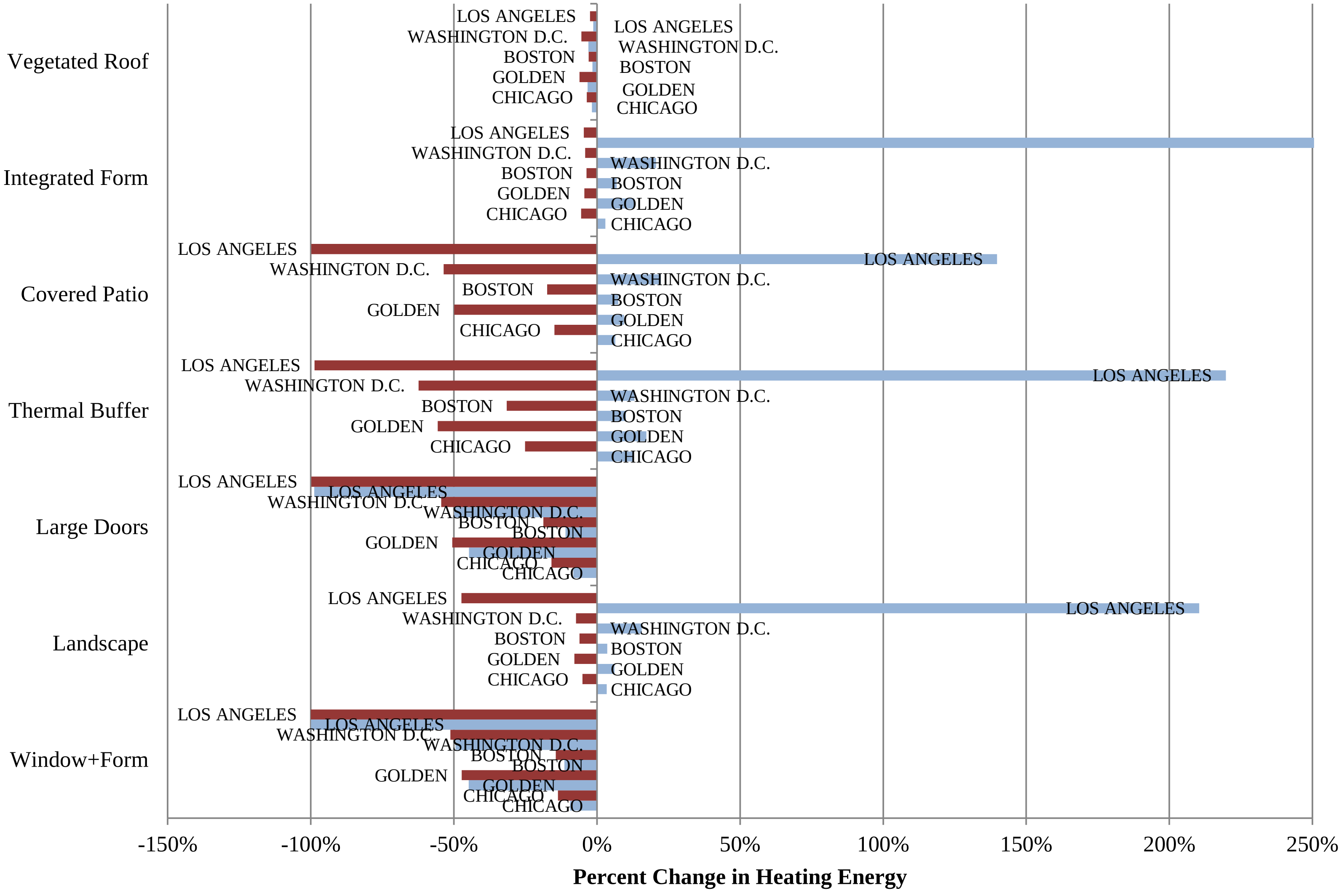


Figure 6.32: Performance Range of Building Features by Location – Heating Energy

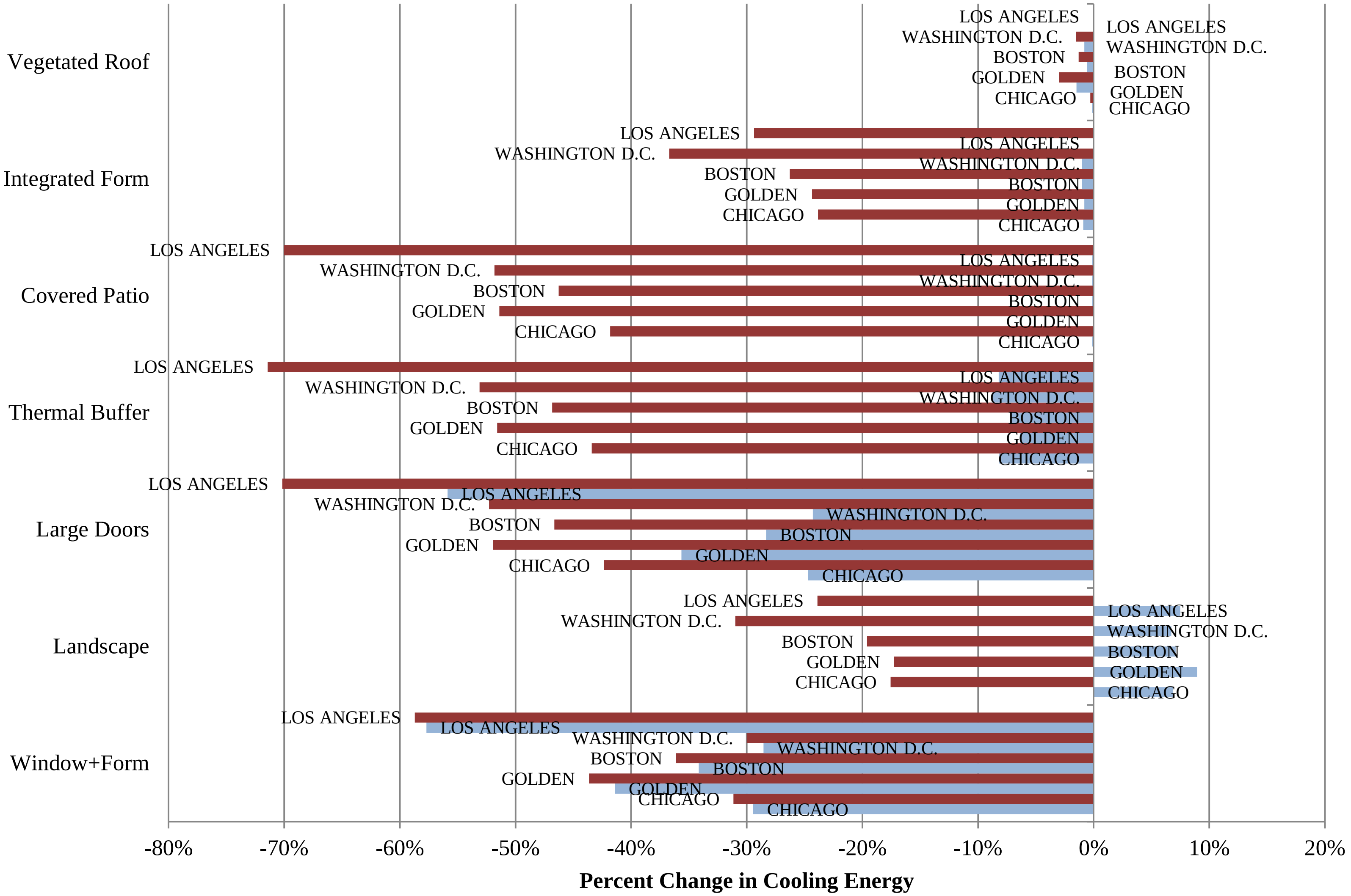


Figure 6.33: Performance Range of Building Features by Location – Cooling Energy

Results of specific building systems or features were analyzed in terms of overall performance ranges as presented in Section 6.3.2. However, the results observed for potential impact to heating energy for Los Angeles shown in Figure 6.32 drew immediate attention and appeared to be impractical. Because of the climate for Los Angeles, heating requirements are minimal as noted by the absence of a heating season listed in Table 6.9. Because of the low heating requirements, the heating energy consumption for Los Angeles is minimal, which magnified the impact of even small changes in heating energy relative to the base case. Therefore, while Los Angeles may have represented the greatest potential impact to heating energy for some cases, the actual magnitude of this impact was nearly insignificant when compared to the magnitude of the changes in heating energy use at the other locations evaluated.

6.3.1.2 Representative Performance

In order to determine the relative importance to energy of the building systems or features evaluated, the results for the individual locations were consolidated to give the representative average performance range of each simulation group. Figure 6.31 through Figure 6.33 show the same general trends for case results; therefore, consolidation of the location results into an average provides a reasonable represntation of performance range. In a few select cases, there were differences between the cases that generated the greatest reduction in one geographic location versus another. For these items, the case occurring most frequently amongst the five locations was used as representative of all. Representative average results were compiled for building energy intensity, heating energy, and cooling energy. Figure 6.34 displays the representative average performance range for building energy intensity impact.

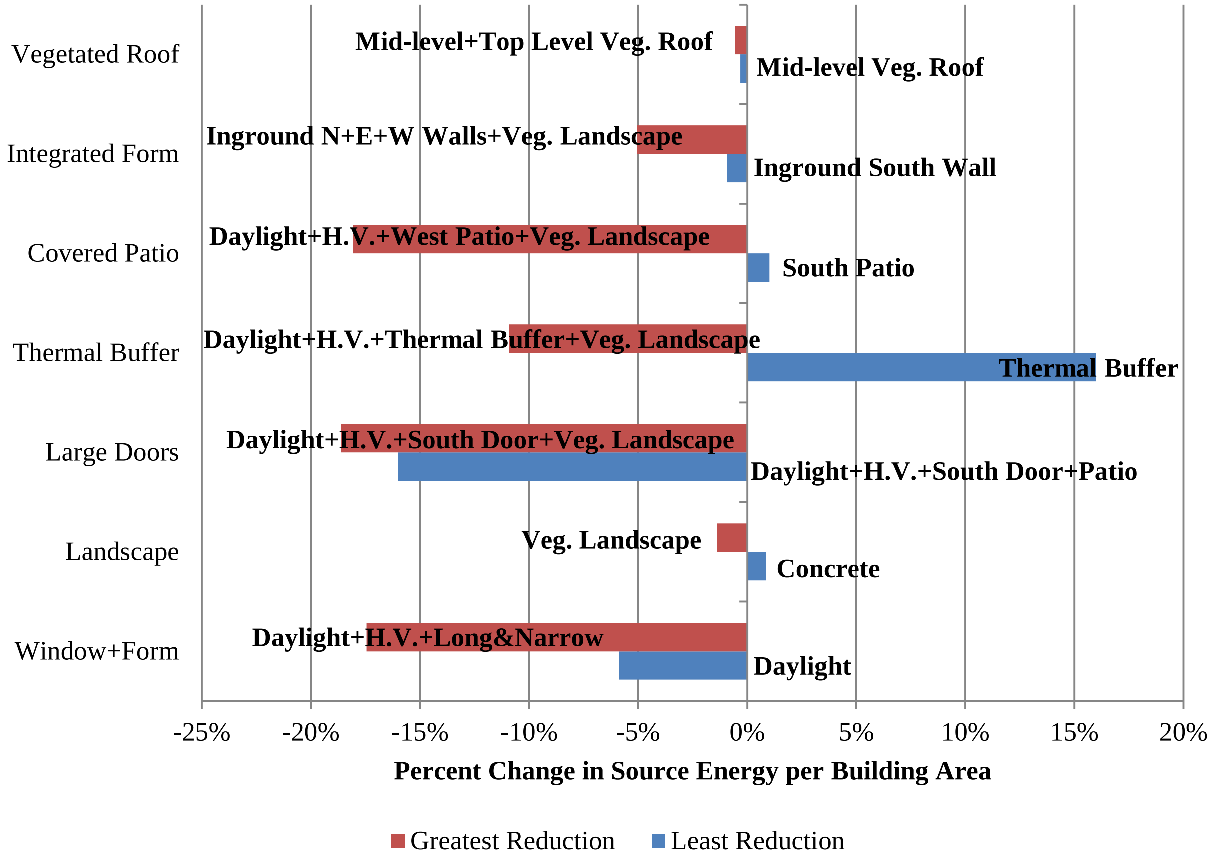


Figure 6.34: Representative Performance Range of Building Features – Building Energy Intensity

Based on the results in Figure 6.34, several building systems or features could achieve reductions of nearly 20 percent in building energy intensity. Because systems and features were combined in many models to address the Density aspect, much of the savings in the best performing groups were largely attributable to use of hybrid ventilation in conjunction with the respective feature.

The use of large doors to aid in the indoor to outdoor transition together with daylight control and hybrid ventilation appeared to have the not only the greatest potential impact for building energy intensity but also the best performance range, with reductions in building energy intensity between approximately 15 and 20 percent. The daylight and hybrid ventilation model, with or without a covered patio and vegetated landscape, could potentially provide similar energy reductions to the large doors. The largest performance range was seen for the thermal buffer, which indicated a potential increase in energy intensity of over 15 percent when not used in combination with daylight control and hybrid ventilation, but possible reductions in energy intensity greater than ten percent when combined with daylight control, hybrid ventilation, and a vegetated landscape.

Figure 6.35 displays the representative average performance range for heating energy impact. As noted in the discussion of location specific data, the results for percent change in heating energy for Los Angeles gave inflated perceptions of the impact of building systems or features. Because the actual changes in heating energy for Los Angeles were not significant when compared to the magnitude of the other locations, the heating energy impacts for Los Angeles were not included in the consolidation of results to determine an overall average performance range for heating energy.

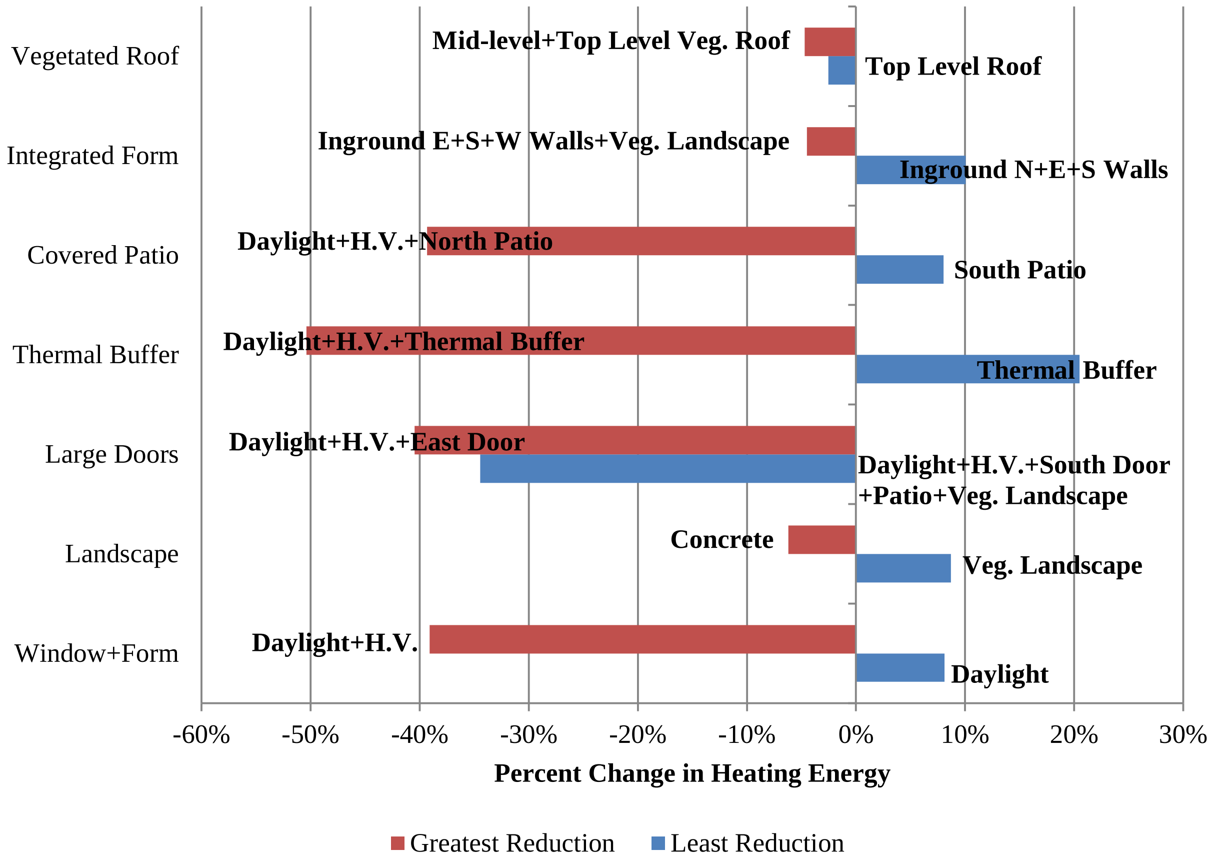


Figure 6.35: Representative Performance Range of Building Features – Heating Energy

Results for the overall average heating energy performance were similar in profile to those for the building energy intensity. Again, the building systems or features that combined with the hybrid ventilation system provided the greatest potential for heating energy reductions – the greatest being approximately half the energy used for heating.

In terms of heating energy, large doors to aid in the indoor to outdoor transition and the use of thermal buffer spaces combined with daylight control and hybrid ventilation appeared to have the greatest potential impact for reduction in heating energy. As seen in Figure 6.35, use of the thermal buffer spaces may provide additional reductions in heating energy of more than ten percent compared to simply using daylight control and a hybrid ventilation system. However, if not combined with the daylight control and hybrid ventilation, the thermal buffer could result in increased heating energy use of approximately 20 percent. Integrating the building into the landscape could produce small reductions in heating energy, depending on which walls are in ground contact. The vegetated roof model may provide modest reductions in heating energy use, with the greatest reduction achieved when combining vegetated roofs on both the lower and upper levels of a bi-level building.

Figure 6.36 displays the representative average performance range for cooling energy impact.

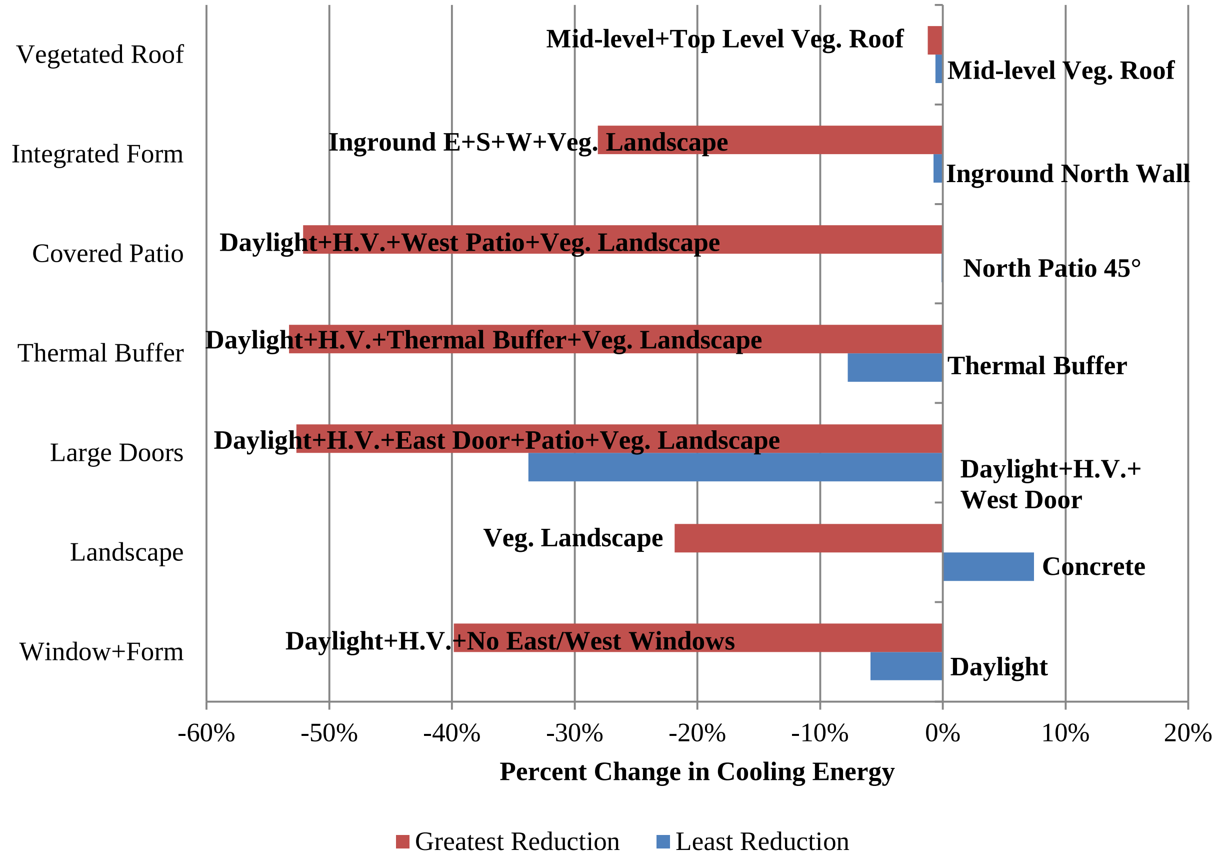


Figure 6.36: Representative Performance Range of Building Features – Cooling Energy

Results for the representative average cooling energy performance were similar in profile to those for the heating energy. Again, the building systems or features that combined with the hybrid ventilation system provided the greatest potential for cooling energy reductions – the greatest being greater than half the energy used for cooling.

The thermal buffer, large doors, or covered patio all could achieve reductions of greater than 50 percent of cooling energy when combined with daylight control, hybrid ventilation, and a vegetated landscape. Each of these features could provide a potential improvement of more than ten percent to a building using daylight control and hybrid ventilation alone. Integrating the building into the landscape has a more significant impact on cooling energy compared to heating energy and may therefore be more applicable in climates dominated by cooling. The vegetated roof model provided similar reductions in cooling energy as it had for heating energy use.

The data supporting the information in Figure 6.34 through Figure 6.36 are provided for reference in Table 6.14.

Table 6.14: Overall Performance Range of Building Features

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Window+Form								
Form								
Least Reduction	Daylight Control	-6%	Daylight Control	8%	Daylight Control	-6%	Daylight Control	-6%
Greatest Reduction	Daylight+Hybrid Vent.-Long+Narrow (40 ft wide)	-17%	Daylight + Operable Windows	-39%	Daylight+Hybrid Vent.-Long+Narrow (40 ft wide)	-38%	Daylight+Hybrid Vent.-Long+Narrow (40 ft wide)	-18%
Window								
Least Reduction	Daylight+Hybrid Vent.-No East+West Windows	-17%	Daylight+Hybrid Vent.-Louvers for East+West Windows	-34%	Daylight+Hybrid Vent.-Reduced East+West Windows	-38%	Daylight+Hybrid Vent.-No East+West Windows	-17%
Greatest Reduction	Daylight+Hybrid Vent.-Reduced East+West Windows	-17%	Daylight+Hybrid Vent.-Reduced East+West Windows	-36%	Daylight+Hybrid Vent.-No East+West Windows	-40%	Daylight+Hybrid Vent.-Reduced East+West Windows	-17%
Transition								
Landscape								
Least Reduction	Concrete	1%	Vegetated Landscape	9%	Concrete	7%	Concrete	1%
Greatest Reduction	Vegetated Landscape	-1%	Concrete	-6%	Vegetated Landscape	-22%	Vegetated Landscape	-1%
Large Doors								
Least Reduction	Daylight+Hybrid Vent.+Large Doors (south)+Cov. Patio	-16%	Daylight+Hybrid Vent.+Large Doors (south)+Cov. Patio+Veg. Landscape	-34%	Daylight+Hybrid Vent.+Large Doors (west)	-34%	Daylight+Hybrid Vent.+Large Doors (south)+Cov. Patio	-16%
Greatest Reduction	Daylight+Hybrid Vent.+Large Doors (south)+Veg. Landscape	-19%	Daylight+Hybrid Vent.+Large Doors (east)	-40%	Daylight+Hybrid Vent.+Large Doors (east)+Cov. Patio+Veg. Landscape	-53%	Daylight+Hybrid Vent.+Large Doors (east)+Cov. Patio+Veg. Landscape	-20%
Thermal Buffer								
Least Reduction	Thermal Buffer	16%	Thermal Buffer	21%	Thermal Buffer	-8%	Thermal Buffer	-5%
Greatest Reduction	Daylight+Hybrid Vent.+Thermal Buffer+Veg. Land.	-11%	Daylight+Hybrid Vent.+Thermal Buffer	-50%	Daylight+Hybrid Vent.+Thermal Buffer+Veg. Land.	-53%	Daylight+Hybrid Vent.+Thermal Buffer+Veg. Land.	-27%

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Covered Patio								
Least Reduction	Covered Patio-South	1%	Covered Patio-South	8%	Covered Patio-North 45° Tilt	0%	Covered Patio-South	1%
Greatest Reduction	Daylight+Hybrid Vent.+Covered Patio-West+Veg. Landscape	-18%	Daylight+Hybrid Vent.+Covered Patio-North	-39%	Daylight+Hybrid Vent.+Covered Patio-West+Veg. Landscape	-52%	Daylight+Hybrid Vent.+Covered Patio-West+Veg. Landscape	-18%
Integrated Form								
Least Reduction	Inground South Wall	-1%	Inground East+South+West Walls+Vegetated Landscape	10%	Inground North Wall	-1%	Inground South Wall	-1%
Greatest Reduction	Inground West+North+East Walls+Vegetated Landscape	-5%	Inground North+East+South Walls	-4%	Inground East+South+West Walls+Vegetated Landscape	-28%	Inground West+North+East Walls+Vegetated Landscape	-5%
Vegetated Roof								
Least Reduction	Tiered Roof+Lower Vegetated Roof	0%	Tiered Roof+Upper Vegetated Roof	-3%	Tiered Roof+Lower Vegetated Roof	-0.6%	Tiered Roof+Lower Vegetated Roof	0%
Greatest Reduction	Tiered Roof+Upper and Lower Vegetated Roof	-1%	Tiered Roof+Upper and Lower Vegetated Roof	-5%	Tiered Roof+Upper and Lower Vegetated Roof	-1.2%	Tiered Roof+Upper and Lower Vegetated Roof	-1%

6.3.2 Relative Importance of Building Features and Beauty Determinants

The representative average performance results for the energy simulations were used to determine the relative importance to energy of the building systems or features evaluated. The relative importance of each building system or feature evaluated by energy simulation was calculated as a weighting factor compared to the other building systems or features. Weighting factors were established by normalizing the location averaged maximum potential reduction in energy use among the modeling groups. Weighting factors calculated in terms of energy intensity, heating energy, and cooling energy are provided in Table 6.15.

Table 6.15: Energy Weighting Factors for Building Features

Group	Source Energy per Building Area	Heating Energy	Cooling Energy
Window+Form			
Form	0.94	0.78	0.72
Window	0.92	0.71	0.75
Transition			
Landscape	0.07	0.12	0.41
Large Doors	1.00	0.80	0.99
Thermal Buffer	0.59	1.00	1.00
Covered Patio	0.97	0.78	0.98
Integrated Form			
	0.27	0.09	0.53
Vegetated Roof			
	0.03	0.09	0.02

To complement the energy weighting factors for the building systems or features that were evaluated in the quantitative analysis, the Beauty Determinants were also assigned weighting factors based on the results of the qualitative analysis. The Beauty Determinants were normalized based on being first, second, third, or fourth level. First and second level Beauty Determinants were those identified as overall first level or second level in Table 6.3. Third level Beauty Determinants were any not identified as overall first or second level but which were represented at least once in Table 6.3. Fourth level Beauty Determinants were those which did not occur in Table 6.3. First level Beauty Determinants were assigned a value of unity, and the remaining levels were assigned values in decreasing increments of 0.25. The Beauty Determinants and associated weighting factors are listed in Table 6.16.

Table 6.16: Weighting Factors for Beauty Determinants

Beauty Determinant	Weighting Factor
(1) Optimize passive daylighting	0.5
(2) Optimize passive heating	0.25
(3) Optimize passive cooling	0.5
(4) Optimize stormwater	1.00
(5) Localized geographic fit	0.75
(6) Locally durable material	0.5
(7) Building controllability	1.00
(8) Indoor/outdoor transition	1.00
(9) Cycles of restoration	0.5
(10) No waste	0.5

Based on the energy weighting factors from the quantitative evaluation and the weighting factors for the Beauty Determinants based on the qualitative evaluation, composite weighting factors were developed for the Beauty Determinants. The composite weighting factors were calculated by multiplying the weighting factors for the Beauty Determinants by the average of the appropriate energy weighting factors. Composite weighting factors were not calculated for Beauty Determinants not evaluated as a part of the quantitative analysis of building systems or features and are listed as “NA” and appear grey in the respective tables. Composite weighting factors were determined relative to building energy intensity, heating energy, and cooling energy and are listed in Table 6.17, Table 6.18, and Table 6.19, respectively. The factors were color coded for easy visual representation of the building systems or features most heavily weighted for impact on beauty and energy performance. Items shown in green indicate the heaviest weighting, items in white indicate moderate weighting, and items in red the lowest weighting.

Tables showing composite weighting factors for each of the five locations evaluated are included in Appendix D.

Table 6.17: Composite Weighting Factors for Beauty Determinants – Building Energy Intensity

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.47	0.46	NA	0.50	0.29	0.49	NA	NA
(2) Optimize passive heating	0.23	0.23	0.02	0.25	0.15	0.24	0.07	0.01
(3) Optimize passive cooling	0.47	0.46	0.04	0.50	0.29	0.49	0.14	0.02
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.70	0.69	0.06	0.75	0.44	0.73	0.20	0.02
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.94	0.92	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.07	1.00	0.59	0.97	0.27	0.03
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table 6.18: Composite Weighting Factors for Beauty Determinants – Heating Energy

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.39	0.36	NA	0.40	0.50	0.39	NA	NA
(2) Optimize passive heating	0.19	0.18	0.03	0.20	0.25	0.20	0.02	0.02
(3) Optimize passive cooling	0.39	0.36	0.06	0.40	0.50	0.39	0.04	0.05
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.58	0.53	0.09	0.60	0.75	0.59	0.07	0.07
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.78	0.71	NA	0.80	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.12	0.80	1.00	0.78	0.09	0.09
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table 6.19: Composite Weighting Factors for Beauty Determinants – Cooling Energy

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.36	0.37	NA	0.49	0.50	0.49	NA	NA
(2) Optimize passive heating	0.18	0.19	0.10	0.25	0.25	0.24	0.13	0.01
(3) Optimize passive cooling	0.36	0.37	0.21	0.49	0.50	0.49	0.26	0.01
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.54	0.56	0.31	0.74	0.75	0.73	0.40	0.02
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.72	0.75	NA	0.99	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.41	0.99	1.00	0.98	0.53	0.02
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

The composite weighting factors calculated are reasonably consistent between overall building energy intensity, heating energy, and cooling energy. Differences are observed in the values of the weighting factors for specific building systems or features, but all show similar trends in terms of relative importance as indicated by the color scale in each table. Based on the results, the best relative performance is observed for the building systems or features which represent combined, or dense, systems. In particular, those building systems or features combined with daylight control and hybrid ventilation provided the greatest impacts in terms of the beauty characteristics and building energy performance. The building systems or features with the lowest weighting were those implemented independently. For example, while the use of vegetated landscape provided the greatest reduction in building energy intensity among the landscape and hardscape options, when implemented as a lone feature of the building the impacts to both beauty and energy performance were relatively low. However, if the vegetated landscape is part of a building strategy that includes large doors and a covered patio that improve the transition between indoors and outdoors, the overall effect of a design with that density is significant.

6.4 Conclusions for Quantitative Evaluation

Section 6.1 provided a list of distinguishing building systems or features for inspiring and high performing buildings based on the case study population evaluated. In line with conclusions from the qualitative evaluation, a key aspect of these building systems or features is forming a connection between the occupants and the built environment through occupant control, and then extending this connection to the surrounding environment through visual, audible, and physical access to nature.

Translating the distinguishing building systems or features into building energy models allowed for quantitative evaluation of energy performance through energy simulation. Performance ranges, specific to various geographic locations as well as representative averages, were provided for the evaluated building systems or features. Based on the energy simulation results, the building systems or features combined with daylight control and hybrid ventilation provided the greatest impacts for building energy performance. The relative importance of the distinguishing building systems or features was calculated from the energy simulation results and multiplied against a factor indicating the importance of each Beauty Determinant to provide composite weighting factors of the evaluated building systems or features. The composite weighting factors illustrate the benefits of building systems or features that combine multiple individual systems. Where many of the high performing buildings, especially those with the lowest assessed project values, appeared to treat various technical systems or building features as individual components, the inspiring and high performing buildings with the highest assessed project values displayed a density in their designs that considered interactive and integrative effects of building systems or features and ultimately the building as a whole.

The color-scaled presentation of composite weighting factors in Table 6.17 through Table 6.19 provide useful references for architects and engineers seeking to design built environments that are both inspiring and high performing. The composite weighting factors may be used to guide considerations of different building systems or features during design charrettes. In addition, the location specific energy performance ranges included in Appendix C and the associated color scaled weighting factor matrices in Appendix D may be consulted for differences that may exist between climate regions.

However, the composite weighting factors only provide a representation of the building systems or features evaluated through energy simulation in this research. For example, the impacts of stormwater management and rainwater collection were not evaluated through energy simulation and therefore do not have a composite weighting. There are bound to be additional building systems or features important for designing inspiring and high performing buildings that are not reflected in the case study population used for this research. Future additions to the composite weighting factor matrices will continue to increase their applicability and utility as design decision references and tools for architects and engineers.

Chapter 7

Summary and Recommended Future Work

7.1 Summary of Findings

This research aimed to identify distinguishing building systems or features of beautiful buildings and to understand how these may impact a building's energy performance. The research was approached in five main sections:

The Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research consists of the first three sections:

- Identification of shared characteristics common to beautiful buildings and building systems or features that represent these characteristics
- Development of metrics and criteria for evaluating beautiful building energy performance
- Qualitative evaluation of a sample population of high performing versus inspiring and high performing buildings

The specific focus of this thesis research includes the remaining two sections:

- Investigation of contributing factors to and identification of distinguishing building systems or features of beautiful buildings
- Quantitative evaluation of the relative importance of distinguishing building systems or features of beautiful buildings to building energy performance

In the first Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research section, characteristics common to beautiful buildings were identified and organized in three categories:

- **Beauty Attributes** – broad qualities of beautiful buildings that describe fundamental concepts
- **Beauty Determinants** – building features or systems that translate the concepts of the Beauty Attributes to a practical level that may be tied to building energy performance
- **Beauty Filters** – features of beautiful and inspiring buildings that lie behind the systems and components

Two Beauty Attributes were identified to describe how buildings relate to their surrounding environment and how occupants may relate to the building. Ten Beauty Determinants were identified relating these Beauty Attributes to building systems or features. Two Beauty Filters were identified for evaluating building systems or features relation to the beauty characteristics. The Beauty Attributes, Beauty Determinants, and Beauty Filters were combined to develop the Beauty Characteristics Matrix.

The second Beauty in Buildings (Robles, Zhai, & Goodrum, 2012) research section compiled metrics and criteria for evaluating energy performance of beautiful buildings. The CASBEE, CHPS, and LEED rating systems were used as resources to identify 22 appropriate metrics for building performance evaluation. Simple criteria were developed for each metric to improve the ease of evaluating building strategies. The metrics and criteria were compiled to form the Evaluation Metrics Matrix. The Beauty Characteristics Matrix and the Evaluation Metrics Matrix together form the BiB Matrix (Robles, Zhai, & Goodrum, 2012), a qualitative evaluation tool for assessing beautiful building performance. Development of the BiB Matrix and its components was led by ml Robles of the PatternMapping® institute.

Using the BiB Matrix (Robles, Zhai, & Goodrum, 2012), a sample of 35 case studies were evaluated for building performance in the third section. The case study sample consisted of 12 LEED Platinum projects and 23 LEED Platinum + AIA COTE Top Ten selected projects. The results of the qualitative evaluation were analyzed to identify apparent differences between high performing and inspiring and high performing buildings. Results of the qualitative evaluation indicated that the inspiring and high performing buildings included building systems or features that more consistently provide an experienced connection between the occupants, the built environment, and ultimately the surrounding environment. Comparisons of the assessed values for each project to various building factors revealed that inspiring and high performing buildings, on average, had higher construction cost per building area than the projects that were high performing but also had lower annual building energy consumption per building area than the high performing buildings.

The next section identified distinguishing building systems or features for inspiring and high performing buildings based on the qualitative evaluation. In line with the conclusions from the qualitative evaluation, a key aspect of these building systems or features is forming a connection between the occupants and the built environment through occupant control and then extending this connection to the surrounding environment through visual, audible, and physical access to nature.

Building energy models representing the distinguishing building systems or features were developed for quantitative evaluation of energy performance through energy simulation. The results of the energy simulations were used to determine the relative importance of the distinguishing building systems or features as energy weighting factors. The energy weighting factors were combined with the importance of each Beauty Determinant to provide composite weighting factors of the evaluated building systems or features. The composite weighting factors illustrated that building systems or features that exhibit density – combination of multiple systems – in their designs offered better performance relative to both beauty and energy.

The BiB Matrix (Robles, Zhai, & Goodrum, 2012) and the color-scaled quantitative references developed in this research provide useful tools for architects and engineers seeking to design built environments that are both inspiring and high performing.

7.2 Contributions of the Research

A contribution of the Beauty in Building (Robles, Zhai, & Goodrum, 2012) research and this thesis work was the development of tools for use by building designers seeking to produce inspiring and high performing buildings. Two different, but complementary, tools were developed from this work. The BiB Matrix (Robles, Zhai, & Goodrum, 2012) is a qualitative evaluation tool that may be used during the design process for initial evaluation, or afterward for assessment of existing building performance. The second tool is a quantitative reference designed to inform decisions considering both beauty and energy performance during the design process.

7.2.1 Qualitative Evaluation Tool, BiB Matrix

The BiB Matrix (Robles, Zhai, & Goodrum, 2012), whose development led by ml Robles at the PatternMapping® institute, may be used to assess performance of existing buildings, or may be used to evaluate potential design considerations for new buildings. The tool combines the Beauty Characteristics Matrix and the Evaluation Metrics Matrix to assess the performance of building strategies relative to beauty and energy performance. The BiB Matrix (Robles, Zhai, & Goodrum, 2012) is included in Appendix B with permission of the PatternMapping® institute.

7.2.2 Quantitative Design References

The quantitative references are based upon the results of the parametric analyses performed with EnergyPlus. The results of the energy simulations were translated into a matrix showing the relative importance, or weighting, of building systems or features to beauty and energy performance. The reference tables use a color scale for easy visual identification. In addition, location specific energy performance ranges for building systems or features were tabulated. These references may help inform building designers as to the impacts of specific design strategies and decisions, as well as provide information to guide such decisions for achieving inspiring and high performing buildings. The location averaged quantitative references are included in Table 6.17 through Table 6.19. Location specific quantitative references are included in Appendix D. The supporting data for the quantitative references is provided in Table 6.14 and Appendix C.

7.3 Limitations of the Research

7.3.1 Case Study Evaluation

Case study evaluations were performed by the author with as systematic an approach as possible employed to maximize the objectivity of the results. However, it is difficult, if not impossible, to remove from such evaluations all subjectivity or potential bias when the evaluator has knowledge of the building's case study population. It is possible that knowledge of the building classification – whether a building belonged to the high performing, or the inspiring and high performing building population – could impact the evaluation. Although it is unlikely that such bias would significantly impact the results, it is possible that the assessed values of some buildings used in this research could be debated. While certain project case studies may shift in rank as a result of opinion differences related to assessed value, the general trends observed between the high performing and the inspiring and high performing buildings are expected to remain valid. The same should hold true for the identified building systems or features used in the quantitative analysis.

7.3.2 Building Data

The research conducted is based on a case study population of 35 projects representing a variety of building types and locations. This was a very small sample population for the built environment. The sample population for the LEED Platinum only buildings was exceptionally limited based on availability of published case study information. The limited sample size for the case study populations may not provide a fully accurate representation of the high performing and the inspiring and high performing buildings. It is almost certain that there are building systems or features important to beauty and inspiration, as well as energy performance, that are not represented in the case study population used for this research. These features may reveal additional beauty characteristics that have been omitted in this work. Though they are understood to not be comprehensive, the beauty characteristics, building populations, and building systems or features important to beauty and inspiration used in this research are expected to be reasonably representative of beautiful and inspiring built environments.

In addition to limitations of sample size, building-specific information provided in the case studies may have omitted certain building systems or features that could impact the evaluation of the building in the qualitative evaluation tool. The evaluation performed was generally restricted to utilizing the information that project teams prioritized for publication. The case studies no doubt reflect the project teams' priorities and biases on what they perceived as key systems or features, with a focus on achieving certification within systems that did not prioritize beauty and inspiration. Thus, the reports may or may not have captured all of the systems or features related to the beauty characteristics utilized for this evaluation. Actual field visits to the individual projects to perform a complete assessment of the building would yield more complete data sets and project profiles for use in evaluation.

7.3.3 Occupant Surveys

Beauty characteristics identified in this research were developed based on the work of Christopher Alexander and his colleagues at the Center for Environmental Structure. Alexander's work is the result of extensive study and research, and provides an excellent resource for understanding building patterns that make up inspiring buildings. Beauty is defined as experiential in Alexander's work. With this in mind, a valuable input to the development and determination of beauty characteristics would be data collected from surveys of actual building occupants identifying or highlighting features in the built environment that represent beauty and provide inspiration. The use of such data would provide an empirical dataset of building systems or features that make up beautiful buildings which could be used to confirm or deny the characteristics of beautiful buildings identified in this research as well as supplementing this list of beautiful building characteristics with new building systems or features. Occupant surveys could be conducted for a variety of building types and among a varied population of occupants to provide a better characterization of beauty and inspiration and broaden the applicability of the results.

7.3.4 Building Simulation

EnergyPlus is a state of the art building simulation tool that allows exploration and modeling of a myriad of building systems or features. However, like most building simulation tools, EnergyPlus focuses on building energy consumption and does not include assessment of other building aspects. Assessment of other building aspects would be useful for evaluating potential impacts of building systems or features representative of all Beauty Determinants and in developing a broader understanding of the relative energy impact of each Beauty Determinant. Possible additions to EnergyPlus that could expand the capability to evaluate energy performance relative to beauty and inspiration include:

- Embedding the embodied energy of building construction and finishing materials to allow comparisons of the impact of using different types of building materials, including recycled or reclaimed materials.

- Modeling the immediate landscape to better understand the impact of various hardscape materials such as asphalt and concrete compared to green lawns or landscaped areas. The thermal mass of some hardscape materials may contribute to the urban heat island effect, ultimately impacting the building energy consumption. Conversely, the impact of evapotranspiration from vegetated landscape may help mitigate the urban heat island effect, also impacting the building energy consumption.

- Expanding the vegetated roof model to account for contributions in capturing and storing rainwater and the contribution to reducing stormwater runoff from the site. The current vegetated roof model makes adjustments to soil moisture levels based on precipitation and irrigation schedules, but excess water is not treated within the model. The vegetated roof model may be connected with the rainwater collection model in EnergyPlus to capture the effects of combining these building features for improvements in both building energy performance and water conservation.

7.4 Recommended Future Work

The results of this research provide useful tools and references related to the impacts of beauty and inspiration on building energy performance. Still, this research is considered to be an initial step in understanding and identifying the characteristics that are representative of beautiful buildings as well as investigating how specific building systems or features representative of these characteristics may impact building performance. Building performance in this context is expanded to a broader framework encompassing energy performance, environmental performance, and human performance. Specific recommendations for future research topics and logical next steps based on this work are described below.

7.4.1 Independent Case Study Evaluation

Independent evaluation of the project case studies would help eliminate potential effects of bias that may arise from an understanding of which building populations a given case study represents. A small group of volunteers could be recruited to evaluate the project case studies using the qualitative evaluation tool. Case studies could be provided in a standard format with no indication of whether a building was considered high performing or both inspiring and high performing. In addition to anonymous evaluation of the project case studies, written evaluation criteria could be provided to increase the objectivity of each evaluation. By enlisting multiple volunteers, a range of assessed values would be obtained for each project case study and an average performance could be determined.

7.4.2 Increased Case Study Population Size

As noted in Section 7.2.1, the case study population size was a limiting factor in this research. Expansion of the case study population of both the high performing and the inspiring and high performing buildings would improve the results and increase confidence that the distinguishing building systems or features identified are representative of inspiring and high performing buildings. If the case study populations were expanded beyond LEED Platinum certified buildings to include other LEED certification levels such as Gold or Silver, a greater number of project case studies would be available, for both high performing and inspiring and high performing buildings. While the expanded population would not represent the best performing buildings as rated by the USGBC, they would still represent high performing buildings and could be useful in furthering research in beautiful building performance.

7.4.3 Field Visits to Project Sites

In addition to the information given in the case studies for specific buildings, field data and information collected through visits to project sites would also be a valuable next step for assessing both the buildings and the accuracy of the beauty characteristics. Physical visits to the project sites would provide the opportunity to “experience” the built environment and better evaluate the building systems or features documented in the project case studies, especially whether or not these building systems or features satisfied the Sense Beauty Filter by means of physical engagement with occupants. Physical site visits would also likely result in the identification of building systems or features that inspired but were not documented in the project case studies. The ability to experience and engage in the built environments considered for evaluation would improve the accuracy of the building evaluations and assessed values for performance determined through the qualitative evaluation tool.

7.4.4 Consideration of Human Factors

Research and texts related to human factors were reviewed as part of this work and the general themes of the importance of occupant control and access to nature were noted. However, the impacts of specific building systems or features on occupant satisfaction or comfort were not evaluated in the scope of this study. Studies have been conducted to assess the impact of various aspects of the built environment not only on occupant satisfaction and comfort, but on productivity, health, and learning. Human factors in the built environment can be used to inform and append this research in two ways.

First, there is great value in increased occupant productivity and improved health as a result of the built environment. While often overlooked, improvements in productivity can prove significant and ultimately dwarf other costs associated with building construction and operation. Therefore, understanding how building systems or features representative of the beauty characteristics may relate to human performance in terms of productivity, health, and learning would be a valuable complement to the assessment of energy performance impact.

Second, as relationships between human performance and building systems or features representative of beauty characteristics are developed, ideally a connection will be established between human performance and energy performance based on the features of the built environment. This would allow evaluation of the energy performance of building systems or features relative to human factors and the establishment of decision scales for optimization of building systems or features for both energy and human performance.

7.4.5 Structured Testing of Building Evaluation Tools with Building Design Teams

The BiB Matrix (Robles, Zhai, & Goodrum, 2012) that was developed as led by ml Robles at the PatternMapping® institute provides a means for evaluating and assessing building performance relative to both beauty and energy performance. A next step in the development of this tool would be to conduct structured testing with building design teams to refine the functionality and improve the ease of use of the tool. Focus groups comprised of teams of architects and engineers could be enlisted to evaluate their own projects and to provide feedback and suggestions for improvements in the tool in terms of content, clarity, and format. Refining the qualitative evaluation tool through such focus groups would increase its functionality and utilization in evaluating buildings for beauty and energy performance.

7.4.6 Further Quantitative Evaluation of Investigated Building Systems and Features

The building models developed and evaluated in Section 6.2.1 represent initial evaluations of the various building systems or features, each of which could be further studied for sensitivity to specific parameters. Some features, such as hybrid ventilation and the vegetated roof model, are the subject of many research studies, but other features, especially those for the transitional spaces, could benefit from further evaluation.

7.4.6.1 Large Doors

The impact of the large doors modeled in Section 6.2.2.3.2 could be evaluated for sensitivity to a number of parameters. The door size and shape could be adjusted to understand their impact on the air exchange rate and airflow pattern between the outdoor environment and the interior space. These changes may be made in the existing EnergyPlus models to understand impacts to building energy use based on the Zone Ventilation model. For better resolution of the impacts to airflow patterns and air exchanges, computational fluid dynamics (CFD) software could be employed and the results used for defining discharge coefficients and air exchange rates between zones in the EnergyPlus models.

The impacts of the materials and construction of the doors could also be adjusted to understand their impacts to thermal performance, and ultimately energy performance, of the buildings. Different door construction materials could be modeled, including opaque versus translucent or transparent materials, representing the difference between a metal roll top door and a glass sliding door. For opaque materials, the thickness of the door may affect the insulative properties and therefore could impact the energy use. For doors with glazing, both the glazing type and the percentage of door area composed of glazing could be adjusted to determine their relationship to building energy use.

The depth of the space or zone served by the large opening doors could also be evaluated for impacts to energy use. The depth of the space may affect the air exchange rates with interior zones and may also provide thermal buffer effects for interior spaces. CFD software could again be used to model the changes to airflow patterns and air exchange rates between zones as they depend on the depth of the space. Energy use impacts from these changes could be evaluated in the EnergyPlus models developed for this research.

7.4.6.2 Thermal Buffer

The impact of the thermal buffer modeled in Section 6.2.2.3.3 could be evaluated for sensitivity to parameters similar to those noted for the large doors. The depth of the thermal buffer space may impact the insulative effects for the heating and cooling of interior spaces. This impact could be assessed by simulating building energy use for models with thermal buffers of various depths. The internal loads used to represent the thermal buffer space could also be adjusted to understand their relationship to energy use. Changes in the internal loads for the thermal buffer space may impact the heating or cooling required in these areas, which could also impact the effectiveness of the thermal buffer at insulating the interior zones and reducing energy use.

The materials and construction of both the interior and exterior building walls could also be analyzed for impacts to energy use. For interior walls, the number of fenestrations, such as internal windows, doors, or corridors, may impact the energy use through changes in daylight penetration and ventilation effectiveness to core spaces. For exterior walls, the amount and type of glazing used may impact the daylighting and ventilation rate of the thermal buffer, as well as thermal losses to the outdoors. The placement of the windows, whether high or low, could also impact daylighting, solar gains, and ventilation within the thermal buffer space. For both interior and exterior walls, different material types and thicknesses could be evaluated for changes in R-value and associated heat transfer, which would likely affect building energy use.

7.4.6.3 Covered Patio

The impact of the covered patio area modeled in Section 6.2.2.3.4 could be evaluated for sensitivity to the size and shape of the building shade. The depth and width of the shade relative to building height could be adjusted to establish impacts to heating or cooling energy use. The distance of the shade from the building could also be evaluated, whether the shade is attached to the building or is separated by some distance as in the Queens Botanical Garden Visitor Center.

7.4.6.4 Rainwater Collection

As mentioned in 6.2.2.6, the potential water savings of rainwater collection systems could not be evaluated in EnergyPlus Version 6.0.0.023. The recently released EnergyPlus Version 7.0 includes a working rainwater collection model, which would allow for the evaluation of water savings. New building models could be developed, or existing models revised, to include the rainwater collection feature and determine water savings. However the rainwater collection model will not evaluate the effectiveness of different forms of collection systems or their placement on the project site, which are an important distinguishing factor in providing and encouraging access and engagement that can inspire occupants.

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Appendix A

Beauty Characteristics Matrix – Case Study Evaluation

This Appendix provides the initial qualitative case study evaluation of Beauty Attributes and Beauty Determinants in its entirety. The development of the Beauty Characteristics Matrix (Robles, Zhai, & Goodrum, 2012) used for this evaluation was led by ml Robles and is included with permission of the PatternMapping® institute.

	BUILDING & LOCATION		Jewish Reconstructionist Congregation Evanston, Illinois
	RATING		LEED NC 2.1 - Platinum AIA COTE Top 10
LOCAL: Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place, are reconciled within it.	Optimize passive strategies to daylight interior spaces.	x	Large windows and high ceilings to increase daylighting; Open floor plans and room placement to take advantage of daylighting
	Optimize passive strategies for heating.	x	North staircase acts as thermal buffer in winter
	Optimize passive strategies for cooling.	x	Operable windows placed for natural ventilation; south staircase acts as thermal buffer in summer; minimize east and west windows
	Optimize building figure strategies for stormwater management.	x	Pervious materials, indigenous plants, underground store and timed release tanks
	Localized geographical fit.	x	Window placement for daylighting and reduced solar loads; reduction in noise and light pollution to neighborhood; use glass that lessens impact on birds
	Locally durable material.	x	Reclaimed lumber from local sources
DENSITY: Many building patterns overlap in the same physical space, without inner contradictions, the building is very dense, it has many meanings captured in a small space, through this density it becomes profound.	Multi-use: Spatial use is assigned more than one function.	x	Building spaces designed with flexibility and efficiency in mind, used for various community activities
	Multi-functional material: Material is utilized for more than one purpose.		
	Multi-functional interior wall: Walls used for more than one function.	x	
CONNECTIVITY: A true relationship, free from inner contradictions, between ourselves and our surroundings.	Building controllability: seasonal adjusting; day-night adjusting.	x	Building automation system allows for adjustment of building systems; operable windows may be controlled by occupants
	Optimize passive strategies for indoor-outdoor transitions.	x	Staircases provide transition space?
	Self-maintaining: cycles of restoration or evolution.	x	
	No waste: everything that comes into the building goes out in a useful condition.	x	Construction process utilized reclaimed building materials (some from demolition on site); Reclaimed lumber from local sources; ongoing?
Represented Determinants	Number of "Local" Determinants Represented		6
	Number of "Density" Determinants Represented		2
	Number of "Connectivity" Determinants Represented		4
	Total Number of Determinants Represented		12
	Percent of "Local" Determinants Represented		**100%**
	Percent of "Density" Determinants Represented		67%
	Percent of "Connectivity" Determinants Represented		**100%**
	Total Percent of Determinants Represented		**92%**

BUILDING & LOCATION	Queens Botanical Garden Visitor Center Flushing, New York		Heifer International Headquarters Little Rock, AR	
RATING	LEED NC 2.0 - Platinum AIA COTE Top 10		LEED NC 2.1 - Platinum AIA COTE Top 10	
Optimize passive strategies to daylight interior spaces.	x	Office building long and narrow, oriented along East-West axis to allow daylight penetration.	x	Narrow semicircular floor plan and East-West axis provides daylight (and views) for all employees.
Optimize passive strategies for heating.				
Optimize passive strategies for cooling.	x	Canopy shades office building in summer but allows sunlight penetration in winter and is covered with a material to reduce solar heat gain; Wooden brise-soliel wraps western and southern walls to reduce solar heat gain but allow views; sliding doors and operable windows allow cross ventilation	x	Vertical fins and horizontal sunshades limit unwanted solar heat gain. High u-value glazing.
Optimize building figure strategies for stormwater management.	x	Rainwater drains from canopy to biotope pools and water channel that feeds the gardens	x	Restored wetland surrounding building collects stormwater for irrigation. Rainwater, greywater, and condensate collected and used for toilets and building cooling (cooling tower).
Localized geographical fit.	x	Auditorium built into gardens with gently sloped garden roof; building orientation to take advantage of solar resource		
Locally durable material.			x	Building designed to last 100 years; materials selected for durability, maintainability, low toxicity, recycled content, and regional availability.
Multi-use: Spatial use is assigned more than one function.	x	Variety of assembly spaces, both open to the landscape and sheltered from the elements enhance programming flexibility; design based on community feedback and participation	x	Easily reconfigurable office systems. Building operates as headquarters office and public education facility.
Multi-functional material: Material is utilized for more than one purpose.	x	Building materials (concrete, steel, glass) exposed as much as possible with finish materials used sparingly	x	Exposed building systems offer educational opportunities.
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.	x	Sliding glass doors and operable windows in all building spaces for natural ventilation in temperate weather; lighting controls respond to occupancy and daylight levels		
Optimize passive strategies for indoor-outdoor transitions.	x	Entrance forecourt with canopy making transition from buildings to gardens; variety of assembly spaces, both open to the landscape and sheltered from the elements		
Self-maintaining: cycles of restoration or evolution.	x	During rainy days, water cascades off of the sheltering canopy roof and into a channel flowing between the main building and the auditorium. The captured rainwater moves through biotope pools filled with gravel and native wetland species that cleanse the rainwater before it is piped underground. The water then emerges at the entry plaza fountain, moves through the landscape via a meandering stream, and returns to the biotope to begin the cycle anew. The water levels vary in response to the weather and season.	x	Building designed to last 100 years; materials selected for durability, maintainability, low toxicity, recycled content, and regional availability.
No waste: everything that comes into the building goes out in a useful condition.	x	Recycled content construction materials; greywater use (toilet flushing) and 100% stormwater management; comprehensive recycling and waste-reduction program		
Number of "Local" Determinants Represented		4		4
Number of "Density" Determinants Represented		2		2
Number of "Connectivity" Determinants Represented		4		1
Total Number of Determinants Represented		10		7
Percent of "Local" Determinants Represented		67%		67%
Percent of "Density" Determinants Represented		67%		67%
Percent of "Connectivity" Determinants Represented		**100%**		25%
Total Percent of Determinants Represented		77%		54%

BUILDING & LOCATION		Yale Sculpture Building and Gallery New Haven, CT
RATING		LEED NC 2.1 - Platinum AIA COTE Top 10
Optimize passive strategies to daylight interior spaces.	x	Building oriented to minimize Eastern exposure and almost eliminate Western exposure. South-facing windows were designed to provide daylighting without glare in summer and provide daylighting in addition to heat gain in the winter.
Optimize passive strategies for heating.	x	Building oriented to minimize Eastern exposure and almost eliminate Western exposure. South-facing windows were designed to provide daylighting without glare in summer and provide daylighting in addition to heat gain in the winter. Exposed concrete slabs and high-performance insulation reduce demand on heating and cooling systems.
Optimize passive strategies for cooling.	x	Building oriented to minimize Eastern exposure and almost eliminate Western exposure. South-facing windows were designed to provide daylighting without glare in summer and provide daylighting in addition to heat gain in the winter. Exposed concrete slabs and high-performance insulation reduce demand on heating and cooling systems.
Optimize building figure strategies for stormwater management.	x	Rainwater collected from the roof of the sculpture building and surrounding landscape is used to flush toilets. Impervious surfaces replaced with rain garden , porous asphalt, native plantings and shade trees. Green roof for Gallery will reduce runoff.
Localized geographical fit.	x	Connection to community - inclusion of paths providing transition between community and campus, provision of light and security offices for safety. Cooler site slightly reduces the cooling loads of surrounding buildings and sets precedent for future development Connection to nature - Green roof and native landscaping (including mature trees) serve as a connective habitat for birds moving between local parks. Landscape designed to reduce site's ambient temperature and lessen contribution to urban heat-island effect. Connection to environment - Based on solar analysis, Sculpture building oriented to minimize solar heat gain and maximize daylighting.
Locally durable material.		
Multi-use: Spatial use is assigned more than one function.	x	Each building provides spaces for a variety of uses; galleries, studios, classrooms, parking, retail, restaurant, and office spaces. The studio building was conceived as a loft to remain as flexible as possible and houses multiple types of spaces. The upper floors are flexible and can be divided to suit the needs of the inhabitants.
Multi-functional material: Material is utilized for more than one purpose.	x	Interior spaces are utilitarian, unfinished surfaces with exposed steel structures.
Multi-functional interior wall: Walls used for more than one function.		
Building controllability: seasonal adjusting; day-night adjusting.	x	Operable windows allow the building to be naturally ventilated in spring and fall, reducing fan loads and providing surplus ventilation capacity while connecting occupants to the external environment. To enhance occupant control over the interior environment, every space is provided with interior shades.
Optimize passive strategies for indoor-outdoor transitions.	x	Front of the gallery opens completely, providing natural ventilation and a welcoming street presence.
Self-maintaining: cycles of restoration or evolution.		
No waste: everything that comes into the building goes out in a useful condition.		
Number of "Local" Determinants Represented		5
Number of "Density" Determinants Represented		2
Number of "Connectivity" Determinants Represented		2
Total Number of Determinants Represented		9
Percent of "Local" Determinants Represented		**83%**
Percent of "Density" Determinants Represented		67%
Percent of "Connectivity" Determinants Represented		50%
Total Percent of Determinants Represented		69%

BUILDING & LOCATION	Hawaii Gateway Energy Center Kailua-Kona, HI		Aldo Leopold Legacy Center Baraboo, WI	
RATING	LEED NC 2.1 - Platinum AIA COTE Top 10		LEED NC 2.1 - Platinum AIA COTE Top 10	
Optimize passive strategies to daylight interior spaces.	x	The building orientation and configuration allow daylighting to eliminate the need for electric lighting during daylight hours. The long axis of the building is oriented east-west for ideal shading and daylighting.	x	The main building's long narrow footprint, oriented along an east-west axis, allows occupied spaces to be daylit during the day.
Optimize passive strategies for heating.			x	The main building's long narrow footprint, oriented along an east-west axis, allows occupied spaces to be naturally ventilated during the day. Overhangs designed to allow passive heat gain during winter. Earth tube system to temper ventilation air year round.
Optimize passive strategies for cooling.	x	All glazing is shaded to prevent direct solar gain. Designed as thermal chimney, using building form and thermodynamic principles to move outside air for ventilation without the us of a mechanical system. Use seawater for cooling ventilation air (not entirely passive, uses some pumping energy).	x	The main building's long narrow footprint, oriented along an east-west axis, allows occupied spaces to be naturally ventilated during the day. Overhangs provide shading to shield sun during summer months. Earth tube system to temper ventilation air year round.
Optimize building figure strategies for stormwater management.	x	Parking area drains to landscaping and rockscaping on all sides. Extensive use of condensation from cooling coils for irrigation and toilets.	x	All rainwater is managed on site. Collected rainwater sent to raingarden before filtering back to aquifer. Impervious areas were minimized; crushed gravel used in lieu of paving.
Localized geographical fit.			x	Shaded parking pockets to reduce heat-island effect. Roadways designed to circulate around existing trees.
Locally durable material.	x	Locally manufactured materials: concrete, lava rock, and concrete masonry units, are inherently durable and should require no regular maintenance.	x	A majority of the lumber was taken from the Leopold forest.
Multi-use: Spatial use is assigned more than one function.	x	Multipurpose space supports a variety of activities, including exhibits, conferences, outreach, education, seminars, and community meetings. Raised access flooring allows for configuration of outlets and data ports for various activities.		
Multi-functional material: Material is utilized for more than one purpose.			x	Exposed timber construction.
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.			x	South-facing thermal flux zone allows staff members to manage natural ventilation, solar gain, and glare.
Optimize passive strategies for indoor-outdoor transitions.				
Self-maintaining: cycles of restoration or evolution.				
No waste: everything that comes into the building goes out in a useful condition.				
Number of "Local" Determinants Represented		4		6
Number of "Density" Determinants Represented		1		1
Number of "Connectivity" Determinants Represented		0		1
Total Number of Determinants Represented		5		8
Percent of "Local" Determinants Represented		67%		**100%**
Percent of "Density" Determinants Represented		33%		33%
Percent of "Connectivity" Determinants Represented		0%		25%
Total Percent of Determinants Represented		38%		62%

BUILDING & LOCATION		Alberici Corporate Headquarters Overland, MO		Chartwell Seaside, CA
RATING		LEED NC 2.1 - Platinum AIA COTE Top 10		LEED NC 2.1 - Platinum AIA COTE Top 10
Optimize passive strategies to daylight interior spaces.	x	Addition of a "saw-tooth" wall effectively reoriented building due south rather than southwest to take advantage of daylight.	x	Tall north-facing windows and clerestories provide excellent daylighting. Half of the classroom windows wrap around corners, helping reduce contrast and glare.
Optimize passive strategies for heating.	x	Addition of a "saw-tooth" wall effectively reoriented building due south rather than southwest to take advantage of daylight.		
Optimize passive strategies for cooling.	x	Addition of a "saw-tooth" wall effectively reoriented building due south rather than southwest to take advantage of daylight but blocks western sun with masonry walls. External sunscreens also block unwanted solar gain.	x	Cooling is avoided completely and natural ventilation is used in the majority of the spaces through the use of operable windows. Fenestration is organized for cross-ventilation with low windows on one side and high windows or skylights on another. To avoid solar heat gain, glazing is primarily oriented north, with smaller amounts facing south, and very little facing east or west. South facing glazing is shaded by roof overhangs or sunshades.
Optimize building figure strategies for stormwater management.	x	Retention ponds and constructed wetlands retain all stormwater runoff and form a filtration process in the forebay pool. Rainwater from 60% of garage roof area stored in large cistern and used for sewage conveyance and cooling tower makeup.	x	All rainwater is either captured in a cistern for use or infiltrates on site. Fog is also captured in the cistern and supplies water for toilet flushing. Stormwater not collected in the cistern is discharged and infiltrated on site.
Localized geographical fit.				
Locally durable material.			x	Siding is largely reclaimed wood, such as Douglas fir, which is local to the area.
Multi-use: Spatial use is assigned more than one function.			x	Multi-purpose building provides several uses. Gymnasium, library, theater with stage, etc.
Multi-functional material: Material is utilized for more than one purpose.			x	Exposed ceiling rafters in several spaces. Tree trunk column in entrance for learning.
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.			x	Ventilation is controlled by occupants, primarily through operable windows.
Optimize passive strategies for indoor-outdoor transitions.			x	Multi-use building opens to the north courtyard through four glass garage doors.
Self-maintaining: cycles of restoration or evolution.			x	Piped for water recycling system to provide courtyard irrigation. Built based upon research in Design for Disassembly (DfD) to increase flexibility of the building in the future and minimize construction waste at the end of building life.
No waste: everything that comes into the building goes out in a useful condition.			x	Piped for water recycling system to provide courtyard irrigation. Large use of reclaimed wood for interior and exterior siding as well as recycling of construction demolition and waste. Built based upon research in Design for Disassembly (DfD) to increase flexibility of the building in the future and minimize construction waste at the end of building life.
Number of "Local" Determinants Represented		4		4
Number of "Density" Determinants Represented		0		2
Number of "Connectivity" Determinants Represented		0		4
Total Number of Determinants Represented		4		10
Percent of "Local" Determinants Represented		67%		67%
Percent of "Density" Determinants Represented		0%		67%
Percent of "Connectivity" Determinants Represented		0%		**100%**
Total Percent of Determinants Represented		31%		77%

BUILDING & LOCATION	CBF Phillip Merrill Environmental Center Annapolis, MD		Sidwell Friends Middle School Washington, DC	
RATING	LEED NC 1.0 - Platinum AIA COTE Top 10		LEED NC 2.1 - Platinum AIA COTE Top 10	
Optimize passive strategies to daylight interior spaces.	x	Daylighting emphasized by large windows, clerestories, and open interior design.	x	Use large exterior windows and high ceilings to increase daylighting. Buildings exterior sunscreens designed to balance thermal performance with optimal daylighting. No screens on north side, horizontal screens above windows on south side, and screens arrayed vertically at 51° north of west for minimal heat gain and maximum daylight.
Optimize passive strategies for heating.	x	Building sited to take advantage of southern solar exposure.		
Optimize passive strategies for cooling.	x	Building sited to take advantage of prevailing winds for natural ventilation.	x	Solar-ventilation chimneys, operable windows, and ceiling fans minimize the need for mechanical cooling.
Optimize building figure strategies for stormwater management.	x	Rainwater captured in cisterns and reused on site for sinks and other items.	x	A green roof and wetland (biology pond and rain garden) reduce water runoff and improve the quality of infiltrated runoff. To further reduce runoff, parking was relocated underground, reducing paved area. Naturally treated runoff is reused in toilets and cooling towers.
Localized geographical fit.	x	Building sited to take advantage of southern solar exposure and prevailing winds for natural ventilation. Built on the footprint of existing buildings to not disturb local environment. Landscaping and exterior material choices to minimize the heat island effect.		
Locally durable material.			x	Exterior cladding made from 100 year old red cedar barrels, flooring and decking from pilings in Baltimore Harbor, as well as stone for outdoor wetland, walks, and walls.
Multi-use: Spatial use is assigned more than one function.			x	Programmatic uses share spaces through creative scheduling; allowing programs to coexist.
Multi-functional material: Material is utilized for more than one purpose.				
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.	x	Energy management system opens and closes windows automatically and also alerts occupants when manually operable windows should be opened. Electric light levels adjusted automatically for daylight.		
Optimize passive strategies for indoor-outdoor transitions.				
Self-maintaining: cycles of restoration or evolution.	x	Building design considered material composition for current construction as well as future use at end of building life. Existing structures on site were disassembled and reused or recycled.		
No waste: everything that comes into the building goes out in a useful condition.	x	Building design considered material composition for current construction as well as future use at end of building life. Existing structures on site were disassembled and reused or recycled.		
Number of "Local" Determinants Represented		5		4
Number of "Density" Determinants Represented		0		1
Number of "Connectivity" Determinants Represented		3		0
Total Number of Determinants Represented		8		5
Percent of "Local" Determinants Represented		**83%**		67%
Percent of "Density" Determinants Represented		0%		33%
Percent of "Connectivity" Determinants Represented		75%		0%
Total Percent of Determinants Represented		62%		38%

BUILDING & LOCATION	NREL Science and Technology Facility Golden, CO		Audubon Center at Debs Park Los Angeles, CA	
RATING	LEED NC 2.1 - Platinum		LEED NC 2.1 - Platinum	
Optimize passive strategies to daylight interior spaces.	x	Building, especially laboratory wing, oriented to take advantage of daylight	x	Windows provide balanced natural light in all normally occupied areas of the facility, and artificial light is required only in the evening during winter months
Optimize passive strategies for heating.				
Optimize passive strategies for cooling.	x	Building oriented along East-West axis	x	Exposed concrete walls and floors, along with high windows that open to flush out heat, moderate temperatures throughout the building; shade south windows; high thermal mass in building
Optimize building figure strategies for stormwater management.	x	Roof designed to capture rainwater and direct to infiltration basins; Left areas undeveloped to allow paths for stormwater runoff; Colorado law prohibits use of greywater or wastewater	x	Stormwater held and treated onsite before release to groundwater
Localized geographical fit.				
Locally durable material.			x	Local recycled steel; cast in place concrete walls
Multi-use: Spatial use is assigned more than one function.	x	Interaction spaces		
Multi-functional material: Material is utilized for more than one purpose.			x	Exposed concrete walls and floors
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.				
Optimize passive strategies for indoor-outdoor transitions.				
Self-maintaining: cycles of restoration or evolution.			x	
No waste: everything that comes into the building goes out in a useful condition.			x	Construction waste recycling; All wastewater treated on site (no water utility)
Number of "Local" Determinants Represented		3		4
Number of "Density" Determinants Represented		1		1
Number of "Connectivity" Determinants Represented		0		2
Total Number of Determinants Represented		4		7
Percent of "Local" Determinants Represented		50%		67%
Percent of "Density" Determinants Represented		33%		33%
Percent of "Connectivity" Determinants Represented		0%		50%
Total Percent of Determinants Represented		31%		54%

BUILDING & LOCATION	IEUA Headquarters Chino, CA		NRDC Santa Monica Office Santa Monica, CA	
RATING	LEED NC 2.1 - Platinum		LEED NC 2.1 - Platinum	
Optimize passive strategies to daylight interior spaces.	x	Extensive skylights provide daylight evenly throughout the buildings.	x	Light wells, clerestories, and architectural glass provide natural daylighting throughout the building.
Optimize passive strategies for heating.				
Optimize passive strategies for cooling.			x	Light colored roofing along with shading provided by plants and overhangs, keeps temperatures down in the building.
Optimize building figure strategies for stormwater management.	x	Reclaimed water from the treatment plant, buildings, and stormwater collection is used both indoors and outdoors. Recycled water is used for an onsite, drip irrigation system and water features. Water from the treatment process is also reclaimed and used for industry and recharging regional aquifers.	x	Rainwater is collected, pre-filtered, and integrated into the greywater use system (for toilets and irrigation). Porous pavement in courtyards to allow percolation, rather than runoff, of stormwater.
Localized geographical fit.			x	Reduced contribution to the urban heat-island effect. Outdoor fixtures designed to avoid light pollution.
Locally durable material.	x	Concrete exterior walls withstand desert temperature cycle of up to 100 °F between night and daytime. 67% of construction materials were manufactured within 500 miles and 89% of these were made from materials from within 500 miles.		
Multi-use: Spatial use is assigned more than one function.	x	Includes center for community events and community group meetings as well as temporary office space for nonprofit organizations.		
Multi-functional material: Material is utilized for more than one purpose.				
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.				
Optimize passive strategies for indoor-outdoor transitions.				
Self-maintaining: cycles of restoration or evolution.				
No waste: everything that comes into the building goes out in a useful condition.	x	Building foundation made of crushed ceramic toilets and used large portion of recycled material. IEUA implemented a waste-management plan that includes separation and collection of recyclable materials at individual desks.		
Number of "Local" Determinants Represented		3		4
Number of "Density" Determinants Represented		1		0
Number of "Connectivity" Determinants Represented		1		0
Total Number of Determinants Represented		5		4
Percent of "Local" Determinants Represented		50%		67%
Percent of "Density" Determinants Represented		33%		0%
Percent of "Connectivity" Determinants Represented		25%		0%
Total Percent of Determinants Represented		38%		31%

BUILDING & LOCATION	0142 CNT Renovation Chicago, IL		Home on the Range Billings, MT	
RATING	LEED NC 2.1 - Platinum		LEED NC 2.1 - Platinum	
Optimize passive strategies to daylight interior spaces.	x	Operable, energy-efficient windows provide daylight, views, and fresh air. Use large exterior south-facing windows for daylighting and open floor plan with high ceilings to allow daylight to penetrate the interior.	x	Building envelope renovated to include windows and light shelves for daylighting. North facing clerestory windows in monitors provide daylight to the building core. Although building orientation predetermined, the floor plan was designed East-West to take advantage of daylighting.
Optimize passive strategies for heating.	x	Additional building insulation was used to improve the building's thermal performance.	x	Additional building insulation was used to improve the building's thermal performance. Solar thermal system provides domestic hot water.
Optimize passive strategies for cooling.			x	Additional building insulation was used to improve the building's thermal performance.
Optimize building figure strategies for stormwater management.	x	A rain garden and permeable surface in the parking lot decrease the quantity and rate of runoff. More than 45% of the site is pervious and captures 26% of the stormwater it receives.	x	All stormwater is treated on site: permeable paving made of pulverized glass allows stormwater infiltration and bioswales handle any remaining runoff.
Localized geographical fit.				
Locally durable material.			x	Local materials, such as oak doors from 100 year old building downtown, used to furnish building. Wheatboard cabinetry and trim and dakota burl for desks?
Multi-use: Spatial use is assigned more than one function.				
Multi-functional material: Material is utilized for more than one purpose.				
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.				
Optimize passive strategies for indoor-outdoor transitions.				
Self-maintaining: cycles of restoration or evolution.				
No waste: everything that comes into the building goes out in a useful condition.	x	Reused existing building in urban setting to conserve resources, using all of the building structure and 90% of the building shell. 70% of the project materials brought in were recycled. Designed in-house recycling and composting systems for use by occupants.	x	During construction, 92% of all construction and demolition waste was diverted from the landfill through reuse, salvaging, recycling, and composting.
Number of "Local" Determinants Represented		3		5
Number of "Density" Determinants Represented		0		0
Number of "Connectivity" Determinants Represented		1		1
Total Number of Determinants Represented		4		6
Percent of "Local" Determinants Represented		50%		**83%**
Percent of "Density" Determinants Represented		0%		0%
Percent of "Connectivity" Determinants Represented		25%		25%
Total Percent of Determinants Represented		31%		46%

BUILDING & LOCATION	Half-Moon Outfitters Distribution Center North Charleston, SC		Greensburg Business Incubator Greensburg, KS	
RATING	LEED NC 2.1 - Platinum		LEED NC 2.2 - Platinum	
Optimize passive strategies to daylight interior spaces.			x	Strategic window placement, light shelves, and skylights allow most of the incubator to be daylit. Even with an east-facing storefront, glazing was oriented to optimize south and north facing daylighting.
Optimize passive strategies for heating.			x	Even with an east-facing storefront, glazing was oriented to optimize south and north facing passive solar gain. Well insulated building envelope.
Optimize passive strategies for cooling.			x	East-facing glazing was recessed to minimize early morning glare and unwanted solar gain. Well insulated building envelope.
Optimize building figure strategies for stormwater management.	x	A significant portion of the previously existing parking lot was removed an replaced with native vegetation to help reduce runoff. Rainwater from the roof is collected in storage tanks and used for flushing toilets and excess is used in drip irrigation for the plantings.	x	Rain gardens and other best-management practices for stormwater collection will allow water to naturally reenter the underground reservoirs in the earth. Rainwater is collected and used to supplement the greywater system.
Localized geographical fit.				
Locally durable material.	x	Interior finish materials are almost entirely salvaged, locally harvested, rapidly renewable, or high in recycled content. 40% of materials came from within 500 miles of the site. Linoleum made with linseed oil and dakota burl used for workstations.	x	Building materials were chosen for storm resistance, durability, and low maintenance.
Multi-use: Spatial use is assigned more than one function.				
Multi-functional material: Material is utilized for more than one purpose.				
Multi-functional interior wall: Walls used for more than one function.				
Building controllability: seasonal adjusting; day-night adjusting.				
Optimize passive strategies for indoor-outdoor transitions.				
Self-maintaining: cycles of restoration or evolution.				
No waste: everything that comes into the building goes out in a useful condition.	x	More than 55% of materials were recycled or donated for reuse.		
Number of "Local" Determinants Represented		2		5
Number of "Density" Determinants Represented		0		0
Number of "Connectivity" Determinants Represented		1		0
Total Number of Determinants Represented		3		5
Percent of "Local" Determinants Represented		33%		**83%**
Percent of "Density" Determinants Represented		0%		0%
Percent of "Connectivity" Determinants Represented		25%		0%
Total Percent of Determinants Represented		23%		38%

BUILDING & LOCATION		Blackstone Station Office Renovation Cambridge, MA
RATING		LEED NC 2.1 - Platinum
Optimize passive strategies to daylight interior spaces.	x	A three-story, skylit atrium and a 100-foot-long lightslot to allow daylight deep into the building for the longest possible duration each day. An open floor plan and the location of floor openings under top-lighting increase daylighting penetration as does the extensive use of transparent and translucent materials.
Optimize passive strategies for heating.	x	A spray-on, open-cell urethane foam was used to insulate the existing masonry walls from the inside.
Optimize passive strategies for cooling.	x	Every exterior window in the building is operable, allowing for fresh air and cross-ventilation whenever the weather permits. A spray-on, open-cell urethane foam was used to insulate the existing masonry walls from the inside. The new white membrane roof reduces the project's cooling load.
Optimize building figure strategies for stormwater management.	x	A new bioretention pond and adjoining bioswale behind building collect and retain stormwater so that it can recharge the groundwater table. A filtration process purifies the water: microorganisms break down oil and grease, nutrient uptake through plants reduces phosphorus, and a sand bed traps solids. The adjacent parking lot, previously impervious, was resurfaced with permeable paving, reducing runoff.
Localized geographical fit.		
Locally durable material.		
Multi-use: Spatial use is assigned more than one function.	x	Semiprivate, shared offices along the perimeter walls are enclosed by a mixture of wheatboard panels perpendicular to the exterior walls and large translucent panels on sliding hardware. This system defines the interior space on each floor while allowing for changes in the office layout. All multipurpose rooms employ the full-height fin and translucent-panel system to provide acoustic privacy.
Multi-functional material: Material is utilized for more than one purpose.		
Multi-functional interior wall: Walls used for more than one function.		
Building controllability: seasonal adjusting; day-night adjusting.	x	Every exterior window in the building is operable, allowing for fresh air and cross-ventilation whenever the weather permits.
Optimize passive strategies for indoor-outdoor transitions.	x	The 100-foot long, two-story lightslot brings daylight into the core of the building and provides a passive transition space between two areas.
Self-maintaining: cycles of restoration or evolution.		
No waste: everything that comes into the building goes out in a useful condition.	x	Dirt excavated during the construction process was used to create a sculpted, raised, universally accessible courtyard and gathering space with lawn, trees, and outdoor seating. More than 99% of all construction waste, by weight, was reused or recycled. The project team ground unpainted wood into mulch, donated salvaged plumbing fixtures to a town in Guatemala for a water shelter, and sent salvaged windows to Jamaica to help rebuild areas affected by recent hurricanes.
Number of "Local" Determinants Represented		4
Number of "Density" Determinants Represented		1
Number of "Connectivity" Determinants Represented		3
Total Number of Determinants Represented		8
Percent of "Local" Determinants Represented		67%
Percent of "Density" Determinants Represented		33%
Percent of "Connectivity" Determinants Represented		75%
Total Percent of Determinants Represented		62%

Appendix B

Qualitative Evaluation Tool

Development of the BiB Matrix (Robles, Zhai, & Goodrum, 2012) presented in this Appendix was led by ml Robles and is included with permission of the PatternMapping® institute. The BiB Matrix is designed to evaluate building performance relative to the beauty characteristics described in Chapter 3 and Chapter 4 of this publication.

<table>
<tr><td colspan="2"></td><td colspan="10">**BEAUTY ATTRIBUTES: built environment qualities that make us feel fully alive**</td></tr>
<tr><td colspan="2"></td><td colspan="6">LOCAL: Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place, are reconciled within it.</td><td colspan="4">CONNECTIVITY: A true relationship, free from inner contradictions, between ourselves and our surroundings.</td></tr>
<tr><td colspan="2"></td><td colspan="10">**DETERMINANTS: an element that determines the nature of something or fixes an outcome**</td></tr>
<tr><td colspan="2">**PROJECT**</td><td>**1:** Optimize passive strategies to daylight interior spaces.</td><td>**2:** Optimize passive strategies for heating interior spaces.</td><td>**3:** Optimize passive strategies for cooling interior spaces.</td><td>**4:** Optimize building figure strategies for stormwater management.</td><td>**5:** Localized geographical fit.</td><td>**6:** Locally durable material.</td><td>**7:** Building controllability: seasonal adjusting; day-night adjusting.</td><td>**8:** Optimize passive strategies for indoor-outdoor transitions.</td><td>**9:** Self-maintaining: cycles of restoration or evolution.</td><td>**10:** No waste: everything that comes into the building goes out in a useful condition.</td></tr>
<tr><td rowspan="16"></td><td>fill if included</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">List building strategies used</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td rowspan="2">FILTERS: strategies must meet these 2 conditions to be considered</td><td colspan="10">SENSE: Strategy must be experienced by a physical engagement or in a sensory accessible manner (by sight, touch, smell, and/or sound)</td></tr>
<tr><td colspan="10">DENSITY: Many building patterns overlap in the same physical space, without inner contradictions, the building is very dense, it has many meanings captured in a small space, through this density it becomes profound (strategy must be part of a system: multi use, multi function).</td></tr>
<tr><td rowspan="2">fill if meet criteria
high perf:regen pts</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td rowspan="4">List building strategies that meet filter criteria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

					USE METRICS TO DETERMINE PERFORMANCE IMPACT OF BUILDING STRATEGIES: high performing points : regenerative points																		
				Related Determinants	building strategy		building strategy		building strategy		building strategy		building strategy		building strategy		building strategy		building strategy		building strategy		TOTAL	
	METRICS				HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		HIGH PERFORMING (O); REGENERATIVE (+)		**High Performing**	**Regenerative**
1	Building Thermal Load				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+		
	The efforts to improve the reduction of thermal gains and losses due to insolation and interior-exterior temperature gradients, and thermal load control as a means of reducing energy consumed by cooling and heating.																							
	CONVENTIONAL	(0)	(+)	1																				
	Requires a mechanical system	Requires a reduced mechanical system	Mechanical system is optional but not required	2																				
				3																				
				5																				
				7																				
				8																				
2	Building Envelope Performance				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+		
	The ability to block thermal infiltration from the surroundings: whether window systems and exterior walls have been selected to exclude outside disturbances as far as possible, in order to maintain room temperature.																							
	CONVENTIONAL	(0)	(+)	2																				
	Requires a mechanical system	Requires a reduced mechanical system	Mechanical system is optional but not required	3																				
				5																				
				7																				
				8																				

3	Daylight Control				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Measures against glare produced by direct sunlight: are there eaves, awnings, screens, curtains, blinds, shades, and similar elements around openings.																					
	CONVENTIONAL	(0)	(+)	1																		
	Glare from direct sunlight experienced during all seasons	Seasonal glare from direct sunlight	No glare	5																		
				7																		
				8																		
4	Direct Use of Natural Forces				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The unconverted use of natural forces such as sun, light, and wind as appropriate.																					
	CONVENTIONAL	(0)	(+)	1																		
	Natural forces are not used to meet building energy needs	Natural forces are used to partially meet building energy needs	Use of natural forces exceeds building energy needs (and replaces some building systems)	2																		
				3																		
				5																		
				7																		
				8																		
				9																		
5	Daylighting				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The effective use of daylight to maintain illuminance for occupants and required tasks during daytime hours. Encourages awareness of day, night and season cycles.																					
	CONVENTIONAL	(0)	(+)	1																		
	Requires continuous electric lighting during daytime hours, no seasonal change	Requires electric lighting only a portion of daylight hours, seasonal opportunities	Electric lighting system is optional but not required and maximized seasonally	3																		
				5																		
				7																		
				8																		
				9																		
6	Openings by Orientation				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The orientation of apertures make use of daylight, solar, encourage ventilation, and do not contribute to building thermal load.																					
	CONVENTIONAL	(0)	(+)	1																		
	Apertures are not oriented to allow daylight, solar, or ventilation during any season and ignore site topography or other potential obstructions.	Some apertures are oriented to allow daylight, solar or seasonal ventilation. Apertures may account for site topography or other potential obstructions.	All apertures are oriented to allow daylight, solar, or ventilation during all seasons. Apertures account for site topography and other obstructions.	2																		
				3																		
				5																		
				7																		
				8																		

7	Natural Ventilation				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Whether indoor air temperature and ventilation can be maintained with building features.																					
	CONVENTIONAL	(0)	(+)	1																		
	No natural ventilation enabled by building features	Building features allow for some seasonal maintenance of indoor air temperature and ventilation.	Building features allow for maintenance of indoor air temperature and ventilation during any season.	3																		
				5																		
				7																		
				8																		
8	Outside Air Intake/Building Air Exchange				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Outside air intakes designed to take in the best outside air available (clean, temperate, no foul odor).																					
	CONVENTIONAL	(0)	(+)	3																		
	Air intakes provide air with bad odor or extreme (high or low) temperatures	Some air intakes provide sufficient ventilation of temperate air with no bad odor.	All air intakes provide more than sufficient ventilation of temperate air with no bad odor.	8																		
9	Stormwater Use Directly Attributed to Building Figure				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Building figure collects and directs stormwater.																					
	CONVENTIONAL	(0)	(+)	4																		
	No system to control and collect stormwater.	Building figure collects and directs most stormwater.	Building figure collects and directs all stormwater for use.	5																		
10	Stormwater Discharge				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Stormwater permeation measures and temporary storage measures limit rainwater runoff flow.																					
	CONVENTIONAL	(0)	(+)	4																		
	All stormwater runs off site and is not used	Stormwater runoff is reduced	All stormwater is used on site	5																		
				9																		
11	Greywater Use System				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The level of greywater use.																					
	CONVENTIONAL	(0)	(+)	9																		
	All greywater is discharged from site and is not used	Greywater discharge is reduced but not eliminated;	All greywater is used on site	10																		

12	Efforts Enhance the Durability/Reusability				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The levels of reuse of building structural elements and reducing building material waste and promote local building material reuse during construction, renovation, or disassembly.																					
	CONVENTIONAL	(0)	(+)	6																		
	No existing building structures or materials are reused or repurposed	Some existing structure and building materials are reused and repurposed in some phases	All structure and building materials are reused and repurposed in all phases	9																		
				10																		
13	Design for Adaptability				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Provide spaces that are adaptable and flexible.																					
	CONVENTIONAL	(0)	(+)	9																		
	Building structure (walls and floor layout) cannot be changed for different uses. Building systems are immovable and difficult to adjust for different uses.	Some buildings walls and building systems may be relocated allowing conversion of some building space for different uses.	All walls may be relocated allowing building to be used for any potential uses. Building systems are easily adjustable or relocatable for any potential uses.	10																		
14	Durability of Structural Frame Materials				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The interval at which failure of structural frame materials to fulfill their functions necessitates major repair work to maintain function.																					
	CONVENTIONAL	(0)	(+)	6																		
	Structural frame materials require annual maintenance	Structural frame materials require maintenance within 5 years	Structural frame materials require no maintenance	9																		
				10																		
15	Durability of Main Interior and Exterior Finishes				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The interval at which failure of interior finishes and exterior walls to fulfill their functions necessitates repair work to maintain function.																					
	CONVENTIONAL	(0)	(+)	6																		
	Building exterior and interior finish require seasonal maintenance	Building exterior and interior finish require maintenance every 5 years	Building exterior and interior finish require no maintenance	9																		
				10																		

16	Use of Recycled Materials				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Recycled, reclaimed, or reused materials for building structure and for building components.																					
	CONVENTIONAL	(0)	(+)	6																		
	Building structure, materials, and finish do not use any recycled, reclaimed, or reused materials	Some building structure, materials, and finish are recycled, reclaimed, or reused materials	All building structure, materials, and finish are recycled, reclaimed, or reused materials	9																		
				10																		
17	Building waste				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	Efforts to reduce the generation of waste when the building is in operation.																					
	CONVENTIONAL	(0)	(+)	10																		
	No building waste is reused or recycled	Some building waste is reused, composted, or recycled	All building waste is reused, composted, or recycled																			
18	Preservation and Creation of Biotope				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The efforts made for conservation and creation of habitat by the building, with a view to conserving and regenerating the natural environment and securing biodiversity.																					
	CONVENTIONAL	(0)	(+)	4																		
	Existing habitat is destroyed and building grounds are unusable for natural habitat and growth of local vegetation	Existing habitat is partially conserved and building grounds are usable for natural habitat and growth of local vegetation	Existing habitat is enhanced and building grounds are usable for natural habitat and growth of local vegetation	5																		
19	Attention to Local (Urban) Character				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+
	The impact of the building and site on the surrounding urban context and scenery, and what kind of contribution it makes to improving them. Evaluate efforts such as continuation of local history, contribution to city and district amenities, activities, and vitality, formation of rich intermediate spaces and a living environment with a high level of local amenity.																					
	CONVENTIONAL	(0)	(+)	4																		
	Building is generic	Building creates some continuity and amenity with surrounding area	Building is continuous with and improves the surrounding area	5																		
				8																		

20	Light Pollution				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+		
	Light pollution caused by buildings including exterior lights at night, light spill from the interior, lighting for advertising displays, etc.																							
	CONVENTIONAL	(0)	(+)	5																				
	Light from building pollutes surroundings	All light from building stays on site	Light from building enhances night time hours	8																				
21	Improvement of the Thermal Environment on Site				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+		
	Measures to assist in reducing the thermal load on areas both inside and outside the site in order to alleviate the on-site thermal environment.																							
	CONVENTIONAL	(0)	(+)	3																				
	Building and grounds increase thermal load of surrounding area	Building and grounds produce seasonal reductions in thermal load of surrounding area	Building and grounds alleviate thermal load of surrounding area	5																				
22	Reflected Solar Glare from Building Walls				0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+	0	+		
	Measures to mitigate the glare cast on the surrounding area by reflection of daylight from building walls																							
	CONVENTIONAL	(0)	(+)	5																				
	Building wall reflectance results in glare and increased thermal load to surrounding area	Building wall reflectance may produce seasonal glare and increased thermal load to surrounding area	Building wall reflectance does not produce glare or increase thermal load of surrounding area during any season	8																				
			6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			14	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			11	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			IMPACT TOTAL		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
			do the strategies or systems have the ATTRIBUTES?		LOCAL: Never twice the same: takes its shape from the particular place in which it occurs; the transitory forces of nature in that particular place, are reconciled within it.																			
					CONNECTIVITY: A true relationship, free from inner contradictions, between ourselves and our surroundings.																			

Appendix C

Building Feature Energy Performance Ranges by Location

Table C.1 through Table C.5 provide the results for percent change in energy use by modeling group for each location evaluated. The tables list the cases associated with the least and greatest reductions in energy use together with their associated reductions. Positive percent changes represent increased energy use relative to the base case; negative percent changes represent reduced energy use relative to the base case.

The relative impact of the building systems or features are shown for the energy use per building area to allow for translation to a variety of projects. In addition to the energy use per building area, the relative impact to the heating energy and cooling energy were also compiled for the simulations, allowing consideration of the importance of building systems or features for specific climates or building applications that may be predominantly heating or predominantly cooling. Finally, the relative impact as measured in terms of the carbon equivalent is provided in each table. While the potential carbon impact was not directly utilized in this research, the data is provided to allow for future use and evaluation of impacts related to building materials and construction that may be associated with Beauty Determinants 6, 9, and 10.

Table C.1: Performance Range of Building Features – Los Angeles

	Source Energy per Building Area [kWh/ft^2]		Heating Energy [kWh]		Cooling Energy [kWh]		Carbon Equivalent [tons]	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Window+Form								
Form								
Least Reduction	Daylight Only	-6%	Daylight Only	99%	Daylight Only	-5%	Daylight Only	-6%
Greatest Reduction	Daylight+HV-Long	-16%	Daylight+HV-Long	-100%	Daylight+HV-Long	-59%	Daylight+HV-Long	-17%
Window								
Least Reduction	Daylight+HV-NoEorW_Window	-14%	Daylight+HV-Louvers	-99.9%	Daylight+HV-Red_EandW_Window	-58%	Daylight+HV-NoEorW_Window	-15%
Greatest Reduction	Daylight+HV-Louvers	-16%	Daylight+HV-NoEorW_Window	-100%	Daylight+HV-Louvers	-59%	Daylight+HV-Louvers	-16%
Transition								
Landscape								
Least Reduction	Concrete	1%	Vegetation	210%	Concrete	7%	Concrete	1%
Greatest Reduction	Vegetation	-2%	Concrete	-47%	Vegetation	-24%	Vegetation	-3%
Large Doors								
Least Reduction	D+HV-EastDoor-Patio	-16%	D+HV-WestDoor+CY	-99%	D+HV-WestDoor	-56%	D+HV-SouthDoor-Patio	-17%
Greatest Reduction	D+HV-SouthDoor+CY	-19%	D+HV-WestDoor-Patio	-100%	D+HV-EastDoor-Patio+CY	-70%	D+HV-EastDoorE+CY	-20%
Thermal Buffer								
Least Reduction	ThermalBuffer	8%	ThermalBuffer	220%	ThermalBuffer	-8%	ThermalBuffer	-12%
Greatest Reduction	DHV+ThermalBuffer+CY	-15%	DHV+ThermalBuffer	-99%	DHV+ThermalBuffer+CY	-71%	DHV+ThermalBuffer+CY	-31%
Covered Patio								
Least Reduction	NorthPatio-45°	0%	WestPatio-Horizontal	140%	NorthPatio-45°	0%	D+HV-NorthPatio -15°	3%
Greatest Reduction	D+HV-WestPatio-30°+CY	-18%	D+HV-WestPatio-Horizontal	-100%	D+HV-WestPatio-Horizontal+CY	-70%	D+HV-WestPatio-30°+CY	-18%

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Integrated Form								
Least Reduction	Inground_North	0%	Inground_ESW+CY	2089%	Inground_North	0%	Inground_North	0%
Greatest Reduction	Inground_ESW+CY	-4%	Inground_North	-5%	Inground_ESW+CY	-29%	Inground_ESW+CY	-4%
Vegetated Roof								
Least Reduction	VegRoof-Lower	-0.10%	VegRoof-Lower	-1%	VegRoof-Lower	-0.01%	VegRoof-Lower	-0.1%
Greatest Reduction	VegRoof-Both	-0.18%	VegRoof-Both	-2%	VegRoof-Upper	-0.03%	VegRoof-Both	-0.2%

Table C.2: Performance Range of Building Features – Washington D.C.

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Window+Form								
Form								
Least Reduction	Daylight Only	-6%	Daylight Only	9%	Daylight Only	-6%	Daylight Only	-6%
Greatest Reduction	Daylight+HV-Long	-20%	Daylight+HV	-53%	Daylight+HV-Long	-29%	Daylight+HV-Long	-20%
Window								
Least Reduction	Daylight+HV-NoEorW_Window	-19%	Daylight+HV-Louvers	-49%	Daylight+HV-Red_EandW_Window	-29%	Daylight+HV-NoEorW_Window	-19%
Greatest Reduction	Daylight+HV-Louvers	-20%	Daylight+HV-Red_EandW_Window	-51%	Daylight+HV-NoEorW_Window	-30%	Daylight+HV-Louvers	-20%
Transition								
Landscape								
Least Reduction	Concrete	1%	Vegetation	16%	Concrete	7%	Concrete	1%
Greatest Reduction	Vegetation	-2%	Concrete	-7%	Vegetation	-31%	Vegetation	-2%
Large Doors								
Least Reduction	D+HV-EastDoor	-20%	D+HV-SouthDoor-Patio+CY	-50%	D+HV-WestDoor	-24%	D+HV-SouthDoor-Patio	-19%
Greatest Reduction	D+HV-NorthDoor+CY	-23%	D+HV-EastDoor	-54%	D+HV-EastDoor-Patio+CY	-52%	D+HV-EastDoor-Patio+CY	-24%
Thermal Buffer								
Least Reduction	ThermalBuffer	15%	ThermalBuffer	13%	ThermalBuffer	-9%	ThermalBuffer	-5%
Greatest Reduction	DHV+ThermalBuffer+CY	-17%	DHV+ThermalBuffer	-62%	DHV+ThermalBuffer+CY	-53%	DHV+ThermalBuffer+CY	-32%
Covered Patio								
Least Reduction	SouthPatio-Horizontal	1%	D+HV-WestPatio-30	22%	NorthPatio-45°	0%	SouthPatio-Horizontal	1%
Greatest Reduction	D+HV-WestPatio-Horizontal+CY	-23%	D+HV-NorthPatio-Horizontal	-54%	D+HV-WestPatio-Horizontal+CY	-52%	D+HV-WestPatio-Horizontal+CY	-23%

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Integrated Form								
Least Reduction	Inground_South	-1%	Inground_ESW+CY	21%	Inground_North	-1%	Inground_South	-1%
Greatest Reduction	Inground_WNE+CY	-5%	Inground_North	-4%	Inground_ESW+CY	-37%	Inground_WNE+CY	-7%
Vegetated Roof								
Least Reduction	VegRoof-Upper	-0.5%	VegRoof-Upper	-3%	VegRoof-Lower	-1%	VegRoof-Upper	-0.4%
Greatest Reduction	VegRoof-Both	-0.9%	VegRoof-Both	-5%	VegRoof-Both	-2%	VegRoof-Both	-0.7%

Table C.3: Performance Range of Building Features - Boston

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Window+Form								
Form								
Least Reduction	Daylight Only	-5%	Daylight Only	8%	Daylight Only	-6%	Daylight Only	-6%
Greatest Reduction	Daylight+HV-Long	-15%	Daylight+HV-Long	-17%	Daylight+HV-Long	-33%	Daylight+HV-Long	-16%
Window								
Least Reduction	Daylight+HV-Louvers	-13.6%	Daylight+HV-Louvers	-11%	Daylight+HV-Red_EandW_Window	-34%	Daylight+HV-Louvers	-15%
Greatest Reduction	Daylight+HV-NoEorW_Window	-14%	Daylight+HV-Red_EandW_Window	-14%	Daylight+HV-NoEorW_Window	-36%	Daylight+HV-NoEorW_Window	-17%
Transition								
Landscape								
Least Reduction	Concrete	0%	Vegetation	4%	Concrete	7%	Concrete	1%
Greatest Reduction	Vegetation	-1%	Concrete	-6%	Vegetation	-20%	Vegetation	-1%
Large Doors								
Least Reduction	D+HV-SouthDoor-Patio	-13%	D+HV-SouthDoor-Patio+CY	-11%	D+HV-WestDoor	-28%	D+HV-SouthDoor-Patio	-14%
Greatest Reduction	D+HV-SouthDoor+CY	-15%	D+HV-EastDoor	-19%	D+HV-EastDoor-Patio+CY	-47%	D+HV-EastDoor-Patio+CY	-17%
Thermal Buffer								
Least Reduction	ThermalBuffer	16%	ThermalBuffer	10%	ThermalBuffer	-7%	ThermalBuffer	-3%
Greatest Reduction	D+HV-ThermalBuffer+CY	-7%	D+HV-ThermalBuffer	-32%	D+HV-ThermalBuffer+CY	-47%	D+HV-ThermalBuffer+CY	-23%
Covered Patio								
Least Reduction	SouthPatio-Horizontal	2%	SouthPatio-Horizontal	7%	NorthPatio-45°	0%	SouthPatio-Horizontal	1%
Greatest Reduction	D+HV-WestPatio-Horizontal+CY	-15%	D+HV-NorthPatio-Horizontal	-17%	D+HV-WestPatio-Horizontal+CY	-46%	D+HV-WestPatio-Horizontal+CY	-16%

	Source Energy per Building Area [kWh/ft^2]		Heating Energy [kWh]		Cooling Energy [kWh]		Carbon Equivalent [tons]	
	Case	% Red.	Case	% Red.	Case	% Red.	Case	% Red.
Integrated Form								
Least Reduction	Inground_South	-1%	Inground_ESW+CY	7%	Inground_North	-1%	Inground_South	-1%
Greatest Reduction	Inground_WNE+CY	-4%	Inground_N_Boston	-4%	Inground_ESW+CY	-26%	Inground_WNE+CY	-5%
Vegetated Roof								
Least Reduction	VegRoof-Upper	-0.3%	VegRoof-Upper	-2%	VegRoof-Lower	-0.6%	VegRoof-Upper	-0.2%
Greatest Reduction	VegRoof-Both	-0.6%	VegRoof-Both	-3%	VegRoof-Both	-1.3%	VegRoof-Both	-0.4%

Table C.4: Performance Range of Building Features - Chicago

	Source Energy per Building Area [kWh/ft^2]		Heating Energy [kWh]		Cooling Energy [kWh]		Carbon Equivalent [tons]	
	Case	% Red.	Case	% Red.	Case	% Red.	Case	% Red.
Window+Form								
Form								
Least Reduction	Daylight Only	-5%	Daylight Only	7%	Daylight Only	-6%	Daylight Only	-6%
Greatest Reduction	Daylight+HV-Long	-14%	Daylight+HV	-15%	Daylight+HV-Long	-29%	Daylight+HV-Long	-15%
Window								
Least Reduction	Daylight+HV-Louvers	-13%	Daylight+HV-Louvers	-9%	Daylight+HV-Red_EandW_Window	-29%	Daylight+HV-Louvers	-14%
Greatest Reduction	Daylight+HV-NoEorW_Window	-14%	Daylight+HV-Red_EandW_Window	-14%	Daylight+HV-NoEorW_Window	-31%	Daylight+HV-NoEorW_Window	-16%
Transition								
Landscape								
Least Reduction	Concrete	0%	Vegetation	3%	Concrete	7%	Concrete	1%
Greatest Reduction	Vegetation	-1%	Concrete	-5%	Vegetation	-18%	Vegetation	-1%
Large Doors								
Least Reduction	D+HV-SouthDoor-Patio	-12%	D+HV-SouthDoor-Patio+CY	-8%	DHV-WestDoor	-25%	D+HV-SouthDoor-Patio	-13%
Greatest Reduction	D+HV-SouthDoor+CY	-14%	DHV-EastDoor	-16%	DHV-EastDoor-Patio+CY	-42%	DHV-EastDoor-Patio+CY	-16%
Thermal Buffer								
Least Reduction	ThermalBuffer	17%	ThermalBuffer	12%	ThermalBuffer	-8%	ThermalBuffer	-2%
Greatest Reduction	DHV+ThermalBuffer+CY	-5%	DHV+ThermalBuffer	-25%	DHV+ThermalBuffer+CY	-43%	DHV+ThermalBuffer+CY	-22%
Covered Patio								
Least Reduction	SouthPatio-Horizontal	1%	SouthPatio-Horizontal	6%	NorthPatio-45°	0%	SouthPatio-Horizontal	1%
Greatest Reduction	DHV+WestPatio-Horizontal+CY	-14%	DHV+NorthPatio-Horizontal	-15%	DHV+WestPatio-Horizontal+CY	-42%	DHV+WestPatio-Horizontal+CY	-15%

	Source Energy per Building Area [kWh/ft^2]		Heating Energy [kWh]		Cooling Energy [kWh]		Carbon Equivalent [tons]	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Integrated Form								
Least Reduction	Inground_South	-1%	Inground_West+CY	3%	Inground_North	-1%	Inground_South	-1%
Greatest Reduction	Inground_WNE+CY	-4%	Inground_NES	-6%	Inground_ESW+CY	-24%	Inground_WNE+CY	-6%
Vegetated Roof								
Least Reduction	VegRoof-Lower	-0.4%	VegRoof-Upper	-2%	VegRoof-Lower	-0.1%	VegRoof-Lower	-0.2%
Greatest Reduction	VegRoof-Both	-0.7%	VegRoof-Both	-4%	VegRoof-Both	-0.3%	VegRoof-Both	-0.4%

Table C.5: Performance Range of Building Features - Golden

	Source Energy per Building Area [kWh/ft^2]		Heating Energy [kWh]		Cooling Energy [kWh]		Carbon Equivalent [tons]	
	Case	% Red.	Case	% Red.	Case	% Red.	Case	% Red.
Window+Form								
Form								
Least Reduction	Daylight Only	-6%	Daylight Only	10%	Daylight Only	-7%	Daylight Only	-6%
Greatest Reduction	Daylight+HV-Long	-20%	Daylight+HV	-50%	Daylight+HV-Long	-41%	Daylight+HV-Long	-20%
Window								
Least Reduction	Daylight+HV-NoEorW_Window	-18.7%	Daylight+HV-Louvers	-45%	Daylight+HV-Red_EandW_Window	-41%	Daylight+HV-NoEorW_Window	-18.9%
Greatest Reduction	Daylight+HV-Red_EandW_Window	-19.5%	Daylight+HV-Red_EandW_Window	-47%	Daylight+HV-NoEorW_Window	-44%	Daylight+HV-Red_EandW_Window	-19.5%
Transition								
Landscape								
Least Reduction	Concrete	0.3%	Vegetation	6%	Concrete	9%	Concrete	1%
Greatest Reduction	Vegetation	-0.4%	Concrete	-8%	Vegetation	-17%	Vegetation	-1%
Large Doors								
Least Reduction	D+HV-SouthDoor-Patio	-19%	D+HV-SouthDoor-Patio+CY	-45%	D+HV-WestDoor	-36%	D+HV-SouthDoor-Patio	-18%
Greatest Reduction	D+HV-SouthDoor-+CY	-20%	D+HV-EastDoor	-51%	D+HV-EastDoor-Patio+CY	-52%	D+HV-EastDoor-Patio+CY	-21%
Thermal Buffer								
Least Reduction	ThermalBuffer	17%	ThermalBuffer	17%	ThermalBuffer	-6%	ThermalBuffer	-3%
Greatest Reduction	DHV+ThermalBuffer+CY	-13%	DHV+ThermalBuffer	-56%	DHV+ThermalBuffer+CY	-52%	DHV+ThermalBuffer+CY	-28%
Covered Patio								
Least Reduction	SouthPatio-Horizontal	2%	SouthPatio-Horizontal	9%	NorthPatio-45°	0%	SouthPatio-Horizontal	2%
Greatest Reduction	DHV+WestPatio-Horizontal+CY	-20%	DHV+NorthPatio-Horizontal	-50%	DHV+EastPatio-Horizontal+CY	-51%	DHV+WestPatio-Horizontal+CY	-20%

	Source Energy per Building Area [kWh/ft^2]		**Heating Energy [kWh]**		**Cooling Energy [kWh]**		**Carbon Equivalent [tons]**	
	Case	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**	**Case**	**% Red.**
Integrated Form								
Least Reduction	Inground_South	-1%	Inground_ESW+CY	13%	Inground_North	-1%	Inground_South	-1%
Greatest Reduction	Inground_WNE+CY	-3%	Inground_North	-4%	Inground_ESW+CY	-24%	Inground_WNE+CY	-5%
Vegetated Roof								
Least Reduction	VegRoof-Lower	-0.6%	VegRoof-Upper	-3%	VegRoof-Lower	-1%	VegRoof-Lower	-0.6%
Greatest Reduction	VegRoof-Both	-1.2%	VegRoof-Both	-6%	VegRoof-Both	-3%	VegRoof-Both	-1%

Appendix D

Composite Weighting Factors by Location

Table D.1 through Table D.15 provide the composite weighting factors calculated from the energy weighting factors and beauty weighting factors for each location evaluated. The tables are color scaled to indicate the building systems or features with the greatest and least impact on both beauty and energy performance from the base case. The results indicate relative impact compared to all Beauty Determinants and building systems or features evaluated in Chapter 6. The factors were color coded for easy visual representation of the building systems or features most heavily weighted for impact on beauty and energy performance. Items shown in green indicate the heaviest weighting, items in white indicate moderate weighting, and items in red the lowest weighting. Combinations of Beauty Determinants and building systems or features not evaluated are marked “NA” and appear grey in the respective tables.

The location specific color scaled references are shown for the energy use per building area, heating energy, and cooling energy, allowing consideration of the importance of building systems or features for specific climates or building applications that may be predominantly heating or predominantly cooling. Location specific color scaled references for energy per building area are shown in Table D.1, Table D.4, Table D.7, Table D.10 and Table D.13. Location specific color scaled references for heating energy are shown in Table D.2, Table D.5, Table D.8, Table D.11, and Table D.14. Location specific color scaled references for cooling energy are shown in Table D.3, Table D.6, Table D.9, Table D.12, and Table D.15.

Table D.1: Building Energy Intensity Composite Weighting Factors – Los Angeles

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.44	0.43	NA	0.50	0.39	0.48	NA	NA
(2) Optimize passive heating	0.22	0.22	0.03	0.25	0.20	0.24	0.06	0.00
(3) Optimize passive cooling	0.44	0.43	0.07	0.50	0.39	0.48	0.12	0.00
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.66	0.65	0.10	0.75	0.59	0.72	0.17	0.01
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.88	0.86	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.13	1.00	0.78	0.96	0.23	0.01
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.2: Heating Energy Composite Weighting Factors – Los Angeles

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.50	0.50	NA	0.50	0.49	0.50	NA	NA
(2) Optimize passive heating	0.25	0.25	0.12	0.25	0.25	0.25	0.01	0.01
(3) Optimize passive cooling	0.50	0.50	0.24	0.50	0.49	0.50	0.02	0.01
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.75	0.75	0.36	0.75	0.74	0.75	0.03	0.02
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	1.00	1.00	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.47	1.00	0.99	1.00	0.05	0.02
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.3: Cooling Energy Composite Weighting Factors – Los Angeles

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.41	0.41	NA	0.49	0.50	0.49	NA	NA
(2) Optimize passive heating	0.21	0.21	0.08	0.25	0.25	0.25	0.10	0.00
(3) Optimize passive cooling	0.41	0.41	0.17	0.49	0.50	0.49	0.21	0.00
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.62	0.62	0.25	0.74	0.75	0.74	0.31	0.00
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.82	0.82	NA	0.98	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.33	0.98	1.00	0.98	0.41	0.00
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.4: Building Energy Intensity Composite Weighting Factors – Washington D.C.

Beauty Determinant	Form	Window	Landscape	Large Doors	Thermal Buffer	Covered Patio	Integrated Form	Vegetated Roof
(1) Optimize passive daylighting	0.44	0.43	NA	0.50	0.37	0.49	NA	NA
(2) Optimize passive heating	0.22	0.22	0.02	0.25	0.18	0.24	0.05	0.01
(3) Optimize passive cooling	0.44	0.43	0.03	0.50	0.37	0.49	0.11	0.02
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.65	0.65	0.05	0.75	0.55	0.73	0.16	0.03
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.87	0.86	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.07	1.00	0.74	0.98	0.21	0.04
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.5: Heating Energy Composite Weighting Factors – Washington D.C.

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.43	0.41	NA	0.44	0.50	0.43	NA	NA
(2) Optimize passive heating	0.21	0.21	0.03	0.22	0.25	0.22	0.02	0.02
(3) Optimize passive cooling	0.43	0.41	0.06	0.44	0.50	0.43	0.03	0.04
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.64	0.62	0.09	0.65	0.75	0.65	0.05	0.07
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.86	0.82	NA	0.87	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.12	0.87	1.00	0.86	0.07	0.09
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.6: Cooling Energy Composite Weighting Factors – Washington D.C.

Beauty Determinant	Form	Window	Landscape	Large Doors	Thermal Buffer	Covered Patio	Integrated Form	Vegetated Roof
(1) Optimize passive daylighting	0.27	0.28	NA	0.49	0.50	0.49	NA	NA
(2) Optimize passive heating	0.14	0.14	0.15	0.25	0.25	0.24	0.17	0.01
(3) Optimize passive cooling	0.27	0.28	0.29	0.49	0.50	0.49	0.35	0.01
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.41	0.42	0.44	0.74	0.75	0.73	0.52	0.02
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.55	0.56	NA	0.98	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.58	0.98	1.00	0.98	0.69	0.03
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.7: Building Energy Intensity Composite Weighting Factors – Boston

Beauty Determinant	Form	Window	Landscape	Large Doors	Thermal Buffer	Covered Patio	Integrated Form	Vegetated Roof
(1) Optimize passive daylighting	0.48	0.46	NA	0.50	0.25	0.48	NA	NA
(2) Optimize passive heating	0.24	0.23	0.01	0.25	0.12	0.24	0.06	0.01
(3) Optimize passive cooling	0.48	0.46	0.02	0.50	0.25	0.48	0.12	0.02
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.73	0.69	0.03	0.75	0.37	0.72	0.18	0.03
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.97	0.92	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.04	1.00	0.49	0.96	0.24	0.04
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.8: Heating Energy Composite Weighting Factors – Boston

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.28	0.23	NA	0.30	0.50	0.28	NA	NA
(2) Optimize passive heating	0.14	0.11	0.05	0.15	0.25	0.14	0.03	0.02
(3) Optimize passive cooling	0.28	0.23	0.10	0.30	0.50	0.28	0.06	0.05
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.41	0.34	0.15	0.45	0.75	0.41	0.09	0.07
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.55	0.46	NA	0.59	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.19	0.59	1.00	0.55	0.12	0.09
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.9: Cooling Energy Composite Weighting Factors – Boston

Beauty Determinant	Form	Window	Landscape	Large Doors	Thermal Buffer	Covered Patio	Integrated Form	Vegetated Roof
(1) Optimize passive daylighting	0.36	0.39	NA	0.50	0.50	0.49	NA	NA
(2) Optimize passive heating	0.18	0.19	0.10	0.25	0.25	0.25	0.14	0.01
(3) Optimize passive cooling	0.36	0.39	0.21	0.50	0.50	0.49	0.28	0.01
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.53	0.58	0.31	0.75	0.75	0.74	0.42	0.02
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.71	0.77	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.42	1.00	1.00	0.99	0.56	0.03
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.10: Building Energy Intensity Composite Weighting Factors – Chicago

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.48	0.47	NA	0.50	0.19	0.48	NA	NA
(2) Optimize passive heating	0.24	0.24	0.01	0.25	0.09	0.24	0.07	0.01
(3) Optimize passive cooling	0.48	0.47	0.03	0.50	0.19	0.48	0.15	0.02
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.72	0.71	0.04	0.75	0.28	0.72	0.22	0.04
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.95	0.95	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.05	1.00	0.38	0.96	0.29	0.05
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.11: Heating Energy Composite Weighting Factors – Chicago

Beauty Determinant	Form	Window	Landscape	Large Doors	Thermal Buffer	Covered Patio	Integrated Form	Vegetated Roof
(1) Optimize passive daylighting	0.29	0.27	NA	0.32	0.50	0.29	NA	NA
(2) Optimize passive heating	0.15	0.14	0.05	0.16	0.25	0.15	0.06	0.04
(3) Optimize passive cooling	0.29	0.27	0.10	0.32	0.50	0.29	0.11	0.07
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.44	0.41	0.15	0.47	0.75	0.44	0.17	0.11
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.58	0.54	NA	0.63	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.20	0.63	1.00	0.59	0.22	0.14
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.12: Cooling Energy Composite Weighting Factors – Chicago

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.34	0.36	NA	0.49	0.50	0.48	NA	NA
(2) Optimize passive heating	0.17	0.18	0.10	0.24	0.25	0.24	0.14	0.00
(3) Optimize passive cooling	0.34	0.36	0.20	0.49	0.50	0.48	0.27	0.00
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.50	0.54	0.30	0.73	0.75	0.72	0.41	0.01
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.67	0.72	NA	0.98	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.40	0.98	1.00	0.96	0.55	0.01
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.13: Building Energy Intensity Composite Weighting Factors – Golden

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.48	0.48	NA	0.50	0.32	0.48	NA	NA
(2) Optimize passive heating	0.24	0.24	0.00	0.25	0.16	0.24	0.04	0.01
(3) Optimize passive cooling	0.48	0.48	0.01	0.50	0.32	0.48	0.08	0.03
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.72	0.71	0.01	0.75	0.48	0.73	0.12	0.04
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.97	0.95	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.02	1.00	0.64	0.97	0.17	0.06
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.14: Heating Energy Composite Weighting Factors – Golden

Beauty Determinant	Form	Window	Landscape	Large Doors	Thermal Buffer	Covered Patio	Integrated Form	Vegetated Roof
(1) Optimize passive daylighting	0.45	0.42	NA	0.45	0.50	0.45	NA	NA
(2) Optimize passive heating	0.22	0.21	0.04	0.23	0.25	0.22	0.02	0.03
(3) Optimize passive cooling	0.45	0.42	0.07	0.45	0.50	0.45	0.04	0.05
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.67	0.64	0.11	0.68	0.75	0.67	0.06	0.08
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.89	0.85	NA	0.91	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.14	0.91	1.00	0.90	0.08	0.11
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA

Table D.15: Cooling Energy Composite Weighting Factors – Golden

Beauty Determinant	**Form**	**Window**	**Landscape**	**Large Doors**	**Thermal Buffer**	**Covered Patio**	**Integrated Form**	**Vegetated Roof**
(1) Optimize passive daylighting	0.39	0.42	NA	0.50	0.50	0.49	NA	NA
(2) Optimize passive heating	0.20	0.21	0.08	0.25	0.25	0.25	0.12	0.01
(3) Optimize passive cooling	0.39	0.42	0.17	0.50	0.50	0.49	0.23	0.03
(4) Optimize stormwater	NA	NA	NA	NA	NA	NA	NA	NA
(5) Localized geographic fit	0.59	0.63	0.25	0.75	0.74	0.74	0.35	0.04
(6) Locally durable material	NA	NA	NA	NA	NA	NA	NA	NA
(7) Building controllability	0.79	0.84	NA	1.00	NA	NA	NA	NA
(8) Indoor/outdoor transition	NA	NA	0.33	1.00	0.99	0.99	0.47	0.06
(9) Cycles of restoration	NA	NA	NA	NA	NA	NA	NA	NA
(10) No waste	NA	NA	NA	NA	NA	NA	NA	NA